Attachment A

Zero-Emission Battery Bus Preliminary Implementation Plan

September 30, 2020

King County

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II. Proviso Text

Enacted on February 13, 2020, Ordinance 19052 Section 3, subsection C, directed Metro transit department's authority to develop a zero-emission battery bus preliminary implementation plan. The proviso directed that the plan include, but not be limited to:
1. Identification of major milestones through the 2021-2022 biennium related to planning, testing, procurement, and deployment of battery buses and the installation of charging infrastructure;
2. A preliminary fleet procurement plan by type of bus through 2040;
3. A high-level schedule through 2040 for the anticipated installation of charging infrastructure at new, existing, and interim bases as well as in-route charging;
4. A summary of the results of any studies or evaluations related to zero emission battery bus implementation completed after December 1, 2019, and a summary of the scope of any ongoing studies or evaluations;
5. Updated cost projections comparing the cost of a zero-emission fleet and continuing Metro transit department's current fleet practice;
6. A preliminary high-level financing plan for transition to zero-emission bus fleet by 2040 that evaluates financing options;
7. An assessment of market availability for battery buses that meet Metro's needs and the availability of supporting technology;
8. A zero-emission ADA paratransit evaluation, including a review of the state of the industry and vehicles, as well as opportunities and barriers associated with ADA paratransit buses;
9. An evaluation of options, including public-private partnerships for increasing electric charging or other zero-emission vehicle technologies at King County-owned park-and-rides, with the goal of increasing opportunities for zero-emission vehicle access to transit. The evaluation should include options to integrate the parking spaces with chargers into the Metro transit department permit parking program.

Ordinance 19052, Section 4, subsection C[1]

[1] Link to Ordinance 19052

III. Executive Summary

In 2017, King County Metro Transit Department (Metro) committed to making its fixed-route vehicles (buses) zero-emission by 2040. Metro is one of the largest contributors of greenhouse gas emissions (GHGs) in County Government, and this commitment was made in support of the 2015 King County Strategic Climate Action Plan (SCAP). This goal will be met through a combination of Battery Electric Buses (BEBs) and zero-emission Trolley Buses (Trolleys).

Fixed-Route Fleet

Since that commitment, Metro has been making progress towards the 2040 zero-emission goal. The agency has launched 11 short-range BEBs on the Eastside of King County, with supporting charging infrastructure at Eastgate park-and-ride. Metro has announced the purchase of 40 longer-range BEBs that will begin service in South King County in 2022. To charge these buses, Metro is building a nine-charger installation at South Base known as the South Base Test Facility (SBTF). This location will not only charge the first 40 long-range BEBs, but will demonstrate interoperability between various charger and bus manufacturers. Metro is also working with various internal and external groups on information technology (IT) solutions to manage electrical usage and lower electrical costs as the program grows.

With the impacts of COVID-19 (COVID), Metro no longer expects service growth projected in Metro Connects and instead faces a structural deficit that limits service growth in the near term and could require service reductions by 2025-2026 unless a new revenue source is secured. This has resulted in a plan for minimal fleet growth in the near term and reduced fleet size in 2025-2026 and outyears, consistent with the anticipated service levels. This report shows how Metro plans to meet its target of electrifying the resulting fixed-route fleet by 2040. Based on current capital planning, the newly constructed Interim Base at South Campus (Interim Base) will be electrified in 2025, and South Annex Base at South Campus (South Annex base) will open as an electrified base in 2027. Subject to additional funding, existing bases will begin converting in 2028 and continue through the decade. At the same time, the fleet will be converted to zero-emission buses and Metro will purchase no more diesel-hybrids after 2023 (13 RapidRide coaches will be purchased for the opening of Madison G line in 2023). Section 2 and Section 3 of this report provide fleet plans and construction milestones to support zero-emission by 2040 and 2035.

The tables below describe two scenarios to reach electrification. Table 1 describes construction milestones required to support full electrification by 2040, and Table 2 describes construction milestones required to support full electrification by 2035.

Table 1: 2021–2022 Executive Budget—2040 Electrification Plan

Year	2024	2025	2026	2027	2028	2029	2030
Number of Metro BEBs	51	156	156	156	311	341	488
New Metro BEBs	0	105	0	0	155	30	147
Number of ST BEBs							
Approximate Infrastructure Capacity for BEBs	9 at SBTF 3 on the Eastside	156	156	311	311	311	590
Budget Requirements	Funding in 3rd supplemental approved in Q3 2020	Funding for Interim Base and South Annex Base in 2021-2022 budget					
Notes	40 BEBs at South Base and 11 at Eastside Charging supported through additional operational staff moving buses at SBTF	Interim Base fully electrified		South Annex Base electrified			Atlantic and Central Base electrified

Table 1 continued on next page

Table 1 continued

Year	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Number of Metro BEBs	540	705	765	765	863	868	887	925	940	940
New Metro BEBs	52	165	60	0	98	5	19	38	15	0
Number of ST BEBs					80	80	80	80	80	80
Approximate Infrastructure Capacity for BEBs	590	816	816	973	973	1157	1157	1278	1278	1393
Budget Requirements										
Notes		East Base electrified		North Base electrified		Ryerson Base electrified		Bellevue Base electrified		South Base fully electrified

Table 2: 2021 2022-Executive Budget– 2035 Electrification Plan

Year	2024	2025	2026	2027	2028	2029	2030
Number of Metro BEBs	51	156	156	156	311	341	488
New Metro BEBs	0	105	0	0	155	30	147
Number of ST BEBs							
Approximate Infrastructure Capacity for BEBs	9 at SBTF 3 on the Eastside	156	156	311	311	590	590
Budget Requirements	Funding in 3rd supplemental approved in Q3 2020	Funding for Interim Base and South Annex Base in 2021-2022 budget					
Notes	40 BEBs at South Base and 11 at Eastside Charging supported through additional operational staff moving buses at SBTF	Interim Base fully electrified		South Annex Base electrified		Atlantic and Central Base electrified	

Table 2 continued on next page

Table 2 continued

Year	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Number of Metro BEBs	540	705	765	765	940	940	940	940	940	940
New Metro BEBs	52	165	60	0	177	0	0	0	0	0
Number of ST BEBs					80	80	80	80	80	80
Approximate Infrastructure Capacity for BEBs	816	973	973	1157	1157	1272	1393	1393	1393	1393
Budget Requirements										
Notes	East Base electrified	North Base electrified		Ryerson Base electrified		Bellevue Base electrified	South Base electrified			

Metro has also embarked on testing of various BEB manufacturers including New Flyer, Proterra, and BYD. All manufacturers met range requirements in most weather conditions. However, Metro learned through testing that at some extreme cases, such as very cold weather or aged batteries, range was impacted. And some BEBs did not perform as well in the County's hilly topography.

Since 2017, Metro has analyzed various charging methods. The agency found that overhead, pantograph down charging was the best option because it provided the most efficient and safest power transfer method available in the industry. This decision will provide the basis for base design and conversion moving forward.

The fixed-route sections of this report finishes with an overview of the costs associated with BEBs and various financial structures Metro can use for financing BEBs. At this time, any model would involve debt financing, primarily for charging infrastructure. The updated cost models show that BEBs are more expensive than diesel-hybrids, even when societal benefits are factored in. It is estimated that BEBs, when using current data, in the most favorable case, when societal costs are included, is one percent less expensive than diesel-hybrids. In the moderate case, when societal costs are included, BEBs are 42 percent more expensive than diesel-hybrids. The report ends with an overview of the state of BEB technology including procurement rates in the last ten years and various BEB styles.

Metro is optimistic that zero-emission buses can deliver world-class transportation benefiting drivers, mechanics, passengers, and residents living along the routes served, and, when fully implemented, a 100 percent zero-emission fleet can further improve the quality of life of all residents in King County.

Non-Bus Fleets

The electric vehicle (EV) market for paratransit and rideshare services is a developing field. There are a range of small buses, vans, and cutaways[2] on the market, but vehicles that meet Metro's current requirements in terms of suitable size, passenger capacity, and travel range are currently limited. Many of the electric paratransit-capable vehicles available at the time this report was developed do not have sufficient range to cover all Metro Access service in the way that service is planned today. Another challenge for the Access program is providing vehicle charging infrastructure. Metro currently uses leased bases to support its Access service. Metro could consider options for installing charging infrastructure on leased property, but will want to ensure the lease is of a long enough term to get useful life out of the infrastructure. Alternatively, Metro may want to explore purchasing property for Access bases. Purchasing property to support Access operations has the potential to not only facilitate electrification and installation of infrastructure, but could have other long term benefits too.

For the rideshare program, there are no smaller electric vans, such as minivans, available at the time this report was developed. The larger vans that are available are notably bigger and more expensive than what the rideshare program currently uses today. Charging infrastructure is also a challenge. While Access vehicles typically return to a base at night, the rideshare fleet is dispersed, with many of the vehicles parked at homes of volunteer drivers. Workplace charging is especially critical in supporting wider use of electric rideshare vehicles, but this is largely beyond Metro's control. Workplaces are developing more EV charging infrastructure, but it still not broadly available.

[2] A cutaway is a medium-duty vehicle built on light truck chassis with a specialized passenger cab; as used by the Access program.

These non-bus vehicles—and the associated vehicle charging infrastructure to support them—cost more than using conventional vehicles. Preliminary estimates suggest that the vehicles could cost 40 percent to over 100 percent more than conventional fuel vehicles. The vehicle market is expanding, with frequent advancements, which can be further spurred as transit agencies and other groups continue to push for these vehicles. Metro can continue to monitor and seek opportunities to test vehicles when they become available. As the market advances, the cost and availability of vehicles is expected to improve. There are also interim steps available for consideration. Metro's rideshare program has incorporated the zero emission Nissan Leaf and is conducting a pilot program with plug-in hybrid vans. Continued exploration of these and other options can help move Metro on the path to lower emissions while the EV market matures.

Ultimately there are opportunities to move forward on electrification goals, but budget is currently a major barrier for such implementation. Given Metro's current financial constraints, it's important to consider a strategic approach toward electrification goals at a pace that fits within financial resources.

Vehicle Charging Options at Park and Rides

The report also includes an evaluation of options for installing EV chargers at park-and-rides and other means of increasing opportunities for zero-emission access to transit. The availability of more EV chargers will contribute to a more robust EV system, but it will be important to strategically plan for provision of chargers in terms of both where and when and to consider policy questions. Focusing initially on King County-owned park and rides is a first step, since Metro controls these properties. There may be opportunities through partnerships to locate EV charging in additional locations such as other transit and mobility hubs to increase access to EV charging and to promote zero emission access to transit. Further matters to consider include where the highest demand is for EV charging and how can installing publicly-accessible chargers be used to increase equitable access to charging, while also balancing equitable access to transit.

Further planning and design will be needed to understand the cost of installing additional chargers at park-and-rides. The cost to install charging infrastructure can vary widely and depends on various factors, such as the existing electrical infrastructure at King County park-and-rides. It will be important to conduct a thorough assessment of electrical capacity in planning for charger installation. Partnerships could help offset costs to install such chargers. There may be other opportunities for strategic partnerships to help broaden the access to zero-emission mobility choices, including innovative programs such as electric carsharing in lower income areas and areas. It will be important to integrate EV charging into the overall management of Metro's and potentially other regional agencies parking management strategies. Opportunities include aligning pricing approaches, integrating payment platforms, and aligning with parking management goals and agency policies.

IV. Background

Department Overview: King County Metro is among the ten largest transit agencies in the United States, with approximately 1,500 buses and 215 routes. Metro operates a diverse service profile, including: local bus routes, RapidRide (similar to bus rapid transit), van pools and rideshare, ADA paratransit (Access) vans, and marine routes, serving a 2019 daily average of 332,000 bus passengers.[3] The bus fleet includes diesel-hybrids, trolleys, and battery-electric buses (BEB). Fifty-five percent of Metro buses are 60-foot, articulated buses. The non-bus revenue fleets include approximately 2,040 vanpool and rideshare vehicles and the ADA paratransit program, Access, which includes about 400 active vehicles. As noted below, Metro is forecasting service hour reductions in future years and, therefore, bus fleet reductions in 2025-2026. More detail about the underlying service hours assumptions and fleet plan can be found in Section 2.

Table 3: King County Metro Fleet

Fall 2020 Metro Operated Bus Fleet	1,486
Trolleys	174
ST Buses	125
Total Current Metro Buses to Electrify (total fleet–trolleys)	1,187
Current Metro and ST Buses to Electrify	1,312
Long-term Metro Buses to Electrify[1]	940

1. Does not include the trolley bus fleet

Key Context: In 2004, Metro became an early adopter of diesel-hybrid buses to reduce Greenhouse Gas (GHG) emissions. Originally starting service in 1940, Metro renewed its commitment to the trolley fleet by purchasing 174 new zero-emission trolley buses in 2015. The trolley and diesel-hybrid fleets have reduced the agency's GHG emissions and supported Metro's climate goals.

King County's 2015 Strategic Climate Action Plan (SCAP) [4] set targets and priority actions for reducing emissions and increasing efficiency. In the 2015 SCAP, the County committed to reducing GHGs for its own operations by 25 percent by 2020 and 50 percent by 2030, relative to a 2007 baseline. The updated SCAP, submitted to Council in August 2020, strengthen those targets, and it includes goals for Metro's non-bus fleets to begin transitioning to zero-emission operations as well. In the 2015 SCAP, Metro committed to increasing ridership without increasing operational GHG through fleet fuel efficiency, increased adoption of alternative fuels for fleets including electricity, and the transition to an all diesel-hybrid and electric bus fleet by 2018. Additionally, Metro committed to a BEB pilot. An overview of BEB Technology can be found in Appendix D: Overview of BEB Technology.

[3] Link to APTA ridership
[4] Link to SCAP

KING COUNTY VEHICLE EMISSIONS BY COUNTY AGENCY (2017)

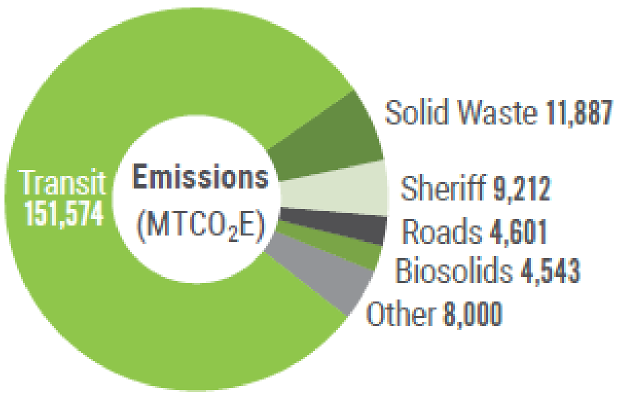

Figure 1: 2020 SCAP

In 2016, Metro purchased three short-range BEBs currently running in Bellevue. Metro-operated BEBs increased to 11 in the ensuing years. A short-range BEB generally has a smaller fast-charging battery pack, which lowers bus cost as batteries are the most expensive component of a BEB; a smaller battery pack also reduces the bus range. These BEBs have a range of approximately 25 miles and a charge time of 10 minutes.

In 2017, Metro released a report on the "Feasibility of Achieving a Carbon-Neutral or Zero-Emission Fleet" (2017 Study) in response to Council Motion 14633, requesting an assessment of the feasibility of achieving either a carbon-neutral or zero-emission Metro vehicle fleet. The 2017 Study found a zero-emission fleet was attainable by 2040, and BEBs with a range of 140 miles satisfied 70 percent of service needs without changing service profiles. The 2017 Study also acknowledged that BEB technology was rapidly changing and Metro's zero-emission strategy could change based on technology shifts. Based on this information, Metro developed an internal strategy to electrify its bus fleet. The internal strategy had electrification beginning in South King County and expanding throughout the County over time. Each base was to be electrified one-half at a time, and all bases would be converted by 2040. In concert with base electrification, the bus fleet would transition to BEBs.

As part of the 2017 Study, Metro conducted an equity impact review, which included assessment of Metro bus routes and the vulnerability to air pollution of communities along routes. The analysis found that local communities located along corridors of routes served from Metro's South Base have historically been disproportionately affected by air pollution. Metro conducted a public stakeholder process, and a primary recommendation of this group was to focus service out of South Campus to prioritize the benefit of improved air pollution in communities disproportionately burdened.[5]

In Figure 2 below from the 2017 study, darker shaded areas are more vulnerable to air pollution than lighter shaded areas. Red bus routes are the highest priority quintile to be served by zero-emission buses, green routes are the lowest.[6] In the 2017 Study, the Executive and Metro recommended – and

[5] King County Department of Transportation, Metro Transit Division, "Feasibility of Achieving a Carbon-Neutral or Zero-Emission Fleet," (2017): 58 Link to 2017 Study

[6] Metro, "2017 Study," 16.

the Council approved – the goal of transitioning to an all zero-emission bus fleet powered by renewable energy by 2040, to order 120 BEBs by 2020, and to scale up electrification first in South King County.

The 2017 Study emphasized that several requirements must continue to be met by Metro and the bus industry for this target to be achievable, including: vehicle and charging technology meeting operational needs especially for 60-foot vehicles, standardization of charging infrastructure, and availability of renewable energy supplies. The 2017 Study also highlighted that Metro and partners would need to continue to assess: safety for customers and employees, staff training, equity impacts, emergency preparedness planning, and total costs of transitioning to a zero-emission fleet to ensure that incremental costs do not limit Metro's ability to deliver and expand service.

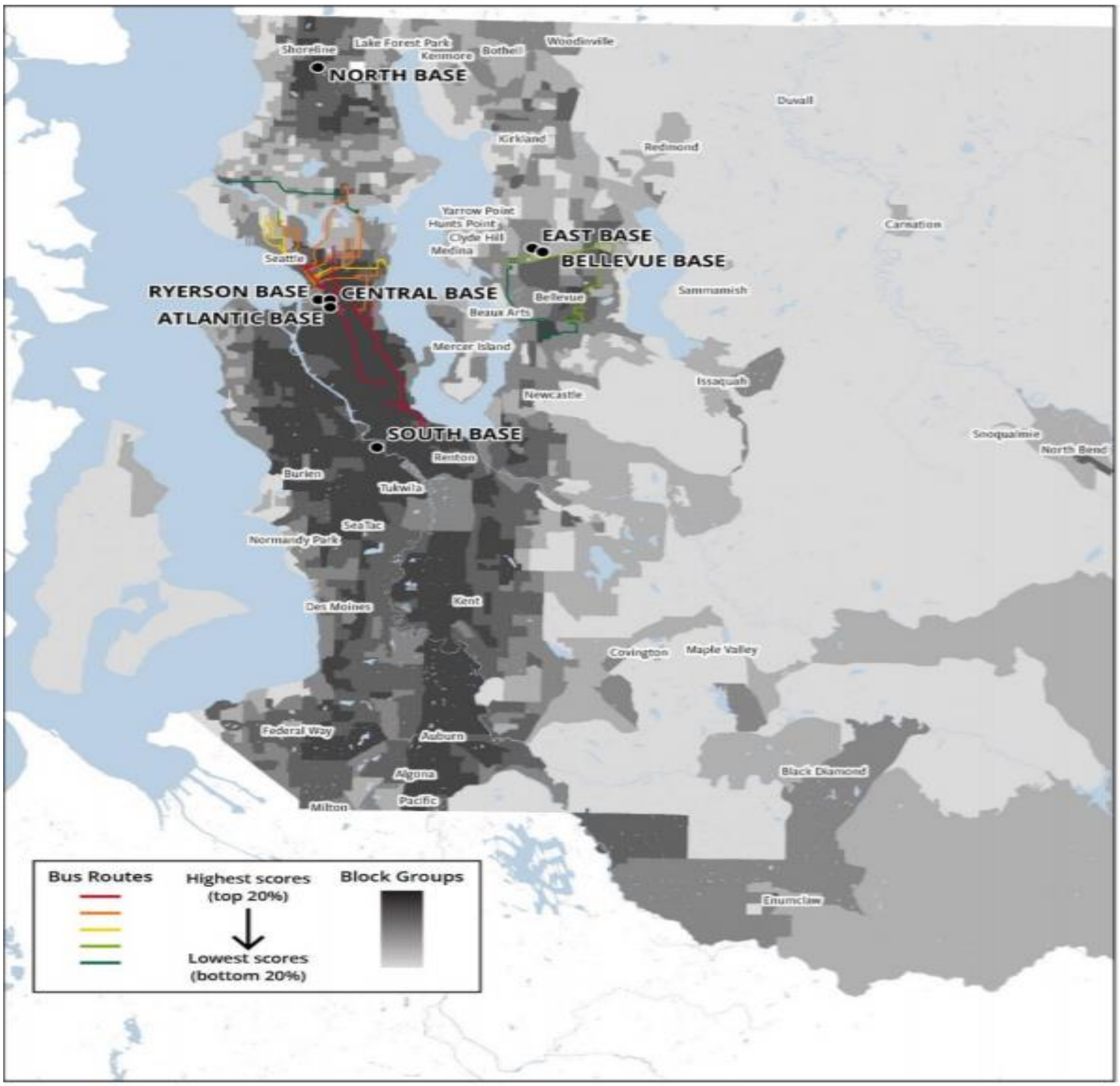

Figure 2: Map of air pollution vulnerability and bus routes in King County

Metro announced its first large-scale purchase of 40 long-range BEBs in January 2020. These BEBs, a mix of 40-foot and 60-foot buses, will have a range of 140 miles, and service will begin in South King County.

As recently as April 2020, King County was considering a ballot measure to support regional transit service and system expansion along with other elements of the Metro Connects long-range vision. Consistent with this service growth, Metro intended to grow its fleet to approximately 1,800 zero-emission buses by 2040. The procurement of the first 40 BEBs was to be followed by an additional 80 BEBs in 2021. Simultaneously, base electrification and installation of layover (i.e., on route) charging was to occur throughout the County beginning with South King County and ending in the East.

Due to the unprecedented budgetary impacts of COVID – and the forecasted sales and property tax revenue declines – Metro's budget forecast for service hours and a fleet to support service has significantly reduced. Once COVID-suspended service hours are restored in 2021-2022, service levels are anticipated to be held fairly constant through 2024. However, a structural deficit between current revenue forecasts and service costs will require service levels to decline between 2024 and 2027 unless additional revenues are obtained. After these reductions, Metro is not forecasting any service increases in the out years. This revenue decline forced Metro to reduce over 30 percent of budget expenditures across its Capital Improvement Program (CIP) through 2028, resulting in cuts across all capital programs. In addition, the cost to electrify the fleet and provide required charging infrastructure was not funded in earlier financial planning. The significant reductions to sales tax and fares within the current year, upcoming biennium, and outyears has impacted Metro's ability to fund fleet electrification costs. In the near term, Metro has funded the first 40 BEB and associated charging infrastructure, and in the longer term (mid 2020s), Metro has proposed funding in the CIP of another 260 BEBs and associated charging. In the out years of the proposed budget, no additional BEB fleet or charging infrastructure projects are funded beyond those noted above.

Report Methodology: This report was written and compiled by Metro staff. Additionally, Metro staff worked with consultants from WSP Global Inc. (WSP) and The Center for Transportation and the Environment (CTE) to update cost projections in Section 5. Metro also worked with CTE, Nelson Nygaard, and DKS Consulting on the evaluation of Access services and reviewed opportunities to increase electric vehicle charging at Metro park-and-rides. The cost projections have been reviewed by the Office of Performance, Strategy, and Budget. Additional information on analysis methodology is provided in the appendices.

1. Identification of major milestones through the 2021-2022 biennium related to planning, testing, procurement and deployment of battery buses and the installation of charging infrastructure

In the next two years, Metro will begin building large-scale electrical charging infrastructure and continue developing information technology (IT) solutions for charge management. Metro has completed testing of multiple bus manufactures BEBs, which informed procurement decisions. Further detail can be found below.

Ongoing Infrastructure Development – South and Interim Bases

The South Base Test Facility (SBTF), located on Metro's South Base in Tukwila, is approaching final design, and a construction permit application will be submitted to Tukwila in Fall 2020. This facility will have nine charge locations supported by three charger manufacturers and the capability to charge the

40 BEBs beginning service in January 2022. Construction is estimated to begin in Q4 2020, with phase 1 completed by Q2 2021. Phase 1 consists of three mast-style overhead and three plug-in charging dispensers from three charger Original Equipment Manufacturers (OEM). Phase 2 consists of overhead gantries and six additional charging dispensers and is expected to be completed by the end of Q4 2021.

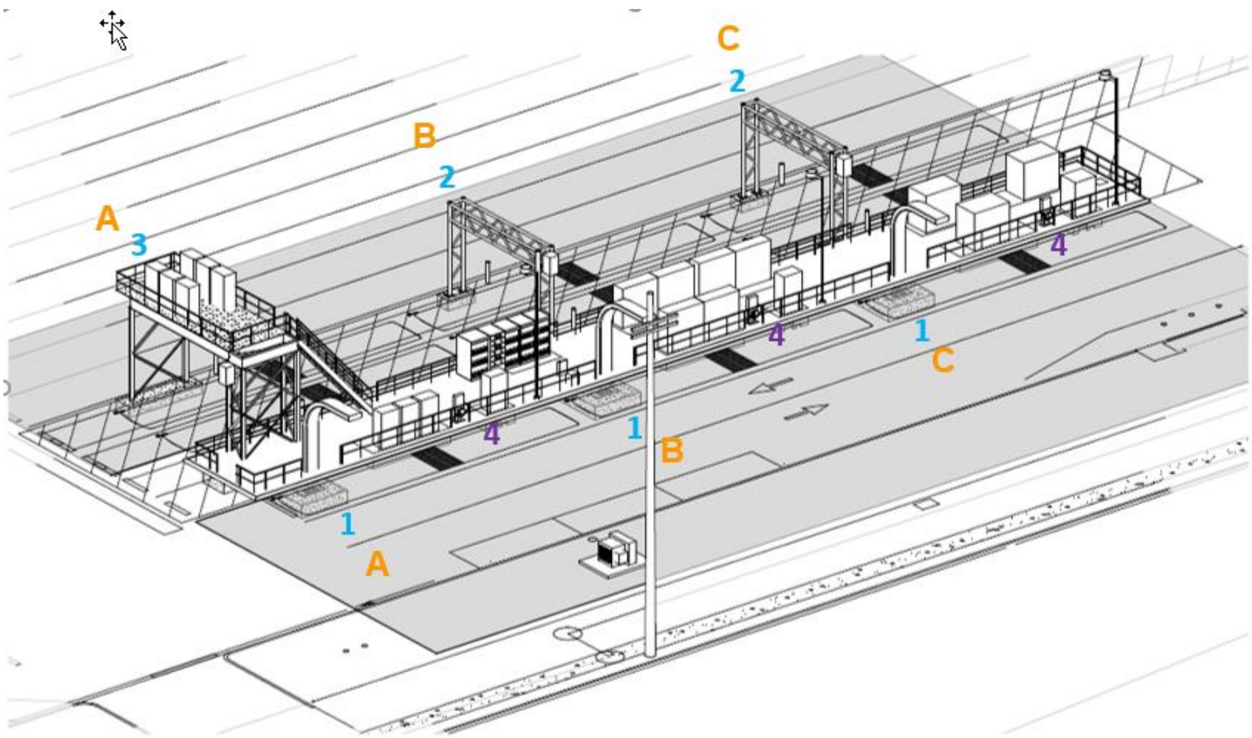

Figure 3: South Base schematic

The SBTF provides the following benefits to Metro:

- The size of SBTF is large enough to provide charging infrastructure for the 40 BEBs without affecting operational integrity;
- It allows Metro to test compatibility between various charger and bus manufacturers demonstrating interoperability[7];
- In the next decade as charger software develops, Metro can deploy new or upgraded charge management software in a controlled environment removed from base charging infrastructure. Like all software upgrades there is a chance of an IT failure, and this testing facility ensures the failure is localized to a non-essential facility; and
- It serves as a facility for the development of training and maintenance practices.

[7] Interoperability ensures that products from different bus and charger manufacturers work together and allows Metro to purchase buses and chargers based on quality and cost of a product and not be tied to a single manufacturer.

The Interim Base at South Campus (Interim Base) is currently being built as a diesel-hybrid base and will be electrified by 2025. The Interim Base will support the 105 BEBs arriving in 2025.

IT Planning

A charge management system (CMS) is a software/firmware/hardware system that provides control mechanisms over the amount of power being deployed by the charge heads. In theory, this system can prevent unnecessary utility fees and efficiently manage power to batteries while communicating with the utility to avoid peak demand or grid instability. At its most basic, a CMS can be deployed at the charger level; the charger is prevented from providing above a preset amount of power, thus preventing multiple chargers from charging at high levels and triggering utility demand fees. The technology for this type of charge management exists and is expected to be deployed at SBTF.

Moving forward, a more sophisticated CMS will be required to ensure quality operations. In this version of charge management, a backend cloud service integrates with the utility, and, based on signals from the utility, charging is decreased or increased. Additionally, these systems can reduce or increase power to specific chargers based on the needs of the attached bus, helping maximize battery life while ensuring buses are charged sufficiently to support service. These systems also provide alerts when charging infrastructure is not working. This type of CMS exists in the electric vehicle space but is not as robust in the bus space. Charger manufacturers, third-party software companies, and some bus manufacturers are developing competing solutions that Metro will evaluate in the upcoming years.

Current BEB Testing

In addition to the data that Metro has obtained from operating the 11 fast charge BEBs noted above, Metro has just finished testing a total of 10 long-range, slower-charging BEBs – four 60-foot and six 40-foot buses – from a mix of Build Your Dreams (BYD), New Flyer, and Proterra. From BYD, two 40-foot long and two 60-foot long coaches were tested. One of each length was operated with passengers (also known as revenue service), and the other BYD buses were tested by drivers in various conditions. The tests ran for approximately six months. Additionally, Metro completed testing of four New Flyer buses – two 40-footers and two 60-footers – and two 40-foot Proterra buses (Proterra does not manufacture 60-foot buses) in revenue service in various conditions. The tests for New Flyer and Proterra ran for approximately one year to gather seasonal data and were completed in spring 2020. The test buses and charging infrastructure were leased from the bus manufacturers, and all leased equipment was returned to the manufacturers. Key performance indicators (KPIs) were captured for each bus manufacturer, and these results are summarized in Section 4.

Procurement and Deployment

In January 2020, the purchase of 40 BEBs, twenty 40-foot BEBs and twenty 60-foot BEBs, manufactured by New Flyer, was announced. These buses are expected to begin service in early 2022 in South King County and will charge, as described above, at SBTF.

