Zero-Emission Bus Transition Strategy

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Acronyms and Abbreviations

APTA	American Public Transportation Association
ASE	Automotive Service Excellence
ATU	Amalgamated Transit Union
BEB	battery electric bus
BESS	battery energy storage systems
BRT	bus rapid transit
CDL	commercial driver's license
CES	Clean Energy Standard
CFS	Clean Fuel Standard
CHARGE	Consortium for Hydrogen and Renewably Generated E-fuels
CNG	compressed natural gas

CTE	Center for Transportation and the Environment
DER	distributed energy resource
ESS	energy storage systems
EV	electric vehicle
EVSE	electric vehicle supply equipment
FCEB	hydrogen fuel cell electric bus
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
GEM	Grounds, Equipment, and Maintenance
GHG	greenhouse gas
GTFS	General Transit Feed Specifications
ICE	internal combustion engine
JLM	journey level mechanic
kW	kilowatt
kWh	kilowatt hour
LOTO	Lock-Out-Tag-Out
MW	megawatt
NFPA	National Fire Protection Agency
NTI	National Transit Institute
OEM	original equipment manufacturers
OTJ	On the job
PPE	personal protective equipment
PSRC	Puget Sound Regional Council
PV	photovoltaic
RCW	Revised Code of Washington
RNG	renewable natural gas
RSG	responsibly sourced gas
RSI	related/supplemental instruction
SME	subject matter expert
SOC	state of charge
TDP	Transit Development Plan
WAC	Washington Administrative Code
WSDOT	Washington State Department of Transportation
WSTA	Washington State Transit Association
WSTIP	Washington State Transit Insurance Pool
ZEB	zero-emission bus
ZEBRA	Zero Emissions Bus Resource Alliance
ZEV	zero emission vehicle
ZEVIP	Zero Emission Vehicle Infrastructure Partnership

Executive Summary

Analysis

HDR worked with Pierce Transit to create a Zero Emission Bus Strategy to further the agency's electrification efforts and align with Federal Transit Administration (FTA) Zero Emission Transition Plan guidelines by developing a pathway to operating a zero-emission bus (ZEB) fleet. This plan analyzed a variety of aspects of Pierce Transit's fleet, operations, facilities, and staff to create a recommended path forward for ZEBs. The following are high-level takeaways from each portion of the analysis.

- **Industry Research**: There are a wide variety of battery electric and hydrogen fuel cell vehicles that fit Pierce Transit's vehicle specifications.
- **Stakeholder Engagement**: The community, including public utilities, is generally supportive of Pierce Transit's decision to incorporate more ZEBs into the fleet.
- **Policy and Legislative Impacts**: There are a variety of programs at the local and state level that support vehicle electrification, in addition to competitive federal transit programs.
- **Route Modeling**: Detailed modeling of Pierce Transit's existing transit service showed how ZEBs could operate service in three scenarios (Scenario 1: fully battery electric bus fleet with depot-only charging; Scenario 2: fully battery electric bus [BEB] fleet with depot and on-route charging; and Scenario 3: fully hydrogen fuel cell bus [FCEB] fleet). Scenarios 2 and 3 showed operational viability and were explored further for the near term (2023–2028) and long term (2029–2042).
- **Workforce Development**: Pierce Transit staff would need to complete various types of training to prepare mechanics and operators to work with ZEBs. A training program would be adopted or developed by Pierce Transit to train existing staff in ZEBs and avoid workforce displacement from adopting a new technology. Additionally, Pierce Transit is creating a career pathways trainee program to recruit new workforce.
- **Utility Coordination**: Pierce Transit met with public utilities to discuss the ZEB transition and was able to confirm incentives and power availability at multiple proposed charging locations. The agency will continue coordinating with the utilities to ensure successful and cost-effective ZEB deployments.
- **Financial Analysis**: The project team estimated costs associated with the long-term transition of the fleet to zero-emission vehicles (ZEVs). Additional funding is needed for the purchase of ZEBs and charging stations, as well as utility upgrades and charger design/construction.

Transition Plan Overview

Transition Strategy: As a result of this analysis, HDR and Pierce Transit developed a phased transition schedule to transition the bus fleet to primarily BEBs using on-route and depot charging. This transition schedule allows Pierce Transit to meet their goal of a 20 percent electric fleet by 2030 and anticipates a fully ZEB fleet by 2042. This plan is split into a near-term plan (2023–2028) and a long-term plan (2029–2042). The near-term plan is focused on BEB deployments and some previously planned internal combustion engine (ICE) deployments. The plan then provides two options when moving into the long-term plan: long-term BEB deployment and long-term FCEB deployment. At this time, Pierce Transit is anticipating the Long-Term BEB deployment; however, the agency remains open to FCEBs in the future if costs come down and fuel availability increases. This transition plan is written under the assumption that Pierce Transit continues adopting BEBs in both the near-term and long-term and provides high level information on how Pierce Transit could pivot toward FCEBs if conditions changed. (*See **Fleet Transition Plan** for more information*.)

Facility Plan: To support future BEBs, the Lakewood Base would need to undergo utility upgrades and charger installations for both the near-term and long-term BEB deployment. Pierce Transit would require 1.69 megawatts (MW) at peak load to satisfy the near-term BEB deployment (2023–2028) and 1.95 MW at peak load in the long term; Pierce Transit will need to coordinate with Lakeview Light and Power to ensure energy availability. The consultant team recommends a gantry system with overhead pantograph chargers to charge the buses overnight. (***See Facilities and Infrastructure Plan** for more information*.)

On-Route Charging: During the day, some buses would charge at on-route charging locations. The project team identified the need for 18 on-route chargers to provide midday charging at five different transit centers. In the near-term deployment, Pierce Transit would install one plug-in charger at Commerce Street Transit Center (charger was planned prior to making this strategy) and four pantograph or inductive chargers at the Lakewood Transit Center. In the long-term deployment Pierce Transit would install pantograph or inductive chargers at the following: four chargers at the Tacoma Community College Transit Center, four chargers at the Commerce Street Station, three chargers at the South Hill Mall Transit Center, and three chargers at the Tacoma Mall Transit Center. (*See **On-Route Charging** for more information*.)

Financial Plan: Transitioning the fleet to BEBs or FCEBs will require a larger up-front cost compared to the baseline fleet. The vehicles themselves cost more in 2023; however, the bulk of this increased cost comes from the infrastructure needed to support a new propulsion type. The project team evaluated the capital costs of three scenarios: (1) a compressed natural gas (CNG) Baseline Scenario where Pierce Transit continued moving toward a fully CNG fleet, (2) a BEB Long-Term Scenario where Pierce Transit was fully BEB by 2042, and (3) a Long-Term FCEB Scenario where Pierce Transit adopted BEBs in the near-term then transitioned to FCEBs in the long-term. The CNG Baseline Scenario is the lowest cost at $410 million, the Long-Term BEB Scenario is $590 million, and the Long-Term FCEB Scenario is estimated to be the highest cost at $648 million. To transition to a fully BEB fleet, it is estimated to cost $180 million more than the baseline scenario and to transition to a fleet of FCEBs it is estimated to cost $238 million more than the baseline scenario. A ZEB transition will require Pierce Transit to secure additional funding, and the speed of the transition will be heavily dependent on funding. (*See **Financial Analysis** for more information*.)

Introduction

Pierce Transit has long been committed to sustainability. The agency has a variety of initiatives including responsible fuel sourcing, recycling, participating in the American Public Transportation Association (APTA) Sustainability Commitment, having a dedicated green team, and prioritizing alternative fuels. Pierce Transit has been opting toward alternative fuels since the 1980s – the agency has operated compressed natural gas (CNG) buses for decades and introduced their first nine battery electric buses (BEBs) within the past few years.

The agency continues to explore other alternative fuel options in the coming years as they continually strive to become a cleaner, greener agency. In April 2008, the Agency's CEO issued Executive Order No. 1, which directs staff to continue the purchase of alternative-fuel vehicles, implement conservation strategies, and engage in other "green" practices. In June 2022, the Executive Order was amended by the new CEO to direct staff to explore and implement petroleum conservation and renewable fuel/energy. The executive order includes the following below.

- Committing to 20% electrification of revenue fleet by 2030
- Reducing vehicle idling time
- Implementing energy conservation strategies
- Implementing water conservation strategies
- Reducing toxic chemical use
- Sustainable procurement practices
- Pollution prevention, re-use, and recycling
- Green design in buildings and facilities
- Transit-oriented development

To further fleet efforts, in April 2022, Pierce Transit hired HDR to evaluate the feasibility of zero-emission vehicles (ZEVs) and to develop a zero-emission bus (ZEB) transition plan that would lay out a roadmap for Pierce Transit to convert the existing bus fleet to 100 percent ZEVs. This study included route modeling and simulations, lifecycle cost analysis, infrastructure and facility needs, utility coordination and identification of hydrogen fuel providers, and a phased fleet transition strategy. This ZEB Transition Plan also meets the federal requirements to apply for Federal Transit Administration (FTA) funding.

FTA Zero Emission Bus Transition Plan

The Bipartisan Infrastructure Law has introduced a new requirement that any federal grant application for projects related to ZEVs must include a zero-emission transition plan. Therefore, the FTA requires a Zero Emission Bus Transition Plan from each transit agency that applies for the FTA Low or No Emission Grant Program and the FTA Bus and Bus Facilities Grant Program for zero emission bus projects.

The FTA Zero Emission Bus Transition Plan must include the following six elements:

1. **Policy & Legislative Impacts:** Consideration of policy and legislation impacting relevant technologies.
2. **Fleet Transition Plan:** Demonstration of a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions.
3. **Facility & Infrastructure Plan:** Evaluation of existing and future facilities and their relationship to the technology transition.
4. **Utility & Fuel Partnerships:** Description of the partnership of the applicant with the utility or alternative fuel provider.
5. **Funding Plan:** Address the availability of current and future resources to meet costs for the transition and implementation.
6. **Workforce Transition Plan:** Examination of the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers. This focuses on supporting the applicant's short-term and long-term needs to operate and maintain ZEVs while avoiding displacement of the existing workforce.

The Pierce Transit Zero Emission Bus Transition Plan addresses each of these topics in the following report and the accompanying appendices.

Policy and Legislative Impacts

Local and regional climate action plans, in combination with nationwide alternative fuel initiatives, highlight supportive policy and legislation that encourages zero emission transit vehicle and infrastructure adoption. The following actions support Pierce Transit in zero-emission transitions at the local, regional, and state levels. As Pierce Transit begins transitioning its fleet into ZEVs with initial procurements of BEBs, it is also important to note that local utility partners are working to reduce emissions from the electric grid, from which the energy is pulled to power the bus fleet.

Pierce Transit Policies and Commitments

Pierce Transit believes sustainability practices must make good business, public, and environmental sense by balancing the community's economic, social, and environmental needs. At Pierce Transit, sustainability is a core value, addressed in terms of both the services provided and how the agency operates. Pierce Transit plays a key role in reducing the number of single-occupant vehicles on the road and the pollution they generate. In 2022, Pierce Transit customers skipped 5.5 million car trips, taking Pierce Transit buses, paratransit rides or vanpools instead. By seeking more efficient alternatives to existing practices, sustainability programs often lead to cost savings over time. Pierce Transit's commitment to sustainability is reflected throughout the conception, planning, design, construction, and operation of the system. Further, the following highlights demonstrate these commitments:

- **1986: CNG Demonstration Project.** In 1986, the Agency launched a four-year demonstration project to test the feasibility of using CNG as a fuel source for its bus fleet. Since 2004, the agency's entire fleet has been converted to alternative fuels. Smog-producing hydrocarbon emissions are 80 percent lower, and CNG buses produce very little black soot or other harmful particulates. Pierce Transit has nine BEBs. Electric vehicles emit no air pollutants directly. Pierce Transit's electricity source is 96 percent fossil-fuel free and produced within our region. Pierce Transit's clean-air efforts have garnered several awards from such groups as the American Lung Association, the Natural Gas Vehicle Coalition, American Gas Association, and the U.S. Department of Transportation. The U.S. Department of Energy honored Pierce Transit with a Clean Cities National Partner Award.
- **2008: Strategic Goals.** In 2008, the Board of Commissioners of Pierce Transit adopted Strategic Goals to provide Agency employees with a list of organizational values. Included in the list of values is a continued commitment to green technologies and strategies that respond to climate change and energy independence.
- **2016: APTA Sustainability Pledge.** In 2016, Pierce Transit pledged to adopt sustainable business practices and strategies by tracking, measuring, and reporting progress. Pierce Transit administers these practices on an ongoing basis to continually improve them over time. As a signatory to the APTA Sustainability Commitment, Pierce Transit actively supports and responsibly serves the community.

- **2022: Executive Order No. 1, Establishing a Commitment to Utilize Green Technologies and Strategies.** This Executive Order reinforces the Agency's environmental commitment and responsibility, and sets the framework for a more ambitious, comprehensive approach for addressing sustainability throughout the agency. Section 1 includes sustainable business practices and strategies that will be integrated throughout the Pierce Transit organization over time, including planning, designing, constructing, and operating existing and new transit systems and facilities. Section 2 directs staff to explore and implement the following measures to the maximum extent viable: Petroleum Conservation and Renewable Fuel/Energy; Energy Efficiency; Water Conservation, Toxics Reduction, Procurement, Pollution Prevention, Re-Use, and Recycling; Building and Facility Performance (Green Design/Green Building); Land Use; and Equity. Section 3 directs staff to identify measurable targets and timeframes, and Section 4 focuses on finances and resources.
- **2022: Sustainability Report and FTA Sustainable Transit for a Healthy Planet Challenge.** Pierce Transit signed onto the FTA Sustainable Transit for a Healthy Planet Challenge initiative in 2022 and submitted the comprehensive Pierce Transit Sustainability Report.
- **2022: Phase 1 Battery Electric Bus Fleet Transition Plan.** Pierce Transit created the Phase 1 Plan to illustrate a path towards achieving a comprehensive and equitable rollout of a clean transit fleet and infrastructure.

In addition, the following actions and policies highlight additional keys to Pierce Transit actions in place:

- **Dedicated Green Team:** Pierce Transit's Green Team comprises representatives from a variety of departments including Data Analytics, Marketing, Communications, Maintenance, Safety & Training, Community Development, ADA Eligibility, and Planning. The goal of the Green Team is to establish sustainability outcomes for the agency and develop best practices, benchmarks, and data collection protocol to measure outcome attainment. The Green Team works to improve public awareness of agency sustainability efforts, emphasize modernization, increase community partnerships, and expand our community experience.
- **Idling Reduction:** In 2018, Pierce Transit approved a vehicle idling policy intended to protect the health of our employees, passengers, and communities; conserve fuel, reduce pollution and harmful effects to the environment; prevent premature engine wear; and minimize operating costs. This policy applies to every Pierce Transit-owned vehicle.
- **Sourcing Fuel:** Pierce Transit currently purchases its CNG through a distributor, United Energy Trading, on the open market. As the market fluctuates, so does the price of gas per therm (a unit of heat equivalent). By purchasing several years' worth of gas at a time, Pierce Transit was able to lock in a reduced rate at a third of what the market averages right now. As good stewards of public funds, Pierce Transit seeks such opportunities to

reduce costs. Currently, market price of CNG is 90 cents per therm, and Pierce Transit pays 30 cents per therm, significantly saving the agency money.

- **Responsibly Sourced Natural Gas:** In late 2021, Pierce Transit began transitioning its vehicles that operate on CNG to responsibly sourced gas (RSG). This gas is mined, and during the mining process, there are greenhouse gas (GHG) emissions emitted. These emissions impact the air and therefore have a carbon footprint associated with them. RSG comes from mines that offset GHGs created during the mining process with other sustainable practices. While some would argue that using RSG is not a perfect process, it is far cleaner than running buses on diesel. In addition, each bus—regardless of its fuel source—takes potentially dozens of single-occupant vehicles off the road, which further reduces carbon output. Pierce Transit is also investigating using renewable natural gas (RNG). This gas comes from dairy farms or landfills that produce methane. This gas costs more, but the advantage is that it offsets exhaust emissions. By using this fuel, Pierce Transit would effectively operate with a neutral carbon footprint. Effective January 1, 2023, the Washington State will give companies carbon credits for using RNG. Moving to RSG and eventually RNG represents another step taken toward making Pierce Transit services sustainable.
- **Energy Efficiency:** Pierce Transit has installed LED lighting at Tacoma Dome Station parking garages, transit centers, and at headquarters on bus lot. This new lighting provides brighter illumination, movement- and daylight-sensitive fixtures to reduce time lit, and lower utility bills. With efficiency and sustainability in mind, Pierce Transit provides Toyota Prius and Ford Fusion Energi plug-in hybrid electric vehicles (EVs) to employees for use when travelling to meetings or running agency errands. There are charging stations set aside for these cars at headquarters. Pierce Transit also recently installed EV charging stations for employees to charge their personal vehicles; these are very popular and encourage employees to go electric. Hybrid electric vanpool vehicles are now part of the fleet, available for community use. Tacoma Public Utilities partnered with Pierce Transit to become the first recipient of eight plug-in Vanpool vans for their employees.
- **Carbon Footprint Monitoring:** There are different methods used to calculate the carbon footprint of a transit agency. A carbon footprint is the total amount of GHGs (including carbon dioxide and methane) that are generated by an entity's actions. Some agencies use the number of vehicles in their fleet, how much fuel is used for those vehicles, and the cost of utilities that support the vehicle operation. Pierce Transit has chosen to take a more comprehensive approach that includes not only fleet vehicles, but commute trips taken by employees in personal vehicles and in vanpools and carpools. Considering the operations of the agency as well as the associated travel made by its employees gives a more holistic picture of resource use. Calculating the agency's true carbon footprint, and planning ways to reduce that footprint, captures all aspects of service. To that end, Pierce Transit is working with an industry expert to examine data on resource use and process to establish the carbon footprint baseline. Having a clear understanding of the starting point then empowers the agency to make smart decisions

on what bus specifications, bus types, and other resources to procure. This is what has allowed the agency to reinvest fuel savings into other efforts.

City of Tacoma

2030 Climate Action Plan: In 2019, the Tacoma City Council declared a climate emergency in Tacoma and called for a new plan that would set climate strategies and actions that get us on a low carbon track by 2030 and works toward the goal of net zero emissions in 2050. While the 2030 Climate Action Plan contains numerous actions that are generally supportive of this transition effort, most specifically in support of Pierce Transit Zero Emissions is Action #19 by 2024, as part of the Better Breathing category (page 26, Community; and page 49, Section 2): *Provide support to Pierce Transit to develop a zero-emission transit plan and help Pierce Transit compete effectively for state and federal funding opportunities*.

Through the Phase II Community Input Summary, one of the top three strategies in the Top Draft Big Move Climate Strategies is: Zero emission transportation is affordable and available to all. Additionally, the action entitled Develop a zero-emission public transit plan with Pierce Transit was also strongly supported through this outreach. Finally, the plan also includes many actions related to transit including rail zero emissions, electrify city fleet, and expand transit mode share.

Pierce County

Transportation is the second largest contributor of GHG emissions in Pierce County, responsible for approximately 40 percent of all GHG emissions. Reducing GHG emissions in the transportation sector will reduce particulate matter pollution and improve air quality and human health. Communities living closest to busy roads will see the greatest improvement.

- **Sustainability 2030: Pierce County's Greenhouse Gas Reduction Plan (Sustainability 2030 Plan).** This plan builds on prior County sustainability efforts. In 2010, the County launched a Sustainability Initiative that met seven of its ten internal goals and saved millions of dollars. This initial effort evolved into a Sustainability 2020 Plan, which has resulted in more efficient internal operations and a reduction in GHG pollution. Washington State is calling for a 45 percent reduction of GHG emissions by 2030, a 70 percent reduction by 2040 and a 95 percent reduction by 2050. In alignment with the state mandates, the Sustainability 2030 Plan calls for Pierce County to reduce government operational and community wide GHG emissions by 45 percent by 2030. This plan establishes clear and actionable strategies to ensure Pierce Transit meets this goal through five areas of focus. The five areas of focus are: Energy and the Built Environment; Transportation; Consumption and Waste Reduction; Carbon Sequestration;

and Education and Outreach. From within the Transportation area of focus, three Actions support Pierce Transit zero emission transition:

- Action Identifier T-1: Support Pierce Transit's efforts to increase bus rapid transit with electric buses and to electrify their fleet.
- Action Identifier T-5: Support and participate in regional and statewide efforts to accelerate transportation electrification.
- Action Identifier T-8: Develop fleet electrification plan, including necessary charging infrastructure, and implement electric-first policy when purchasing replacement vehicles and other fuel burning equipment. When electric vehicles are inadequate, hybrid vehicles are preferred choice.

- **Climate Change Resilience Strategy for Pierce County:** Underway now, this strategy will soon develop recommendations with priority action steps that also support Pierce Transit zero emission transition. (Link: https://www.piercecountywa.gov/5558/Climate-Change-Resilience)

Puget Sound Regional Council

The region comes together at Puget Sound Regional Council (PSRC) to make decisions about transportation, growth management and economic development. PSRC develops policies and coordinates decisions about regional growth, transportation and economic development planning within King, Pierce, Snohomish and Kitsap counties. PSRC is composed of nearly 100 members, including the four counties, cities and towns, ports, state and local transportation agencies, and Tribal governments within the region. The mission is to ensure a thriving central Puget Sound, now and into the future, through planning for regional transportation, growth management. and economic development.

PSRC created Vision 2050 as the regional plan for sustainably managing growth over the coming decades. The plan prioritizes a comprehensive transportation system with all modes of travel and notes that two million people will be connected to the region's high-capacity transit system by 2050. The plan also highlights the need for GHG emissions reductions and aims to see an 80 percent decrease in GHGs by 2050 (compared to 1990 levels). While the plan does not explicitly call out electric vehicles, the plan promotes low-carbon travel choices and has overarching goals which electric vehicle adoption could help support.

Washington State

In Washington, the transportation sector is the largest source of GHG emissions and a major contributor to other types of air pollution. Under a 2020 law, Washington is required to reduce its overall GHG emissions 45 percent by 2030, 70 percent by 2040, and 95 percent by 2050. Since almost 45 percent of Washington's annual GHG emissions come from transportation, cleaner cars and trucks are essential to meeting these limits. Increasing the number of ZEVs on our roads will reduce total GHG emissions by the equivalent of 1 million metric tons of carbon dioxide a year by 2030.

Motor Vehicle Emission Standards – Zero Emission Vehicles Bill

Governor Jay Inslee signed the Motor Vehicle Emission Standards – Zero Emission Vehicles bill (Revised Code of Washington [RCW] 70A.30.010) on March 25, 2020. The result of this bill will be the adoption of California vehicle emission standards, including new requirements to increase the number of ZEVs sold in Washington. The law does not ban any gas or diesel vehicle currently on the road, but steadily replaces fossil fuel-powered vehicles with cleaner models for new vehicle sales.

Climate Commitment Act

Washington's comprehensive climate law is the Climate Commitment Act, signed by Governor Jay Inslee on May 17, 2021. The Climate Commitment Act establishes a "cap and invest" program that sets a limit on the amount of GHGs that can be emitted in Washington (the cap) and then auctions off allowances for companies and facilities that emit GHGs until that cap is reached. Over time, the cap will be reduced, allowing total emissions to fall to match the GHG emission limits set in state law. Auctioning allowances will raise money that will raise funds for investing in climate resiliency, reducing pollution in disproportionately affected communities and expanding clean transportation. Rulemaking for the Climate Commitment Act began in 2021, and the program's first compliance period will begin in 2023.

Clean Fuel Standard & Credit Generation Program

On May 17, 2021, Governor Jay Inslee signed the Clean Fuel Standard (HB 1091). The standard will cut statewide GHG emissions by 4.3 million metric tons a year by 2038 and will stimulate economic development in low carbon fuel production. The Clean Fuel Standard (CFS) will work beside the Climate Commitment Act to target the largest source of emissions in Washington. The CFS law requires fuel suppliers to gradually reduce the carbon intensity of transportation fuels to 20 percent below 2017 levels by 2038. There are several ways for fuel suppliers to achieve these reductions, including:

- Improving the efficiency of their fuel production processes
- Producing and/or blending low-carbon biofuels into the fuel they sell
- Purchasing credits generated by low-carbon fuel providers, including electric vehicle charging providers

The CFS creates the possibility of credit generation opportunities for public transit operators in Washington State, specifically those using alternative fuels, renewable fuels, electrification, and hydrogen. As a result of this legislation, the Washington State Transit Association (WSTA) is seeking consultant support in aggregating and marketing CFS credits on behalf of its membership. WSTA is seeking to act as an agent to aggregate the needs of its members under a single contract that would serve to assist members in education and generation of CFS credits and realizing the credits.

ZEV Infrastructure Partnership Program

The Washington State Alternative Fuel Vehicle Charging and Refueling Infrastructure Program (RCW 47.04.350) directs the Washington State Department of Transportation's (WSDOT's) Innovative Partnerships Office to develop and maintain a program to support the deployment of clean alternative fuel vehicle charging and refueling infrastructure supported by private financing. WSDOT refers to the program as The Zero Emission Vehicle Infrastructure Partnership (ZEVIP) program. ZEVIP consists solely of projects that provide a benefit to the public through development, demonstration, deployment, maintenance, and operation of clean energy technologies that save energy and reduce energy costs, reduce harmful air emissions, or otherwise increase energy independence for the state. Program funds are invested in the deployment of EV charging and hydrogen fueling stations at key intervals along state and federal highway corridors to support interurban, interstate, and interregional travel for clean alternative fuel vehicles.

Green Transportation Grant Program

The WSDOT Green Transportation Capital grant program provides funding to transit agencies for capital projects that reduce the carbon intensity of the Washington transportation system. This grant is supported by state funding through RCW 47.66.120. Project types include fleet electrification, including battery and fuel cell electric vehicles; modification or replacement of capital facilities to facilitate fleet electrification and/or hydrogen refueling; necessary upgrades to electrical transmission and distribution systems; and construction of charging and fueling stations. It is anticipated that there will be a minimum of $12 million and up to $50 million in state funding for Green Transportation Capital Grants in the 2023–2025 biennium. The Legislature will determine the funding level in the 2022–2023 legislative session.

Other State Policies

SB 5910: This legislation advances Washington's first statewide strategy to pursue a renewable hydrogen economy by authorizing financial support from the state for a public-private partnership, in efforts to apply for the Bipartisan Infrastructure Law's clean hydrogen hub funding. Existing renewable energy resources in the Pacific Northwest make Washington an ideal location for a hydrogen hub that is supported by both public and private partnerships. The bill passed on June 9, 2022, and now authorizes public utility districts to produce, sell, and own/operate pipelines to supply green electrolytic hydrogen. It also created an Office of Renewable Fuels within the Washington State Department of Commerce and allows the State to support a funding application for a public-private partnership to produce clean hydrogen.

HB 1988: This act establishes a retail sales and use tax deferral program for certain investment projects in clean technology manufacturing, clean alternative fuels production, and renewable energy storage. Permitted investments include renewable hydrogen production and ZEV refueling infrastructure. Investments in these areas will work to expand accessibility to clean hydrogen resources, while encouraging more robust deployment and use.

Federal Programs

The FTA has been a major influence on the progression to a ZEB fleet for transit agencies nationwide. The following are some of the national programs and policies that are pushing the fleets of the future towards zero emissions:

- **FTA 5339 (a): Buses and Bus Facilities Program:** Provides funding through a competitive allocation process to states and transit agencies to replace, rehabilitate, and purchase buses and related equipment. This includes the purchase of ZEVs and related infrastructure.
- **FTA 5339 (c): Low or No Emission Competitive Program:** Provides funding to state and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses as well as acquisition, construction, and leasing of required supporting facilities.
- **U.S. Department of Energy's Energy Earthshots Initiative:** Launched in 2021, the Hydrogen Shot program seeks to reduce the cost of clean hydrogen by 80 percent to $1 per 1 kilogram in 1 decade.
- **Clean Energy Standard (CES):** This initiative is still being developed. The CES is intended to set a national standard for emissions-free power with a goal of generating 80 percent clean electricity by 2030 and 100 percent by 2035.

Fleet Transition Plan

This section details the recommended near term and long-term deployment of ZEBs for Pierce Transit's revenue bus fleet. The near-term deployment is intended to be more detailed and provide a roadmap to meeting Pierce Transit's goal of 20 percent ZEBs by 2030. The long-term strategy provides a vision to operate ZEBs on all Pierce Transit bus routes by the 2042. While Pierce Transit is committed to fully transition the fleet, actual long-term deployments will depend on funding availability and future vehicle capabilities.

The consulting team and Pierce Transit utilized all parts of the ZEB analysis to develop this plan. Some major points of consideration when building the transition plan included the following: (1) route modeling and projected ZEB performance on Pierce Transit routes, (2) energy needs for ZEBs, (3) existing transit asset management plan, (4) existing bus facility conditions, (5) identifying possible on-route charging locations, (6) existing funding and additional funding needed for ZEB deployments, (7) utility coordination and incentives, and (8) environmental justice considerations and prioritizing Justice40 communities.

Pierce Transit Zero Emission Bus Goals

Near-Term Goal: Operate **20%** of bus fleet with zero emission buses **by 2030**

Long-Term Goal: Operate **100%** of bus fleet with zero emission buses **as soon as feasibly possible**

Zero Emission Vehicles and Fueling Options

Transit agencies across the globe seeking to reduce GHG emissions are adopting alternative vehicle technologies to replace conventional diesel and CNG buses as the vehicles reach the end of their useful life. The two alternatives taking the lead in the North American market are BEBs and FCEBs, both of which produce zero tailpipe emissions. **Figure 1** shows how each technology utilizes an energy source to power a battery, which in turn powers the rest of the vehicle while producing no tailpipe emissions.

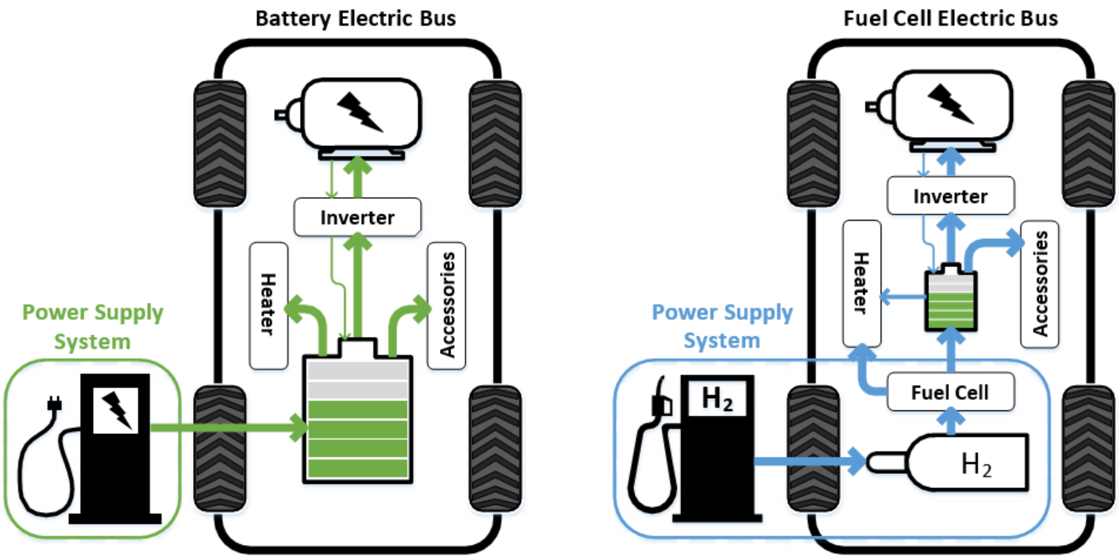


Figure 1: Battery Electric and Fuel Cell Bus Technologies

Battery Electric Buses: BEBs are currently the preferred alternative vehicle technology for North American agencies for a variety of reasons. Because there have been significantly more BEB deployments than FCEB deployments, there is a larger North American market for BEBs. Additionally, the fuel source for BEBs is delivered by the same extensive electric grid that powers the rest of North America's infrastructure. BEBs store power in battery packs that is converted to kinetic energy as a bus moves. BEBs also recuperate a percentage of battery life through regenerative braking – the preservation of kinetic energy that occurs when BEBs idle and/or decelerate. Charging infrastructure for BEBs can be located inside or outside of bus depots or maintenance facilities as well as in locations along established bus routes using either overhead or inductive (wireless) chargers. Charge time can vary from minutes to hours depending on the charging technology deployed. BEBs have a limited operational range compared to conventional buses, and the distance they can travel per charge is impacted by elevation, route profile, ambient temperature, and driver habits. While on-route charging infrastructure extends the operational range of BEBs, it is not always enough to provide BEBs with the same operational range as conventional buses.

Fuel Cell Electric Buses: FCEBs are not as prevalent as BEBs in North America but are quickly gaining traction with the increase of manufacturers entering the market and increased hydrogen supply reliability. FCEBs hydrogen storage tanks, fuel cells, and battery packs smaller than those located within BEBs. The hydrogen stored onboard an FCEB is used by its fuel cell to provide power to its battery packs as needed, and the energy residing in the battery packs is converted to kinetic energy as the bus moves. FCEBs also have regenerative braking, which preserves a percentage of energy that would otherwise be lost during idling and decelerating. Hydrogen refueling is practically identical to CNG refueling. Fueling infrastructure for FCEBs is typically limited to a designated location with specialized hydrogen storage tanks and dispensers. FCEBs refuel in a matter of minutes from empty; due the energy density of hydrogen, the operational range for FCEBs is similar to that of conventional diesel buses. The lack of need for supplemental refueling makes FCEBs a more attractive zero-emission option for transit agencies with longer routes.

While there are no emissions produced in the operation of BEBs or FCEBs, there are still well-to-wheel emissions – the total emissions related to the production, processing, distribution, and use of fuel[1] that power these alternative vehicle technologies. The amount of well-to-wheel emissions can vary for either form of technology depending on the source of electricity or hydrogen. The use of renewable power sources such as solar, wind, and hydropower can assist in mitigating well-to-wheel emissions, as the lack of emissions produced during energy production in addition to the lack of tailpipe emissions produced during operations yields zero well-to-wheel emissions. **Table 1** shows a high-level comparison of BEB and FCEB technologies.

[1] Alternative Fuels Data Center: Emissions from Electric Vehicles (energy.gov)

Table 1: Summary Comparison of BEB and FCEB Technology1F[2]

Consideration	Battery Electric Bus	Fuel Cell Electric Bus
Reliable Range	Likely less than 150 miles in transit service on a single charge (or indefinite range with on-route charging)	Between 200 and 320 miles in transit service before refueling
Fueling Technology	Depot or on-route charging • Plug-in charging • Overhead conductive charging • Wireless inductive charging	Hydrogen storage and fueling station • Purchase delivered gaseous or liquid hydrogen • Produce hydrogen on-site through electrolysis or natural gas reformation
Capital Costs	• BEBs are more expensive than diesel buses in 2023 • Charging infrastructure costs vary and may not scale easily depending on facility • Incremental costs or space requirements increase with fleet size	• FCEBs are more expensive than BEBs in 2023 • Fueling infrastructure costs vary and depend on the required fueling rate • Infrastructure is scalable; additional buses may not require additional infrastructure
Refueling Considerations	• Depot-charged buses may require hours to fully charge • Electricity rates will have a significant impact on operational costs • AC or DC charging options available depending on bus OEM	• Refueling procedure and time required are slower than diesel buses, but similar to CNG refueling • Electricity costs may be significant if producing hydrogen on site • Costs will vary based on production method or delivery distance

[2] TCRP Guidebook for Deploying Zero-Emission Transit Buses (2021)

Route Modeling

Transitioning to a zero-emissions fleet involves more than simply buying a vehicle and fueling system. The transition introduces new technology and requirements into day-to-day operations. Successful fleet transition plans take a holistic approach to consider operational requirements, market conditions, available power, infrastructure demands, and costs. The in-depth route modeling summarized below provides Pierce Transit with data to guide important decisions involving capital programs and operations necessary to transition the bus fleet to ZEVs. For complete details on the route modeling performed, see **Appendix A: Route Modeling Technical Memorandum**.

