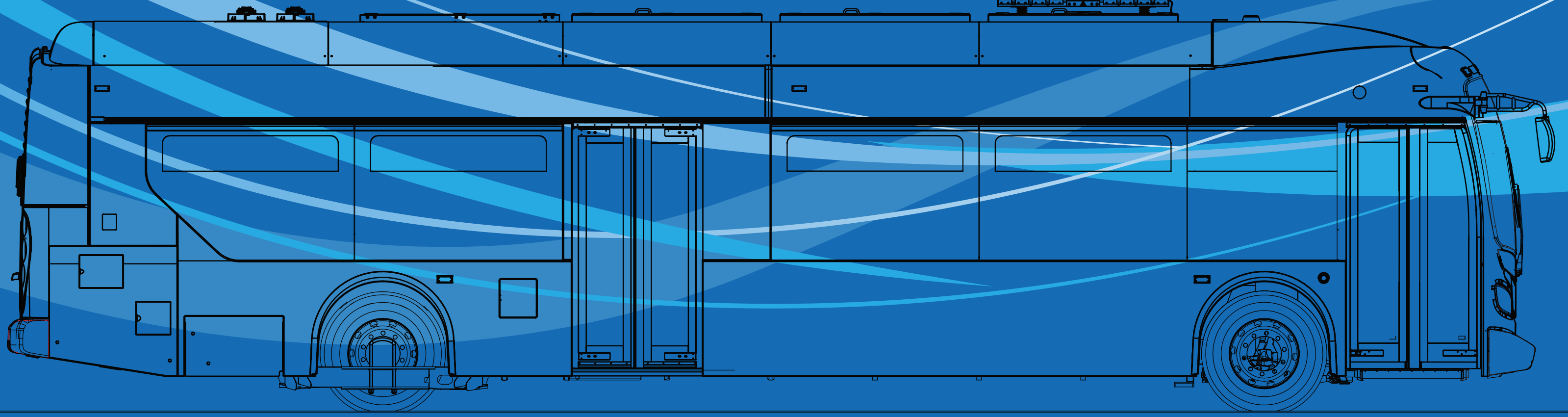
TRIMET

Non-Diesel Bus Plan

September 2018



Introduction

TriMet has long been a leader in the Portland region's efforts to reduce air pollution. In the 1970s, expansion of the TriMet system played an important role in reducing the region's chronic smog. In more recent years, the agency has invested heavily in clean diesel technology, incorporated biodiesel into its fuel and switched to ultra-low sulfur diesel to reduce bus emissions significantly while continuing to expand service.

Expanded and improved transit service is central to achieving the region's climate change goals. By reducing the number of single-occupancy car trips and encouraging compact, walkable neighborhoods, TriMet services reduce the level of global climate change-inducing carbon emissions by an estimated 21,000 metric tons per year. TriMet's MAX Light Rail system, powered with lower carbon intensity electricity, today provides one-third of all transit trips in the system.

In the coming years, TriMet expects to significantly expand service— particularly to unserved and underserved areas – increase frequency, add evening and weekend service and speed transit travel times. These improvements will help promote additional transit use, reduce auto trips, help alleviate congestion and promote a more compact land use pattern – all of which reduce our collective carbon footprint.

TriMet's bus fleet, while diesel powered, is being rapidly modernized to high efficiency, low emissions models. Today 65 percent of TriMet's fleet has post-2012 emissions technology, employing cleaner-burning diesel engines and selective catalytic reduction (SCR) technology, which scrubs nitrogen oxides and particulates from the exhaust. TriMet uses a biodiesel blend to further reduce its carbon footprint.

Although TriMet's existing service delivers extensive benefits to the environment and supports efforts to reduce carbon emission, we also recognize that more can and should be done to reduce the environmental impact of the region's transportation sector. Moving away from diesel buses, combined with expansion of service, will provide a double win: reducing emissions by expanding transit use while using vehicles that themselves emit less carbon. TriMet does not believe a one-sided strategy that sacrifices additional service to achieve low emissions or providing only more service without embarking on the transition to a non-diesel fleet will best serve the community. The following plan seeks to achieve the twin goals of expanded service with cleaner technology.

Chapter 1: Context

TriMet has the 11th largest bus fleet in the United States. TriMet operates 658 buses, the vast majority of which (97 percent) are standard 40-foot diesel buses. The average bus is 7.4 years old. The oldest bus is 19 years old. The fleet also contains 22 smaller, 30-foot buses. Today, 65 percent of TriMet's fleet has post-2012 emissions technology, employing cleaner-burning diesel engines and SCR technology, which scrubs nitrogen oxides and particulates from the exhaust. Seventy percent of TriMet's fleet has 2007 or better emissions technologies and TriMet began using biodiesel fuel blends in 2006.

Diesel buses are a tried and true technology. Historically, they have been cost-effective and reliable. On a full tank of fuel, they have sufficient range for any typical service route and can be refueled easily and safely within a matter of minutes. Mechanics have been servicing them for decades, original equipment manufacturers (OEMs) have honed the technology and established trusted relationships with transit agencies. Lifecycle statistics regarding reliability and maintenance costs also are well documented.

On the other hand, even low-emission buses running on a biodiesel blended fuel still rely on fossil fuels that generate emissions, contributing to climate change. Although TriMet's total carbon emissions are low relative to the entire transportation sector, TriMet is Oregon's largest single consumer of diesel fuel, and – with anticipated growth in TriMet services – its consumption of diesel will continue to increase unless alternatives are developed.

State, regional and local governments have adopted legislative and policy direction to address climate change. The Oregon State Legislature established a goal, through House Bill 3543, of reducing greenhouse gas emissions 10 percent below 1990 levels by 2020 and 75 percent below 1990 levels by 2050. To support these goals and improve sustainable transportation infrastructure in the state, the Oregon Legislature passed House Bill 2017 (HB 2017) to fund public transportation and other transportation improvements through a variety of revenue sources. This bill establishes a Statewide Transportation Improvement Fund (STIF) for public transit, which can be used for the purchase of electric or natural gas buses.

The Metro Council has adopted the Climate Smart Strategy, which fulfills a 2009 mandate by the Oregon Legislature requiring Metro to develop and implement a strategy to reduce the region's per capita greenhouse gas emissions from cars and light trucks at least 20 percent by 2035. One specific action recommended as part of this strategy is to lead by example by increasing the number of alternative-fuel vehicles in public sector fleets.

The City of Portland and Multnomah County have also created a joint Climate Action Plan, which calls for transition to 100 percent clean energy by the year 2050 and provides a roadmap to achieve an 80 percent reduction in carbon emissions by 2050, with an interim goal of a 40 percent reduction by 2030. This plan also includes a public transit system electrification strategy. Similarly, in 2017, both the City of Portland and Multnomah County adopted a 100 percent renewable energy resolution that calls for collaboration between Portland, Multnomah County, Metro and TriMet to expand service, reduce fares for those with a low income and complete a rapid transition to an electric fleet.[1]

While progress has been made in a number of areas toward meeting the state, regional and local emissions reduction goals, achieving progress in the transportation sector has been more challenging. In the past two reporting years, greenhouse gas emissions in the transportation sector have actually risen in Oregon, either due to increased economic activity or vehicle miles traveled. A TriMet transition to non-diesel buses would begin to contribute to reversing this trend in Oregon and achieving relevant state, regional and local climate goals.

Fortuitously, improving technology and decreasing costs of non-diesel buses, combined with credit programs and new funding from HB 2017, provide an opportunity to begin the process of transitioning away from diesel buses.

[1] https://multco.us/file/100-renewable-resolution-finaldoc.

Chapter 2: Evaluation Process

This report summarizes the results of an assessment of whether TriMet should transition from a primarily diesel bus fleet to a non-diesel fleet, and, if so, how. The assessment is based on four interrelated analyses.

Industry Review of Non-Diesel Bus Technology: Several non-diesel bus technologies are in operation or development, each with its unique set of advantages and disadvantages; and the technologies are rapidly evolving. It was concluded that a preferred technology should be selected for testing prior to fully committing to a specific technology. To make this choice, as discussed in Chapter 3, TriMet assessed the performance, operations, cost-efficiency and challenges of alternative non-diesel bus options based on industry reports and discussions with industry officials. As explained in Chapter 5, as a result of this assessment, battery electric buses (BEBs) is recommended as the preferred option for testing. However, it is also recommended that continued assessment of two other technologies (renewable natural gas and hydrogen fuel cells) is warranted during the testing period.

Net Present Value Analysis of Transitioning to a BEB Fleet: While BEBs' initial capital costs are greater than diesel buses, industry reports indicate they may be less expensive to operate than diesel over the long term. In addition, BEBs generate less air and noise emissions, which are societal costs that can be measured in monetary terms. Generally a BEB fleet would be more expensive than a diesel fleet in the early years of the transition and less expensive in the later years, taking into account the total cost to TriMet and the societal costs. Net present value (NPV) analysis is a traditional methodology to compare differing cost streams. It addresses the monetary value of time by applying discount rates to the year-by-year costs of both the BEB fleet scenario and diesel bus scenario, and then totaling the discounted values. While the totaled discounted values are not actual costs, a comparison of these values shows, as described in Chapter 4, that the BEB fleet is less expensive than diesel, i.e., most cost-efficient, given the value of time.