2. A preliminary fleet procurement plan by type of bus through 2040

Currently, Metro operates 185 zero-emission buses, which is 12 percent of the fleet. Eleven are short range, faster-charging Proterra 40-foot buses deployed on the Eastside with a range of approximately 25 miles, requiring a charge time of 10 minutes. The remainder (174) are zero-emission trolley buses providing service throughout Seattle. When the 40 long-range BEBs begin service in January 2022, Metro will have 225 zero-emission buses, which will be approximately 15 percent of the fleet.

Two fleet plans are described below. The 2021-2022 Executive Budget – 2040 Electrification Fleet Plan (2040 Electrification Fleet Plan) was reviewed by the Office of Performance, Strategy, and Budget and is part of Metro's proposed budget. To answer Council's question about meeting zero-emission by 2035, a separate fleet plan was developed using the same service levels as the 2040 Fleet Plan and accelerating electrification to 2035. This plan is referred to as the 2021-2022 Executive Budget – 2035 Electrification Plan (2035 Electrification Fleet Plan). To support these plans, electrical charging infrastructure is required. See Section 3 for additional detail.

Underlying Service Assumptions for the Fleet Plans

The 2040 Electrification Fleet Plan and the 2035 Electrification Fleet Plan reflect the following underlying service assumptions. Service during 2020-2024 will focus on COVID recovery and ongoing integration with Link light rail expansions. Some service reduced because of Covid-19 impacts is anticipated to return in 2021. Service reductions are assumed in 2021 as the Seattle Community Mobility Contract (CMC) ends with the Seattle Transportation Benefit District (STBD) funding expiration. Further service reductions in Metro-funded service will occur between 2024 and 2026, driven by the structural deficit noted above. The Metro forecast assumes no service growth between 2027 and 2040 (i.e., service remains at the 2026 levels through 2040). The Madison RapidRide G-Line is implemented in 2023, requiring the purchase of 13 RapidRide diesel-hybrid buses. There is some continued investment in the Rapid Ride program (RR I and RRH) by converting existing routes to Rapid Ride and restructuring other services. In aggregate, all these assumptions result in a long-term bus fleet of 940 vehicles requiring electrification (excluding trolley buses).

Description of 2021-2022 Executive Budget – 2040 Electrification Fleet Plan

For Metro to reach zero-emission by 2040, it will require both trolley and BEB buses. Metro will purchase its last 13 RapidRide diesel-hybrid coaches in 2023 to support the RapidRide G line. In 2022, 40 BEBs will begin service from South Base Test Facility (purchased in the 2021-2022 budget biennium). Beginning in 2025, Metro will resume purchasing electric fleet with ten 40-foot BEBs, sixty-five 60-foot BEBs, and the first 30 RapidRide BEBs. Metro will continue to replace its diesel-hybrids with BEBs through 2040. In addition, Metro will grow its trolley fleet in Fall 2029, from 174 to 204, with the purchase of an additional thirty 60-foot trolleys.

Table 4 below summarizes anticipated BEB purchases. A full fleet plan for implementing a zero-emission fleet by 2040 can be found in Appendix A: 2040 Electrification Fleet Plan. Column AB in Appendix A shows that Metro is operating a 100 percent zero-emission trolley and BEB fleet by 2040. This is based on an assumption that Sound Transit will electrify its 80 Metro-operated buses in 2035. If Sound Transit chooses not to electrify, all Metro-owned buses will be zero-emissions by 2040.

Table 4: BEB Purchase Rate for 2040 Electrification Fleet Plan

	Fall 2021	Fall 2022	Fall 2023	Fall 2024	Fall 2025	Fall 2026	Fall 2027	Fall 2028	Fall 2029	Fall 2030
New BEB	0	40	0	0	105	0	0	155	30	147
Total BEB	11	51	51	51	156	156	156	311	341	488

	Fall 2031	Fall 2032	Fall 2033	Fall 2034	Fall 2035
New BEB	52	165	60	0	98
Total BEB	540	705	765	765	863

	Fall 2036	Fall 2037	Fall 2038	Fall 2039	Fall 2040
New BEB	5	19	38	15	0
Total BEB	868	887	925	940	940

Table 5: Total Number of Zero-Emission Buses Operated by 2040

Metro-owned BEBs	940
Metro-owned Trolleys	204
Metro operated Sound Transit Buses	80
Total zero-emission buses	1,224

Description of 2021-2022 Executive Budget– 2035 Electrification Fleet Plan

Similar to the 2040 electrification fleet plan, to reach zero-emission by 2035 Metro will continue to operate and upgrade its trolley fleet and stop purchasing diesel-hybrids after 2023. BEB purchases from 2025-2034 remain the same as the 2040 Electrification Fleet Plan. However, in 2035, Metro would purchase 177 BEBs to reach its zero-emission goal.

Table 6 below summarizes the purchases of BEBs under the 2035 fleet plan. A detailed fleet plan for 2035 zero-emissions can be found in Appendix B: 2035 Electrification Fleet Plan. Column AB in Appendix B shows that Metro is operating a 100 percent zero-emission fleet by 2035.

Table 6: BEB Purchase Rate for 2035 Electrification Fleet Plan

	Fall 2021	Fall 2022	Fall 2023	Fall 2024	Fall 2025	Fall 2026	Fall 2027	Fall 2028	Fall 2029	Fall 2030
New BEB	0	40	0	0	105	0	0	155	30	147
Total BEB	11	51	51	51	156	156	156	311	341	488

	Fall 2031	Fall 2032	Fall 2033	Fall 2034	Fall 2035
New BEB	52	165	60	0	177
Total BEB	540	705	765	765	940

Table 7: Total Number of Zero-Emission Buses Operated by 2035

Metro-owned BEBs	940
Metro-owned Trolleys	204
Metro operated Sound Transit Buses	80
Total zero-emission buses	1,224

3. A high-level schedule through 2040 for the anticipated installation of charging infrastructure at new, existing and interim bases as well as in-route charging

Recent Electrification Developments

When Metro first purchased BEBs, the industry standard was short-range, fast-charging buses like the 11 Proterra buses currently servicing the Eastside. Use of the Proterra buses requires layover (i.e., on route), higher-powered chargers installed at Eastgate park-and-ride to ensure batteries have enough range to complete the service profile without returning to the base to charge (see Figure 4 below). If not properly managed through a CMS, higher-power charging at layover facilities will lead to unnecessarily high electrical bills.[8] The CMS collects data from chargers and batteries at a centralized location and can determine if certain charge locations are approaching electrical load limits that lead to fees from the utility. The software can automatically lower or stop power levels to buses that do not require charging (i.e., batteries with enough charge to complete assigned work) and prioritize buses that require the most charging.

Layover charging without CMS controls leads to buses charging in brief spurts all day and at times of peak electrical demand, like the evening, which could result in extra costs. Additionally, with small battery-pack buses, routes are limited. Smaller battery packs can only support charging on lower mileage routes and on routes where charging can be accommodated every 25 miles (i.e., routes would have to be adjusted to accommodate the range of small battery-packs, which hinders operational efficiency). Recently, transit agencies and bus OEMs have begun moving towards large battery-pack, slower-charging buses. These buses charge overnight at lower power, and the large battery packs allow for longer ranges. While on-base charging lowers electricity costs, the current battery packs do not have the range to support all service profiles without some midday charging.

[8] Jean-Baptiste Gallo, Ted Bloch-Rubin and Jasna Tomić, "Peak Demand Charges and Electric Transit Buses" (2014), https://calstart.org/wp-content/uploads/2018/10/Peak-Demand-Charges-and-Electric-Transit-Buses.pdf.

Figure 4: Eastgate park-and-ride charging

To mitigate this issue, North American transit agencies are moving towards a mixed approach to electrical infrastructure consisting of both on base charging as well as on route charging.[9] It is worth noting another change in technology that occurred since the 2017 Study. At that time, charging and fleet types were viewed as distinct, either slow or fast charge options. Now BEB battery types and charging have converged to allow for both charging options within the same bus. In general, the industry is moving to having most of the charging located on bases with low-power, overnight charging. However, for longer blocks of work, layover charging locations are available. At layover locations buses charge during regularly scheduled driver breaks. This approach does not keep batteries in a full state of charge, but provides enough energy to allow the batteries to complete blocks of work and return to base for most charging.

The decision regarding battery-pack sizing versus layover charging is a balance. The battery-pack must be large enough to support all blocks of work. However, an overly large battery is expensive and heavy. Batteries also deteriorate over time and lose range. By building layover charging infrastructure strategically throughout the County, operational efficiency will not be impacted as buses can charge as needed during scheduled layovers. However, battery packs must be large enough to support significant blocks of work, unlike the first 11 Proterras. This strategy also allows Metro to purchase the smallest battery packs needed to support these blocks of work, thereby reducing the cost and weight of the bus. An additional benefit to this approach is the resulting resiliency – if a charging location is unavailable,

[9] Metro's BEB Strategic Program Manager regularly meets with other transit agencies developing BEB programs and most are pursuing a strategy of base and on route/layover charging.

the layover sites provide alternate locations to charge the buses and, as batteries degrade and require more charging, the layover locations can be used more frequently to support the ranges these buses need to meet.

North American transit agencies have begun settling on civil infrastructure to support charging. Generally, large, North American transit agencies like Los Angeles Metro, New York City Metropolitan Transportation Authority, and the Chicago Transit Authority are designing charging infrastructure with an overhead bridge-like structure (gantry), like that at the Eastgate Park-and-ride. This system allows for either higher or lower powered charging and provides operational efficiency for bases because, unlike plug-in charging, there are no cords to manage. At layover locations, either a gantry or mast-style can be used.[10] Metro will be building overhead gantry charging infrastructure at its bases and layover locations to support BEBs. Section 4 below describes the study that led to this conclusion.

Figure 5: Mast charging

Base Capacity Considerations

When planning to upgrade or build a base, operational impact to the system needs to be considered as electrification infrastructure and charging activities may require reconfiguring space and other changes at bases. One way to measure this impact is to track Level of Service (LOS), which is a measurement of system-wide base capacity and, in the case of electrification, reflects charge capacity. Metro targets LOS C where there is an optimal balance between system capacity and demand. In the construction milestones found below in Figure 6 and Figure 7, LOS C (the green line) is compared to the fleet plan

[10] Metro's BEB Strategic Program Manager regularly meets with other transit agencies developing BEB programs and most are building overhead charging infrastructure.

(blue line). The fleet plan includes Sound Transit buses but excludes trolleys because trolleys do not require the same charging infrastructure. These two markers are what Metro's Capital Planning department uses to ensure that capital projects do not impact existing operations.

Electrification Construction Milestones 2021-2022 Executive Budget Service – 2040 Electrification Fleet Plan

The 2040 Electrification Fleet Plan construction milestones are shown in Figure 6 below. This plan provides the electrical infrastructure to support a fleet that is zero-emission by 2040. As shown below, Interim Base will be electrified in 2025 with charging capacity for 105 buses. South Annex base follows in 2027 with capacity to charge 155 buses. Under this plan, 62% of the capacity of SAB would be electrified in 2027. Based on forecasted 2040 system capacity, this level of electrification would be the peak required to support service. Should service demands increase and South Annex Base be forecast to exceed a fleet size of 155 BEBs, Metro would then need consider further electrification of the site. Beginning in 2030, with electrification of Atlantic and Central bases, Metro coverts bases every two years and concludes with South Base in 2040 for a total of 1,393 charging locations to support 940 Metro-owned BEBs and 80 Metro-operated Sound Transit BEBs. In addition, required layover (i.e., on route) charging will be built as bases electrify. The graphic below shows the system-wide charging infrastructure needs and demonstrates that Metro can build enough charging infrastructure to support the whole fleet. However, the timing of bringing electrical infrastructure on-line may not support operational needs, and Metro anticipates reassessing these infrastructure milestones as the agency further plans and deploys charging infrastructure.

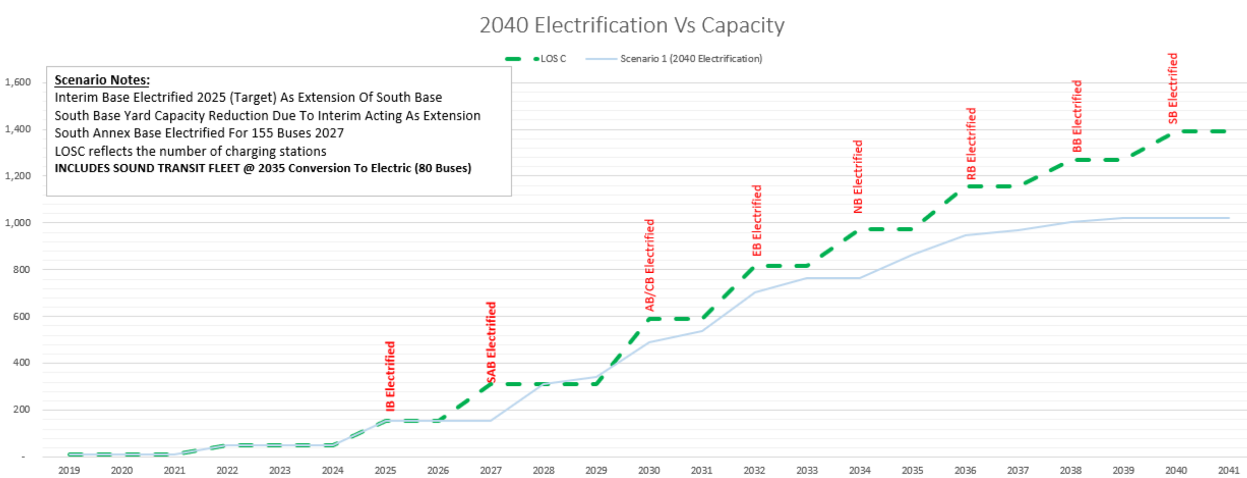

Figure 6: Electrification construction milestones, 2040 Electrification Fleet Plan

Electrification Construction Milestones 2021-2022 Executive Budget Service – 2035 Electrification Fleet Plan

To support full electrification by 2035, Interim Base is electrified by 2025, followed by South Annex Base in 2027. Those two bases along with the SBTF will have charging infrastructure to support 311 BEBs. This is followed by Atlantic and Central Base electrifying in 2029. Between 2031 and 2036, East Base, North Base and Ryerson Base and Bellevue Baseare converted. South Base completes electrification in 2037 for a total of 1,393 charging locations. Associated layover (i.e. on route) charging will be built throughout the County. This graphic is meant to demonstrate the amount of charging infrastructure required to support full electrification. However, this may not support Metro's operational needs and adjustments to this schedule are anticipated as infrastructure is planned and deployed in conjunction with operational requirements.

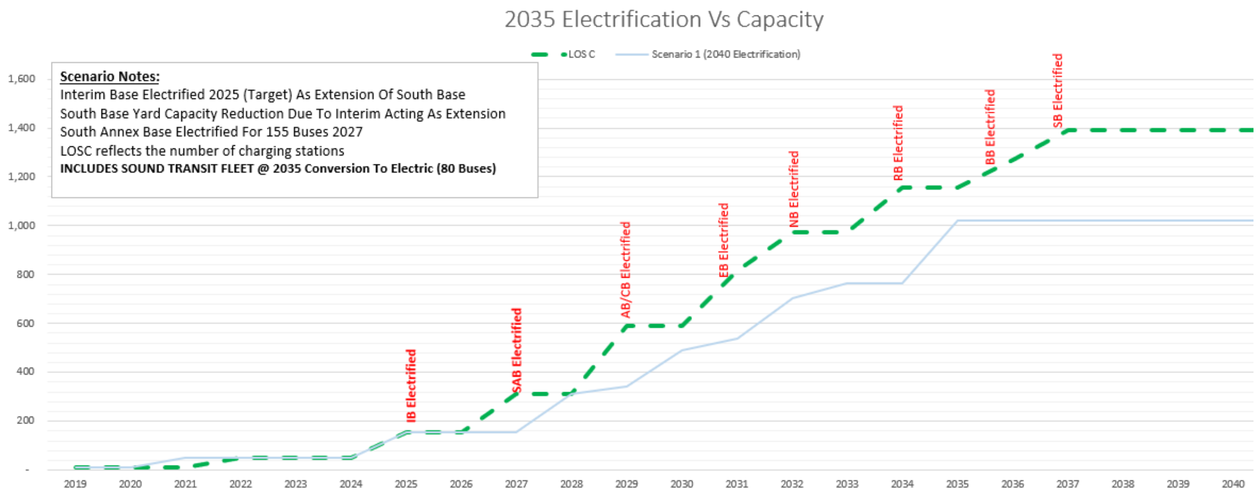

Figure 7: Electrification construction milestones, 2035 Electrification Fleet Plan

4. A summary of the results of any studies or evaluations related to zero-emission battery bus implementation completed after December 1, 2019, and a summary of the scope of any ongoing studies or evaluations

Electric Base Conceptual Design Study

In 2019, Metro commissioned a study relating to electrification of a proposed 120 BEB base located at Interim Base. Though specific to Interim Base, the study's analysis regarding power levels, base layouts, IT, and charging infrastructure are applicable to all Metro bases. SBTF is not using this layout because the charging infrastructure occupies a small part of a larger base. Future electrification efforts at Metro will likely use Layout 2, described below, as a starting point for design.

The study modeled various charging profiles that would allow Metro to meet operational needs while minimizing energy costs. It was concluded that 7.5 megawatts of power supported service needs with minimal midday, higher-cost charging. Three types of civil charging infrastructure, including plug-in cables, T-Poles, and gantry/bridges, were analyzed (Layouts 1-3 described in Figure 9 below). Though the infrastructure costs for Layout 2 (gantry/bridge) are the most expensive, the alternatives analysis examined additional factors and led Metro to choose Layout 2 for its base design. Overall, Layout 2 scores high for site use/operational efficiency and power distribution complexity, two factors that were very important to Metro's operations. Layout 2 also allows each charger to charge multiple buses, maximizing charger efficiency. A chart summarizing these factors can be found at Table 8: Alternatives Analysis for Interim Base LayoutsTable 8 and detail about these factors can be found in Appendix E: Alternatives Analysis for Charging Infrastructure and Layout. A picture of Layout 2 is shown in Figure 8 below.

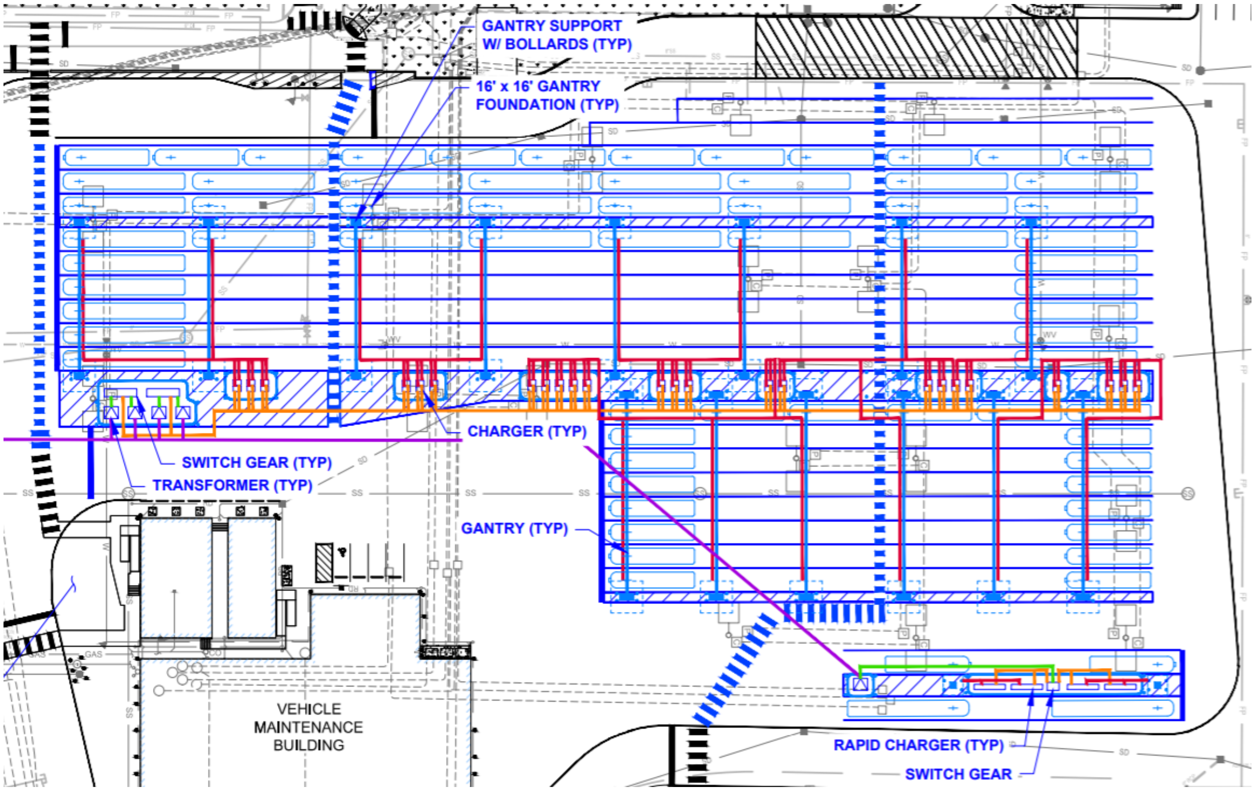

Figure 8: Layout 2

Comparison of Physical Parameters for each Alternative Layout

Feature/Layout	Layout 1 (T-Poles and Pantographs)	Layout 1 (Plug-In Cable)	Layout 2 (Bridges and Pantographs)	Layout 3 (Bridges and Pantographs – Limited)
Charging Positions	100	100	100	57
Chargers (base)	48	48	48	53
Chargers (rapid)	4	4	4	4
Total Parking Spaces	129	129	135	129
Estimated Additional FTE Labor Requirement	0	1	0	3
Concept Level Construction Cost	$ 30.1 M	$ 20.2 M	$ 33.6 M	$ 28.3 M
Concept Level 10-year Life Cycle Cost	$ 21.3 M	$ 20.9 M	$ 21.3 M	$ 24.5 M
Concept Level Total Cost	$ 51.4 M	$ 41.1 M	$ 54.9 M	$ 52.8 M

Figure 9: Comparison of physical parameters for each alternative layout

Table 8: Alternatives Analysis for Interim Base Layouts

Alternative Analysis Factors	Layout 1	Layout 1A	Layout 2	Layout 3
Semi-formal Name	T-poles	Plug-in	Bridge/Gantry	Ltd. Bridge/Gantry
Site Use and Operational Efficiency	3.0	3.0	4.0	2.0
Power Distribution Complexity	2.0	2.0	4.0	3.0
Construction Risks	3.0	3.0	1.0	1.0
Site Disruption	2.0	2.0	3.3	3.7
Construction Schedule	3.0	3.0	3.0	4.0
Future Proofed	3.0	3.0	4.0	1.0
Decommissioning	1.0	1.0	3.0	4.0
Cost	2.5	3.0	2.5	2.5
Total Score	**19.5**	**20**	**24.8**	**21.2**

Scores were from 1 to 4, with 4 being the highest.

The study also concluded that CMS-developed software should be deployed at Metro bases. This software is necessary to minimize electrical usage and costs. See IT Planning in Section 1 above.

Key Performance Indicators from Leased Bus testing

Metro tested 10 buses from three bus manufacturers over the last 18 months: two 40-foot and two 60-foot buses manufactured by New Flyer, two 40-foot and two 60-foot buses manufactured by BYD, and two 40-foot buses by Proterra (Proterra does not manufacture 60-foot buses). The Proterra and New Flyer buses were returned to the manufacturers in March 2020 after a year of testing. The BYD buses, which arrived later than the Proterra and New Flyer buses, concluded testing in July 2020.

Through June 2020, the buses were in service for over 7,000 hours and drove nearly 120,000 miles. The 40-foot buses averaged nearly 2 kWh/mile. The 60-foot buses averaged approximately 3 kWh/mile. The 60-footers, as expected, required more energy than the 40-footers. Additional Key Performance Indicator (KPI) data can be found in Appendix C: Key Performance Indicators.

The buses were driven in all types of weather, including snow, and on all route types from freeways to local service with hills – all factors that impact battery performance. The New Flyer and Proterra buses performed to expectations. The Proterra and New Flyer 40-foot buses met and exceeded range expectations in all weather and routes types, while the 60-footers met range expectations in most cases but did not perform as well in cold weather. However, because of the multi-axle configuration of the New Flyer 60-foot buses, they perform better in snow than 60-foot diesel-hybrid buses. The BYD buses met range expectations but did not perform well in the County's hilly topography. A change in the traction power motor is required for better performance on hills, but a change of this sort may impact battery range.

Generally, drivers were happy driving the BEBs. Operations and maintenance were given an opportunity to work with the charging infrastructure and buses to learn the new technology. The buses and infrastructure had various failures, but all were able to return to testing. This testing allowed Metro to provide feedback to New Flyer regarding the placement of battery packs in passenger compartments of 60-foot buses. Based on this feedback, New Flyer agreed to remove battery packs from the passenger compartments, and the purchased BEBs will have a different battery configuration than the leased test buses.

5. Updated cost projections comparing the cost of a zero-emission fleet and continuing Metro transit department's current fleet practice.

The 2017 Study provided an initial cost benefit analysis of transitioning to a zero-emission fleet using battery-electric technology. That study examined the capital, operating, disposal, and societal costs between a zero-emission fleet and a diesel-hybrid fleet. At the time, it was found that the total life-cycle costs to Metro would increase six percent by transitioning to a zero-emission fleet from a diesel-hybrid fleet.[11] The 2017 Study concluded the 194 million dollar difference, if spread over the lifetime of the bus fleet replacement horizon of approximately 30 years, was equivalent to 55,000 annual service hours.[12] When factoring in societal costs (tailpipe and utility emissions and noise) the 2017 study found the total incremental costs for BEBs to be two percent higher. With the 2017 Study, Metro committed to continued monitoring of the total costs for transitioning to a zero-emission fleet; this will ensure incremental costs do not limit Metro's ability to deliver and expand service.

Metro has updated this model based on the current cost of BEBs and associated electrical infrastructure. The analyzed fleets included: 35-foot, 40-foot, and 60-foot diesel-hybrid fleets and 35-foot, 40-foot, and 60-foot BEB fleets consistent with the fleet plans contained in Appendix F: Data Model Memo. The BEB fleet costs are based on the bus and infrastructure costs from Metro's 40 BEB order and the SBTF. The cost estimates for the SBTF have been validated with other agencies building overheard charging infrastructure. The attached memo in Appendix F: Data Model Memo includes detail about all data used for this model.

The analysis assumes fueling and charging infrastructure are amortized over the life of the infrastructure. Electrical infrastructure has an assumed asset life of 40 years, direct vehicle charging infrastructure has an assumed asset life equivalent to the vehicle life of 15 years, and diesel underground storage and pumps have an assumed asset life of 40 years. Additionally, the costing is based on maintaining the current diesel-hybrid fueling infrastructure compared to building new BEB charging infrastructure. The initial cost of designing and installing the supporting electrical infrastructure is included in the analysis while conventional fueling infrastructure is excluded from the analysis as storage tanks and pumps have already been installed at each of the bases and only future replacements to maintain these assets are assumed. Amortization assumes a set number of vehicles per base that does not change over the life of the asset. Cost per each BEB would include the total cost of electric infrastructure divided by the assumed number of vehicles per base, divided by the assumed 40 year life of the asset and applied each year for the 15 years the vehicle is operational. The 2017 Study assumed a single capital cost for each base divided by the number of vehicles per base in the year the vehicle was purchased.

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[11] Metro, "2017 Study," 42.
[12] Metro, "2017 Study," 43.

Metro ran two scenarios: the moderate case and a favorable BEB case, where input variables were adjusted to favor BEBs. The diesel-hybrid was the control, or zero-value fleet, and the BEB was compared to the diesel-hybrid fleet. The moderate case modeled current data for both diesel-hybrid and BEBs. The favorable BEB modeled favorable capital, fueling, and operating pricing for BEBs compared to current data for diesel-hybrids. This favorable scenario assumes the costs for BEBs decrease over time as the technology develops.

In the favorable BEB case, a BEB fleet is more expensive than a diesel-hybrid fleet by six percent. When including societal costs like emission and noise reduction in the favorable scenario, a BEB fleet is one percent less expensive than a diesel-hybrid fleet. In the moderate case, where input variables were based on current data, the BEB buses and associated infrastructure are 53 percent more expensive than diesel-hybrid buses. The 660 million dollars that this percentage represents could purchase approximately 270,000 annual service hours over 19 years (2021-2040). When including societal benefits, the BEB buses are 42 percent more expensive than diesel hybrid buses. This cost delta, 574 million dollars, could purchase approximately 237,000 annual service hours over 19 years (2021-2040). See Table 9 below for a summary table and additional detail about both scenarios.