The first step in exploring ZEVs is use existing conditions to evaluate the current routes and fleet vehicles used to provide service. The evaluation began by collecting and reviewing all available background documents and data relevant to the study. All data collected and reviewed feeds into the modeling effort and analysis that follows. Key data inputs included:

- Operator blocks for weekdays and weekends
- Block- and bus-type assignments
- General Transit Feed Specifications (GTFS) data from pre-COVID service for transit blocks on weekdays and weekends
- Ridership data by route or block for typical weekdays and weekends
- Transit Service Plan and Transit Development Plan (TDP)
- Background policy documents
- Operations information including revenue and deadhead hours and miles
- Fleet replacement plan
- Drawings and as-built electronic drawings of the Pierce Transit operations and maintenance facility
- Maintenance costs required to develop the financial model baseline
- Scheduled maintenance and overhaul plan
- Financial plan

Battery Electric Bus Depot Charging Simulation

Depot charging only was modeled first to establish a baseline feasibility. This scenario allows the Zero+ Model to identify which existing service blocks can be electrified without an increase in peak vehicle requirements, the need for on-route charging, or the need for schedule modifications to achieve the same level of service. By electing a depot-only charging profile, the model calculates what staff, vehicle, and service modifications would be needed to maintain the current level of service.

Simulation Assumptions

To develop a model relevant for Pierce Transit's fleet and operations, a set of assumptions and variables were identified (**Table 2**). Depot charger power is assumed to be 150 kW as this is standard today, however manufacturers have recently started creating 180 kW depot chargers. Modeling assumes charging at a rate of 150kW but it should be noted that the buses could charge at a rate of 180 kW. 150 kW was used to create a more conservative model. While these attributes are typical of most vehicle original equipment manufacturers (OEMs), not every vehicle would meet this specification. When Pierce Transit procures vehicles for this transition, it is crucial to ensure that vehicle procurements meet or exceed this minimum specification to deploy BEBs that can match the operations simulated in this profile.

Table 2: BEB Depot-Charging Simulation Assumptions

Variable	Input
Battery Capacity 40-ft Buses	466 kWh
Battery Capacity 60-ft Buses	525 kWh
End-of-Life Battery State of Health	80% (Max Battery Degradation)
Energy Reserve	20% State of Charge (SOC)
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity
Depot Charger Power	150 kW (95% Efficiency)

Model Results

Key Takeaways (**Figure 2**):

- Revenue Hours and Miles remain the same
- Non-Revenue Hours: **70% increase**
- Non-Revenue Miles: **62% increase**
- Peak Vehicle Requirement: **44% increase**
    - Increase Fleet from 128 to 184 buses
    - 56 more vehicles required
- At least 77 Depot Chargers will be required

Figure 2: BEB Depot-Only Model Outputs

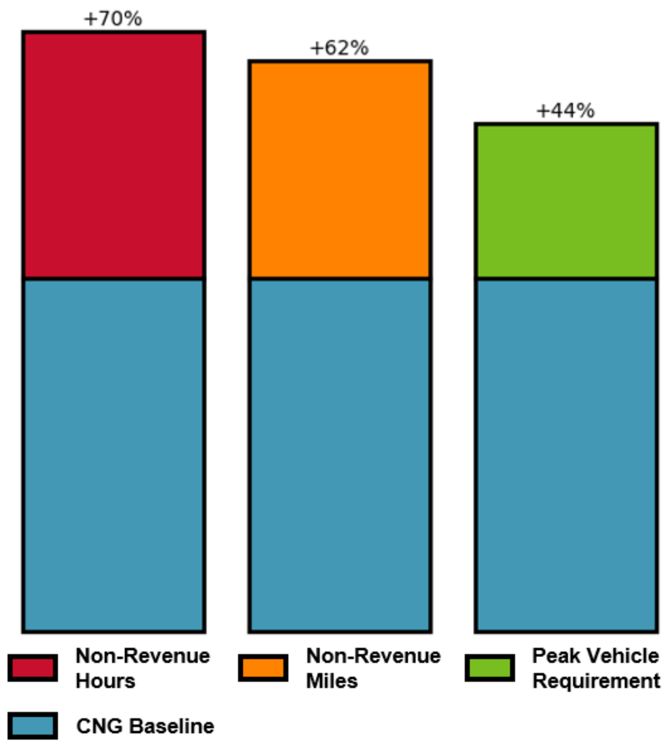
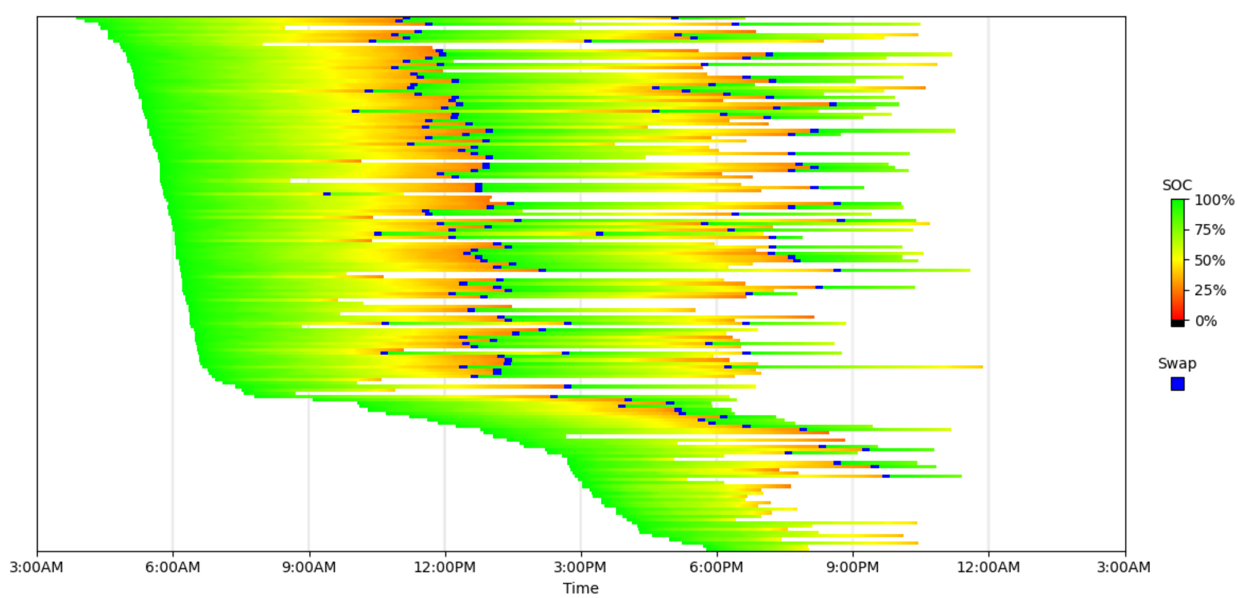


Figure 3 shows the vehicle battery SOC plot for each time block during for weekday service. Weekend service was also modeled, but fleet and charging requirements are driven by weekday service, which illustrates the most demanding operations for Pierce Transit. Each block is represented by a line on the chart with the color of the line corresponding to the SOC of the vehicle. The color changes from green to yellow to red as the SOC drops from 100 to 0 percent. Bus swaps (shown in blue) are introduced only between trips to minimize service impacts.

Figure 3: BEB Depot-Only Block State of Charge (Weekdays)



Bus swaps are also inserted in locations to guarantee the minimum SOC does not dip below the required 20 percent reserve capacity, including the energy needed to return the vehicle to the depot when a swap is needed. Whenever a vehicle is swapped out, it is replaced with a BEB that has a fully charged battery. Swapping buses is only helpful when the bus either stays near the depot all day or returns within a close distance to the depot at multiple points throughout the day. If a block is scheduled to travel a long distance one way away from the depot, then there is no opportunity for a swap. Pierce Transit could deploy 29 BEBs before fleet increases will be required.

Battery Electric Bus Depot + On-Route Charging

On-route charging is an enhancement that can greatly improve the feasibility of BEBs in many situations. This is particularly helpful with circulatory routes where the same on-route charger can be used by a vehicle multiple times throughout the day. On-route charging infrastructure is ideally located at places such as transit centers where buses operating on multiple routes all have scheduled layover time. On-route charging is capable of greatly extending the range of a BEB and facilitating one-to-one replacement of diesel vehicles when the routes are conducive to this charging strategy.

Simulation Assumptions

The simulation assumptions for the BEB Depot + On-Route Charging Scenario, as shown in **Table 3**, are similar to the assumptions for the BEB Depot Charging Scenario. The only difference is the assumption for on-route charger power and charging efficiency. Although there are on-route chargers on the market that offer more power (450 kW), there are currently no vehicles on the market that can accept this level of power. Route modeling assumed BEBs will be able to charge at 450kW in the future. OEMs have prioritized increasing the charge speed and it is expected that the vehicles will soon be able to charge at 450kW. When Pierce Transit procures vehicles for this transition, it is crucial to ensure that vehicle procurements meet or exceed this minimum specification to deploy BEBs that can match the operations simulated in this profile.

Table 3: BEB Depot + On-Route Charging Simulation Assumptions

Variable	Input
Battery Capacity 40-ft Buses	466 kWh
Battery Capacity 60-ft Buses	525 kWh
End-of-Life Battery State of Health	80% (Max Battery Degradation)
Energy Reserve	20% State of Charge (SOC)
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity
Depot Charger Power	150 kW (95% Efficiency)
On-Route Charger Power	300 kW (95% Efficiency)

On-Route Charger Locations

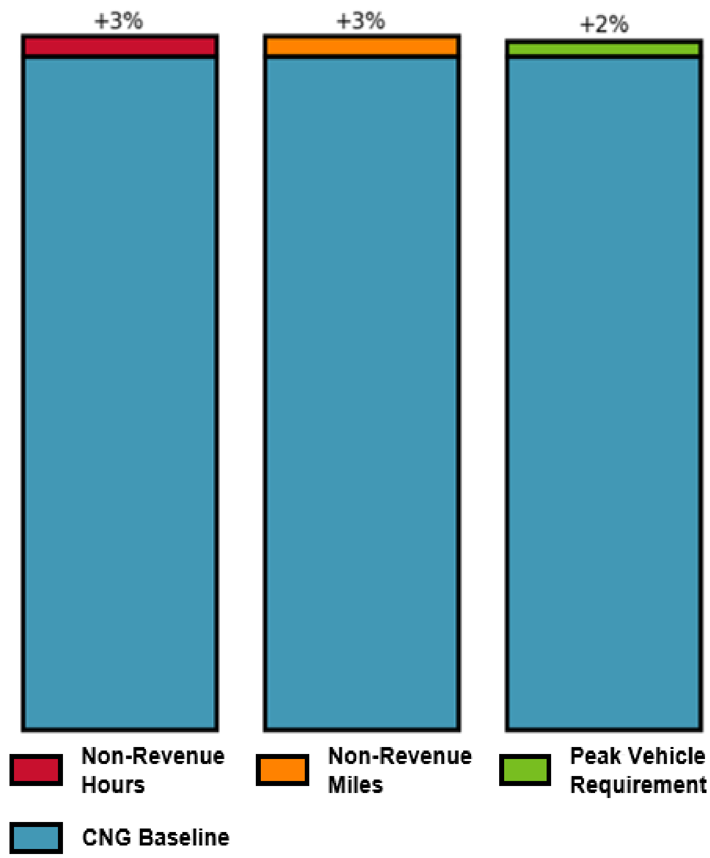
Layover times in the existing schedule were used to identify the most ideal locations for on-route chargers. There were twelve transit center, eight of which had good layover time and five of which were identified as good candidates for on-route charging. Most of these locations could make good use of a single charger, while some locations may require more chargers. The usefulness of an additional charger is dependent on how layover times overlap between vehicles. The **Facilities and Infrastructure Plan** section of this report will provide details on potential on-route charging locations.

Model Results

Key Takeaways (**Figure 4**):

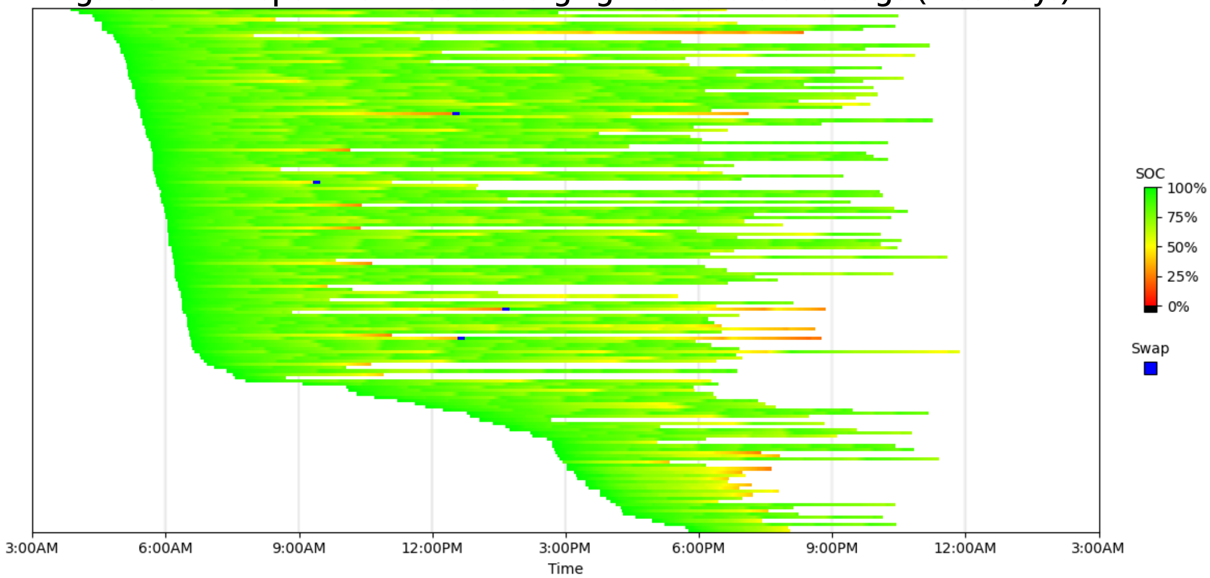
- Revenue Hours and Miles remain the same
- Non-Revenue Hours: **3% increase**
- Non-Revenue Miles: **3% increase**
- Peak Vehicle Requirement: **2% increase**
  - Increase Fleet from 128 to 131 buses
  - 3 more vehicles required
- At least **11 depot chargers** will be required
- Up to **18 on-route chargers** could be required

Figure 4: BEB Depot + On-Route Model Outputs



The vehicle battery SOC plot shown in **Figure 5** illustrates the SOC for each time block during weekday service for the BEB Depot + On-Route Charging Scenario. Weekend service was also modeled, but fleet and charging requirements are driven by weekday service, which illustrates the most demanding operations for Pierce Transit. Bus swaps are also inserted in locations to guarantee the minimum SOC does not dip below the required 20 percent reserve capacity, including the energy needed to return the vehicle to the depot when a swap is needed. By introducing on-route charging, the number of bus swaps required dropped significantly. For this scenario, 161 blocks can be operated without bus swaps while only 4 blocks require one or more swaps. Pierce Transit could operate up to 18 BEBs before on-route charging is needed. Because Pierce Transit is underway with an on-route charging station at Commerce Street Station, the agency can exceed the 18 BEBs modeled.

Figure 5: BEB Depot + On-Route Charging Block State of Charge (Weekdays)



Hydrogen Fuel Cell Bus Simulation

As transit agencies look for a zero-emission technology to replace diesel buses, there are two primary options, BEBs and FCEBs. Currently, BEBs are the most popular replacement choice because they use the electrical grid as their fuel source, which is universally available and relatively easy to connect into to get the required power. However, the vehicles have a limited range compared to diesel, which means they are not capable of directly replacing buses with long duty cycles or blocks. In some cases, it is not possible to re-cut the routes into pieces that are within the capability of a BEB, so an alternative zero-emission technology is needed. This portion of the route modeling assessed the use of FCEBs on Pierce Transit's fleet and **Table 4** explains the assumptions used to run the model.

Table 4: FCEB Simulation Assumptions

Variable	Input
Service Data	2020 (Pre-COVID)
Fuel Capacity	37.5 kg
Energy Density	33.6 kWh per kg of Hydrogen
Energy Reserve	5% or less remaining fuel
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity

Model Results

Key Takeaways:

- Revenue Hours and Miles: **0% increase**
- Non-Revenue Hours and Miles: **0% increase**
- Non-Revenue Miles: **0% increase**
- Peak Vehicle Requirement: **0% increase**

All 161 existing service blocks are capable of being operated by FCEBs without an increase in peak vehicle requirements, revenue hours and miles, or non-revenue hours and miles. In addition, there would be no need for mid-block refueling or schedule modifications to achieve the same level of service as a diesel-operated service. An exact 1-to-1 replacement of diesel buses is possible because FCEBs typically have an operational range comparable to diesel buses and only require 7 to 10 minutes on average to refuel. There would be a large infrastructure cost in preparing to deploy FCEBs, but little operational impact to refueling, unlike the complex operations required to manage BEB charging.

Recommended Fleet Replacement Schedule

Through extensive discussion with Pierce Transit, it was determined that a primarily battery electric fleet with depot and limited on-route charging would best fit the needs of the agency. **Figure 6** shows the proposed fleet composition from 2022 to 2042 by fuel type. **Figure 7** shows the year-by-year procurement from 2022 to 2042. This schedule aligns with the current transit asset management plan bus replacement schedule. At the start of the ZEB transition, Pierce Transit would be procuring few BEBs. The 2023 procurement is already in motion and the 2024 procurement is already set due to a previous electric bus grant award. Pierce Transit is using previously secured grant funding to purchase three BEBs, three 62.5 kW depot chargers, and one on-route 180 kW charger with three dispensers. These plans were set in motion prior to creating the ZEB transition plan. Starting in 2025, Pierce Transit would start ordering larger quantities of BEBs, and by 2027 the agency would only be replacing retired buses with BEBs.

Figure 6: Proposed Fleet Composition from 2022-2042

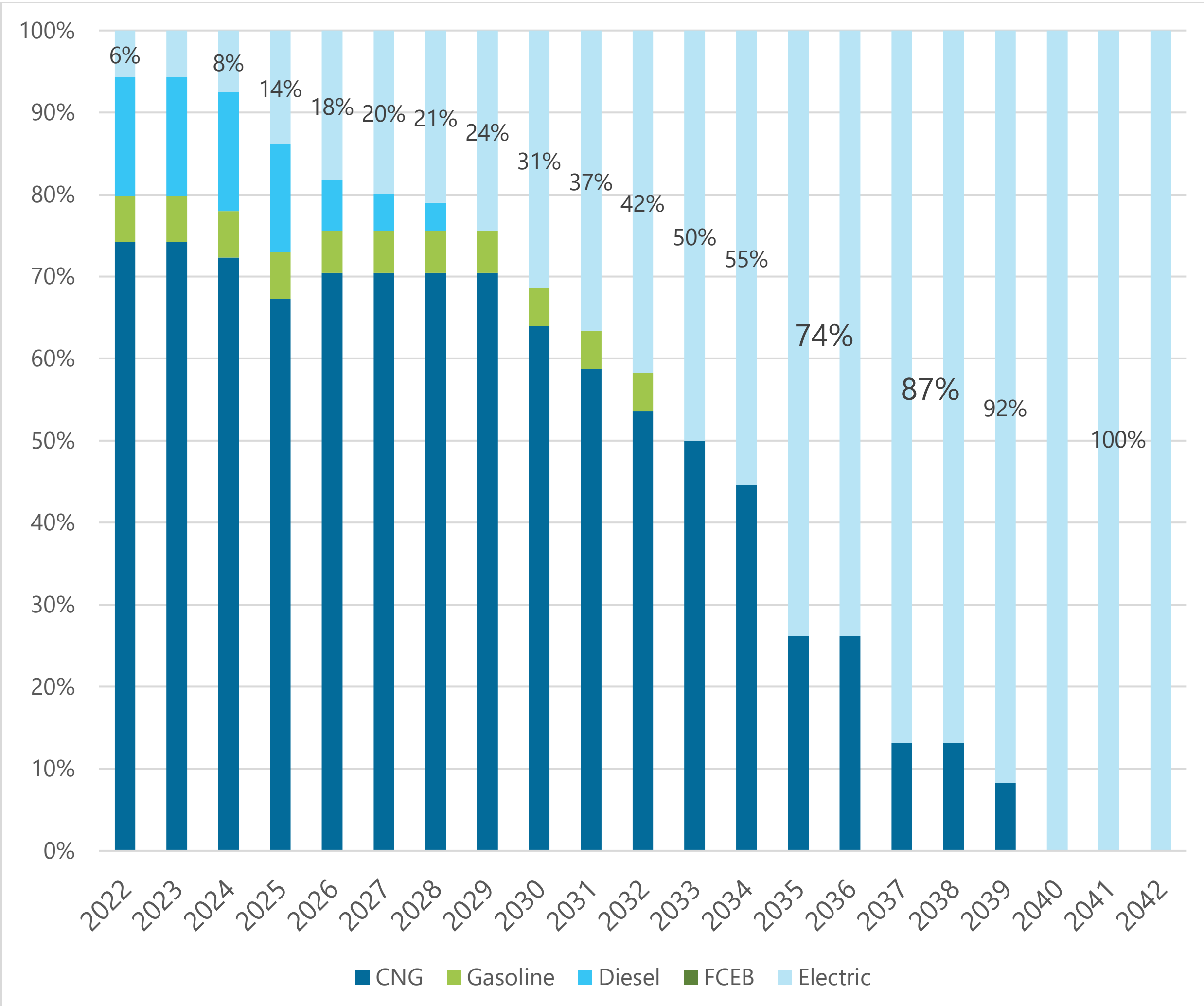
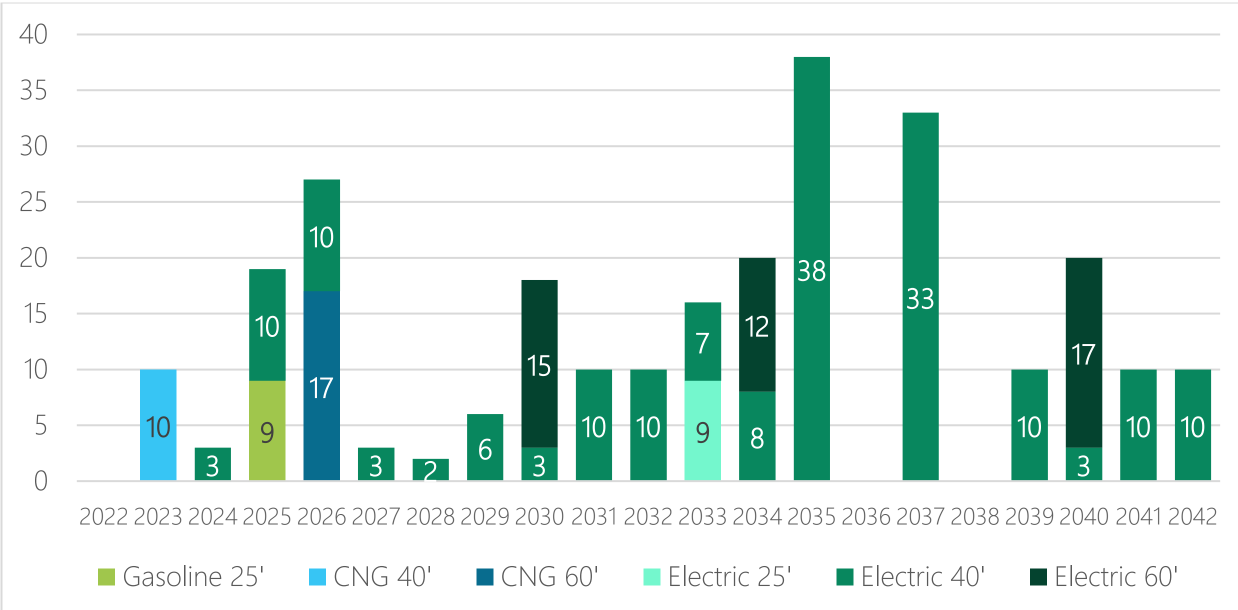


Figure 7: Vehicle Purchases by Year



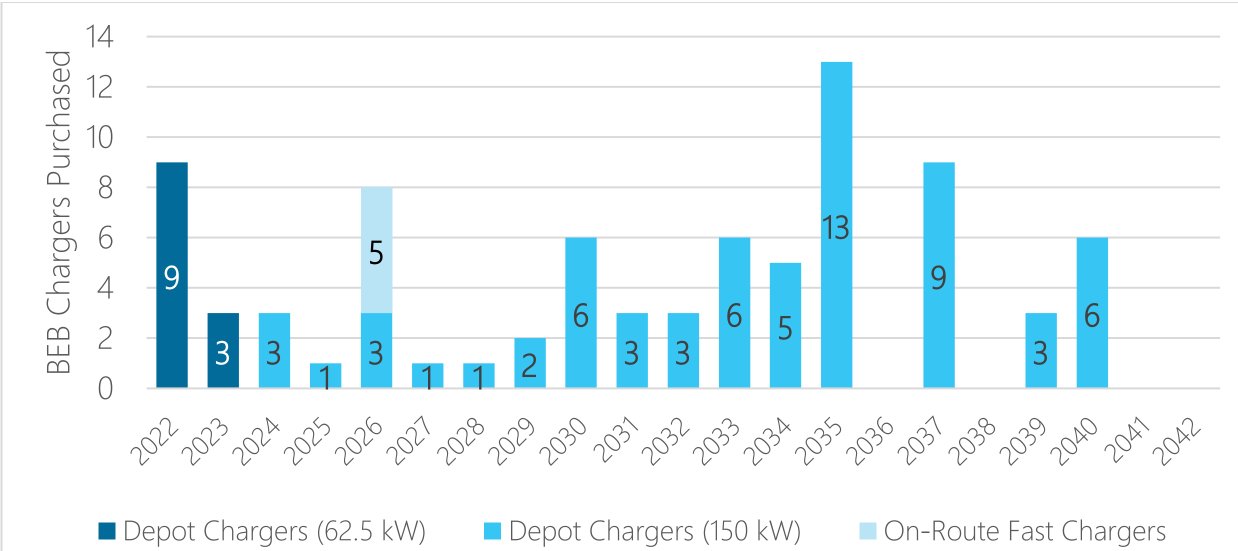
In order to operate BEBs, additional charging infrastructure will be required incrementally. Pierce Transit would primarily use 150 kW depot chargers to charge buses; however, a few on route chargers are needed once the fleet exceeds 18 BEBs. The charging infrastructure deployment will need to be completed by the time the buses arrive, so planning, design, and construction will need to occur prior to the deployment.

The infrastructure purchase schedule is indicated in **Figure 8**.

All 150 kW depot chargers are planned for a 3:1 dispenser-to-charger ratio. This report shows conceptual designs of depot charging with pantograph chargers and a gantry system, however Pierce Transit has yet to decide the charge dispense method so pantographs should be regarded as a conceptual design.

The 62.5 kW depot chargers will have a single dispenser. The on-route charging will be comprised of one 180 kW charger with three dispensers and four 450 kW chargers each hooked to one inductive charging pad.

Figure 8: BEB Chargers Purchased by Year



Near-Term Deployment: 2023–2028

37 Battery Electric Buses | 21 Depot Chargers | 5 On-Route Chargers

Bus Procurement

The near-term deployment is defined as 2023 to 2028. The consulting team is recommending a near term deployment schedule that will help Pierce Transit reach their 20 percent ZEB goal three years earlier than planned. The goal called for 20 percent ZEBs by 2030 and this transition schedule shows Pierce Transit operating 20 percent ZEBs by 2027. While this is sooner than the goal calls for, it appears feasible to purchase and operate this quantity of BEBs at Pierce Transit. To reach the 20 percent goal Pierce Transit would need to operate 26 BEBs. Pierce Transit plans to replace 26 buses by 2027.

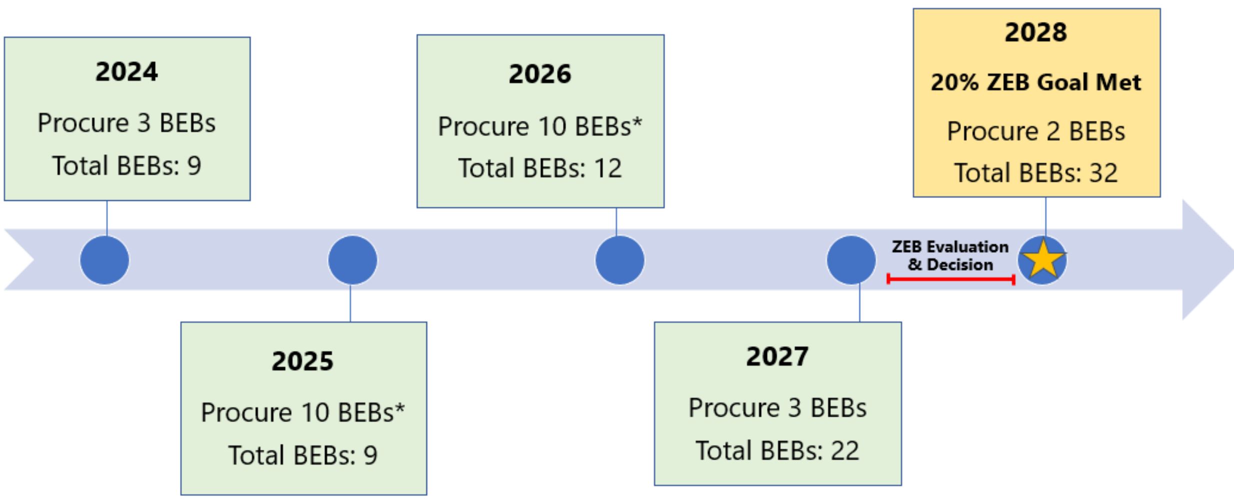
Table 5 shows the recommended bus purchases by fuel type from 2023 to 2028. Based on this schedule, Pierce Transit would proceed with their planned ten 40-foot CNG bus purchase in 2023 and utilize grant funds to purchase three 40-foot BEBs in 2024 to replace vehicles at the end-of-life. In 2025, the agency would purchase ten 40-foot BEBs and nine 25-foot gasoline cutaways to replace existing vehicles. In 2026, Pierce would purchase seventeen 60-foot CNG buses to operate the new bus rapid transit (BRT) line and ten 40-foot BEBs to replace vehicles at the end-of-life. From 2027 to 2028, the agency would continue purchasing BEBs to replace vehicles at the end of their useful lives.

Table 5: Bus Purchases by Year from 2023-2029

Fuel Type	Length	2023	2024	2025	2026	2027	2028
CNG	60'	-	-	-	17	-	-
CNG	40'	10	-	-	-	-	-
Electric	40'	-	3	10	10	3	2
Gasoline	25'	-	-	9	-	-	-

During 2027 and 2028, Pierce Transit should begin evaluating the status of the near-term deployment and the development of BEB and FCEB technology to confirm how to proceed in the long term. This plan assumes the continuation of BEBs with depot and on-route charging, however Pierce Transit could decide they want to integrate hydrogen fuel cell buses. See **Figure 9** for a BEB and charging infrastructure procurement timeline.

Figure 9: Near-Term Bus Procurement and Deployment Timeline



**Part of 2023 Lo/No Ask*

Depot Charging Strategy

To charge the BEBs in the near-term scenario, Pierce Transit would need to install 12 depot chargers and four on-route chargers. Pierce Transit currently has nine depot chargers. In total, Pierce Transit would have 21 depot chargers and four on-route chargers by 2028. Of the new depot chargers, nine would be 150 kW (charge delivery method proposed as pantograph but not yet confirmed) and three would be 62.5 kW plug-in chargers. In this conceptual design, each 150-kW charger would dispense power through pantograph chargers on a gantry system. The gantry system would be constructed in 2025 and built to accommodate chargers up to 2028. With three pantograph dispensers per one 150 kW charger, the facility would have 25 pantograph charging spots. This charging configuration could accommodate up to 27 pantograph charging spots; however, the parking layout only allows for 25. This brings the total number of charging ports for the near-term deployment to 37.

Figure 10 shows the conceptual charging layout for the new pantograph chargers. Note that this is a conceptual design rather than an approved charging plan; more discussion will occur internally at Pierce Transit before deciding on a charging delivery method.

Each 150-kW charger would have three pantograph dispensers and the gantry system would be sized to charge twenty-five 60-foot buses. Buses would be parked nose-to-tail. To the south of the gantry system would be the nine existing 62.5 kW plug-in chargers and three additional plug-in chargers used to power the BEBs purchased in 2024. Each charger has one dispenser and buses would be parked side-by-side. To the north of the gantry system would be existing parking for twenty-one 45-foot MCI buses.

Figure 10: Lakewood Base Charging Layout (2028)

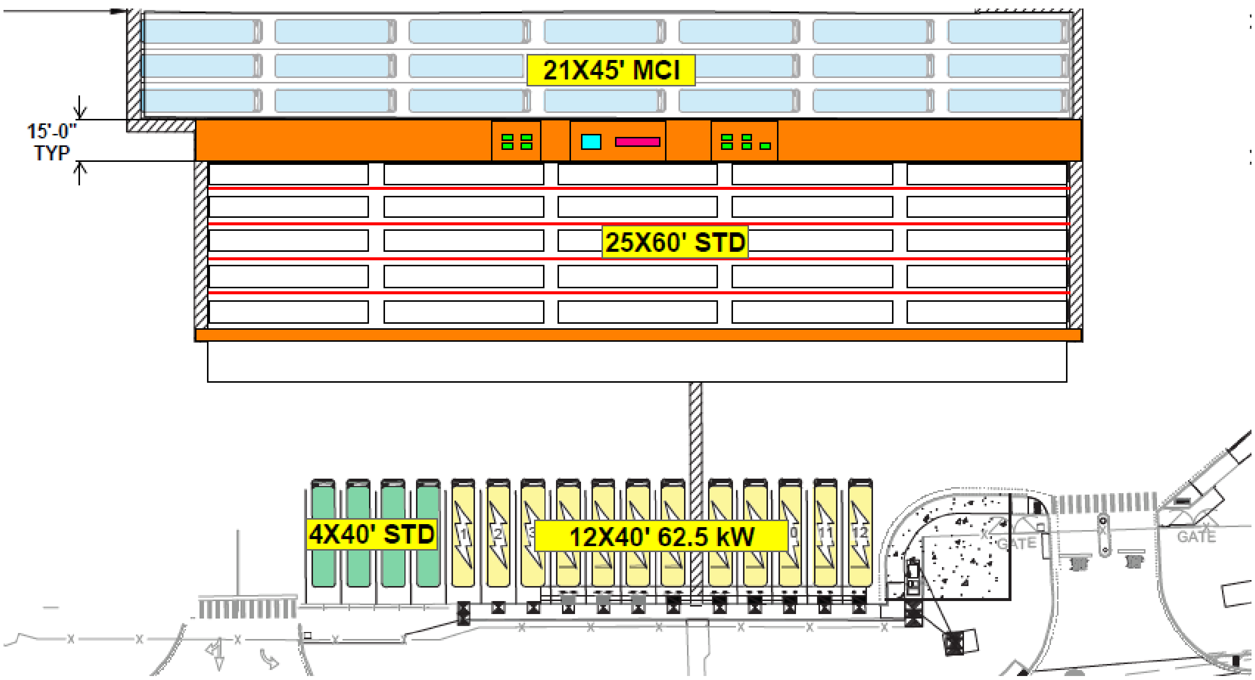
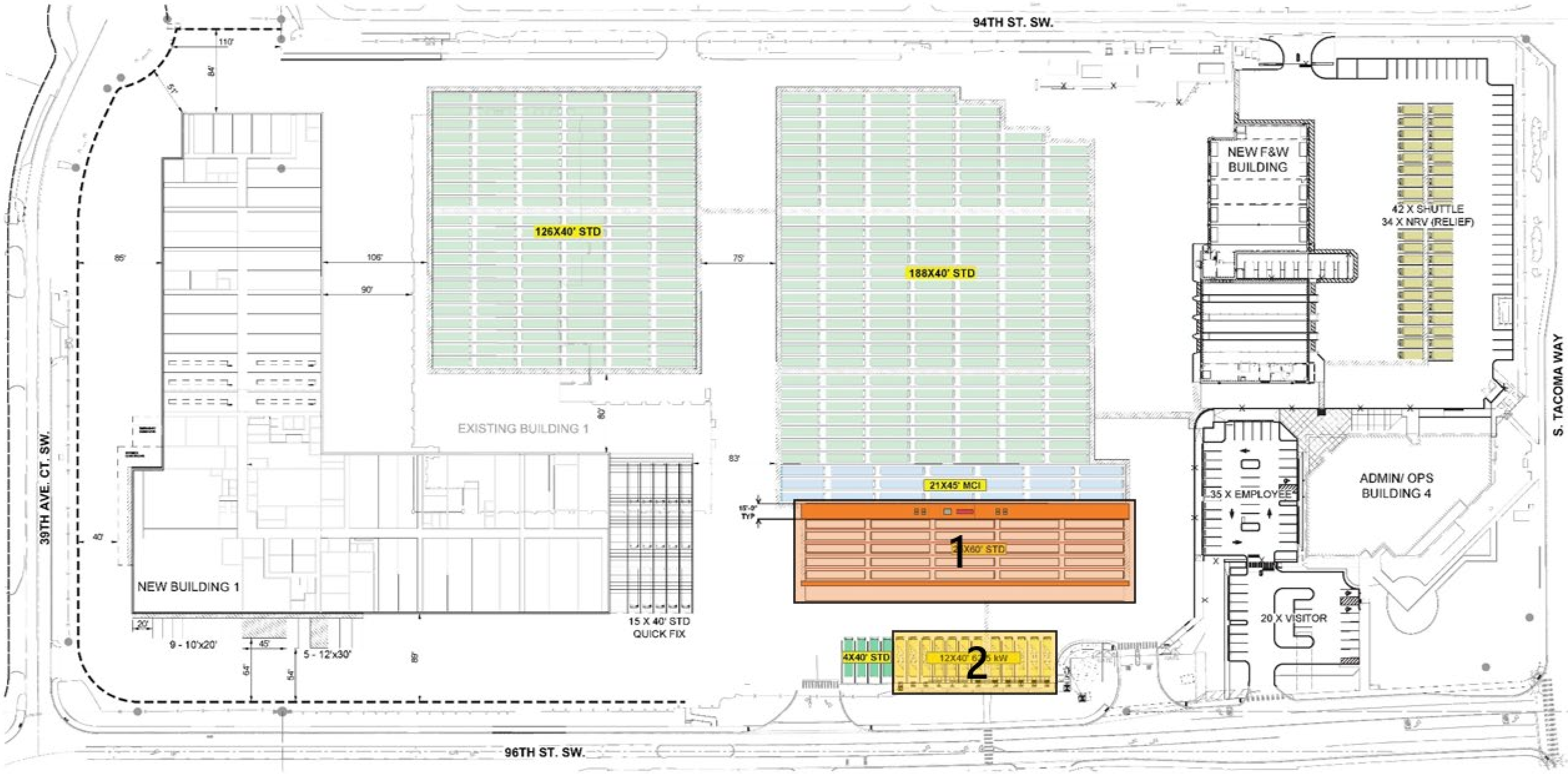


Figure 11 shows the entire Lakewood Base to provide context on the location of BEB charging in the near-term deployment.