Recommendation for Short- and Long-Range Strategy: Chapter 5 of the report recommends a two-step approach for converting the TriMet fleet to a non-diesel system. The long-range strategy is to adopt a goal of converting the entire TriMet fleet to non-diesel vehicles by the year 2040 or before. While this strategy will require the identification of additional resources to be successful, TriMet believes it is important to signal its commitment to achieving this important goal. The plan also suggests a short-term strategy for testing BEBs as the initial step in this long-term strategy. The test period will involve purchasing 80 BEBs over the next five years.

Fiscal Analysis of Transitioning to a BEB Fleet: Where the NPV analysis focuses on which fleet scenario is most cost efficient in relative terms, the fiscal analysis addresses the actual cost that would be incurred by TriMet in implementing the short- and long-term strategies – assuming BEB is the technology for all diesel bus replacements and expansions. Instead of using discounted present values, the fiscal analysis focuses on the anticipated year-by-year costs in year-of-expenditure (inflated) dollars. It does not consider the societal costs (air and noise emissions), only the capital and operating costs to be paid by TriMet, minus tax credits. The analysis considered the use of a portion of the state funding made available by HB 2017 to offset a portion of the added costs of BEBs, but notes the need for added funding for a full fleet conversion. The results are shown in Chapter 5.

Chapter 3: Industry Review of Non-Diesel Bus Technology

In evaluating potential non-diesel bus technologies, TriMet seeks to find a technology that has the fewest negative impacts on current operations and customer service. This approach helps to ensure that the community gains the benefits of reduced emissions without sacrificing good customer service and the efficiencies gained from an experienced and expert maintenance staff.

While BEBs are the non-diesel bus technology that is being deployed most widely today, there are other zero- (or near zero) emission technologies in use or under development. In addition to non-diesel technologies, many transit agencies have sought to reduce their emissions through the use of hybrid-electric buses that get greater fuel efficiency through the use of regenerative breaking and other features. Many others have transitioned some or all of their fleets to compressed natural gas (CNG), which produces much less particulate matter and other pollutants but, depending on a number of variables such as sourcing and pipeline leakage, can vary in the amount of greenhouse gas emissions. The technologies that were evaluated as part of this analysis are as follows.

Battery-Electric Buses (BEBs)

BEBs have a number of benefits that make them an appealing technology for transit agencies. They emit zero point source pollution and lifecycle emissions are related to the emissions from associated power generation. In Portland General Electric's (PGE) service area,[2] an overall reduction in emissions of 57 percent is estimated with the current mix of electrical generation.[3] As PGE implements strategies to integrate more renewable electric energy sources this is expected to improve. BEBs also have significant noise-related benefits relative to traditional diesel buses.

However, BEBs also come with challenges and limitations at this point in their development. Purchase prices are currently much higher for BEBs than for comparable diesel buses (nearly twice as expensive). BEBs also require additional infrastructure to accommodate electric charging. While these capital costs have been declining in recent years, they are expected to remain higher than those of equivalent diesel buses for the foreseeable future.

In addition, in the United States, experience with BEB technology is relatively limited. Most U.S. transit agencies would need to learn to operate and maintain this type of vehicle. A growing number of transit providers are conducting trials with BEBs, so in the coming years there will be more peer experience to share about practical performance, maintenance techniques and operational best practices.

One vulnerability of BEBs is the potential for electric outages that could prevent buses from being charged. TriMet is working with PGE to understand strategies for preventing outages, such as redundant feeders and hardening against cyber intrusion, and contingency options should outages occur. Generally, TriMet's maintenance facilities are near major PGE substations and transmission facilities.

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[2] Although there are two electric utilities serving the Portland area, this analysis examined only PGE energy supply characteristics because TriMet's three existing bus maintenance facilities are located in PGE service territory. Given the depot-based charging technology recommended in this report, it anticipated that all battery recharging during the initial phases of BEB adoption will occur at PGE-served facilities.

[3] This reduction reflects PGE's current generation portfolio. However, PGE has adopted plans to reduce greenhouse gas emissions by more than 80 percent by 2050, including transitioning away from coal-fired power generation by 2035. As these transitions take place, the emissions savings from transitioning to BEBs will also increase.

During outages, these are typically the first equipment restored, so even if outages occur they tend to be for shorter periods.

One question that remains to be answered is the projected useful life of BEB batteries. Many BEB manufacturers are currently projecting a 14-year lifespan,[4] which is a standard retirement age for many transit properties in the U.S. However, TriMet keeps its buses for an average of 16 years to reduce the cost of vehicles. The longevity of the vehicle plays an important role in its overall lifecycle costs. Achieving a 16-year lifespan for BEBs will be an important factor in implementing a long-term BEB adoption strategy.

Depot-Based and On-Route Opportunity Charging

There are two dominant varieties of BEBs: depot-based charging and on-route opportunity charging vehicles. Depot-based charging involves charging vehicles at the bus depot during a midday layover or overnight. Their large batteries hold more energy than the smaller batters in on-route opportunity charging buses but require between one and four hours to charge, depending on battery capacity and charger type. On-route opportunity-charging vehicles, on the other hand, can charge during the course of their scheduled service using chargers at layover terminals. Opportunity charging batteries hold a smaller amount of energy, but only require several minutes to fully charge. Each of these technologies comes with tradeoffs related to neighborhood impacts, TriMet's scheduling, maintenance, operations and costs.

On-route opportunity-charging technology is quickly developing, and some manufacturers currently advertise nominal ranges of 50-70 miles between charges. However, based on a review of King County Metro's experience with opportunity charging technology, a "real-world" range of 25 miles is considered most realistic to allow for variations in topography, traffic congestion and use of heating and air conditioning, among other factors. A planned pilot of BEBs on TriMet's Line 62-Murray Blvd will provide a more precise understanding of how opportunity-charging technology performs locally.

The challenges related to opportunity charging are primarily associated with the need for distributed charging infrastructure located along transit routes. To use the infrastructure efficiently, charging locations should be sited where they can serve multiple routes, and ideally up to six to eight buses per hour. These locations would require approval of the appropriate local municipalities and property owners. Additionally, schedule revisions also might be needed to ensure adequate charging time between bus trips, and the costly location of on-route charging equipment does not easily allow for route changes.

Sufficient power supplies may not be available at all potential opportunity charging locations, and daytime charging means that buses are charging when electricity rates tend to be higher. Lastly, and importantly, opportunity chargers are significantly more expensive than depot chargers, and more of them may be needed depending on configuration at layover locations. In 2018, one depot charger costs approximately $69,000, whereas one opportunity charger costs approximately $584,000. This can make a difference in whether an agency BEB plan is financially viable or not.

Depot-charging technology is also developing rapidly. Again, taking account of real world factors such as traffic congestion, varying topography and use of heating and cooling systems, it is estimated that

[4] Projected lifespans assume one battery replacement. This is similar to diesel buses, which typically have at least one major engine rebuild during their lifespan.

today's depot-charging buses can reliably travel up to 150 miles on a single charge This is not sufficient to support all of TriMet's current routes. This issue can be addressed by deploying the first generations of depot-charging buses on shorter routes. Battery ranges are growing steadily as battery technology is developing, and 300-mile ranges on a single charge, comparable to a full tank of fuel in a diesel bus, are generally expected in the coming years. As battery ranges expand, the universe of routes within TriMet's system that could be served by BEBs will grow.

Depot-charging buses also have tradeoffs related to the space the charging infrastructure consumes at depots. Installation of new charging infrastructure would require reconfiguration of bus depot space used for storage and fueling. Overall this would cause a net reduction in storage capacity, on the order of 12-17 percent, depending on site configuration. In addition, while these buses would not need to be fueled as part of the normal bus intake process, they would need to be plugged in during their midday and overnight layovers, requiring attendant attention at this point in the daily schedule.

A number of transit agencies are buying and testing on-route opportunity charging buses (including TriMet's purchase of five opportunity charging buses using Federal Transit Administration (FTA) Low-No funding), and there are uses for which this is the preferred technology. However, because they perform more like a traditional diesel bus, have lower charging infrastructure costs and fewer community impacts, the trend among transit agencies planning for a full transition to BEBs is to assume the use of all depot-charging technology.

Lastly, while 40-foot BEBs are in relatively widespread deployment, 60-foot BEBs (articulated buses) are still relatively new to market. While some agencies such as LA Metro and King County Metro are currently testing 60-foot BEBs, many agencies are still waiting for early-adopting agencies to more extensively report on their experiences with them. Although TriMet does not currently operate any 60-foot buses, it will begin doing so with the opening of the Division Transit Project and is interested in deploying 60-foot vehicles on other high ridership routes in the future.

For both depot-charging and on-route opportunity charging technologies, it will be important for the electric utilities to work with TriMet to ensure that adequate service is available at the necessary locations and that major facilities, such as maintenance depots, have redundant service to ensure TriMet's ability to serve its customers in the event of natural disasters.

Fuel Cells

Hydrogen fuel cell buses currently are less widely deployed than BEBs. This technology uses on-board liquid hydrogen as fuel, and tailpipe emissions include only water vapor and warm air. Lifecycle emissions depend on the type of power used to generate the hydrogen, but in many cases it is generated using clean, renewable energy sources.

