Park City Transit
Phase I Zero Emission Bus Transition Plan

Contents

Executive Summary

The transportation sector is a significant driver of greenhouse gas emissions (GHG) in Utah. Public transit plays an important role in reducing GHG pollution by reducing vehicle miles traveled. Transitioning the vehicle fleet of transit agencies to electric vehicles further reduces emissions, improving local air quality and public health. The Zero-Emission Transition Plan is Park City Transit's (PCT) plan to guide the agency as it responds to emission targets set by Park City and Summit County. Summit County aims to reduce emissions by 80% before 2050, and Park City aims for carbon neutrality and 100% renewable energy used within the city by 2030. The Plan identifies opportunities and challenges for PCT to reach their goal of offering fully-electric service by 2030.

The Plan begins with an overview of the context and purpose, identifying relevant policies, initiatives, and studies. It also includes an overview of the various technologies and associated considerations for each vehicle type. These are discussed in the Electric Bus Technology Overview section and describe various vehicle types as well as battery and charging infrastructure.

The evaluation of existing and future facilities and their relationship to the technology transition is discussed in the document's Electrification Analysis & Evaluation section. In-depth description of the service & fleet analysis, the current fleet composition, early transition opportunities, and a facility analysis are also included in this section.

The Plan addresses resource availability, both current and future, to meet costs associated with transition and implementation. Resources including power from utility providers, funding availability, and the agency's workforce, are described in this section. The utility coordination section outlines the partnership between PCT and the utility provider, Rocky Mountain Power. PCT plans to maintain open communication and work in concert with the utility company to provide sufficient lead time to ensure continuing service availability as the electric fleet grows. The workforce section also examines the impact of the transition on the workforce and identifies strategies to avoid displacing existing workers. PCT will empower the existing maintenance team to work on all battery equipment. This includes hands-on training and potential collaboration with the Utah Transit Authority (UTA).

Lastly, this report will identify next steps for the agency, near-term fleet and facility changes, strategies to overcome barriers and associated risks, and help to highlight areas for further research. PCT will be pursuing an additional Transition Plan later this year as a Phase 2 item and continuation to this document, which will seek to address many of the questions and areas identified for further research within this document. This Phase 2 Plan will include a more thorough operations analysis, as well as a detailed facilities upgrade timeline in order to better inform PCT's long-range transition and meet the fleet conversion goals.

Transition Plan Context and Purpose

Reducing transportation-related emissions helps improve not only local air quality, but also helps to reduce GHG pollution that contributes to negative global impacts. PCT is committed to reducing the environmental impacts of its transit operations by evaluating and implementing a zero-emissions transition plan. Park City also has a proven history of committing to technologies to reduce emissions since deploying six battery electric buses (BEBs) in 2017 and an additional seven in 2018.

Park City Bus System and Facilities

PCT is a rural transit provider servicing the Park City Municipal corporation in Summit County, Utah. PCT's service spans a wide variety of ridership, providing service for both visitors and employees to the local resorts, festival goers to events, and other trips for local residents to important services such as Park City Hospital and medical campus.

PCT operates a mixed fleet of 38 35-foot and 40-foot buses on fixed routes, as well as 17 cutaways and other vehicle types for on-demand trips and other various applications. PCT's bus fleet is currently a mix of diesel and electric vehicles, with 30% of the bus fleet being fully-electric vehicles. These buses are short-range Proterra vehicles, powered via overhead chargers situated in-route in order to top off the charge of the vehicles in service. PCT endeavors to be operating fully-electric service by 2030, and so is developing this transition plan to identify opportunities and challenges for near-term BEB transition. This report will help to highlight areas for further research, as well as documenting PCT's current experience with BEBs to date.

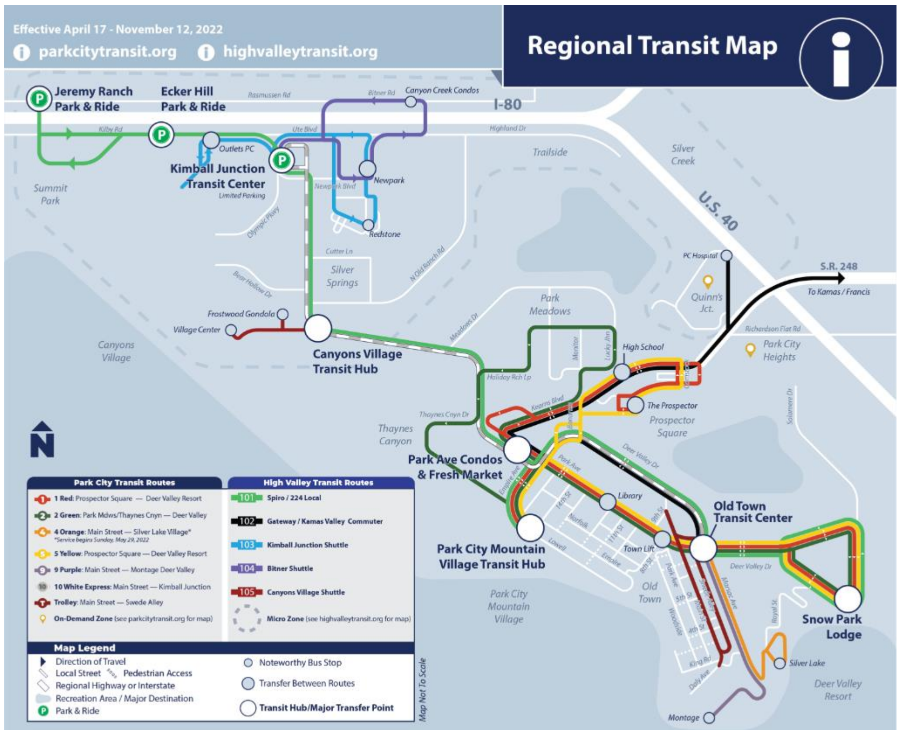

Figure 1: Park City Transit Route Map

Environmental Impacts of Transit

Transit has an important role to play when it comes to reducing a region's overall GHG emissions. Any time a passenger chooses to ride transit rather than drive their own vehicle, overall vehicle mileage traveled is reduced along with net emissions. These net benefits can be further improved upon by reducing the emissions emitted from transit vehicle operations. According to the Strategic Action Plan for Building Decarbonization in Park City and Summit County, about 37% of the GHG emissions in Park City come from transportation alone.

Trend Towards Zero-Emission Buses

Transit agencies both across the country and internationally are implementing strategies to reduce emissions from their fleets by integrating more low- and no-emissions technologies. Zero emission bus (ZEB) adoption in the United States is anticipated to accelerate due to increased funding availability to support ZEB purchases, as well as increased adoption of emissions-reducing policies by local governments and municipalities. As of September 2021, 3,533 ZEBs were counted to be in operation in the U.S., which accounts for a 27% growth since 2020.[1] While nearly half (49%) of this value is based in California alone, nearly every state except for New Hampshire, West Virginia, and North and South Dakota has at least one ZEB on the road or on order to date.

Existing Policies, Initiatives, and Studies

Nationally and locally, reducing emissions has been of an increasing concern as research continues to demonstrate the wide range of environmental and health benefits that result. This section will identify policy and legislation with implications on Park City's zero-emission transition.

Infrastructure Investment and Jobs Act (IIJA)

Signed into law by President Biden on November 15, 2021, the Infrastructure Investment and Jobs Act (IIJA), also known as the "Bipartisan Infrastructure Law," invests "$89.9 billion in guaranteed funding for public transit over the next five years—the largest Federal investment in public transit history."[2] As part of these transit investments, the IIJA includes provisions to support and increase investment in zero-emission vehicles through grant programs, studies, fleet funding, and other measures.[3] In particular, the IIJA includes provisions to continue the grants for the Buses and Bus Facilities program with increased funding levels compared to that of previous authorizations. The IIJA also includes funding appropriation for the Low-No Grant program at around 1.1 billion dollars annually from 2022 through 2026, which is a program within the FTA's Buses and Bus Facilities program. This discretionary grant program requires agencies to have a zero-emission fleet transition plan. It also requires that five percent of Low-No Grants related to zero-emission vehicles and related infrastructure must be used for workforce development activities, unless the applicant certifies that less is needed to carry out their zero-emission fleet transition plan. It should be noted, however, that federal transit funding focuses on capital needs, not addressing the costs associated with operation and maintenance of ZEBs or other transit services.[4,5]

Strategic Action Plan for Building Decarbonization in Park City and Summit County

Park City and Summit County have both made commitments to reduce local emissions, with Summit County aiming to reduce the countywide greenhouse gas footprint by 80% before 2050, and Park City aiming to achieve carbon neutrality and run on 100% renewable energy by 2030. Both groups are developing plans to further these pursuits, and while this document prioritizes

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[1] Source: *Zeroing in on ZEBs,* CALSTART, December 2021.
[2] Source: *Fact Sheet: The Bipartisan Infrastructure Deal,* The White House, November 6, 2021
[3] Source: *Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act of 2021)*, Alternative Fuels Data Center, 2021
[4] Source: *Fact Sheet: Buses and Bus Facilities Program*, Federal Transit Administration, December 9, 2021
[5] Note: Several COVID-19 Relief laws allowed federal funds to be used for operating and maintenance costs. However, funds provided for transit to large urban areas outside of COVID relief bills have been restricted to capital projects.

the identification of goals and strategies to approach these goals from a building and construction perspective, it also identifies the percentage of local emissions resulting from transportation. In Summit County, 44% of the region's CO2 equivalent results from transportation and mobile sources, while Park City's associated value is 37%.[6]

[6] Strategic Action Plan for Building Decarbonization in Park City and Summit County, Ryan Anderson, Jeff Bousson, & Kevin Emerson; Utah Clean Energy, September 2021

Electric Bus Technology Overview

Currently, three zero-emission bus technologies are commercially available: electric trolleybuses, fuel cell electric buses (FCEBs), and battery electric buses (BEBs).