Figure 11: Lakewood Base Charging Layout (2028)



1) New Pantograph Charging & Gantry System
2) Existing Plug In Charging

On-Route Charging

Prior to starting this study, Pierce Transit made plans to install one 180 kW charger with three dispensers at the Commerce Street Station. Route modeling showed that additional on-route charging is needed by 2027 to support the near-term deployment. When considering layover times, construction feasibility, and number of routes served, The Lakewood Transit Center was identified as the preferred location for BEB on-route charging for the near-term deployment. Installing four 450 kW chargers would accommodate a fleet of up to 49 BEBs. Each charger would be hooked to a pantograph dispenser. It is recommended that Pierce Transit begins construction on these charging stations in 2025 to provide ample time to have them ready for use in 2027. **Figure 12** shows a possible charging configuration for this transit center.

Figure 12: BEB Charging Layout at Lakewood Transit Center

Long-Term Deployment: 2029–2042

206 Battery Electric Buses | 77 Depot Chargers | 18 On-Route Chargers

Starting in 2029, it is planned that Pierce Transit would begin larger procurements of ZEBs. Pierce Transit should use the experience of operating the initial BEB fleet to inform decisions on how to further transition the fleet long term. If certain aspects of operating BEBs are presenting continual challenges for the agency, Pierce Transit could consider operating BEBs differently or incorporating another fuel type. For example, the agency could decide they have a preferred charging method and opt toward only using one type of charging. Another scenario could be that BEB ranges increase to a point where on-route charging is no longer needed. Lastly, FCEB costs could significantly decrease, clean hydrogen availability could increase, and FCEBs adoption could be much easier in the future.

Pierce Transit should evaluate the near-term transition and decide on how to proceed with ZEBs (BEBs or FCEBs) in 2027. The long-term deployment outlined in this memo assumes that a BEB fleet with depot and on-route charging continues to meet Pierce Transit's needs. This deployment also assumes that the planned BRT route starts operating with BEBs starting in 2030. **Table 6** shows the recommended vehicle purchases from 2028 to 2042. By 2027, it is expected that BEB technology will have advanced enough that all routes could be operated with BEBs therefore ceasing the purchase of internal combustion engine (ICE) vehicles.

Table 6: Electric Bus Purchases by Year from 2028-2042

Size	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
60'	-	-	15	-	-	-	12	-	-	-	-	-	17	-	0
40'	2	6	3	10	10	7	8	38		33		10	3	10	10
25'	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-

Depot Charging Strategy

Pierce Transit would need to purchase fifty-six 150 kW depot chargers from 2029 to 2042. Utility upgrades would be done in 2029 and would be sized to accommodate the full build out. The gantry system would be expanded in a few phases and chargers would be purchased incrementally.

Figure 13 shows the full build-out of electric bus charging at the Lakewood Base. The completed charging plan would have 195 charging ports available for the 206-vehicle fleet. Chargers would not be provided on a 1:1 ratio because the current parking layout only accommodates for 195 charging stalls. This should not present a problem because it is assumed that some buses will meet their charging needs on-route, some buses may not need to charge every night, some buses would come back during the day to charge while others would charge at night, and buses could be moved around to share dispensers if needed.

Phase 1 would be completed during the near-term deployment. Within the long-term deployment there would be five phases. Phase 2 includes the installation of twenty-two 150 kW chargers and 56 pantograph dispensers under a gantry designed to park 40-foot buses. This phase would be completed by 2033. Phase 3 includes fourteen 150 kW chargers and 20 pantograph dispensers under a gantry designed to park 60-foot buses. Phase 3 would be completed by 2034. Phase 4 includes sixteen 150 kW chargers and 56 pantograph dispensers under a gantry designed to park 40-foot buses. Phase 4 would be completed by 2036. Finally, Phase 5 includes the installation of 20 pantograph dispensers by 2039. These dispensers would be powered by the charging stations installed in Phase 4.

Figure 14 shows the Lakewood Base with all charging infrastructure in place in 2042.

Figure 13: Lakewood Base Charging Layout (2042)

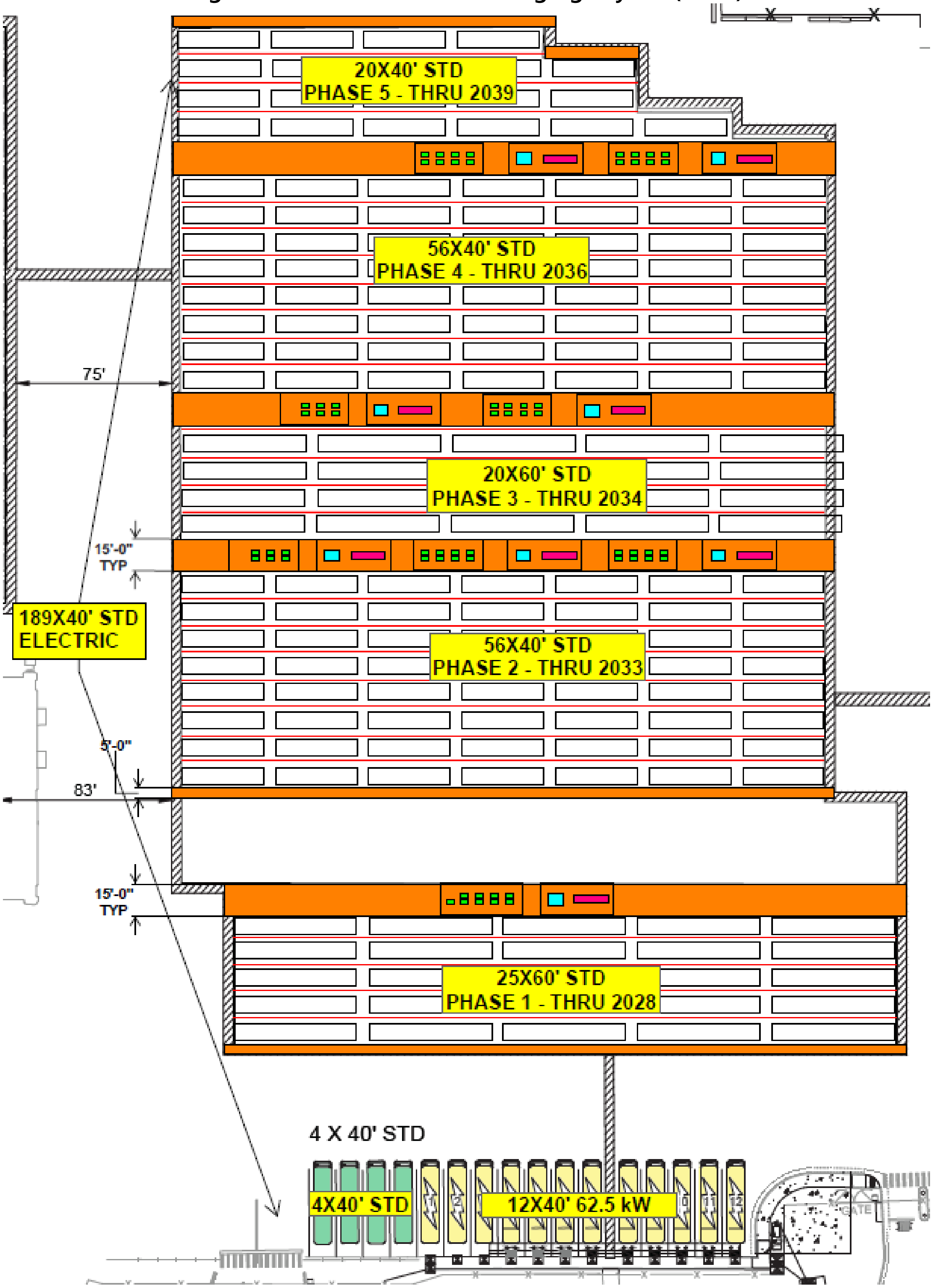
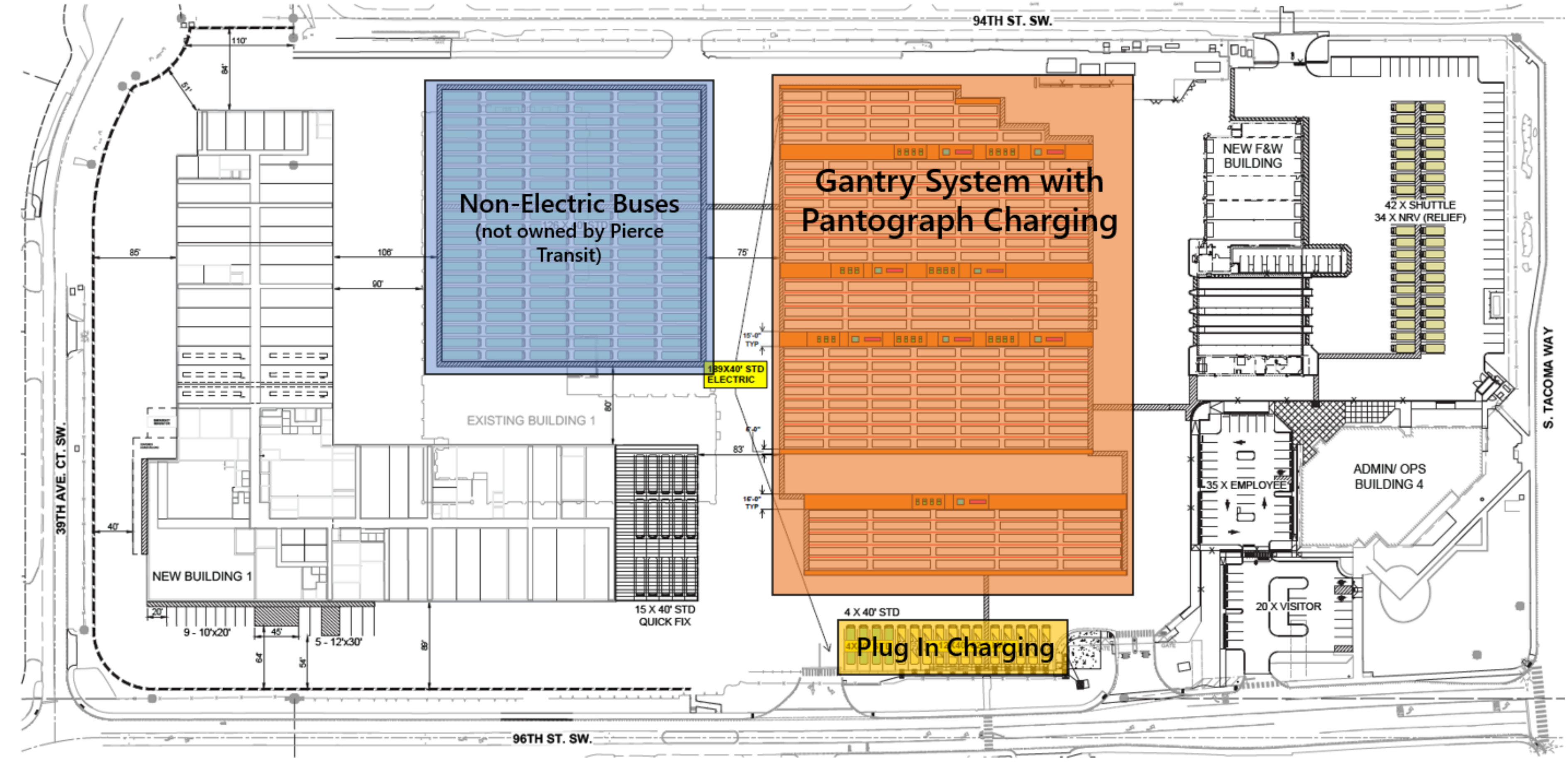


Figure 14: Lakewood Base Charging Layout (2042)



On-Route Charging Strategy

Pierce Transit would need 18 on-route chargers to operate a fully battery electric bus fleet. The near-term deployment would provide Pierce Transit with five on-route chargers, meaning that from 2029 to 2042 Pierce Transit would need to install 13 on-route chargers. This estimate does not include the previously planned 180 kW charger at the Commerce Street Station. Below is the suggested on-route charging plan based on route modeling outputs and conversations with the public utilities. More information on on-route charging plans can be found in the **Facilities and Infrastructure Plan** section.

- 2031: Begin construction of four 450 kW chargers at the Tacoma Community College Transit Center (plan to have operational by 2033)
- 2033: Begin construction of four 450 kW chargers at the Commerce Street Transit Center (plan to have operational by 2035)
- 2034: Begin construction of three 450 kW chargers at the South Hill Mall Transit Center and three 450 kW chargers at the Tacoma Mall Transit Center (plan to have all chargers operational by 2035)

Facilities and Infrastructure Plan

Introduction

This facilities and infrastructure plan identifies infrastructure and energy needed to incorporate ZEB technology into Pierce Transit's fleet. This section is built around the recommended near-term and long-term fleet transition strategy while also considering results from Zero+ modeling. It will provide infrastructure requirements for the near term and long-term transition, including charging equipment, maintenance facility modifications, fuel storage, fuel pumping requirements, and power requirements including back-up power generation. After estimating the energy demands and facilities upgrades needed, this plan will detail resiliency considerations associated with each option.

Energy Needs

Lakewood Base Power Requirements

Pierce Transit would require 1.69 MW at peak load to satisfy the near-term BEB deployment (2023–2028) and 1.95 MW at peak load in the long term. The power requirement is very high for the initial build-out because most of the charging would happen at the depot. It is also expected the power profile has a higher peak in the near-term deployment because buses would be charged mid-day so they could be used on multiple blocks. The peak demand is high, but the total energy consumed would be lower in the near-term compared to the long term because Pierce Transit would have fewer buses to charge at the depot in the near-term than in the long-term deployment. For the long-term deployment there would be large additional power requirements at the on-route locations (which would end up supplying the bulk of the required energy), and the power at the depot would be more continuous overnight. Overall, the peak load at the Lakewood base is expected to be significant at the start of the transition and level off over time.

This is an estimate that assumes the worst-case daily energy requirements, meaning the maximum energy that would be required during weekday service with cold weather (10th percentile temperatures) and 80 percent battery degradation. This places an upper limit on the energy requirements for beginning the conversation with the electrical utility or planning for backup power. The cost of energy depends not only on the amount of energy but also on the time of day when the energy is consumed.

Energy is only one component for determining the electric load and costs. In addition to energy costs, there is also a charge for the peak demand, or maximum power level seen over a billing period. Pierce Transit will need to coordinate with Lakeview Light and Power to determine the best rate plan for the facility, understand any energy incentives, and work together to reduce costs to charge the BEB fleet.

On-Route Power Requirements

In the recommended transition scenario, Pierce Transit would be installing on-route chargers starting in 2025. The fleet would rely primarily on depot charging and use on-route to supplement the longer routes. It is estimated that Pierce Transit would need 18 on-route chargers and 5.4 MW of energy to be available for these on-route chargers. The project team identified five different sites that could accommodate on-route chargers

Pierce Transit is already planning to deploy an on-route charger at the Commerce Street Station. This site is recommended for additional on-route charging because of the high amount of layover time and variety of routes that pass through this transit center. The Lakewood Transit Center, South Hill Mall Transit Center, Tacoma Mall Transit Center, and Tacoma Community College (TCC) Transit Center are also recommended sites for on-route chargers based on available space and power. Below is an overview of the proposed on-route charging:

- **Commerce Street Station:** 4 New Chargers at 450kW (1.2 MW), 1 Existing Charger at 180kW (0.2 MW), Total 1.4 MW
- **TCC Transit Center:** 4 New Chargers at 450kW (1.2 MW)
- **Tacoma Mall Transit Center:** 3 New Chargers at 450kW (0.9 MW)
- **Lakewood Transit Center:** 4 New Chargers at 450kW (1.2 MW)
- **South Hill Mall Transit Center:** 3 New Chargers at 450kW (0.9 MW)

Lakewood Base Hydrogen Fuel Requirements

Pierce Transit is committed to integrating ZEBs into the fleet, and while the agency is currently shifting toward BEBs, the consulting team is providing preliminary information on hydrogen in case the agency decides to have a mixed fleet later on. The most significant impact transitioning to FCEBs is the need for hydrogen instead of diesel. The Zero+ simulation results provide an estimate for the kilograms of hydrogen needed each day in the worst case (cold temperatures with a maximum passenger load).

It is expected that the hydrogen fueling infrastructure would require about 500–750 kW of power. If Pierce Transit were to shift toward a long-term FCEB scenario, the fleet would consume about 2,861 kg of hydrogen on weekdays, 1,474 on Saturdays, and 1,038 on Sundays.

Facilities and Infrastructure

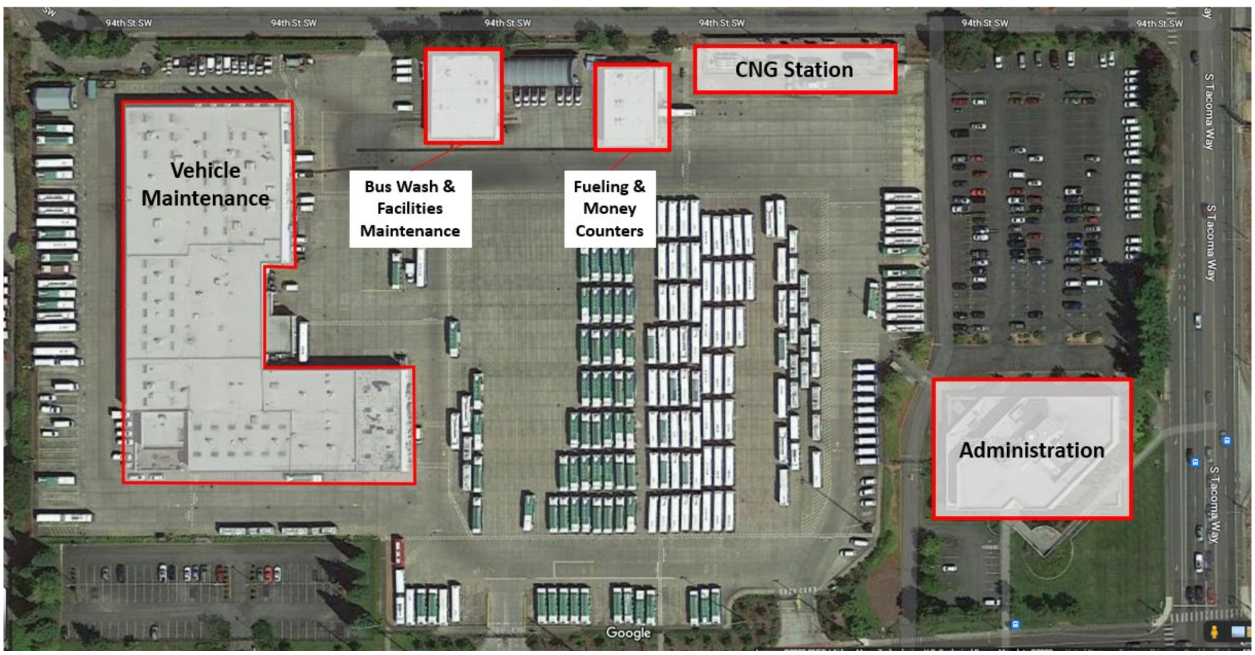
Existing Conditions

Pierce Transit's operations and maintenance facility, commonly referred to as the Lakewood Base, is located at 3701 96th Street SW in Lakewood, Washington. Pierce Transit's maintenance and operations facility was constructed in 1986 and designed to serve a fleet of 200 revenue vehicles. Today it supports a fleet of 300 buses, plus additional shuttles, vanpool, and support vehicles. Lakewood Base is undergoing expansion and modifications so that it can accommodate vehicle expansions through 2040. The expansion is detailed in the Pierce Transit

Base Master Plan (Source). This plan will only be looking at the Main Base area within this facility because this is the only space planned to house electric bus infrastructure. This plan will only cover upgrades occurring at the Main Base or upgrades relevant to the ZEB transition.

Figure 15 shows an aerial view of the Lakewood Base. The facility has four buildings each with the following functions: (1) vehicle maintenance, (2) bus wash and facilities maintenance, (3) fueling and money counters, and (4) administration. Through the planned renovations, the Lakewood Base will include new maintenance bays, bus washers, fueling bays, and bus parking, as well as renovate the administrative office. Pierce Transit removed the public CNG fueling station, which is no longer in use. The agency will also be constructing a training building at the South Base across the street (which would be used partially for electric bus trainings) and expanding their employee parking lot.

Figure 15: Lakewood Base Aerial View



Pierce Transit already operates nine battery electric buses and has nine plug-in charging stations at the Lakewood Base to charge the existing BEB fleet. Pierce Transit built this charging infrastructure to accommodate the initial nine BEBs with the intention of determining future charging station needs during this study.

The current route blocks require 128 routed buses for weekday service, not including vehicles for the planned BRT route or spare buses. Based on Pierce Transit's current fleet and operational use case, parking must be available for 150 40-foot transit buses and nine 25-foot cutaway vehicles.

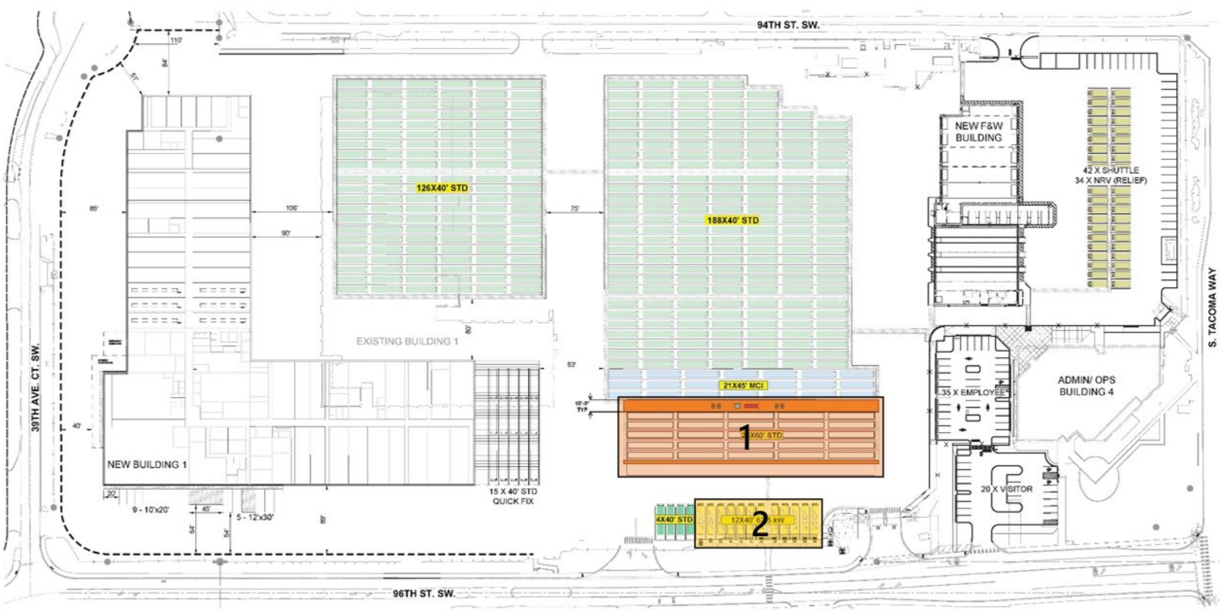
Lakewood Base Infrastructure Needs

Equipment and Layout

Figure 17 depicts the battery electric bus charging layout for the Lakewood Base in the recommended BEB transition scenario in the near term. The equipment and layout depicted in this section are recommendations put forth by the consulting team to provide a path for charging BEBs in the near-term deployment. More conversation and analysis is planned to occur on the Pierce Transit side before committing to this design, and for the time being this should be regarded as a concept rather than an official plan.

To charge the new BEBs, Pierce Transit would need to install 12 depot chargers. Nine of the depot chargers would be 150 kW and three would be 62.5 kW plug-in chargers. Each 150-kW charger would dispense power through pantograph chargers on a gantry system. The gantry system would be constructed in 2024 and built to accommodate chargers up to 2028. Each 150-kW charger would have three pantograph dispensers and the gantry system would be sized to charge twenty-five 60-foot buses. Buses would be parked nose-to-tail. To the south of the gantry system would be the nine existing 62.5 kW plug-in chargers and three additional plug-in chargers used to power the BEBs purchased in 2024. Each charger has one dispenser and buses would be parked side-by-side. To the north of the gantry system would be existing parking for twenty-one 45-foot MCI buses.

Figure 16: Aerial View of Lakewood Base Charging Layout (2028)



1) New Pantograph Charging & Gantry System
2) Existing Plug In Charging

Table 7 shows the recommended charger purchases from 2023 to 2028. The Lakewood Base already has nine 62.5 kW single-port chargers and plans to purchase three more in 2023. By 2028, Pierce Transit would have 20 chargers and 37 total charging ports.

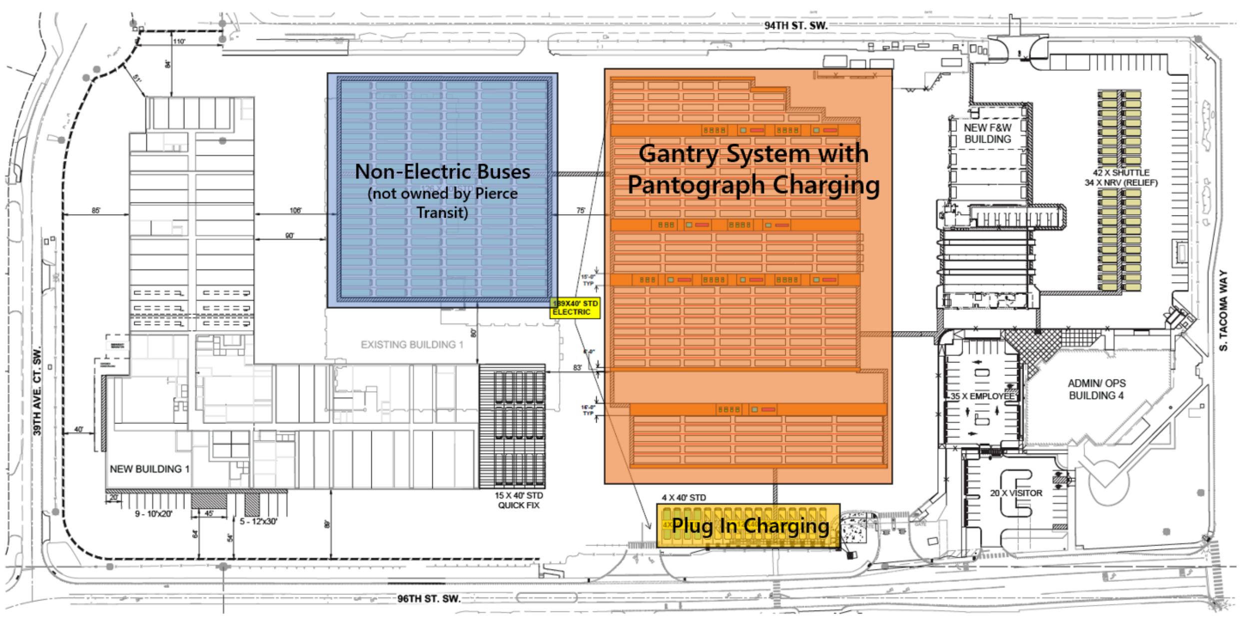
Table 7: Charger Purchases from 2023-2028

Charger Type	2022	2023	2024	2025	2026	2027	2028
Depot Chargers (62.5 kW)	9	3	-	-	-	-	-
Depot Chargers (150 kW)	-	-	3	1	3	1	1

In the long-term deployment, the facility would be equipped with a total of seventy-four 150 kW depot chargers (9 single port chargers and 54 triple port chargers). The long-term deployment assumes the use of pantograph chargers, however like stated previously, Pierce Transit has yet to determine the charge delivery method. Pantographs should be considered conceptual.

Conceptually, pantograph chargers would be installed under the gantry system and charge the fleet primarily overnight. The Lakewood Base would have 204 ports available to charge BEBs at the depot. **Figure 18** shows the proposed charging layout for the Lakewood Base in the long term.

Figure 17: Aerial View of Lakewood Base Charging Layout (2042)



Construction Considerations

While chargers would be purchased and installed incrementally, it is recommended to perform electrical upgrades for the facility initially so that the facility is “EV Ready.” Electric vehicle supply equipment (EVSE) readiness can be thought of in three categories.

1. **EV Capable**: Enough electrical capacity is installed at the panel to support future EV charging stalls. Additionally, there is a dedicated branch circuit to make sure enough power is available for future charging stations without overloading the system and conduit to future charging spots.
2. **EV Ready**: EV capable requirements are met, with the addition of wiring and junction box.
3. **EV Installed**: All of the above are met, plus installing the actual EV charging station.

It is recommended that Pierce Transit aims to be EV Ready with its near-term charging infrastructure if funding allows for these upgrades to be done at once. Sizing all electrical equipment for the near-term chargers up front will save time and money through the near-term deployment. Pierce Transit should also aim to construct as much of the gantry system as is feasible up front. Once Pierce Transit gets closer to 2030, the agency should reassess the ZEB fleet and determine what electrical upgrades make sense to do at the beginning of the long-term deployment.

The timeline from purchasing a charger to having it in operation is about one to two years in 2023. This time could expand or shrink depending on types of chargers constructed, supply chain conditions, and individual site conditions. It is generally best practice to have chargers purchased at the same time or before the BEB is purchased. Charger installation is typically faster than the time needed to build a BEB; however, it is critical that the charging infrastructure is ready prior to the delivery of the BEB to ensure the BEBs can operate. Each element of charger construction and installation has different timelines but can be done simultaneously. Pierce Transit should plan for about a year to make the Lakewood Base EV Ready, 1 to 1.5 years to construct a gantry system, and 6 months to a year for charger procurement and design.

On-Route Charging Infrastructure Needs

Route modeling showed that 18 on-route chargers are needed for a Long-Term BEB deployment. The project team identified 12 transit centers that serve Pierce Transit buses, and of those 12, five sites have enough layover time and space available to be considered for on-route charging. Route modeling showed that Pierce Transit could operate 18 BEBs before needing on-route charging. The following section details the conditions at each of these sites and includes a preliminary concept for installing on-route chargers.

Pierce Transit will have purchased 22 BEBs by 2025, and, assuming two-year lead times, the agency will surpass the 18 BEB threshold and require on-route charging in 2027. It is recommended that Pierce Transit install four on-route chargers at the Lakewood Transit Center and plan to utilize them starting in 2027. Four on-route chargers at Lakewood Transit Center could accommodate a fleet up of to 48 BEBs.

Another four on-route chargers at TCC Transit Center would accommodate a fleet of up to 76 BEBs. Pierce Transit plans to have 71 BEBs ordered by 2031, so again assuming two-year lead times, the agency would need to have four new on-route chargers operational by 2033.

The last phase of on-route charging installations would occur in 2033 and 2034. It is recommended to add four on-route chargers to Commerce Street Station in 2033 and six on-route chargers to the Tacoma Mall and South Hill Mall transit centers in 2034 (three chargers at each site).

Table 8 outlines each site's proposed chargers and installation year. The installation year is the year to begin constructing the on-route chargers. It is assumed that the design, construction, and installation process will take two years. The year that the on-route chargers are needed is two years after the installation date listed below.

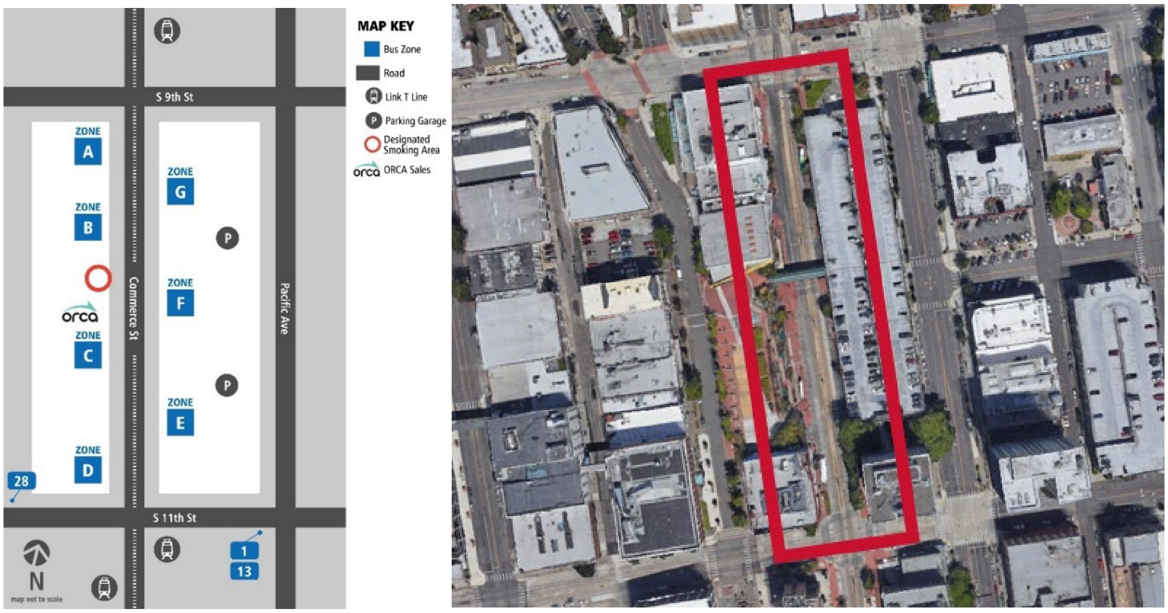
Table 8: On-Route Charging at Transit Centers

Transit Center	Number of Chargers	Number of Charging Ports	Energy Needed (in MW)	Design to Commissioning
Commerce Street Station	(4) 450 kW (1) 180 kW	**7 ports total** 1 port per 450 kW 3 ports per 180 kW	1.38	2022-2023: (1) 180 kW charger 2033-2035: (4) 450 kW chargers
Lakewood	(4) 450 kW	**4 ports total** 1 port per 450 kW	1.2	2025–2027
TCC	(4) 450 kW	**4 ports total** 1 port per 450 kW	1.2	2031–2033
Tacoma Mall	(3) 450 kW	**3 ports total** 1 port per 450 kW	0.9	2034–2036
South Hill Mall	(3) 450 kW	**3 ports total** 1 port per 450 kW	0.9	2034–2036

Commerce Street Station

The Commerce Street Station is located in downtown Tacoma and has seven transit berths and four layover locations. An aerial photo of the Commerce Street Station is shown in **Figure 19**.