Table 9: 2019–2040 Fleet Replacement Cost Comparison

2019-2040 Fleet Replacement and Associated Infrastructure Cost Comparison between Diesel-Hybrid and BEBs (2019 $ million); assuming electrification by 2040		Favorable BEB		Moderate Case	
		BEB - Battery Electric Bus Replacement	**Continuing Current Fleet Use of Hybrids**	**BEB - Battery Electric Bus Replacement**	**Continuing Current Fleet Use of Hybrids**
Capital	Vehicle Purchase Price	$666	$646	$832	$656
	Modifications & Contingency	$35	$33	$36	$33
	Charging/Fueling Infrastructure	$131	$10	$163	$12
	Total Capital Costs	*$832*	*$689*	*$1,032*	*$701*
Operating	Vehicle Maintenance	$286	$348	$636	$372
	Vehicle Tires	$19	$19	$19	$19
	Vehicle Fuel/Charging Costs[13]	$104	$172	$88	$132
	Charging/Fueling Infrastructure	$1	$0	$2	$0
	Battery Replacement[14]	$32	$3	$80	$6
	Total Operating Costs	*$444*	*$541*	*$824*	*$529*
Disposal	Battery Disposal	$24	$2	$24	$2
	Bus Disposal	$28	$24	$36	$24
	Total Disposal Costs	*$53*	*$25*	*$60*	*$26*
Total Cash Costs		**$1,328**	**$1,255**	**$1,916**	**$1,256**
Comparison to Base	*Dollars*	*$73*	*$0*	*$660*	*$0*
	Percent	*6%*	-	*53%*	-
Total Cash Cost per Mile		**$2.25**	**$2.13**	**$3.25**	**$2.13**
Environmental	Emissions - Tailpipe	$11	$82	$11	$82
	Emissions - Refining/Utility	$1	$12	$1	$12
	Noise	$15	$20	$15	$20
	Total Env. Costs	*$27*	*$113*	*$27*	*$113*
Total Cash and Non-Cash Costs		**$1,355**	**$1,368**	**$1,943**	**$1,369**
Comparison to Base	*Dollars*	*-$13*	*$0*	*$574*	*$0*
	Percent	*(1%)*	-	*42%*	-
Total Cash and Non-Cash Costs per Mile		**$2.29**	**$2.32**	**$3.29**	**$2.32**

BEB costs are driven by the price of the bus, the cost of electrical charging infrastructure, and overall maintenance fees. A BEB is more expensive to procure. The charging infrastructure requires a large capital outlay due to the civil and electrical engineering work required to support overhead charging. Currently, Metro is assuming that for the moderate case, BEBs are more expensive to maintain; however, there is much volatility in maintenance cost forecasts. Some reports show BEB maintenance costs to be significantly lower than diesel maintenance costs,[15] and there is a good chance that BEB maintenance costs will be lower than diesel-hybrid maintenance costs as the technology becomes more widely adopted and transit agencies become familiar with it. Additionally, battery replacement costs are higher for BEBs than for other bus fleets. In total, these higher costs for BEBs are not fully offset by the fact that electricity is cheaper than diesel or by the societal benefits of eliminating emissions and noise. The 2017 study significantly underestimated the cost of electrical charging infrastructure, assuming charging equipment that more resembles light-duty vehicles, whereas now the industry has moved to overhead gantry systems and more of a blend of slow and fast charging. Metro has better data for the 2020 update to the cost projection model and has higher confidence in the accuracy of the charging infrastructure costs, as they are based on contractor estimates for SBTF and these estimates are validated by other transit agencies, which are further in their construction projects of overhead charging than Metro is. Metro feels confident that the current modeling for the moderate scenario is an accurate estimate for the cost to procure, maintain, and operate a fully BEB fleet.

A June 2020 study produced by the National Renewable Energy Lab[16] found that BEBs, after three years of service, made up the difference in upfront costs between BEBs and diesels. According to this study, from the three-year point forward BEBs should be less expensive than diesel buses. The study attributed this to operating, maintenance, and energy costs which, during the first three years, were low enough to compensate for the up-front capital costs. Metro has concerns about the applicability of these findings to the agency for the following reasons:

1. The price of diesel in the study was much higher than Metro's current forecast and, unlike transit agencies that buy diesel wholesale, this model assumed retail prices for diesel. The difference between retail and wholesale prices can be as much as a dollar per gallon;[17]
2. The modelers assumed an annual decline in electricity charges, which is counter to what Metro has seen with Seattle City Light and Puget Sound Energy.

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[13] In these scenarios, the cost forecasts for fuel and electricity are tied together based on macro-level economic trends and assumptions on demand and supply for various energy products. The "favorable electric case" assumes overall higher energy cost escalation but significantly higher increases in crude/refined products (30%) compared to electricity (18%).

[14] For the forty BEBs beginning service in 2021, Metro is considering purchasing a 12 year extended warranty. Since exact battery life is still unknown, when modeling battery replacement cost Metro took a conservative approach and assumed 90% of batteries would need to be replaced after the 12 year warranty expired. With a 15 year bus lifecyle, this results in new batteries being on buses for three years when the bus carriage is retired. However, batteries can be reused on different bus carriages and Metro will explore this option.

[15] Caley Johnson, Erin Nobler, Leslie Eudy, and Matthew Jeffers, "Financial Analysis of Battery Electric Transit Buses" (Golden: National Renewable Energy Laboratory, 2020) https://www.nrel.gov/docs/fy20osti/74832.pdf.

[16] Caley Johnson, Erin Nobler, Leslie Eudy, and Matthew Jeffers "Financial Analysis of BEBs," 13-14.

[17] http://www.seattlegasprices.com/index.aspx?fuel=D versus https://des.wa.gov/services/contracting-purchasing/current-contracts/fuels-pricing

3. The BEB charging equipment cost was much lower than Metro estimates, which is likely related to modeling plug-in electrical infrastructure costs previously considered by Metro and found to be more costly in the long term (see Section 4); and
4. The authors included grant funding to lower the purchase cost of BEBs. Generally, grants should not be included in cost projections as they are an unreliable source of funding.

6. A preliminary high-level financing plan for transition to zero-emission bus fleet by 2040 that evaluates financing options.

Policies Guiding Metro Finance Options

Generally Metro uses cash financing and some grant funding for bus procurement and capital projects. These revenue options will be discussed below. Alternative capital financing structures include debt financing and leasing. Within each of these broad categories, there are numerous options discussed below. Metro's financing is guided by the following policies:

- **Motion 12660 (2007): Debt Management Policy for King County** describes the appropriate uses of debt (construction of acquisition of capital assets and not operations), the term of the debt, level debt payments, and states debt should be tax exempt. The policy states that refinancing shall be pursued when savings occur. The policy also covers the use of variable rate debt, general obligation and revenue debt, and credit enhancement.[18] Metro's use of debt would need to comply with this overarching Debt Management Policy.

- **Comprehensive Financial Management Policies (2018)** describe the appropriate uses of debt, the use of debt as an option for financing the acquisition and construction of the County's capital assets and that these assets should have a lifespan of at least seven years. The policies state that short-term needs can be financed by bond anticipation notes, or similar, while longer term debt should be tax-exempt municipal debt. The issuing agency should designate a fund manager to ensure the use of bond proceeds and compliance with the County's post-bond issuance procedures.

- **Ordinance 18321 (2016): Fund Management Policies for Public Transportation Fund** require Metro to create and prioritize a 10-year needs list and a 20-year fleet replacement funding methodology. These needs are reflected in the six-year CIP. A bond sub-fund is created, which has a balance, "sufficient to meet the obligations of the Transit Division's bond requirements." The requirements are addressed in the bond official statement and cover principal and interest balances. Short-term bond proceeds can be used to smooth peak fleet acquisition needs. This ordinance supersedes many elements of Ordinance 17225 (2011), an earlier set of fund management policies for the public transportation fund.

- **CIP Processes and Procedures (2017):[19] Bonding Guidance** is a 2017 document prepared by PSB and Finance. The document describes in detail the process by which debt issuances should be

[18] The policy also describes the Counterparty Policy: although this policy was followed it still resulted in an ongoing loss in the Victoria investment.
[19] Link to Bonding Guidance

developed, issued, and managed from concept to retirement. It describes an extensive process between the department and PSB/Finance.

- **Written procedures for post-bond issuance compliance with Federal tax law (2019)** is currently under consideration by the Executive Finance Committee (EFC). The procedures provide detailed guidance on the management, record keeping, expenditure, and reporting requirements associated with debt issuance consistent with changes in federal tax law from the Tax Cuts and Jobs Act of 2017.
- **County Code 2.96.010** addresses leasing and requires that numerous conditions be met including that there are economic advantages to leasing, that it meets a temporary need, and shifts risk. Departments considering leasing must perform a lease versus purchase cost analysis and provide written explanation of why a lease is needed.

Current Metro Financing Practices
As noted above, Metro has historically financed fleet acquisitions from cash and grants. Debt financing has been used for property and physical assets. Debt could be used for rolling stock as well as BEB charging equipment, consistent with policies described above. Metro purchases approximately 100 buses per year using local and federal funds. However, bus needs are dependent on retirable fleet and service growth, so larger purchases may be followed by several years with no purchases.

Table 10 below notes that between 2013 and 2018, fleet capital expenditures ranged from 54 million dollars to over 254 million dollars. To date, there have been no major electrification infrastructure projects completed. The first, SBTF, will begin construction in Q4 2020.

Table 10: Revenue Historic Fleet Capital Spending

Revenue Fleet Expenditures in Millions								
	2012	2013	2014	2015	2016	2017	2018	2019
Expenditures	$119.88	$54.23	$67.22	$122.35	$233.22	$132.07	$254.51	$109.84
Grants						$43.01	$110.75	$38.57

As part of this proviso response, a cash flow forecast for the various scenarios described in Section 5 has been prepared (see below). The annual expenditures for fleet purchases are summarized in Table 11 below.

Table 11: Annual Expenditures for Fleet Purchases

2019-2040 Fleet Replacement Cost Comparison (2019 $ million)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Moderate Case BEB											
Capital (2019 $s)	$1.7	$1.7	$6.1	$7.1	$7.1	$18.9	$18.8	$18.7	$36.5	$39.4	$55.3
Operating (2019 $s)	$0.6	$0.8	$3.3	$4.0	$4.5	$10.9	$11.9	$13.4	$23.1	$26.8	$37.5
Disposal (2019 $s)	$0.1	$0.1	$0.3	$0.4	$0.4	$1.1	$1.1	$1.1	$2.1	$2.3	$3.3
Environmental (2019 $s)	$0.3	$0.3	$0.4	$0.5	$0.5	$0.8	$0.8	$0.8	$1.1	$1.2	$1.5
Moderate Case HYB											
Capital (2019 $s)	$1.7	$1.7	$6.1	$7.1	$7.1	$14.6	$14.6	$14.5	$25.8	$27.7	$37.7
Operating (2019 $s)	$0.6	$0.8	$3.3	$4.0	$4.5	$8.3	$9.5	$10.7	$16.9	$19.1	$25.7
Disposal (2019 $s)	$0.1	$0.1	$0.3	$0.4	$0.4	$0.6	$0.6	$0.6	$1.0	$1.1	$1.4
Environmental (2019 $s)	$0.3	$0.3	$0.4	$0.5	$0.5	$1.8	$1.8	$1.8	$3.7	$4.0	$5.8

Table 11 continued

(2019 $ million)	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Moderate Case BEB											
Capital (2019 $s)	$59.8	$76.5	$81.9	$81.0	$89.0	$88.8	$87.1	$88.9	$88.8	$78.4	$1,031.6
Operating (2019 $s)	$41.7	$54.5	$63.4	$65.3	$73.6	$77.2	$78.7	$80.3	$79.9	$72.8	$824.3
Disposal (2019 $s)	$3.5	$4.5	$4.8	$4.7	$5.2	$5.2	$5.1	$5.2	$5.1	$4.5	$60.1
Environmental (2019 $s)	$1.6	$2.0	$2.1	$2.0	$2.0	$2.0	$1.9	$1.8	$1.8	$1.6	$27.0
Moderate Case HYB											
Capital (2019 $s)	$40.6	$51.5	$55.0	$54.4	$59.1	$59.1	$56.6	$57.6	$57.6	$51.0	$701.3
Operating (2019 $s)	$28.4	$35.3	$40.9	$41.6	$45.8	$47.8	$46.9	$49.0	$47.2	$42.9	$529.2
Disposal (2019 $s)	$1.5	$1.9	$2.0	$2.0	$2.1	$2.1	$1.9	$2.0	$2.0	$1.7	$25.6
Environmental (2019 $s)	$6.4	$8.3	$9.0	$8.9	$9.9	$9.9	$10.1	$10.2	$10.2	$9.1	$113.0

Table 12: Cost Differential between BEB and Diesel-Hybrids

Total Costs (2019 $) ($ Million)	Moderate Case BEB	Moderate Case Diesel Hybrid	Difference
Capital	$1,032	$701	$331
Operating	$824	$529	$295
Disposal	$60	$26	$34
Environmental	$27	$113	($86)
Total	$1943	$1369	$574

The pending executive budget proposal provides a financing plan for an additional 260 BEBs and associated infrastructure by 2028 but does not address BEB and associated infrastructure in the out years. This proviso response does not develop a specific financing plan, as that will be developed in the context of future budget processes. However, financing these projects will require new revenue and various financing methods that Metro could use are described below. Historically, Metro has paid for buses using cash and, per current practice, utilizes the revenue fleet replacement reserve for years where large fleet expenditures are incurred. The revenue fleet replacement reserve was developed to help mitigate the impact of variability in the replacement costs from year to year. Metro prefers to finance long-life infrastructure using debt. The exact mix of cash funding, reserve use and debt financing will be developed based on Metro's financial condition and other economic considerations.

Financing Methods

There are four general financing models that public agencies can use to fund capital infrastructure like electrification. These are cash financing, which is Metro's current model; debt financing where Metro sells bonds to fund electrification; leasing buses and charging infrastructure from bus manufacturers; or grant funding, which Metro uses for bus procurement. There are also private partnerships which are not included in these models.

Table 13 below summarizes the benefits and risks of each method of financing.

Table 13: Benefits and Risks of Financing Methods

	Benefits	Risks
Cash Financing	• Lowest cost since it doesn't incur interest or leasing costs • Consistent with existing practice	• Requires large up-front capital expenditures • Doesn't match expenditures with beneficiaries (Intergenerational equity)
Debt Financing	• Debt financing costs currently low • Future users pay for capital costs • Can use "Green Bonds" • TIFIA funding provides guaranteed rates prior to project construction at favorable terms	• Incurs long-term obligations, which if large, impair Metro's financial flexibility • Some types of debt require complex reporting requirements • Higher overall cost because of interest costs

Leasing	• Lifespan and price risks are transferred to vendor • Maintenance costs paid by lessor • Lessor may gain tax advantages which are passed on to Metro • Metro doesn’t maintain batteries, vehicles, or charging infrastructure • Leases may be faster to execute • Leases can be for less than the full lifespan	• Market prices for batteries may be lower than in a lease • Metro pays higher private cost of capital • Potential labor contract issues with outside maintenance
Private Partnership	• Private equity may provide financing under beneficial terms	• Requires significant expertise to evaluate transaction
Grant Funding	• Provides low cost funding	• Highly competitive, limited sources • Can restrict uses

Within each of these broad categories, tax exempt and taxable debt, and/or grants and other funding sources are often used for transportation purposes. These are described in Table 14 and Table 15 below.

Table 14: Tax Exempt and Taxable Debt Funding Sources

Tax exempt and Taxable Debt	
	• Metro and King County have excellent access to credit due to their high credit ranking. Metro has issued debt for some assets • Taxable debt is generally discouraged by policy and has not been pursued. Depending on the type of asset there may be situations where this is preferred. Wastewater frequently issues both short and long-term debt
Commercial paper or bank debt	• Short term debt from commercial sources could be used. • Other agencies in the County have used short-term debt
TIFIA loans	• These loans provide low interest rates and guaranteed rates prior to expenditures. • Sound Transit and many other transportation agencies have used this source
Green Bonds	• These bonds have appealed to purchasers due to their linkage with environmentally friendly projects. • Sound Transit has issued these bonds at favorable rates
Private Activity Bonds	• These bonds provide municipal rates to private borrowers. • Metro is not aware of US funded electrification projects using this source
Private equity	• Transit Oriented Development projects have used private equity to finance joint development. • Metro is not aware of US funded electrification projects using this source

Table 15: Grants and Other Funding Sources

Grants and Other Funding Sources	
Grants	• Numerous federal, state, and private sources exist for funding electrification. Metro has successfully used these sources in the past (like Federal Transit Administration's Low or No Emission Vehicle Program)
Value capture mechanisms such as Local Improvement District (LID) and Tax increment Financing (TIF)	• LID/TIF financing has been used for several local projects, such as the Alaskan Way Viaduct and the Seattle Streetcar. These projects must determine the benefits which accrue to property owners and the assessments must be related to those benefits. These types of mechanisms have been used with fixed guideway systems, but Metro is not aware of bus related US projects
Naming Rights	• Many local projects have used naming rights, such as the stadiums and in transportation, the Pronto bikes funded by Alaska Airlines (and others). Metro sells advertising on buses
Pass pricing for green programs	• Metro could consider the sale of carbon offsets similar to that done by ski resorts or some airlines

7. An assessment of market availability for battery buses that meet Metro's needs and the availability of supporting technology.

The zero-emissions bus market includes trolleys, battery-electric and fuel cell electric buses. The market is rapidly developing. Transit agencies also have access to funding aimed at offsetting the incremental costs between conventionally fueled buses and zero-emission buses (e.g., the Federal Transit Administration's Low or No Emission Vehicle Program). As policies are pushing for cleaner technology and more agencies adopt electric buses, technology providers – including bus manufacturers, charging equipment vendors, and software developers – are offering more products that contribute to market growth. At the same time, industry standards are evolving to reduce barriers to cleaner bus technology. Figure 10 below shows the increase in awards and actual deliveries of zero-emission buses since 2009. The market is also benefiting from the introduction of products from new OEMs. As a result, competition for zero-emission bus technologies is increasing and should lead to better and more affordable technologies.

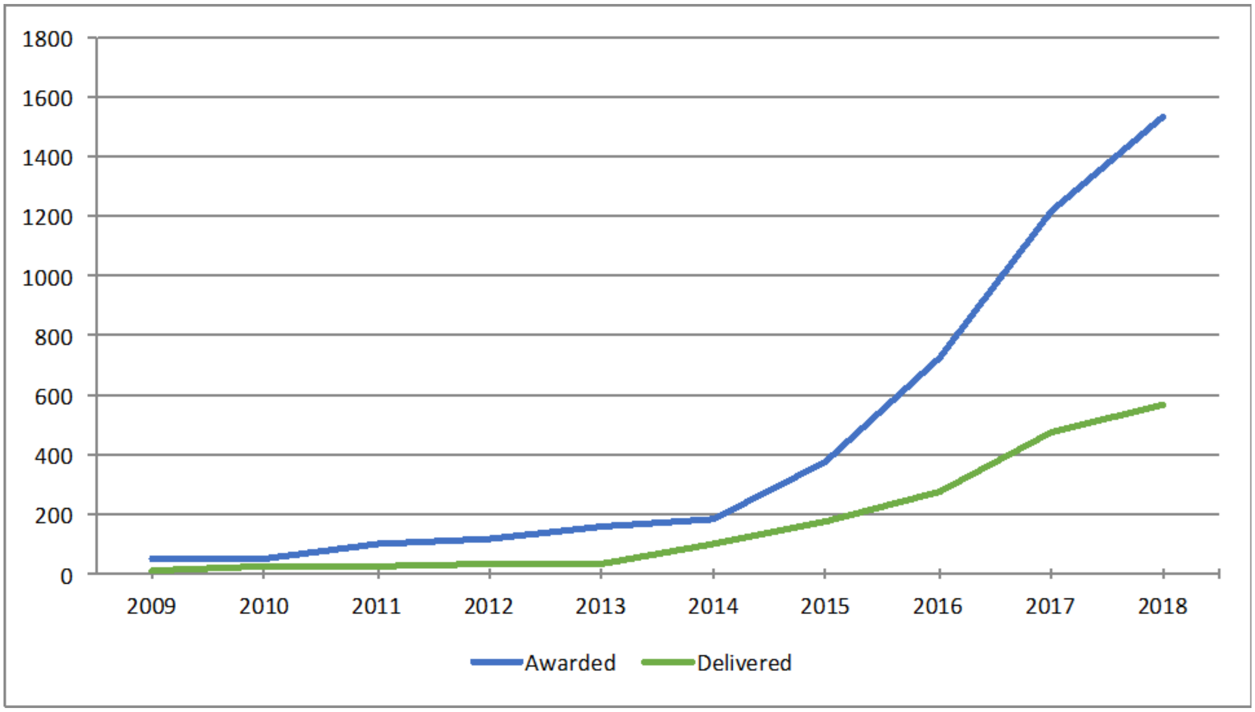

Figure 10: Zero-emission bus cumulative awards and deliveries by year

**2018 represents awards and deliveries through August*

*** Some Low-No award quantities are estimated*

Table 16 below highlights currently available zero-emission bus body styles by energy storage capacity and Original Equipment Manufacturer (OEM). (Note that the information in the table may not reflect all currently available bus models in the U.S. market) The greatest number of vehicle offerings is in 40-foot low floor models, followed by 35-foot vehicle offerings. In order to ensure the buses are eligible for federal funding, OEMs are presenting buses to undergo testing at the Altoona Bus Research and Testing Center. Reports for zero-emission buses that have successfully completed Altoona testing are available on the testing center's website: http://apps.altoonabustest.psu.edu/

Table 16: Available Zero-Emission Bus Styles by Energy Storage Capacity and OEM

Body Style	Length	Energy Storage (kWh)			BYD	CCW	ENC	GILLIG	GreenPower	MCI	NovaBus	Proterra	New Flyer	Van Hool	Total
Battery Electric Bus Low Floor	30	210	-	496	2	1			1						**4**
	35	94	-	440	1	1			1			5	1		**9**
	40	94	-	660	2	1	1	1	1		1	7	3		**17**
	45	320	-	323	1				1						**2**
	60	320	-	818	1								3		**4**
Battery Electric Bus Coach	23	134	-	134	1										**1**
	35	348	-	348	1										**1**
	40	391	-	391	1										**1**
	45	496	-	496	1					1				1	**3**
Battery Electric Bus Double Decker	35	170	-	170	1										**1**
	45	230	-	478	1				1						**2**
Battery Electric Bus Total					**13**	**3**	**1**	**1**	**5**	**1**	**1**	**12**	**7**	**1**	**45**
Fuel Cell Electric Bus Low Floor	40						1						1		**2**
	60												1		**1**
Fuel Cell Electric Bus Total					**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**3**
Zero Emission Bus Total					**13**	**3**	**2**	**1**	**5**	**1**	**1**	**12**	**9**	**1**	**48**

8. A zero-emission ADA paratransit evaluation, including a review of the state of the industry and vehicles, as well as opportunities and barriers associated with ADA paratransit buses.

Ordinance 19052 sets a goal for 67 percent of the Access fleet to be zero-emission by 2030 and a goal for 100 percent of the rideshare fleet to be zero-emission by 2030. This section provides background on Metro's Access program, including information about the fleet and operations. It also reviews the state of the vehicle industry and discusses opportunities and barriers to consider in a transition to zero-emission. The section also includes a discussion of the Rideshare program, providing program background, fleet and operations information, and opportunities and barriers.

Access Program Overview

King County Metro's Access paratransit service provides trips to customers not able to use the fixed-route system. Per the 1990 Americans with Disabilities Act (ADA), Access services are complementary to the fixed-route system and intended to offer a comparable level of service to regular bus service. Access provided over 1,000,000 trips in 2019.

Metro contracts with a private contractor to operate the Access service and maintain the vehicles. Metro provides the vehicles and covers the cost of leasing the facilities to park and maintain the fleet, although the leases are held by the contractor, not Metro. Access vehicles operate out of five leased base facilities listed in the following Table 17. Access also operates a call center out of a leased facility.

Table 17: Access Facilities

Access Facilities			
Facility	Address	Vehicle Distribution*	Percent of fleet
1. Kent Base	8002 S. 208th Street, Building E-105 Kent, WA. 98032	~ 150 vehicles	36%
2. Shoreline Base	16325 5th Avenue NE Shoreline, WA 98155	~ 108 vehicles	26%
3. Bellevue Base	2000 118th Ave SE Bellevue, WA. 98004	~ 60 vehicles	14%
4. South Park Base. (includes propane fueling)	8100 8th Avenue S Seattle, WA 98108	~ 92 vehicles	22%
5. Vashon	19001 Vashon HighwaySW Vashon Island, WA 98070	~4 vehicles	1%
6. International Building Call Center (4th floor)	675 South Lane Street. Seattle, WA	10,000 square feet of office space; no vehicles stored at this location.	
***The number of vehicles operating out of a given facility fluctuates; the percentage of vehicle distribution is fairly consistent.**			

Access Fleet

Metro's active paratransit fleet consists of about 400 vehicles (December, 2019). About 90 percent of the active Access vehicles are 'cutaways' - vehicles with a bus body on top of a truck chassis. The remainder of the active fleet vehicles are SUVs (Figure 12). All of Metro's active Access vehicles are wheelchair accessible to ensure equity for all Access customers and maintain service planning flexibility and optimization. Access vehicles can generally accommodate three wheelchairs or 12 ambulatory passengers.

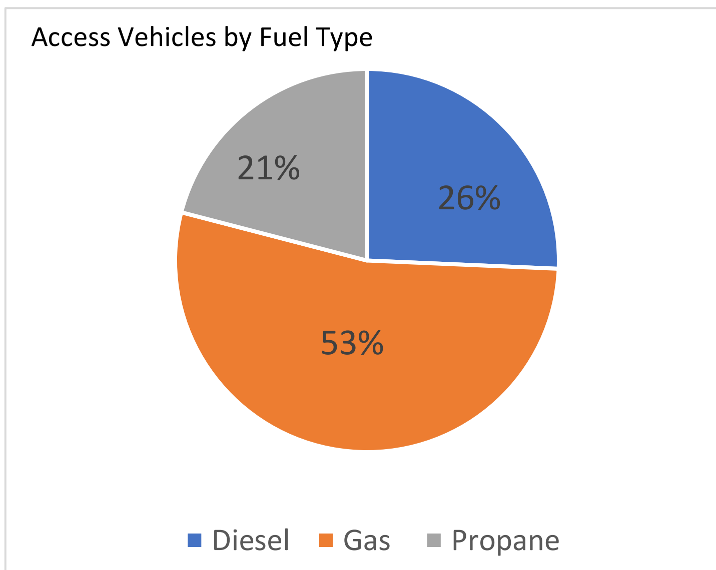

Figure 11: Access vehicles by fuel type

Over half of all Metro's active Access vehicles are fueled with gasoline, with about 100 diesel vehicles and 84 propane vehicles (Figure 11). The South Park facility is equipped with propane fueling infrastructure to support the propane vehicles.

Figure 12: Photographs of current Access service vehicle types

Accessibility Demand

Riders on about 40 percent of all trips on Access require the use of a lift or a ramp to enter the vehicle. Access vehicles are also stationary for a high percentage of their operating time, up to about 40 percent, primarily while passengers are being picked up and dropped off. The vehicles need to be kept at a comfortable temperature during these extended stationary periods.

Daily Vehicle Use

Metro's Access vehicles generally spend all day in the field providing service and return to a base overnight. Ninety percent of vehicles perform one pullout (one departure from a base) per weekday (Table 18) and travel an average of 105 miles per pullout (Figure 13). Nearly 95 percent of all Access vehicles travel fewer than 160 miles per pullout. Approximately 90 percent of Access vehicle pullouts are scheduled as eight or ten hours, with an average overnight downtime of 16 hours (
Figure 14). Only a small portion of the vehicles (about 9 percent) return to a base during midday.

Table 18: Access Fleet Average Operational Metrics per Pull-Out by Vehicle Type

Vehicle Type	Avg. Distance (miles)	Avg. Time (hrs:mins)	Avg. Trips	Avg. Distance per Trip (miles)	Avg. Time per Trip (hrs:mins)	Avg. Speed (mph)*
Cutaway	105	8:52	8	13	1:06	12
SUV	108	8:21	7	16	1:13	13

Source: King County Metro, November 2019 through February 2020
****Average speed is calculated as distance traveled divided by the duration of the trip. Vehicle speeds can vary widely depending on traffic conditions and roadway type (i.e., highway versus urban arterial).***

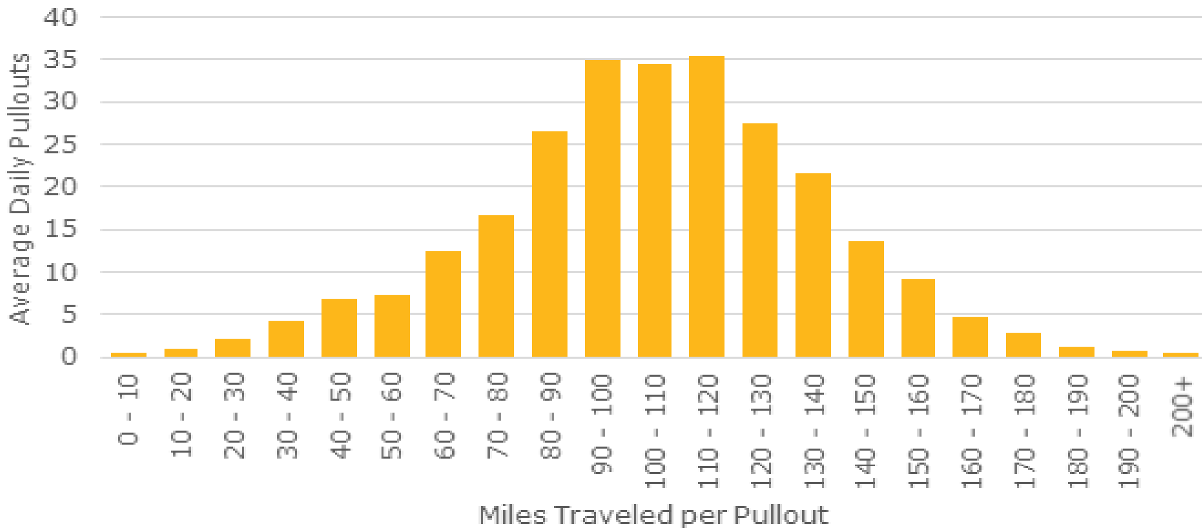

Figure 13: Distance traveled per Access vehicle pull-out
Source: King County Metro, November 2019 through February 2020.

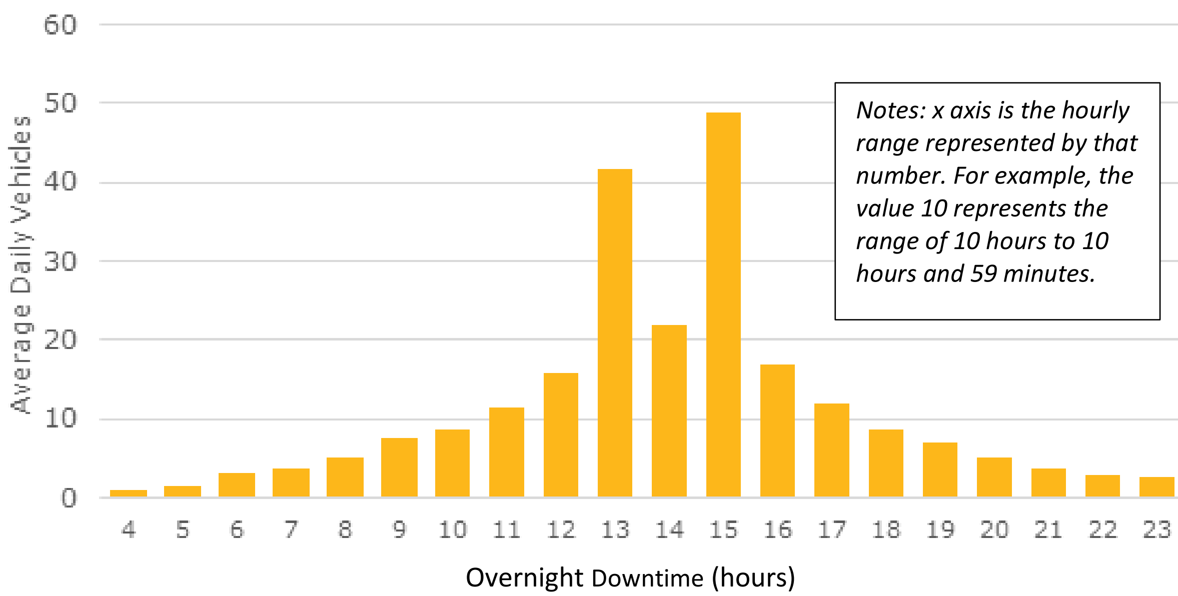

Figure 14: Access vehicle overnight downtime in hours between pullouts
Source: King County Metro

Industry Review

An industry review of battery-electric vehicles considered vehicles that could potentially support Metro's Access service, as well as other Metro services such as Rideshare. The review included 15 vehicles in three categories - six cutaways and small buses, three large vans, and six sedans as shown in Table 19. A description of the vehicle categories is below. The minivan and sedan vehicles were included as potential vehicles for the rideshare program. At the time of this review, there were no battery electric vehicles in the minivan category.