Hydrogen fuel is still comparatively expensive and distribution networks are limited. Hydrogen cost ranges from $5–$8/kilogram at the three California transit fueling sites, which is approximately $0.71–$1.14/mile (compared to a diesel fuel cost of approximately $0.67 per mile). As more buses are deployed, the increased fuel demand is expected to lower the price of hydrogen on a per-mile basis and lead to a more robust distribution network.[5] The fuel cell vehicles themselves also are at least as expensive as BEBs. The Orange County Transportation Authority (OCTA) announced in February that it

[5] https://cafcp.org/sites/default/files/CHBC-CaFCP-Fuel-Cell-Electric-Bus-Fact-Sheet.pdf.

will purchase 10 fuel cell buses for approximately $12 million.[6] The National Renewable Energy Laboratory cites an industry goal of reducing the average cost of a fuel cell bus to approximately $1 million in coming years. Maintenance costs for fuel cell buses also have preliminarily been shown to be higher than for diesel or CNG buses at this stage of technological development.[7]

The advantages of a fuel cell bus are that it can be operated more like a diesel bus than a BEB, as it relates to fueling and operating range. Hydrogen bus refueling can be done in a matter of minutes at a refueling station, providing operational efficiency and reducing the space impacts associated with BEB charging. Hydrogen buses are reporting operating ranges of between 280 and 530 miles between refueling, which is also comparable to a traditional diesel bus.[8] Buses with these ranges could serve all of TriMet's existing routes.

While some OEMs are offering fuel cell passenger cars, fuel cells are more ideally suited for large vehicles that need to refuel quickly and store a large amount of on-board energy. For example, long-haul trucking operations may be more suited to fuel cells than battery technology. While some transit agencies are purchasing fuel cell buses, more agencies by far are purchasing BEBs. Alameda-Contra Costa Transit District (AC Transit); SunLine Transit Agency in Palm Springs; and the University of California, Irvine have purchased hydrogen fuel cell buses.

Renewable Natural Gas (RNG)

While CNG is in relatively widespread use as an alternative fuel for transit buses and produces significantly less particulate pollution, it does not produce a notable reduction in carbon dioxide (CO_2) compared to diesel and produces significantly more carbon monoxide. In terms of point source pollution, CNG and RNG are identical. However, the benefit of RNG as an alternative fuel can be seen in a lifecycle carbon intensity comparison. RNG, or biomethane, is sourced from gases released by decomposing organic matter such as can be found in landfills, wastewater facilities and agricultural waste. If left uncaptured, this matter decomposes to release methane into the atmosphere, which has

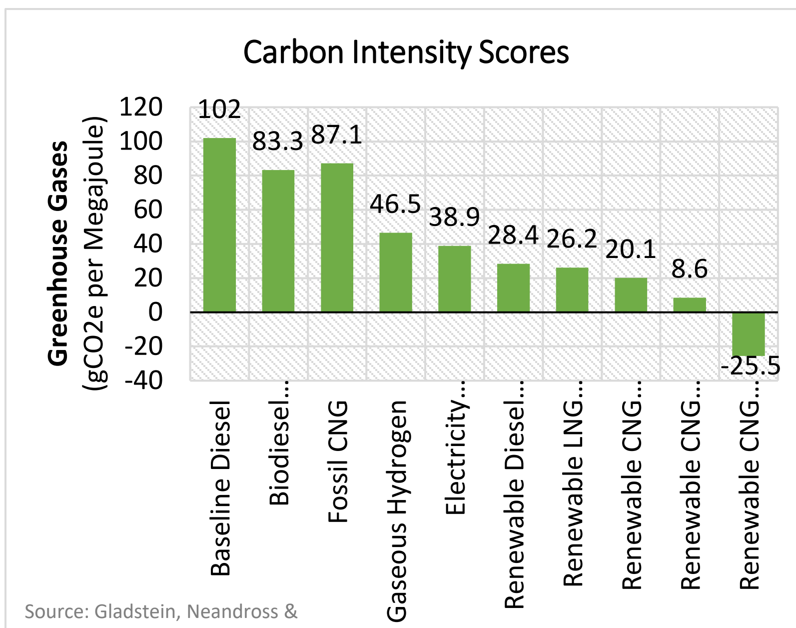

Figure 1. Comparative Carbon Intensity Scores. Source: https://www.trilliumcng.com/en/fueling-solutions/renewable-natural-gas

[6] https://www.ocregister.com/2018/02/07/octa-to-purchase-10-hydrogen-fuel-electric-buses-at-cost-of-about-12-million/.

[7] https://www.nrel.gov/docs/fy18osti/70075.pdf.

[8] http://www.gppq.fct.pt/h2020/_docs/brochuras/fch-ju/20121029%20urban%20buses,%20alternative%20powertrains%20for%20europe%20-%20final%20report_0.pdf.

been found to have 20–25 times the atmospheric warming effect as does CO_2. Capturing RNG generated by anaerobic digestion, or other means, eliminates almost all harmful emissions and can provide dramatic benefits to the environment. In fact, capturing methane and converting it to RNG can have an overall net negative carbon impact, depending on the source, as shown in the comparative carbon intensity scores in Figure 1. For this reason, it is considered in this evaluation among non-diesel fuel sources.

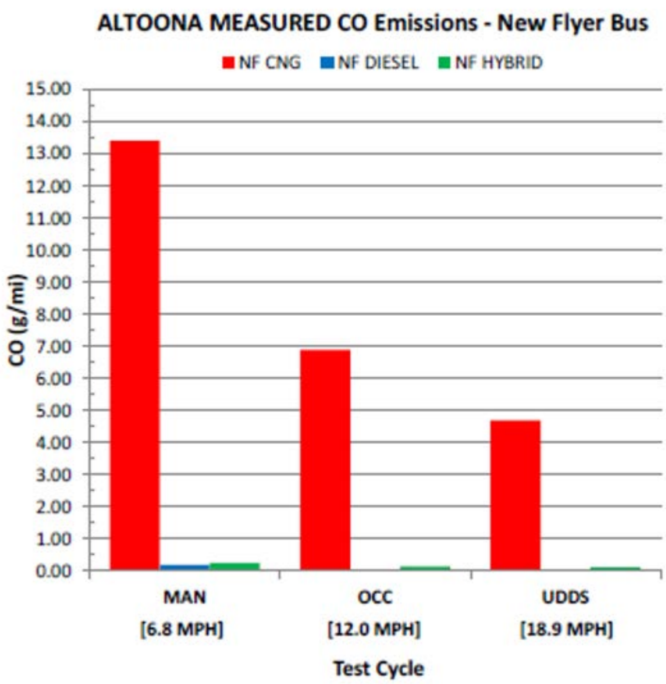

Figure 2. Altoona Measured CO Emissions - New Flyer Bus. Source: https://mjbradley.com/sites/default/files/CNG%20Diesel%20Hybrid%20Comparison%20FINAL%2005nov13.pdf

However, while RNG can have a net negative lifecycle carbon intensity score, it also may not, depending on the source of the methane gas, as shown in Figure 1. And, while particulate and nitrogen oxides (NO_x) pollution with RNG is much reduced, like CNG, carbon monoxide emissions are actually much higher, as shown in Figure 2.

The cost per gallon equivalent for RNG is roughly comparable to the per-gallon cost of diesel, but it can vary by location. Clean Energy Fuels is offering RNG fuel, branded as “Redeem” to transit agencies in California, such as LA Metro and Santa Monica’s Big Blue Bus. It is not yet being provided in Oregon, but an arrangement with Clean Energy Fuels may be possible.

Table 1 below summarizes the key considerations for BEB, fuel cell and RNG buses in relation to existing diesel buses.

Table 1. Comparison of zero or near zero emission technologies

Technology	Cost Relative to Diesel	Emissions Relative to Diesel	Operational Impacts	Status of Deployment in the U.S. Today
Battery-Electric Buses (BEB)	Higher in initial years	Lower	Significant	Peer agencies experience
Fuel Cell Buses	Higher overall	Lower	Minimal	Limited
Renewable Natural Gas (RNG) Buses	Similar	Lower	None	Peer agencies experience

Preferred Technology

After extensive evaluation of available and developing technologies, TriMet's near-term preference is for depot-based charging BEBs. There are several reasons for this choice. Non-diesel fuel cell buses are somewhat less cost effective at this stage of technological development than BEBs, with fuel cell bus vehicle costs at least as much as BEBs but fuel and maintenance costs significantly more than diesel or CNG buses. BEBs, on the other hand, have lower fuel and maintenance costs than diesel or CNG buses, which can help to offset the higher vehicle purchase prices compared to diesel or CNG.

RNG is not preferred over BEBs at this time; however, further exploration of this option is warranted. While CNG buses are currently less costly than BEBs, CNG maintenance costs are projected to be higher than BEBs, they have point source emissions and there are still questions that need to be addressed regarding the supply and characterization of RNG carbon impacts.

Hydrogen, like RNG, appears to hold some promise for meeting the agency's needs, if technological advances and energy supply issues can be addressed. While these technologies are not TriMet's preferred approach at this time, the agency fully intends to continue to investigate the long-term potential of integrating these technologies into its fleet over the coming years. This may include seeking grant funding for acquisition of test vehicles and associated fueling equipment.[9]

Between depot-charging and on-route opportunity charging BEB technologies, depot charging is the preferred agency technology. Depot-charging buses can charge at bus depots with minimal operational impacts. While plugging in buses to charge overnight is a change from the current practice of refueling buses in a matter of minutes and then parking them, the essential experience of being able to send buses out for a full block of service without the need for refueling until they return to the depot would be similar to diesel buses. In addition, eliminating the need for on-route charging equipment will reduce more expensive daytime charging, allow for greater agency flexibility to adjust routes over time and avoid the neighborhood impacts of installing opportunity chargers.