Figure 18: Commerce Street Station Aerial View

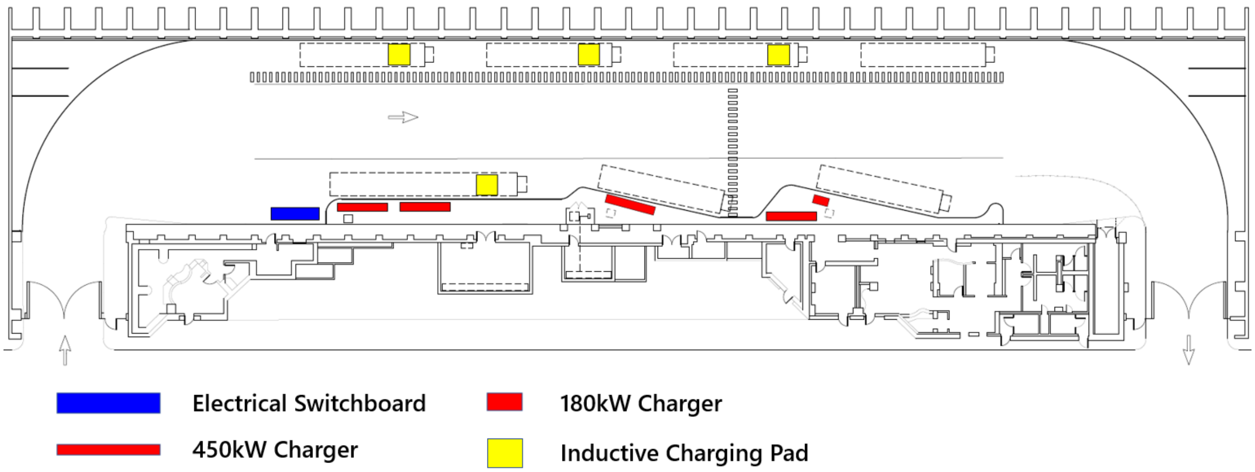


There are currently no charging stations at this transit center; however, there are existing plans to install one 180 kW plug in charger with three dispensers in the Commerce Street Station tunnel in 2023. In addition to this charger, this site could accommodate up to four pantograph or inductive chargers. This site is preferred for on-route charging because it offers the highest number of layover hours (229 per year) and serves the highest number of routes (16 routes) of all the transit centers assessed.

While this site offers the highest number of routes and longest layover times, Commerce Street Station also poses the most significant challenges because of limited space and expected disruption during construction. The Commerce Street Station operations facility is within a structure. The roof enclosing the tunnel is not a public park but Pierce Transit allows programming of the roof deck for public events such as farmers markets and concerts. Bus parking is constrained to the lower level. This site is constrained by available locations to install chargers, which could take up room on the deck since no room is available in the current layover area on the lower level. Construction would also temporarily reduce the use of the upper facility. Penetrating through the area above the enclosed parking area with conduit could cause potential concerns for water intrusion. Pierce Transit completed a major midlife renovation of the facility in 2022, which included repairs to the failing roof membrane. In addition the ceiling height above the buses needs to be considered prior to designing and installing pantographs over the buses. Despite these challenges, the site offers the largest on-route charging benefit.

Figure 20 shows the proposed on-route charging configuration on the lower level of the Commerce Street Station. The design includes four 450 kW chargers, each with one inductive charging pad and one plug in 180 kW charger. The site is estimated to require 1.38 MW at peak load for the five on-route chargers (1.2 MW for the proposed 450 kW chargers and 0.18 for the 180-kW charger). Note that while this design shows inductive charging pads, it should be studied more to determine if pantograph chargers will fit in this space.

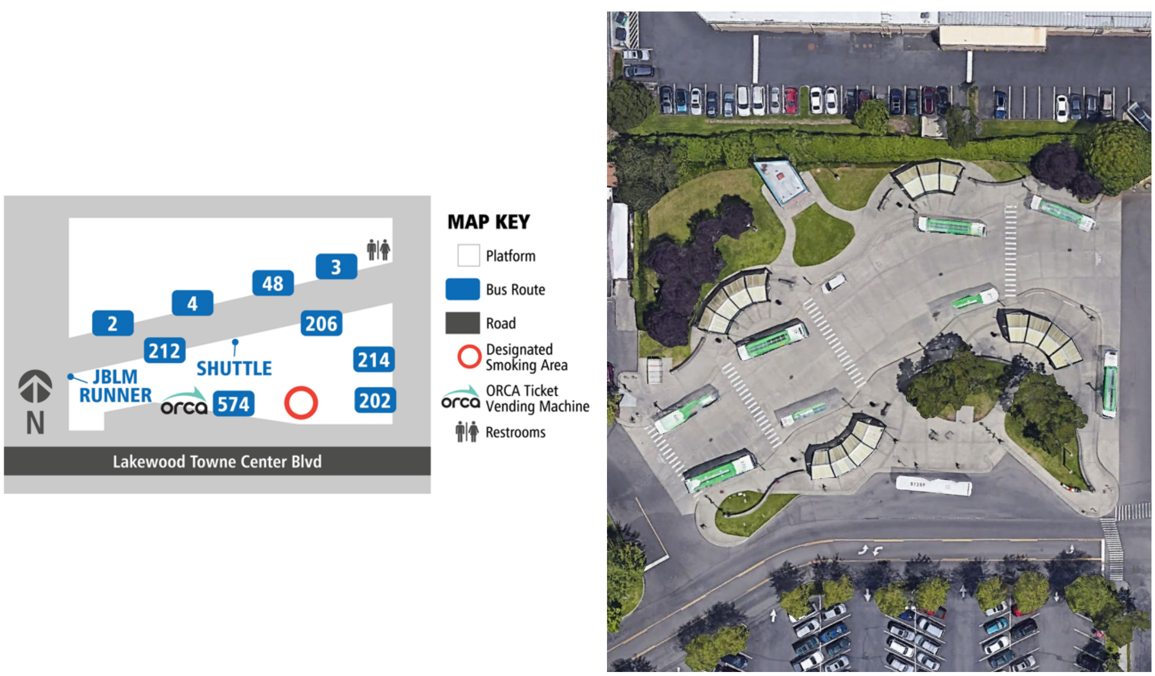
Figure 19: Commerce Street Station Electric Bus Charging Layout



Lakewood Transit Center

The Lakewood Transit Center has nine transit berths and four layover locations. It is located in a shopping plaza in Lakewood. An aerial photo of the Lakewood Transit Center is shown in **Figure 21**.

Figure 20: Lakewood Transit Center Aerial View

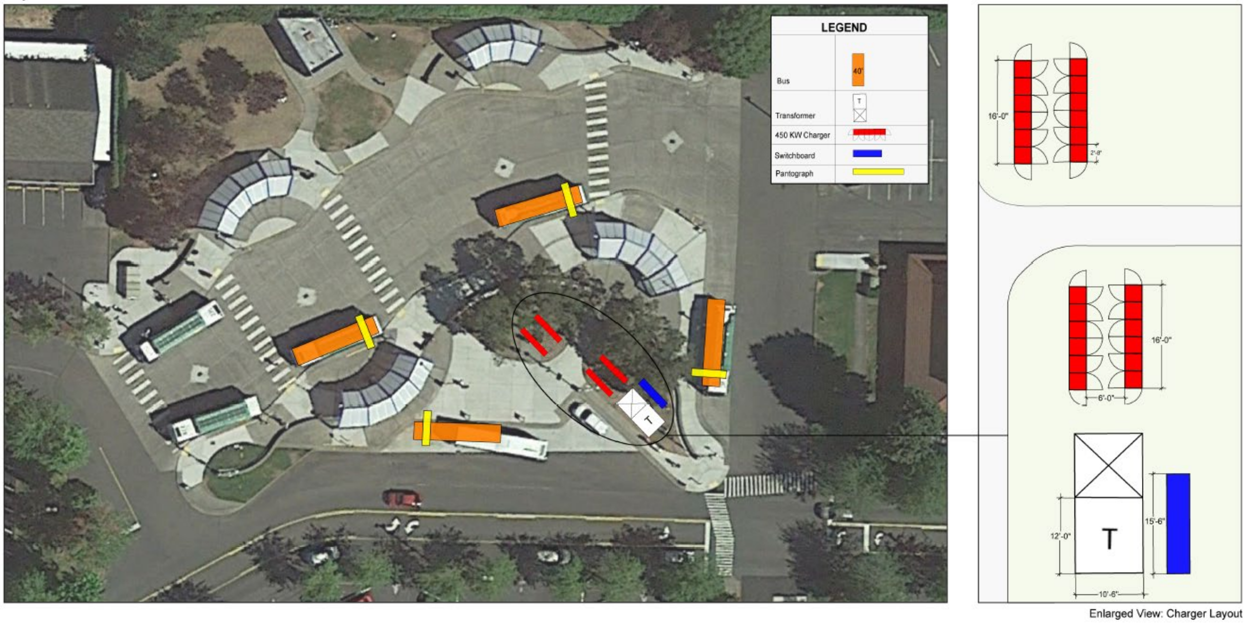


There are currently no charging stations at this transit center, however the Lakewood Transit Center was identified as one of the transit centers that could support on-route bus charging. **Figure 22** and **Figure 23** depict the battery electric bus charging layouts that were discussed with Pierce Transit. **Figure 22** shows Option A, where the chargers are grouped together on the western side of the transit center and **Figure 23** shows Option B, where the chargers are located in the middle of the transit center. For these layouts, four buses could charge simultaneously, and all four chargers would be constructed at the same time. The four on-route chargers would either be pantograph or inductive chargers and would require an estimated 1.2 MW at peak load.

This is a viable site for on-route charging because of power availability and no preliminary indication of conditions that would be prevent on-route charging. The utility confirmed that there is power available at this location and that there are no major constraints to installing on-route chargers. HDR anticipates a typical construction process to install on-route charging at this site.

Figure 21: Lakewood Electric Bus Charging Aerial View - **Option A**

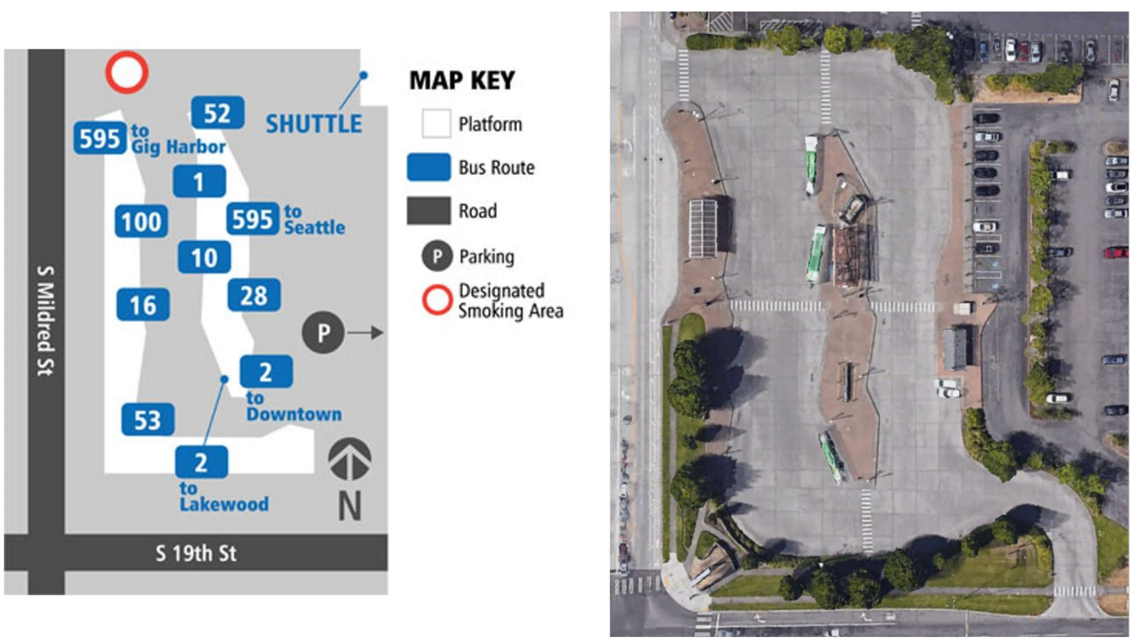
Figure 22: Lakewood Electric Bus Charging Aerial View - Option B



Tacoma Community College Transit Center

The TCC Transit Center is located in the southwestern corner of Tacoma Community College has 11 transit berths and four layover locations. An aerial photo of the TCC Transit Center is shown in **Figure 24**.

Figure 23: TCC Transit Center Aerial View



No chargers have yet been installed at this transit center. The TCC Transit Center was also identified as one of the transit centers that could support on-route bus charging. **Figure 25** and **Figure 26** depict the modified battery electric bus charging layouts that were discussed with Pierce Transit. Both options have pantographs or inductive chargers in the same place but chargers, switchboards, and transformer at different parts of the transit center. For this layout, four buses could charge simultaneously, and all four chargers would be constructed at the same time. It is estimated that the site would require 1.2 MW of power at peak load.

The TCC Transit Center is a small site that may not be suitable to add much electrical infrastructure without purchasing/leasing additional property. Aside from site size, there are no other major constraints other than the typical challenges of construction at an active site. This site is viable for on-route charging but would require more spatial analysis installing on-route charging.

Figure 24: Tacoma Community College Electric Bus Charging – Option A

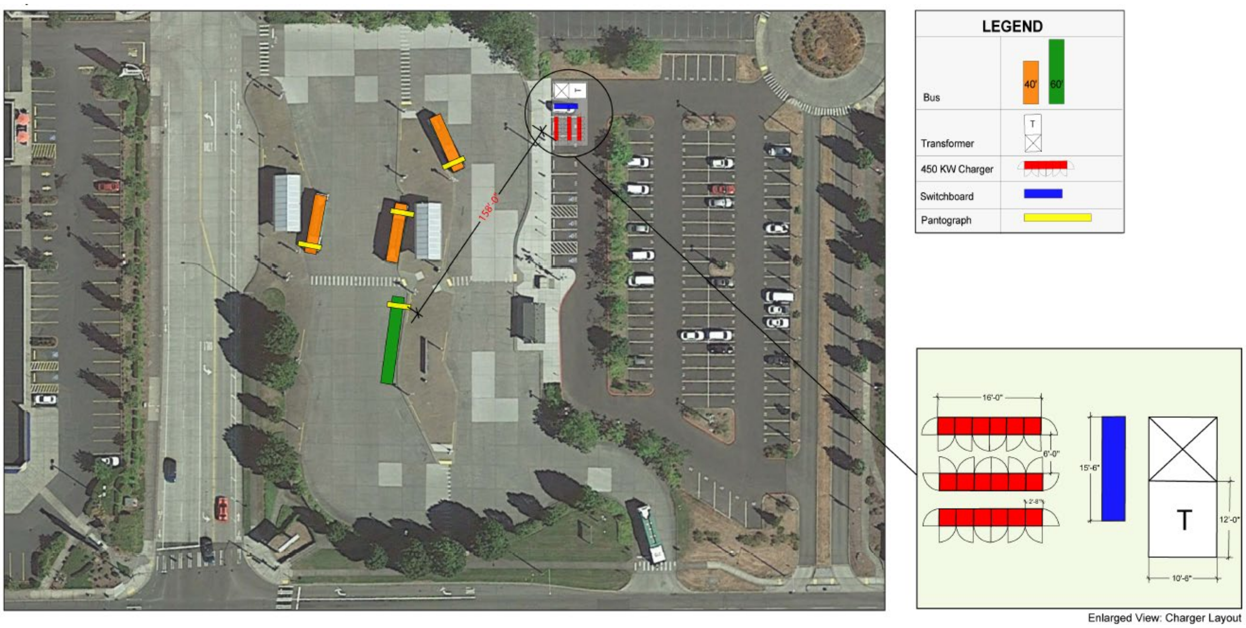
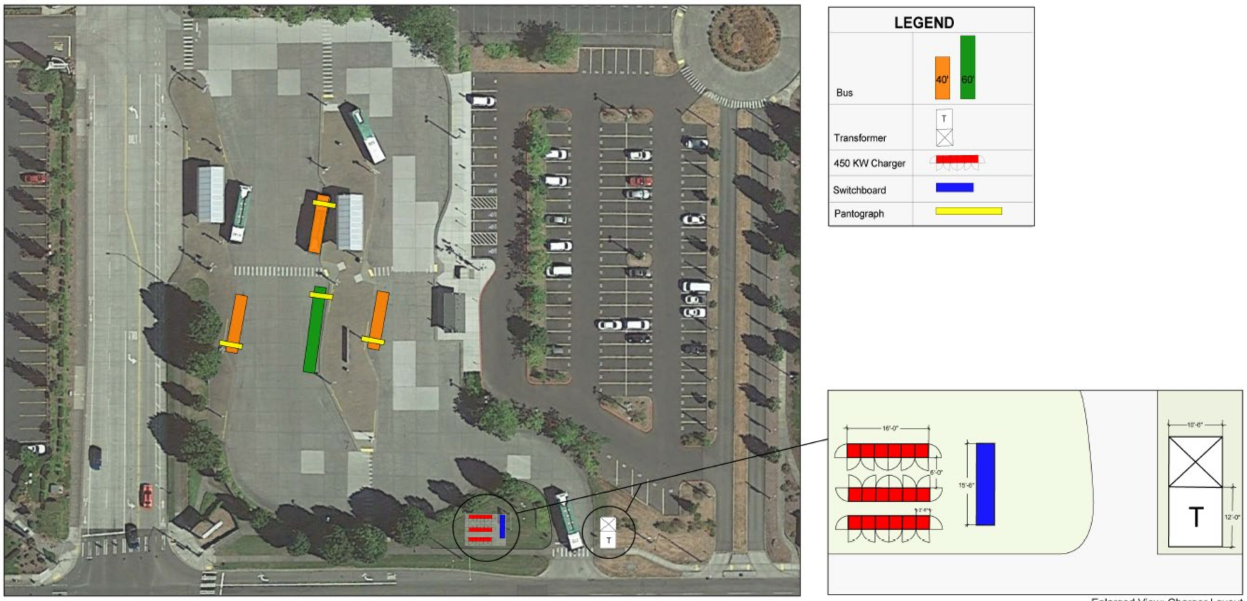


Figure 25: Tacoma Community College Electric Bus Charging – Option B



Tacoma Mall Transit Center

The Tacoma Mall Transit Center has eight transit berths and three layover locations. An aerial photo of the Tacoma Mall Transit Center is shown in **Figure 27.**

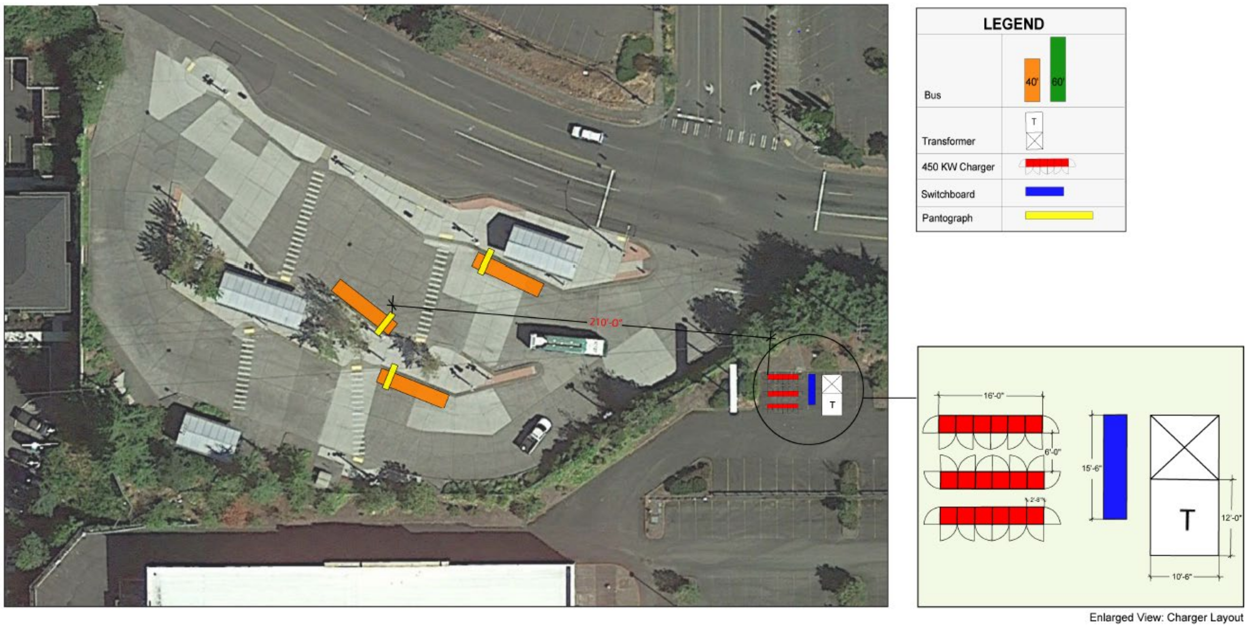
Figure 26: Tacoma Mall Transit Center Aerial View

No chargers have yet been installed at this transit center. The Tacoma Mall Transit Center was also identified as one of the transit centers that could support additional on-route bus charging. **Figure 28** and **Figure 29** depict the modified battery electric bus charging layout that was discussed with Pierce Transit. The primary difference between the two options is the location of the chargers, switchboards, and transformer. Both options would utilize either pantograph or inductive chargers. In Option A the buses would all charge toward the center of the site and for Option B the buses would charge toward the eastern side of the site. For this layout, three buses could charge simultaneously, and all three chargers could be constructed at the same time. The site is expected to require an estimated 0.9 MW of power at peak load.

Like the TCC Transit Center, this is a small site that may not be suitable to add much electrical infrastructure without purchasing/leasing additional property. Aside from site size, there are no other major constraints other than the typical challenges of construction at an active site. This site is viable for on-route charging but would require more spatial analysis installing on-route charging.

Figure 27: Tacoma Mall Electric Bus Charging – Option A

Figure 28: Tacoma Mall Electric Bus Charging – Option B



South Hill Mall Transit Center

The South Hill Mall Transit Center has six transit berths and three layover locations. An aerial photo of the South Hill Mall Transit Center is shown in **Figure 30**.

Figure 29: South Hill Mall Transit Center Aerial View

The South Hill Mall Transit Center was also identified as one of the transit centers that could support additional on-route bus charging. No chargers have yet been installed at this transit center. **Figure 31** and **Figure 32** depict the modified battery electric bus charging layout that was discussed during following discussions with Pierce Transit. For this layout, three buses could charge simultaneously, and all three chargers would be constructed at the same time. The three on-route chargers would either be pantograph or inductive charging. Options A and B show the pantograph/inductive charging in slightly different locations, but the primary difference is the location of the transformer, chargers, and switchboard. Option A shows the infrastructure at the center of the facility while Option B shows the infrastructure at the southeast corner. The site is expected to require an estimated 0.9 MW of power at peak load.

This is a viable site for on-route charging because of power availability and no preliminary indication of conditions that would be prevent on-route charging. The utility confirmed that there is power available at this location and that there are no major constraints to installing on-route chargers. HDR anticipates a typical construction process to install on-route charging at this site.

Figure 30: South Hill Mall Electric Bus Charging – Option A

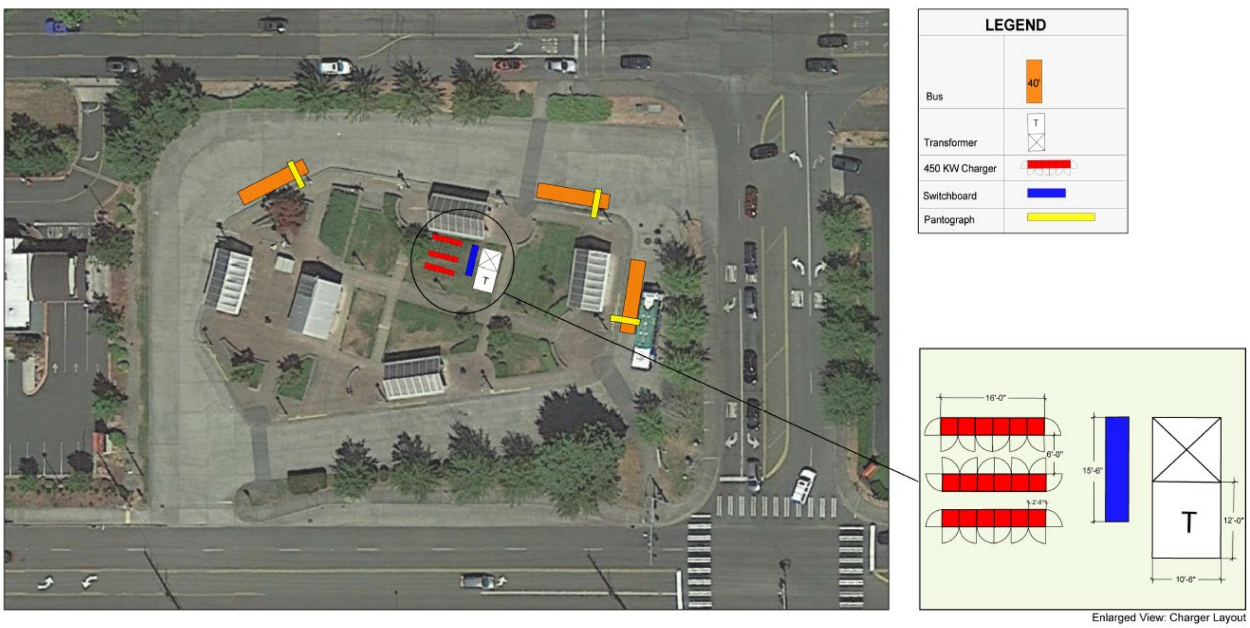
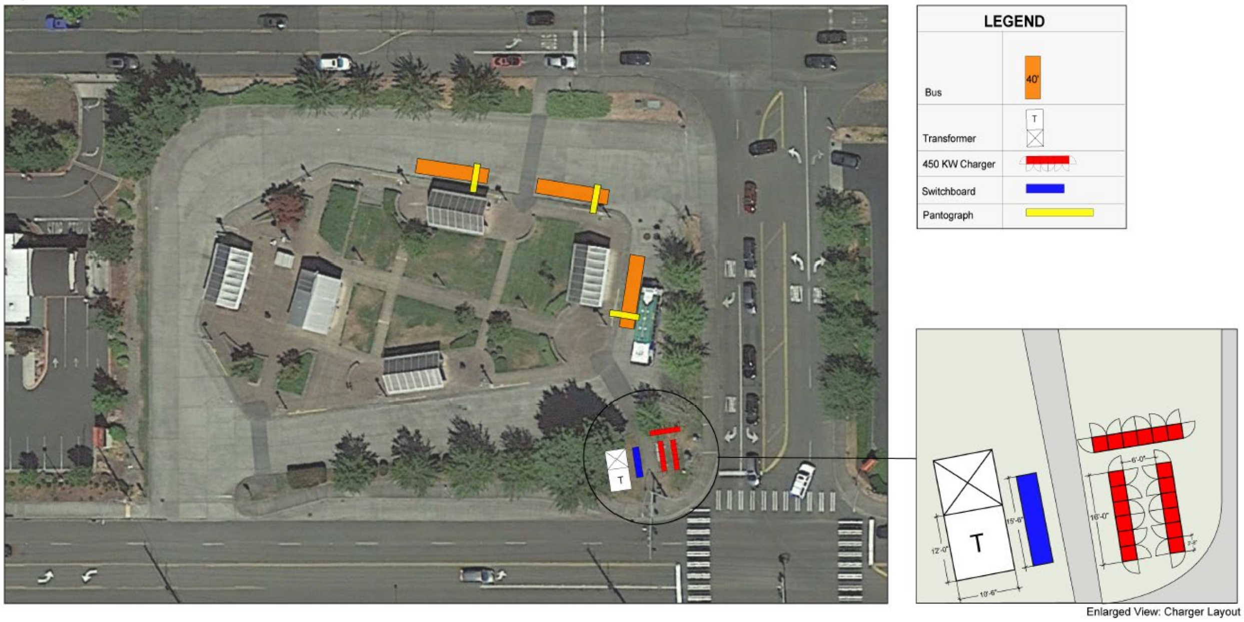


Figure 31: South Hill Mall Electric Bus Charging – Option B



Hydrogen Fueling Infrastructure

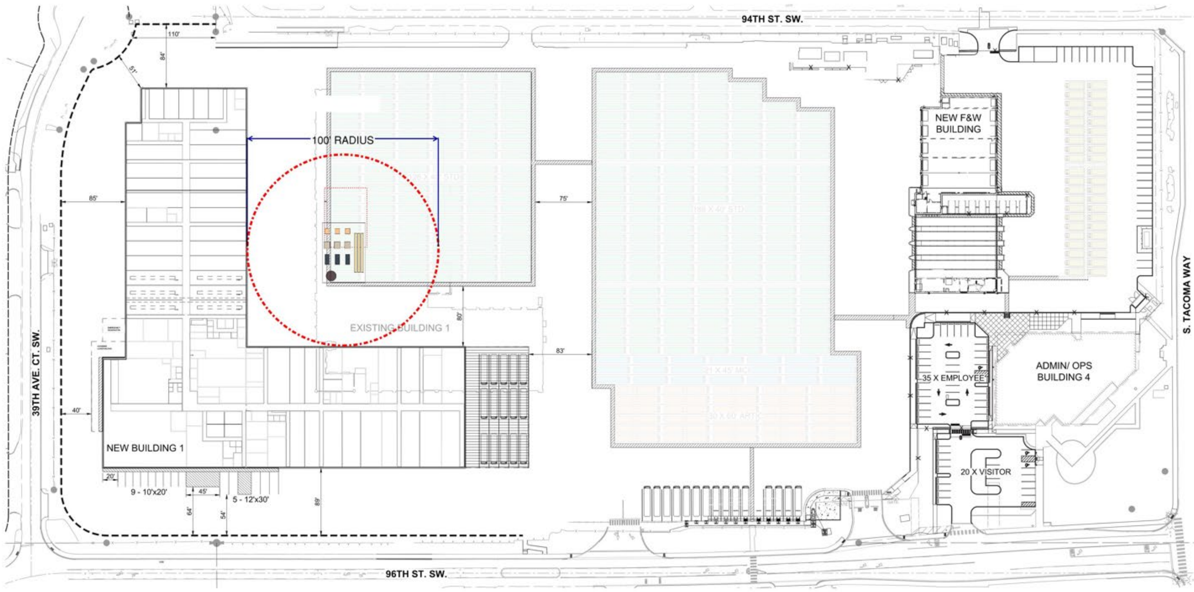
Equipment & Layout

While Pierce Transit is currently looking to procure BEBs, this section will provide high-level detail on operating hydrogen fuel cell buses. ZEB technology is evolving and it is possible that the agency could choose to adopt FCEBs in the future. This section aims to describe facility considerations for installing a hydrogen fueling system for trucking in liquid hydrogen.

Hydrogen buses operate similarly to diesel or hybrid buses and do not require additional buses to perform the same level of service as the current fleet. Hydrogen buses require fueling for the buses like a diesel pump, but do not require any other special attachments.

Figure 33 depicts the layout for hydrogen fueling located at the western side of the property. The hydrogen buses would park similar to the existing buses and undergo a daily refueling process that is almost identical to ICE fueling. With this conceptual design, it is estimated that the facility would lose 27 to 36 parking stalls to make room for hydrogen infrastructure and necessary setbacks.

Figure 32: Lakewood Base Layout to Accommodate Hydrogen Bus

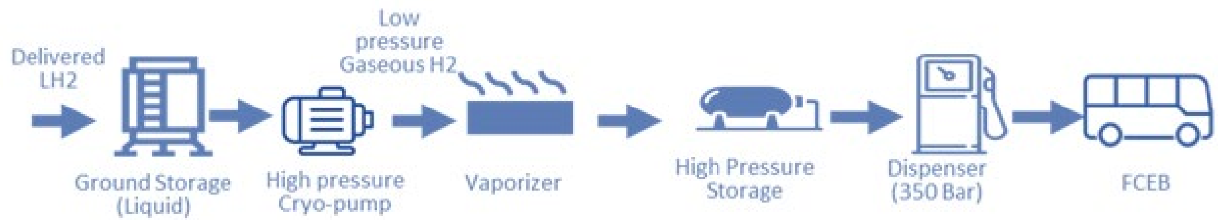


Hydrogen Fueling Station Components

Liquid hydrogen (LH_2) stations are composed of five main components: LH_2 tanks, LH_2 pumps, vaporizers, gaseous hydrogen (GH_2) tanks, and dispensers. The LH_2 tanks function as liquid storage; the hydrogen that is delivered via the trailers is unloaded into the liquid tanks and stored on-site. The LH_2 tanks are oversized for the amount of hydrogen to be dispensed on a daily basis to provide a buffer if a delivery is missed. LH_2 is pumped out of the liquid tanks by a cryogenic LH_2 pump. The LH_2 pumps used in this design are high-pressure cryopumps that allow the GH_2 compression step to be omitted. These cryopumps are an emerging technology, and it should be noted that other station designs will include a gaseous compressor after the vaporization to bring the hydrogen up to desired pressure. The hydrogen is next pumped to a vaporizer, which converts the liquid hydrogen to gaseous hydrogen. The GH_2 is then transferred to gaseous storage tanks, where it is stored until buses are ready to fuel. GH_2 then travels from the GH_2 storage to the dispenser. The dispenser functions the same way as a diesel dispenser; operators simply insert the nozzle into the bus's fuel tank and hydrogen is dispensed. The hydrogen must be cooled before flowing through the dispenser in order to ensure safe and complete fueling. The temperature and flow rate are designed to comply with SAE standard J2601/2.

Figure 34 shows the major pieces of equipment typical of this type of station. The sizing and specifications of each component vary by equipment supplier, but most will follow this general process.

Figure 33: Key Components of a Delivered Liquid Hydrogen Station



Construction Considerations

A key consideration for hydrogen fueling infrastructure is the required distances from other equipment and other items. The defined setback requirements from various types. **Table 9** outlines the setback requirements for gaseous and liquid storage with relative to various types of exposure as defined by the Washington Administrative Codes (WACs).

Table 9: Setback Requirements by Exposure Type for Washington State[3] [4]

Type of Exposure	Distance from Gaseous Storage Under 3,000 CF (ft)	Distance from Liquid Storage Under 15,000 gal. (ft)	Distance from Liquid Storage Over 15,000 gal.(ft)
Fire resistive buildings and fire walls	0	5	5
Noncombustible buildings	0	50	75
Other Buildings	0	75	100
Flammable liquids*	10 - 25	75	100
Flammable Gas Storage	-	75	100
Open flames, smoking, welding	25	50	50
Concentrations of people**	25	75	75
Public ways, railroads, and property lines	5	50	75
Public sidewalk	15	50	75

* Distance to above ground storage or to nearest venting point from below ground storage
** In congested areas such as offices, lunchrooms, locker rooms, time-clock areas, and places of public assembly.