- **Cutaways and small buses** are medium-duty vehicles that accommodate ambulatory passengers, wheelchair passengers, or a mix of the two. Cutaways are medium-duty vehicles built on light truck chassis with specialized passenger cabs. These vehicles typically have wheelchair lifts and are commonly used for paratransit service. Fossil-fueled cutaways are currently in use in Metro Access and Dial-a-Ride (DART) fleets.
- **Large vans** are factory-direct passenger vehicles that accommodate up to 15 passengers. These vehicles do not typically have wheelchair lifts (although lifts can usually be installed). Metro's Vanpool and Vanshare program includes this category of vehicle.
- **Minivans and sedans** are small, light-duty factory-direct passenger vehicles that accommodate up to seven passengers. Minivans can be outfitted with wheelchair lifts but sedans typically cannot. These vehicle types are currently used in Metro Rideshare programs.

The review considered passenger capacity, wheelchair accessibility, range, cost, and vehicle availability. The information gathered came from a combination of manufacturer and seller marketing materials, press releases, and direct correspondence and conversations. Range estimates, in particular, are assumed to be best case scenarios, recognizing that range can vary greatly depending on a variety of factors including operating conditions, terrain and vehicle load. A list of all vehicles reviewed is in Table 20 and more information can be found in Appendix G: Electric Vehicles Research. Vehicles that are generally considered sports or luxury vehicles were excluded from this review since the current Washington State Department of Enterprise Services motor vehicles contract (#05916) excludes sports and luxury vehicles. The Washington State Department of Transportation (WSDOT) does make an exception for BMW i3 and Tesla Model 3.

There is also discussion of vehicle charging infrastructure to support electric vehicles.

Table 19: Electric Vehicle Review Summary Table

Vehicle Type	Number of Models Reviewed	Vehicle Ranges (miles)	Cost	Conventional Vehicle Cost
Cutaways and Small Buses	6	80-170	$200,000-300,000	$80,000 (Access vehicles)
Large Vans	3	77-190	$160,000-$200,000	$30,000 (12/15 passenger van, not wheelchair equipped)
Sedans	5	150-260	$30,000-$40,000	~$25,000

Observations

The cutaways and large vans had similar travel ranges, between 77 miles and 190 miles. The cutaways were more expensive than the large vans. The sedans, which had a 5-passenger capacity (including driver), were considerably less expensive, costing between 30,000 dollars and 40,000 dollars, and had travel ranges up to about 260 miles.

- **Electric cutaways, small buses, and large vans are emerging markets in the US that are in the early stages of development and use.** Battery-electric vehicles of these classes are just beginning to be used in the U.S., primarily by municipalities and transit agencies in California.

- **Many of the electric vehicles currently available in these classes are 'repowered,'** meaning they are built on an original equipment manufacturer (OEM) or factory truck chassis, such as those manufactured by Ford or Chevrolet. These vehicles are rebuilt with third-party electric drivetrains and have specialized passenger bodies installed. The process of rebuilding or 'repowering' an OEM chassis with an electric drivetrain involves removing the internal combustion engine and related parts and replacing them with an electric motor and drivetrain.
- **Not much experience to date in large deployment**. There has not been widespread use of these vehicles in the transit industry to date and data is limited on cost and performance.
- **Limited range and higher costs**. The vehicles currently available in the cutaway and van classes have limited driving range between charges and are comparably higher cost than the fossil-fuel alternative.
- **Few vehicles have been through federal testing**. The Federal Transit Authority (FTA) conducts bus testing, often referred to as Altoona testing (see Altoona testing inset). To be eligible for federal funding, vehicles must successfully pass the FTA testing and must also satisfy Buy America guidelines. At the time of this report, one large van, the GreenPower EV Star had successfully Altoona-tested. To date, none of the repowered battery-electric ADA paratransit vehicles have yet been Altoona-tested or certified to meet the Buy America requirements.
- **Repowered vehicles offer a familiar configuration for customers**. Repowered vehicles often maintain the popular passenger body and ramp designs used by fossil-fueled ADA paratransit vehicles, and many of the non-drivetrain parts and systems are industry-standard.
- **Third-party electrification repowers are generally performed by smaller companies** that may not be able to offer the warranty, maintenance, and parts support that larger OEMs can provide for factory-direct battery-electric vehicles. Purchasing and maintaining vehicles from third-party repower manufacturers may be logistically challenging at the scale required to support Metro's Access fleet.

Altoona Testing

The Federal Transit Administration's (FTA) Model Bus Testing Program - often referred to as "Altoona Testing" due to the location of the main testing center – was developed to improve the process of ensuring the safety and reliability of new transit buses. It provides for minimum performance standards, a standardized scoring system, and a pass-fail threshold that better informs local transit agencies as they evaluate and purchase buses. The process also generates data from the scoring system that makes it easier to compare similar bus models from different manufacturers.

The process tests new transit bus models for:

- safety
- structural integrity and durability
- reliability
- performance (including brakes)
- maintainability
- noise
- fuel economy
- emissions

Bus models that fail to meet one or more minimum performance standards will "fail" their test and thus be ineligible for purchase with FTA funds until the failures are resolved

Figure 15: Altoona Testing ensures safety and reliability

Table 20: Industry Review

Cutaways and Small Buses	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Phoenix Motorcars Zeus 400 Shuttle Bus	Up to 2 wheelchair and 12 ambulatory passengers	Yes	Up to 160 miles	California and Texas airports, City of Redlands, and City of Santa Cruz	*~$300,000*
Lightning Electric Ford E-450 Shuttle Bus. An electric cutaway built on a Ford E-450 chassis	2 wheelchairs and 12 ambulatory passengers	Yes	80 or 120 miles, depending on battery option.	Available	$230,000
Lightning Electric Ford F-550 Shuttle Bus. Built on a Ford F-550 chassis, allowing for more passenger capacity than an E-450.	2 wheelchairs and 20-30 ambulatory passengers.	Yes	120 miles	Available	$270,000
Micro Bird DS-Series Paratransit. A lift-equipped cutaway built on a Ford or GM chassis. Little info available.	Up to two wheelchairs. 28 ambulatory passengers.	Yes - Wheelchair lift typically in the rear	Not in widespread enough use for reliable estimate	Available	Not in widespread enough use for reliable estimate
Motiv Power EPIC E-450 Shuttle Bus. A Ford E-450 platform with a Champion passenger body.	More info needed from manufacturer	Yes. Wheelchair lift typically in the rear.	85 miles	Mountain View, CA and other California locations	*~$250,000*

SEA E450 Shuttle Bus. Built on a Ford E-450 chassis with the SEA-Drive 100 electric drivetrain.	2 wheelchairs and 12 ambulatory passengers	Yes	130-170 miles	Available	$200,000
Large Vans	**Capacity**	**Wheelchair Accessible**	**Range**	**Use/Availability**	**Cost**
Greenpower EV Star ADA Large passenger van built entirely by Greenpower. Altoona testing completed in the winter of 2020	2 wheelchairs and 12 ambulatory passengers	Yes – side or rear	77-150 miles	The Port of Oakland, Sacramento Regional Transit District, and California's Green Commuter vanpool service	$200,000
Lightning Electric Ford Transit The Lightning Electric Ford Transit is a large passenger van built on the Ford Transit platform	One wheelchair and 4 ambulatory passengers, or up to 15 ambulatory passengers	Yes	60-120 miles	In use in Porterville, CA; planned for use in Los Angeles, CA; in use in private sector operations in Seattle	$173,000
SEA Electric Ford Transit. The SEA Electric Ford Transit is built on a Ford Transit chassis and incorporates a SEA-Drive 70 electric drivetrain	Two wheelchair and 9 ambulatory passengers Ambulatory positions can be eliminated to add wheelchair	Yes	190 miles	Currently being tested by the United States Postal Service	$160,000

Sedans (Rideshare)	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Nissan Leaf S, SV, S Plus, and SV Plus A four-door hatchback in widespread use throughout the U.S; available in four models with varying cost, range, and features	Up to five ambulatory passengers, including driver	No	149-226 miles	Available. Currently in use in Metro's Metropool Program	$31,600-$39,750
Chevy Bolt. A four-door hatchback that is widely available in the U.S	Up to five ambulatory passengers, including driver	No	259 miles	Available	$37,500
Hyundai Ioniq SE. Four-door sedan	Up to five ambulatory passengers, including driver	No	170 miles	Available	$33,000
Hyundai Kona Electric SEL A crossover SUV	Up to five ambulatory passengers, including driver	No	258 miles	Available	$37,200
Kia Niro EV A subcompact crossover vehicle	Up to five ambulatory passengers, including driver	No	239 miles	Available	$38,500

Vehicle Charging Infrastructure Options

There are three primary levels of chargers available to charge light and medium duty electric vehicles (such as passenger vehicles, vans and minibuses): Level 1, Level 2, and DC Fast Chargers. These chargers recharge vehicles at different rates, with higher levels indicating faster charging speeds, and they

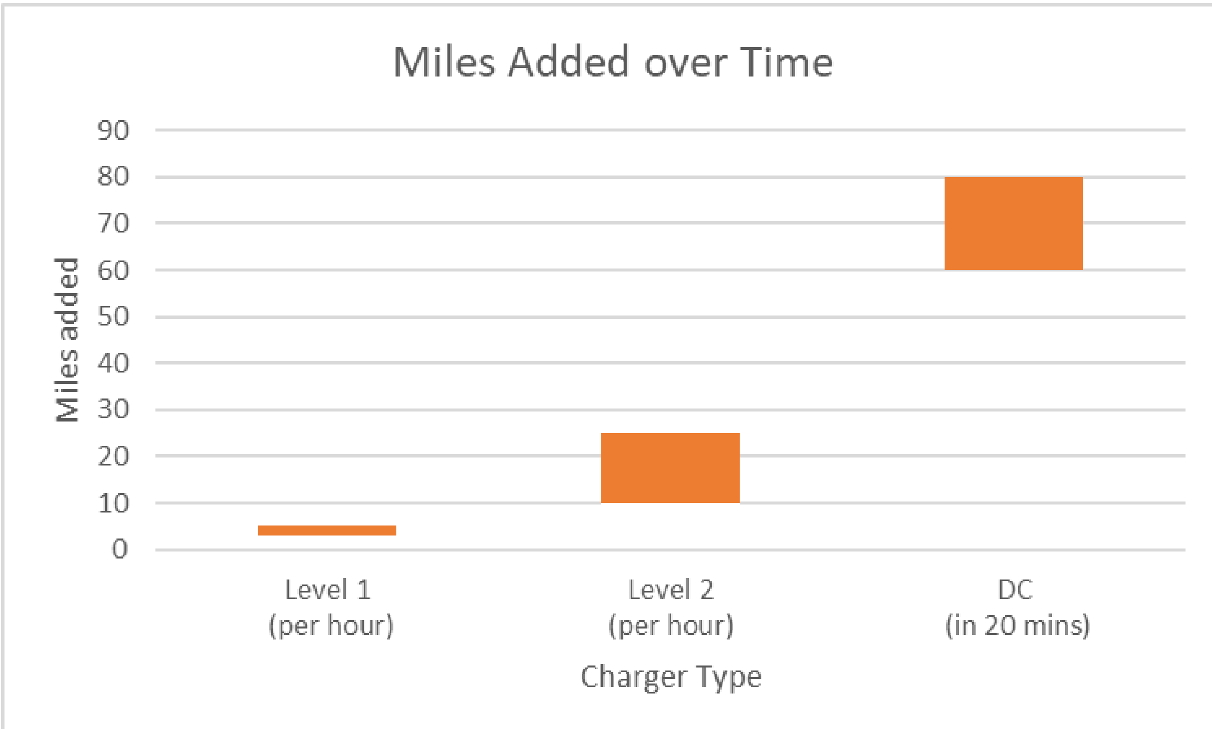

Figure 16: EV charger speed comparison

support different types of use and charging needs. Figure 16 illustrates the difference in charging speeds (miles of range added per hour) from the three charging levels. Level 2 chargers are what is currently available at King County's parking garages and park-and-rides.

Level 1 chargers provide charging through a 120-volt alternating volt (AC) plug. Level 1 chargers can be a simple and inexpensive solution when there is only a 120V outlet available, but they charge vehicles slowly. They can be a good option when vehicles can charge for eight hours or more at a time, such as at homes and workplaces, but there is no way to track usage. These chargers are not likely candidates to support larger fleet vehicles such as cutaways and vans, as they would take too long to recharge that class of vehicle.

Level 2 chargers provide charging through a 240-volt (residential application) or a 208-volt AC (commercial application) plug and require a higher degree of electrical infrastructure than Level 1. Level 2 chargers are more expensive than Level 1 and are available with more advanced controls and monitoring capabilities. They are a good option for workplaces and parking garages and are frequently used to support public and private fleets. Level 2 is available in both networked ('smart') and nonnetworked charging. "Smart' chargers allow for more advanced controls, billing options, and usage analytics to allow tracking and reporting. 'Smart' chargers are often accompanied by a paid service to help manage and report data. Non-networked Level 2 chargers don't have internet connection and essentially provide an access point to plug in and charge. Level 2 chargers can be equipped with one or two charging heads. Chargers with two charging heads can charge two vehicles at one time by splitting power between each vehicle. The cost of Level 2 chargers can range from 400 dollars for non-networked chargers to 5,000 dollars per unit for networked chargers, not including installation or on-going network costs.

Direct Current (DC) Fast Chargers (DCFC) are the fastest and most expensive option for charging vehicles. DC fast chargers typically use 480-volt input to the charger, and adds 60-80 miles of range to a light duty vehicle in as little 20 minutes. They can quickly recharge a battery while the driver waits. They are expensive and require a lot of power and a higher level of investment in supporting electrical infrastructure. Some DC chargers are available with two charge cords enabling them to charge two vehicles by splitting the power between each vehicle and distributing the current at reduced amperage for each vehicle. The charge rate would be slower when the power is split. Not all EVs are equipped with the hardware required for DCFC. DCFC units can usually cost between 35,000 and 100,000 dollars, with some very high power DCFCs costing up to 200,000 dollars. (This doesn't include installation costs.)

Installation

As noted above, the cost of the chargers is actually a small portion of the charging infrastructure costs. The technical challenges and resulting capital costs of charger installation can vary widely from site to site, depending on such factors as available electrical capacity and location of parking relative to electrical service. Typical installation costs include trenching for electrical conduit and upgrades to electrical services panels. Larger installations can include upgrades to the local electrical distribution grid, such as transformer upgrades.

Opportunities for and Barriers to Transitioning Metro Access to Zero-Emission Vehicles

Opportunities and barriers to transitioning Metro's Access fleet to zero-emission can be identified in three main categories: (1) vehicle availability and suitability, (2) vehicle charging infrastructure, and (3) cost.

Vehicle Availability and Suitability

An initial question: What vehicles are available in electric options and are those vehicles suitable for Access paratransit service? Vehicles need to be available in the US market and produced on a timeline that supports Metro's vehicle demand. Vehicle suitability can be considered in terms of how it meets the requirements of service and customer needs. Important factors include range between charges, capacity, wheelchair accessibility, and cost. Performance and reliability are other important considerations, which can be hard to assess in vehicles that are relatively new to the market.

Access Vehicle Requirements

Based on the operational overview, a Metro Access vehicle travels for 8-10 hours on average and up to about 160 miles between fueling. Access vehicles usually return to base overnight, though rarely return during the day. Access vehicles typically have capacity for three wheelchairs or 12 ambulatory passengers, and are completely wheelchair accessible in order to ensure equitable service for customers and scheduling flexibility. Metro currently only uses vehicles with side wheelchair access. Metro moved away from rear lifts primarily because of safety. Rear lifts on a busy street can be unsafe for passengers and drivers, as (1) there are often no curb cuts to safely travel to and from the street when exiting from the rear, (2) loading on hills is particularly challenging, and (3) wheelchairs need to be secured in the back where the ride can be rougher and passengers can feel isolated.

Additionally, all the vehicles in Metro's existing Access fleet have all passed federal Altoona testing. Successful Altoona testing along with Buy-America certification qualifies a vehicle for purchase with federal funds. While Metro does not use Federal Funds to purchase Access vehicles, the contracts that Metro traditionally uses through the state to purchase vehicles require Altoona testing. It is also an industry best practice to use vehicles that have successfully completed Altoona testing.

Successful Federal Testing

At the time this report was developed, only one battery-electric ADA paratransit-capable vehicle that had passed Altoona testing - the GreenPower EV Star (Figure 17). Below is a discussion of how the EV Star matches the Access program requirements.

Figure 17: GreenPower EV Star

Range

The GreenPower EV Star has an estimated range of between 77 and 120 miles on a single battery charge, based on results from the Altoona test and estimates of actual battery performance under operating conditions. Assuming a conservative range limit of 77 miles would mean that approximately 20 percent of current Access pullouts could be served by the EV Star without adjusting operations or charging the vehicle while it is in the field (Figure 18).

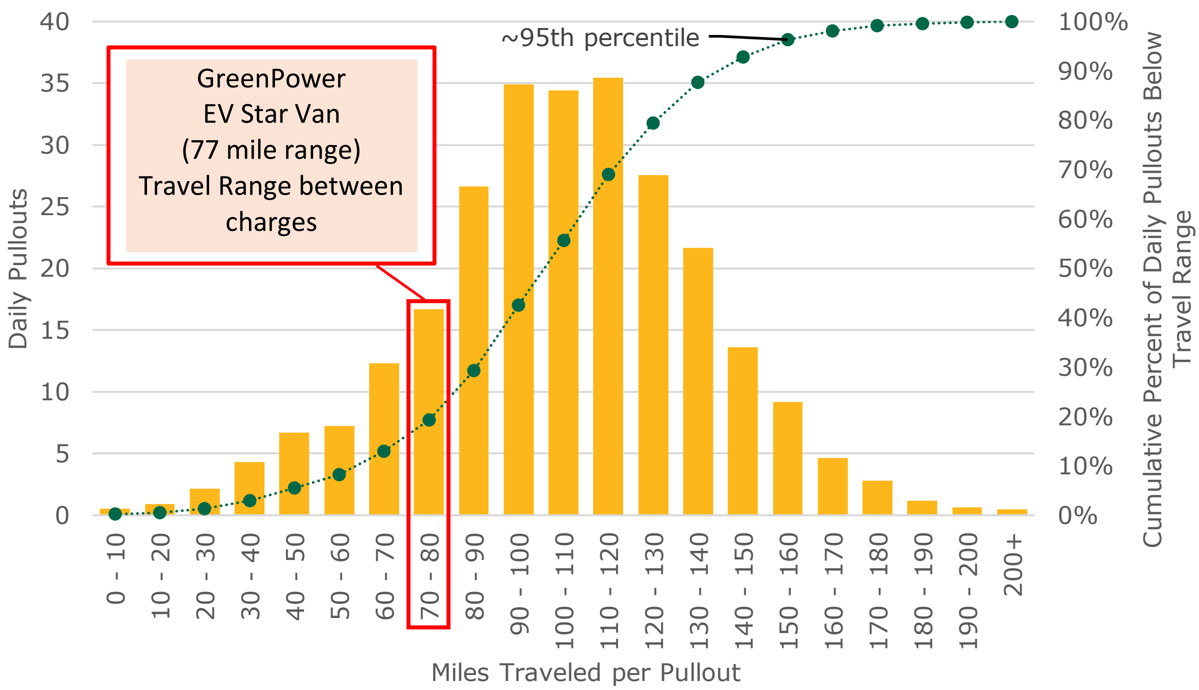

Figure 18: Distance traveled per Access vehicle pull-out

Source: King County Metro, November 2019 through February 2020.

Cost

The EV Star costs approximately 200,000 dollars, which is more than twice the approximate 80,000 dollars Metro currently pays for Access vehicles.

EV Star Availability
The GreenPower EV Star is currently available for purchase in the US, and the communicated production capabilities could meet Metro's pace of vehicle orders. At the time of this report, based on conversations with GreenPower, the company estimated its manufacturing capacity to be 30 vehicles per month with a 180-day lead time. On a regular vehicle replacement schedule, Metro usually purchases between 30 and 80 Access vehicles per year. Vehicle production schedule would need to be confirmed with any manufacturer and considered in planning for vehicle transition.

Expanding Market
Although the EV Star is currently the only battery-electric ADA paratransit vehicle that has been Altoona tested, it is likely more vehicles meeting this threshold will be available at scale in coming years. The industry shows promise for further development. All the cutaways and large vans in the review have capacity comparable to Metro's current Access vehicles and all were wheelchair accessible, although two of them had rear lifts, which Metro does not currently use. The biggest challenge with currently available vehicles is the range between charges. The stated conservative estimates for the travel range between charges on these vehicles varies from 77 to 190. A vehicle that can travel about 77 miles between charges, such as the GreenPower EV Star, can cover about 20 percent of the Access pull outs as shown in Figure 18. To reach customers served by the remaining 80 percent of Access pullouts with the EV Star, the Access fleet would need to be expanded and/or scheduling practices would need to be changed. To serve the same number of customers, it would take both more vehicles and drivers. A vehicle that can travel 190 miles between charges can cover nearly all of the pull outs.

The market for cutaways and vans is still under development. The current demand for more electric cutaways, small buses, and vans, will help push the market. Legislation at the state level can also help spur the market to respond to increased demand for electric vehicles of this type. For example, California could enact stricter zero-emission paratransit regulation. A new Washington state law became effective on June 11, 2020, which supplements previous legislation (from 2007) by replicating the vehicle emission standards established in California. The zero-emission vehicle (ZEV) standard requires automakers to deliver a certain number of zero emission vehicles each year, starting with five percent of all vehicles sold in the state by 2022 and eight percent by 2025. The law is intended to create greater availability of zero emission vehicles on the retail market in the state. Depending on legislation-enacting rules that the Department of Ecology adopts, such legislation could increase the availability of vehicles suitable for Access-supportive or rideshare operations in the state.

Vehicle Charging Infrastructure
Under Metro's current paratransit operational model, most vehicles have long downtimes at night which makes overnight charging at a base ideal. A likely scenario to support a fleet of Access vehicles would be to have a combination of Level 2 chargers with a small proportion of fast chargers. This combination would provide Level 2 overnight charging for the vehicles, with fast charger access for emergency charging if a vehicle needs to be recharged quickly. In the field chargers could also play a role in the charging system, as discussed in the 'In the Field Charging' section. The actual charging infrastructure plan would require further analysis, and is dependent on the type of vehicles selected and how those vehicles perform in the field.

Metro's Access service is currently operated out of 5 bases which are all leased through a contractor. In order to provide charging infrastructure, the most likely scenarios would be for Metro to either (1) arrange for vehicle charging infrastructure on property that it leases or (2) consider purchasing property where it could build electrified bases. There are considerations to either approach.

Infrastructure on Leased Property
Metro could consider investing in charging infrastructure on a leased base or negotiating with the property owner to install the infrastructure.

Metro has previously made capital investments on leased property. For example, Metro invested in propane fueling infrastructure on its leased facility in South Park. The technical challenges and resulting capital costs of electric vehicle charger installation can vary widely from site to site, depending on such factors as available electrical capacity, type of charging equipment, infrastructure needed to support the electrical supply to the chargers, and location of vehicle parking relative to electrical service. Ideally, in order to consider major infrastructure investments, Metro would need lease terms with long term control and ability to modify the property to meet its operational needs. It may not make financial sense to make a substantial investment in the charging infrastructure and necessary electrical grid infrastructure upgrades without assurance that Metro can use the infrastructure long enough to recoup an acceptable level of its investment.

The useful life of the actual chargers is estimated to be approximately 10-12 years, based on a report from Foothills Transit in California. It is potentially feasible that the actual charging equipment could be relocated if Metro moves to another facility. However, much of the infrastructure investment is in the supporting electrical infrastructure, which is not transferable, and in the installation labor.

Additionally, when a facility lease ends, Metro's lease search and negotiation for new property would need to consider both the suitability for Access operational efficiency (i.e., location) and compatibility with electric charging infrastructure requirements. Depending on the real estate market, it's possible that in order to identify a site that's compatible with the required electric charging infrastructure, Metro would need to select a site that is less ideally located in terms of operational efficiency. This issue would need more thorough analysis to understand the trade-offs and cost effectiveness of investing in electric charging infrastructure on leased facilities.

Purchase Property
Metro could also consider purchasing property or using existing property to provide one or more permanent Access bases. This would make it more attractive to make long term investments in facilities such as installing electrification infrastructure. Establishing permanent Access base(s) could have other benefits as well, such as lessening the risk of unpredictable and rising lease costs, decreasing the risk of not being able to find leased land in a desirable location, securing properties in locations with predictable operational costs, and creating potential opportunities for co-location with other Metro fleets.

The challenge this approach is the substantial capital investment that is required to purchase property and build facilities to support operations. As Metro faces significant financial constraints at this time, a capital investment may be more difficult to consider. Additionally, Metro would become responsible for maintaining the property. It would also be important to consider how a contract would be structured if Metro owned its facilities but continued to use contractors to operate and maintain it vehicles and bases.

In the Field Charging

In the field charging (that Access vehicles could use during a layover, during the day) may be a way to help address some of the charging needs as well. This solution could help increase opportunities for recharging during operations and potentially augment the daily range of vehicles. The range of the currently available Access candidate vehicles does not meet the demand of many daily pull outs, but an opportunity to recharge during the day can help address this problem. Further consideration would be needed to understand how charging downtime during the day would impact service scheduling. Further investigation would include where chargers might be located (whether such infrastructure could be built into future transit centers and hubs for example), whether they were shared or public chargers, and the associated costs.

Overall Cost

Electric vehicles and the charging infrastructure cost more than traditional vehicles. The maintenance and fueling/charging costs of vehicles could be lower, based on initial industry experience, but more analysis and experience is needed to fully understand the cost.

Based on a preliminary cost analysis conducted by the Center for Environment and Transportation (CTE) in early 2020, Access capital costs could double with a transition to electric vehicles. (About five percent of the 2020 Access budget was dedicated to capital expenses). These added costs are due primarily to higher vehicle costs and the need for vehicle charging infrastructure. Viable Access vehicle alternatives available now are estimated to cost about 200,000 dollars – about twice as much as Metro currently pays for a vehicle. These costs will likely decrease as the technology develops. The charging infrastructure would be in addition to that. The preliminary analysis suggests that operating costs could potentially decrease due to the lower cost of fueling with electricity. Metro is conducting a consultant study now to refine estimates for what it would cost to transition the Access fleet to zero-emission, with results expected this fall.

The transition timeline to achieve the 2030 target

Under Metro's current replacement cycle for Access, Metro would need to begin transitioning the fleet no later than 2024 to meet the goal of 2/3 of Access vehicles being electric by 2030, assuming the active fleet remains the same size as it is today. Metro currently plans for a 10-year replacement cycle for its paratransit vehicles. While Metro's practice is to keep paratransit vehicles for 10 years, the FTA has specified the life of Access vehicles at 5 years. If Metro were to follow the FTA-established minimum vehicle life, it could transition vehicles more quickly than its current practice. If Access vehicles were to be replaced at five years of age, assuming the active fleet remains the same size, Metro could begin transitioning the fleet in 2029 and still meet the goal of 2/3 of Access vehicles electric by 2030. This would entail a large fleet turnover in 2030 however, with potentially up to 281 vehicles eligible for retirement and replacement with electric vehicles in one year. Current Access fleet planning typically plans for purchase of 30-80 vehicles in a year. The risks of such a big turnover in one year include the challenge of preparing so many new vehicles for service at the same time and reliance on one new vehicle type for a high percentage of its fleet. There is also risk in preparing an appropriately trained workforce to drive and maintain the vehicles, and whether vehicle manufacturers could provide enough vehicles at one time.

A rolling replacement of vehicles that more closely matches Metro's current approach to vehicle replacement would allow phased implementation of battery-electric vehicles. This could give Metro time to build familiarity with the technology and develop supportive infrastructure such as charging equipment. Slower deployment could also potentially allow efficiencies in the electric vehicle manufacturing industry to grow and potentially reduce the cost of vehicles during later procurements.

Building in Time for a Pilot Program

It will be important for Metro to have opportunity to test potential Access vehicles, in terms of performance and appeal to both customers and drivers. Testing and pilot programs are a best practice before adoption of new technology and equipment. There are no known large-scale deployments of these vehicles in the U.S. at this time, so there is not a large amount of documentation to learn from yet. Additionally, it is important to test the stated ranges and understand the impact on range and battery life from other paratransit operational requirements, such as lift deployment and the amount of energy needed to keep vehicles comfortable for riders in extended stationary periods.

Rideshare Evaluation

Ordinance 19052 sets a goal for 100 percent electrification of Metro's Rideshare fleet by 2030. While the legislation did not specifically request it, this section provides a high level industry review and discussion of opportunities and barriers to electrifying the rideshare fleet, similar to the discussion of Access.

Rideshare Program Overview

Metro's Rideshare program provided 3.4 million trips in 2019 with the largest publicly-owned vanpool fleet in the United States. The Rideshare program includes VanPool, Vanshare, and MetroPool. These services, further described below, are operated by volunteer drivers with vehicle maintenance coordinated and paid by Metro. By definition, a commuter rideshare must have at least 5 people and not exceed 15 people registered (Chapter 46.74.010 RCW). Registered members are not required to ride every day. In December 2019, there were 1,564 vanpool groups and 85 vanshare groups in operation. Of those groups, 26 were 5-person rideshares using Nissan Leafs.