Figure 2: Trolleybus in operation

Source: *Flying Flyers—Muni Trolley Buses Then and Now*, SFMTA, May 3, 2018

While electric trolleybuses have been in use for nearly a century, only five transit agencies across the country currently operate this type of ZEB as a part of their regular service offerings.[7] Power to these buses is provided via two trolley poles connecting the top rear of the bus to overhead catenary wires. Due to trolleybuses limitations including limited flexibility for off-wire operation, extensive costs associated with building and maintaining a network of overhead wires, and the significant visual impacts of these wires, PCT does not intend to pursue the implementation of electric trolleybuses.

Conversely, FCEBs—buses that use an on-board electrochemical hydrogen fuel cell for propulsion—are growing in prevalence across the United States with adoption of these buses nearly doubling between 2020 and 2021[8]. Despite this significant increase, the deployment of FCEBs remains limited to only 10 states and only California and Ohio have adopted more than 10 FCEBs in total as of September 2021[8]. Due to the significant upstream carbon emissions associated with creating and trucking hydrogen, the high cost of FCEBs, and the current lack of an identified source of hydrogen supply, PCT does not currently plan to implement FCEBs in the short-term.

BEBs use onboard battery packs for bus propulsion and power rather than using conventional fuels such as diesel or compressed natural gas (CNG). BEBs are charged either at garages, or on-route during operation. Transit agencies located in colder climates typically include an auxiliary diesel heater on their BEBs for supplemental heat to increase bus range. As of September 2021, approximately 95% of the full-size (30+ feet in length) transit ZEBs on the road or on order in the United States are BEBs. Due to the several challenges associated with FCEBs outlined above as well as comparatively lower capital costs and increased industry experience associated with BEBs, PCT plans to focus on a zero-emission transition towards BEBs. As such, the following sections of this transition plan focus on an analysis and evaluation of BEB technologies.

BEB Vehicle Considerations

The batteries onboard a BEB are used to provide both the energy required to drive the bus as well as the energy necessary to operate all vehicle auxiliary functions including heating and cooling the passenger cabin. The amount of energy provided by the battery is described by its energy capacity measured in kilowatt-hours (kWh). Analogous to a fuel tank on a diesel bus, larger battery capacities translate to increased energy (fuel) storage, and thus, increased range. Unlike conventional diesel buses which typically have 100+ gallon fuel tanks that allow a bus to travel more than 300 miles before refueling, BEBs typically have a reliable range in transit service

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[7] Source: *The National Transit Database (NTD)*

[8] Source: *Zeroing in on ZEBs*, CALSTART, December 2021.

of 150 miles or less on a single charge.[9] A BEBs range is a function of two primary characteristics: (1) battery capacity, and (2) energy usage.

Larger **battery capacity** translates to increased energy (fuel) storage, and thus, increased range. As of Spring 2022, BEB manufacturers offer on-board BEB batteries with capacities typically ranging from approximately 215 kWh to 686 kWh.[10,11] Expanding on these capacities, Proterra has announced that starting in 2023, they will offer a 40-foot BEB that can be equipped with up to 738 kWh of onboard energy.[12] These advertised capacities, also referred to as nameplate or nominal battery capacities, indicate the capacity of a new battery pack. Unfortunately, however, not all the nominal battery capacity can be used for BEB operation. Instead, batteries wear down and become less efficient over time as they are constantly charged and discharged. Furthermore, charging a BEB to full capacity or charging it from a zero state of charge (SOC) increases the rate at which the batteries degrade as this process puts additional strain on the physical and chemical components of the battery, and so many manufacturers carve out an unusable portion of the battery to preserve the longevity of the hardware. An additional consideration for the unusable portion is that at low enough states of charge, the battery will not be able to produce enough power to move the vehicle. Additionally, just as operators avoid driving a conventional bus until the fuel tank is empty, a portion of a BEB's battery capacity is typically preserved for operational flexibility. By preserving this capacity, transit agencies are able to ensure that BEBs will have sufficient range to return to the garage in the event of an unforeseen delay or other unexpected event requiring a BEB to remain in service longer than originally planned. These factors translate to usable battery capacities between approximately 145 kWh and 465 kWh.

The amount of **energy usage** by the bus (kWh/mile) also impacts BEB range. When the energy used to heat and cool the bus cabin is the same energy that would be used for the propulsion of the bus, bus range can be substantially reduced in cold weather as increased energy must be devoted to maintaining a comfortable temperature in the passenger cabin. The speed at which a BEB operates also influences energy usage and therefore BEB range. Typically, slower speeds are a result of either busy or congested environments. In busy environments, buses often see greater energy usage, owing to bus doors being open more often and for longer periods of time. When the doors are open, heating and cooling the bus cabin is more difficult as extra energy needs to be drawn from the battery. Additionally, when buses are stuck in congested environments, they spend an increased time idling and accelerating from rest, thereby also requiring greater energy usage. Efficient operation of the vehicle through gentle accelerations and decelerations can reduce energy usage by not only requiring less energy to accelerate from rest, but also to maximize the bus's ability to regenerate energy. When the bus is rolling forward, BEBs are capable of recapturing some of that energy and improving overall energy usage. From this combination of factors, energy usage on the same bus can vary widely within a single transit agency's operation, and therefore lead to different functional ranges.

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[9] Source: *Guidebook for Deploying Zero-Emission Transit Buses*, The National Academies Press, 2021
[10] Source: *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses*, National Renewable Energy Laboratory, April 2021
[11] Source: *GILLIG's next-generation battery to provide 32 percent increase in onboard energy*, Gillig, November 2021
[12] Source: *Proterra Introduces ZX5 Electric Bus With 738 Kilowatt Hours of Energy*, Proterra, April 14, 2022

Charging Infrastructure

In the North American BEB industry there are currently three primary types of BEB chargers: (1) plug-in chargers, (2) overhead conductive chargers with inverted overhead pantograph dispensers, and (3) in-ground wireless inductive chargers (Figure 3). Plug-in chargers are typically used at garages and in bus service / maintenance bays, whereas overhead and inductive chargers can be used for either garage or on-route (opportunity) charging. BEB charging infrastructure typically includes transformers, switchgear, chargers (charger “bases / cabinets” where the majority of charging equipment is housed including AC – DC rectifiers, charge controls and communication) and dispensers (e.g., pantographs or plugs).