Major repairs and refurbishments to potential FCEBs would need to be performed in a facility compliant with established hydrogen safety standards. There are specific requirements for facilities which perform maintenance or refurbishment on hydrogen equipment. Pierce Transit's existing facilities will require upgrades to become compliant with all applicable safety codes and regulations.

[3] https://app.leg.wa.gov/wac/default.aspx?cite=296-24-31503
[4] https://app.leg.wa.gov/wac/default.aspx?cite=296-24-31505

Resiliency Considerations

BEBs rely on grid power, meaning that a power outage could have significant operational impacts within a BEB fleet. Short power outages may disrupt equipment while prolonged power outages jeopardize the ability to provide transit service. Multiple technologies can be utilized to create a more resilient and reliable system for Pierce Transit's ZEB fleet. Technologies and methods applicable to Pierce Transit include on-site generation, temporarily increasing on-route charging, redundant grid sources, utilizing spare buses, reducing service, installing solar, and utilizing battery energy storage. Each method provides different support for the fleet and its infrastructure. Multiple strategies can be used together. The sections below discuss each technology and method for providing increased system resiliency to Pierce Transit's ZEB fleet.

Internal Combustion Engine Generation

ICEs are the standard practice for powering vehicles and operating backup generators. Renewable and cleaner sources are starting to enter the market; however, the technology is still developing and more costly than its ICE counterpart. Pierce Transit could consider ICE generators as a backup to grid power in the event that there is a prolonged power outage. While this is not clean energy, ICE generators can provide much needed power in an emergency and should be considered as a resiliency strategy especially as Pierce Transit adopts more BEBs.

Typically, combustion turbines have a larger power output (500 kW to 25 MW) but can still be utilized to meet larger distributed loads. These machines require hydrocarbon fuel input (i.e., natural gas, oil, or fuel mix) and typically have a lower power conversion efficiency. ICE generators come in a variety of sizes, making them highly scalable. These systems have a high degree of reliability and can operate on demand but require fuel input and maintenance. While they provide high degrees of reliability and some resilience, they fall short in terms of sustainability due to the utilization of fossil fuels.

ICE generation is normally not an ideal solution to offset BEB charging loads because the fuel input, high maintenance costs, and emissions are not suitable for consistent use. These generation methods can serve as backup generation to allow reduced transit operations to continue in the event of an electric service outage. The large ICE generator footprint is an important consideration. A typical stationary diesel ICE backup generator will require a footprint of approximately 75 ft^2/MW. Therefore, a 2 MW stationary backup generator would require approximately 150 ft^2, not including ancillary equipment such as transfer switches or noise reduction enclosures.

On-Route Charging

In the event of an outage localized to a transit base, on-route chargers could be utilized to keep transit routes in service. Pierce Transit could reroute buses to charge at on-route charging locations, assuming that the on-route location is not affected by the power outage. This strategy could be utilized for a short period of time to keep a single day's routes in service without major revision of the transit routes. This would be dependent on the final charging infrastructure design and the location of on-route chargers. It should also be noted that the total cost of charging may differ if on-route chargers are utilized as a method of sustaining services during an outage. Rerouting a large number of buses to charge on-route is not a long-term solution but could provide much needed battery power during a power outage.

Redundant Grid Sources

Another method to increase energy resiliency is to employ a redundant feeder from the utility grid to the Lakewood Base. Ideally, this secondary redundant source is served by a separate circuit than the primary feeder and could provide power to the Lakewood Base in the event the primary source experiences an outage or fault. Additional conversations with the public utility would be needed to determine if this is feasible. There are several main grid components that affect the grid source reliability.

Substation

The electric utility typically takes service from the generation and transmission grid at the utility's substation. The substation converts electricity from a high transmission voltage to the local medium voltage system. Due to land constraints and large load requirements, the local utilities generally operate multiple transformers within each substation and each transformer is connected to multiple medium voltage, distribution feeders. Most outages at the substation level are localized to a single substation transformer. The presence of multiple substation transformers provides redundancy during most normal operations. The utility usually plans maintenance outages to avoid impacting the entire substation; however, when planning for redundant power to the transit base chargers, Pierce Transit should request redundant distribution feeders be fed from separate substations or at the least from separate substation transformers.

Distribution Feeders

Medium voltage distribution feeders are installed and operated by the utility to supply electricity to their customers. Utility planners work to ensure that the grid will operate as reliably and efficiently as possible. Utility planners consider how to add new loads to the grid and how to best operate the local grid when maintenance or other outages impact an area or customer. In most cases, impacts to the distribution feeders are seldom known or experienced by the utility customer.

Unexpected outages at the distribution level are often localized and able to be fed from a separate distribution feed. Underground distribution feeder outages are most commonly caused by digging into the line. Underground feeder outages do not happen frequently but occur for a longer duration. To avoid long-duration underground outages, utilities typically operate a loop system that can be switched from one source to another to avoid lengthy delays.

Overhead distribution feeders are installed nearer to the ground than transmission lines, so they are more likely to be impacted by tree branches and animals contacting the bare conductors and shorting the system. Overhead distribution feeders are also not built to the same strength as the transmission lines, so wind and downed trees can also impact these overhead feeders.

Overhead feeder outages occur more frequently than underground outages but are repaired much quicker because they are more accessible. Overhead feeders are often configured to allow multiple sources to back feed the line in the event of outage or maintenance.

Some factors for consideration of the distribution feeders may include:

- Does the charging infrastructure require a 100 percent redundant backup source? If 100 percent redundancy is required, this will increase cost and on-site space required for the utility to provide this level of redundancy.
- Providing separate distribution sources from two separate substations is most desirable but also most costly. If redundant distribution feeds are installed, consider utilizing sources from a single substation but from separate transformers within that substation.

Spare Bus Utilization

Maintaining a fleet of spare buses (zero-emissions or conventional combustion engines) is a viable option to maintain a more operational transit routes in the event of an outage. Depending on the type and length of a potential outage, buses can be swapped with fully charged spares for a reserve fleet once they reach a low state of charge. Maintaining a reserve fleet of BEBs would allow for Pierce Transit to maintain their emissions goals while enabling a greater sense of resiliency for transit operations. However, a reserve fleet of this style is still limited by the charging infrastructure which may be impacted by the potential outage.

A reserve fleet containing diesel buses can provide a greater amount of bus swaps as they are not limited by potential charging outages. While this method may be viable during a phased fleet conversion, this would no longer be viable once the entire fleet became battery electric. However, a mixed fleet of BEBs and FCEBs may be viable.

While a reserve bus fleet can provide a greater sense of resiliency and allow for increased transit operations during an outage, there are significant costs and space requirements associated with purchasing and maintaining a reserve fleet that should be weighed against the benefits of developing and storing one.

Reduced Bus Services

In the case of a power outage, service reductions could be considered for the duration of the outage. Services can be reduced to a maintainable level depending on the severity, type, and outage duration (utility, local, software, etc.) and then returned to baseline operation once an outage is restored and buses are fully charged for operation. Different plans can be developed to optimize services for different outage categories to streamline service reductions. It should be noted that in the event of a large-scale outage, such as those caused by a large natural disaster, the overall demand for different transit service will likely decrease as the disaster has larger regional impacts beyond transit services. This should be considered if reduced operations plans are developed in the future. Overall, service reduction plans are dependent on the type and scale of an outage and are a viable option as a primary or secondary method of operation resiliency.

Solar Photovoltaics

Solar photovoltaic (PV) energy provides a scalable choice for no emission energy generation. Over the past decade solar PV has become more reliable and requires little maintenance over its lifetime. Solar PV requires a large area/footprint to achieve large power output and is subject to fluctuations in solar irradiance. Given the use case for Pierce Transit, solar PV could be installed over gantry-mounted bus chargers or above existing buildings with some upgrades to the overall support structure. This helps alleviate some concern for a large footprint required by PV systems. The overall solar PV system can be scaled depending on the available space or module size but may be subject to fluctuations depending on module tilt and azimuth angles.

Solar PV is typically not capable of offsetting the entire bus charging energy demand. However, PV can offset a meaningful portion of overall demand resulting in a "net load" that is lower than scenarios without PV. Solar PV would not provide backup power unless designed to include battery energy storage; the primary benefit of a solar PV system would be offsetting the increasing energy consumption at the Lakewood Base. The overall impact of solar PV is also dependent on the bus charging schedule. A solar installation will have a greater impact if more of the charging occurs during peak solar generation hours. However, with the addition of energy storage, a greater amount of solar energy can be utilized if the bus charging load is less than PV output during some daylight hours.

Battery Energy Storage

Battery energy storage can play a critical role within a microgrid or distributed energy resource (DER) system. Although energy storage systems (ESS) are not a generation method they can provide greater reliability and resiliency for a microgrid, along with potential energy bill reduction applications. ESS are especially useful when utilizing renewable generation methods because it can help reduce some of the intermittency issues and extract more value out of those types of assets. Battery energy storage systems (BESS) are typically the most prominent and mature technology for distributed scale systems and microgrids. BESS systems are scalable and can help provide a greater sense of resiliency for a more renewable focused system but typically come at a relatively high installation cost and may experience degradation in energy capacity over the system's life.

For transit bases, BESS systems are typically utilized for shifting load and/or generation in a strategic way that may help reduce demand charges and total energy costs associated with large charging loads that occur during peak rate hours. The size and duration of a potential BESS is heavily dependent on the available space for installation because the size of the system will increase as the nameplate capacity and operational duration increases. BESS size will vary from vendor to vendor, but most solutions are typically of a containerized style. Systems of this nature are generally modular and flexible in terms of system size with footprints ranging from 8 feet by 12 feet upwards to 40 feet by 8 feet (40-foot ISO containers). Further analysis and optimization would help determine the optimum BESS size and configuration for Pierce Transit.

Utility Coordination

As part of this fleet transition planning process, Pierce Transit and HDR worked together to establish communication with all public utilities that serve Pierce Transit. Pierce Transit purchases power from three public utilities: Lakeview Light and Power, Puget Sound Energy (PSE), and Tacoma Power. Pierce Transit also met with the Northwest Hydrogen Association to discuss ZEB plans.

Lakeview Light and Power

Pierce Transit met with Lakeview Light and Power on January 18, 2022, to provide an overview of the ZEB study and begin high level utility coordination. Lakeview Light and Power provides energy for the Lakewood Base and Lakewood Transit Center, which is a potential on-route charging location. This public utility offered a few incentives for electric vehicles and was generally supportive of Pierce Transit's ZEB strategy. Lakeview was able to confirm power availability for Lakewood Transit Center and the Lakewood Base; however, upgrades would be needed to support the charging infrastructure installed at the Lakewood Base. Pierce Transit and Lakeview Light and Power will continue working together to coordinate the utility upgrades needed at this site.

Puget Sound Energy

Pierce Transit met with PSE on January 30, 2022, to provide an overview of the ZEB study and begin high level utility coordination. PSE offered a variety of electric vehicle incentives for fleets and charging stations that can be further explored for Pierce Transit's ZEB transition. PSE provides energy for the South Hill Mall Transit Center and was able to confirm power availability for the site. Overall, PSE was highly supportive of Pierce Transit's ZEB strategy.

Tacoma Power

Pierce Transit met with Tacoma Power on March 10, 2023, to provide an overview of the ZEB study and begin high level utility coordination. Tacoma Power did not yet offer EV incentives, but they are developing a program and plan to have a fleet program toward the end of 2023. Tacoma Power provides energy to the Commerce Street Station, TCC Transit Center, and Tacoma Mall Transit Center. The utility is working to confirm power availability at the three sites. Overall, the utility was supportive of Pierce Transit's ZEB strategy.

Northwest Hydrogen Association and Consortium for Hydrogen and Renewably Generated E-fuels

Pierce Transit is actively communicating with partners at the Pacific Northwest Hydrogen Association (PNWHA) and Consortium for Hydrogen and Renewably Generated E-fuels (CHARGE) to provide an overview of the ZEB plan. Increased coordination will continue to explore ways the association can partner with and support the ZEB study going forward. Pierce Transit met with CHARGE on March 31, 2023, to provide an overview of the ZEB study and talk about the interest in creating a hydrogen hub in the Pacific Northwest. At the time of this report, the two hydrogen entities were still developing plans and did not have much public information that could be shared. Pierce Transit intends to maintain communication and stay up to date on hydrogen developments in the area.

Financial Analysis

When undertaking any major transit technology and infrastructure project, the first concern is typically how much it will cost to implement. This financial analysis evaluates the lifecycle costs associated with the two zero-emission fleet transition scenarios currently being considered by the Pierce Transit for its public transit bus fleet in comparison to a baseline CNG scenario. The costs evaluated include capital, maintenance, and fuel/electricity over a 20-year period, from 2023 through 2042. The transition scenarios considered involves a full BEB fleet transition and an FCEB dominant transition. These are compared to a CNG baseline scenario where Pierce Transit continues to utilize CNG vehicles and does not fully transition to ZEVs. A lifecycle cost analysis is used to inform a decision between acquiring one of two assets, determining each assets benefits, and creating an informal budget. In this case, the analysis will show how the cost schedule of continuing with a CNG fleet compares to transitioning to ZEVs. The analysis will not consider any external benefits to the transition that may play a large part in policy choices. Primarily, the reduction of harmful emissions into the atmosphere are not monetized as a benefit but should be considered in fleet decisions.

ZEB Transition Costs

The costs evaluated in this section included capital and lifecycle costs over the entire transition plan (2023–2042). See **Appendix B: Financial Assumptions, Methodology, and Lifecycle Cost Comparisons** for further details on the following:

- An overview of the key inputs and assumptions used in the BEB transition, FCEB transition, and the CNG baseline scenario analyses;
- A detailed discussion of the methodology used to develop 20-year capital, maintenance, and fueling requirements and costs estimates for all scenarios; and
- A description of the lifecycle cost comparison results between the electric transition scenarios and the baseline.

The project team compared the costs of the CNG Baseline Scenario (procuring only CNG buses), a Long-Term BEB fleet, and a Long-Term FCEB fleet. The FCEB fleet assumes that Pierce Transit decides to pivot to FCEBs after the near-term deployment and starts procuring FCEBs beginning in 2031. The Long-Term FCEB fleet would have both BEBs and FCEBs, but the long-term goal would be to integrate as many FCEBs as feasible.

The fleet makeup, fleet operating statistics, and additional infrastructure purchases with related maintenance result in differences in the transition scenarios. Differences – shown in **Table 10** – are categorized as capital costs, operation and maintenance (O&M) costs, and fueling costs. As expected, capital costs in both electric transitions are far more than the CNG-heavy baseline scenario. This is due to the BEBs and FCEBs being more expensive than their ICEB counterparts, along with the need for additional infrastructure to support the BEB and FCEB fleets. The per-mile maintenance cost was not estimated to be lower for ZEBs, and therefore the ZEB scenarios are more expensive than the CNG Baseline Scenario over the lifecycle as well. There are minimal fueling savings for the BEB scenario and significant fueling cost increases for the FCEB scenario.

Between the two transition scenarios, the BEB scenario will be more cost effective but is still about $180 million more than the baseline scenario.

Table 10: Lifecycle Cost Breakdown, 2023 to 2042 (2023 $)

Capital Costs	Baseline	BEB Transition	FCEB Transition
Vehicle Purchases	**$227,747,900**	**$329,789,400**	**$352,248,500**
ICE Vehicle Purchases	$181,355,000	$27,250,000	$27,250,000
BEB Purchases	$38,400,000	$274,220,000	$40,800,000
FCEB Purchases	-	-	$266,200,000
Mid-Life Rehab	$7,992,900	$28,319,400	$17,998,500
Infrastructure Purchases	**N/A**	**$73,185,120**	**$8,000,000**
Chargers	-	$73,185,120	-
Utility Infrastructure	-	-	$8,000,000
Capital Cost Subtotal	**$227,747,900**	**$402,974,520**	**$360,248,500**
O&M Costs	**Baseline**	**BEB Transition**	**FCEB Transition**
Vehicle Maintenance	**$130,668,035**	**$137,417,365**	**$159,901,193**
ICEB	$123,817,670	$58,143,418	$58,143,418
BEB	$6,850,365	$79,273,947	$24,623,257
FCEB	-	-	$77,134,518
Infrastructure O&M	**$90,000**	**$1,167,000**	**$2,890,000**
EV Chargers	$90,000	$1,167,000	$90,000
Utility Infrastructure	-	-	$2,800,000
O&M Cost Subtotal	**$130,758,035**	**$138,494,365**	**$162,791,193**
Fueling Costs	**Baseline**	**BEB Transition**	**FCEB Transition**
Gasoline	$5,284,079	$18,311,085	$2,766,440
Diesel	$22,358,749	$2,145,583	$4,804,443
CNG	$20,162,746	$10,740,202	$10,740,202
Electricity	$3,636,919	$16,779,520	$6,640,295
Hydrogen	-	-	$100,384,370
Fueling Cost Subtotal	**$51,442,494**	**$47,976,390**	**$125,335,751**
Scenario Total	**$409,948,429**	**$589,535,275**	**$648,375,444**

Funding Plan

With a clear understanding of costs associated with a ZEB transition, Pierce Transit can begin to incorporate these costs into future operating and capital budgets. Grant funding will be essential in helping Pierce Transit meet their goal of 20 percent ZEVs by 2030 and achieving a long-term vision of a zero-emission fleet. Pierce Transit will utilize formula funding and previously awarded grant funding to continue transitioning the fleet in the near term. The agency will also apply for funding from any relevant competitive grant programs at the local, regional, state, and federal level including the WSDOT ZEVIP Program, the WSDOT Green Transportation Capital Grant Program, the FTA Low or No Emission Vehicle Grant Program, and the FTA Bus and Bus Facilities Grant Program. Pierce Transit will also explore innovative funding strategies like the Washington CFS Credit Generation Program, public-private partnerships, utility partnerships, and leasing opportunities.

Workforce Development

Overview

With the introduction of zero emission technology to the Pierce Transit bus fleet, proper training on bus systems and subcomponents unique to ZEBs is critical to ensure safe, efficient operation and maintenance of the transitioned fleet. Pierce Transit will work with internal training departments in close coordination with OEMs to acclimate the existing workforce to the new technology, avoiding displacement of the existing workforce.

This section will address the necessary steps to evaluate the skills of the existing workforce, identify skill gaps on an individual basis, and develop a plan to build and implement an effective training program for both bus operators and bus maintenance personnel. In addition to the further development of the existing workforce, this document will also convey a workforce growth strategy for attracting new employees, retaining new and current employees, and funding opportunities to sponsor the growth.

Training Program Development

Pierce Transit intends to deploy ZEBs and provide an in-house comprehensive training curriculum to operate and maintain these vehicles. Training will focus on BEBs. While there are no immediate plans to adopt FCEBs, workforce development will include FCEBs because this technology could be incorporated at a later date. The development of a high-quality training program will entail coordination with internal and external resources. The following list identifies potential resources that may assist Pierce Transit with program development:

- Vehicle and charger OEM training curriculum purchased as part of new rolling stock procurements
- Technical and safety training curriculum developed and delivered by Pierce Transit's in-house Maintenance Training Program
- Vehicle subsystem/subcomponent OEM training curriculum
- Partnership with local first responding agencies
- Collaboration with transit agencies with operational zero emission fleets and in-house training programs such as King County Metro
- Washington State Transit Insurance Pool (WSTIP)
- GEM (Grounds, Equipment, and Maintenance), a Pacific Northwest Interagency Cooperative for all public agencies to the mutual benefit of all constituents
- Membership through training consortiums like National Transit Institute (NTI)
- Participation in transit associations like WSTA, APTA, Center for Transportation and the Environment (CTE), and Zero Emissions Bus Resource Alliance (ZEBRA)

Pierce Transit will work to develop a training program that integrates ZEB curriculum with its existing internal training program, including bus maintenance technical training and behind-the-wheel training. Technical training includes shop and system safety, system familiarization and operations, troubleshooting and diagnostics, rebuild, and preventative maintenance. All ZEB curricula will be jointly developed and reviewed by Pierce Transit and Amalgamated Transit Union (ATU) Local 758 prior to being approved by Pierce Transit's Bus Operations Training Assistant Manager, and Executive Director of Maintenance, and Maintenance Training Coordinator.

Training Curriculum

Pierce Transit's operator training program is a 28-day program built upon curriculum from WSTIP guided by the Federal Motor Carrier Safety Administration (FMCSA); the program includes 21 days of classroom training followed by 7 days of behind-the-wheel training. Pierce Transit works closely with Enterprise Asset Management, parts procurement, and bus OEMs to provide operator training. As the technology evolves and OEM training curriculum is updated, Pierce Transit will schedule operators to attend new training courses.

Both BEBs and FCEBs contain high voltage batteries, requiring all maintenance technicians to be certified to work on high voltage systems. Pierce Transit Bus Maintenance and Training Departments, with the inclusion of ATU, will work to supplement the existing electrical safety training curriculum with guidance from the National Fire Protection Agency (NFPA 70E), OSHA, OEMs, and industry best practices. The program will include the following curriculum:

- Proper use and inspection of personal protection equipment (PPE)
- CPR and first aid training
- High voltage onboard systems familiarization and identification
- Lock-Out-Tag-Out (LOTO) training and compliance
- FCEB workplace safety and hazard response protocol

Current entry level training for BEBs from OEMs is very thorough about LOTO and PPE and Pierce Transit goes above and beyond suggested safety standards wherever possible to create an extra buffer for personnel safety. Pierce Transit is currently working with Proterra on a four-day formal, in-house training course that will include both classroom and on the job modules. This training course will be offered in six-person classes at an estimated cost of $15,000 per class. Additionally, **Table 11** details the forecasted BEB training courses Pierce Transit identified in their Phase 1 Plan.

Table 11: Battery Electric Bus Driveline Training Transition Forecast

Course	Type	Units	Cost	Notes
Electric Drivelines	Cummins	Per Person	$4,000	Incl. Per Diem, Hotel
Door Training	Vapor	Class (4-6)	$3,400	1-day, in-house
BEB JLM Familiarization	GILLIG	Class (4-6)	$5,000	3-day, in-house (GILLIG)
Multiplex I/O	Dinex G5	Class (4-6)	$5,000	3-day, in-house (GILLIG)
HVAC	ThermoKing	Class (4-6)	$4,800	3-day, in-house (ThermoKing)
Charging Stations	ChargePoint	Class (4-6)	Free	ChargePoint Univ. Installers Course

Skills Assessment, Categorization, and Gap Identification

This section will outline the workplace hierarchy structure and authorized responsibilities of individuals based on qualifications, the skill level requirements for work needing to be performed, and initial, refresher, and proficiency guidelines and requirements for training and associated qualifications. Generally, operational staff can be grouped into four categories:

1. **Bus Operations Support:** Staff in this category would include those who are critical to bus operations but do not directly interact with the buses. Minimal training is required and typically only covers a high-level overview of the technology and its capabilities. For example, it's important for dispatchers and schedulers to understand the operational range of the vehicles to avoid assigning vehicles to unsuitable routes.
2. **Bus Operations:** Staff in this category would include operational staff who directly interact with the buses but do not perform any vehicle maintenance. Bus Operations will require more training than Bus Operations Support staff given their direct interaction with the vehicles. For example, bus operators must be familiar with all dash indicator lights, operation of doors and wheelchair access, and safety procedures.
3. **Bus Maintenance Support:** Staff in this category include operational specialists who directly interact with the buses, support, or lead bus maintenance training, and/or are responsible for the assignment and oversight of maintenance functions. Bus Maintenance Support will receive the same training as bus maintenance personnel as their roles require full familiarity with all vehicle systems and mechanical components.
4. **Bus Maintenance:** Staff in this category include operational specialists who directly interact with the buses and perform routine and unplanned maintenance functions. Bus Maintenance personnel require the most training as they have the most frequent and in-depth interaction with the vehicles. Within Bus Maintenance, personnel will be

individually assessed on current skills and assigned to training modules as necessary, ensuring that all Bus Maintenance personnel receive all training required without duplicating the effort. For example, maintenance personnel who can demonstrate proficient multiplexing skills would not be assigned to multiplexing courses.

Table 12 shows the composition of Pierce Transit's existing operations and maintenance staff, including the number of full-time equivalent employees (FTE), number of authorized positions, union affiliation, and role categorization with respect to the zero-emission transition.

Table 12: Pierce Transit Operations and Maintenance Job Titles & Staffing (2022)

Job Title	Role Category	# FTEs	Authorized Positions	Representation
Scheduler	Bus Operations Support	2	2	ATU Local 758
Service Impacts Supervisor	Bus Operations Support	1	1	ATU Local 758
Service Supervisor	Bus Operations Support	40	43	ATU Local 758
Service Supervisor - SHUTTLE	Bus Operations Support	2	2	ATU Local 758
Service Support Training Coordinator	Bus Operations Support	1	1	ATU Local 758
Specialized Transp. Dispatcher	Bus Operations Support	7	7	ATU Local 758
Transportation Assistant Manager	Bus Operations Support	7	7	Non-Represented
Transportation Manager	Bus Operations Support	2	2	Non-Represented
Transportation Manager, Specialized	Bus Operations Support	1	1	Non-Represented
Bus Training Assistant Manager	Bus Operations	1	1	Non-Represented
CSR Fixed Route	Bus Operations	8	10	ATU Local 758
CSR SHUTTLE	Bus Operations	9	9	ATU Local 758
Instructor	Bus Operations	12	13	ATU Local 758
Relief Transit Operator	Bus Operations	0	81	ATU Local 758
Transit Operator	Bus Operations	434	450	ATU Local 758
Transit Operator Trainee	Bus Operations	16	42	ATU Local 758
Executive Director of Maintenance	Bus Maintenance Support	1	1	Non-Represented
Fleet Assistant Manager	Bus Maintenance Support	4	4	Non-Represented
Fleet Care Attendant	Bus Maintenance Support	9	15	ATU Local 758
Fleet Manager	Bus Maintenance Support	1	1	Non-Represented
Labor Negotiator	Bus Maintenance Support	1	1	Non-Represented

Job Title	Role Category	# FTEs	Authorized Positions	Representation
Maintenance Training Coordinator	Bus Maintenance Support	1	1	Non-Represented
Training And Workforce Development Manager	Bus Maintenance Support	1	1	Non-Represented
Zero Emissions Fleet Coordinator	Bus Maintenance Support	1	1	Non-Represented
Travel Trainer	Bus Maintenance Support	1	2	ATU Local 758
Apprentice Diesel Mechanic	Bus Maintenance	1	3	ATU Local 758
Body Repair Technician	Bus Maintenance	6	8	ATU Local 758
Journey Level Mechanic	Bus Maintenance	40	48	ATU Local 758
Lead Maintenance Mechanic	Bus Maintenance	0	1	ATU Local 758
Lead Mechanic	Bus Maintenance	6	7	ATU Local 758
Maintenance Mechanic	Bus Maintenance	6	6	ATU Local 758
Mechanic I	Bus Maintenance	1	1	ATU Local 758
Preventative Maintenance Service Technician	Bus Maintenance	3	3	ATU Local 758
Transit Maintenance Worker	Bus Maintenance	3	3	ATU Local 758
Transit System Maintenance Worker	Bus Maintenance	6	9	ATU Local 758

Training Program Implementation

Pierce Transit's current technical training program is constantly evolving as old systems are retired and new systems are integrated; their in-house program will include a comprehensive curriculum on all vehicle systems and subsystems through internal training, peer-to-peer training, "Train the Trainer" through vendors and OEMs, and collaboration with local fire departments and vehicle towing companies. All maintenance department training will be specialized to provide employees with current information about new and existing equipment, including modern electronic and mechanical bus systems, OEM changes that impact maintenance practices, and refresher training if necessary. Additionally, Pierce Transit encourages all fleet maintenance personnel become Automotive Service Excellence (ASE) H-, S-, and T-series certified; these certifications are not mandatory, but technicians are awarded premium pay for achieving and maintaining ASE Master Transit Bus Technician Certification status per the ATU Local 758 Labor Agreement.

Initially, Pierce Transit plans to identify and develop a core group of subject matter experts (SME) to serve as BEB and FCEB fleet specialists. This approach will lend itself to the proactive development of qualified fleet specialists through hands-on experience and learning. In turn, this will influence the transition to an entirely zero-emission-certified workforce on a timeline that aligns with the integration of new ZEBs to the Pierce Transit fleet. The training effort is envisioned to be phased so that as the zero-emission fleet grows, more mechanics will complete zero-emission maintenance training. For example, if Pierce Transit is expecting delivery of 10 BEBs, transition training for five mechanics to become BEB- and FCEB-certified fleet specialists will begin one month prior to delivery. This ensures Pierce Transit is staffed appropriately when taking delivery of new buses in alignment with the identified fleet replacement schedule, with a 20 percent ZEB transition taking place by 2030.

In addition to the plans and training stated above Pierce Transit is currently under contract with Gillig for On-Call Training for maintenance through March 31, 2026. The training topics covered under the contract and relevant to Battery Electric Buses are:

- Gillig Battery Electric Bus Operator Training
- Maintenance Department General Vehicle Orientation
- Gillig Battery Electric Bus Service Personnel Training
- Basic Bus Electrical Systems
- Multiple Electrical Systems G3, G4, and G5

Workforce Right-Sizing

As Pierce Transit transitions to ZEBs, the agency will re-evaluate staffing needs on a rolling basis, based on overall fleet growth, and approve additional Apprentice Mechanic, Mechanic, and Lead Mechanic positions as determined by the Maintenance Department. A summary of Pierce Transit's current Operations and Maintenance staff by position category is shown in **Table 13**.

Table 13: Pierce Transit Operations and Maintenance Employees Summary

Role Category	Full Time Employees	Authorized Positions
Bus Operations Support	63	66
Bus Operations	480	606
Bus Maintenance Support	19	26
Bus Maintenance	72	89
Total	**634**	**787**

Pierce Transit jointly sponsors an apprenticeship program with ATU Local 758 and the Washington State Department of Labor and Industry. Apprenticeship occupational objectives under this program include Bus Body Repairer, Coach Heavy Duty Diesel Mechanic, and Facilities Maintenance Mechanic; all three programs establish on the job (OTJ) training that leads the apprentice to the status of State Certified Journey Level Heavy Duty Diesel Mechanic after completion of 8,000 hours of reasonably continuous employment and at least 144 hours per year of related/supplemental instruction (RSI) per the Washington State Apprenticeship and Training Council's Apprenticeship Program Standards. RSI hours can be satisfied through State

Community/Technical Online College as approved by the Committee or through in-house training classes conducted at Pierce Transit under the maintenance training program.

Pierce Transit partners with local trade schools and educational institutions to promote careers in automotive technology and student applications to the apprenticeship program, as seen in the Career Pathway Trainees Program. Specific to the apprenticeship program, Pierce Transit will give preference to internal over external applicants. By doing so, Pierce Transit is advancing the careers of current employees as the agency is contractually obligated to offer full-time employment into a Journey-Level Mechanic (JLM) position to all individuals who successfully complete their apprenticeship through the Apprenticeship Standards Revision.

To fill mechanic position vacancies, Pierce Transit will first evaluate whether any apprentices are nearing program completion, then post externally in partnership with local trade schools if the position cannot be backfilled internally. While a degree is preferred for JLM positions, it is not required provided the applicant has successfully completed his or her apprenticeship.

For Operators and all other positions requiring a commercial driver’s license (CDL) (fleet maintenance positions), applicants are not required to have a CDL to be hired. However, prior to a final offer for any positions that require a CDL, candidates are required to obtain a Class B Commercial Learner’s permit with Passenger endorsement. The hiring and training requirements and qualifications are shown below:

Required Qualifications:

- Must be at least 21 years of age at the time of hire.
- Must have been licensed for a minimum of five years to be considered.
  - Five years of continuous, recent driving history is required (i.e., no gaps in license status to include suspensions and withdrawals)
  - Must have an excellent driving record (no revocations or suspensions).
  - Applicants may apply with an out-of-state license but must possess a valid Washington State driver's license at the time of hire

Applicants that meet qualifications go through the following process:

- Interview
- Conditional offer
- Driving record review
- Criminal background check
- Reference checks
- Functional Assessment appointment to determine if they can perform the essential functions of the Operator position
- DOT Physical with a certified medical provider
- Pre-employment drug screening

- Verification of Class B CDL permit w/ passenger endorsement
- Final offer

Once hired, Operator trainees go through the six-week CDL training course and are tested onsite by third-party testers. If they complete the CDL training they then go into Mentorship training for a few weeks and then to route training. Once that is complete, they start their probationary period as an Operator.

Pierce Transit will continue to develop more creative recruitment strategies to combat the nationwide shortage of mechanics and bus operators. Properly marketing the Pierce Transit Zero Emission Fleet Transition, including the opportunity for a cutting-edge technical career, is critical to the attraction, development, and retention of the required workforce.

Funding Opportunities

The cost of workforce training will likely fluctuate in response to the adoption of ZEBs. Funding is anticipated to come from a number of sources, including procurement (where the cost of training is included in the budgeted cost of the vehicle or infrastructure procurement), existing funding sources used for training, and federal or local funding shares such as:

- FTA Low or No Emission Vehicle Program – 5339(c)
- FTA Bus and Bus Facilities Program – 5339(b)
- CMAQ Bipartisan Infrastructure Law Grant
- Washington State Bus and Bus Facilities Grant
- Washington State Green Transportation Capital Grant
- WSDOT Zero Emission Vehicle Infrastructure Partnerships (ZEVIPs) Grant

Historically, Pierce Transit allocated approximately $8,000 towards each bus purchased (80% Federal, 20% Local Match) to be utilized for training and specialized tooling and equipment needs. This allocation was sufficient to sustain and support tooling and critical training needs for maintenance staff. But since that funding has been removed, additional funding has been added to Pierce Transit’s annual training budget.

While the cost of the training itself is one item to consider, the labor cost to train Bus Maintenance personnel is anticipated to be high. As highlighted by the International Transportation Learning Center, the following costs will be considered when budgeting for workforce training:

- Classroom training hours
- Instructor hours (instruction and prep)
- Instructor hourly wages and benefits
- Instructor costs per class
- Instructor cost per trainee
- OTJ training hours
- Mentor hours
- Mentor hourly cost
- Mentor cost per trainee
- Facilities cost
- Training materials/mock-ups/software/simulation cost

A sample curriculum of known training modules as detailed in **Table 14** will be used as a foundation for the larger training program. Bus Operations staff will be assigned to complete both Operations Support modules and Bus Operations modules; Bus Maintenance Support and Bus Maintenance staff will be required to complete all training modules. If the training module is marked with an "X", this means that the training is required for this fuel type. Shown at the bottom are the total estimated hours of training required for each fuel type.

Table 14: Sample ZEB Curriculum

Role Category	Training Module	Training Hours	Diesel	Battery Electric	Fuel Cell Electric
Operations Support	Vehicle Familiarization, Systems and Sub-Systems Overview	8	x	x	x
	Hydrogen Fuel Safety	8			x
	Advance Communication System	16	x	x	x
Bus Operations	Operator Orientation, including safety, charging procedures, onboard systems (includes behind the wheel training)	6.5		x	
Bus Maintenance	Shop Safety and Procedures	16	x	x	x
	Fundamentals of Troubleshooting	16	x	x	x
	Basic Repair Skills	16	x	x	x
	Heating, Ventilation, and Air Conditioning	16	x	x	x
	Air Brake Systems	24	x	x	x
	Hydraulic Brake Systems	8	x	x	x
	Steering and Suspension Systems	16	x	x	x
	Basic Electrical	24	x	x	x
	Multiplex Systems	24	x	x	x
	Low Voltage Systems Troubleshooting and Repair	16		x	x
	High Voltage Systems Troubleshooting and Repair	24		x	x
	Automatic Transmissions (phased out with 100% ZEB fleet)	24	x		
	Diesel Engine Tune-Up and Troubleshooting (phased out with 100% ZEB fleet)	24	x		
	Diesel Engine Electronic Control Systems (phased out with 100% ZEB fleet)	16	x		
	FCEB Propulsion Systems (Drive Motor and Gearbox)	24			x
	BEB Propulsion Systems (Drive Motor and Gearbox)	24		x	
	Total Hours of Training	**396**	**284**	**300**	**308**

Pierce Transit Career Pathway Trainees

The Pierce Transit Career Pathways program will design multiple pathways to employment in the transit industry including a pre-apprenticeship program (a first in Washington State) for young adults to earn a living wage without the time and expenses of a post-secondary education. This program provides options for underserved, minority, and first-generation college participants to train for and enter leadership and exempt positions in transit, and a direct pathway for women to employment as bus operators; a career that was historically dominated by men since the end of the second world war. These programs can only exist with discretionary grant funds and will strengthen connections between our organization and the communities we serve.