The Rideshare program helps reduce greenhouse gas emissions and vehicles on the road, as an alternative to single-occupant vehicles. Based on Metro staff analysis, in 2019 the rideshare program:

- Eliminated 49 million single occupancy vehicle miles traveled
- Saved ~ 1.9 million gallons of fuel
- Reduced ~ 18,000 metric tons of CO_2 from tailpipe emissions
- Took an average of about 5,600 vehicles off the road daily

Metro's Rideshare program descriptions

- **Vanpool**: A group of five to 15 commuters with a similar commute who travel together to work, using a seven, 12, or 15 passenger van. Vans are kept at a driver's house or other secure location, and riders usually select convenient pickup and dropoff points, such as a park-and-ride.
- **Vanshare**: The Vanshare program provides vans to groups of five to 15 commuters who share rides between a worksite and a transit hub, such as park-and-ride, rail station, or a ferry terminal. Metro provides staff support, maintenance, fuel, and insurance. Vanshares are different from vanpools in that vehicles are parked at either the work destination or the transit hub when not commuting, as opposed to at or near driver's homes. Vanshares are usually driven shorter distances and often provide a first/last mile solution to access high capacity transit.

Vehicles are former Vanpool vehicles that have satisfied their seven-year lifecycle in revenue service.

- **MetroPool**: MetroPool is a vanpool-type program using five-passenger Nissan Leaf electric vehicles, where charging stations are available at the destination, such as a worksite. These vehicles have the minimum capacity required to support an official rideshare - there must be five active members signed up for a Metropool, although not all members are required to ride every day.

Figure 19: Photographs of Rideshare and Commuter Van vehicles

Rideshare Fleet

The rideshare program fleet consists of a combination of 12- and 15- passenger vans, seven-passenger minivans, and five-passenger zero emission Nissan Leafs (see Figure 19). Metro owns around 2,040 total vehicles distributed across Vanpool, Vanshare, and Metropool services. The seven-passenger minivans are the most popular vehicle, comprising about 89 percent of the fleet. Approximately nine percent of rideshare vehicles are 12- or 15-passenger vans and the remaining two percent are electric Leaf sedans.

Vehicle Use

The majority of the current rideshare groups drive a relatively short distance on a daily basis; 95 percent of all rideshare round trips are fewer than 80 miles. A large portion of the vans are driven to the same employer sites; approximately 80 percent of rideshare destinations are concentrated in 24 employment site areas.

Opportunities and Barriers to Transitioning Metro Rideshare to Zero-Emission Vehicles

Similar to the Access programs, the opportunities and barriers fall into the main categories of: (1) vehicle availability and suitability, (2) charging infrastructure, and (3) cost.

Vehicle Availability and Suitability

- **Few vehicles are currently available**. Based on the industry review included earlier, there are relatively few available battery-electric alternatives for vans at the time this report was developed. The review identified three large vans - the GreenPower EV Star, the Lightning Electric Ford Transit, and the SEA Electric Ford Transit that are potential options, but they are expensive. The current cost is between five to seven times that of a Chevrolet Express 12-passenger van, and they are bigger vehicles than the majority of vanpool vehicles used by Metro today. The seven passenger minivan comprises nearly 90 percent of the vanpool fleet. There are some electric vans in Europe, and there is anticipation that Mercedes is developing a van for sale in the US which could be a viable option.

- **Interim solutions may be a good choice.** Despite the lack of a fully electric van, Metro has taken steps towards lower emission rideshare fleets.
  - **Metropool:** Metro has implemented the Metropool electric vehicle rideshare program, which operates 30 Nissan Leafs. These vehicles can carry five people, and are granted rideshare status. The distance that most rideshare groups travel is within the range of battery-electric passenger vehicles currently on the market. The vehicles have been well–received and there is a waitlist for them. A primary challenge with Metropools is the size of the vehicle. A rideshare must have a minimum of five participants, as defined in Washington code (RCW 46.74.010), which means a Leaf must be at maximum occupancy. Fitting five adults into a Leaf can be difficult and some groups are not willing to be squeezed that tightly. Additionally, the flexibility of groups is reduced when they are required to have five subscribers but cannot have more, if all are daily riders. With no ridership cushion, groups are immediately forced into recruitment mode to maintain status as a rideshare whenever a participant leaves a group.
  - **Plug-in hybrid vans:** Metro is also piloting 10 plug-in hybrid (PHEV) Chrysler Pacifica minivans, which use both gasoline and electricity. The vehicles are able to travel about 30 miles round trip on just the battery. After that distance, the engine kicks in. The Pacificas have capacity for seven people. The vanpool groups selected for the pilot have access to workplace charging. Early results are identifying positive user response as well as greenhouse gas reductions. The inset box has more discussion of the pilot, and a full six-month review can be found in Appendix H: PHEV Six Month Review.
- **To reach full vanpool electrification by 2030, Metro would need to begin purchasing electric vehicle replacements in 2024.**
  - Per the current purchasing approach based on a seven-year lifecycle for vanpool vehicles, procurement would have to begin in 2024 in order to achieve full electrification of the vanpool fleet by 2030. To enable procurement to begin by 2024 however, it will be important to be able to conduct a pilot test on candidate vehicles prior to a large fleet purchase. It is uncertain whether a suitable, all-electric van will be available on that timeline. Pilots are an important opportunity to understand factors such as performance, suitability, customer acceptance, and operational costs. Metro can seek to implement pilot programs and vehicle tests when all-electric options are available.
  - Vanshare will be challenged to achieve electrification by 2030, as the program uses retired assets which would not start filtering into the fleet until 2031, based on current replacement cycle.

Charging Infrastructure

Rideshare vehicles do not return to few specific locations each evening, so it is not possible to have concentrated charging facilities to charge them overnight as is the case with Access vehicles. Volunteer drivers take them to their homes or they are parked at dispersed locations like park-and-rides at night. The main options for rideshare charging locations include work place, park-and-rides, or homes. Public chargers at or near these locations could also be an option.

Workplace charging

The concentration of rideshare vehicles' work destinations represents an opportunity for the electrification of Metro's Rideshare fleet. Approximately 80 percent of rideshare destinations are concentrated in 24 employment site areas, which could streamline provision of charging infrastructure. Workplace charging is the most straightforward opportunity for charging, since vehicles usually spend a number of hours parked at a worksite.

The challenge is that Metro is not in control of the workplace charging environment. Employers need to take the lead on providing EV chargers at a workplace. Metro can support, promote and potentially even partner with employers to install work place chargers. Metro has made public charging available at some of its parking garages, which can provide access to charging while at work. Alternatively, publicly available chargers could be installed at or near work places. Additionally, there are grant programs and pilot programs through utilities to promote workplace charging.

To further encourage employers to invest in work site charging, King County could also advocate for modification of the Washington Clean Air Act (RCW 70.94). Modifications could incentivize or require employers affected by commute trip reduction (CTR) planning efforts to make charging stations available for employees, as a percentage of the overall parking capacity, and include incentives for High Occupancy Vehicle (HOV) charging stalls. Metro could further explore opportunities to promote this option and work with partners.

Park-and-Ride Charging

Another option to consider for charging rideshare vehicles is with chargers at park-and-rides. There are some vanpools and vanshares that park overnight at park-and-rides that could use chargers there if they were available. There is also the potential for these chargers to serve both rideshare users at night, and be available for the general public during the day.

Some challenges with this approach is taking up space at crowded park-and-rides and potential security risks of leaving vans at a park-and-ride lot overnight. A number of Metro park-and-rides are above 90 percent utilization. If vanpool members meet at a well-used park-and-ride, they are taking up spaces that could otherwise be available for customers who are trying to access the bus system. An alternative could be to explore options to install chargers at less crowded park-and-rides, and encourage rideshares to use those locations. This option can be further evaluated and explored.

Home Based Charging

The majority of vanpools are currently parked overnight at volunteer drivers' homes. There may be vanpool drivers who would find it convenient to charge their vans at home. The challenges to home based charging include safety risks, cost, equipment installation, and the potential for driver turnover. The cost and complexity to install vehicle chargers varies, depending on factors such as existing electrical capacity and infrastructure. Many homes may require an additional, dedicated circuit along with the charging equipment. It could also be challenging to track energy use for vehicle charging. Vehicle energy use is important because rideshare fuel costs are included in the monthly costs paid by riders. Metro would need to explore this option further to determine if it has potential as a viable solution.

Cost

Electrification of the Rideshare program would increase capital costs. The added cost would primarily come from the higher cost of the vehicles. Without examples of a comparable electric vans on the market, it is difficult to estimate what the additional costs would be but per a preliminary cost analysis conducted by CTE, the vehicle costs to achieve full conversion by 2030 would be about forty percent more than our current costs. This is a high level cost analysis that assumes that a suitable small van or similar electric vehicle becomes available. It also assumes that rideshare vehicles will charge primarily at vehicle chargers available at the workplace, where they have long dwell times. Metro would be required to invest in some infrastructure at its facilities to support vehicle prep, commissioning, storage, and training. Metro is conducting a consultant study now to refine estimates for what it would cost to transition the Rideshare fleet to zero emission, with results expected this fall.

Cost Recovery

Per county code (4A.700.130) Metro is required to establish rates of fare for vanpools at a level reasonably estimated to recover the operating and capital costs of, and at least 25 percent of the cost of administering, the vanpool program. (Ord. 17292 § 66, 2012: Ord. 12643 § 8, 1997. Formerly K.C.C. 4.150.130. Formerly K.C.C. 28.94.185). This means that if Metro incorporates vehicles and other capital investments into the program that are more expensive, vanpool users will have higher costs. Increased costs are likely to be a concern to users. Currently, because the LEAFs and the plug-in hybrid vans are a small portion of the fleet, any added costs have been absorbed by the system. Participants in those rideshares do not pay a proportionally higher amount, but if the entire program is converted to electric vehicles, then costs would rise for all users.

Potential opportunities and actions to help offset the added cost and make a transition more affordable:

- **Advocate for more grant and funding programs** to help offset the costs of purchasing the vehicles. For example, Washington State's Department of Transportation (WSDOT) has a reoccurring Vanpool Investment Program (VIP) grant fund to promote vanpooling across the State. Currently, that grant reimburses transportation agencies 95 percent of qualified expansion vehicle and 65 percent of qualified replacement vehicle costs up to a capped amount. Metro could seek to lobby for changes in the VIP grant to cover 100 percent of all EV capital costs. This would not only promote all electric vanpools, but also expose riders to the benefits of owning an operating an EV through their exposure to the program's electric vanpools.
- **Allow for a flexible transition timeline that responds to more affordable vehicle costs and more prevalent workplace charging.** As more vehicle choices appear on the market, it is possible that the price of suitable vehicles may come down. Timing transition to the market could also enable more charging infrastructure to be in place.

The transition of Metro's non-bus revenue fleets is an important component of achieving the County's SCAP goals. As the industry review observed, the vehicle market is still evolving for both Access and Rideshare vehicles. Additionally, there are considerations for both programs related to charging infrastructure. Metro will continue to monitor both vehicles and infrastructure developments as it considers opportunities to electrify.

9. An evaluation of options, including public-private partnerships for increasing electric charging or other zero-emission vehicle technologies at King County-owned park-and-rides, with the goal of increasing opportunities for zero-emission vehicle access to transit.

Ordinance 19052 sets a goal for the installation of one hundred twenty-five chargers at King County owned park-and-rides by 2030. This section provides an overview of King County owned park-and-rides, Metro's parking program, and options and considerations for increasing electric charging at these park-and-rides as an opportunity to increase zero-emission access to transit. Most options for expansion of electric charging and zero-emission technologies would result in some costs to Metro, which would reduce resources available for other capital investments.

Overview of the King County Park-and-Ride System

King County Metro owns 22 park-and-ride lots in King County with more than 8,500 parking spaces. Figure 20 shows Metro owned park-and-ride location, stalls, and utilization. These park-and-rides are part of a larger park-and-ride system in King County, which includes 119 park-and-ride lots with approximately 25,979 spaces. The lots not owned by King County are a combination of permanent lots whose owners include WSDOT, Sound Transit and local cities, and privately leased lots. A full list of park-and-rides in King County is included in Appendix I: King County Park and Ride Lots.

King County-owned park-and-rides include both parking garages and surface lots and range in size from 48 spaces to more than 1,000 spaces. Pre-COVID, nine of the lots averaged 90 percent or higher utilization. Fourteen have more than 50 percent utilization.

Metro-Owned Park-and-Rides

Source: Park and Ride Management quarterly counts for Q4 of 2019.

Figure 20: Map of Metro-owned park-and-rides

Existing Electric Vehicle (EV) Charging at King County Park-and-Rides

Three King County-owned park-and-rides have electric vehicle chargers currently installed. Issaquah Highlands, South Kirkland, and Burien have a combined total of 29 Level 2 EV chargers (Table 21). These chargers are part of a system of King County-managed chargers comprised of a mix of public use, fleet and rideshare use, and shared public-fleet-rideshare use throughout the county. The existing chargers were originally installed with grant funds that King County received from the Department of Energy as part of Federal stimulus program in 2009. King County contracts with Chargepoint to maintain the chargers and to collect and report on charger data. Metro is in the process of upgrading the nineteen electric vehicle charging stations located at Issaquah Highlands and South Kirkland with new chargers that meet current network standards.

Table 21: Existing EV Chargers and King County Metro Park-and-Rides

Park-and-Ride Name	Charging Ports	Average Charger Utilization (October 2019)
South Kirkland P&R	7	62%
Issaquah Highlands P&R	12	47%
Burien P&R	10	14%
Total:	29	
Source: Chargepoint data reports; weekday data		

The chargers are each located in dedicated parking spaces that are labeled as EV spots. Per Metro and state requirements, people that park at EV chargers at park-and-rides are required to be charging their vehicle and using the parking space to access transit or join a vanpool or carpool. Per RCW, it is a parking infraction for vehicles to be parked in an electric vehicle parking station if the vehicle is not connected to charging equipment (RCW 46.08.185).

Figure 21: Examples of EV charging

Utilization of the chargers at King County park-and-rides varies by location, with the chargers at South Kirkland showing the highest utilization based on the available data. Utilization data also shows that at all three park-and-rides - Issaquah Highlands, South Kirkland, and Burien - the time needed to charge a vehicle or 'charging session' is often much shorter than the time the vehicle is left at the charger. Vehicles are charging on average for about half the time they are parked at a charger. For example, at South Kirkland in October 2019, the average charger usage per day was 4.5 hours while average occupancy during the month was approximately 9 hours per weekday. The issue of time parked versus time charging is a challenge associated with chargers at park-and-rides. Vehicles are usually left at a park-and-ride for the entire day while users head to work or school on the bus. It would not be convenient for a user to return to a park-and-ride midday to move a vehicle that was done charging.

Charger Fee and Usage
The current fee for using a charger is a flat two dollars regardless of how long the session is or how much electricity is used. Per county code (4A.700.700), the fee is not to exceed five dollars. The current fee was established by the Executive in 2012. Subsequent fee-setting authority was assigned to the King County Department of Transportation and transferred to Metro when Metro became a Department.

Metro's Parking Program
Parking spaces at many of the park-and-rides in King County are in high demand. About forty percent of the permanent lots in King County are at 80 percent capacity or higher (pre-COVID), and some fill up completely before the morning commute ends. Historically, Metro has employed a 'first come, first served' strategy for managing parking which can create challenges for people with later start times for work, school, or appointments. In response, Metro has been exploring a range of new strategies to both manage and expand parking supply. As part of that effort, Metro implemented a parking program to offer reserved parking spots using paid permits, while encouraging carpooling through offering free carpool permits. Pre-COVID, Metro offered free high occupancy vehicle (HOV) permit parking and monthly paid permit parking for single occupancy vehicles (SOV) at select King County-owned lots that are at or above 90 percent occupancy during weekday mornings before 8am. (Table 22). Metro offered a reduced rate paid permit for ORCA LIFT transit users. Only a portion of spaces in these lots was dedicated to permit parking (not more than 50 percent of the total parking stalls) and the remainder of spaces were available on a first come, first-served basis.

The permits aim to provide more equitable access to parking resources by giving drivers who cannot take advantage of first-come, first-served free parking to have reliable parking based on their schedule. Additional goals of the parking management program include: encouraging use of transit; spreading peak-of-the-peak demand for transit; increasing ridership in the region; improving access to transit parking for low-income populations, communities of color, immigrants and refugees, limited-English-speaking populations, transit-dependent populations, individuals who work nontraditional schedules or during off-peak travel periods and other transit riders; increasing use of carpooling; and covering program costs. Since COVID has reduced demand for transit parking, Metro has suspended the permit program. As demand returns, Metro plans to reinstate the program at high-utilization lots.

Two of King County's lots with the permit program have EV chargers – Issaquah Highlands and South Kirkland. Currently the permit parking areas at these lots do not overlap with spaces designated for EV charging. As Metro explores options for expanding EV charging capacity at park-and-rides, integration with the existing parking program will be important, including aligning pricing approaches, integrating payment platforms, and aligning with parking management goals.

Table 22: Permit Locations and Pricing

Location	Occupancy (2019)	Total Stalls	Max Stalls Permitted	HOV	SOV	ORCA LIFT
Aurora Village Transit Center	101%	202	101	$0	$90	$20
Bear Creek Park-and-Ride	99%	283	141	$0	$90	$20
Bothell Park-and-Ride	98%	220	110	$0	$90	$20
Issaquah Highlands Park-and-Ride	99%	1010	505	$0	$60	$20
Kenmore Park-and-Ride	100%	606	303	$0	$90	$20
Redmond Park-and-Ride	99%	377	188	$0	$90	$20
Shoreline Park-and-Ride	96%	393	196	$0	$60	$20
South Kirkland Park-and-Ride	99%	833	416	$0	$90	$20
Tukwila Park-and-Ride	96%	267	133	$0	$90	$20
Northgate Transit Center	100%	448	224	$0	NA	NA

Options for increasing electric vehicle chargers at King County Park-and-Rides

As Metro explores options for increasing electric charging at King County-owned park-and-rides, considerations include who potential users are, how the availability of chargers at park-and-rides increases opportunities for zero-emission access to transit, and how to address equity. The cost and feasibility of installing EV chargers is also important to consider. Partners can play an important role by helping to share the cost and expanding the market for EV charging.

Potential EV Charger Users

Primary users include customers accessing transit and rideshare groups. There may also be opportunities to support services that facilitate access to transit including innovative mobility providers, ride hailing providers services, and carsharing programs.

- **Transit Customers.**

Park-and-rides are foremost a means to access transit, both bus service and rideshares. EV chargers facilitate access to transit by electric vehicles by ensuring an opportunity for vehicles to recharge. This increases charging options and driver confidence that they will be able to recharge their vehicles when needed. It will be important to continue to monitor and understand how transit customers use chargers. For example, based on license plate data collected at Metro park-and-rides, many park-and-ride users typically come from within a two-mile radius of a given lot. This is well within the round trip range of an average electric vehicle. Many EV users who travel short distance may not be regular EV charger users. They may choose to charge at home if they are able, especially if there's a fee for public charging at park-and-rides. Users who travel farther distances however may have more need of EV chargers – they may need to charge in order to return home or travel to another destination.

There may be policy considerations about who the EV users are and if there is a need to prioritize EV charger access. For example, Metro may want to consider opportunities to encourage carpooling in electric vehicles. The EV program could have an approach similar to Metro's parking program where carpools are granted free parking permits. While it may not make sense to provide free charging to carpools, there may be a way to overlay the parking program with the EV parking and provide discounts or priority EV parking.

- **Rideshare groups**

EV chargers at park-and-rides could potentially support electric commuter vans and Metropool, thereby further enhancing the climate benefits of ridesharing. Some rideshare vehicles are parked overnight at park-and-rides and they could take advantage of EV chargers to recharge. As rideshare transitions to electric vehicles, how to charge those vehicles is a question (as discussed in Section 8) and park-and-ride charging is one option. There is also the potential for these chargers to serve both rideshare vehicles overnight, and be available for the general public during the day.

Figure 22: EV chargers at parking rides contribute to public charger access.

First/Last Mile Providers

Another aspect of increasing zero-emission access to transit is to support emission reductions for first and last mile mobility options. To do this could include better integration with emerging modes including shared mobility services like carshare and ridehailing as well as micromobility vehicles like electric scooters and bikes.

- **On-Demand Mobility Services.** EV chargers at park-and-rides could facilitate the use of electric vehicles on-demand services and other innovative mobility providers that connect people to transit. For example, Metro's Via to Transit is a pilot on-demand service that connects riders to and from select transit hubs. For the pilot, Via is the contracted service provider and they provide the vehicles. The availability of chargers could make it more feasible for private contractors and service providers to use electric vehicles.
- **Transportation Network Companies (TNCs)/Ride-hailing.** Shared mobility options like ride hailing will likely play a growing role in providing access to transit. Helping to support the conversion of mobility provider vehicles to electric will help promote zero-emission access to transit and promote climate goals. A 2018 case study of electrified ride hailing by Atlas Public Policy determined that access to charging infrastructure is one of the primary barriers to EV ownership within the ride-hail driver community. The same case study stated that DC fast charging is critically important to ride-hail drivers. Since ride-hail drivers only earn income when providing rides, time spent charging must be minimized. Accessible, available fast charging is needed to support EV ride-hail drivers. Lyft has a stated goals are to provide 1 billion miles of travel in electric vehicles powered by 100 percent renewable energy by 2025 and (pre-COVID) had announced its intention of 100 percent electric vehicles by 2030. Metro could consider opportunities to work with TNCs to help promote installation of chargers, especially DC fast chargers at or near park-and-rides, and other passenger nodes.
- **Micromobility**
  Micromobility modes like electric bikes and electric scooters could potentially be zero-emission

options for getting to and from park-and-rides and other transit hubs. Park-and-rides and other transit facilities could support micromobility through availability of charging stations for these modes.

Options such as these offer possibilities but also raise potential policy questions. Metro park-and-rides are intended to support access to transit, which traditionally means providing parking for vehicles while people use the bus or rideshare. In the evolving mobility landscape, park-and-rides could increasingly serve as mobility hubs which support multiple modes, including services that provide access to transit. Mobility hubs could be designed to support zero-emission transit access by incorporating E-Mobility Hubs that provide an integrated suite of electromobility services like e-bikeshare, EV-carshare, and EV-ride hailing. An E-Mobility Hub is where transportation connections, travel information, and community amenities are aggregated into a comfortable, seamless, understandable, and on-demand travel experience that reduces the carbon footprint of transportation by supporting electrification of each mobility mode. Ultimately, it would be important to consider how to provide equitable access to transit across modes and users.

Equity and Access to EV Chargers

Providing additional vehicle chargers at park-and-rides would contribute to a more robust system of public chargers which could be particularly valuable for people who may not have reliable access to charging at home. For example, EV users who reside in multifamily housing units or without garages may not be able to reliably charge where they live. If EV users know they have alternatives for vehicle recharging, it can make charging more convenient and reliable.

Metro could also explore opportunities for partnerships to pair EV infrastructure investment with programs to promote electric transportation. For example, as a step to help promote EV use in lower income and disadvantaged communities, Metro could seek opportunities to invest in vehicle chargers at park-and-rides in those communities. From an initial review, four King County owned park-and-rides are located in priority census tracks from an equity and social justice (ESJ) perspective:

- Redondo Heights Park-and-ride
- Bear Creek Park-and-ride
- Kent/James Street Park-and-ride
- Tukwila Park-and-ride

There may be other park-and-rides lots whose catchment areas extend into areas with higher ESJ scores as well. These park-and-rides are located in areas with a higher proportion of people who speak English as a second language, who have lower median household incomes, and a higher percent of population that identifies as a racial or ethnic minority.

Simply installing EV chargers does not necessarily facilitate more electric vehicle use. Electric vehicles cost more than traditional vehicles, which can make them less accessible to lower income communities. However, these areas could be part of holistic strategies for increasing zero-emission access to transit. For example, the ‘Our Community Car Share’ is a program in Sacramento, California that places EV car share vehicles and Level 2 charging at low-income housing communities throughout the city. If similar programs were to develop in King County, Metro could work with them in planning for EV charger installation.

EV Charging Infrastructure

Cost of charging infrastructure is an important consideration. The cost and feasibility of installing chargers at park-and-rides depends largely on the existing electrical infrastructure, electrical capacity, and type of charger desired. There are three primary types of chargers available to charge light duty electric vehicles (such as passenger vehicles) - Level 1, Level 2 and DC Fast Chargers, as discussed in Section 8. Level 2 chargers are what is currently available at Metro's park-and-rides. Typical installation costs include trenching for electrical conduit and upgrades to electrical services panels. In larger installations, it can include upgrades to the local electrical distribution grid, such as transformer upgrades.

The electrical capacity of Metro's park-and-rides varies by age and facility type. When planning for addition of chargers at Metro park-and-rides, it will be important to conduct a thorough analysis of the electrical capacity at each park-and-ride. In general, many of the garages at Metro's park and rides were constructed in the early 2000s and are more likely to have been built with sufficient electrical panel capacity and electrical conduit to support increased electrical demand such as would be needed to support EV chargers. For example, South Kirkland, Issaquah Highlands and Burien garages each have existing EV chargers, though these sites may need some upgrades to support additional chargers.

A number of the King County park-and-ride lots are surface lots. Generally, surface lots only have a small electrical panel to support a comfort station and/or lighting. These sites will likely require a new service in order to support increased electrical demand, such as would be needed for EV chargers. Appendix I: King County Park and Ride Lots lists King County Metro-owned park and rides, including the date of opening. Some of these lots have been upgraded with parking garages since they were opened.

Smart Charging and Load Management

Public facing chargers would likely need to be networked ('smart' chargers), in order to track usage and be able to bill customers. Additionally, 'smart' charging and power load management software can help make sure chargers are using power in a manageable way. Such software can limit and balance power loads to avoid exceeding circuit capacity and avoid or minimize charging at times of day when costs are higher. Such software uses customizable algorithms to intelligently share power among networked chargers so every EV charges as fast as possible without exceeding the site's rated electrical capacity. Software can also help monitor the charging and distribute power among chargers within a group of networked chargers. This can allow users to identify the charging status of each charger, determine the availability status of chargers in real time, and enable reservations in advance. Software can also allow Metro to limit duration of charging sessions, or implement restrictions by day or time for specific users. Many EV charger providers offer a data tracking service for an added fee – these services facilitate real-time data tracking on a dashboard, collecting data on charger use, electrical consumption, revenue, and CO_2 Equivalent. For example, Metro currently contracts with Chargepoint for data tracking on its existing chargers.

Power management and power sharing within a bank of chargers could help address the issue of utilization versus charging time. As noted earlier one of the challenges with EV charger use at park-and-rides is that park-and-ride users usually park a vehicle for long periods which often exceeds the amount of time needed to charge. With power sharing among a bank of chargers, that power could be managed to charge multiple vehicles over the course of a day.

Payment

Metro currently charges a flat two dollars for a charging session, regardless of duration or amount of energy used. Metro currently uses networked Chargepoint chargers and users must have a Chargepoint account. Payment is through a smart phone app. Many systems are similar where customers pay though a smartphone app, which eliminates the need for a credit card reader. Any public facing chargers will need similar capabilities. Going forward it will be important to explore opportunities to integrate payment for vehicle charging with Metro's parking management system.

Public Private Partnerships

To help offset the costs of installing EV charging infrastructure and/or to encourage use of its chargers, there may be opportunities for Metro to develop public-private partnerships. Partnerships may offer a promising way forward and accelerate the development of charging infrastructure by tapping the private sectors' financial resources and industry experience. Metro could also explore opportunities to work with local jurisdictions and other public agencies. The potential partners include charging networks, utilities, and mobility providers.

Charging Network Programs

There are a number of groups with an interest in building and expanding the electric charging network. As part of their efforts, these groups offer pilot programs to install, operate and maintain vehicle chargers. Electrify America and EVGo are two examples that are offering opportunites right now. Both EVGo and Electrify America are more focused on DC Fast Chargers.

- **Electrify America**: Electrify America is one of the largest open DC Fast Charging networks in the United States. Funded by mitigation funding from its parent organization Volkswagen Group of America, Electrify America is investing over two billion dollars in mitigation funding over the next 10 years in Zero Emission Vehicle (ZEV) infrastructure, education, outreach, and exposure. The group is building a nationwide network of workplace, community, and highway chargers. Now completing its Cycle 2 round of charger installations, Electrify America is seeking urban locations that lack charging as target areas to install chargers. They are seeking partners who can provide sites for chargers. Electrify America would provide and maintain the charger. Some of the King County park-and-rides may be appropriate candidates for their DC Fast charging investment.

- **EVgo:** EVgo is a private EV charging company that specializes in developing high powered, fast chargers. EVgo owns and operates these chargers to serve the general public, ideally near high density residential development and retail. EVgo seeks partnerships with site hosts, prioritizing large, heavily utilized facilities in walkable, urban locations surrounded by amenities for its charging facility siting. There are some King County owned park-and-rides that could be good matches for EVgo criteria.

Both Electrify America and EVgo are focused on high power charging facilities. As discussed earlier, the availability of fast charging at King County park-and-rides could help create a network of chargers to enable service providers to use electric vehicles. Metro would need to further consider the pros and cons of locating fast chargers at its park-and-rides. Some of those considerations include the fact that fast chargers can take up a lot of room and require notable support infrastructure. This could displace existing parking stalls and could present a potential policy conflict for King County, if a DC fast charger is drawing people to the park-and-ride who are seeking a quick charge rather than a means to access transit. However, there are also potential opportunities that a DC Fast Charger can offer. Park-and-ride users who need to quickly charge before they return home or head to their next destination could benefit. Additionally, DC Fast Chargers are more conducive to supporting electric mobility services providing first/last mile connections such as ridehailing services. It could also support fast charging of a potential electric rideshare vehicle and other Metro and King County fleet vehicles.

Utilities

Other potential partners to a public-private contract could include the local electrical utilities—Seattle City Light or Puget Sound Energy. Both utilities are expanding their respective transportation electrification offerings. They are offering a range of pilot programs to increase access to electric vehicle charging. The programs currently offered are not necesarily the best fit for park-and-ride charging but both agencies have a greater vision for increasing vehicle charging and there are likely to be additional opportunities in the future.

Seattle City Light. Seattle City Light has developed an Electrification Stategy that identifies a number of actions that could support Metro, such as:

- Partner directly with King County Metro, the Port of Seattle, and Washington State Ferries to enable their transition to electricity.
- Based on gap analysis and stakeholder engagement, deploy City Light-owned DC Fast Chargers to satisfy underserved or undercapitalized markets where private network operators are less likely to invest.
- Develop creative solutions for customers without dedicated off-street parking.
- Provide incentives and technical expertise for commercial or industrial customers to install workplace chargers.
- Support charging for carsharing or other equity-focused programs, such as EV community carsharing. For example, rebates or incentives for charging infrastructure installation located at carshare parking spaces.