Figure 3: BEB Charging Infrastructure

Plug-In

Source: The Herald, Kevin Clark, Oct. 2021

Overhead Conductive

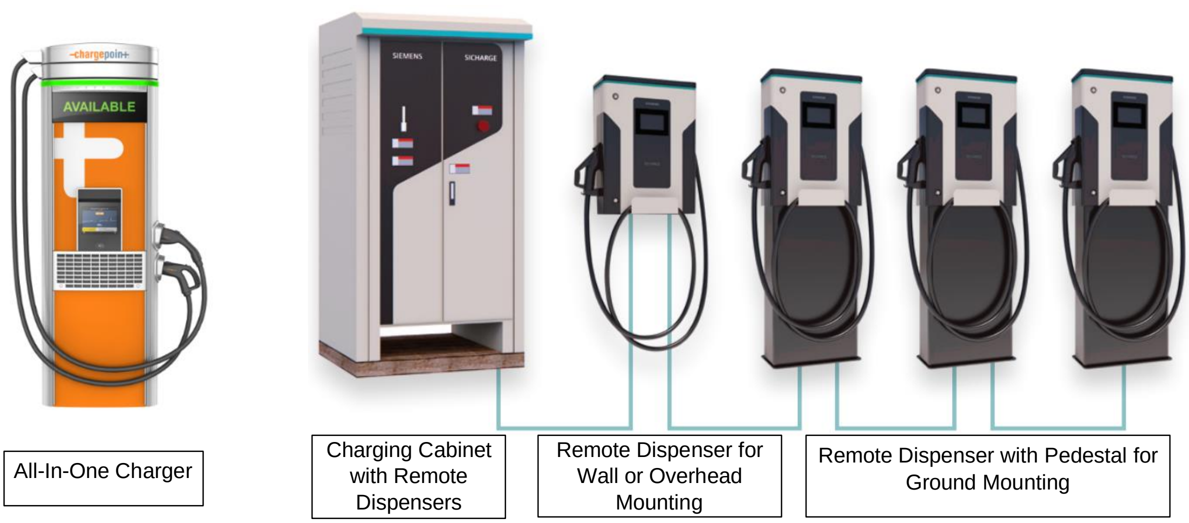
Source: TriMet, March 2021

Wireless Inductive

Source: Link Transit & eVehicle Technology

Plug-in chargers can be either an ‘All-in-one’ unit with dispensing plug-in cord attached directly to the charger cabinet or a charging cabinet connected to remote plug-in dispensers.

Figure 4: Plug-In Charger Detail

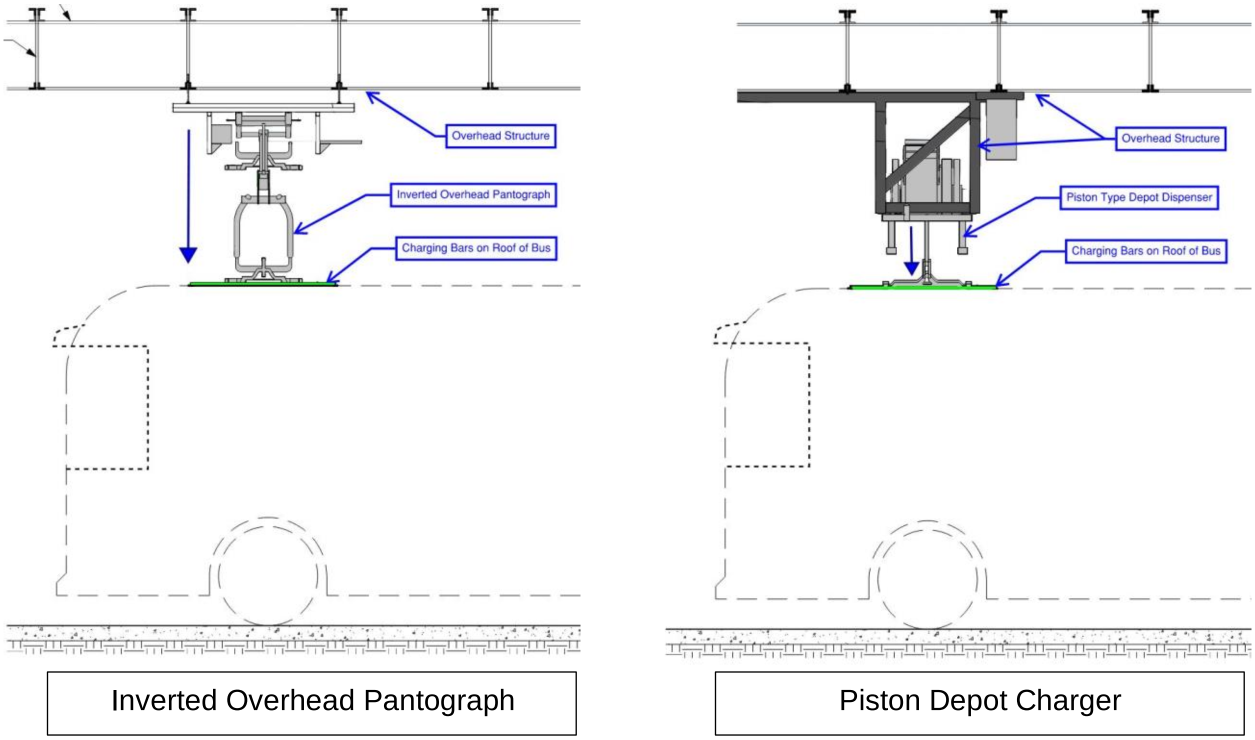


Typically, a plug-in all-in-one unit has one or two cords and a remote dispenser cabinet that can energize between one and four+ dispensers allowing for scheduled charging of multiple buses.

Charge power for plug-in chargers ranges from 50 to 180 kW. Due to this relatively low power, plug-in chargers typically take several hours to fully charge a bus and are therefore often used for overnight charging. A factor to be considered with shared charging (one charging cabinet energizing multiple dispensers) is that depending on the charger manufacturer and model, the name plate rating of the charger (180kW for example) might only output a maximum of 60kW if the one charger cabinet is energizing three dispensers (expressed as a 1:3 charging ratio). There is no industry standard yet for shared charging configuration so any shared plug-in charging assumed performance operations, such as 'ability to provide 180kW to any dispenser at a time…' is recommended to balance the planned incoming charging equipment with the anticipated charging operational time. BEBs by default have charging ports located in similar locations to conventional internal combustion engine fuel ports – curb side, rear quarter of bus. Buses can be specified to have plug-in ports on both sides of the vehicle or only one at the center rear to the bus to increase flexibility in parking positions especially at ground mounted charger islands and curbs. Per-unit capital costs for plug-in chargers are lower than for other types of charging infrastructure. The J1772 standard, published by the Society of Automotive Engineers, allows for interoperability of plug-in chargers with different types of buses from multiple manufacturers, analogous to the standardized pump size for gasoline vehicles across manufactures which allows you to fill your gas tank at any gas station. Note that retrofitting ground mounted charger cabinets (2ft to 3ft 6 inch) in depth adjacent to parked buses in existing dense bus parking arrangements can lead to blocking of staff circulation at or create a bus to charger impact danger. On large retrofit deployments at existing dense close parked bus lanes, 12ft wide or less, it is not uncommon to have to eliminate some bus parking spaces to allow for ground mounted chargers. Overhead suspended dispenser plug-in cords mounted over parked buses energized by charging cabinets located remotely away from bus parking can be used where ground mounted plug-in cord equipment is impractical or not desired. Overhead plug-in cords over buses, if not left always dangling protected by bollard or other structure, do require some means to retract and extend down cord. Currently the charging equipment OEMs do not off a remote overhead reel or retraction system and rely on third party vendors or site-specific custom solution from the simple, suspended rope tagline connected to a manual pull charging cord, to powered retraction systems using reels or winches.

Overhead conductive chargers typically use an extending arm pantograph or piston mounted charging bars that lowers down from the charger to connect to the roof mounted charge rails on the bus. Two examples of overhead chargers can be seen in Figure 5 below.

Figure 5: Example Schematics of Overhead Conductive Chargers



There are pantographs mounted to the bus that extend up to connect to an energized charge point mounted to overhead structure but this type of pantograph is rarely used in the US market due to the added weight of the pantograph to the bus and the single source proprietary overhead connector. Charge power for overhead conductive chargers ranges from 150 to 600kW.[9] The lower capacity units are typically used at depot bus parking similar to where plug-in chargers would be used but with the benefit of not requiring ground space. Higher capacity units, 300+ kW, are used at shared charging positions at depots or at on-route charging locations. Overhead conductive chargers can be flexibly used to “top-up” a bus’s charge for 5 to 20+ minutes at higher power or for longer durations at lower power. Overhead conductive chargers historically rely on a smaller ratio of chargers to buses due to their higher power output that reduces the footprint for the charging equipment. However, it also means that a malfunction of a charging station may have a larger impact on service if the charger is not available.

It should be noted that OEM-Proprietary overhead conductor chargers, chargers that use proprietary conductor contact configurations and non-SAE standard charge communication and charge control protocols also exist. Proterra’s horizontal-articulating charger mast uses semi-autonomous bus-to-charger alignment paired with a 500kW charger is an example of a proprietary overhead conductive charger. However, most manufacturers of both BEBs and chargers have moved to producing SAE 3105/1712-compliant chargers which are interoperable with different combinations of buses and chargers and improves flexibility for the operating agencies.

A number of charging OEMs producing SAE 3105 /1712-compliant overhead conductive chargers now offer charger cabinets that can energize multiple overhead conductor chargers and even support a mix of connected dispensers (i.e. plug-in cords and overhead conductors connected to the same cabinet). Overhead conductive charging can be operationally challenging as proper alignment between a bus and pantograph is critical in achieving proper charging. Similar to the standard established for plug-in chargers, the J3105 standard for overhead conductive chargers allows transit agencies to operate different models of buses from multiple vehicle manufacturers with the same overhead conductive charger. Compared to plug-in chargers, overhead conductive chargers have higher capital and construction costs.