Pre-Apprenticeship Pilot

To better support those with systemic barriers to employment, Pierce Transit will seek grant funds to design the first Transit Pre-Apprenticeship Program in Washington. Partnering with the Labor and Industries, Washington State (L&I), local technical colleges, Consulting Experts, Staff, and workforce partners we will design a Transit Pre-Apprenticeship program to serve as a pathway to positions including facilities or vehicle custodians, service station attendants, and maintenance mechanics. These entry-level positions provide a benefitted, labor-represented, living wage job to serve as a career step into other apprenticeship programs at Pierce Transit including Journey Level Mechanic and Communications Technicians (application in process with L&I).

Pierce Transit would complete an open competitive procurement process before entering contracts with supportive service partners. Pierce Transit has identified potential supportive services partners such as ANEW, and Palmer Scholars. Both organizations are non-profits and if selected will participate in recruitment efforts of minority, women, and underserved populations within Pierce and King counties. Future grant monies would be made available from Pierce Transit to partners. Services and supports would vary between partners but may include paid internships, emergency transportation funds, childcare stipends, relocation assistance, and emergency housing and utilities support. These funds would be disbursed by these agencies for Pierce Transit career pathway participants. Additional services provided by Palmer Scholars and ANEW include financial support for uniforms, union dues, Commercial Driver License (CDL) testing fees, one-on-one mentoring, relocation assistance and career readiness training. In addition, participants would receive a guaranteed interview for operator positions to anyone who meets minimum qualifications including hiring assessments.

ANEW was founded in 1980 by people dedicated to improving the access and advancement of women in non-traditional career pathways such as construction and manufacturing. This partnership will allow them to expand career pathways for transit to meet regional demands and provide a family wage for our community members.

Palmer Scholars offers the Palmer Pathways, serving young adults between 18 and 26 years old, who are neither enrolled in a postsecondary program nor gainfully employed and have an interest in pursuing a career in the trades. The Legacy Program serves young adults from the time they are juniors in high school through postsecondary program completion. Scholars may choose to attend any postsecondary program, whether that is an apprenticeship or two-year or four-year degree. Palmer Scholars would be eligible for paid internships/job shadowing for non-represented or hard to fill jobs at Pierce Transit. Additionally, Pierce Transit will host a 5-day career exploration week (summer session) for young adults (18-24 years of age).

These programs will:

- Serve as a career pathway for local underserved communities
- Support confirmed Workforce Innovation Opportunity Act (WIOA) recipients/partners
- Partner with Local Community Colleges
- Develop a new career pathway (transit pre-apprenticeship)

- Provide recruitment and career pathways into family-wage careers in areas of need for Pierce Transit (bus operations, maintenance-division)

Pierce Transit will use grant funds to develop and establish these programs. The necessary support positions to advance these pilot programs will be temporary/contract/grant limited:

- Two full time specialists focused on Workforce Development Apprenticeship and Internship Coordinating
- Contract – Labor and Industries developer
- Pierce Transit Workforce Development Manager overseeing and directing the development and operation of this program 10% time.

Pierce Transit Employee Retention Pilot

Operator Retention with Phased Route Training. Operator recruitment and retention continues to be a challenge for transit organizations across the country. Efforts to recruit additional operators are improving but the retention of new operators at the 6-month milestone is dropping. We seek to conduct pilot project to assess, improve, and expand the access to training and enhanced mentorships during an operator's first year. Three cohorts of participants (both trainer and new operators) will complete this pilot and results will be used for agency training recommendations for new operators.

Workforce Development Budget

Pierce Transit is anticipating additional costs in order to train existing operators and mechanics and to start the new Career Pathway Trainees Program. **Table 15** shows the estimated costs for ZEB workforce development activities outlined in the Career Pathway Trainees Program.

Table 15: Workforce Development Budget

Item	Description	Cost
Contracted Supportive Service Partner	Non-profit supporting women in nontraditional careers. 100 participants.	$125,000
Contracted Supportive Partner	Non-profit supporting underserved young adults. 10 paid internships.	$265,000
Conference of Minority Transportation Officials (COMTO)	Nine internships	$120,000
Technical College Lakewood Vicinity Program	Development and coordination of program	$100,000
Washington State Labor and Industries (LNI)	One developer	$40,000
Pierce Transit Positions	Two specialist positions 100% time over 4 years	$670,000
Workforce Development Manager	10% time over ten years	$180,000
Operator Training	Curriculum development for "Train the Trainer", instructional designers, and training for 550 operators	$275,000

Item	Description	Cost
Miscellaneous Workforce Development Support Budget	Costs projected over five years	$74,740
Human Resources	Outreach effort to under-represented populations	$50,000
Training Room Upgrades	To support full cohort of new operators (24 seats)	$195,000
Pilot Project	Operator retention with phased route training	$130,000
Additional Training Tools	Electrical and mechanical training software	$100,000
Zero Emissions Tooling and Equipment	For bus maintenance	$211,000
Knowledge Transfer Activities	Budget to present findings and share knowledge at conferences and other events	$32,000
Battery Electric Bus Retraining	Training for incumbent and new staff	$42,000
Total		**$2,610,240**

Stakeholder Engagement

Stakeholder engagement for this ZEB strategy focused on information sharing and gauging attitudes and awareness of ZEBs. Pierce Transit worked with a local community engagement organization to develop an engagement strategy for this plan. The team decided that the most effective outreach would include a virtual roundtable, community interviews, and social media polling. See **Appendix C: Stakeholder Engagement Supplemental Information** for additional information and documentation of outreach efforts.

Outreach Efforts:

1. A virtual roundtable on January 25, 2023, with local jurisdictions, agencies, and industry organizations to introduce Pierce Transit's zero emissions planning process and establish partnerships for future efforts.
2. Invitations for initial conversations with environmental justice focused organizations that serve Pierce County.
3. Social media polling on attitudes and awareness toward the zero-emissions fleet transition.

Key Takeaways:

- Partners are supportive of Pierce Transit's and are eager to get information.
- Partner emphasized that Pierce Transit's plan should prioritize safety, reliability, sustainability, and partnership.
- Community-focused organizations are overburdened at the time of the ask. While information sharing and attempts to establish a relationship are important, Pierce Transit should consider consulting these and other similar organizations with a less rigid timeline outside of legislative session, and perhaps with more specific asks.
- The social media polls revealed that Pierce Transit's audience is split on the value and need for a transition to a zero-emissions fleet. Pierce Transit could do more to talk through plans and phases of work with riders and the broader community.

Conclusion & Next Steps

This ZEB transition strategy is a roadmap for Pierce Transit to convert its existing bus fleet to 100 percent ZEBs by 2042. This study included route modeling of Pierce Transit's service, infrastructure and facility analysis, utility coordination and identification of hydrogen fuel providers, cost analysis, stakeholder outreach, and a phased fleet transition strategy. This ZEB Transition Strategy also meets the federal requirements to apply for FTA funding, including:

1. Policy & Legislative Impacts
2. Fleet Transition Plan
3. Facility & Infrastructure Plan
4. Utility & Fuel Partnerships
5. Funding Plan
6. Workforce Transition Plan

Pierce Transit will cease purchasing CNG and gasoline buses by 2027 and 100 percent of all future bus procurement will be zero emission. Pierce Transit will have 32 BEBs from by 2028 as part of the near-term transition plan. During this period, the market is expected to mature, technological advancements will occur, and Pierce Transit will continue to gain experience operating BEBs and learn how to scale their BEB fleet. By 2030, Pierce Transit would either continue purchasing BEBs or could look to incorporate FCEBs in addition to BEBs.

Grant funding will be essential in helping Pierce Transit meet the ambitious goal of reaching zero emission by 2042. Pierce Transit will utilize formula funding and apply for funding from any relevant competitive grant programs at the local, regional, state, and federal level including the WSDOT ZEVIP Program, the WSDOT Green Transportation Capital Grant Program, the FTA Low or No Emission Vehicle Grant Program, and the FTA Bus and Bus Facilities Grant Program.

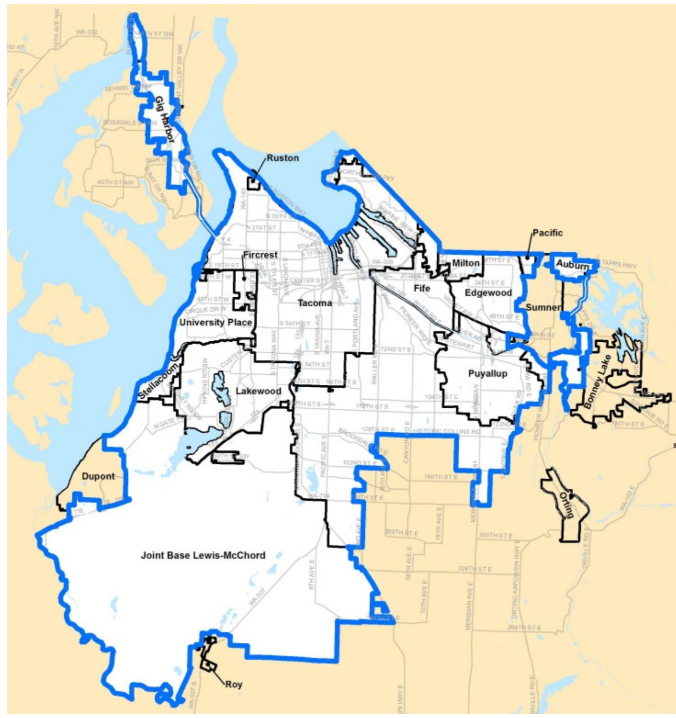
Sustainability is at the core of what Pierce Transit does as a public transportation provider. This Zero Emission Bus Transition Strategy will help Pierce Transit continue its commitment to sustainability by reducing emissions to improve air quality in the community and to protect the environment.

Appendix A: Route Modeling Technical Memorandum

Introduction

Transitioning to a zero-emissions fleet involves more than simply buying a vehicle and fueling system. The transition introduces new technology and requirements into day-to-day operations. Successful fleet transition plans take a holistic approach to consider operational requirements, market conditions, available power, infrastructure demands, and costs. The in-depth route modeling summarized below provides Pierce Transit with data to guide important decisions involving capital programs and operations necessary to transition the bus fleet to ZEVs.

Figure 34: Pierce Transit Service Area



Existing Conditions

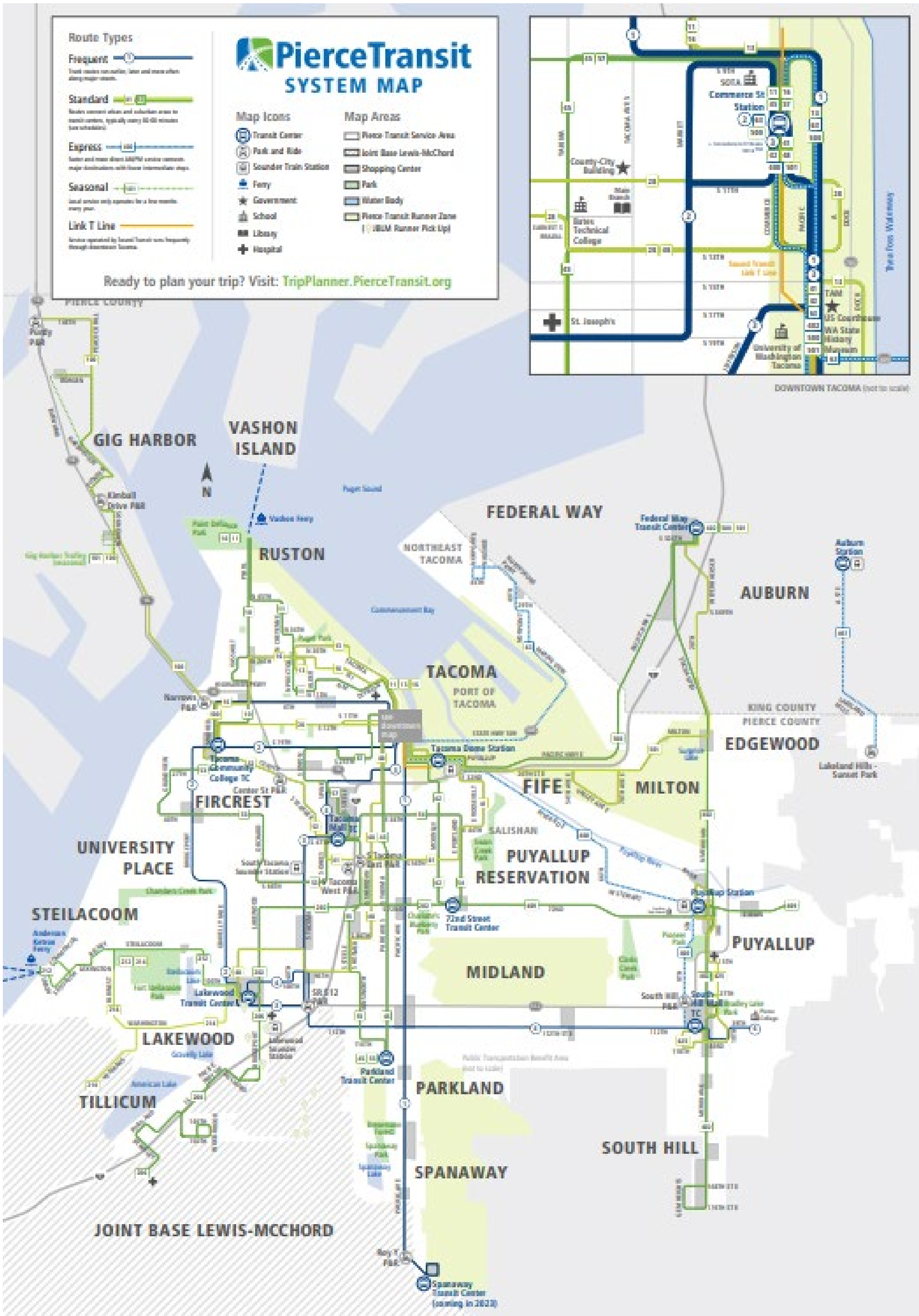
Serving Washington's second largest county, Pierce Transit provides three types of service—Fixed Route, SHUTTLE paratransit, and Vanpools—that help passengers meet their daily travel needs. Pierce Transit's service area covers 292 square miles of Pierce County with roughly 70 percent of the county population **(Figure 34**).

Pierce Transit has been operating alternative fuel vehicles since the 1980s – the agency has operated CNG buses for decades, introduced their first three battery electric buses (BEBs) in 2018, then added six more BEBs in 2021. Pierce Transit's fleet currently consists of 118 CNG buses, 23 diesel buses, 9 gasoline buses, and 9 battery electric buses. All CNG, diesel, and electric buses are 40-foot and all gasoline buses are 25-foot cutaways. **Table 16** depicts the buses owned by Pierce Transit. The agency operates 31 fixed bus routes and is planning a 14.4-mile BRT route which would enhance Pierce Transit's highest ridership route – Route 1. **Figure 35** shows Pierce Transit's System.

Table 16: Pierce Transit Fixed Route Vehicles

Fleet Type	Fuel Type	# of Vehicles	Vehicle Make
40′ Transit Bus	CNG	21	New Flyer
		97	Gillig
	Diesel	23	Gillig
	Electric	3	Proterra
		6	Gillig
25′ Cutaway	Gasoline	9	Ford

Figure 35: Pierce Transit System Map



Fleet Data Evaluation

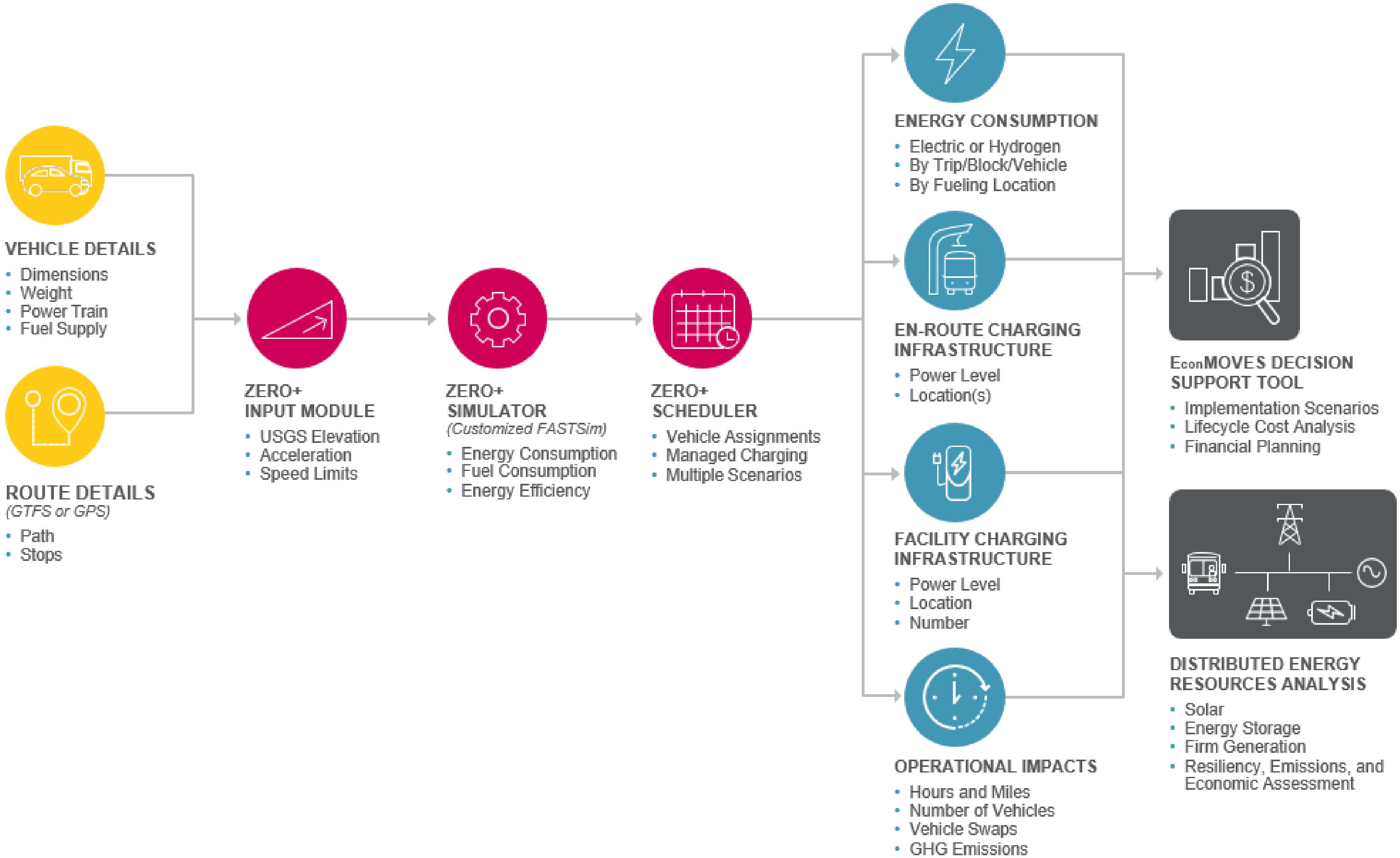
The first step in exploring ZEVs is to use existing conditions to evaluate the current routes and fleet vehicles used to provide service. The evaluation began by collecting and reviewing all available background documents and data relevant to the study. All data collected and reviewed feeds into the modeling effort and analysis that follows. Key data inputs included:

- Operator blocks for weekdays and weekends
- Block- and bus-type assignments
- General Transit Feed Specifications (GTFS) data from pre-COVID service for transit blocks on weekdays and weekends
- Ridership data by route or block for typical weekdays and weekends
- Transit Service Plan and Transit Development Plan (TDP)
- Background policy documents
- Operations information including revenue and deadhead hours and miles
- Fleet Replacement Plan
- Drawings and as-built electronic drawings of the Pierce Transit operations and maintenance facility
- Maintenance costs required to develop the financial model baseline
- Scheduled maintenance and overhaul plan
- Financial plan

Energy Consumption & Route Modeling Analysis

Understanding energy consumption is a key component of fleet transition planning, as it informs the choice of vehicle technology, infrastructure requirements, finances, and fleet replacement strategies. The energy consumption model, Zero+, provides a comprehensive understanding of the potential impacts zero emission bus (ZEB) technology may have on Pierce Transit's existing service. **Figure 36** shows the Zero+ Model inputs, outputs, and process. Energy consumption is impacted by several factors including slope and grade of the bus routes, number of vehicle stops, anticipated roadway traffic, and ambient temperature. The Zero+ model also analyzes variables known to impact lifetime vehicle performance, like energy density; battery degradation; operating environment; heating, air conditioning, and auxiliary power loads; as well as the lifecycle of bus batteries and hydrogen fuel cells. The model is fed by GTFS data, GIS data, and vehicle profile assumptions to create an accurate energy consumption profile unique to Pierce Transit's existing service. In sum, Zero+ results include many data variables, yielding the most accurate results possible to influence strong, effective decision making.

Figure 36: Zero+ Model Inputs, Outputs, and Process



The Zero+ model results, combined with discussions with Pierce Transit staff, provide the basis upon which the preferred ZEB technology (battery electric and/or hydrogen) for fleet conversion and the preferred refueling strategy will be determined. For a BEB scenario, this basis examines whether the optimal charging strategy is depot charging only, a mix of depot and on-route charging, or on-route charging only, and identifies potential strategies that best complement Pierce Transit's service and fleet plans. Simulations were performed at the granular level, so that the strategy can inform individual vehicles, routes, and blocks as well as the full Pierce Transit fleet. Examining each vehicle individually drives decisions for the right technology at the system, depot, route, and block levels. This analysis balances impacts to operations, overall fleet size, and infrastructure requirements. This ultimately provides Pierce Transit with the information to make a data-driven determination of the preferred ZEB transitional technologies and deployment pace.

By using this data and applying existing Pierce Transit service information, the Zero+ tool produced a heat map showing the vehicle state of charge (SOC) throughout the day on any given route block. This report details which blocks and routes could perform within currently available ZEB vehicle range capabilities, as well as forecasts at what point in each route ZEB range is exceeded. This insight provides clear data for planning operational adjustments and fleet demands to maintain service levels and maximize ZEB utilization while highlighting changes that may affect riders and recommending tactics to avoid or mitigate these impacts.

Scenarios Modeled

Based on the evaluation and collection of data described above, a baseline scenario is simulated of current Pierce Transit service to validate both the data provided and the functionality of the model by comparing simulation results to observed Pierce Transit existing operations. This validation provides confidence that the simulations of ZEB scenarios are not missing critical data points that influence the transition. ZEB scenarios simulated include three alternatives: BEBs with depot charging only, BEBs with depot and on-route charging combined, and fuel cell electric buses (FCEBs) with depot refueling only. Though Pierce Transit could implement a mixed fleet of both BEBs and FCEBs, each ZEB technology is kept separate during the initial modeling scenarios, so that the best applications of each technology can be understood within a single simulation.

Battery Electric Bus Depot Charging Simulation

Depot charging only was modeled first to establish a baseline feasibility. This scenario allows the Zero+ Model to identify which existing service blocks can be electrified without an increase in peak vehicle requirements, the need for on-route charging, or the need for schedule modifications to achieve the same level of service. By electing a depot-only charging profile, the model calculates what staff, vehicle, and service modifications would be needed to maintain the current level of service.

Simulation Assumptions

To develop a model relevant for Pierce Transit's fleet and operations, a set of assumptions and variables were identified (**Table 17**). While these attributes are typical of most vehicle original equipment manufacturers (OEMs), not every vehicle would meet this specification. When Pierce Transit procures vehicles for this transition, it is crucial to ensure that vehicle procurements meet or exceed this minimum specification to deploy BEBs that can match the operations simulated in this profile.

Table 17. BEB Depot-Charging Simulation Assumptions

Variable	Input
Battery Capacity 40-ft Buses	466 kWh
Battery Capacity 60-ft Buses	525 kWh
End-of-Life Battery State of Health	80% (Max Battery Degradation)
Energy Reserve	20% State of Charge (SOC)
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity
Depot Charger Power	150 kW (95% Efficiency)

Model Results

Key Takeaways (**Figure 37**):

- Revenue Hours and Miles remain the same
- Non-Revenue Hours: **70% increase**
- Non-Revenue Miles: **62% increase**
- Peak vehicle requirement: **44% increase**
    - Increase fleet from 128 to 184 buses
    - 56 more vehicles required
- At least 44 Depot Chargers will be required

Figure 37: BEB Depot-Only Model Outputs

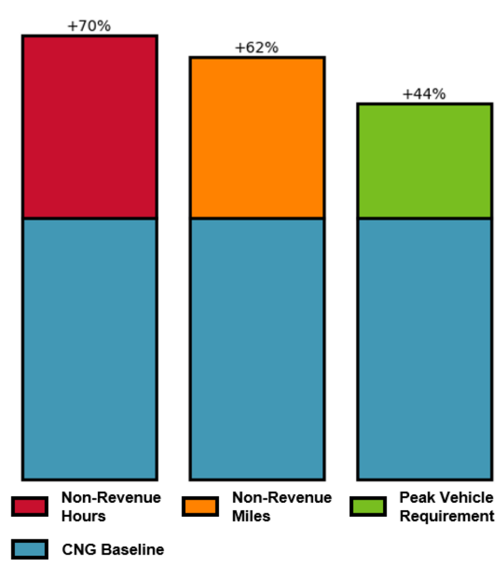
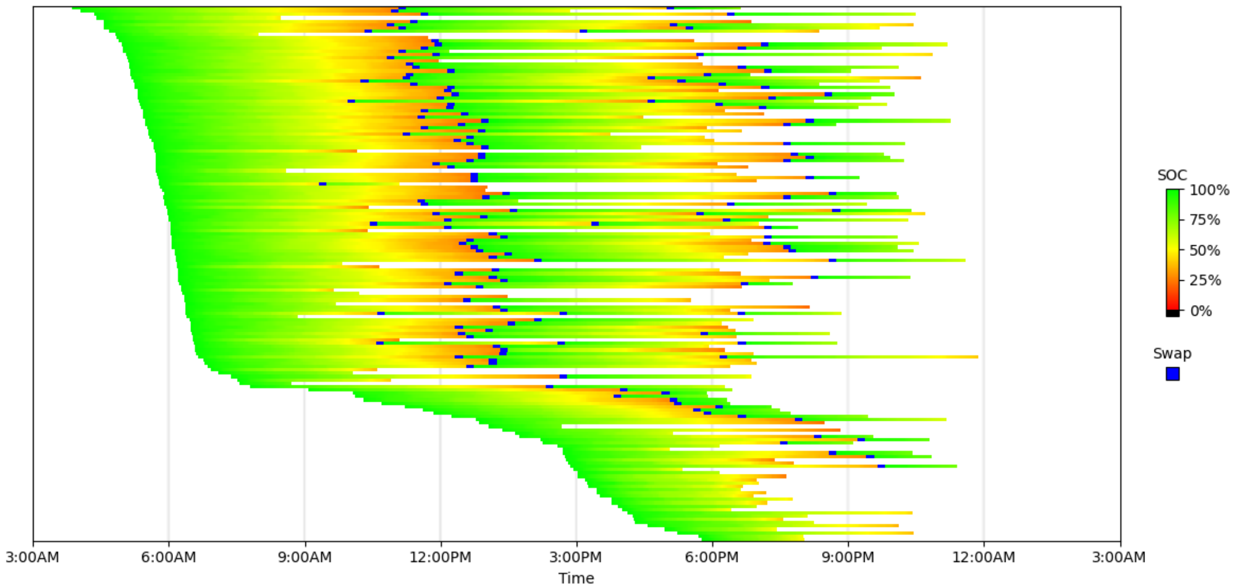


Figure 38 shows the vehicle battery SOC plot for each block during for weekday service. Weekend service was also modeled, but fleet and charging requirements are driven by weekday service which illustrates the most demanding operations for Pierce Transit. Each block is represented by a line on the chart with the color of the line corresponding to the SOC of the vehicle. The color changes from green to yellow to red as the SOC drops from 100 to 0 percent. Bus swaps (shown in blue) are introduced only between trips to minimize service impacts.

Figure 38: BEB Depot-Only Block State of Charge (Weekdays)

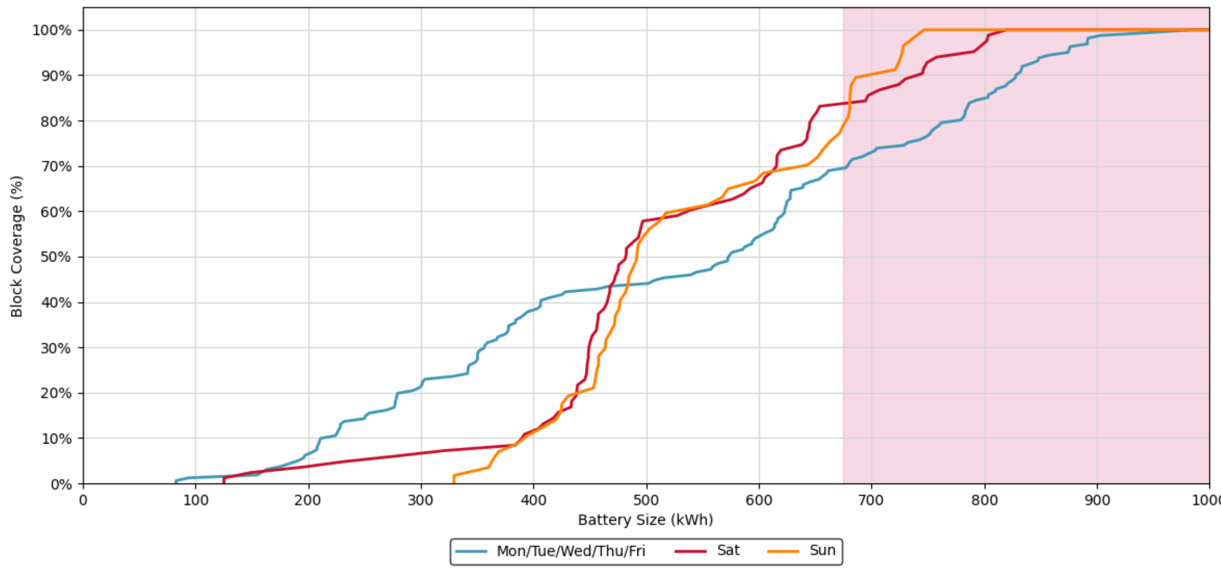


Bus swaps are also inserted in locations to guarantee the minimum SOC does not dip below the required 20 percent reserve capacity, including the energy needed to return the vehicle to the depot when a swap is needed. Whenever a vehicle is swapped out, it is replaced with a BEB that has a fully charged battery. Swapping buses is only helpful when the bus either stays near the depot all day or returns within a close distance to the depot at multiple points throughout the day. If a block is scheduled to travel a long distance one way away from the depot, then there is no opportunity for a swap. Pierce Transit could deploy 29 BEBs before fleet increases will be required.

Vehicle Battery Sizes

With technological advances expected in the coming years, it may be possible to improve the feasibility of a BEB Depot Charging Scenario by purchasing buses with larger battery sizes. **Figure 39** illustrates that Pierce Transit would be able to operate more blocks with a 466-kWh battery compared to a 525-kWh battery, and the greatest impacts would be seen during Saturday and Sunday service. Also, it is important to note that vehicles with larger batteries have higher capital costs and higher weights.

Figure 39: BEB Depot Charging Block Coverage vs. Battery Size



Battery Electric Bus Depot + On-Route Charging

On-route charging is an enhancement that can greatly improve the feasibility of BEBs in many situations. This is particularly helpful with circulatory routes where the same on-route charger can be used by a vehicle multiple times throughout the day. On-route charging infrastructure is ideally located at places such as transit centers where buses operating on multiple routes all have scheduled layover time. On-route charging is capable of greatly extending the range of a BEB and facilitating one-to-one replacement of diesel vehicles when the routes are conducive to this charging strategy.

Simulation Assumptions

The simulation assumptions for the BEB Depot + On-Route Charging Scenario, as shown in **Table 18**, are similar to the assumptions for the BEB Depot Charging Scenario. The only difference is the assumption for on-route charger power and charging efficiency. Although there are on-route chargers on the market that offer more power (450 kW), there are currently no vehicles on the market that can accept this level of power. When Pierce Transit procures vehicles for this transition, it is crucial to ensure that vehicle procurements meet or exceed this minimum specification to deploy BEBs that can match the operations simulated in this profile.

Table 18. BEB Depot + On-Route Charging Simulation Assumptions

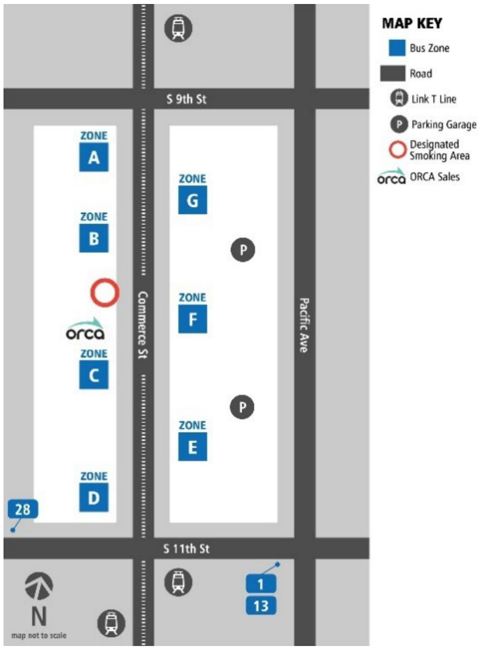
Variable	Input
Battery Capacity 40-ft Buses	466 kWh
Battery Capacity 60-ft Buses	525 kWh
End-of-Life Battery State of Health	80% (Max Battery Degradation)
Energy Reserve	20% State of Charge (SOC)
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity
Depot Charger Power	150 kW (95% Efficiency)
On-Route Charger Power	300 kW (95% Efficiency)

On-Route Charger Locations

Layover times in the existing schedule were used to identify the most ideal locations for on-route chargers. There were 12 transit center layovers, eight of which had good layover time and five of which were identified as good candidates for on-route charging. Most of these locations could make good use of a single charger, while some locations may require more chargers. The usefulness of an additional charger is dependent on how layover times overlap between vehicles.

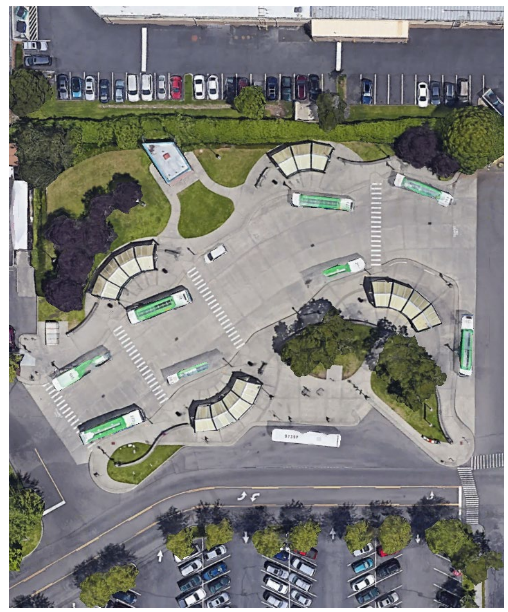
Commerce Street Station

The Commerce Street Station is located at 1119 Commerce Street, Tacoma, Washington. Routes 2, 3, 11, 16, 41, 42, 45, 48, 57, 63, 102, 400, 500, 501, 590, and 594 serve this transit center. Commerce Street Station has about 229 hours of layover time on an average weekday.