Puget Sound Energy (PSE). Pugest Sound Energy is also offering a number of pilot programs to support a range of markets, and could be a potential partner. It currently is operating the Up & Go program to promote the adoption of more electric cars in Washington State, support carbon reduction goals, and invest in charging infrastrcuture to meet customer demand for charging services. The program has six major components – education and outreach, residential charging, multifamily charging, workplace charging, public charging, and low income customers.

Other Opportunities.

There are other mechanisms that could help reduce the cost to Metro of deploying park-and-ride chargers. These include partnering with ridehailing services and, transit oriented developers, and seeking grant programs.

- **Ridehailing Services.**
  Ridehailing services such as Lyft and Uber have noted goals to encourage electrification of their fleets, as mentioned earlier. A robust network of electric chargers will be important to support this goal. Park-and-rides could be a valuable location for chargers to support these providers and, by doing so, promote opportunties for zero-emission access to transit. Supporting services

such as Uber and Lyft would be a broadening of park-and-ride uses from the current focus of offering vehicle storage for users to access transit to facilitating other modes of zero-emission access to transit. It will be important to consider the trade-offs. For example, dedicating space to support charging ridehailing vehicles could decrease capacity available transit users to park.

- **Transit-oriented development.**
  As development opportunities are considered at Metro park-and-rides, EV chargers could be a consideration. For example, if a park-and-ride is developed to include housing or commercial uses, it could be a target for installation of vehicle charging as well. To maximize chargers, it's helpful to combine markets such as making chargers available to commuters during the day and available for entertainment goers or shoppers in the evenings. This approach is dependent upon willing partners and appropriate facilities.
- **Grant programs.**
  Grant programs can help fund charger installation. The chargers currently in King County's system were largely funded initially through grants. With a growing interest in climate solutions, there are grant opportunities in support of electrification. Grants are not a guaranteed funding source however, and grant resources are finite. Pursuing grants could mean competing against other Metro interests.

Integration with Metro's Parking Program.
Integrating EV chargers into Metro's parking program would be a natural step as more chargers are in place. Managing the EV stalls could benefit from the parking management services utilized at the permit parking lots. Metro's permit program could potentially be expanded to manage EV charging by bundling the cost of reserved parking with the cost of EV parking, allowing them to park at designated "EV-Only" parking stalls accessible to chargers at Park-and-Rides. Options could be available for both SOVs and HOVs as well as for ORCA LIFT customers using pricing as a mechanism to manage demand for charging and incentivize EV usage and ridesharing, especially for priority populations.

Metro's permit program could also serve as a potential mechanism to help track EV charging fees.

V. Conclusion/Next Steps

Supporting zero-emission transit is integral to the County's SCAP and ESJ goals. Transportation is a significant driver of GHG emissions throughout the County, and Metro is one of the largest contributors to GHG emissions in County government. Additionally, the impacts of these pollutants disproportionately impact historically marginalized populations. Moving to zero-emission fleets will be costly and take time, but this is at the core of the County's values.

The COVID budgetary climate has impacted the agency's finances, Metro has included investments in the six-year capital improvement plan that would support the implementation of an additional 220 BEB (in addition to the 40 BEBs within the 2021-2022 biennium by 2028. The capital program also includes a number of projects that support ongoing planning efforts to advance electrification of the fleet and implementation of associated charging infrastructure. This will continue Metro down the path to becoming a zero-emission bus fleet by 2040. Under Metro's proposed fleet plan (2021-2022 Executive Budget Service – 2040 Electrification Fleet Plan) Metro's last purchase of diesel-hybrids is in 2023 and, beginning in 2025 ,only zero-emission fleet (either trolly buses or BEBs) are procured. All Metro-owned vehicles will be zero-emission by 2040. Electrical infrastructure begin as South Campus, located in Tukwila, with electrification of Interim Base and South Annex Base. Base electrification continues throughout the County to support a zero-emission fleet and is completed by 2040. With current commitments and current resources, the CIP Plan is recommended to move electrification forward and allows Metro meet its SCAP and emissions goals.

Metro is a leader in transit and adopting BEBs is a value statement demonstrating the agency and the County's commitment to the one of the most pressing issues of this generation: the reduction or elimination of tailpipe greenhouse gas and air pollution emissions providing both environmental and health benefits to the population, particularly historically, underserved populations. BEBs and their supporting infrastructure cost more than diesel-hybrids. Nearly two decades ago, transit agencies supported diesel-hybrids as a bridge technology that would allow for the maturation of BEB technologies. King County Metro was a leader in adopting this technology and currently operates one of the largest hybrid fleets in North America. At this time, hybrid buses, while still more expensive than diesels, are just as reliable diesels and provide reductions in emissions.

BEBs are now reaching their prime as evidenced by larger scaling efforts in New York City, Chicago, Los Angeles, Toronto, Edmonton, and other North American agencies. They have reached deeper market penetrations in Europe, South America and China, where there are thousands. This should result in procurement costs beginning to lower in the near term.[20]

The transition of Metro's non-bus revenue fleets is an important component of achieving the County's SCAP goals. Metro continues to consider opportunities to electrify balanced with a pace that is affordable given Metro financially constrained reality and that is in step with the industry. The Access vehicles are an emerging market that continues to develop. There is currently only one ADA compliant paratransit vehicle that has passed federal testing. However, Metro continues to monitor the market and explore opportunities to pilot vehicles. Metro could potentially pilot vehicles that are not federally tested to continue to assess available technology and push the industry. It would take further consideration however about whether it would be appropriate for system-wide use of a vehicle that was

[20] https://www.sustainable-bus.com/electric-bus/electric-bus-public-transport-main-fleets-projects-around-world/

not Altoona tested. The electric Access vehicle options are costly and there is a large capital cost to installing charging infrastructure. Metro needs to continue to evaluate the best locations to install this charging infrastructure and the property ownership (lease versus owning) model that supports such large capital investments.

Like Access, the rideshare vehicle options are limited but developing. The most in-demand vehicle in Metro's rideshare fleet is the 7-passenger van, for which there is no currently available electric alternative. Metro will monitor the vehicle market and will be poised to pilot electric alternatives as they become available. Metro could also continue and potentially expand its pilot of hybrid vehicles as a bridge to suitable rideshare options. Metro could also continue to incorporate smaller zero emission vehicles such as the Nissan Leaf where feasible. Customer feedback is generally positive for both the plug in hybrid vans and the Nissan Leafs, suggesting that fully electric vans would be well received. The higher cost of the electric vehicles may be a barrier that will need to be addressed since the rideshare program is required by King County code to recover 100 percent of its operating expense. Some ideas to help address this include modifying the cost-recovery requirements for electric rideshare vehicles, though this could have budgetary implications for Metro, and pursuing and encouraging development of grants and other funding to support electric rideshare purchase and operations. Additionally, there needs to be further development and investment in workplace charging to facilitate use of these vehicles. Charging opportunities at worksites whether through employers or public need to be available and convenient to use. This is largely beyond Metro's control, although Metro may be able to support and influence development in this area.

Installing additional vehicle chargers at park and rides could contribute to a more robust system of public chargers and facilitate zero emission access to transit. It will be important to develop a strategic approach that considers when and where chargers should be installed and who the target users should be while ensuring these chargers are equitably distributed throughout the County. Focusing initially on King County owned park and rides is a first step, since Metro controls these properties. It would be worth further exploring opportunities to work with jurisdictions and private entities. There may be opportunities through partnerships to locate EV charging in additional locations such as other transit and mobility hubs to increase access to EV charging and to promote zero emission access to transit.

There is the additional consideration of balancing dedicated parking for EVs with the parking needs of other customers. And, like all electric vehicles, the charging infrastructure adds expense but these could be mitigated by partnership opportunities, grants, and planning around transit-oriented development. As Metro moves this program forward it will need to balance the costs and equity needs with the best way to integrate these chargers into Metro's parking program. It will be important to integrate EV charging into the overall management of Metro's and potentially other regional agencies parking management strategies. Opportunities include aligning pricing approaches, integrating payment platforms, and aligning with parking management goals.

Investments in both Access/Rideshare electric vehicles and charging as well as charging infrastructure at Metro-owned park-and-rides will impact the resources available to invest in other capital programs.

Both the fixed-route and non-fixed route programs within Metro are actively working towards a zero-emission future. Metro will move forward in a way that balances its current fiscal reality with its desire to meet its SCAP and ESJ goals to make King County a more equitable place for all its citizens. The agency has taken it first step by ordering 40 BEBs which begin service in early 2022 from South Base Test

Facility in Tukwila. Additionally, in its proposed 2021-2022 budget, Metro plans to support 260 BEBs by 2028. While additional resources will be needed to reach the zero-emission goal, Metro will continue to work towards a zero-emission future.

VI. Appendices

King County Metro Transit
Future Fleet Planning

Appendix A: 2040 Electrification Fleet Plan

Color Key
- **OLDEST -** Retirable Fleet
- **CURRENT -** Fleet under FTA requirement
- **COMMITTED -** Planned/Incoming Purchases
- **PROJECTED -** Uncommitted Future Purchases

Major Fleet Assumptions:
- * 20% Spare Ratio as ongoing target
- * 55% Artic Target
- * Seattle CMC Svc/Fleet ends in 2020/21
- * Madison/G Line, 13 hybrid coaches, 2023
- * 20 60' & 20 40' Extended Range Battery Buses in 2022
- * RapidRide Program Continues to grow and adds 40' Fleet
- * The fleet is very old in '24 in anticipation of major reductions in '25-'26
- * NO Service Growth 2027-2040
- * 30 new 60' Trolley Coaches in '29
- * All Procurements in 2025 or later are ZEV (Battery & Trolley)
- * 60 35' Battery Bus replace 35' Hybrid Fleet in '30-'31 (North, Bellevue, South)
- * 100% ZEV in 2040

	Fleet Name	Fleet #	Fall 2019	Spr 2020	Fall 2020	Spr 2021	Fall 2021	Spr 2022	Fall 2022	Fall 2023	Fall 2024	Fall 2025	Fall 2026	Fall 2027	Fall 2028	Fall 2029	Fall 2030	Fall 2031	Fall 2032	Fall 2033	Fall 2034	Fall 2035	Fall 2036	Fall 2037	Fall 2038	Fall 2039	Fall 2040
Small (<40') Fleet	30' Diesel Gillig	1100	4	4	-																						
	35' Hybrid New Flyer	3700	60	60	60	60	60	60	60	60	60	60	60	60	60	60	30	-									
	40' Diesel New Flyer	3600	31	-																							
	40' Hybrid Daimler-Orion	7000	199	199	199	199	199	199	199	199	179	50	20	20	-												
	40' Hybrid New Flyer	7200	60	60	60	60	60	60	60	60	60	60	60	60	41	26	21	20	-								
	40' Hybrid Gillig	7300	177	195	195	195	195	195	195	195	195	195	195	195	195	195	195	195	134	103	103	47	42	38	-		
Artic (60') Hybrid Fleet	60' Hybrid New Flyer	2600	188	158	7	7	7	7	-																		
	60' Hybrid New Flyer	6800	187	187	187	187	187	187	154	146	146	35	17	17	-												
	60' Hybrid New Flyer (ODOT)	8000	85	85	85	85	85	85	85	85	85	85	85	85	72	35	8	-									
	60' Hybrid New Flyer (WSDOT, 2 Door)	8100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	15	5	-								
	60' Hybrid New Flyer (WSDOT, 3 Door)	8200	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	21	17	17	-					
Electric Fleet (Trolley & Battery)	40' Proterra Fast Charge (2016)	4600	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8	5									
	40' Trolley New Flyer	4300	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	-								
	60' Trolley New Flyer	4500	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	-								
	60' Battery	4800							20	20	20	20	20	20	20	20	20	20	20	20	20	14	13	4	1	1	-
	40' Battery	4900							20	20	20	20	20	20	20	20	20	20	20	20	20	19	15	14	12	7	-
	60' Future Trolley	100														30	30	30	30	30	30	30	30	30	30	30	30
	40' Future Battery	1000										10	10	10	45	45	55	55	55	55	55	55	55	55	36	36	10
	60' Future Battery	5000										65	65	65	95	95	200	200	200	200	200	200	185	174	151	115	105
	35' Future Battery	1200															30	60	60	60	60	60	60	60	60	60	60
	60' Future Battery	5200																	80	90	90	125	140	140	165	185	185
	40' Future Battery	1300																	90	90	90	110	120	120	180	180	200
BRT/RapidRide Hybrid or	40' RapidRide Battery Replacement+Growth	6500										30	30	30	30	30	30	30	30	30	30	30	30	30	30	24	-
	60' RapidRide Battery Replacement+Growth	6600													90	90	90	90	90	90	90	90	90	90	90	87	-
	60' RapidRide Battery Replacement + Growth	6700														10	15	40	40	65	65	80	80	115	115	145	250
	40' RapidRide Battery Replacement + Growth	6800														20	20	20	20	45	45	80	80	85	85	100	130
	METRO TOTAL FOR 2017/2018 BUDGET		**1,552**	**1,516**	**1,361**	**1,361**	**1,361**	**1,361**	**1,361**	**1,366**	**1,346**	**1,211**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**
Sound Transit	40' Sound Transit LF	90/91	5	5	3	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	40' Hybrid Sound Transit LF	9200	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	60' Diesel Sound Transit LF	9500	53	53	53	53	53	53	53	31	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	60' Hybrid Sound Transit LF	9600	60	60	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69
	ST TOTAL		**119**	**119**	**125**	**125**	**125**	**125**	**125**	**100**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
	ST Peak Signout		100	100	105	105	105	105	105	84	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
	TOTAL METRO OPERATED		**1,671**	**1,635**	**1,486**	**1,486**	**1,486**	**1,486**	**1,486**	**1,466**	**1,426**	**1,291**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**
	Metro Peak Signout		1,231	1,228	1,000	1,080	1,135	1,135	1,135	1,139	1,122	1,009	953	953	953	953	953	953	953	953	953	953	953	953	953	953	953
	Metro Spare Ratio		26.1%	23.5%	36.1%	26.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
	Metro Artic Ratio		58%	58%	53%	53%	53%	53%	52%	52%	53%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%
	Metro Retireable Fleet Ratio		14%	11%	1%	1%	14%	14%	24%	23%	33%	16%	17%	18%	20%	15%	16%	15%	19%	14%	14%	10%	9%	9%	13%	10%	0%
	% Electric (Battery + Trolley)		12%	12%	14%	14%	14%	14%	17%	16%	17%	25%	26%	26%	32%	37%	50%	55%	69%	74%	74%	83%	83%	85%	88%	90%	100%
	Battery Buses		11	11	11	11	11	11	51	51	51	156	156	156	311	341	488	540	705	765	765	863	868	887	925	940	940

King County Metro Transit
Future Fleet Planning

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* Madison/G Line, 13 hybrid coaches, 2023
* 20 60' & 20 40' Extended Range Battery Buses in 2022
* RapidRide Program Continues to grow and adds 40' Fleet
* The fleet is very old in '24 in anticipation of major reductions in '25-'26
* NO Service Growth 2027-2040
* 30 new 60' Trolley Coaches in '29
* **All Procurements in 2025 or later are ZEV (Battery & Trolley)**
* 60 35' Battery Bus replace 35' Hybrid Fleet in '30-'31 (North, Bellevue, South)
* **100% ZEV in 2035**

	Fleet Name	Fleet #	Fall 2019	Spr 2020	Fall 2020	Spr 2021	Fall 2021	Spr 2022	Fall 2022	Fall 2023	Fall 2024	Fall 2025	Fall 2026	Fall 2027	Fall 2028	Fall 2029	Fall 2030	Fall 2031	Fall 2032	Fall 2033	Fall 2034	Fall 2035	Fall 2036	Fall 2037	Fall 2038	Fall 2039	Fall 2040
Small (<40') Fleet	30' Diesel Gillig	1100	4	4	-																						
	35' Hybrid New Flyer	3700	60	60	60	60	60	60	60	60	60	60	60	60	60	60	30	-									
	40' Diesel New Flyer	3600	31	-																							
	40' Hybrid Daimler-Orion	7000	199	199	199	199	199	199	199	199	179	50	20	20	-												
	40' Hybrid New Flyer	7200	60	60	60	60	60	60	60	60	60	60	60	60	41	26	21	20	-								
	40' Hybrid Gillig	7300	177	195	195	195	195	195	195	195	195	195	195	195	195	195	195	195	134	103	103	-					
Artic (60') Hybrid Fleet	60' Hybrid New Flyer	2600	188	158	7	7	7	7	-																		
	60' Hybrid New Flyer	6800	187	187	187	187	187	187	154	146	146	35	17	17	-												
	60' Hybrid New Flyer (ODOT)	8000	85	85	85	85	85	85	85	85	85	85	85	85	72	35	8	-									
	60' Hybrid New Flyer (WSDOT, 2 Door)	8100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	15	5	-								
	60' Hybrid New Flyer (WSDOT, 3 Door)	8200	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	21	17	17	-					
Electric Fleet (Trolley & Battery)	40' Proterra Fast Charge (2016)	4600	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8	5	-								
	40' Trolley New Flyer	4300	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	-								
	60' Trolley New Flyer	4500	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	-								
	60' Battery	4800							20	20	20	20	20	20	20	20	20	20	20	20	20	20	19	15	10	5	5
	40' Battery	4900							20	20	20	20	20	20	20	20	20	20	20	20	20	20	16	11	9	4	1
	60' Future Trolley	100														30	30	30	30	30	30	30	30	30	30	30	30
	40' Future Battery	1000										10	10	10	45	45	55	55	55	55	55	55	55	55	5	5	-
	60' Future Battery	5000										65	65	65	95	95	200	200	200	200	200	200	200	184	166	140	124
	35' Future Battery	1200															30	60	60	60	60	60	60	60	60	60	60
	60' Future Battery	5200																	80	90	90	120	120	120	135	150	150
	40' Future Battery	1300																	90	90	90	155	160	160	220	220	220
	40' Future Trolley	200																	110	110	110	110	110	110	110	110	110
	60' Future Trolley	400																	64	64	64	64	64	64	64	64	64
BRT/RapidRide Hybrid or Battery	60' RapidRide (2010-2014)	6000	113	113	113	113	113	113	113	113	113	113	94	94	8	-											
	60' RapidRide (2016)	6200	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	39	39	14	14	-					
	60' Hybrid (RapidRide Ready) (2018)	620+	21	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	-					
	60' RapidRide 5-Door Hybrid (Madison BRT)	6400								13	13	13	13	13	13	13	13	13	13	13	13	-					
	40' RapidRide Battery Replacement+Growth	6500										30	30	30	30	30	30	30	30	30	30	30	30	30	30	21	-
	60' RapidRide Battery Replacement+Growth	6600													90	90	90	90	90	90	90	90	90	90	90	90	-
	60' RapidRide Battery Replacement + Growth	6700														10	15	40	40	65	65	110	110	130	130	145	260
	40' RapidRide Battery Replacement + Growth	6800														20	20	20	20	45	45	80	80	85	85	100	120
	METRO TOTAL FOR 2017/2018 BUDGET		**1,552**	**1,516**	**1,361**	**1,361**	**1,361**	**1,361**	**1,361**	**1,366**	**1,346**	**1,211**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**	**1,144**
Sound Transit	40' Sound Transit LF	90/91	5	5	3	3	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	40' Hybrid Sound Transit LF	9200	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	60' Diesel Sound Transit LF	9500	53	53	53	53	53	53	53	31	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	60' Hybrid Sound Transit LF	9600	60	60	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69
		ST TOTAL	**119**	**119**	**125**	**125**	**125**	**125**	**125**	**100**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**80**
		ST Peak Signout	100	100	105	105	105	105	105	84	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
		TOTAL METRO OPERATED	**1,671**	**1,635**	**1,486**	**1,486**	**1,486**	**1,486**	**1,486**	**1,466**	**1,426**	**1,291**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**	**1,224**
		Metro Peak Signout	1,231	1,228	1,000	1,080	1,135	1,135	1,135	1,139	1,122	1,009	953	953	953	953	953	953	953	953	953	953	953	953	953	953	953
		Metro Spare Ratio	26.1%	23.5%	36.1%	26.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
		Metro Artic Ratio	58%	58%	53%	53%	53%	53%	52%	52%	53%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%
		Metro Retireable Fleet Ratio	14%	11%	1%	1%	14%	14%	24%	23%	33%	16%	17%	18%	20%	15%	16%	15%	19%	14%	14%	3%	3%	21%	27%	23%	11%
		% Electric (Battery + Trolley)	12%	12%	14%	14%	14%	14%	17%	16%	17%	27%	29%	29%	42%	48%	60%	65%	79%	85%	85%	100%	100%	100%	100%	100%	100%
		Battery Buses	11	11	11	11	11	11	51	51	51	156	156	156	311	341	488	540	705	765	765	940	940	940	940	940	940

King County Metro Zero-Emissions Fleet

Battery Electric Bus Leased Testing KPIs

From: 9/23/2019
To: 6/20/2020

	Bus # 1750	Bus # 1751	Bus # 1752	Bus # 1753	Bus # 1754	Bus # 1755	Bus # 1756	Bus # 1757	Bus # 1758	Bus # 1759	New Flyer	BYD	Proterra	Total Program
Miles	948.10	7,958.10	12,815.99	12,281.48	10,556.37	9,683.28	8,887.79	7,785.36	3,393.10	617.70	45,337.12	20,683.95	8,906.20	**74,927.27**
Hours	67.98	428.84	770.06	608.60	544.16	475.95	680.58	630.34	323.22	40.35	2,398.77	1,674.49	496.82	**4,570.08**
kWh	1,812.70	14,311.75	27,050.85	24,822.53	31,529.96	26,878.98	17,988.69	15,490.14	8,324.47	1,412.10	110,282.32	43,215.40	16,124.45	**169,622.17**
kWh/mile	1.91	1.80	2.11	2.02	2.99	2.78	2.02	1.99	2.45	2.29	2.43	2.09	1.81	**2.26**
kWh/hr	26.67	33.37	35.13	40.79	57.94	56.47	26.43	24.57	25.75	35.00	45.97	25.81	32.46	**37.12**
In Service	94	119	170	172	142	102	145	141	73	21	586	380	213	**1,179**
OOS	178	153	102	100	130	170	1	5	73	125	502	204	331	**1,037**
Total days	272	272	272	272	272	272	146	146	146	146	1,088	584	544	**2,216**
Availability (%)	35%	44%	63%	63%	52%	38%	99%	97%	50%	14%	54%	65%	39%	**53%**
Utilization (%)	66%	71%	88%	76%	56%	53%	86%	32%	0%	19%	69%	40%	69%	**59%**
Failures	5	7	2	1	2	2	1	2	4	3	7	10	12	**29**
MDBF	189.62	1,136.87	6,408.00	12,281.48	5,278.19	4,841.64	8,887.79	3,892.68	848.28	205.90	6,477	2,068	742	**2,584**
OEM	Proterra	Proterra	New Flyer	New Flyer	New Flyer	New Flyer	BYD	BYD	BYD	BYD				
Length	40'	40'	40'	40'	60'	60'	40'	40'	60'	60'				
Passenger/Shadow	Shadow	Passenger	Passenger	Shadow	Shadow	Passenger	Shadow	Passenger	Passenger	Shadow				
ViriCiti Installed	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No				

Buses accepted by Metro	**10**	**pax svce**	in svce date	in pax date	end pax date
New Flyer 40'	2	**1**	1/11/2019	9/23/2019	3/20/2020
New Flyer 60'	2	**1**	1/10/2019	9/23/2019	3/20/2020
BYD 40'	2	**1**	8/6/2019	1/27/2020	TBD
BYD 60'	2	**0**	8/6/2019	3/11/2020	TBD
Proterra 40'	2	**1**	12/20/2018	9/23/2019	3/20/2020

Appendix D: Overview of BEB Technology

Battery-Electric Bus Technology Description

This section was prepared by the Center for Transportation and the Environment[21] and reflects industry-wide concepts that are applicable to other transit agencies as well as King County Metro.

Battery-electric buses use energy stored in an on-board battery pack to drive an electric motor (or motors) which turns the drivetrain and propels the bus. In addition to the energy provided for propulsion, the battery system provides energy to drive electric accessories, such as the heating, ventilation, and air conditioning (HVAC) system, air compressor, and power steering pump. Inverters are used to convert current from the battery (direct current, or DC) to a form that is useable by the motor and accessories (alternating current, or AC).
A down converter is used to reduce the DC voltage for delivery to the low voltage batteries, which are used to provide small amounts of electricity required while the bus is not operating or in motion. Components such as the multiplex I/O system, cameras, Wi-Fi and farebox can draw a load even while the vehicle itself is not being powered. Furthermore, a low voltage current is also required to close the contactors to start the bus. This type of current is provided by the low-voltage batteries. A high-level schematic of the vehicle systems is provided in Figure 1.

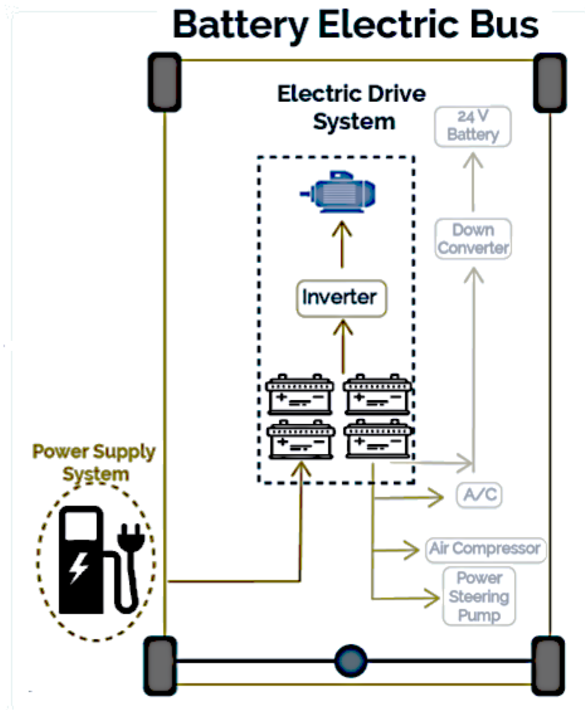

Figure 1. Basic Schematic of a Battery-Electric Bus

Table 1. Energy and Power Comparisons between Diesel and Battery-Electric Buses

Unit	Describes what?	Conventional Equivalent	Example
kWh (kilowatt-hours)	**Energy**	**Gallons** (of diesel)	The bus stores 450 kWh (12 gallons diesel)
kW (kilowatts)	**Power**	Output for Performance: **Horsepower**	The battery pack can provide 230kW (308hp)
		Input for Fueling: **Gallons/min**	The charger can provide up to 150 kW

Unlike a conventional diesel engine or a diesel-electric hybrid where the fuel is pumped from an external source into an onboard tank, the "fuel" for a battery-electric bus is provided by the electrical grid and applied to the vehicle by a charging system. Please refer to Table 1 for a summary of the primary concepts relative to battery-electric buses.

[21] Visit https://cte.tv/ for more information on the Center for Transportation and the Environment.

Energy
In a conventional diesel bus the amount of energy available on the bus is represented by the number of **gallons** of fuel in the tank. In an electric bus the amount of energy stored in the battery is represented in terms of **kilowatt-hours (kWh)**.

One limitation of today's battery-electric buses is that they cannot store as much energy as a diesel bus. Using the example in Table 1, the equivalent of 450kWh of energy is approximately 12 gallons of diesel fuel in a conventional bus. At four miles per gallon, a diesel bus that holds 12 gallons of fuel would only be able to travel **48 miles** before needing to refuel. However, battery-electric buses are much more efficient than diesel buses. Therefore, using that same amount of energy capacity, an electric bus may be able to travel **140 miles** or more on average (depending on conditions) before needing to recharge. However, a typical diesel bus may have a 100-gallon tank, giving it a **400-mile range** using the same assumptions. Using today's technology, the only way to match that range (on one charge) in a battery-electric bus is to add heavier and/or more batteries. Due to weight and space considerations, adding more batteries to compensate for the difference is not a viable option. As a result, a battery-electric bus currently has a shorter operating range than its diesel counterpart. Industry research efforts continue to focus on battery density and new chemistries to address the amount of energy batteries can store. Battery density has been improving year-to-year. It is not unreasonable to expect that battery-electric buses will be able to carry more stored energy without increasing weight or limiting passenger loads in the future, further reducing the energy deficit relative to diesel buses.

"Refueling" battery-electric buses takes longer than filling a diesel tank. The time required to charge a battery-electric bus (and provide the energy to operate) will vary based on the charging technology used. Typical base charging (using pedestal mounted chargers, for example) requires the bus to be plugged in for several hours in order to be fully charged. On-route charging, also called layover charging, takes advantage of scheduled stops or layovers to restore the state of charge of the battery and therefore extending the operational range. Using layover charging, range would be governed by the number of layovers and the amount of time available to charge at each opportunity.

It is critical for transit agencies to assess how battery-electric buses will perform in service prior to deployment. Developing a deployment strategy prior to purchasing and placing buses in service allows a transit agency to make decisions about energy storage and charging options, which are two of the distinct operating characteristics of battery-electric buses. It is also important to coordinate with the utility while developing a deployment strategy. Decisions about charging strategies will affect the time of day and amount of electricity consumed, which in turn affects costs. It is important that a transit agency understand all these factors related to providing energy to the buses prior to deployment.

Power
Power describes the rate of applying or using energy over time. In a conventional diesel vehicle, a common way this is used is to express the output or "performance" of an engine in terms of horsepower. The equivalent unit of measure in electric vehicles is **kilowatts (kW).** Power is what the battery pack can provide as an <u>output</u> to the vehicle for performance, such as speed and acceleration. However, power can also be used to describe the rate of energy being applied by the charger as an <u>input</u> into the battery to replenish it. When power is used to describe the input, the conventional equivalent is how fast a diesel pump can fill a tank (i.e., gallons/minute).

Power as an input is an important consideration during battery-electric bus operational planning because it determines the amount of time it will take to charge the battery. As discussed in relation to **Energy**, it is important to engage with the utility during planning. Depending on the power being applied by each charger and the number and type of chargers operating at the same time, it can also significantly impact the electricity bill.