In addition, depot-charging buses are more cost effective at this time than on-route opportunity charging buses, due primarily to the lower cost of charging equipment. Lastly, depot-charging technology would be compatible with more of the existing TriMet service profile. According to an analysis of agency routes, comparing the expected range for BEBs and route lengths, it is estimated that 59 percent of existing service blocks can be served by depot-based charging compared to only 38 percent for opportunity charging technology. It is generally expected that depot-charging technology will improve over the coming years and be sufficient to accommodate virtually all of TriMet routes.

National and International BEB Experience

Internationally, there are almost 400,000 BEBs deployed with approximately 99 percent of those located in China. Within the U.S., at least 38 transit agencies have some experience with BEBs – most with fewer than 10 buses. Within the U.S., most transit agencies with BEBs are in the process of testing the technology and evaluating the desirability of a longer-term commitment to them.

A handful of transit agencies in the U.S. have committed to purchasing only BEBs. Notably, Antelope Valley Transportation Authority in Southern California is anticipating a full transition in 2018, LA Metro

[9] TriMet has determined that due to training, staffing, parts management and infrastructure needs, it would be inefficient and costly to have buses using more than two fuel types at any one maintenance facility. Therefore, the agency intends to house the initial BEB fleet at its Powell Operations Facility.

aims to have a fully electrified fleet by the year 2030 and King County Metro in Washington has committed to a full transition to BEBs but is still testing a number of different OEMs before beginning to purchase BEBs exclusively.

Current Battery Electric Bus Initiative
TriMet is experimenting with on-route opportunity charging with a pilot project deploying five BEBs on Line 62 slated for 2019. TriMet's BEB pilot project is funded jointly by the FTA, TriMet and a partnership with PGE. Some of the project objectives include eliminating vehicle emissions, reducing noise, reducing costs and training the workforce. The pilot will involve training for operators, maintenance team and first responders, as well as a year of revenue service data collection and monitoring. The pilot will use both on-route charging and depot charging to provide the broadest experience. Under a pilot project approved by the Oregon Public Utility Commission (PUC), PGE is assisting by installing, maintaining and designing the necessary charging infrastructure.

Chapter 4: Net Present Value Analysis of Transitioning to a BEB Fleet

A detailed lifecycle cost model was developed to understand the fiscal impact of transitioning to a new BEB fleet. This model evaluates all categories of costs (or credits) that TriMet is projected to experience when purchasing and operating BEBs. The factors included in the analysis are vehicle purchase costs, including assumptions about future price changes due to economies of scale and technology, as well as maintenance, fuel use, electricity use, facility upgrades, charging infrastructure and Clean Fuel Credits. The model also addresses social costs including emissions and noise. All of these costs are calculated for each bus in the transition scenario at each year to measure the full cost of each scenario. The model then compares those costs with an equivalent diesel bus fleet purchase and operations plan.

TriMet replaces buses, on average, at 16 years of age. Each bus in the fleet will reach its retirement age and be replaced with a new bus over the course of an average 16-year lifecycle. Thus, this lifecycle cost model examined a 16-year time period.

The bus purchases in the model are all based on TriMet's Fleet Plan from November 2017.[10] That plan outlines projected fleet replacement needs and fleet growth through 2027. Beyond that point, the model assumes the total fleet grows by 14 buses annually, reflecting historical growth rates.[11] The purchases each year are assigned to replace retiring vehicles and meet the target fleet growth. In the model, diesel buses and BEBs both have a lifetime of 16 years, matching current TriMet experience with diesel buses. As noted earlier, for the lifecycle costs to meet acceptable thresholds for a full conversion to BEBs, TriMet will need to see evidence that suggests such lifecycles are achievable.

The model assigns each bus to one of TriMet's operating facilities. All purchases are assigned to Powell, Center, Merlo, or a new facility that is expected in the coming years. This allows the model to include different service profiles and operating characteristics at the different facilities. It also enables planning for the facilities' capacity levels. Preliminary engineering work at the Powell facility indicates that converting an operating garage to house BEBs results in a capacity reduction of about 17 percent due to space needed for charging equipment and new directional ingress and egress. Anticipating these

[10] Note: Only 40-foot buses are considered as part of this analysis.

[11] To smooth out annual budgets in the lifecycle cost model, occasionally bus lifetimes may be extended as long as 17 years to offset "lumpy" fluctuations in purchase needs.

capacity losses will allow TriMet to plan its facility space to accommodate all of the BEBs for the proposed pilot period.

Cost modeling required making projections concerning many future conditions that involve a number of uncertain variables. The analysis reviewed relevant research findings, manufacturer claims, peer agency experiences and TriMet's own experiences, as well as conducted scenario testing to understand the implications of various assumptions. Initially, the potential conditions were framed as representing optimistic, pessimistic and moderate scenarios. However, because financial planning for multiple scenarios is not practical, after discussions with stakeholders, the model conditions were merged into a single, highest-confidence model scenario.

The key measures that serve as inputs into the highest-confidence model scenario are described below, along with the logic behind their selection.

Vehicle Purchase Costs
Vehicle purchase prices are a crucial variable and a source of significant future uncertainty.

- The base year purchase price of BEBs using depot -based charging is $1,008,794.[12] This is based on averaging quotes from New Flyer and King County Metro's experience with Proterra. Note that this price is "fully loaded" to include vehicle acquisition, warranties, parts, training and after-market features.

- The purchase price of depot-charging BEBs declines relative to equivalent diesel buses (with improvements in technology and economies of scale) and then increases (due to normal inflation) in line with the average of two different scenarios from the California Air Resources Board.[13] Figure 3 below illustrates this trend over the study period.

- The base year purchase price of diesel buses is $532,019. This is based on TriMet's cost for new buses being added in Fiscal Year 2019. Note that this price is also "fully loaded" to include vehicle acquisition, warranties, parts, training and after-market features.

- The purchase price of diesel buses grows by approximately $17,894 annually, in year of expenditure dollars, due largely to inflation. This is based on the average trend of new bus deliveries over the period 2001-2015 as reported in the American Public Transportation Association's 2015 Public Transportation Fact Book. Figure 3 below illustrates this trend over the study period.

- Total costs for both diesel and BEBs also include two types of special equipment requirements particular to TriMet. All new buses require an operator protective enclosure costing $5,000, and all fleet expansion buses (as opposed to replacement buses) require a package of equipment costing approximately $25,000.

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[12] Dollar figures are in 2018 dollars unless otherwise noted. Base BEB cost assumptions are based on preliminary quotes for manufacturers and range from approximately $930,000 to approximately $1,087,000.

[13] California Air Resources Board. "5th Innovative Clean Transit Working Group Meeting." June 26, 2017.

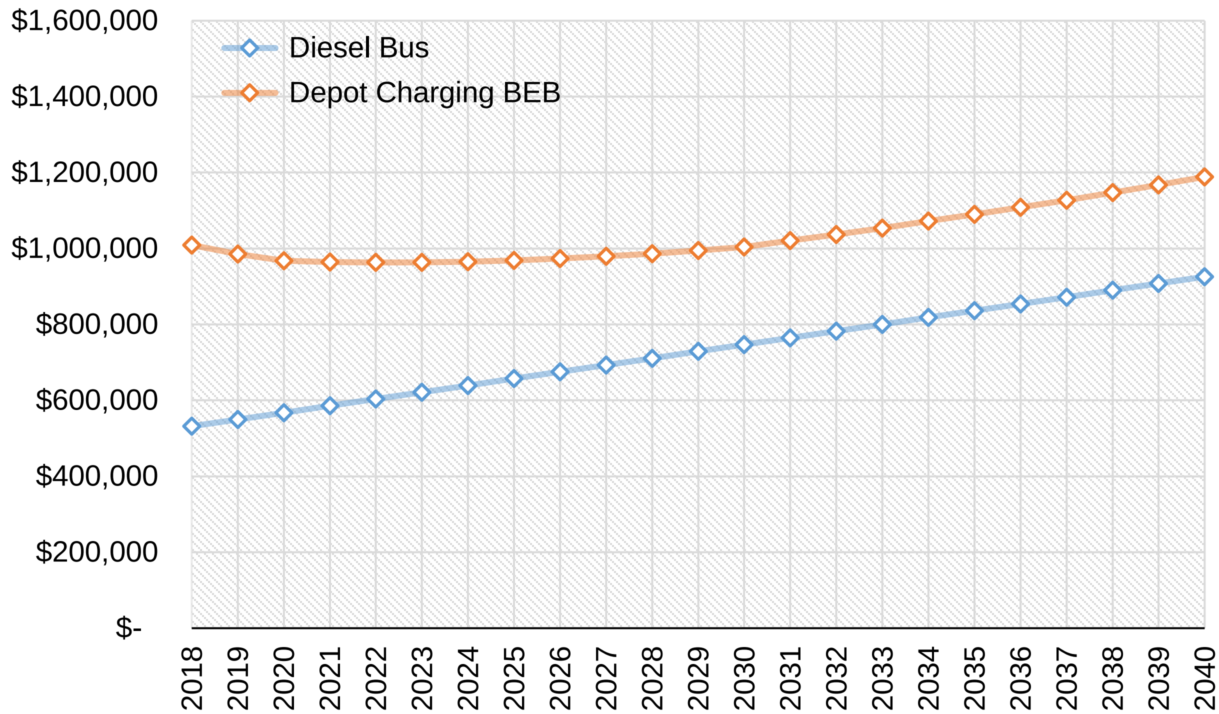

Figure 3. Projected purchases prices for diesel buses and BEBs using depot-based charging.