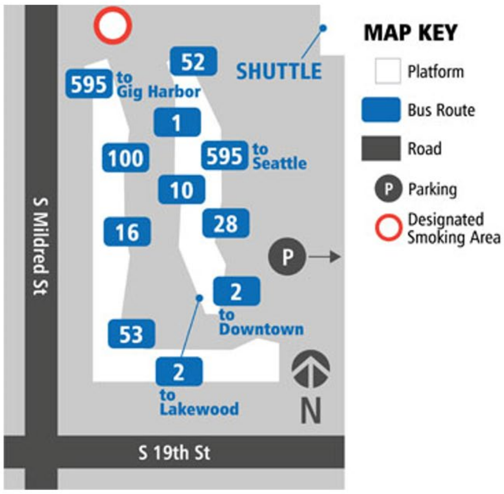
Lakewood Transit Center

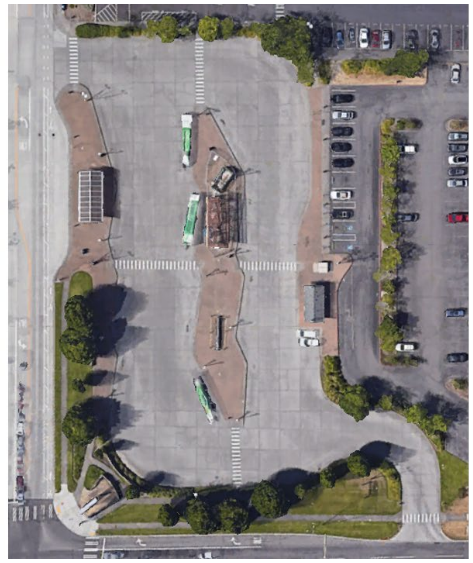
The Lakewood Transit Center is located at 5719 Lakewood Towne Center Boulevard SW, Lakewood, Washington. Routes 2, 3, 4, 48, 202, 206, 212, 214, and JBLM Runner serve this transit center. Lakewood has about 196 hours of layover time on an average weekday.



Tacoma Community College Transit Center

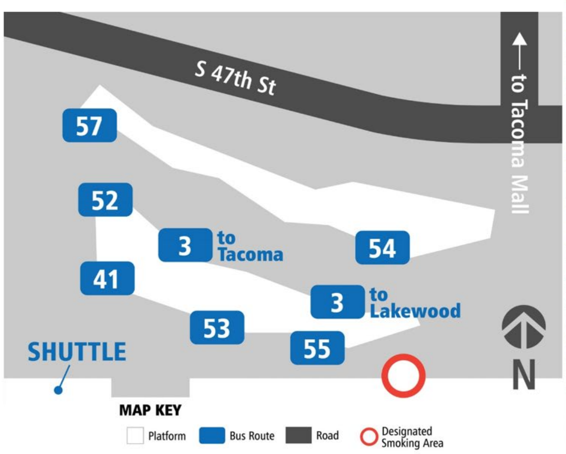
The Tacoma Community College Transit Center is located at 6615 S 19th Street, Tacoma, Washington. Routes 1, 2, 10, 16, 28, 52, 53, and 100 serve this transit center. The Tacoma Community College has about 172 hours of layover time on an average weekday.

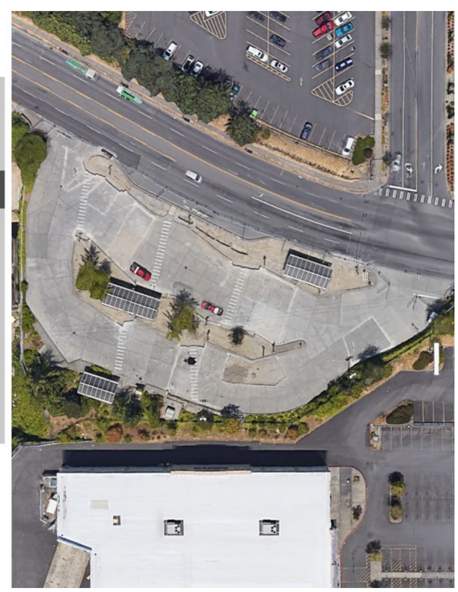




Tacoma Mall Transit Center

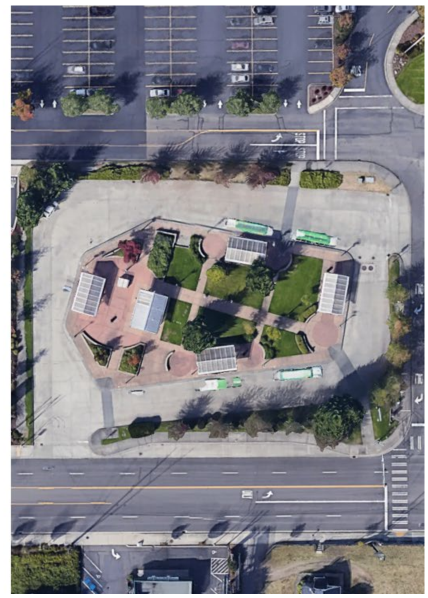
The Tacoma Mall Transit Center is located at 222 S 47th Street, Tacoma, Washington. Routes 3, 41, 52, 53, 54, 55, and 57 serve this transit center. The Tacoma Mall has about 108 hours of layover time on an average weekday.





South Hill Mall Transit Center

The South Hill Mall Transit Center is located at 503 39th Avenue SW, Puyallup, Washington. Routes 4, 400, 402, and 425 serve this transit center. The Tacoma Mall has about 65 hours of layover time on an average weekday.

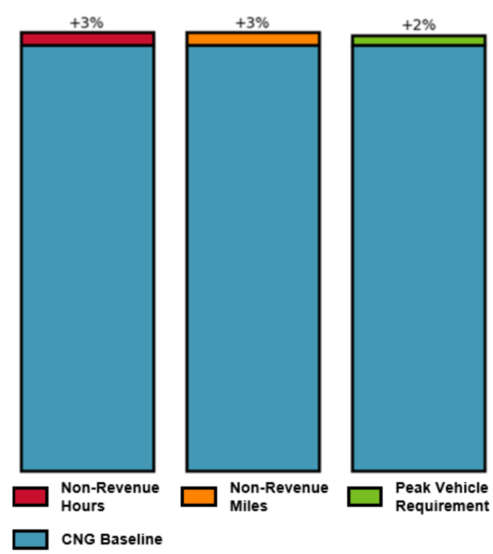


Model Results

Key Takeaways (**Figure 40**):

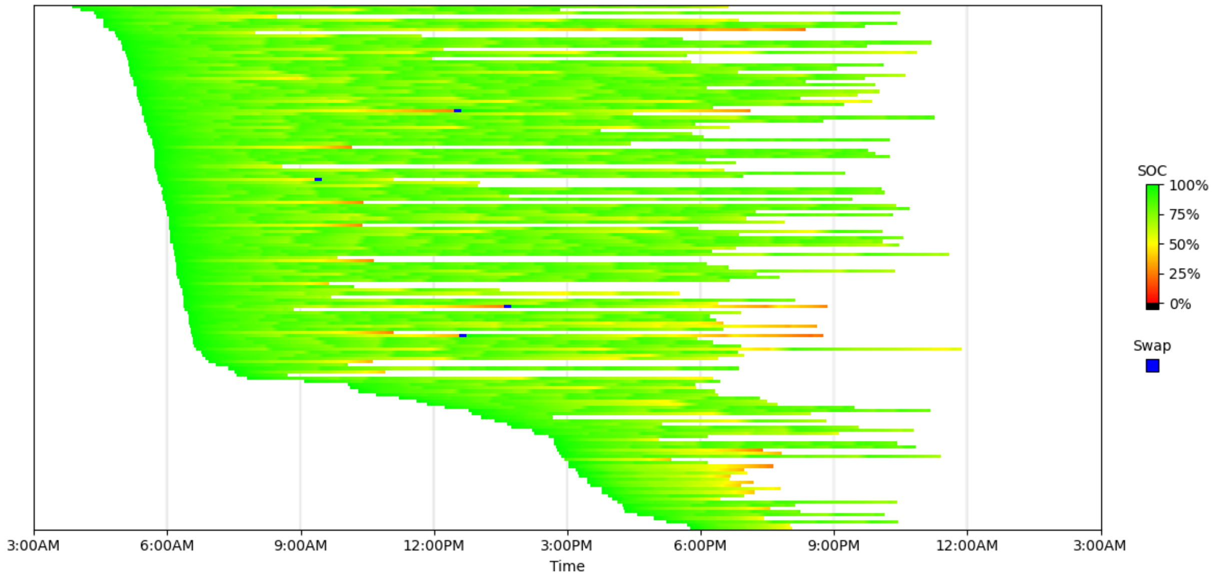
- Revenue Hours and Miles remain the same
- Non-Revenue Hours: **3% increase**
- Non-Revenue Miles: **3% increase**
- Peak Vehicle Requirement: **2% increase**
    - Increase Fleet from 128 to 131 buses
    - 3 more vehicles required
- At least **11 depot chargers** will be required
- Up to **18 on-route chargers** could be required

Figure 40: BEB Depot + On-Route Model Outputs



The vehicle battery SOC plot shown in **Figure 41** illustrates the SOC for each block during weekday service for the BEB Depot + On-Route Charging Scenario. Weekend service was also modeled, but fleet and charging requirements are driven by weekday service which illustrates the most demanding operations for Pierce Transit. Bus swaps are also inserted in locations to guarantee the minimum SOC does not dip below the required 20 percent reserve capacity, including the energy needed to return the vehicle to the depot when a swap is needed. By introducing on-route charging, the number of bus swaps required dropped significantly. For this scenario, 161 blocks can be operated without bus swaps while only 4 blocks require one or more swaps.

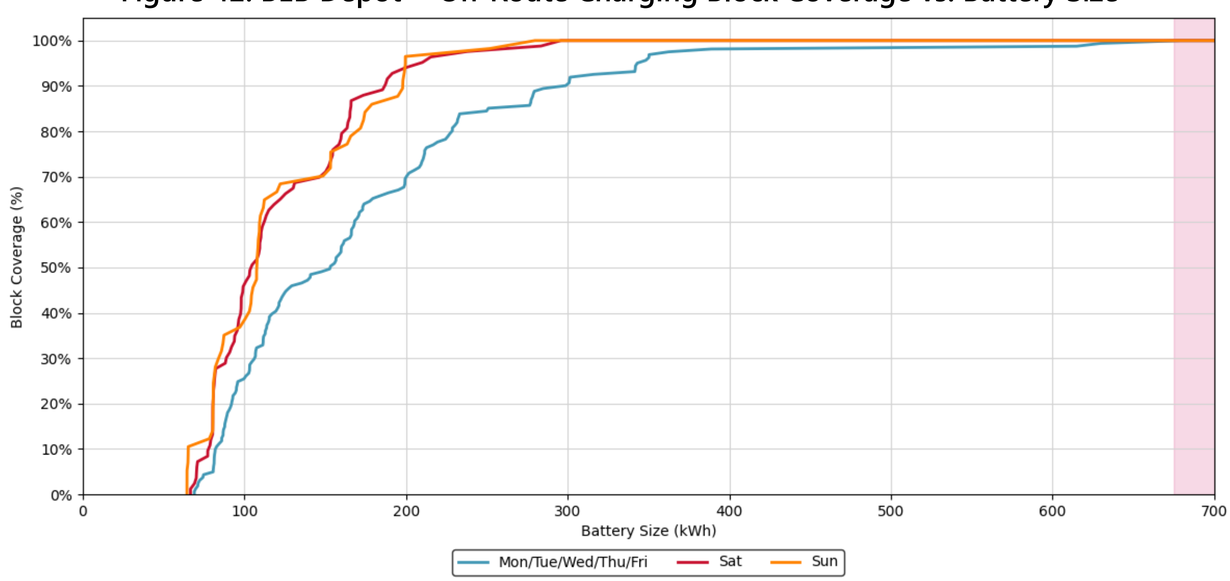
Figure 41: BEB Depot + On-Route Charging Block State of Charge (Weekdays)



Vehicle Battery Sizes

Increasing the vehicle battery size is less beneficial for the BEB Depot + On-Route Charging Scenario compared to the BEB Depot Charing Scenario. **Figure 42** illustrates minor block feasibility increases with increased battery size and shows there is almost no gain in block feasibility when comparing a 466-kWh battery with longer battery sizes.

Figure 42: BEB Depot + On-Route Charging Block Coverage vs. Battery Size



Hydrogen Fuel Cell Bus Simulation

As transit agencies look for a zero-emission technology to replace diesel buses, there are two primary options, BEBs and FCEBs. Currently, BEBs are the most popular replacement choice because they use the electrical grid as their fuel source, which is universally available and relatively easy to connect into to get the required power. However, the vehicles have a limited range compared to diesel, which means they are not capable of directly replacing buses with long duty cycles or blocks. In some cases, it is not possible to re-cut the routes into pieces that are within the capability of a BEB, so an alternative zero-emission technology is needed.

Hydrogen FCEBs are the other primary option as a propulsion type for a zero-emission transition. While hydrogen is not as readily available as electricity, FCEBs do not have the same range limitations as BEBs. FCEBs use a drivetrain similar to that of a BEB. However, they have a small battery on-board instead of a large battery. The small battery is recharged by an on-board fuel cell that generates electricity from hydrogen as the vehicle travels. The energy density of hydrogen is much higher than a battery, which allows for the range of these vehicles to closely match a conventional diesel bus.

Simulation Assumptions

To develop an FCEB model relevant for Pierce Transit's fleet and operations, a set of assumptions and variables were identified (**Table 19**). While these attributes are typical of most vehicle OEMs, not every vehicle will meet this specification. When Pierce Transit procures vehicles for this transition, it is crucial to ensure that vehicle procurements meet or exceed this minimum specification to deploy FCEBs that can match the operations simulated in this profile.

Table 19: FCEB Simulation Assumptions

Variable	Input
Service Data	2020 (Pre-COVID)
Fuel Capacity	37.5 kg
Energy Density	33.6 kWh per kg of Hydrogen
Energy Reserve	5% or less remaining fuel
Heating	Electric Heater
Ambient Temperature	Coldest Day (10th Percentile)
Passenger Capacity	Maximum Seated Capacity

Model Results

Key Takeaways:

- Revenue Hours and Miles: **0% increase**
- Non-Revenue Hours and Miles: **0% increase**
- Non-Revenue Miles: **0% increase**
- Peak Vehicle Requirement: **0% increase**

All 161 existing service blocks are capable of being operated by FCEBs without an increase in peak vehicle requirements, revenue hours and miles, or non-revenue hours and miles. In addition, there would be no need for mid-block refueling or schedule modifications to achieve the same level of service as a diesel operated service. An exact 1-to-1 replacement of diesel buses is possible because FCEBs typically have an operational range comparable to diesel buses and only require 7 to 10 minutes on average to refuel. There would be a large infrastructure cost in preparing to deploy FCEBs, but little operational impact to refueling, unlike the complex operations required to manage BEB charging.

Conclusion

The project team modeled three scenarios: BEB depot-only charging, BEB on-route & depot charging, and Hydrogen FCEB only. If Pierce Transit were to shift toward a fully zero-emission fleet today, both BEB on-route & depot charging and Hydrogen FCEB scenarios proved to be operationally viable options that did not require drastically increasing fleet size or changing operating conditions.

There are many other factors that contribute to the feasibility of transitioning a fleet to ZEVs, so energy feasibility alone cannot be the basis in which an agency decides to transition to ZEVs. Additionally, this modeling looked at a hypothetical scenario where ZEBs would operate Pierce Transit's bus service today. In reality, transit routes change to meet the needs of the community, a fleet would transition over time, and ZEBs are projected to be more efficient in the future.

This modeling should serve as an example of what is possible, and Pierce Transit can use this information in conjunction with other information from this project to determine ZEB transition strategy.

Appendix B: Financial Assumptions, Methodology, and Lifecycle Cost Comparisons

Key Inputs and Assumptions

The following summarizes the key inputs and assumptions that were used to develop capital costs, operating and maintenance (O&M) costs, and the lifecycle cost analysis results.

Capital Cost Assumptions

Table 20 provides the key inputs used to generate annual capital expenses and reflects the following assumptions.

Vehicle Costs: The prices for ICEBs are sourced from existing market information, and previous HDR findings. Pricing for BEBs and FCEBs come from manufacturer estimates and other available market data for the relevant vehicles. The replacement period for each bus is based on its size: 25-foot buses are replaced every 8 years, 40-foot buses every 16 years, and 60-foot buses every 13 years. This follows the existing fleet's replacement plan.

Mid-Life Rehabilitation Costs: In order for each bus to operate for the entire replacement period, mid-life rehabilitation is needed at the halfway point in each bus's life. These prices are categorized by bus fuel type (gasoline, diesel, CNG, electric, and hydrogen), and can be found in **Table 20**. The prices for ICEB rehabs are from existing market information and previous project experience. BEB rehab costs are built from an assumed $500 per kWh of battery storage, with an additional $300 for an upgraded battery management system. FCEB rehab costs follow the BEB rehab costs, but with an additional $1,000 per peak kW of fuel cell power output. The rehab costs for BEBs and FCEBs are comprised of only replacing the battery and (when applicable) fuel cell and do not account for additional cosmetic upgrades that may be needed.

Charging Equipment: The BEB fleet requires additional chargers, not already implemented, at both the depot and the on-route facilities. Old chargers are assumed to be replaced every 8 years, but this is subject to change because charger quality depends on use, and each charger is likely to not be used equally. The FCEB transition will not require the purchase of any additional chargers.

Utility Infrastructure: There is no additional infrastructure needed to accommodate the BEB fleet or its chargers – initial facility analysis shows there is enough electric capacity to support a BEB transition. The FCEB transition will require a one-time $8 million infrastructure upgrade that will allow for hydrogen fueling at the depot transit facility.

Table 20: Capital Cost Assumptions, 2023$

Item	Value	Unit	Source
ICEB Prices			
25' Gas	$250,000	2023 $	HDR Market Research
40' CNG	$800,000	2023 $	Pierce Transit Purchase Price
60' CNG	$1,000,000	2023 $	HDR Market Research
40' Diesel	$585,000	2023 $	Pierce Transit Purchase Price
BEB Prices			
25' BEB	$500,000	2023 $	HDR Market Research
40' BEB	$1,200,000	2023 $	HDR Market Research
60' BEB	$1,330,000	2023 $	HDR Market Research
FCEB Prices			
25' FCEB	$700,000	2023 $	HDR Market Research
40' FCEB	$1,300,000	2023 $	HDR Market Research
60' FCEB	$1,800,000	2023 $	HDR Market Research
62.5kW Depot Charger	$38,760	2023 $	Pierce Transit Purchase Price
150kW Depot Charger	$270,000	2023 $	InductEV Wireless Charging Cost Estimate
450kW On-Route Fast Charger	$900,000	2023 $	InductEV Wireless Charging Cost Estimate
Hydrogen Infrastructure	$8,000,000	2023 $	HDR Assumption, 1 Year Prior to First FCEB

O&M Cost Assumptions

Table 21 provides the key inputs used to generate (O&M) expenses and reflect the following assumptions:

- **Vehicle Operating Costs:** Operating costs are assumed to be same across all scenarios because bus drivers will have the same wage rate for each vehicle type. As such, this cost is not included in the analysis.
- **Vehicle Maintenance Costs:** Maintenance costs are estimated by two per-mile charges: a maintenance parts cost associated with each vehicle fuel type, and a corresponding maintenance labor cost. The maintenance costs for gasoline, diesel, CNG, and battery electric buses are provided by Pierce Transit in their existing fleet's O&M cost information. For FCEBs, the maintenance labor cost is assumed to be the equal to the BEB labor cost. The BEB maintenance parts cost is estimated from ICEBs, per the US Department of Energy report[5] on the total cost of ownership for electric vehicles. FCEB

[5] Lower BEB maintenance costs described in US DOE, Vehicle Technologies Office: *FOTW #1190, June 14, 2021: Battery-Electric Vehicles Have Lower Scheduled Maintenance Costs than Other Light-Duty Vehicles | Department of Energy.*

maintenance costs are estimated from the National Renewable Energy Laboratory comparison[6] between CNG buses and FCEBs.

- **EV Charger Maintenance Costs:** Each EV charger has an additional monthly O&M cost that starts accruing when a charger is implemented and supports efforts to minimize degradation of the equipment. Since Level 2 (62.5-kWh and 150-kWh) Chargers are easier to maintain than DC Fast (450-kWh Inductive) Chargers, the yearly preventative maintenance costs are much lower. The monthly charge is an estimate of charger maintenance and is likely to differ once implemented.

- **Hydrogen Infrastructure Maintenance:** There is an associated recurring cost to operate hydrogen storage and distribution infrastructure for FCEBs. It is standard practice to set up a service agreement with the installer or a qualified third party to operate and maintain the infrastructure through its useful life. HDR estimates this service to be about $200,000 per year.

Table 21: Operations and Maintenance Cost Assumptions, 2023$

Item	Value	Unit	Source
Vehicle Maintenance Labor Cost			
Gas	$1.80	$ per mile	Pierce Transit Bus Fleet CPM
CNG	$0.83	$ per mile	Pierce Transit Bus Fleet CPM
Diesel	$1.04	$ per mile	Pierce Transit Bus Fleet CPM
BEB	$3.02	$ per mile	Pierce Transit Bus Fleet CPM
FCEB	$3.02	$ per mile	Assumed Same as BEB Maintenance Labor
Vehicle Maintenance Parts Cost			
Gas	$0.21	$ per mile	Pierce Transit Bus Fleet CPM
CNG	$0.52	$ per mile	Pierce Transit Bus Fleet CPM
Diesel	$0.69	$ per mile	Pierce Transit Bus Fleet CPM
BEB	$0.43	$ per mile	10% Savings from ICEB Average
FCEB	$0.72	$ per mile	Maintenance Cost Differential
O&M Cost Differentials			
CNG	$0.460	costs per mile	National Renewable Energy Laboratory
FCEB	$0.660	costs per mile	National Renewable Energy Laboratory
Charger Maintenance			
Level 2 Single Port - Depot	$500	$ per charger per year	HDR EV Charger Research
DCFC - Inductive	$1,500	$ per charger per year	HDR EV Charger Research
Hydrogen Infrastructure Maintenance	$200,000	$ per year	Service agreement with system installer

[6] FCEB/CNG bus maintenance differentials sourced from National Renewable Energy Laboratory; *Orange County Transportation Authority Fuel Cell Electric Bus Progress Report - Data Period Focus: Feb. 2020 through Jul. 2021 (nrel.gov).*

Fuel and Electricity Cost Assumptions

Table 22 provides assumptions related to each fuel source that is used in the analysis. Current gasoline, diesel, CNG, and electricity prices were provided by the Pierce Transit. Current hydrogen delivery prices are sourced from market and distributor information. As described in more detail in the Fueling Expenditures section, these unit prices are projected to have separate dynamics over the analysis period based on forecasts provided by the US Energy Information Administration.[7] The price movement between 2022 and 2050 are calculated as compound annual growth rates (CAGRs) to interpolate gasoline and electricity unit prices between 2023 and 2049.

The electricity rate structure includes a per-kWh charge, a monthly peak kW demand charge, and a fixed monthly customer charge. The demand and customer charge are not assumed to grow at the rates described below. Only the base per-kWh charge is assumed to have price movement over the analysis period. **Table 23** shows the electricity rate structure conversions.

Table 22: Fueling Assumptions

Item	Value	Unit	Source
Fueling Unit Prices			
Gasoline	$3.21	2023 $/gal	Client Provided
Diesel	$3.68	2023$/gal	Pierce Transit Bus Fleet CPM
CNG	$0.68	2023$/GGE	Pierce Transit Bus Fleet CPM
Hydrogen	$12.00	2023 $/kG	HDR Assumption, from previous study
Electricity[8]	$0.0501	2023 $/kWh	Rates – Lakeview Light & Power, Pierce Transit
Electricity Customer Charge	$75	2023 $/month	Rates – Lakeview Light & Power, Pierce Transit
Electricity Demand Charge	$6.06	per peak monthly kW (2023 $)	Rates – Lakeview Light & Power, Pierce Transit
Fuel Price Dynamics			
Gasoline Growth, 2022-2050	-0.94%	CAGR	USEIA: Wholesale Price: Gasoline
Diesel Growth, 2022-2050	-1.16%	CAGR	*Wholesale Price: Diesel
Natural Gas Growth, 2022-2050	-1.41%	CAGR	USEIA: Delivered Prices, Transportation
Electricity Growth, 2022-2050	-0.07%	CAGR	USEIA: Transportation End-Use Price: Electricity
Hydrogen Growth, 2022-2050	-1.41%	CAGR	Tied to Natural Gas Price Growth

[7] Gasoline and Electricity price changes sourced from the Energy Information Administration *Components of Selected Petroleum Product Prices; Gasoline Wholesale Price* and *Electricity Supply, Disposition, Prices, and Emissions; Transportation End-Use Prices: Electricity.*
[8] Electricity rate structure sourced from the 830 Rate Class, converted from per-kVA(h) to per-kW(h) using a power factor of 91.11%, provided by Pierce Transit.

Table 23: Electricity Rate Structure Conversion

	Amperes	Conversion Factor	Kilowatts
Unit Charge	$0.055 per kVAh	91.11%	$0.05 per kWh
Demand Charge	$6.65 per peak kVA	91.11%	$6.059 per peak kW
Customer Charge	$75 per month	-	$75 per month

Lifecycle Cost Analysis Assumptions

The assumptions used in this lifecycle cost analysis follow standard industry practice. Shown in **Table 24**, discounting at 5 percent falls within ranges recommended by the US Department of Transportation, while a range of likely inflation values will be used to provide sensitivity results. Discounting is used to account for the idea that a dollar now is worth more than a dollar in the future as a dollar now can be invested and grow in value. Inflation measures are used in the sensitivity analysis to simulate the effects of growth in the US economy that leads to an increase across all prices.

Table 24: General Assumptions

Item	Value	Unit	Source
Discount Value	5%	percent per year	Standard Assumption
Inflation	3% - 7%	percent per year	Historic/Current Inflation Rate
Annualization	365	days per year	Operating Days

Lifecycle Cost Estimates

Table 25, **Table 26**, and **Table 27** collectively detail the projected lifecycle costs for the three scenarios. The "Capital Expenditures" column is comprised of vehicle purchases and infrastructure purchases, and the "Operations and Maintenance" column is comprised of vehicle and infrastructure O&M and fueling costs.

Table 25: Annual Baseline Lifecycle Costs (Millions of 2023 $)

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2023	$8.0	*$8.0*	-	$8.1	*$5.5*	*$2.5*	**$16.05**
2024	$2.4	*$2.4*	-	$8.0	*$5.5*	*$2.5*	**$10.43**
2025	$9.8	*$9.8*	-	$8.0	*$5.5*	*$2.5*	**$17.83**
2026	$22.9	*$22.9*	-	$8.7	*$6.1*	*$2.6*	**$31.57**
2027	$1.8	*$1.8*	-	$8.7	*$6.1*	*$2.6*	**$10.45**

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2028	$1.2	*$1.2*	-	$8.7	*$6.1*	*$2.6*	**$9.85**
2029	$3.5	*$3.5*	-	$8.7	*$6.1*	*$2.5*	**$12.88**
2030	$15.0	*$15.0*	-	$9.3	*$6.6*	*$2.7*	**$24.28**
2031	$8.4	*$8.4*	-	$9.3	*$6.6*	*$2.6*	**$17.66**
2032	$8.1	*$8.1*	-	$9.2	*$6.6*	*$2.6*	**$17.35**
2033	$9.0	*$9.0*	-	$9.2	*$6.6*	*$2.6*	**$18.24**
2034	$20.4	*$20.4*	-	$9.7	*$7.0*	*$2.7*	**$30.09**
2035	$30.6	*$30.6*	-	$9.7	*$7.0*	*$2.6*	**$40.31**
2036	$0.2	*$0.2*	-	$9.6	*$7.0*	*$2.6*	**$9.81**
2037	$30.6	*$30.6*	-	$9.6	*$7.0*	*$2.6*	**$40.24**
2038	-	-	-	$9.6	*$7.0*	*$2.6*	**$9.60**
2039	$8.4	*$8.4*	-	$9.6	*$7.0*	*$2.6*	**$17.99**
2040	$21.0	*$21.0*	-	$9.6	*$7.0*	*$2.5*	**$30.56**
2041	$12.8	*$12.8*	-	$9.5	*$7.0*	*$2.5*	**$22.31**
2042	$12.9	*$12.9*	-	$9.5	*$7.0*	*$2.5*	**$22.45**
Total Costs	**$227.7**	*$227.7*	-	**$182.2**	*$130.8*	*$51.4*	**$409.9**

Table 26: Annual BEB Transition Lifecycle Costs (Millions of 2023 $)

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2023	$8.4	*$8.0*	*$0.4*	$8.87	*$5.54*	*$3.33*	**$17.26**
2024	$4.4	*$3.6*	*$0.8*	$8.83	*$5.55*	*$3.28*	**$13.24**
2025	$18.1	*$14.3*	*$3.9*	$8.69	*$5.58*	*$3.11*	**$26.81**
2026	$29.8	*$29.0*	*$0.8*	$9.21	*$6.09*	*$3.12*	**$39.02**
2027	$3.9	*$3.6*	*$0.3*	$9.03	*$6.08*	*$2.96*	**$12.90**
2028	$2.7	*$2.4*	*$0.3*	$8.91	*$6.06*	*$2.84*	**$11.58**
2029	$8.8	*$7.9*	*$0.9*	$8.62	*$6.03*	*$2.59*	**$17.47**
2030	$26.0	*$23.6*	*$2.4*	$9.42	*$6.72*	*$2.70*	**$35.40**
2031	$20.7	*$12.4*	*$8.3*	$9.39	*$6.77*	*$2.62*	**$30.08**
2032	$14.4	*$12.7*	*$1.6*	$9.36	*$6.82*	*$2.54*	**$23.72**
2033	$21.5	*$16.1*	*$5.5*	$9.30	*$7.02*	*$2.28*	**$30.84**

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2034	$35.0	*$28.0*	*$7.0*	$9.83	*$7.51*	*$2.32*	**$44.86**
2035	$50.8	*$46.3*	*$4.4*	$9.77	*$7.68*	*$2.09*	**$60.55**
2036	$2.9	*$0.5*	*$2.4*	$9.76	*$7.69*	*$2.07*	**$12.68**
2037	$57.7	*$47.0*	*$10.7*	$9.73	*$7.82*	*$1.91*	**$67.40**
2038	$2.4	*$0.7*	*$1.6*	$9.72	*$7.82*	*$1.90*	**$12.08**
2039	$20.8	*$14.5*	*$6.3*	$9.71	*$7.88*	*$1.83*	**$30.46**
2040	$37.3	*$28.7*	*$8.6*	$9.47	*$7.96*	*$1.50*	**$46.77**
2041	$21.1	*$16.7*	*$4.4*	$9.46	*$7.97*	*$1.49*	**$30.56**
2042	$16.4	*$14.0*	*$2.4*	$9.46	*$7.98*	*$1.48*	**$25.85**
Total Costs	**$403.0**	*$329.8*	*$73.2*	**$186.6**	*$138.6*	*$48.0*	**$589.5**

Table 27: Annual FCEB Transition Lifecycle Costs (Millions of 2023 $)

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2023	$8.0	*$8.0*	-	$8.05	*$5.54*	*$2.51*	**$16.05**
2024	$3.6	*$3.6*	-	$8.04	*$5.55*	*$2.49*	**$11.64**
2025	$14.3	*$14.3*	-	$7.95	*$5.57*	*$2.38*	**$22.20**
2026	$29.0	*$29.0*	-	$8.16	*$6.08*	*$2.07*	**$37.16**
2027	$3.6	*$3.6*	-	$7.99	*$6.06*	*$1.92*	**$11.59**
2028	$2.4	*$2.4*	-	$7.87	*$6.05*	*$1.82*	**$10.27**
2029	$15.9	*$7.9*	*$8.0*	$7.75	*$6.21*	*$1.54*	**$23.67**
2030	$27.0	*$27.0*	-	$9.78	*$7.04*	*$2.74*	**$36.78**
2031	$13.4	*$13.4*	-	$10.69	*$7.25*	*$3.43*	**$24.10**
2032	$13.7	*$13.7*	-	$11.58	*$7.47*	*$4.11*	**$25.32**
2033	$18.6	*$18.6*	-	$12.93	*$7.94*	*$4.99*	**$31.48**
2034	$34.5	*$34.5*	-	$15.15	*$8.76*	*$6.40*	**$49.61**
2035	$50.1	*$50.1*	-	$18.50	*$9.57*	*$8.93*	**$68.63**
2036	$0.5	*$0.5*	-	$18.38	*$9.57*	*$8.81*	**$18.87**
2037	$47.0	*$47.0*	-	$21.14	*$10.25*	*$10.89*	**$68.16**

Year	Capital Expenditures	Vehicle Purchases	Infrastructure Purchases	Operations and Maintenance	Vehicle & Infrastructure O&M	Fueling Costs	Total Expenditures
2038	-	-	-	$20.99	*$10.25*	*$10.74*	**$20.99**
2039	$14.1	*$14.1*	-	$21.71	*$10.47*	*$11.24*	**$35.81**
2040	$35.6	*$35.6*	-	$23.20	*$10.88*	*$12.32*	**$58.81**
2041	$15.1	*$15.1*	-	$23.83	*$11.05*	*$12.78*	**$38.93**
2042	$13.9	*$13.9*	-	$24.44	*$11.22*	*$13.22*	**$38.33**
Total Costs	**$360.2**	*$352.2*	*$8.0*	**$288.1**	*$162.8*	*$125.3*	**$648.4**

Capital Investment Needs and Cost Estimates

Capital costs are represented by vehicle purchases (in all scenarios), EV charger purchases (in the BEB transition scenario), and utility infrastructure upgrades (in the FCEB transition scenario). Discussed in the technology review, there will need to be utility infrastructure enhancements at the transit facility and the on-route charging facility in order for the BEBs to fulfill route requirements. The year prior to the first FCEB purchase in the FCEB transition scenario will consist of the one-time utility infrastructure upgrade to allow for sufficient installation time and is shown as a lump-sum.

Table 28: Annual Capital Costs, 2023-2036 (Millions of 2023 $)

	Baseline		BEB Transition			FCEB Transition		
Year	**Vehicles**	**Total**	**Vehicles**	**Chargers**	***Total***	**Vehicles**	**Infrastructure**	***Total***
2023	$8.0	**$8.0**	$8.0	$0.4	**$8.4**	$8.0	-	**$8.0**
2024	$2.4	**$2.4**	$3.6	$0.8	**$4.4**	$3.6	-	**$3.6**
2025	$9.8	**$9.8**	$14.3	$3.9	**$18.1**	$14.3	-	**$14.3**
2026	$22.9	**$22.9**	$29.0	$0.8	**$29.8**	$29.0	-	**$29.0**
2027	$1.8	**$1.8**	$3.6	$0.3	**$3.9**	$3.6	-	**$3.6**
2028	$1.2	**$1.2**	$2.4	$0.3	**$2.7**	$2.4	-	**$2.4**
2029	$4.2	**$4.2**	$7.9	$0.9	**$8.8**	$7.9	$8.0	**$15.9**
2030	$15.0	**$15.0**	$23.6	$2.4	**$26.0**	$27.0	-	**$27.0**
2031	$8.4	**$8.4**	$12.4	$8.3	**$20.7**	$13.4	-	**$13.4**
2032	$8.1	**$8.1**	$12.7	$1.6	**$14.4**	$13.7	-	**$13.7**
2033	$9.0	**$9.0**	$16.1	$5.5	**$21.5**	$18.6	-	**$18.6**
2034	$20.4	**$20.4**	$28.0	$7.0	**$35.0**	$34.5	-	**$34.5**
2035	$30.6	**$30.6**	$46.3	$4.4	**$50.8**	$50.1	-	**$50.1**
2036	$0.2	**$0.2**	$0.5	$2.4	**$2.9**	$0.5	-	**$0.5**
2037	$30.6	**$30.6**	$47.0	$10.7	**$57.7**	$47.0	-	**$47.0**
2038	-	**-**	$0.7	$1.6	**$2.4**	-	-	-
2039	$8.4	**$8.4**	$14.5	$6.3	**$20.8**	$14.1	-	**$14.1**
2040	$21.0	**$21.0**	$28.7	$8.6	**$37.3**	$35.6	-	**$35.6**
2041	$12.8	**$12.8**	$16.7	$4.4	**$21.1**	$15.1	-	**$15.1**
2042	$12.9	**$12.9**	$14.0	$2.4	**$16.4**	$13.9	-	**$13.9**
Total Cost	$227.7	**$227.7**	$329.8	$73.2	**$403.0**	$352.2	$8.0	**$360.2**

Capital Cost Comparison

As is expected, the vehicle and additional capital costs in the electric transition scenarios far outweigh the capital costs accrued in the baseline scenario. This is due to ICEBs being less expensive than their BEB counterparts, along with the necessary EV chargers and utility infrastructure investments needed to support either zero-emission fleet in the transitions. **Table 29** shows a comparison of the total capital costs between both scenarios. Over the 20-year analysis period, Pierce Transit will be expected to spend $402.97 million on capital costs to transition to a BEB-only fleet or $360.25 million to transition to a FCEB-dominant fleet. This is compared to the $227.75 million needed to stay with the CNG-dominant ICEB fleet.