Inductive chargers utilize a wireless power pad as the charging dispenser embedded in the floor of a garage or roadway surface in addition to a power receiver installed under the bus. An above ground charging cabinet similar to a plug-in or overhead conductor cabinet is still needed to convert AC to DC power and energize the charging pad dispenser. Like plug-in and overhead conductor chargers, the charging cabinet is available in ranges from 50-350+ kW. Some inductive chargers are capable of energizing multiple wireless charging pad dispenser in 1:2 and 1:3+ ratios. Inductive chargers eliminate concerns for overhead clearances, as they are built into the floor of a garage or roadway. However, there may be significant costs and operational disruptions to install, repair, or replace the charger and wireless pad since it would be embedded in the floor of the garage or roadway. Retrofitting multiple induction pads and their associated above ground chargers in existing garages will require significant trenching and cutting of the floor slabs. Inductive charging can be operationally challenging as proper alignment between a bus and inductive charger is critical in achieving proper charging. Inductive charging is still considered to be in its infancy as only a small number of North American agencies have implemented inductive chargers either as charge in parking place at a depot or as an offsite opportunity charger. Currently, there is no national standard for inductive charging. As a result, each bus manufacturer could approach this charging strategy differently meaning that different charging equipment may not work for different types of buses or even different bus models from the same manufacturer. These complexities are analogous to how some smartphone charging ports are not compatible with smartphones from different manufacturers or how smartphone companies can change the charging port between phone versions.

Short-Term Charging Strategy

PCT’s existing BEB fleet uses on-route charging to complete service. These low-capacity, short-range buses receive additional energy during service via strategically-placed overhead conductive chargers during layovers in order to meet the range requirements of service. However, the overhead chargers currently installed are a proprietary product of Proterra, and compatible bus-side charging equipment is no longer recommended due to Proterra now supporting SAE 3105/1712-compliant charging infrastructure.

For near-term deployments, PCT will consider depot-charging as the primary charging strategy, as BEB ranges have increased in recent years, making the strategy more viable in Park City’s climate. As the number of blocks viable for depot charging are substituted with BEBs, additional strategies may need to be implemented in order to continue the transition to a zero-emission fleet. These could include additional on-route charging, or even block splitting to have more than one bus replace the duty cycle of a single diesel vehicle. However, this will be an item for further research to ensure an optimized strategy is selected for Park City’s operations.

Electrification Analysis & Evaluation

Service & Fleet Analysis

This section analyzes PCT's bus fleet and service to identify the share of existing bus blocks, platform hours and miles, and revenue hours and miles that are technically viable for a one-to-one transition to BEBs with only garage charging. This analysis looks at three scenarios including: Current Technology BEBs, Moderate Technology Improvement, and Significant Technology Improvement.

Current Fleet Composition

As introduced earlier in the document, PCT's operating fleet is composed of buses of varying lengths operating from one home garages to provide a range of service types. As of Spring 2022 PCT operates 13 ZEBs. PCT's fleet includes a total of 56 vehicles comprised of:

- 14 Gillig 35' diesel buses;
- 7 Proterra 35' electric buses;
- 12 Gillig 40' diesel buses;
- 6 Proterra 40' electric buses;
- 5 Ford cutaway vehicles;
- And 12 assorted trucks, vans, and utility vehicles.

As part of Park City's goals to achieve carbon neutrality by 2030, PCT is seeking adding 5 more BEBs to their fleet in order to expand their BEB transition.

As part of this preliminary analysis, only fixed-route buses will be evaluated as their use is more predictable and therefore better for initial projections. As well, the market for smaller-duty electric vehicles is still developing, and those presently available tend to be more range-limited. Therefore, this part of PCT's fleet will be flagged for further study.

Service Analysis Assumptions

As previously discussed in this document, battery/energy capacity and energy usage are the primary drivers influencing BEB range, and consequently the viability for existing bus service to be served by BEBs. The following section defines the assumptions for each factor used in assessing BEB service viability. Battery capacity and energy usage assumptions are then summarized in Table 1.

Battery/Energy Capacity Impacts on BEB Range

To calculate and model a battery's energy capacity, three factors must be considered: (1) battery degradation, (2) battery life, and (3) operational flexibility.

Battery Degradation

Batteries become less efficient and wear down over time as they are constantly charged and discharged. For example, as smartphone and laptop users are aware, as these devices grow older, they require more frequent charging as a "full charge" no longer provides power for as long as when the device was new. Based on manufacturer warranties, it is estimated that a BEB's battery capacity degrades by as much as 2.4 percent per year.[13] This is equal to a capacity loss

[13] Source: *Battery Electric Bus and Facilities Analysis Final Report*, Milwaukee County Transit System, January 2020

of up to approximately 14 percent after six years (bus mid-life), and up to about 25 percent after 12 years (bus end-life).

Battery Life Capacity Reservations

Beyond general battery degradation, charging a BEB to full capacity or charging it from a zero state of charge (SOC) increases battery degradation rates as additional strain is placed on the battery's physical and chemical components. All battery manufacturers recommend reserving a portion of the battery's capacity to preserve battery life to prevent a more rapid degradation of battery capacity than the annual 2.4 percent described above. The portion of a battery's capacity that is protected and unavailable for use varies by manufacturer and can range from between 5 percent to approximately 35 percent of the battery's capacity.[10]

Operational Flexibility Capacity Reservations

Just as operators avoid driving a conventional vehicle until the fuel tank is empty, a portion of a BEB's battery capacity is typically preserved for operational flexibility.[14] By preserving this capacity, transit agencies can increase the likelihood that BEBs will have sufficient range to return to the garage in the event of unseen delays or other unexpected events that would require a BEB to remain in service longer than originally planned.

Usable Battery Capacity Calculation Summary

Overall, PCT's BEB service planning is based upon a battery's usable, rather than nominal, capacity at bus mid-life to account for battery degradation and capacity reservations. Based on an approximately 2.4 percent annual battery capacity degradation as well as the reservation of 10 percent battery capacity for battery life and 10 percent for operational flexibility, the usable battery capacity at bus mid-life (6 years) is calculated as 70 percent of the nominal (advertised) battery capacity.

Energy Usage Impacts on BEB Range

Along with battery capacity, the amount of energy consumed by the bus (kWh/mile) also impacts BEB range. When the energy used to heat/cool a bus's passenger cabin is the same energy that would be used for the propulsion of the bus, bus range can be substantially reduced in cold weather as increased energy must be devoted to maintaining a comfortable passenger cabin temperature. Park City, Utah sees several months out of the year with average low temperatures below freezing, which can be detrimental to a BEB's range as so much energy will be required to heat the interior.[15] Therefore, while many transit agencies across the county can largely plan BEB service assuming relatively warm average ambient temperatures, PCT must plan BEB service around worst-case range estimates based on winter temperatures to ensure reliable service can be maintained throughout all seasons. Drawing upon the experience of other cold weather agencies operating diesel heated buses, this Transition plan utilizes the same worst-case energy efficiency of 3.5 kWh/mi.

In addition to ambient temperature impacts, a BEB's operational speed also influences energy usage and therefore BEB range. Typically, slower speeds are a result of either busy or congested environments. In busy environments, buses often see greater energy use, owing to bus doors being open more often and for longer periods of time. When the doors are open, bus cabin heating

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[14] Source: *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses*, National Renewable Energy Laboratory, April 2021

[15] Source: Climate Park City - Utah and Weather averages Park City, US Climate Data, 2022

and cooling is more difficult as extra energy needs to be drawn from the battery. Additionally, when buses are stuck in congested environments, they spend an increased time idling and accelerating from rest, thereby also requiring greater energy usage. Due to these considerations, blocks with an average speed of 8 miles per hour or less are assumed to have too significant of an impact on energy consumption to be considered for short-term BEB service.

Summary of BEB Service Analysis Assumptions

Table 1 summarizes the battery capacity and energy usage assumptions and criteria outlined above and used in assessing the suitability of PCT's service blocks for BEB operation. In recognition of the speed at which BEB technology is advancing, battery capacities have increased by more than eightfold from 2014[16] to 2023,[12] three service analysis scenarios have been considered based on differing BEB technology assumptions as quantified by the buses' nominal battery capacity. The three scenarios include: Current Technology (588 kWh), Moderate Technology Improvement (738 kWh), and Significant Technology Improvement (880 kWh). The current technology capacity was selected to align with the battery capacities commonly available in the current BEB market, while moderate technology aligns with announced improvements from Proterra[17], and significant technology improvement is comparable with the trajectory of recent battery capacity improvement within the industry to be available within the near future.