Maintenance Costs

- The base year cost of diesel bus maintenance is $1.82 per mile based on TriMet's current experience.
- The cost of BEB maintenance is estimated to be 20 percent lower than equivalent diesel buses. Manufacturers highlight that BEBs have fewer parts to maintain and do not require oil and liquid fuels. Savings as large as $151,000 over 12 years have been claimed. Despite these optimistic claims, TriMet seeks to balance its expectations based on experience from other agencies operating electric buses. Due to this technology being relatively new to U.S. transit agencies, full lifecycle maintenance cost trends are not yet available, so a moderate assumption is prudent.
- Actual mileage per bus is determined based on the average of each bus's operating facility.
- Charging equipment also requires maintenance. Based on the King County Metro's Feasibility of Achieving a Carbon-Neutral or Zero-Emission Fleet study,[14] this is estimated at $200 annually for a depot charger in the base year.

Fuel Costs

- The base year price of diesel fuel is $1.95 per gallon based on TriMet's current experience.[15]

[14] https://kingcounty.gov/~/media/elected/executive/constantine/news/documents/Zero_Emission_Fleet.ashx.

[15] Source: TriMet Financial Analyst Timothy Kea.

- The price of diesel fuel is projected to grow by 2 percent annually (inclusive of 1.34 percent inflation). Although there is research suggesting that the price of diesel fuel could grow at faster rates in the future,[16] the 2 percent growth trend aligns with TriMet experience. A faster rate of growth would reflect significant policy or economic shifts. [17]

- Actual gallons of fuel used are determined based on the bus's per-bus average for each operating facility.[18]

Electricity Costs

- For electricity costs that depend on vehicle usage, 2.362 kilowatt hour (kWh) of energy is used per mile. This is based on King County research that is in line with preliminary analysis related to TriMet's BEB pilot.

- Actual mileage per bus is determined based on the average of each bus's operating facility.

- For electricity costs that depend on the peak power draw of facilities, each depot charger is assumed to draw 110 kW. This is the worst case manufacturer specification from Proterra,[19] though manufacturer claims are generally optimistic.

- Pricing of electricity would be provided under PGE's Schedule 85 rate structure. This was confirmed in discussions with PGE. This rate structure applies to large nonresidential customers drawing power in the range of 201 kW to 4,000 kW. The power needs of BEB charging are estimated to fall in this range. The pricing under this schedule varies with the share of charging occurring during PGE's peak period (between 6 a.m. and 10 p.m.). Based on service schedules and the differential pricing, our analysis assumes that 25 percent of charging occurs during the 6 a.m. to 10 p.m. window, and the majority would occur overnight.

Facility Upgrades

- Facility upgrade costs were estimated by developing preliminary engineering plans for the existing TriMet bus depots. These plans considered pavement restriping, electrical wiring, power service and adding a substation.[20] For the planned new bus facility, costing assumes the facility upgrade cost per bus matches the average of the three existing bus bases.

- Facility upgrade costs assume that upgrades are deployed to one-third of a bus facility at a time. Thus, one-third of the facility will be upgraded for the first one-third of its fleet. Facility upgrade costs continue in one-third units as the BEB fleet grows at each bus facility.

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[16] Source: National Renewable Energy Laboratory, 2017.

[17] Policy changes, such as federal carbon caps or taxes, could dramatically change the long-range cost of diesel fuel, making it significantly more expensive. Such changes would narrow the gap between the NPV of BEBs versus diesel buses.

[18] Source: September 2017 Bus Maintenance Report.

[19] Source: Catalyst 40-foot bus performance specifications.

[20] Initial facility costs could be reduced if the PUC were to approve a docket expanding on the rule it approved for TriMet's initial five BEBs test and allowing PGE to design, install and maintain charging facilities.

Charger Infrastructure

- The base price for each depot charger is $68,909 to purchase and install. This is based on research from the King County Metro feasibility study and confirmed by manufacturers.[21]
- Based on manufacturer specifications, depot chargers can accommodate two BEBs and have the same lifetime as the associated buses.

Clean Fuel Credits

The Oregon Department of Environmental Quality (DEQ) established a Clean Fuel Credit program that provides credits for BEBs that can be sold in a market. (Its policy currently runs through 2025, beyond which credit distribution is assumed to be static.) The actual value of the credits is subject to market forces.

- The model assumes a value of $100[22] per credit. This approximates the value of similar credits offered in California at the time of writing. While this represents an increase over the current value of the credits in Oregon, it is considered to be a realistic projection of future performance.

Finance Assumptions

The model made the following assumptions regarding finance. All analyses use 2018 dollars, and a discount rate of 3 percent is used to adjust future costs for time value. Second, specific growth rates are assumed for certain categories of costs based on market indexes or TriMet experience: materials and services grow at 3 percent annually and labor costs grow at 1 percent annually. General inflation uses a 10-year average consumer price index value of 1.34 percent. Finally, all financial outputs are presented in constant 2018 dollars.

The overall results of the TriMet fleet replacement net present value (NPV) model through the year 2055 are summarized in Table 2 below.

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[21] For purposes of this analysis it is assumed that TriMet will install, own and maintain charging infrastructure. For the purchase of TriMet's first five on-route opportunity charging BEBs, the PUC approved Order No. 18-054, allowing PGE to install, own and maintain the charging infrastructure. If this approach were available for the full implementation of the BEB plan, TriMet's up front capital costs would be reduced significantly.

[22] Source: Approximate current value in California.

Table 2. Comparison of modeled fleet replacement NPV categories between diesel buses and BEB scenarios

	Diesel Fleet Replacement	BEB Fleet Replacement
NPV to TriMet		
Fuel Use	$189,311,600	$40,957,864
Electricity Use	$351,369	$60,394,841
Maintenance	$979,770,749	$829,111,721
Vehicle Purchase	$678,704,440	$877,366,717
Charger Infrastructure	$872,718	$24,432,563
Clean Fuel Credits	-$606,777	-$83,293,920
Facility Upgrades	$226,207	$30,578,032
Total	**$1,848,630,307**	**$1,779,547,818**
Social NPVs		
Emissions (Tailpipe)	$118,967,159	$27,158,828
Emissions (Power)	$169,545	$22,419,826[23]
Noise[24]	$33,183,247	$23,115,102
Total	**$152,319,951**	**$72,693,757**

Under both scenarios, the total of all lifecycle NPVs to TriMet for replacing, expanding and operating its fleet is approximately $1.8 billion. The NPV of choosing the BEB fleet option saves TriMet approximately $69.1 million, or 3.7 percent of the total cost through the year 2055, in 2018 dollars.

Choosing the BEB fleet option also reduces social costs, with a NPV approximately $79.6 million, related to emissions and noise reductions. These benefits accrue to members of the general public and cannot be monetized by TriMet. While some value of emissions reductions are reflected in state emissions credits, the overall contribution that converting to BEBs makes toward meeting climate goals is not a financial resource that TriMet can use to offset the initial cost of purchasing these vehicles and charging infrastructure.

This model also allows us to understand how the NPV is generated over time. Figures 4 and 5 below show that BEB fleet costs are greatest at the beginning of the bus lifecycle when vehicles and infrastructure are being acquired. In the later years, BEB costs related to operations and maintenance are significantly less than diesel buses. In other words, while BEBs cost somewhat more up front than equivalent diesel buses, the benefits in reduced maintenance and operating costs offset the up-front costs in the long term.

Even though the transition to BEBs is expected to save money in the long term, in the short term it requires additional funding sources to facilitate the transition.

As will be noted in the following sections of this report, with an allocation of Statewide Transportation Investment Funds, TriMet is in a position to move forward with a pilot phase of BEB conversion and an aspirational goal of full fleet conversion. However, to achieve the full fleet conversion, significant additional resources will need to be identified beyond those currently available to the agency.

[23] This NPV is based on PGE's current generating portfolio, which includes the coal plant at Boardman. As PGE transitions to a lower-carbon emissions generation portfolio, the social NPV of moving to BEBs will increase above this figure.

[24] A noise reduction of 51 percent is estimated overall.