Table 29: Capital Cost Comparison – FY 2023 to FY2042 (Millions of 2023 $)

	Baseline	BEB Transition	FCEB Transition
Total Vehicle Capital Costs	**$227.75**	**$329.79**	**$352.25**
Gas Buses	$4.50	$2.25	$2.25
Diesel Buses	$13.46	-	-
CNG Buses	$163.40	$25.00	$25.00
BEBs	$38.40	$274.22	$40.80
FCEBs	-	-	$266.20
Mid-Life Rehabilitation	$7.99	$28.32	$18.00
Total Infrastructure Purchases	**N/A**	**$73.19**	**$8.00**
Chargers	-	$73.19	-
Utility Infrastructure	-	-	$8.00
Total Capital Costs	**$227.75**	**$402.97**	**$360.25**

Operations and Maintenance

O&M costs are based mostly on vehicle hours driven and vehicle miles driven for each bus type. This dictates the level of vehicle operations (hours driven) and maintenance (miles driven) needed to support each fleet. As stated previously, vehicle operations costs are not considered in this analysis. Differences in vehicle O&M come from the incremental fleet transition, the associated vehicle mileage, and the different vehicle maintenance costs. **Figure 43** and **Figure 44** show the dynamics of the vehicle O&M costs in the transition scenarios (the baseline scenario is assumed to stay static at 2023 levels through the analysis). Additional O&M costs will be incurred for EV charger infrastructure. As shown in **Table 21**, the Level 2 62.5-kWh and 150-kWh chargers have a yearly $500 charge to slow degradation, while the 450-kWh Inductive DC Fast Charger has a yearly $1,500 cost. The utility infrastructure upgrades are assumed to have no other maintenance cost associated beyond standard repairs that would occur without the upgrades.

Figure 43: Annual BEB Transition Vehicle O&M Costs: FY 2023 to FY 2042 (2023 $)

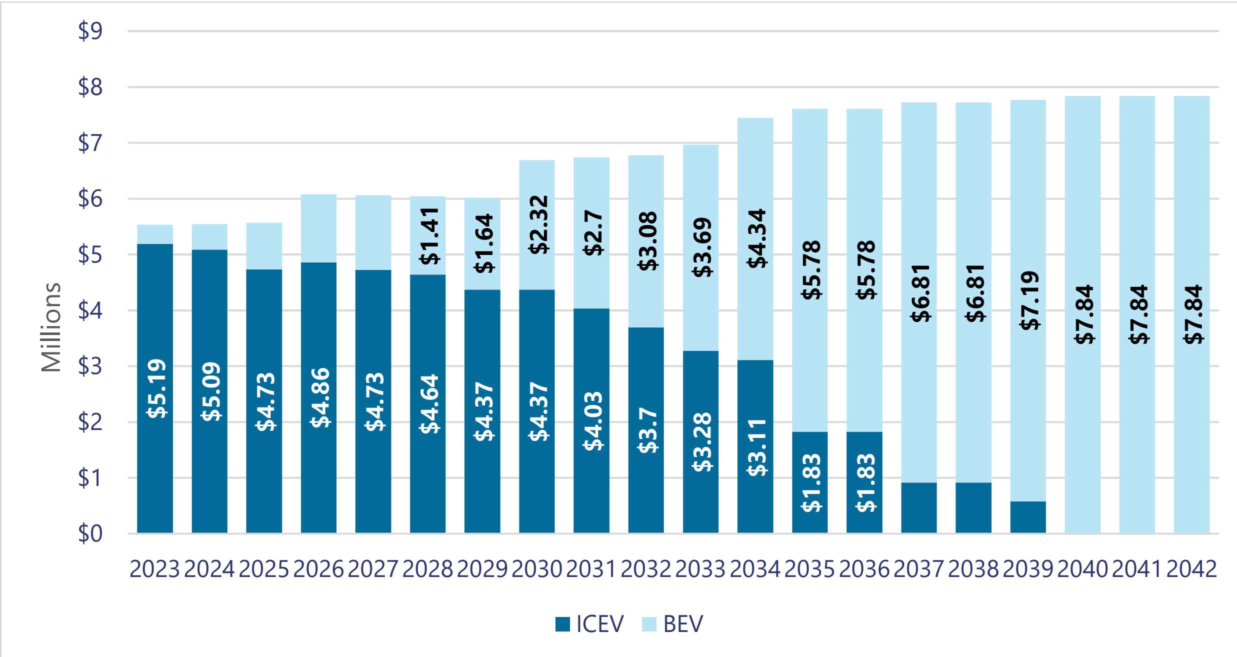
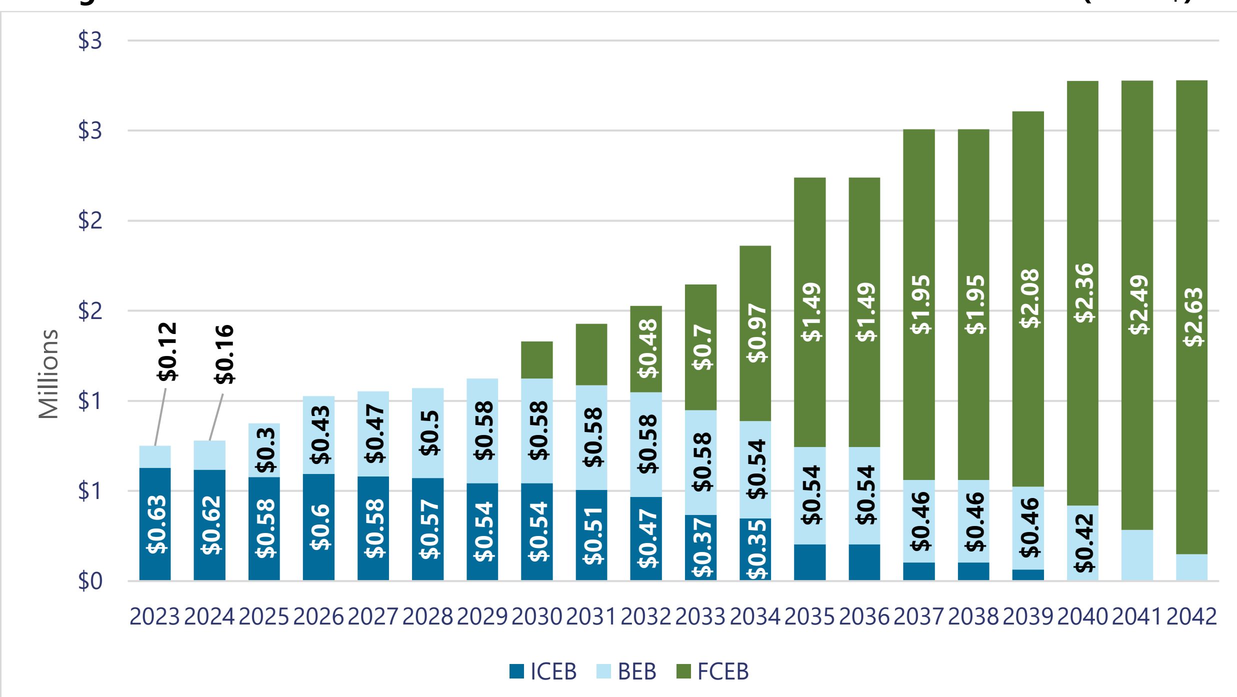


Figure 44: Annual FCEB Transition Vehicle O&M Costs: FY 2023 to FY 2042 (2023 $)



O&M Cost Comparison

As indicated earlier, it is assumed that vehicle operations costs would be the less for ICEBs than the electric vehicles. Vehicle maintenance costs are higher in the BEB scenario by about $7.8 million, and higher in the FCEB scenario by about $32 million, compared to the baseline.

The higher vehicle maintenance cost in the BEB scenario is coupled with additional maintenance cost associated with the EV chargers. The assumed $500 and $1,500 yearly charger maintenance costs for Level 2 Chargers and DC Fast Chargers results in approximately $1.17 million in additional EV charger O&M costs in the BEB transition scenario. This cost is on top of the $0.9 million in EV charger O&M costs for the existing nine chargers that is accrued in all three scenarios. This addition is marginal compared to the vehicle maintenance parts and labor cost differences. A hydrogen storage and distribution system would be operated and maintained through a service agreement with the system installer and is estimated to cost about $200,000 per year. This leads to an extra $2.8 million spent in the FCEB transition scenario.

Table 30: O&M Cost Comparison – FY 2023 to FY 2042 (Millions of 2023 $)

	Baseline	BEB Transition	FCEB Transition
Total Vehicle O&M	**$130.67**	**$137.42**	**$159.90**
Vehicle Maintenance Parts	***$113.41***	***$102.27***	***$124.99***
ICEB	$108.99	$51.12	$51.12
BEB	$4.42	$51.15	$15.89
FCEB	-	-	$57.99
Vehicle Maintenance Labor	**$17.25**	***$35.15***	***$34.91***
ICEB	$14.82	$7.03	$7.03
BEB	$2.43	$28.12	$8.74
FCEB	-	-	$19.15
Total Infrastructure O&M	**$0.09**	**$1.17**	**$2.89**
EV Chargers O&M	$0.09	$1.17	$0.09
Utility Infrastructure O&M	-	-	$2.80
Total	**$130.76**	**$138.58**	**$162.79**

Fueling Expenditures

The most significant long-term dynamic that will affect how financially viable the zero-emission transition plans will be after the analysis period are fueling expenditures. As various US agencies and firms move toward a net-zero future, alternative fueling inputs such as electricity and hydrogen will be more practical. Movement of these prices, as stated, are sourced from the US Energy Information Administration;[9] the only index not available is for the price of hydrogen. To accommodate this, the price index is tied to natural gas; this is standard among firms who deliver hydrogen for transportation use.

Gasoline, diesel, and CNG costs are accrued based on an average fuel economy estimate for Pierce Transit's existing fleet (see **Table 22**); the 2023 price per gallon (or gasoline gallon

[9] Energy price indices sourced from the 2023 Annual Energy Outlook appendix tables; *Annual Energy Outlook 2023 - U.S. Energy Information Administration (EIA)*

equivalent [GGE]) of gasoline, diesel and CNG; and the number of gasoline vehicles in each scenario's fleet. Electricity and hydrogen costs will be based upon the number of vehicles in the fleet and the Zero+ energy modeling that determined the energy demand on a per-vehicle basis. The annual average for each fuel is provided below in **Table 31** on a per-vehicle basis.

Table 31: Annual Average Per-Vehicle Fuel Demand

Vehicle Type	Gasoline/GGE	kWh Electricity	kG Hydrogen
Gas Vehicles	9,994	-	-
Diesel Vehicles	14,438	-	-
CNG Vehicles	10,150	-	-
Battery Electric Vehicles	-	140,619	-
Fuel Cell Electric Vehicles	-	-	7,412

Fueling Cost Comparison

Cost differences between scenarios can be attributed to the demand for each fuel type along with their respective unit prices. Electricity is the cheapest option long-term; even in the 20-year analysis period the BEB transition sees fueling savings. Hydrogen is the least cost-efficient of all fuel types and leads the FCEB transition fueling costs to be more than double those in the baseline and BEB transition. In the long term (post-analysis), electricity will still be the most cost-effective fuel source, although as hydrogen infrastructure is expanded and improved, these costs may decrease as well.

Table 32: Fueling Cost Comparison- FY 2023 to FY 2042 (2023 $ in millions)

	Baseline	BEB Transition	FCEB Transition
Gasoline	$5.28	$18.31	$2.77
Diesel	$22.36	$2.15	$4.80
CNG	$20.16	$10.74	$10.74
Electricity	$3.64	$16.78	$6.64
Hydrogen	-	-	$100.38
Total	**$51.44**	**$47.98**	**$125.34**

Net Present Value & Payback Analysis

A net present value (NPV) and payback period analysis was conducted to compare the alternative-fuel based transition scenarios to the baseline scenario. This analysis includes capital costs (vehicles, charging equipment, and infrastructure needs), O&M costs, and fueling costs for the transition scenario relative to the baseline scenario. In other words, only the incremental cost savings and expenditures on an annual basis were included. All savings and expenditures over the 2023 to 2042 period are presented in 2023 dollars and discounted at 5 percent.

The purpose of this analysis is to determine if the upfront capital expenditures can be overcome by annual vehicle operations, maintenance, and propulsion savings. The analysis does not attempt to quantify external benefits, such as emissions reduction, and assumes no changes to ridership or service levels. The only benefit, or in this case disbenefit, is the change in cost to the agency. In other words, the analysis looks at direct cost impacts to Pierce Transit and does not attempt to quantify costs and benefits on a larger scale. Additionally, the analysis does not assume capital costs will be offset by potential grant funding or Clean Fuel Standard credits that can be sold to other firms and agencies. So, these potential savings do not remove any costs from the NPV calculations but should be considered in the decision-making process.

The systemwide discounted NPV for the zero-emission transition scenarios are negative $107.3 million for the BEB-based transition and negative $131 million for the FCEB-based transition. The negative NPVs reflects that the transition scenario cannot offset higher capital and O&M in the baseline scenario with lower fueling costs in the transition scenario. Therefore, there is no payback period for either scenario within the analysis period.

The analysis is able to tell us that, between the two transition scenarios, the battery electric transition is far more cost effective than the hydrogen fuel cell transition. This is seen in the costs reflected through the analysis, along with market conditions. Battery electric vehicle technology is more developed than its hydrogen counterparts; because of this there is a fair amount of risk in a FCEB scenario because little market testing has been done on a national scale.

Table 33: Systemwide Net Present Value (2023 $)

	NPV, Non-Discounted	NPV, Discounted	Discounted Difference
Baseline	$409,948,429	$256,854,830	-
Battery Electric Transition	$589,535,275	$364,170,827	**-$107,315,997**
Hydrogen Fuel Cell Transition	$648,375,444	$387,861,648	**-$131,006,818**

Sensitivity Analysis

The outcomes presented in the financial analysis rely upon a number of assumptions and long-term projections, which are subject to uncertainty. The primary purpose of this sensitivity analysis is to evaluate the impact of change in individual critical variables. This will show how much the final results vary depending on alternative assumptions.

Stated in the Key Assumptions section, two inflation measures were tested. The main analysis was presented in 2023 dollars, but below results for including 3 percent and 7 percent long-term inflation will be discussed.

Inflation was not considered in the initial analysis, and all results are presented in 2023 dollars. This assumes that there would be no price inflation[10] through the analysis period. Clearly this is not representative of reality. Due to current economic conditions, two inflation rates are presented. The first rate is representative of historical inflation, 3 percent. The second rate, 7 percent, considers current inflation trends that are higher than historical averages. The results

[10] Price movement of fueling costs occur outside of general inflationary trends.

of using the two rates provide a range of outcomes that are more likely to reflect price movement over the 20-year period.

Sensitivity Results

It seems that the BEB is affected the most by inflation based off percent change from no inflation. It is followed by the Baseline transition and then the FCEB transition scenario. As general price growth is added, the FCEB transition scenario starts to become more competitive with the BEB transition, with the undiscounted difference between the two scenarios shrinking from $58.8 million to $41.3 million (with 3 percent inflation), then to $6.1 million (with 7 percent inflation). Though the gap between the two transition scenarios shrinks, the gap between the baseline and the transitions grows. The BEB transition-to-baseline scenario gap grows by $72.4 and $220.9 million at 3 percent and 7 percent inflation, respectively. The FCEB transition-to-baseline gap grows by $54.9 and $168.2 million at 3 percent and 7 percent inflation.

Table 34: Sensitivity Results

Scenario	Inflation Measure	Undiscounted NPV (Millions)	Change in NPV (Millions)	
Baseline Scenario	0%	$409.95	-	-
	3%	$564.23	$154.28	38%
	7%	$884.50	$474.55	116%
Battery Electric Transition	0%	$589.54	-	-
	3%	$816.18	$226.64	38%
	7%	$1,285.02	$695.48	118%
Fuel Cell Electric Transition	0%	$648.38	-	-
	3%	$857.51	$209.14	32%
	7%	$1,291.14	$642.77	99%

Appendix C: Stakeholder Engagement Supplemental Information

Pierce Transit Zero Emission Bus Roundtable Summary

Meeting purpose

Pierce Transit began the transition to a zero emission bus (ZEB) fleet with a grant award from the Federal Transit Administration (FTA) Low or No Emission Vehicle Grant Program in 2018. Currently, Pierce Transit has nine battery electric buses in operation. In order to successfully transition the rest of the fleet, Pierce Transit is in the process of developing a ZEB Transition Plan.

On Wednesday, January 15, 2023, from 2:30 to 4 p.m., Pierce Transit hosted a roundtable discussion with regional partners on the topic to:

- share information about the transition
- gather priorities and concerns, and
- explore opportunities for future partnerships

Attendees:
Jeffrey Arbuckle, King County Metro
Robert Barandon, Puyallup Tribe of Indians
Becca Book, Pierce County
Jamie Brinkley, Sound Transit
Emily Geralds, WSDOT
Kevin Kibet, King County Metro
Kurtis Kingsolver, City of Tacoma
Doug Lowman, King County Metro
Kristin Lynett, City of Tacoma
Ryan Medlen, Pierce County
Jeremy Metzler, City of Edgewood
Roxanne Miles, Pierce County
Tracy Oster, Downtown On the Go!
Wesley Rhodes, Pierce County
Angie Silva, Pierce County
Jen Tetatzin, Pierce County
Kourosh Vahdani, King County Metro
Kendall Wals, City of Puyallup
Kyla Wilson, Pierce County
LaTasha Wortham, Tacoma Public Utilities

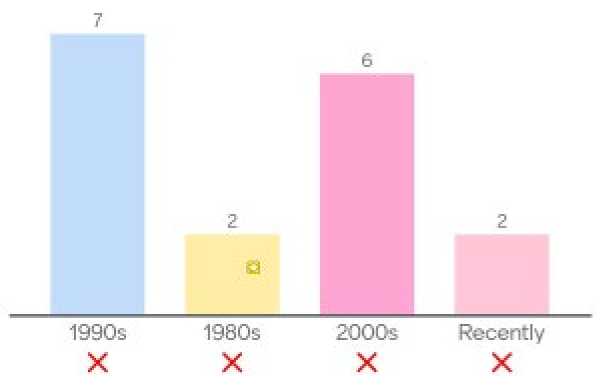
Study team attendees
Katy Asher, PRR
Carly Macias, HDR
Mackenzie McGuffie, HDR
Jennifer Rash, PRR
Kelsey Rudd, HDR

Pierce Transit attendees
Adam Davis
Mark Eldridge
Penny Grellier
Nathan Groh
Marah Harris
Tina Lee
Grantley Martelly
Alexandra Mather
Christopher Schuler

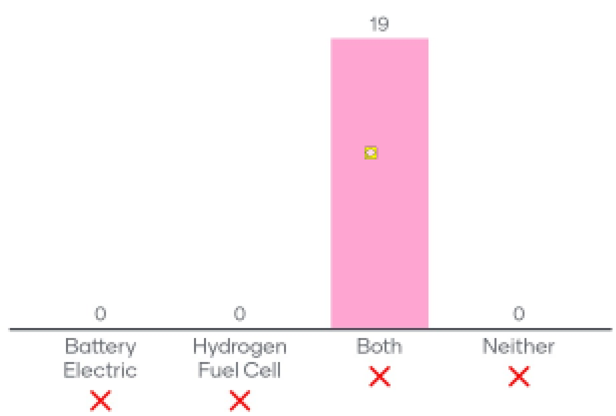
Welcome and Introductions

Tina Lee, Pierce Transit, welcomed attendees, asked them to add their name and organization in the chat, and reviewed the agenda. After a Mentimeter trivia icebreaker (results on pg. 2), Tina provided an overview of the purpose and goals of Pierce Transit's ZEB Study. A PDF of the presentation will be shared with the group.

Mentimeter Question 1: When did Pierce Transit transition from diesel buses? The correct answer is the 1980s, which most participants missed.



Mentimeter Question 2: Pierce Transit is considering what type of zero-emissions buses? The correct answer is both, which all participants selected.



Zero Emission Bus Technology Overview

Carly Macias, study team, provided an overview of the basics of ZEB Technology, reviewing the ZEB vehicle types, batter capacity, types of BEB Charging, Hydrogen Fuel Cell Bus (FCEB) basics, and potential hydrogen fuel sources.

Roundtable attendee comments and questions:

- What's the size difference between Pierce Transit's current fleet and proposed ZEB fleet?

- Goal is to have the buses be as similar in size as possible to current buses.
    - Length and width of buses are intended to stay the same, but weight of vehicles will likely increase.
    - Batteries will create more weight on the vehicle.
- How does inductive charging equipment hold up in rainy climates?
    - The chargers are built to withstand ice, snow, rain, and debris being on inductive chargers.
    - Chargers are installed to have proper drainage.
    - Jeff Arbuckle mentioned that Wenatchee has one.

Mentimeter Question 3: In your opinion, what is the top priority for Pierce Transit's ZEB transition? The words that appear largest are those with the most entries, including safety, funding, realiability, sustainabiliy, and partnership.

<u>Pierce Transit ZEB activities and initiatives</u>

Nathan Groh and Adam Davis, Pierce Transit, provided an overview of Pierce County's most recent ZEB activities and initiatives including a review of their current fleet, recent bus grants and purchases, and facility improvements. Chris Schuler, Pierce Transit, presented on Pierce County's Major Project Capital Expenditures.

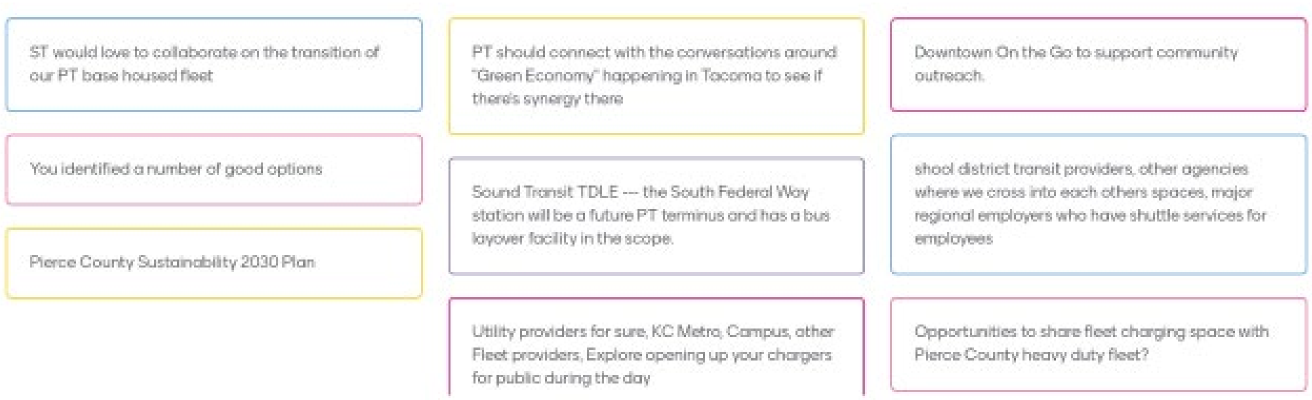
<u>Zero Emission Bus Transition Planning</u>

Carly reviewed some of the planning efforts performed so far for the study. The consultant team and Pierce transit are modeling and simulating various inputs and outputs to better understand infrastructure that is needed and operational impacts they might see. She gave a preview of models and key takeaways of depot charging only and depot plus on-route charging and hydrogen fuel cell buses, and a summary of route modeling results.

Roundtable attendee comments and questions:

- Can sales tax revenue be used for both capital and operating expenses? What is a likely or possible timeline for a vote to increase the sales tax?
  - Pierce Transit's board would have to provide direction on this, and the soonest anything would happen would be 2023-24.
- Ryan Medlen, Pierce County, suggested reaching out to Sound Transit to see if they would consider constructing (or providing space for future) charging facilities at the future TDLE stations, as some will have layover spaces. Jamie Brinkely, Sound Transit, offered to help connect Pierce Transit staff to the TDLE team.
- What is the charge rate for both Depot and On-Route?
  - This study looked at 300 kilowatts, but they can differ.
- How would on-route charging work? Is it a high-speed charge "top off" while the vehicle is in service?
  - Buses would layover at transit centers like they already do but be charged during layover.
  - The buses would regain some energy each time they layover.
    - Some buses on shorter routes would never fully deplete.
    - Other buses on more demanding routes deplete slowly until they can get to depot chargers at the end of the day.
- What is the impact to service by the need to charge throughout the day?
  - Ideally there would be little to no impact.
  - Conditions were modeled with existing schedules and layover times.
  - There is opportunity to make changes to schedules to make on-route charging more effective.
  - If depot-only were selected, there need to be extra planning and possible service impacts to swap buses midday.
- Would the board consider taking on debt if additional revenue is not available?
  - No.

Mentimeter Question 4: Do you have recommendations for partnerships and/or opportunities Pierce Transit should consider for the ZEB transition?



Roundtable attendee comments and questions:

- Jeff Arbuckle, King County Metro, hopes that Pierce Transit opts for pantograph chargers so that the two agencies can share infrastructure.
- If buses with a higher kilowatt charge were implemented, would it reduce the need for charging infrastructure?
  - A faster charge could slightly reduce the need, but it doesn't make a big enough difference to implement. However, this is something that would have to be reevaluated as technology advances.
- An attendee from Pierce Transit asked if HDR been instructed to plan for the first goal of 20 percent electrification; however, the virtual meeting ended as the question posted to chat.
  - Tina and team will follow up with him.

Conclusion and next steps

Tina shared next steps for Pierce Transit during their transition and thanked everyone for attending.

- Tina will send participants a copy of the presentation and Mentimeter results.
- Tina shared Pierce Transit's Zero Emissions Fleet Coordinator Nathan Groh's contact information and encouraged people to contact him for more information: ngroh@piercetransit.org
- Participants are encouraged to share any reports, plans, or studies that might help Pierce Transit with their ZEB transition.

Stakeholder Interviews

In the early stages of developing its ZEB plans, Pierce Transit sought to form relationships with environmental justice-focused and community-based organizations that serve Pierce County. A 30-minute virtual interview or phone call was offered to a select group of organizations, chosen based on

- Previous/current engagement with zero emissions policies
- Proximity to, and organizational interests in the service area
- Ability to represent public interests and provide input

Outreach to schedule these conversations took place from February 23 to March 10, 2023. It's important to note that the Washington State Legislative session was ongoing at this time, as well as several large transportation studies in Pierce County. One organization, Washington Physicians for Social Responsibility, emailed the following message: *At this time, WPSR is swamped with a few projects during this legislative session, and I cannot commit to taking on another project at this time. We won't be able to join the meetings, but we do hope that you will keep us informed of this as we are helping to support these efforts when we can.*

Table 35: Stakeholders Contacted

Organization	Contact	Email/phone	Website/additional info	Contact notes
350 Tacoma	No named contact	hello@350tacoma.org	https://www.350tacoma.org/	Contact page inquiries; no phone
The Black Collective	No named contact	tacomablackcollective@gmail.com	https://theblackcollective.org/	Contact page inquiries; no phone
Centro Latino	No named contact	reception@clatino.org; 253-348-1745		Voicemails and emails sent
Puget Sound Sage	Khristine Cancio, communications manager	khristine@pugetsoundsage.org	https://www.pugetsoundsage.org/	Voicemails and emails sent
Transportation Choices	Matthew Sutherland, Advocacy Director	matthew@transportationchoices.org		Voicemails and emails sent
Washington Physicians for Social Responsibility	Riley Lynch Climate and Health Program Manager	wpsr@wpsr.org; riley@wpsr.org 206.547.2630	https://www.wpsr.org/ - they partner with 350 Tacoma	Per request, sent an emailed version of the interview questions; no response

Social media attitudes and awareness polling

Pierce Transit administered a two Facebook/Instagram poll ads and two organic tweets to get an early pulse on awareness of electric buses in the current fleet and to gauge attitudes toward a full zero-emissions transition. Content was posted on Thursday, March 8, through Sunday, March 12, 2023. Results shows differences in attitudes and awareness across platforms (Facebook, Instagram, Twitter), with a more supportive audience on Instagram and Twitter.

Facebook Poll Ad Results

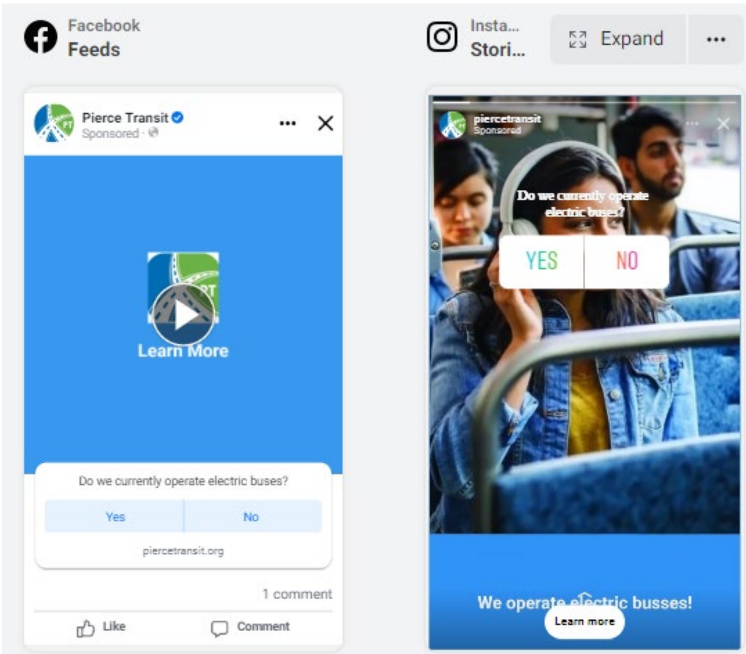
Overview:

Ad Set	Reach	Impressions	Spend	Clicks
Pierce Transit Poll Ad 1	20,061	20,473	$50.00	20
Pierce Transit Poll Ad 2	19,936	20,383	$50.00	33
TOTAL:	**27,289**	**40,856**	**$100.00**	**53**

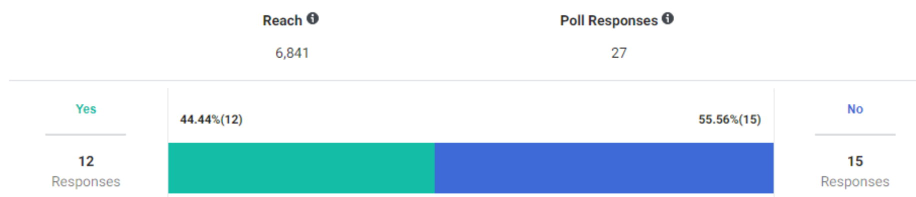
Poll Results:

Question	Yes	No	Total
Do we currently operate electric buses?	13	19	**32**
Is a zero-emissions bus fleet important to you?	11	23	**34**
Total	**24**	**42**	**66**

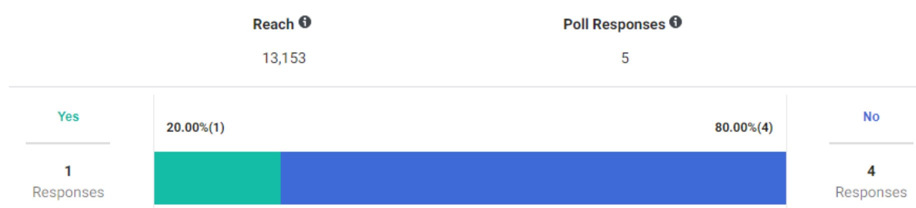
Poll 1: Do we currently operate electric buses?



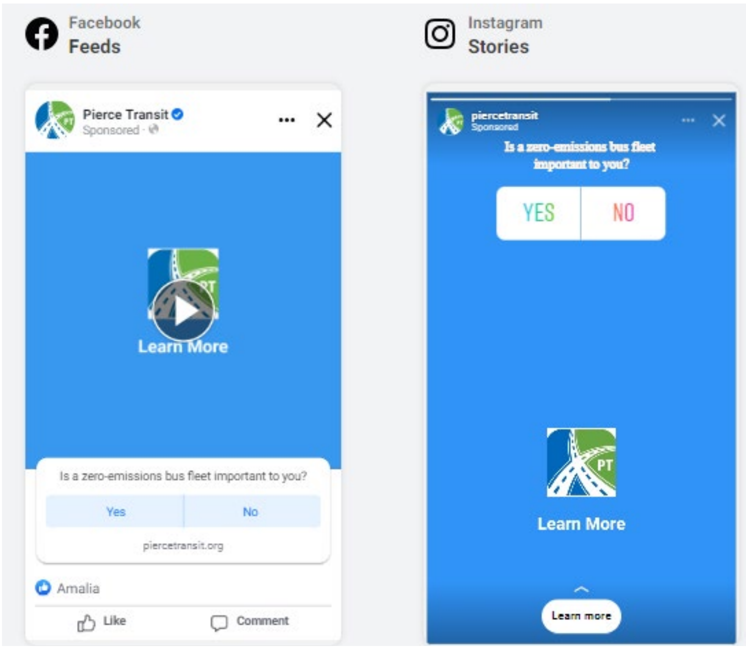
Instagram Stories results



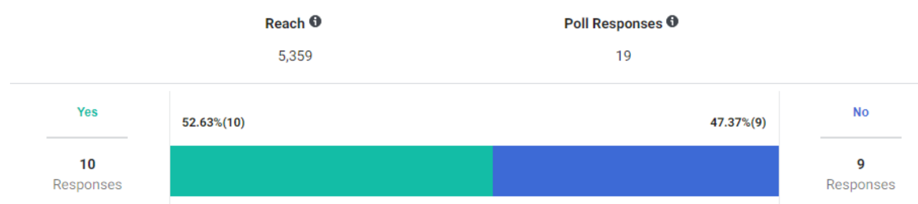
Facebook ad results



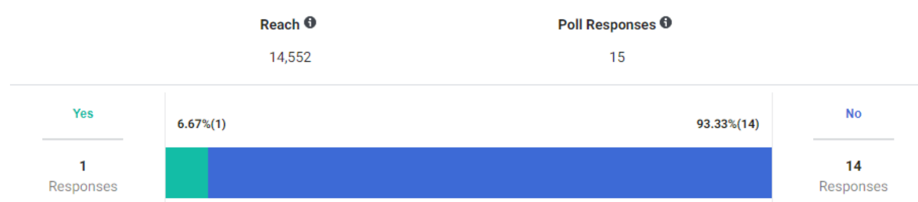
Poll 2: Is a zero-emissions bus fleet important to you? (yes/no)



Instagram Stories results



Facebook ad results



Organic Twitter Engagement