Table 1: Assumptions for Fixed Route BEB Service Analysis

Item	Current Technology	Moderate Technology Improvement	Significant Technology Improvement
Battery size Nominal capacity	588 kWh	738 kWh	880 kWh
Battery size Useable Capacity *	412 kWh	517 kWh	616 kWh
Average kWh per mile**	2.2	2.2	2.2
Average range in miles	187	235	280
Worst-case kWh per mile**	3.5	3.5	3.5
Worst-case (winter in Park City) range in miles	118	148	176
Minimum Average Speed	8 mph	8 mph	8 mph

Note: All analyses assume 40-foot garage-charged BEBs using auxiliary diesel heater

*Usable battery capacity defined as the bus mid-life battery capacity calculated as 70% of nominal battery capacity. This assumes a 2.4 percent annual battery capacity degradation and a total of 20% capacity reserved for a combination of battery health and operational flexibility.

Fixed Route BEB Service Analysis Results

Using the criteria presented in Table 1, each of PCT's bus blocks can be analyzed to assess BEB suitability. For each of the three technology scenarios, a block is determined to be technically viable if:

- The total block distance was less than the BEBs worst-case range; and
- The bus's average speed along the block was at least eight miles per hour.

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[16] Source: *Foothill Transit Battery Electric Bus Demonstration Results*, NREL, 2016
[17] Source: Proterra Introduces 738 kWh Battery Packs For ZX5 Buses, Inside EVs, 2022

- Based on this analysis, the technical viability of the given service schedule for BEB service is summarized in three ways:

- Count (and percent) of total blocks that are technically viable;
- Percent of total annual bus platform and revenue hours that are technically viable;[18]
- Percent of total annual bus platform and revenue miles that are technically viable.[19]

As the length of buses operated on any given block is subject to change in the future, this service analysis is applied to all blocks regardless of the bus length currently operating on the block. BEB service viability analysis results are likely to fluctuate as PCT's block characteristics may be modified up to four times a year due to service changes. To establish a baseline and to illustrate how this methodology can be used to inform BEB transition policies and prioritize BEB deployment, the analysis results of PCT's 2021-22 Winter service schedule are summarized below (Table 2). The winter service schedule is used for analysis as the operating miles and hours per bus are longer than with the summer service schedule, as well as being more representative of worst-case performance.

Table 2:Technically Viable Fixed Route Block Summary for 40-Foot BEBs for 2022 Winter schedule

	Current Technology (588 kWh)	Moderate Technology Improvement (675 kWh)	Significant Technology Improvement (880 kWh)
Number of Technically Viable Blocks	2	3	6
% of Total Blocks	12%	18%	35%
% of Total Seasonal Platform Hours	8%	12%	30%
% of Total Seasonal Platform Miles	7%	11%	27%

**Note: Bus Hours defined as the time between when a bus pulls out of a garage to when it pulls back into the garage and all analyses assume 40-foot garage-charged BEBs using auxiliary diesel heater*

This analysis indicates very few of PCT's 2021-22 Winter fixed route bus blocks, representing approximately less than 10% of both revenue and platform hours and miles can be served by the current technology 588 kWh 40-foot BEBs similar to those that PCT is currently pursuing funding for without altering existing block structures or using opportunity charging. If nominal battery capacities were to reach 880 kWh in the future, more than a third of these bus blocks representing approximately 30% of platform hours would be technically viable. These results are specific to PCT's Winter 2021-22 service schedule and are subject to change.

As shown in Table 2, it is anticipated that an increasing number of blocks will become technically viable in the coming years as BEB technology continues to improve. Additional performance modeling is anticipated to further refine this evaluation by evaluating route-specific efficiencies, and therefore projecting more accurate vehicle ranges. The conservative assumptions used for this effort are being used to establish a baseline prior to vehicle purchases.

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[18] Note: Bus hours defined as the time between when a bus pulls out of a garage to when it pulls back into the garage

However, strategies to extend the vehicles' range will still be necessary to achieve full zero-emission transition. These strategies can include rescheduling blocks based on the range limitations of the BEBs, but this strategy will require additional vehicles and operators to complete the same amount of vehicle miles as well as other operational adjustments. An alternative strategy is on-route charging, which can extend the range of the vehicles by utilizing layovers to quick charge the vehicles but is also associated with increased equipment and charging costs. On-route charging also results in less operational flexibility, as the BEBs must now be tied to the routes that pass near overhead charger installations.

Fleet Transition Projection

Presently, PCT's fleet is 34% electric vehicles, with all buses currently being operated in an on-route charging deployment scenario. Therefore, these vehicles are not subject to the same range limitations as comparable depot-charged vehicles; however, these vehicles are tied to specific routes which have overhead chargers available to support the service. Including the 2022 Low-No Application vehicles, PCT is anticipating acquiring 9 additional vehicles in the next six years in order to support the transition to ZEB.

Figure 6 below shows PCT's anticipated fleet transition through 2031, with all buses anticipated to be electric by 2030. To meet this goal, PCT intends to replace all current vehicles with EVs (electric vehicles). While range limitations are anticipated with the converted fleet, PCT intends to address this with a mix of on-route charging and reconfiguring the block schedule to accommodate the shorter range of BEBs compared to internal combustion engine vehicles. This transition will come with its challenges, but PCT intends to develop a more robust rollout plan to determine a specific deployment strategy for these forthcoming vehicles.

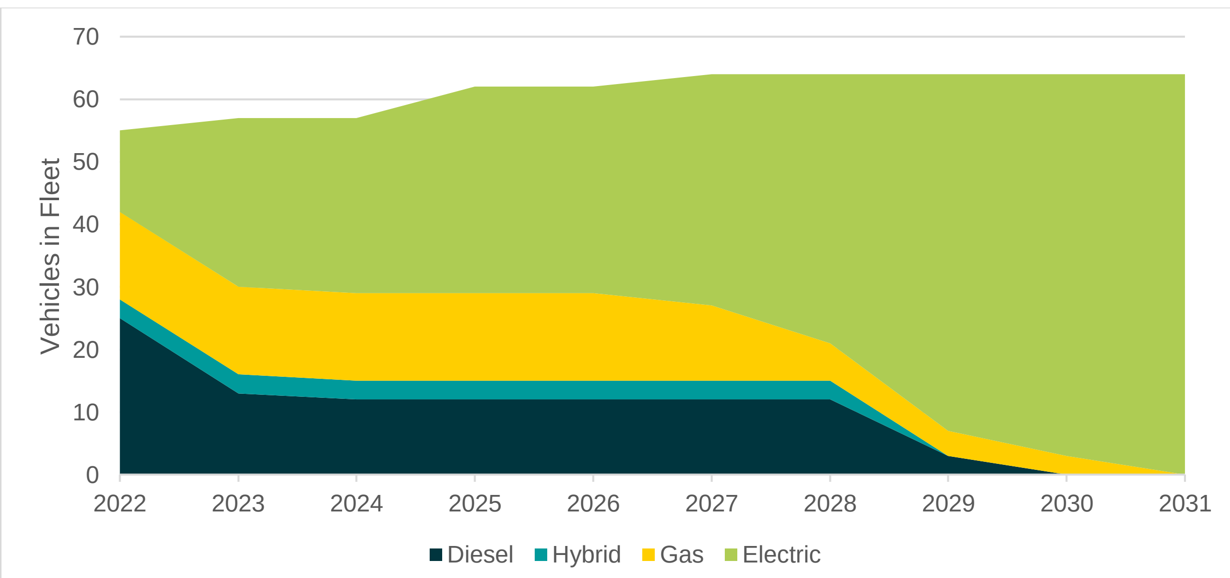

Figure 6: Fleet Composition Projection with Procurement Schedule

Facility Analysis

This section analyzes the suitability of PCT's facilities to support a transition toward BEBs. PCT operates and maintains transit fleet from the municipal owned Iron Horse Facility. The Iron Horse Facility was reviewed for existing configuration, current operational on-site vehicle flow, bus parking configuration and electrical service entrance, and size. PCT's goal for both short- and longer-term electrification will be to incrementally add in BEBs as replacements to outgoing internal combustion engine buses. In preparation for this transition, existing operational bus site flow and bus parking configurations must be identified and documented to allow for the addition of new BEB charging infrastructure in a way that is compatible with a facility and site's existing physical arrangement. As introduced in the Charger Infrastructure overview, there are multiple equipment options to charge a BEB. To plan for and identify BEB charging infrastructure that is most compatible with existing operations and mitigates potential operational impacts during BEB charger construction, the unique physical limitations and challenges of each bus garage were assessed as summarized in this section. Although opportunity charging is not a short-term charging strategy for PCT, BEB infrastructure suitability was also assessed at the Quinns Junction Park and Ride, currently in planning, and at two resort transit stations being proposed for development by two local ski resorts.