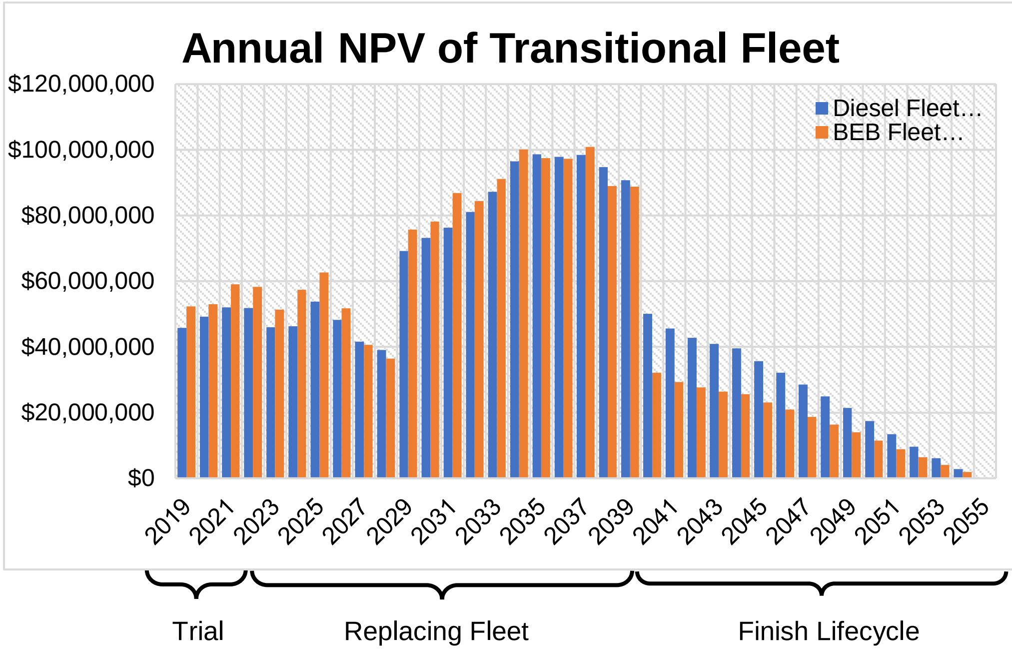

Figure 4. Annual NPV of the transitional fleet

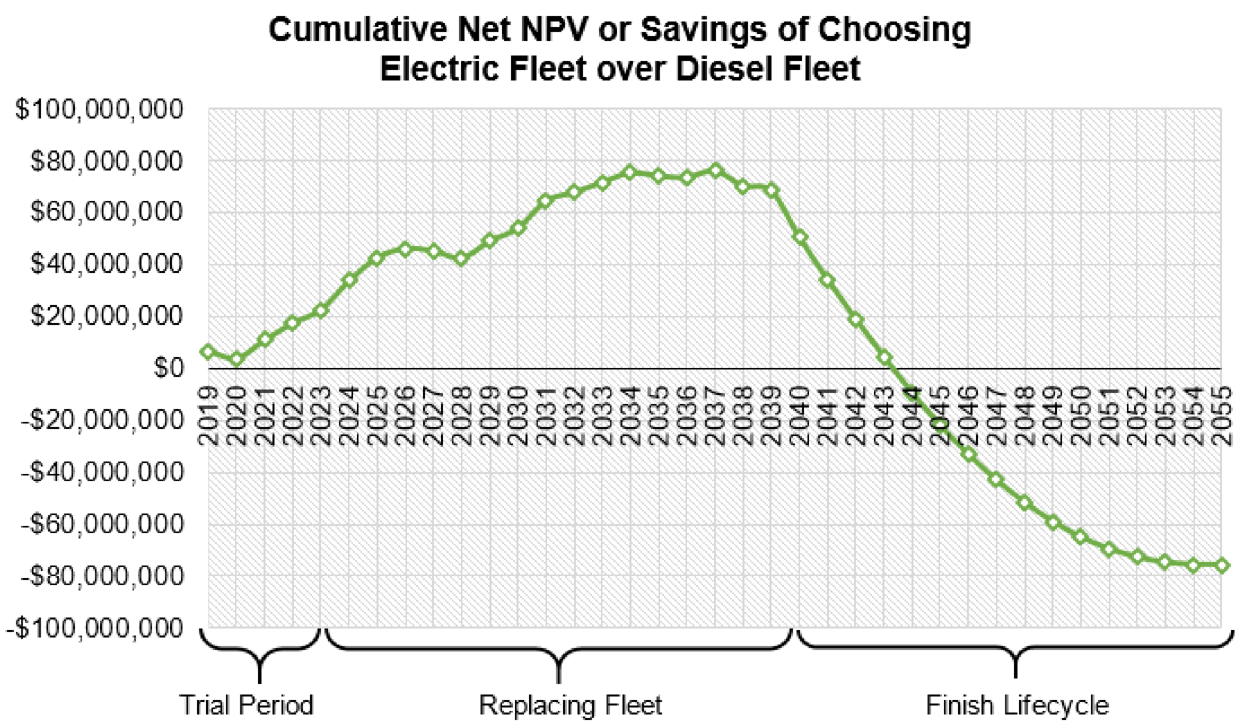

Figure 5. Cumulative NPV or savings of choosing electrical buses over diesel buses for the transitional fleet

Social Costs

Social costs related to emissions were calculated for both tailpipe emissions from diesel buses and from power generation for BEBs. This analysis evaluated the value of the CO_2 and NO_x produced. The social cost per ton of CO_2 is $44.75, while the social cost per ton of NO_x is $8,335.[25] Forty-foot diesel buses emit 2,444 grams of CO_2 per mile and 16.64 grams of NO_x per mile.[26] Thus, a social cost per diesel bus mile can be calculated. Similarly, PGE reports emission rates per megawatt-hour (MWh) of power generated. They report 0.000391 tons of NO_x per MWh and 0.554017 tons of CO_2 per MWh. These statistics can be combined with the energy use per mile to generate a range of social costs per BEB mile.

Social costs related to noise impacts were calculated based on the miles driven for each type of vehicle. The noise costs of diesel buses are 7.6 cents per mile, while the noise costs of BEBs are 4.6 cents per mile.[27] A comparison of total costs of the diesel and BEB transition scenarios, including social costs, are shown in Figure 6 below.

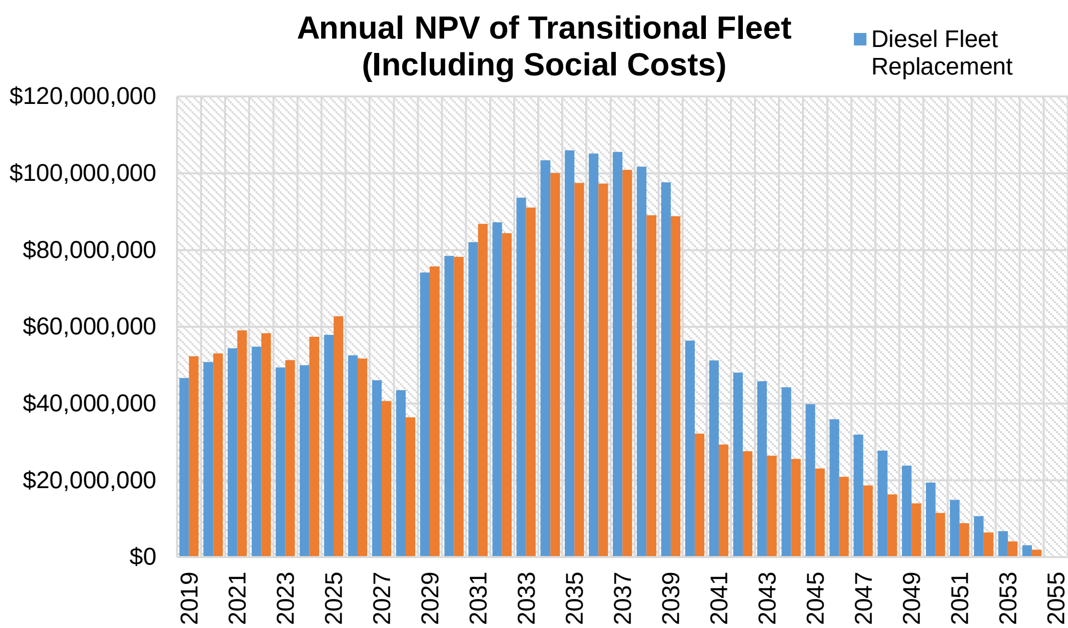

Figure 6. Annual NPV of the transitional fleet, including social costs

Chapter 5: Proposed Implementation Strategy

In order to calculate the year of expenditure costs for converting to a non-diesel fleet, it was necessary to develop a proposed implementation strategy, defining an implementation rate for the purposes of modeling. Based on the findings of the industry review, bus charging type analysis and NPV calculation, TriMet developed the following proposed implementation strategy.

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[25] U.S. Environmental Protection Agency.

[26] EMFAC Web Database, California Environmental Protection Agency, Air Resources Board, https://www.arb.ca.gov/emfac/2014/.

[27] Transportation Cost and Benefit Analysis II, Victoria Transport Policy Institute (VTPI), December 2015. Available at: www.vtpi.org/tca/tca0511.pdf.

Trial Period
Because of the uncertainties associated with the current technology, and in an effort to capture the benefits of improving technologies and innovation, TriMet is suggesting a two-step approach to converting to a non-diesel fleet. The first phase will be to incrementally purchase a 65 BEB test fleet over the next four years. The second phase will be to evaluate the performance, cost and reliability of the test fleet and make a determination over the test period whether to either ramp up, maintain or discontinue purchases of BEBs to pursue some other technology altogether. Assuming the BEBs are performing adequately, TriMet would purchase 20 additional BEBs in 2023 as well.

Full Implementation
Assuming successful outcomes during the four-year trial and the identification of new funding needed after the initial STIF allocation, TriMet would discontinue diesel bus purchases in 2023. Following such a strategy, no diesel buses would remain in the TriMet fleet by 2040. A graph of the fleet conversion progression is show in Figure 7.

TriMet's five year BEB purchase plan:

Fiscal Year	No. of BEBs ordered	
2019	10[28]	Trial Phase
2020	10	
2021	20	
2022	20	
2023	20	1st Year Transition
Total	80[29]	

[28] FTA has approved a Low-No grant to TriMet for the purchase of five depot-based BEBs. In addition, TriMet proposes to purchase an additional 10 BEBs in FY 2019 using STIF funds.

[29] Total BEBs ordered or in use in FY 2023 will be 90 after including the five FTA-funded on-route BEBs approved in FY 2016.