What About Amps and Volts

Because power is an important concept, it is useful to understand what controls the amount of power that can be applied to a battery to charge it. In electrical terms, the basic equation is:

Power = Voltage × Current

or, equivalently, in electrical units:

Watts = Volts × Amps

Amperes, commonly Amps, is a measure of electrical current, and voltage is essentially the amount of electrical "pressure" available to move that current. Using the analogy of a water hose with an adjustable nozzle, one can think of current as the water flow through the hose, and voltage is like the amount of pressure available to spray the water when the nozzle lever is squeezed.

In the context of vehicle charging, the amount of power (rate of energy) applied is determined by both the power rating of the charger as well as the battery system that it is charging. The charger must match the battery pack's voltage, and the current is set according to the battery's ability to accept power. The battery pack and charger are in constant communication during charging and the battery pack will at all times limit the current from the charger based on the battery's capability. For this reason, simply dividing the battery capacity by the charger's power rating will not correctly predict charging times.

Appendix E: Alternatives Analysis for Charging Infrastructure and Layout

Alternatives Analysis Factors Overview

Alternatives Analysis Factors	**Layout 1**	**Layout 1A**	**Layout 2**	**Layout 3**
Semi-formal Name	T-poles	Plug-in	Bridge/Gantry	Ltd. Bridge/Gantry
Site Use and Operational Efficiency	3.0	3.0	4.0	2.0
Power Distribution Complexity	2.0	2.0	4.0	3.0
Construction Risks	3.0	3.0	1.0	1.0
Site Disruption	2.0	2.0	3.3	3.7
Construction Schedule	3.0	3.0	3.0	4.0
Future Proofed	3.0	3.0	4.0	1.0
Decommissioning	1.0	1.0	3.0	4.0
Cost	2.5	3.0	2.5	2.5
Total Score	**19.5**	**20**	***24.8***	**21.2**

Factors were scored from one to four. Four was the highest score.

Notes:

1. Layouts 1 and 1A require more physical space than layouts 2 or 3 either increasing the footprint of the base or reducing the number of buses that can operate from the base. One island is required for each row of buses unless the buses are parked in lanes opposing each other a design that introduces driving methods into the lanes that reduce the safety of drivers.

2. Layouts 1A has risks to Metro personnel engaged in plugging/unplugging buses to the chargers.

3. Layout 3 requires Metro personnel to move half the buses around at night and replacing them with the other half of buses. The layout intentionally has half the charging spots for the number of buses assigned.

4. Industry designs in North America such as LA, Edmonton-CA, Utah and other large scale charging locations align with layout 2 as most analysis supports this design that as the most easy and safe to operate; The bridge/gantry design option lends itself to future addition of solar-panels or battery energy storage to a level that the other three options do not without constructing a new structural element.

Further clarification of the Alternatives Analysis Factors

Site Use and Operational Efficiency – considers if the site will be used in the most operationally efficient manner by analyzing the following questions:

Is additional space provided for parking, maneuverability, and emergency maintenance?

Are the number of coach movements required to meet minimum fleet charge levels minimized?

Power Distribution System Complexity – considers the amount of power required by the utility by analyzing the following questions:

Is the area required for power equipment and conduit runs minimized?

Risks During Construction – considers the risk of construction delays by analyzing the following questions:

Are unusually long lead procurement times required?
And Is subsurface excavation/trenching and dewatering minimized?

Site Disruption and Compatibility with Other Improvements – considers disruptions to the site when converting a diesel-hybrid base to an electric base by analyzing the following questions:

Is there adequate room for shared use of the site?

Are the number of existing utility crossings minimized?

Are existing utilities required to be moved?

Construction Schedule and Phasing – considers meeting the BEB launch date by analyzing the following questions:

Can the phased BEB deployment schedule be met?

Future proof – considers the ability to upgrade technology by analyzing the following question:

Will the system configuration provide operational knowledge and training that is applicable for future BEB bases in other locations?

Future Decommissioning – considers if assets can be removed and repositioned by analyzing the following questions:

Will removing the BEB infrastructure in the future be efficient?

Can the removed infrastructure be more easily reused on another BEB base?

Cost – considers the ten year investment (Interim Base was designed as a life-limited asset) and cost of ownership by analyzing the following questions:

Is this the least total cost alternative?

Are additional costs (compared to other alternatives) justifiable such as for risk mitigation?

Appendix F: Data Model Memo

1. INTRODUCTION AND OVERVIEW

The following documentation includes the financial modeling input sources and calculation assumptions applied in the 2020 vehicle fleet transition evaluation; an update of analysis conducted for King County Metro in 2016-2017.

In addition to updates to the model input assumptions, the structure of the financial model has been refined since the 2016-2017 analysis to include:

- Evaluation of the replacement of Metro's 35-foot buses, previous analysis was limited to 40- and 60-foot vehicles
- Amortization of capital costs over the anticipated life of the vehicle or fueling asset

Values provided are subject to change and represent the assumptions as of July 2020 that were agreed up on by King County Metro in coordination with the consulting team (WSP and CTE).

2. GENERAL MODEL ASSUMPTIONS

The following assumptions are specific to the model structure and general fleet replacement schedule.

FLEET REPLACEMENT SCENARIOS

The financial model evaluates transit bus replacement for vehicles identified in the revised long-range Metro Fleet Plan through 2040. The revised fleet plan includes adjustments for recent revisions in part as a result of COVID-19 as of September 2020. The financial analysis excludes vehicles in the long-range plan, under 35 feet in length, trolley buses, and Sound Transit vehicles.

Three fleet purchase scenarios were evaluated in the model using different vehicle propulsion assumptions, with the first three years remaining constant.

ANTICIPATED NEAR-TERM VEHICLE DELIVERIES

The baseline vehicle procurement assumptions through 2023 assume the near-term vehicle purchases are constant for all scenarios and that existing vehicle orders will not be revised based on outcomes from this analysis. Vehicles purchased through 2023 are assumed to be retired during the long-range plan through 2040. Retired vehicles that are assumed to be replaced within the long-range plan through 2040 are included in the analysis.

Near term vehicle purchase assumptions are provided in *Table 1*.

Table 1: Baseline Vehicle Procurement Assumptions

NUMBER OF VEHICLES	2020	2021	2022	2023
40 Foot Diesel Hybrid Buses	18	-	-	-
60 Foot Diesel Hybrid Buses	7	-	-	13
40 Foot Battery Electric Buses	-	-	20	-
60 Foot Battery Electric Buses	-	-	20	-

LONG-RANGE VEHICLE REPLACEMENT SCHEDULE

Vehicle procurement assumptions after 2023 are based on full replacement of the existing fleet through the end of 2040, consistent with the fleet plan. Two scenarios evaluate the impacts of procuring (1) all diesel-hybrid electric vehicles and (2) all battery electric bus vehicles. In case two the assumption is the vehicles would operate on a blend of 5 percent biodiesel. The fleet purchase schedule is provided in *Table 2* by vehicle length.

Table 2: Forecast Vehicle Purchase Assumptions by Bus Length

NUMBER OF VEHICLES	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
2024	-	-	-
2025	-	40	65
2026	-	-	-
2027	-	-	-
2028	-	35	120
2029	-	20	10
2030	30	10	110
2031	30	-	25
2032	-	90	80
2033	-	25	35
2034	-	-	-
2035	-	55	50
2036	-	10	-
2037	-	5	24
2038	-	41	2
2039	-	9	1
2040	-	-	8

ESCALATION AND DISCOUNT RATES

All cost values are input into the model in current year (2019) dollars and escalated by different economic growth factors. The analysis is based on projections developed prior to the COVID-19 Pandemic and resulting recessionary pressures, and therefor may overestimate near term escalation rates providing a conservative approach in regard to cost projections.

SEATTLE CONSUMER PRICE INDEX FORECAST

The consumer price index for the Seattle-Tacoma-Bellevue metropolitan area is used as the basis for both escalating costs in pre-2019 dollars to the baseline model input values and for purposes of escalating costs to year of expenditure dollars.

Historical data through 2019 is sourced from the Federal Reserve Economic Data (FRED) CPI-U for all urban consumers in the Seattle-Tacoma-Bellevue metropolitan area. Values are based on annual averages without seasonal adjustments.

The forecast data is based on CPI-U forecast data sourced from King County and the State of Washington.

- Years 2020-2029 are sourced from the August 2020 King County Economic and Revenue Forecast published by the Office of Economic and Financial Analysis and based on the Seattle CPI-U projections.
- Years 2030-2040 are sourced from the June 2020 Washington State Office of Financial Management, Traffic and Revenue Forecast Council (TRFC) and based on HIS-Markit's February 2020 long-term growth forecast.

PRODUCER PRICE INDEX FORECAST

For evaluation of transit vehicle production cost projections, an incremental factor is calculated using the historical variance between the CPI-U for Seattle-Tacoma-Bellevue and the PPI for Bus Chassis Manufacturers as sourced from the Federal Reserve Economics Data (FRED) as published by the Federal Reserve Bank of St. Louis. Based on twenty years of historic differentials from 2000 to 2019 the incremental escalation for PPI has been 1.3 percent over the CPI-U.

SENSITIVITY TEST EVALUATION

In addition to scenario analysis based on the fleet propulsion assumptions, sensitivity tests were conducted for a moderate or base case and a favorable BEB vehicle case. The sensitivity tests are meant to provide a range of possible replacement cost outcomes based on different assumptions on the outlook on both capital and operating cost projections. In general, for most input variables a plus/minus twenty percent range was applied to the moderate case values to represent the range of potential cost outcomes. In some cases, including fuel and electricity prices, the forecast is based on source data projections for high and low socio-economic and price scenarios.

Table 3: Primary Sensitivity Test Assumptions – Impact on Results Represents the Percent of Total Cost Variance Between the Sensitivity Tests

COST CATEGORY	FAVORABLE BEB	MODERATE CASE	IMPACT ON RESULTS
BEB Purchase Costs	Moderate – 10%	WA and GA State Contracts	**Medium**
Vehicle Purchase Cost Escalation	No escalation through 2024 for BEBs	CPI-U with PPI Factor	**Very High**
Diesel Price Escalation Rate	USEIA – Table 12._Petroleum and Other Liquids Prices - High Oil Price	USEIA – Table 12._Petroleum and Other Liquids Prices – Reference case	**High**

COST CATEGORY	FAVORABLE BEB	MODERATE CASE	IMPACT ON RESULTS
Electricity Price Escalation Rate	USEIA – Table 8. Electricity supply disposition Prices and Emissions - High Oil Prices	USEIA – Table 8. Electricity supply disposition Prices and Emissions – Reference case	**High**
BEB Battery Cost	*2019 –* • 35 and 40 foot: $220,000 • 60 foot: $233,000 for 60 foot *Beyond 2030 –* • 35 and 40 foot: $64,167 • 60 foot: $67,958	*2019 –* • 35 and 40 foot: $220,000 • 60 foot: $233,000 for 60 foot *Beyond 2030 –* • 35 and 40 foot: $146,667 • 60 foot: $155,333	**High**
BEB O&M Cost	Equated to diesel operating cost	KC Metro vehicle O&M Cost Curve Analysis- Twenty years of detailed operational data by cost category and by fleet	**Very High**

OTHER GENERAL ASSUMPTIONS

In the 2020 analysis vehicle capital costs are amortized over the vehicle life. A simplified approach was taken in that capital costs in year of expenditure dollars were applied to a straight ratio of cost over the assumed life of the asset. A vehicle assumed to last 15 years would be evaluated using the capital costs for the projected year of operation divided by 15 and either provided in year of expenditure dollars or discounted to 2019 dollars.

The analysis assumes fueling and charging infrastructure are amortized over the life of the infrastructure. Electrical utility infrastructure has an assumed asset life of 40 years, direct vehicle charging infrastructure has an assumed asset life equivalent to the vehicle life of 15 years, and diesel underground storage and pumps have an assumed asset life of 30 years. The initial cost of designing and installing the supporting electrical infrastructure is included in the analysis while conventional fueling infrastructure is excluded from the analysis as storage tanks and pumps have already been installed at each of the bases and only future replacements cycles are assumed. Amortization assumes a set number of vehicles per base that does not change over the life of the asset. As an example, a BEB would incur the total cost of electric infrastructure, divided by the assumed number of vehicles per base, divided by the assumed 40 year life of the asset and applied each year for the 15 years the vehicle is assumed to be operating. Previous analysis assumed a single capital cost for each base divided by the number of vehicles per base in the year the vehicle was purchased.

In addition to vehicle and fueling/charging capital costs, amortization was applied to battery replacements for BEB's, periodic battery disposal costs for BEB's and vehicle disposal costs for all vehicle models. The amortization period for all elements are based on the assumed life of the vehicle or battery respectively.

3. CAPITAL COSTS

Capital costs consist of vehicle acquisition, additional options and charges, and supporting charging and fueling infrastructure. Capital costs are one-time costs incurred when the vehicle is acquired.

VEHICLE PURCHASE PRICE

For vehicles ranging in size between 35 foot to 60 foot, bus purchase price for hybrids range from $623,195 to $1,050,000, battery electric bus purchase price range from $698,000 to $1,400,000 and diesel bus purchase price range from $428,361 to $675,702. Bus acquisition costs are escalated annually by PPI Bus Manufacturing Forecast in moderate case. The escalated prices are used to determine the costs of bus procurement made in that particular year.

Vehicle prices are sourced from the existing Washington Statewide purchase contract terms for all vehicles with the exception of 35 foot BEB's which are sourced from the Georgia Statewide purchase contract as the vehicle specifications are more aligned with Metro's anticipated operating requirements than the vehicle models available through the Washington contract.

Table 4: Vehicle Purchase Price (in 2019 dollars) per Vehicle Type and Length in Moderate Case

VEHICLE TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
Hybrid	623,195	835,609	1,050,000
Battery Electric	698,000	956,150	1,400,000

ADDITIONAL OPTIONS AND CHARGES

As shown in *Table 5*, there are six categories under Additional Options and Charges. The costs under these six categories are consistent across all vehicle types and lengths. Contingency, however, varies based on the vehicle type and brand. Contingency is determined either at 5% for large firms or 10% for small firms of initial bus purchase price.

Assumed costs for options and charges are based on historical experience at Metro and consistent with the options and charges that are anticipated to be required on any future vehicle procurements to align with Metro's requirements.

For BEBs only an additional $40,000 is assumed to cover the incremental cost quoted by the vehicle manufacturers for an extended 12-year battery warranty. The standard battery warranty assumed under the base cost is 6-years.

Table 5: Additional Options and Charges (in 2019 dollars) for all Vehicles in Moderate Case

	ALL VEHICLES
Additional Options and Charges	9,597
Project Management	9,717
After Market Equipment	30,832
Training & Manuals	8,038
Service Preparation and Inspection	2.0%
Special Tools & Diagnostic Equipment	0.3%
	BEB Only
Extended 12 year Battery Warranty	$40,000

An additional contingency factor is included on all bus models and is based on the potential risk for costs exceeding the baseline capital cost estimates. For existing vehicle technologies and hybrids, the contingency factor is 5 percent while BEB's assume a 10 percent contingency based on both the risk of cost overruns for some of the smaller producers currently in the BEB market, and to align with recent experience on some BEB procurements with manufacturers that are new to the U.S. market and operational conditions and requirements.

Table 6: Contingency (in % Bus Acquisition Costs) for all Vehicles in Moderate Case

VEHICLE TYPE	ALL VEHICLES
Hybrid	5%
Battery Electric	10%

CHARGING/FUELING INFRASTRUCTURE

Charging and fueling infrastructure costs for hybrid buses are $109 per vehicle, based on replacement of underground storage tanks, pumps, and associated infrastructure. The current inventory of 24 tanks is assumed to be maintained and replaced over the forecast horizon with similar sized tanks at a replacement cost of $125,000 for each tank and pump based on quoted replacement costs. An additional 20 percent factor is applied to account for potential risk of contaminants and potential future tank enhancements to reduce the potential for leaks. The total cost of tank and pump replacements for the system is divided by the average fleet of 1,100 vehicles to derive a cost per bus of $3,273 in 2019 $s. With amortization over 30 years the amortized cost per year per bus is $109 in 2019 $s.

Supporting utility and charging costs for BEBs are based on recent designs on a facility that assumes charging equipment costs for 9 chargers with 12 heads and assuming two buses per charging station based on the South Base Test Facility. The resulting costs for battery electric buses are assumed to be $354,109 per vehicle based on the estimated costs for the South Base Test Facility. Amortized over 40 years results in a cost of $8,853 in 2019 $s per vehicle per year. An additional charging unit cost of $166,667 per vehicle, also based on the South Base Test Facility, is anticipated to be incurred with each vehicle replacement cycle of 15 years resulting in an amortized annual cost per vehicle of $11,111 in 2019 $s.

Table 7: Amortized Annual Charging/Fueling Infrastructure (in 2019 dollars) per Vehicle Type in Moderate Case

VEHICLE TYPE	FUELING INFRASTRUCTURE	CHARGING UNITS
Hybrid	$109	-
Battery Electric	$8,853	$11,111

4. OPERATING AND MAINTENANCE COSTS

Vehicle operations and maintenance (O&M) costs include general vehicle maintenance costs, tire service costs, fueling infrastructure annual costs, battery replacement costs and its frequency, and bus disposal/retirement costs.

VEHICLE MAINTENANCE

Vehicle O&M costs vary between the vehicle types and the length of the vehicles. Overall O&M costs are driven by cost per mile of each vehicle and its annual mileage in the financial model.

Operating and maintenance costs are based on analysis of existing Metro fleet operations for hybrid vehicles for 40- and 60-foot models. Costs are based on historical operating experience at Metro. Costs are evaluated using historical annualized cost curves over 15 years that consider the changing operating cost profile over the life of the vehicle. The one exception is Diesel 60-foot vehicles for which there is only nine years of available data using recent bus models..

The BEB 40-foot vehicle costs are based on five years of operating data and verified with limited industry operational experience through the National Renewable Energy Laboratory (NREL) analysis. NREL is a federal laboratory dedicated to research, development, commercialization, and deployment of renewable energy and energy efficient technologies and they test a wide range of operational vehicles to evaluate performance. After five years of operations the cost curve from 6 years to 15 years is based on annual cost increases for Metro's hybrid 40-foot fleet.

There is very limited data available on the operations of BEB 60-foot vehicles in the United States. Therefor an approach was taken to calculate the differentials in costs between existing trolley electric vehicles for 40-foot and 60-foot models and apply the differential to the BEB 40-foot bus cost analysis over the first five years of operations. After five years of operations the cost curve through 15 years is based on annual cost escalation for Metro's hybrid 60-foot fleet.

For 35-foot vehicles, existing operating costs were limited to Metro's current fleet of 60 35-foot hybrid vehicles. Based on the analysis of the 35-foot fleet the differential with the 40-foot fleet did not provide conclusive statistical differences between the 35- and 40-foot fleets and therefore the 40-foot fleet costs were used as the bases for evaluating the costs of the 35-foot vehicle replacements. The 35-foot fleet for BEBs varies slightly from the 40-foot BEBs after five years as the 35-foot BEB vehicle costs after five years are based on the annual percent increase of the 35-foot hybrid vehicles while the 40-foot BEBs are based on ratios with the 60-foot fleet.

Based on recent analysis of BEB conversions by NREL – *Financial Analysis of Battery Electric Transit Buses (June, 2020)* the cost of operating BEB's was assumed to be 27 percent less than conventional diesel vehicles. While this differs from the agencies evaluated as part of this analysis to confirm BEB operating cost data, the impact of keeping costs for BEB's equivalent to diesel vehicles was evaluated through the favorable electric sensitivity tests. Setting the cost equivalent to diesel vehicles is considered to be a best case scenario in this evaluation as operational evidence of lower costs has not been verified or validated.

Table 8: Vehicle Maintenance Costs (in 2019 dollars per mile) for Hybrid 35', 40' and 60' Buses in Moderate Case

UNIT AGE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
1	0.38	0.38	0.64
2	0.55	0.55	0.79
3	0.63	0.63	0.94
4	0.86	0.86	1.09
5	1.01	1.01	1.29
6	1.07	1.07	1.65
7	1.22	1.22	1.65
8	1.21	1.21	1.80
9	1.52	1.52	1.99
10	1.30	1.30	1.80
11	1.00	1.00	1.68
12	0.99	0.99	1.60
13	1.42	1.42	1.78
14	2.86	2.86	1.84
15	1.32	1.32	1.73

Table 9: Vehicle Maintenance Costs (in 2019 dollars per mile) for Battery Electric 35', 40' and 60' Buses in Moderate Case

UNIT AGE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
1	1.12	1.12	1.06
2	1.21	1.21	1.17
3	1.39	1.39	1.41
4	1.36	1.36	1.86
5	1.74	1.74	2.47
6	1.84	2.22	3.17
7	2.10	2.22	3.16

UNIT AGE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
8	2.07	2.42	3.45
9	2.60	2.68	3.82
10	2.22	2.43	3.46
11	1.72	2.26	3.22
12	1.69	2.16	3.07
13	2.43	2.39	3.41
14	4.90	2.48	3.54
15	2.26	2.33	3.32

VEHICLE TIRES

Vehicle tire service costs per mile are consistent across all vehicle types and vary only by vehicle's length. The financial model applies the tire cost per mile with the annual mileage to determine the overall tire costs incurred in a bus lifetime.

Tire maintenance and replacement costs are based on historical Metro experience and assumed to be the same for all vehicle propulsion types.

Table 10: Vehicle Tires Cost (in 2019 dollars) per Vehicle Type andin Moderate Case

	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
All vehicle types	0.065	0.065	0.065

VEHICLE FUEL COSTS

Battery electric buses utility costs are based on PSE / Seattle City Light (2019 – 2020) prices which includes demand charges. The utility costs are escalated using the United States Energy Information Administration (EIA) growth rates beyond year 2020. Diesel fuel costs are based on the wholesale values from the August OEFA forecast and exclude state and federal fuel taxes.

Total vehicle fuel costs are determined using the fuel efficiency for each vehicle type, fuel consumption per year and vehicle annual mileage.

Table 11: Vehicle Fuel Costs per Vehicle Type in Moderate Case

<table>
<tr><th>FUEL TYPE</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th></tr>
<tr><td>Battery Electric - Utility Costs (YOE $/kwh)</td><td>0.10</td><td colspan="3">Transition based on EIA growth rates</td></tr>
</table>

FUEL TYPE	2020	2021	2022	2023
Diesel - B5 (YOE$/gallon)	1.44	1.78	1.96	2.05

CHARGING AND FUELING INFRASTRUCTURE

Hybrid buses are assumed to have no charging and fueling infrastructure costs. Maintenance of battery electric buses charging and fueling infrastructure costs are based on limited experience to date and assumed at $218 per vehicle share of charging unit in 2019 dollars per year and escalated by Seattle CPI-U Index annually. The analysis applies the charging and fueling unit cost per bus and the annual bus count to determine the total charging and fueling infrastructure costs.

BATTERY REPLACEMENT

Hybrid vehicles do not incur battery replacement costs as they are embedded in the O&M costs. Battery electric buses assume $213,889 for 35 foot and 40-foot buses and $226,528 for 60-foot buses. Costs are based on current contracted disposal cost rates of $2.50 per pound. The analysis then assumes that battery electric buses will incur battery replacement costs every 12 years, primarily based on the anticipated battery life provided by the vehicle manufacturers under an extended battery warranty of 12 years.

Table 12: Battery Replacement Weight (in 2019 dollars.) per Vehicle Type in Moderate Case

VEHICLE TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
Battery Electric	213,889	213,889	226,528

5. DISPOSAL

Battery and bus disposal costs are assumed to occur on a periodic basis and at the end of the assumed vehicle life respectively and are amortized annually over the assumed life of the vehicle.

BATTERY DISPOSAL

Hybrid buses do not assume battery disposal costs. Battery electric buses incur battery disposal costs based on the battery's weight. The analysis applies the battery disposal costs at $2.50 per lb. with the battery weight to determine the overall battery disposal costs.

Table 13: Battery Disposal Costs (in lbs.) per Vehicle Type and Length in Moderate Case

VEHICLE TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
Hybrid	Battery replacement costs are included in O&M		
Battery Electric	8,703	8,703	11,077

BUS DISPOSAL

Bus disposal costs are determined as a percentage of initial bus acquisition costs. When retiring buses, hybrid vehicles assume to recoup 4 percent of the initial bus purchase cost. Battery electric buses assume to recoup 5 percent of the initial bus purchase cost at the time of bus retirement. The slightly higher assumption for BEB's is to account for the higher cost of disposal for some of the lighter weight materials used in the body of the vehicle that may not have the same opportunity and value in regards to potential for salvaging parts or components.

Table 14: Bus Disposal Costs (% of Bus Acquisition Costs) per Vehicle Type in Moderate Case

VEHICLE TYPE	ALL BUSES
Hybrid	4%
Battery Electric	5%

6. ENVIRONMENTAL

Environmental costs consist of tailpipe emissions, upstream emissions, and noise. The analysis converts these non-monetized values to cash costs. The environmental costs are measured in dollars per mile and the total cost calculations are driven by vehicle annual mileage.

EMISSIONS – TAILPIPE AND BRAKES

Tailpipe emissions consist of CO_2, NOx, SOx, PM_{10}, VOC, and $PM_{2.5}$. The analysis assumes different levels of tailpipe emissions in g/vehicle mile traveled (VMT) for hybrid and battery electric buses. Battery electric buses are assumed to only incur PM_{10} and $PM_{2.5}$ tailpipe emissions.

The source for emissions data is AFLEET emission factors, based on data from EPA's MOVES2014b emission factor model and Cal Trains BCA Model Assumptions for monetized values of PM10.

The analysis first converts the tailpipe emission in grams per mile to tons per mile, using the .000001 gram/ton conversion rate. The tons per mile is applied to the annual mileage to determine the overall tailpipe emission amounts. The analysis then applies the tailpipe emission amounts to dollars per tons to determine the total tailpipe emission costs as provided in Table 17.

Table 15: Tailpipe and Brake Emissions (in g/VMT) for Hybrid Vehicles in Moderate Case

EMISSION TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
CO_2	2,057	2,057	2,851
NOx	1.13	1.13	1.57
SOx	0.01	0.01	0.02
PM_{10}– Tailpipe	0.02	0.02	0.03
VOC	0.1	0.1	0.1
$PM_{2.5}$– Tailpipe	0.02	0.02	0.03
PM_{10} – Brakes	.11	.11	.11
$PM_{2.5}$ – Brakes	.01	.01	.01

Table 16: Tailpipe and Brake Emissions (in g/VMT) for Battery Electric Vehicles in Moderate Case

EMISSION TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
CO_2	-	-	-
NOx	-	-	-
SOx	-	-	-
PM_{10}– Tailpipe	-	-	-
VOC	-	-	-
$PM_{2.5}$– Tailpipe	-	-	-
PM_{10} – Brakes	.11	.11	.11
$PM_{2.5}$ – Brakes	.01	.01	.01

Table 17: Tailpipe and Brake Emissions (in 2019 dollars/ton)

EMISSION TYPE	EMISSIONS IN DOLLARS PER TONS
CO_2[22]	74
NOx	8600
SOx	50,100
PM_{10} (Tailpipe and brakes)	160,952
VOC	2,100
$PM_{2.5}$ (Tailpipe and brakes)	387,300

EMISSIONS – UPSTREAM

Upstream emissions consist of CO_2 and CH_4. The analysis assumes different levels of upstream emissions in g/VMT for hybrid buses. Battery electric buses are assumed to not incur upstream emissions.

The source for upstream emissions is AFLEET emission factors based on data from EPA's MOVES2014b emission factor model. No upstream emissions are assumed for BEBs as electricity is assumed to either be sourced from hydroelectric, or electricity from fossil fuel sources is assumed to include a carbon offset cost.

The analysis first converts the upstream emission in grams per mile to tons per mile, using the .000001 gram/ton conversion rate. The tons per mile is applied to the annual mileage to determine the overall upstream emission amounts. The analysis then applies the upstream emission amounts to dollars per tons to determine the total upstream emission costs as provided in Table 18.

[22] CO_2 emission values is in Year of Expenditures dollars per ton and was converted to 2019 dollars using a discount factor in the analysis

Table 18: Upstream emissions (in g/VMT) for Hybrid Vehicles in Moderate Case

EMISSION TYPE	35 FOOT BUSES	40 FOOT BUSES	60 FOOT BUSES
CO_2	291.4	291.4	404
CH_4	2.4	2.4	3.3

Table 19: Upstream Emissions (in Year of Expenditures Dollars/Tons)

EMISSION TYPE	EMISSIONS IN DOLLARS PER TONS
CO_2[23]	74
CH_4[23]	2,224

NOISE

Noise values and costs are derived from a study conducted by MTA in 2007 on noise differentials between various types of buses and FHWA Policy and Governmental Affairs guidance on Cost Occasioned Approach. No distinction was made in either study on the noise attributed to buses of different lengths. Noise costs are 0.067 dollars per mile for hybrid vehicles. Battery electric bus noise costs are at 0.05 dollars per mile. The analysis applies the noise costs per mile to the vehicle's annual mileage to determine the total noise costs.

Table 20: Noise Costs (in 2019 dollars/VMT) per Vehicle Type and Length in Moderate Case

<table>
<tr><th>VEHICLE TYPE</th><th>35 FOOT BUSES</th><th>40 FOOT BUSES</th><th>60 FOOT BUSES</th></tr>
<tr><td>Hybrid</td><td colspan="3">0.067</td></tr>
<tr><td>Battery Electric</td><td colspan="3">0.05</td></tr>
</table>

[23] CO_2 and CH_4 emission values is in Year of Expenditures dollars per ton and was converted to 2019 dollars using a discount factor in the analysis

Appendix G: Electric Vehicles Research

ELECTRIC VEHICLE RESEARCH

Potential battery-electric vehicle options for service in King County Metro's (Metro's) Non-Bus fleets are on the following pages, separated into three primary categories listed below. These vehicles could be considered for services such as Access, and Rideshare.

- **Cutaways** are medium-duty vehicles built on light truck chassis with specialized passenger cabs that accommodate ambulatory passengers, wheelchair passengers, or a mix of the two. These vehicles typically have wheelchair lifts and are commonly used for paratransit service. Fossil-fueled cutaways are currently in use in Metro Access.
- **Large vans** are factory-direct passenger vehicles that accommodate up to 15 passengers. These vehicles do not typically have wheelchair lifts (although lifts can be installed) and are currently used in Metro's VanPool program.
- **Minivans and sedans** are small, light-duty factory-direct passenger vehicles that accommodate up to seven passengers. Minivans can be outfitted with wheelchair lifts but sedans typically cannot. These vehicle types are currently used in Metro Rideshare programs.