Iron Horse Facility

The Iron Horse Facility is located at the corner of Iron Horse Drive and Shortline Road. As a shared facility it houses both Park City Transit and the Public Works Department. The transit buses are serviced maintained in shared vehicle maintenance facility but have separate covered bus parking facilities. Bus parking is at grade covered by an upper staff vehicle parking deck. Two bus parking lanes per one overhead door and lanes are centered on the door. The electrical utility transformer serving the bus garage parking structure was updated in 2018 to accommodate existing seven (7) plug-in chargers and included BEB charger expansion within the new electrical distribution panel. Additionally, stub outs and conduits were also installed for thirteen (13) new BEB charges located near the existing seven (7) chargers. See Figure 7 below for further detail.

Figure 7: Iron Horse Facility Site Context

Existing Bus Circulation

At the end of the daily shift for PM pull-in, buses enter the Ironhorse Facility from Shortline Road and pulling under the Fuel Canopy along the southern property line. Bus operators fuel their buses and then continue to the enclosed bus wash located at the east end of the bus garage structure. After exterior wash, the buses leave the enclosed bus wash and circulate on site to their particular assigned bus parking spaces. Buses park in both pull through lanes where they are left facing south for AM pull-out or pulled into a single loaded parking space. These single loaded bus parking spaces abut operational spaces such as Storage, Electrical, Communications, and the vertical circulation ramp that takes staff vehicles on and off upper parking deck. Single loaded bus parking spaces can be utilized as pull-in / back out spaces or back-in / pull-out parking spaces. Daily fare collection and interior bus cleaning are accomplished during this nightly service and parking cycle. In the morning AM pull-out, regardless of direction buses are parked in the garage, the buses pull out of the parking garage and circulate on-site and exist to Shortline Road to begin daily transit service.

The thirteen (13) existing BEBs are parked at the parking spaces accessible to plug-in charging cords from the existing seven (7) plug-in chargers. After one BEB has completed its charging cycle it is unplugged and cycled out of the BEB charging space and another one of the existing BEBs are circulated into the charging parking space and plug-in. Once all the BEBs have been charged or are connected to the charger, the existing BEBs connected to the existing plug-in chargers remain in that same bus parking position for the rest of the night. The existing BEBs also receive charging during the day from opportunity charges at various PCT transit stations and park and rides outfitted with existing Proterra proprietary 500kW chargers. As such the current BEB fleet is less dependent on receiving a full BEB battery charge than a BEB that would be charged at the depot only. See Figure 8 below for further detail.

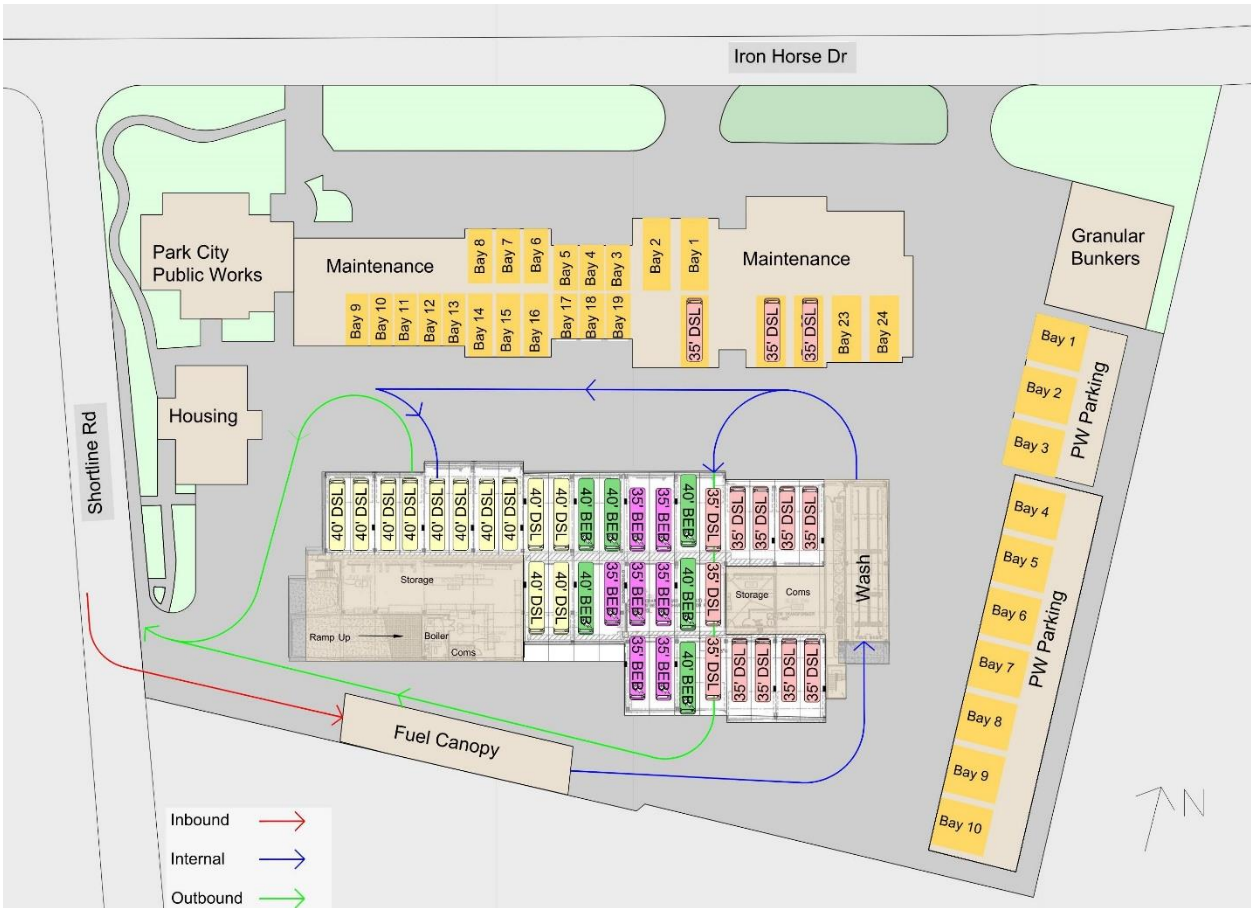

Figure 8: Iron Horse Facility Operations Layout

Short-Term Charger Opportunities

The existing electrical service in the bus parking garage has power capacity and switch capacity for the planned new chargers to support the incoming planned five (5) new BEBs. The updated bus parking garage transformer is rated for 2,000a output (nominal 1,600 kVA transformer) and currently supplies the existing original 120v/208v main switchboard as well as providing 480v power to the existing 60kW chargers and has spare capacity to energize thirteen (13) more 60kW chargers. Seven (7) existing 60kW Proterra plug-in SAE j1772 compliant charging cabinets with integral cords are already in use at the Ironhorse Facility. Electrical conduit stub outs for the thirteen (13) future chargers were installed when the seven (7) existing chargers and new transformer were installed. The existing concrete structure of the existing covered bus parking garage can be used to transition the future charger stub outs to the final future charger locations that will be determined during the future short-term charging detail design project. The existing plug-in chargers and the planned new plug-in chargers to accommodate the next iteration of five

(5) BEBs are located as ground-mounted chargers in the garage between the bus parking space in available areas between the structural columns. This will allow for new charging cabinets to be installed without loss of any parking capacity on site. See Figure 9 below for further details.