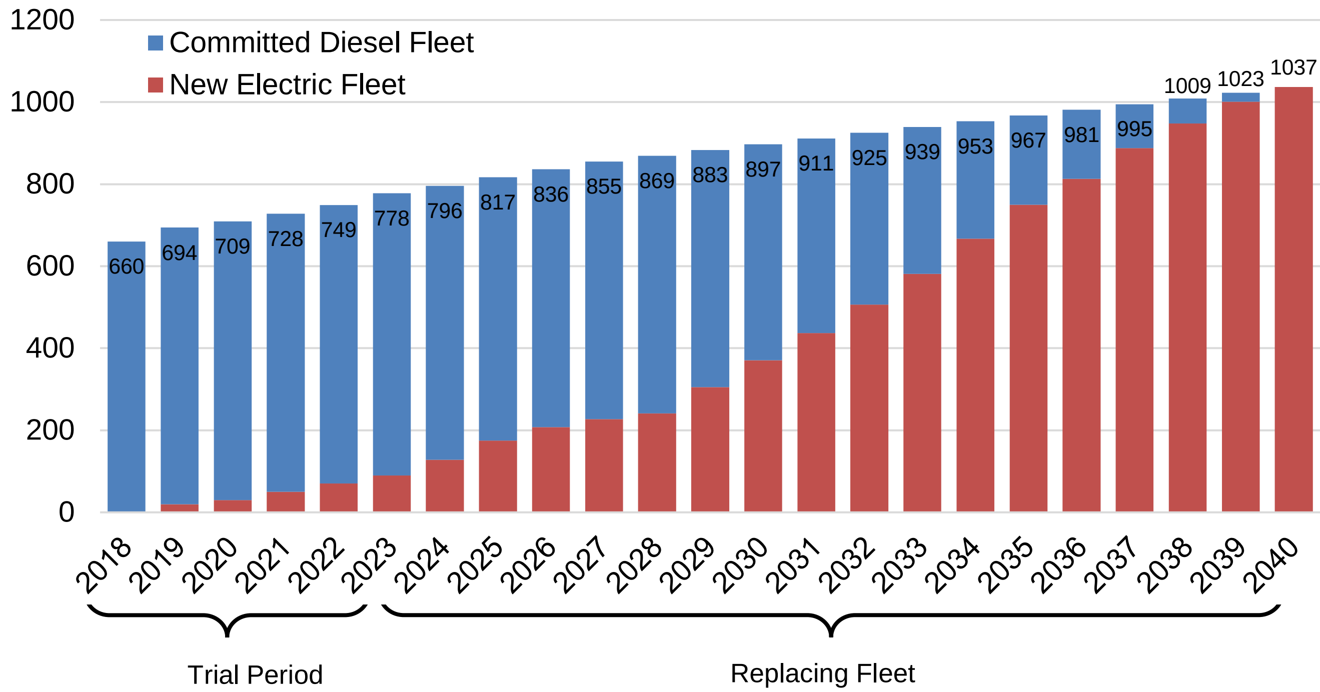

Figure 7. Planned progression of electric fleet to replace diesel fleet by end of 2040. Note: Actual completion of fleet conversion could occur in calendar year 2041 or 2042 depending on manufacturer lead time for construction and delivery of buses.

Long-Term Considerations

During the time required to make the transition to a full BEB or non-diesel fleet, policy, technology and economic considerations are expected to evolve. The following are considerations that will inform either the transition or impact the timeline of such a transition.

- With current battery technology and TriMet's current bus service schedules, it is estimated that approximately 59 percent of bus routes are compatible with depot-charging BEB technology (assuming a "real-world" range of 150 miles). Depot-charging technology will need to improve to accommodate all of TriMet's routes. Some manufacturers already advertise longer ranges and on-the-ground testing over time will evolve the agency's battery range assumptions.

- Future purchase prices of BEBs are uncertain. Some experts argue that prices could decline more than projected in the California Air Resources Board (CARB) model used for this analysis. If purchase prices do not decline at least as much as currently projected in the CARB innovation curve, continued purchase of BEBs may not be feasible. On the other hand, if innovation and economies of scale reduce BEB purchase costs more than projected in the CARB model, less additional funding would be needed to achieve full conversion.[30]

[30] Reducing capital costs do not necessarily speed up the conversion to non-diesel buses because, to manage its bus replacement cycle, TriMet tries to have 1/16th of its bus fleet "age out" each year.

- BEB technology must prove reliable for TriMet's operational needs. If the buses do not perform up to expectations, a full fleet transition may be premature.

- Fuel and maintenance cost savings are currently assumed. If future electricity costs are greater than expected or maintenance costs cannot be reduced to assumed levels, alternative technologies will be explored.

- Although BEBs should eventually cost less than equivalent diesel buses due to lower maintenance and operating costs, TriMet does not have the resources to pay the up-front costs of converting the entire fleet to BEBs. Additional funding, beyond HB 2017, will be needed to support a full transition to BEBs.

- Changes to state and national policies and credit programs may support or detract from BEB viability. Tax credit programs such as Clean Fuel Credits must continue with at least the existing credit value for a transition to BEBs to be viable for TriMet. Policies that increase diesel prices but do not help finance BEB costs, while affecting the NPV calculation, do not make the transition more affordable.

TriMet will continue to monitor and explore alternatives such as hydrogen and RNG during the BEB trial period. If these technologies prove more attractive in terms of cost, emissions, reliability and customer service than BEBs, TriMet may move to pilot those technologies as well. Pilot testing of other technologies will occur at a garage other than Powell, which will have reached its two-fuel type limit with the combined diesel and BEB fleet based there.[31]

Title VI and Equity Considerations

TriMet's commitment to Title VI and equity can be seen across our agency, the transportation system we manage and the community we serve. It is embedded in the policies and practices we develop and implement.

TriMet has established standards and policies for evaluating and addressing equity considerations as set forth in the FTA's Circular 4702.1B. [32] These standards and policies assist in guiding the equitable development and delivery of service in support of TriMet's mission to provide valued transit service that is safe, dependable and easy to use. They also provide benchmarks to ensure that service design and operations practices do not result in discrimination on the basis of race, color or national origin, or place undue burdens on low-income populations. They establish a basis for monitoring and analysis of service delivery, availability and the distribution of amenities and vehicles to determine whether any disparate impacts are evident. In some cases, TriMet has adopted policies that exceed the federal requirements to ensure that its practices meet community expectations regarding equitable allocation of services.

In Oregon and across the U.S., low-income families and people of color are more likely to live in neighborhoods that have high concentrations of air pollution and, as a result, are at higher risk for

[31] TriMet has determined that it cannot support more than two fuel types at any single maintenance facility due to the need for parts, training, equipment and fueling infrastructure. Since diesel buses will remain in service at all TriMet garages for some years to come, each garage will have the capability of housing one alternative fuel bus type.

[32] https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Title_VI_FINAL.pdf.

chronic disease and premature death.[33] In alignment with TriMet's commitment to Title VI and equity, one strategy that TriMet can use to help address these impacts is to deploy non-polluting buses to routes that serve minority and low-income areas.

Historically, TriMet's goal for equitably assigning buses has been to ensure that the average age of vehicles that serve minority and low-income populations is no more than the average age of vehicles on routes in non-minority and higher income areas. However, in adopting this plan, TriMet intends to go beyond its historical practices and instead, prioritize the deployment of non-diesel buses to routes serving low-income and minority communities.

In anticipation of TriMet's plan to transition to zero-emission bus technology, staff has developed strategy to prioritize the deployment of non-diesel vehicles throughout the service area utilizing Title VI and environmental justice principles. Decisions about where to deploy BEBs will need to reflect technical and physical feasibility, such as achievable bus range and availability of charging facilities. Locating the initial BEB trial at the Powell Operations Facility will facilitate this effort because the garage already houses many routes serving low-income and minority neighborhoods. TriMet is in the process of upgrading the Powell facility and is incorporating BEB charging infrastructure into the design of these improvements.

Assuming that the initial BEB trial is successful and funding for a full conversion of TriMet's fleet to BEBs is found, TriMet's strategy is to locate BEBs at the Powell facility until that garage has reached capacity (approximately 300 buses) and then deploy BEBs out of other garages. In addition, if no alternative fuel source, such as CNG or hydrogen, proves attractive, the next facility to house BEBs is likely to be TriMet's new maintenance facility, currently being planned for northeast Portland. It is too early to determine which of the two remaining maintenance facilities, Merlo or Center Street, would be the next to receive BEBs. In any case, regardless of which garage is selected as a BEB base, TriMet will prioritize deployment of BEBs to the routes that serve low-income and minority populations and where characteristics route are consistent with the technology.

Chapter 6: Fiscal Analysis of Transitioning to a BEB Fleet

In evaluating the lifecycle costs of diesel buses versus BEB vehicles, it is appropriate to discount all future costs to current dollars. In looking at the year-by-year funding requirements for the purchase of a BEB fleet, it is appropriate to instead look at cost figures in year of expenditure dollars. The following funding requirements take into consideration all of the factors used in the lifecycle analysis: the costs of vehicle purchase, maintenance savings, tax credits and charging infrastructure, converted to year of expenditure figures to better understand the annual funding necessary to successfully accomplish the fleet conversion.

For purposes of this analysis, TriMet is assuming that the purchase of diesel replacement and expansion buses is already funded from existing resources such as the employer payroll tax, STIF and federal formula funds. Therefore, it is the net additional cost of BEBs that is of interest. Using a year of expenditure approach yields the net additional costs of BEB conversion in Table 3.

[33] http://nationalequityatlas.org/indicators/Air_pollution%3A_Unequal_burden.