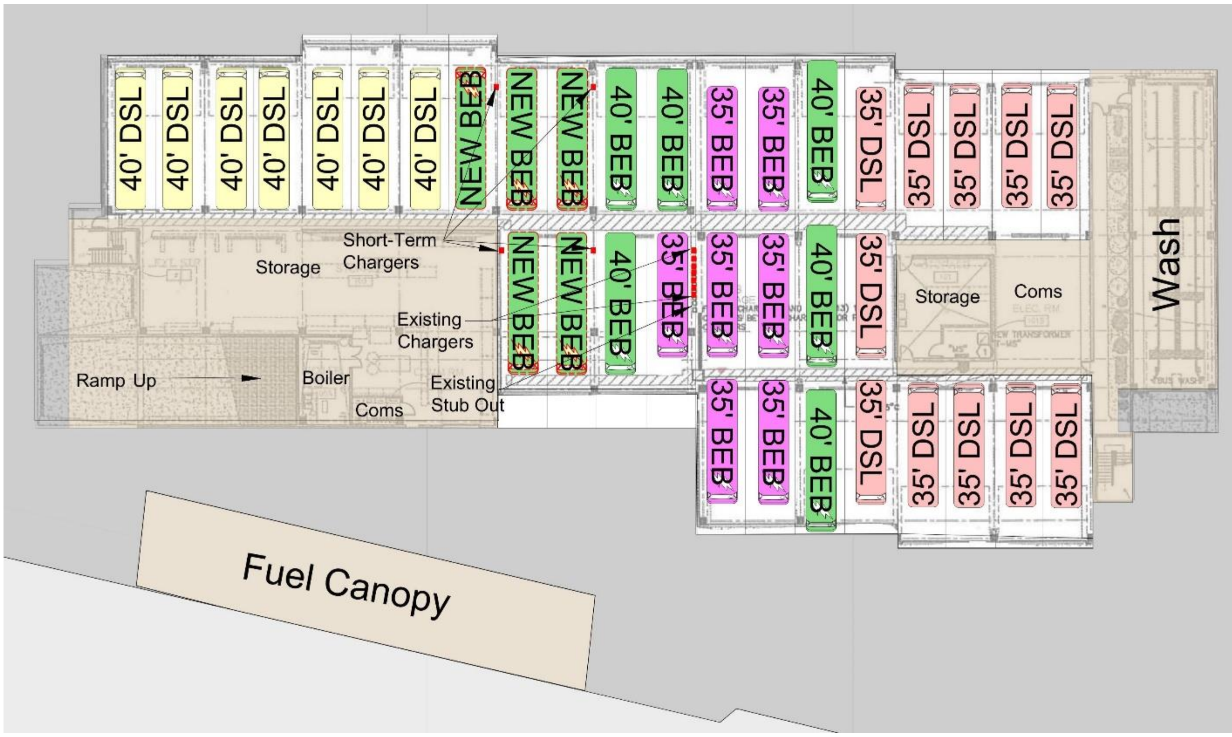

Figure 9: Close-Up of Charger Layout in Garage of Iron Horse Facility

Long-Term Changes to Support ZEB Transition

Even if short-term chargers utilized five (5) chargers in a one-to-one scenario, there will still be additional power and switches for eight more 60kW chargers within the existing distribution panel and the existing transformer. It will also be possible to combine the available power to energize 3-4 nominal 150-200kW depot chargers depending on if far-future BEBs won't utilize the existing or planned off-site opportunity charging and had to rely solely on depot charging. There sufficient floor space in the covered bus garage as well as adjacent exterior paving space to locate larger capacity charging cabinets and potentially even larger 'big box' 1.5MW and larger charging systems that take in medium voltage direct and can energize up to 40 dispensers.

Long-Term Barriers to Supporting ZEB Transition

To support a full BEB fleet additional electrical service and new charging power distribution will need to be brought to the site. If the remaining eighteen (18) diesel buses are replaced with BEB there would be a need to add approximately 1.3MW of power. There is space adjacent to the existing parking garage utility transformer to add additional utility transformer but adding it will displace PCT non-revenue vehicles and Public Works vehicle parking. To bring new utility power to the eastern edge of the parking garage adjacent to the existing utility transformer will require new feed from existing utility sectionalizer on Iron Horse Drive or the addition of new sectionalizer. Coordination with Rocky Mountain Power will be required one to two + years before new power feed is needed to allow utility time to plan and install offsite grid improvements. New chargers will be required to be installed within the parking garage as well as a minimum of three maintenance bays to provide in-place depot charging at each converted diesel bus parking space. The quantity of chargers can be reduced if PCT desires to continue to pull BEBs on then off chargers during a nightly service cycle. The continued and expanded use of off-site opportunity charging will lessen the importance of every BEB parking space having a charger as the BEBs would return to the garage with a high state of charger than non-opportunity charged BEBs. Considerations for resiliency and redundancy of electrical service will be required if the PCT fleet goes full electric. Beyond the associated cost constraints, the traditional resiliency methods (on-site generation, space for portable MW+ generators, battery storage system containers, etc.) all have significant ground space requirements. Potentially, like the shared parking and maintenance on site, if the municipal public works fleet converts some or all of its public works vehicles to be battery electric then any resiliency / redundancy power systems could be shared between public works and PCT. Consideration should be given to utilizing redundant feeds and separate feeder circuits, ideally from different substations, in lieu of on-site generation or power storage systems.

Quinns Junction

The proposed Quinns Junction Park and Ride is to be located along US-40 and Kearns Boulevard, although exact location is not yet determined. The park and ride will have both EV automotive chargers within the park and ride lot for passengers but also is being future-ready prepared by including inground conduits with pull strings, pull boxes and stub-outs for future BEB bus opportunity charging. BEB opportunity charging at Quinns Junction will augment the existing PCT opportunity charging systems already installed at existing park and rides and transit stations throughout the PCT system.

Deer Valley Resort - Snow Park Village – Doe Pass Road Mobility Hub

The Deer Valley Resort is contemplating developing new patron mobility hub to expand their patron’s private car, shuttle and transit service opportunities. PCT serves the surrounding resorts and would have a route(s) that would have the Snow Park Village Mobility Hub. Review of the in-progress design drawing show suitable space along the bus berths to install BEB opportunity charging infrastructure (utility sectionalizer / switch, transformer, meter and distribution panel) and opportunity charger. There are additional non-bus berth layout spaces that are also suitable candidates for electrification if longer dwell times are desired and the bus traffic at the shared bus berths (PCT and third-party shuttle and charter bus operators) would not support extended charging sessions. See Figure 10 below for further details.

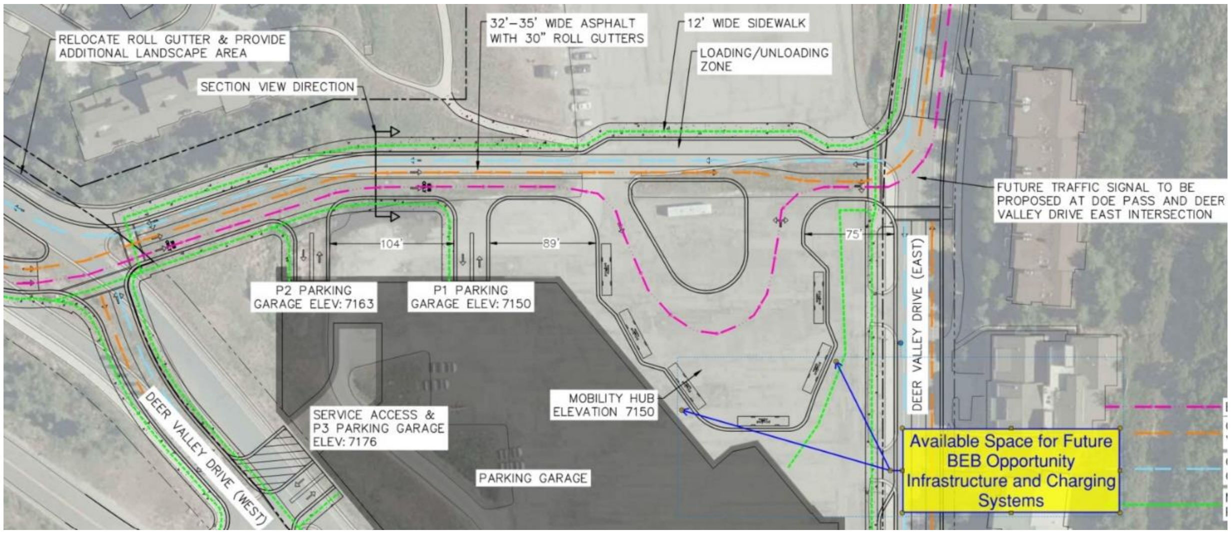

Figure 10: Doe Pass Road Mobility Hub Potential Site

Park City Mountain Resort - Mobility Hub

The Park City Resort is contemplating developing a new patron mobility hub to expand their patron's private car, shuttle and transit service opportunities. PCT serves the surrounding resorts and would have a route(s) that would serve the Park City Resort Mobility Hub. Review of the in-progress design drawing show space along the bus berths to install BEB opportunity charging infrastructure (utility sectionalizer / switch, transformer, meter and distribution panel) and charger. There are additional non-bus berth layout spaces that are also suitable candidates for electrification if longer dwell times are desired and the bus traffic at the shared bus berths (PCT and third-party shuttle and charter bus operators) would not support extended charging sessions. See Figure 11 below for further details.

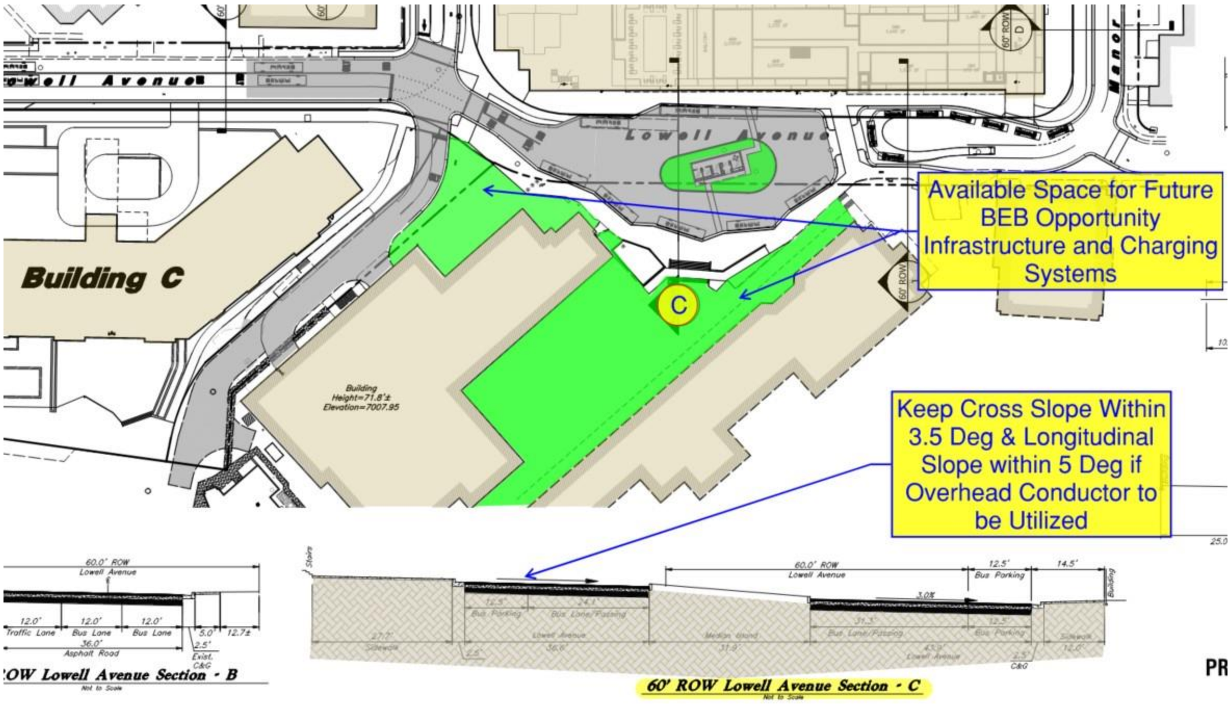

Figure 11: Park City Mountain Resort Mobility Hub Potential Site

Resource Availability

Utility Coordination

Outside of power delivery upgrades required to support the existing BEB fleet, Park City has needed little coordination with the local power provider Rocky Mountain Power. As the percentage of fleet that is BEB continues to grow, power needs will continue to increase. However, with adequate lead time associated with site preparation, service availability is not anticipated to be an issue for a fleet of Park City Transit's size. Prior to charger installations, PCT anticipates the need to coordinate with Rocky Mountain Power to ensure proper site preparations are made.

Funding Availability

BEBs and associated infrastructure require additional funding beyond that which is usually available for transit vehicle acquisition due to the additional costs associated with the technology, and the facility changes. However, one of the primary opportunities for closing this gap includes competitive grant opportunities such as the Low or No (Low-No) Emissions Grant Program.

2022 Low-No Grant

Presently, PCT is working on a Low-No Grant application for five (5) long-range 35-foot Gillig BEBs, along with the three dual-dispenser depot chargers to support the additional vehicles. As these buses will be in addition to PCT's current fleet, they will help bring PCT's fleet to 42% EV. While this is above the minimum depot-charging feasibility, PCT is anticipating service schedule changes to accommodate the range limitations and extend the viability of BEBs in service.

Workforce Development & Training

The success of any new vehicle deployment is dependent on a trained and capable workforce able to ensure vehicles operate in a safe and efficient manner. Battery-electric buses require operators to be knowledgeable of the technology and trained on the techniques required to maximize battery charge. Even more critical are the maintenance staff tasked with keeping vehicles and charging equipment in a state of good repair.

PCT is in the fortunate position of having been operating thirteen (13) Proterra buses for several years. PCT's seven (7) maintenance technicians, two (2) working shop foreman, and fleet manager have all received two weeks of hands-on training for this equipment. The first week of training occurred when the first vehicle was delivered, and the second week came years later once the staff had hands-on experience. This aided in closing any skills gap that may have existed. Additionally, all bus operators have received behind the wheel training on both driving and charging these vehicles. The introduction of a new BEB manufacturer presents a risk of a skills gap with this new technology. We are undertaking steps to ensure this does not occur.

To properly prepare for the five (5) Gillig BEB, PCT will engage the manufacturer to provide training for both operators and mechanics. Operators will receive instruction on how this vehicle may differ from the existing fleet. PCT maintenance staff will receive more thorough training to ensure the equipment is properly maintained through "train the trainer" education and hands on instruction. Curriculum topics will include but will not be limited to,

- Chargers and Batteries
- Work Order system
- Diagnostic Training
- Emergency Response

This deployment will be a continuation of PTC's commitment to zero emission vehicles. While manufacturers' warranties and support will help will aid staff in learning new technologies, the workforce needs to has prepared to operate the fleet into the future with its own staff. For the fleet bus drivers, PCT have already made the operation of a battery electric bus part of the training program all new operators receive. This training will be updated if/when a new BEBs are added to the fleet that may have different capabilities or features.

The goal is to empower the maintenance team to fix all battery electric bus equipment. This includes transitioning away from contracted maintenance of the charging equipment and bringing it in-house. PCT's goal is to send one of the fleet technicians to receive OEM "trainer technician" education who would then teach the remainder of the staff. PCT also looks to partner with UTA who is currently building a training campus. Such a collaboration will empower transit agencies in the region to gain the necessary skills to operate electric fleets, share best practices, and train the next generation of BEB technicians through future apprenticeships.

PCT has a small and dedicated maintenance workforce. The fleet manager, foreman, and technicians all work together on the shop floor diagnosing and fixing battery electric vehicles. Decisions on training needs are made based on what the frontline employees identify as needs. There are no plans to reduce staff based on this technology, in fact, staff may need to increase once vehicle charger maintenance is done by PCT staff.

PCT has a history of continuously training its staff on BEB and plans to continue this workforce development well into the future.

Conclusion

Park City is a challenging climate for BEBs, with steep hills and cold winters to make energy consumption in operation higher and therefore range lower. However, PCT has the benefit of having had experience with the technology already. As of 2022, PCT has 25 overhead-charged Proterra BEBs in its fleet and are already in the process of procuring more BEBs to add to the fleet. While preliminary analysis shows that there will be challenges associated with a one-to-one replacement of PCT's fleet, PCT intends to implement a robust deployment strategy for these forthcoming vehicles.

Next Steps

The next steps identified to move PCT's fleet transition forward include the following:

- Evaluate the suitability of range extending strategies such as opportunity charging and block splitting for blocks unsuitable for a one-to-one replacement with depot-charged BEBs;
- Deploy additional BEBs acquired via awarded grant funding in order to expand experience with zero-emission technology, especially in depot-charged applications;
- And complete a Phase 2 Transition Plan to identify deployment strategies for vehicles where one-to-one replacement of BEBs for internal combustion engines is not viable.

Strategies to Overcome BEB Barriers and Risks

PCT's primary challenges for full-fleet electrification include range limitations, as well as secured funding sources to support the vehicle purchases. Over the course of the transition period, funding availability will be crucial to maintain the procurement timeline. Once each round of funding is established, it will set the timeframe within which electrification projects can be completed. The goal is to have any facility modifications in place and commissioned 3-6 months ahead of first prototype BEB of an incoming BEB order. PCT's next step is to establish the ultimate full BEB master plan agency-wide to include all anticipated facilities, bus operation and maintenance systems as well as transit centers and park and rides. This master plan will establish assumed BEB vehicle configuration and charging infrastructure and act as a basis of design to implement in smaller incremental designs / deployments but in such a way as the incremental design is phase of the master plan.

Updates to the Transition Plan

Moving forward, PCT will be finalizing a Phase Two fleet transition plan, which will follow up on the items identified for further analysis in this report. Not only this, but the additional phase of planning will also incorporate a step to perform additional feasibility evaluations. This analysis will include performance modeling to project BEB performance on PCT routes by leveraging physics-based simulation models to further refine fleet transition projections beyond the minimums evaluated in this report. Based on the outcomes of this assessment, PCT will be able to further refine fleet transition projections and identify blocks in need of additional mitigation strategies for transition. These strategies can include opportunity charging, block splitting, and midday charging, based on scheduling, infrastructure, operational, and cost constraints. This phase of transition planning will also help to right-size infrastructure needs through charging analysis based on BEB schedules.