Table 3. Net BEB premium over equivalent diesel cost in year of expenditure dollars

	Fiscal Year	No. of BEBs Purchased	Equivalent Diesel Bus	Electric Bus	BEB Premium
Phase I	2019	10	$ 5,453,195	$ 19,879,663	$ 14,426,469
	2020	10	$ 5,589,525	$ 10,678,295	$ 5,088,770
	2021	20	$ 11,458,525	$ 21,644,643	$ 10,186,118
	2022	20	$ 11,744,989	$ 21,995,276	$ 10,250,288
Phase II	2023	20	$ 12,038,613	$ 22,383,126	$ 10,344,513
	2024	62	$ 38,252,694	$ 82,071,597	$ 43,818,903
	2025	5	$ 3,162,017	$ 4,186,189	$ 1,024,172
	2026	5	$ 3,241,067	$ 2,625,698	$ (615,369)
	2027	60	$ 39,865,130	$ 81,813,220	$ 41,948,091
	2028	75	$ 51,077,197	$ 89,707,272	$ 38,630,074
	2029	65	$ 45,373,577	$ 97,289,085	$ 51,915,508
	2030	69	$ 49,369,942	$ 83,132,537	$ 33,762,594
	2031	82	$ 60,138,314	$ 129,121,996	$ 68,983,683
	2032	55	$ 41,345,091	$ 65,190,287	$ 23,845,197
	2033	62	$ 47,772,373	$ 75,075,126	$ 27,302,753
	2034	69	$ 54,495,179	$ 116,249,405	$ 61,754,227
	2035	66	$ 53,428,968	$ 82,956,784	$ 29,527,816
	2036	61	$ 50,615,852	$ 75,622,236	$ 25,006,383
	2037	62	$ 52,731,761	$ 102,006,781	$ 49,275,020
	2038	41	$ 35,742,778	$ 42,654,209	$ 6,911,431
	2039	5	$ 4,467,847	$ (21,731,350)	$ (26,199,198)
	2040	5	$ 4,579,543	$ (23,675,627)	$ (28,255,170)

As shown in Table 3, the annual average incremental additional cost of the BEB strategy is about $10 million per year for the period FY 2019 to FY 2023. After that point, the incremental costs increase dramatically due to the larger bus purchases programed for FY 2023 to FY 2027.[34] In those years, the average annual incremental additional cost is approximately $20 million. From FY 2028 to FY 2031, the annual incremental premium jumps to nearly $50 million per year on average.

As noted previously, to pursue a full conversion strategy, significant additional resources would need to be identified or costs would have to decline dramatically.

To begin the conversion process and respond to the legislative direction in HB 2017 (Keep Oregon Moving Act), TriMet approached the STIF advisory committee with the request to allocate a portion of the new regional funding to the Phase I BEB trial and beyond. The advisory committee agreed to consider this request and, subsequently, TriMet included the option of allocating STIF funds to a BEB strategy in its community outreach and engagement process for HB 2017. TriMet anticipates that the STIF committee will allocate both ongoing and one-time STIF resources over the initial five years of the new funding as the agency ramps up expanded services. TriMet suggested the allocation of $5 million in ongoing funding and $28 million in one-time funds. Combined, these resources are sufficient to meet

[34] TriMet's bus replacement schedule shows five buses needed in 2025 and 2026 due to the fact that there are five buses in TriMet's existing fleet that will be reaching 16 years of age in those two years. In all likelihood, TriMet will smooth out bus purchases over these four years, purchasing approximately 30 replacement buses per year in 2024 through 2027. In either case, the average annual premium for BEBs over this period is approximately $20 million per year.

the BEB cost premium for the Phase I trial period and the first year of full fleet conversion in FY 2023. Given current cost projections, this would allow for the purchase of a total 80 BEBs and associated charging infrastructure in addition to the 10 BEBs funded through FTA Low-No grants. After FY 2023, TriMet would have $5 million in ongoing STIF resources to address the premium costs of a full conversion to BEBs; however, additional resources would be needed to address the unfunded portion of the premium.

As of the writing of this report, the STIF advisory committee has made a preliminary allocation of these ongoing and one-time funds. Successful allocation to the BEB trial program will require approval by both the TriMet Board of Directors and the Oregon Transportation Commission (OTC).

TriMet has been successful in securing two federal Low-No grants for the purchase of a total 10 BEBs and associated charging infrastructure. While TriMet will continue to pursue additional grants, these resources are not of a scale to address the bulk of the non-diesel conversion strategy. There are a number of potential sources of funding for the full conversion of the fleet.

- **Carbon cap and invest resources:** If the Oregon Legislature moves forward with a carbon cap and invest program, it could allocate resources in the form of cash or monetizable credits to TriMet to offset BEB premium costs. In addition, it is anticipated that a portion of the new resources generated under a cap and invest bill will fall under the restrictions of Article IX, Section 3 of the Oregon Constitution, requiring that all taxes or fees on motor vehicles or fuel must be used for roads. The state and region could make a policy decision to replace un-flexed federal dollars used for roads with these new cap and invest resources and flex more federal resources to alternative modes, including BEB conversion.

- **Flexible federal transportation funds:** Flexible federal transportation funds are allocated to the Oregon Department of Transportation and a portion of those funds are sub-allocated to the Portland metropolitan region, where the Joint Policy Advisory Committee on Transportation (JPACT) and Metro set funding priorities.

- **Expanded tax credits:** State or federal tax credits that can be earned by virtue of BEB investments that reduce carbon emissions could generate revenue that the agency can use to make the BEB investments. Currently, Oregon has a modest tax credit, which could be expanded. The federal government has stopped issuing renewable identification numbers (RIN) credits, which, if reinstated, could provide additional resources.

There are two policy changes that TriMet believes would help facilitate the full conversion of its diesel fleet to non-diesel.

- **Utility partnerships:** In February 2018, the PUC issued Order No. 18-054, adopting a multi-party stipulation that authorized PGE to undertake a number of initiatives to advance the electrification of transportation. One element of that order allowed PGE to partner with TriMet in the design, installation and maintenance of charging infrastructure for five BEBs using on-route opportunity charging. This approach allowed TriMet to focus its time and resources on its area of expertise, the purchase of the BEBS, rather than on the charging infrastructure, an area outside TriMet's expertise. This approach resulted in the purchase of one additional bus and much more efficient and effective implementation of the new technology. TriMet would encourage the PUC and other policy makers to expand the pilot program contained in Order No.

18-054 to allow TriMet, PGE and other utilities to partner in similar ways on full-scale BEB infrastructure.

- **Bonding STIF resources:** Oregon Department of Transportation's (ODOT) current position is that STIF funds cannot be bonded because, although they are allocated based on a formula, the use of the funds depends on periodic plan approval by both the local STIF advisory committee and the OTC. The inability to bond STIF resources reduces TriMet's ability to effectively use these funds to support the BEB strategy. Given the fact that capital costs for BEB conversion occur up front, but benefits in reduced maintenance and fuel costs occur in later years, bonding for BEBs would appear to be an ideal opportunity to more closely align the costs and benefits of the conversion strategy. TriMet would encourage ODOT and the OTC to reconsider their interpretation and allow the bonding of STIF resources, just as they allow the bonding of their own gas tax revenues.

Conclusion

Global climate change is one of the most important environmental and economic challenges of our times. The impacts of unchecked carbon emissions are almost incalculably large. It is imperative that public entities like TriMet take steps not only to reduce their own carbon emissions but to provide leadership in this effort to help advance technological innovation and broader adoption of carbon emissions reduction strategies. Given imperative advances in technology and funding from HB 2017, TriMet can project conversion of its diesel fleet to alternative fuel by the year 2040 or before.

Successful passage of HB 2017, the Keep Oregon Moving Act, provides the region with the opportunity to pursue the combined strategy of substantially expanding transit service while beginning the conversion to a non-diesel bus fleet. Funding from HB 2017 is projected to be sufficient to both expand service hours and support the purchase of a test fleet of BEBs and associated charging infrastructure, plus one year of conversion over the next five years.

This analysis highlights that converting to BEBs has significant benefits in reduced air and noise pollution and, over the very long run, potential net savings due to lower costs of maintenance, operations and fuel. In the short term, however, BEBs and charging infrastructure cost significantly more than traditional diesel buses. These costs are incurred up front, but the savings are realized over many years of operation, with a "breakeven point" occurring years in the future.

TriMet cannot fully convert to a non-diesel fleet with current revenues. With an allocation of HB 2017 funds, TriMet can begin the conversion process, but completing it will require either significant additional resources starting in 2022 or a reduction in costs from innovation or new technologies beyond that currently projected by industry experts.

The analyses regarding technology and trends in the industry lead us to conclude that BEB conversion is the least-cost/least-risk approach to moving TriMet to a non-diesel fleet at this time. However, other technologies and options may also hold promise, and TriMet, in recommending a BEB strategy, is not foreclosing other options. Hydrogen fuel cell technology appears to be advancing to the stage where hydrogen powered buses would be feasible. Renewable natural gas also appears to be worth examining as an option.

TriMet is proposing to take its conversion strategy one step further, through the adoption of a strategy to convert its so-called “non-revenue vehicle” fleet to renewable energy sources. TriMet has approximately 300 vehicles, in addition to its trains and buses, including pool cars, supervisory vehicles, utility trucks and specialized vehicles. Not all of these vehicles are suitable for conversion to either battery electric or CNG. However, of the approximately 250 that are, TriMet plans to move forward with a strategy that would convert those vehicles by FY 2040 or before.

Equity is an important consideration in pursuing any conversion strategy. Low-income and minority neighborhoods often experience greater levels of air pollution from a variety of sources, both transportation and non-transportation related, than other areas. Strategic deployment of a BEB fleet to routes serving vulnerable communities can help reduce emissions in those neighborhoods.