Many of the electric vehicles below are built on an original equipment manufacturer (OEM) truck chassis, such as those manufactured by Ford or Chevrolet. These vehicles are rebuilt with third-party electric drivetrains and have specialized passenger bodies installed. The process of rebuilding an OEM chassis with an electric drivetrain involves removing the internal combustion engine and related parts and replacing them with an electric motor and drivetrain. Some of the vehicles included in the review are built entirely by a single OEM.

The reviewed vehicles are not a complete inventory of available makes and models but represent the promising battery-electric alternatives for existing Access, Rideshare, and DART fleets. Vehicles that are generally considered sports or luxury vehicles were excluded from this review, as they are not typically operated in public sector fleets. The current Washington State Department of Enterprise Services motor vehicles contract (#05916) excludes sports and luxury vehicles, although it does make exception for BMW i3 and Tesla Model 3.

The Chrysler Pacific Hybrid is included in this evaluation, despite not being a fully electric vehicle, because it is already in service in Metro's Rideshare fleet and is considered a feasible option for eliminating emissions from short trips. The Pacific Hybrid can operate for approximately 30 miles without engaging an internal combustion engine, which is enough purely electric travel to accommodate many Rideshare trips.

The information gathered for this assessment is from a combination of manufacturer and seller marketing materials, press releases, and direct correspondence. Range figures in particular are often best-case scenarios and not always achieved on a consistent basis. High-level vehicle range per charge and cost ranges are provided in Figure 30.

Figure 30 Electric Vehicle Availability Summary Table

Vehicle Type	Number of Models Assessed in This Document	Vehicle Range (miles)	Vehicle Cost Range
Cutaways	6	80-170	$200,000-$300,000
Large Vans	3	120-190	$160,000-$200,000
Minivans & Sedans	6	149-259*	$30,000-$40,000

*This range includes only fully-electric vehicles assessed. The Chrysler Pacifica Hybrid has an all-electric nameplate range of only 32 miles.

Depending on the future operational profile of Metro non-bus fleet operations, it appears there are suitable replacements currently on the market for many existing Metro Non-Bus vehicles, provided Metro is willing to make certain trade-offs. Key takeaways from the vehicle research follow, along with high-level reviews of suitable electric vehicles for Metro's Non-Bus fleets.

Key Takeaways

- Many of the currently available battery-electric light-duty transit vehicles are re-powered with electric drivetrains by third-party electrification companies using body-on-chassis cutaways.
  - The advantage of these vehicles is that they maintain the popular passenger body and ramp designs used by fossil-fueled ADA paratransit vehicles, and many of the non-drivetrain parts and systems are industry-standard.
  - These vehicles also have a number of disadvantages, including their high cost, inability to access federal funding (none of the battery-electric ADA paratransit body-on-chassis vehicles have been Altoona-tested), and lack of robust parts and maintenance ecosystems. Third-party electrification re-powers are generally performed by smaller companies that may not be able to offer the warranty, maintenance, and parts support that larger OEMs can provide for factory-direct battery-electric vehicles. Purchasing and maintaining vehicles from third-party repower manufacturers may be logistically challenging at the scale required to support Metro's Access fleet.
- As of May 2020, the only Altoona-tested ADA-accessible battery-electric light-duty transit vehicle is the GreenPower EV Star ADA (EV Star), which may be a suitable alternative vehicle for Access or Rideshare fleets.
- Battery-electric light-duty transit vehicles (including the EV Star) are typically significantly more costly than their fossil-fueled counterparts. Converting Metro fleets to these battery-electric alternatives will likely require more funding than fossil fuel capital replacement plans prescribe, and/or creative financing.
- There are many battery-electric passenger vehicles (primarily sedans) on the market with advertised single-charge ranges of more than 150 miles. These vehicles may be suitable battery-electric alternatives for Metro Rideshare fleets, should Rideshare programs consider using vehicles with a passenger capacity of fewer than seven people.
  - Reducing passenger capacity below seven passengers may restrict access to certain federal funds and require the purchase of additional vehicles, however.
  - Washington State law sets a minimum threshold of five passengers as the definition of a Rideshare vehicle, meaning the electric passenger vehicles in this document qualify as rideshares. The fifth seat in many of these vehicles, however, is small and uncomfortable for some potential Rideshare group members. Should a Rideshare group drop below five members because of this 'middle seat' problem, the group may no longer be considered a rideshare according to state definition.
- The battery-electric light-duty transit vehicle market is rapidly evolving. Vehicle classes that do not currently have battery-electric alternatives—such as minivans—will likely see multiple new models brought to market in the next few years.

Suitable Vehicles

- **Access:** Metro's Access fleet consists of hundreds of vehicles, all of which must be lift-equipped. Due to the fleet's size, a battery-electric vehicle will likely need to be accessible with federal funding and supported by a reliable warranty and/or maintenance ecosystem. The only vehicle on the market that meets these requirements in the GreenPower EV Star, which is Buy America-compliant and has been

Altoona tested, qualifying it for purchase with federal funds. Federal funds may be necessary to purchase EV Stars at scale, as they are more than twice as costly as Metro's current fossil fueled cutaways.

The EV Star is likely reliably capable of between 77 and 120 miles before needing to be recharged.[24] These ranges represent approximately 13% and 70% of current Access pullouts, respectively. This suggests that many—and perhaps most—Access deployments can be accommodated by the EV Star. Some deployments would need to change to accommodate the range limitations of the EV Star.

GreenPower can currently produce approximately 30 EV Stars per month but is expanding manufacturing capacity. This limit to manufacturing capacity may present supply limitations for Metro in the near-term.

- **Rideshare:** Metro has more options for Rideshare vehicles than for other Non-Bus fleets, as 95% of daily round-trip mileage for Rideshares are below 80 miles. There are a number of available five-passenger electric vehicles with range capabilities significantly greater than 80 miles on a single charge, but these vehicles do not meet the seven-passenger federal definition of vanpool, which may restrict access to funds. These smaller vehicles may also require Metro to purchase additional vehicles, as 98% of Metro's Rideshare vehicles accommodate seven or more passengers.

  The EV Star is also suitable for Rideshare purposes, as it accommodates at least 15 passengers, including the driver. It can be purchased with federal funds, but the base price of $200,000 is more than four times the cost of a small passenger electric vehicle.

[24] The high end of this range (120.2 miles) is the Altoona Orange County test cycle results, which does not account for battery degradation over time. The low end of the range (77 miles) is 80% of the Altoona Manhattan test cycle results (96.3 miles), where the 80% is an assumption of battery capacity after mid-life degradation. This 80% figure is the assumption used in the 2019 Foothill Transit In Depot Charging and Planning Study.

Figure 31 is a table of the vehicles reviewed in this document, including cost, passenger capacity, availability, and applicability for consideration in each of Metro's Non-Bus fleets. The colored circles indicate each vehicle's ranking relative to one another on a qualitative scale within the context of potential application for Metro service.

Figure 31 Electric Vehicles for Metro Non-Bus Fleet Suitability Criteria Matrix

	Cutaways						*Vans*			*Passenger Vehicles*					
Criteria	**Phoenix Zeus 400**	**Lightning Electric E-450**	**Lightning Electric F-550**	**Micro Bird DS-Series**	**Motiv Power EPIC E-450**	**SEA E-450**	**Lightning Electric Transit**	**GreenPower EV Star ADA**	**SEA Transit**	**Chevy Bolt**	**Chrysler Pacifica Hybrid**	**Hyundai Ioniq SE**	**Hyundai Kona Electric SEL**	**Kia Niro EV**	**Nissan Leaf**
Cost				N/A				(Altoona tested and Buy America)							
Passenger Capacity										(no lift and only five passengers)	(no lift)	(no lift and only five passengers)	(no lift and only five passengers)	(no lift and only five passengers)	(no lift and only five passengers)
Availability	Available but likely not at scale	Available but likely not at scale	Available but likely not at scale	Presumed available	Available but likely not at scale	Available but likely not at scale	Available but likely not at scale	Available but likely not at scale	Available but likely not at scale	Available at scale	Available at scale	Available at scale	Available at scale	Available at scale	Available at scale
Applicable for Consideration in Metro Non-Bus Fleets	Applicable to Access and DART	Applicable to Access and DART	Applicable to DART	Applicable to Access and DART	Applicable to Access and DART	Applicable to Access and DART	Applicable to Access and Rideshare	Applicable to Access, DART and Rideshare	Applicable to Access and Rideshare	Applicable to Rideshare	Applicable to Rideshare	Applicable to Rideshare	Applicable to Rideshare	Applicable to Rideshare	Applicable to Rideshare

= Low

= Medium

= High

Cutaways and Small Buses

Note: Because re-powered vehicles are not in widespread use and there have been few—if any—formal evaluations of their performance, specifications such as range and cost are not consistently available for these vehicles. Throughout this document, the letters N/A are substituted when information is not available or not considered reliable.

Phoenix Motorcars Zeus 400 Shuttle Bus

The Phoenix Motorcars Zeus 400 is an electric cutaway that incorporates a Ford E-series chassis and Starcraft passenger body. Phoenix Motorcars is a California-based company that electrifies vehicles in Ontario, CA. These vehicles are available with both rear or side lifts.

Phoenix offers the Zeus 400 with four battery pack sizes, from 63kWh to 156kWh. The weight of the largest battery pack reduces the number of passengers that can be accommodated in the vehicle due to maximum load restrictions of the chassis. More passengers can be included in a vehicle with a small battery pack.

Specification	Specification Value(s)
Passenger capacity	Up to two wheelchair and 12 ambulatory passengers with a 156kWh battery. The number of wheelchair positions can be increased if ambulatory positions are eliminated.
Lift-capable?	Yes, with rear or side configurations
Battery size	63kWh, 94kWh, 125kWh, and 156kWh
Approx. nameplate single-charge range	70 miles, 100 miles, 130 miles, 160 miles
Length	23' to 25'
Approx. cost	$300,000[25]
Availability	In use at California and Texas airports, City of Redlands, and City of Santa Cruz

Sources: <http://www.phoenixmotorcars.com/products/>,
<https://www.latest.facebook.com/PhoenixMotorcarsZEUS/LightningElectric Ford E-450 Shuttle Bus>,
<http://www.phoenixmotorcars.com/city-of-redlands-receives-1st-electric-shuttle-bus/>,
Correspondence with Phoenix Motorcars and Creative Bus Sales

[25] The cost of the Phoenix Motorcars electric drivetrain conversion is reported to be approximately $150,000, and the highest cost for a medium-duty 24-passegenger cutaway bus in Washington State's current Department of Enterprise Services contract #04115 is approximately $150,000 (the lower end of the range is approximately $80,000). Using these figures, a conservative estimate for the cost of this vehicle is $300,000.

Image source: <http://www.phoenixmotorcars.com/wp-content/uploads/2017/08/vehicle-01.jpg>

Lightning Electric Ford E-450
Shuttle Bus

The Lightning Electric Ford E-450 shuttle bus is an electric cutaway built on a Ford E-450 chassis. Lightning Electric is headquartered in Loveland, CO.

Specification	Specification Value(s)
Passenger capacity	Typically two wheelchair and 12 ambulatory passengers, with a 129kWh battery pack. Ambulatory positions can be removed to add wheelchair positions.
Lift-capable?	Yes
Battery size	86kWh or 129kWh
Approx. nameplate single-charge range	80 or 120 miles, depending on battery size.
Length	25'
Approx. cost	$230,000
Availability	Available

Sources: <https://lightningsystems.com//lightningelectric-e450-shuttle/>,
<https://petaluma.granicus.com/MetaViewer.php?view_id=31&clip_id=2728&meta_id=424736
>,
Correspondence with Lightning Systems

Image source: <https://lightningsystems.com/wp-content/uploads/2019/11/E450_shuttle_600px.png>

Lightning Electric Ford F-550 Shuttle Bus

The Lightning Electric Ford F-550 shuttle bus is a larger version of the Lightning Electric E-450 high-floor electric cutaway. The vehicle is built on a Ford F-550 chassis, allowing for more passenger capacity than an E-450, in a similar vehicle. Lightning Electric is headquartered in Loveland, CO.

Specification	Specification Value(s)
Passenger capacity	Typically two wheelchair and 20-30 ambulatory passengers
Lift-capable?	Yes
Battery size	160kWh or 192kWh
Approx. nameplate single-charge range	120 miles
Length	32'

Approx. cost	$270,000
Availability	Available

Sources: <https://lightningsystems.com/lightningelectric-f-550-bus/>, Correspondence with Lightning Systems

Image source: https://lightningsystems.com/wp-content/uploads/2019/11/F550_bus2.png

Micro Bird DS-Series Paratransit

The Micro Bird DS-Series electric shuttle bus is a lift-equipped cutaway built on a Ford or GM chassis. The wheelchair lift on this vehicle is typically installed behind the rear axle. Micro Bird Bus is a joint venture between U.S. school bus manufacturer Blue Bird and Canadian busmaker Girardin. These vehicles are primarily manufactured in Canada. Further information on this vehicle is needed from the manufacturer.

Specification	**Specification Value(s)**
Passenger capacity	N/A
Lift-capable?	Yes
Battery size	N/A
Approx. nameplate single-charge range	N/A
Length	24'-29'
Approx. cost	N/A
Availability	N/A

Sources: <https://mbcbus.com/product/d-series/>

Image source: <https://mbcbus.com/wordpress/wp-content/uploads/2014/09/Microbird-G5-with-Lift-Door-streamer_with-stripes-1140x676.jpg>

Motiv Power EPIC E-450 Shuttle Bus

The Motiv Power Electric Powered Intelligent Chassis (EPIC) E-450 shuttle bus is built on the Ford E-450 platform with a Champion passenger body. The wheelchair lift on this vehicle is typically installed behind the rear axle. Motiv Power is based in Foster City, CA. Further information on this vehicle is needed from the manufacturer.

Specification	Specification Value(s)
Passenger capacity	N/A
Lift-capable?	Yes
Battery size	106kWh
Approx. nameplate single-charge range	85 miles
Length	N/A
Approx. cost	$250,000[26]
Availability	In use in Mountain View, CA and other California locations.

Sources: <https://www.motivps.com/motivps/portfolio-items/epice450-allelectric-shuttlebus/>, <https://www.trucks.com/2018/05/30/motiv-profits-demand-electric-trucks-buses/>, Correspondence with Creative Bus Sales

Image source: <http://www.motivps.com/motivps/wp-content/uploads/2019/06/E450-Champion-shuttle-right-edited-NEW-1000x700.png>

[26] The cost of the Motiv Power electric drivetrain conversion is reported to be approximately $150,000, and the highest cost for a light-duty 12-passegenger cutaway bus in Washington State's current Department of Enterprise Services contract #04115 is approximately $100,000 (the lower end of the range is approximately $60,000). Using these figures, a conservative estimate for the cost of this vehicle is $250,000.

SEA E450 Shuttle Bus

The SEA Electric E450 shuttle bus is built on a Ford E-450 chassis with the SEA-Drive 100 electric drivetrain. Although SEA Electric is an Australian company, this vehicle is primarily manufactured in the U.S.

Specification	Specification Value(s)
Passenger capacity	Typically two wheelchair and 12 ambulatory passengers. Ambulatory positions can be eliminated to add wheelchair positions.
Lift-capable?	Yes
Battery size	100kWh
Approx. nameplate single-charge range	130-170 miles
Length	N/A
Approx. cost	$200,000
Availability	Available

Source: <https://www.sea-electric.com/wp-content/uploads/2019/10/E4B-Commuter-Bus-ebrochure-AU.pdf>,
<https://www.carsales.com.au/editorial/details/aussie-ev-maker-plans-new-production-facility-in-latrobe-valley-115381/>

Image source: <https://www.sea-electric.com/wp-content/uploads/2019/10/SEA-E4B-FRONTFWY.jpg>

Large Vans

Lightning Electric Ford Transit Passenger Van

The Lightning Electric Ford Transit is a large passenger van built on the Ford Transit platform. Lightning Electric is headquartered in Loveland, CO. This vehicle includes double rear-wheel assemblies to accommodate battery weight.

Specification	**Specification Value(s)**
Passenger capacity	One wheelchair and four ambulatory passengers or up to 15 ambulatory passengers
Lift-capable?	Yes
Battery size	43kWh or 86kWh
Approx. nameplate single-charge range	60 or 120 miles
Length	18’-22’
Approx. cost	$173,000
Availability	In use in Porterville, CA; planned for use in Los Angeles, CA; in use in private sector operations in Seattle

Sources: <https://lightningsystems.com/lightningelectric-ford-transit-shuttle/>,
<https://www.californiahvip.org/vehicles/lightning-systems-lightningelectric-drivetrain-on-ford-transit-350hd-passenger-bus-60-mile-range/>,
<https://www.ford.com/commercial-trucks/transit-cargo-van/models/transit-van/>,
Correspondence with Lightning Systems

Image source: <https://lightningsystems.com/wp-content/uploads/2019/11/transit_passenger_01_cropped-1.png>

GreenPower EV Star ADA

The EV Star ADA vehicle is a large passenger van built entirely by GreenPower. This vehicle recently passed Altoona testing, which provides some demonstrated range figures.[27] During the testing process, this vehicle was tested under Manhattan, Orange County, and EPA Heavy-Duty Urban Dynamometer Driving Schedule (HD-UDDS) testing conditions, achieving ranges of 96, 120, and 153 miles, respectively. The Manhattan test cycle simulates a low average speed urban driving context, while the Orange County test cycle simulates a combination of highway and urban driving conditions. The EPA HD-UDDS test simulates longer periods of higher-speed driving.

EV Star vehicles undergo final assembly in California and are Buy America-compliant. At the time of this report, GreenPower estimates manufacturing capacity to be 30 vehicles per month with a 180-day lead time. The lithium-ion battery is warrantied to 80% of its nameplate capacity for five years or 100,000 miles and is rated for 4,000 use cycles. The wheelchair lift can be installed as side- or rear-operating.[28]

Specification	**Specification Value(s)**
Passenger capacity	Two wheelchair and 14 ambulatory passengers but can be reconfigured with more wheelchairs and fewer ambulatory passengers
Lift-capable?	Available with side or rear lift
Battery size	118kWh
Approx. nameplate single-charge range	96-150 miles
Length	25’
Approx. cost	$200,000
Availability	In use at the Port of Oakland, Sacramento Regional Transit District, and Antelope Valley Transit Authority

Sources: <https://www.greenpowerbus.com/product-line/>, Correspondence with GreenPower

Image source: <https://www.greenpowerbus.com/wp-content/uploads/2019/01/shuttle-buses.jpg>

[27] Federal Transit Administration. April 2020. *Federal Transit Bus Test Report Number LTI-BT-R19113*. <http://apps.altoonabustest.psu.edu/buses/reports/515.pdf?1586273484>

[28] Phone correspondence with GreenPower representative. June 23, 2020.

SEA Electric Ford Transit

The SEA Electric Ford Transit is built on a Ford Transit chassis and incorporates a SEA-Drive 70 electric drivetrain. This vehicle has double rear wheel assemblies to accommodate battery weight.

Specification	Specification Value(s)
Passenger capacity	Two wheelchair and nine ambulatory passengers. Ambulatory positions can be eliminated to add wheelchair positions.
Lift-capable?	Yes
Battery size	88kWh
Approx. nameplate single-charge range	190 miles
Length	18’-22’
Approx. cost	$160,000
Availability	Currently being tested by the United States Postal Service.

Sources: <https://www.greenpowerbus.com/product-line/>, Correspondence with SEA Electric

Image source: <https://www.greenpowerbus.com/wp-content/uploads/2019/01/shuttle-buses.jpg>

Minivans and Sedans

Chevy Bolt

The Chevy Bolt is a four-door hatchback that is widely available in the U.S. and is manufactured in South Korea and Michigan.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	66kWh
Approx. nameplate single-charge range	259 miles
Length	~14’
Approx. cost	$37,495
Availability	Available

Source: <https://media.chevrolet.com/media/us/en/chevrolet/vehicles/bolt-ev/2020.tab1.html>, <https://media.chevrolet.com/content/media/us/en/chevrolet/vehicles/bolt-ev/2020/_jcr_content/iconrow/textfile/file.res/2020%20Chevrolet%20Bolt%20EV%20Product%20Guide.pdf>

Image source: <https://www.chevrolet.com/content/dam/chevrolet/na/us/english/index/vehicles/2020/cars/bolt-ev/colorizer/01-images/2020-bolt-2lz-gpj-colorizer.jpg?imwidth=600>

Chrysler Pacifica Hybrid

The Chrysler Pacifica Hybrid is a seven-passenger plug-in hybrid electric vehicle (PHEV) manufactured in Windsor, Canada. Although not a fully electric vehicle, its nameplate range without engaging the internal combustion engine is 32 miles.

Metro has piloted this vehicle in its VanPool program since 2019. The pilot demonstrated that these PHEVs can significantly improve the mileage of Rideshare vehicles, up to 90mpg. The overall mileage achieved by the Pacificas in the pilot program was 63mpg. This vehicle does not, however, meet the goals outlined in King County ordinance 2019-0435.[29]

Specification	Specification Value(s)
Passenger capacity	Up to seven ambulatory passengers, including driver
Lift-capable?	No
Battery size	16kWh
Approx. nameplate single-charge range	32 miles using battery-only
Length	~17’
Approx. cost	$39,995
Availability	Available

Sources:

<https://www.chrysler.com/bmo.pacifica_hybrid.2020.html#/models/2020/pacifica_hybrid?app=bmo&vehicle=pacifica_hybrid&year=2020>, <https://media.fcanorthamerica.com/newsrelease.do?id=344&mid=>

Image source: <https://www.chrysler.com/bmo.pacifica_hybrid.2020.html#/models/2020/pacifica_hybrid?app=bmo&vehicle=pacifica_hybrid&year=2020>

[29] King County Council. 2020. *Ordinance 2019-0435*. <https://mkcclegisearch.kingcounty.gov/LegislationDetail.aspx?ID=4159832&GUID=8B07F910-705E-4EC0-AFEA-99EAEEC5182D&Options=&Search=>

Hyundai Ioniq SE

The Hynudai Ioniq is four-door, battery-electric sedan manufactured in South Korea.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	38.3kWh
Approx. nameplate single-charge range	170 miles
Length	15’
Approx. cost	$33,045
Availability	Available

Source: <https://www.hyundaiusa.com/us/en/vehicles/ioniq-electric>,
<https://www.hyundaiusa.com/us/en/vehicles/ioniq-electric/compare-specs>

Image source: <https://www.hyundaiusa.com/us/en/build/summary/#/379H1N3O1M0>

Hyundai Kona Electric SEL

The Hynudai Kona is a crossover SUV manufactured in South Korea.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	64kWh
Approx. nameplate single-charge range	258 miles
Length	~14’
Approx. cost	$37,190
Availability	Available

Source: <https://www.hyundaiusa.com/us/en/vehicles/kona-electric>,
<https://www.hyundaiusa.com/us/en/vehicles/kona-electric/compare-specs>

Image source: <https://www.hyundaiusa.com/us/en/build/summary/#/368A1N1F1Q0>

Kia Niro EV

The Kia Niro is a subcompact crossover vehicle manufactured in South Korea.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	64kWh
Approx. nameplate single-charge range	239 miles
Length	~14’
Approx. cost	$38,500
Availability	Available

Source: <https://www.kia.com/us/en/niro-ev>, <https://www.kia.com/us/en/niro-ev/specs>

Image source: <https://www.kia.com/us/en/niro-ev/build>

Nissan Leaf S, SV, S Plus, and SV Plus

The Nissan Leaf is a four-door hatchback in widespread use throughout the U.S., including in Metro's MetroPool rideshare fleet. This vehicle is available in four models with varying cost, range, and features, and is manufactured in Tennessee. The low end of the price range included here is the base price for the Leaf under Washington State DES' Contract 05916 for motor vehicles.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	40kWh-62kWh
Approx. nameplate single-charge range	149-226 miles
Length	~15'
Approx. cost	$27,885-$39,750
Availability	Currently in use in Metro's MetroPool Rideshare fleet.

Source: <https://www.nissanusa.com/vehicles/electric-cars/leaf.html>, <https://apps.des.wa.gov/CARS/ContractVehicleMenu.aspx>

Image source: <https://www.nissanusa.com/vehicles/electric-cars/leaf/build-price.html#configure/Apcpq/version>

Appendix H: PHEV Six Month Review

Pacifica PHEV Pilot
February 20, 2020

Pilot Overview

10 Chrysler Pacifica PHEV Hybrid minivans were put into service to test how hybrid technology works in a commuter van program. The vans were place with experienced vanpoolers in a range of commute circumstances. Data is being collected from Fleet Ops as well as from the groups. Some preliminary findings:

- ✓ *6 Months of data collected*
- ✓ *30,117 All-Electric miles driven*
- ✓ *12,730 Gas miles driven*
- ✓ *42,847 Total miles driven*
- ✓ *681 Gallons of gas used*
- ✓ *62.9 mpg avg.*
- ✓ *1,573 Gallons saved*
- ✓ *36,984 lbs. GHG saved*
- ✓ *More regular charging = better savings*

We polled the groups to find out about the "customer experience" aspects of operating and charging a hybrid commute vehicle. Some responses:

- ✓ *Convenience of daily charging rated 33 out of 100*
- ✓ *42% able to find an open charger every day*
- ✓ *65% have to go move the car from the charger during work*
- ✓ *67% say it's important to reduce carbon footprint*
- ✓ *86% overall satisfaction rate with the hybrid*
- ✓ *Groups see value in contributing but charging is difficult*

WHAT GROUPS SAID

"Great choice in van and we love the comfort and drive-ability of the vehicle."

"glad we have this program"

"We have a 4-hour max requirement on our building charger; this does create scheduling issues during the day when moving the van."

"Coordinating with other users on a limited number of charging ports can be challenging"

King County METRO
Moving forward together

King County Mobility Services – Plug-In Hybrid Vanpool Pilot

In the summer of 2019, King County Metro Rideshare Operations launched a pilot program to test how plug-in hybrid (PHEV) technology fits into a traditional vanpooling program. The pilot is in alignment

with King County's 2015 Strategic Climate Action Plan (SCAP), a multi-faceted plan that charts a course of action to reduce greenhouse gas (GHG) emissions created by the burning of fossil fuels used for transportation. Testing EV technology will help inform future fleet direction.
Beginning in July, RO placed 10, 2018 Chrysler Pacifica PHEV vehicles into vanpool service with select, experienced vanpool groups in order to test:

- How effective are hybrid vehicles in saving gas?
- Can hybrid technology be effective in reducing GHG emissions?
- Is workplace EV charging infrastructure robust enough?
- Unique considerations

Fuel Performance

The Pacifica PHEV has a 3.6L V6 gas engine and a dual AC motor/generator hybrid drive powered by a 16kWh, 360V lithium-ion battery. Fiat Chrysler Automobiles estimates it has a 33 mile, all-electric range. The pilot seeks to test the hybrids in varying types of usage, based on the round trip miles (RTM) of each commute, to see how much of that 33 mile all electric range can be utilized. The 10 vehicles were split into 3 groups, 20-30 mile, 40-50 mile and 60 + mile RTMs. The commute groups are asked to submit, monthly, their electric miles traveled, gas miles traveled and days of the week they plug in and charge. The balance of data collected comes from fueling and maintenance records.

In the first 6 months the 10 vans traveled 42,847 miles and consumed 681 gallons of gas, for an average of 62.9 MPG.

RTM Group	Elec Miles	Gas Miles	Total Miles	MPG	Gals Used	Gals Saved**	GHG Saved***(lbs)	Avg GHG savings per Group
20-30	7034	1359	8393	89.9	93.3	348	8188	2729
40-50*	11291	4863	16154	68.7	235.2	615	14453	3613
60 up	11792	6508	18300	51.9	352.8	610	14343	4781
Group Total	30117	12730	42847	62.9	681.3	1573	36984	3698

* 40-50 RTM category has 4 contributing groups. Others have 3.
**Based on estimated MPG for a 2018 Pacifica model with a traditional gas engine.
***Based on Argonne National Laboratory's 2017 GREET model, Well to Wheels calculation.

You can see from the chart that the highest MPG came from the lowest RTM groups who were able to complete the majority of their commute miles (84%) within the all-electric range of the vehicle. The biggest gasoline and GHG savings, however, came from the high RTM groups. The percentage of electric miles traveled (64%) was lower than the other groups but since they traveled more miles, they saved more gas, approximately 610 gallons, (203.3 avg. per group) when compared to a traditional, ICE powered Pacifica.

Greenhouse Gas Savings

In the first 6 months of the pilot, the miles driven on purely electric power have saved the consumption of approximately 1573 gallons of gasoline. Argonne National Laboratory's 2017 GREET model estimates that, for every gallon of gasoline, beginning with extraction of crude oil through refinement, transportation and consumption, 23.5 lbs. of greenhouse gasses are emitted into the atmosphere (Well to Wheels). 1573 gallons saved between 10 cars over 6 months calculates to 36,984 lbs. of greenhouse gasses that were not passed into the atmosphere.

Even though we have groups with shorter commutes who are able to travel the majority of those miles on electric power alone and use very little gasoline, the biggest benefits are derived from the high mileage groups who, by volume, save the most gasoline and the most GHG.

Issues with Charging

Measuring the customer experience is an important part of the pilot. EV charging infrastructure is becoming more widely available but significant challenges still exist in making it convenient to charge an electric vehicle at work. When asked to rate the convenience of daily charging, our pilot groups gave a score of 33 out of 100, citing multiple issues with competition for chargers. Over 50% of groups indicated that they must take time out of their work day to go move their vehicles from the charging stalls so that others may charge.

However, when asked to rate overall satisfaction with commuting in a hybrid vehicle, the score was close to 90% positive. Groups indicated that it was important to them that transit agencies take steps to reduce greenhouse gas emissions from their fleets. Also, they mentioned that the Pacifica platform was very comfortable and offered a nice driving experience.

From this we can conclude that, as inconvenient as it is to deal with the lack of charging infrastructure, our groups still find commuting in an EV to be worthwhile when considering the environmental benefits of producing less greenhouse gas as well as the benefits of commuting in a vehicle that is a couple of steps up in comfort from our standard commute vehicle.

Maintenance and Repair

The basic service schedule for the hybrid Pacifica is almost identical to that of our standard Dodge Grand Caravan platform. The only differences are that the modified Atkinson Cycle V6 requires synthetic motor oil (a few dollars more) and there are additional fluid reservoirs to check. Basic maintenance has been routine and uneventful.

It became obvious, however, that the technology is still very new and different when warranty repairs were necessary on two of the vehicles and the servicing dealerships had some trouble diagnosing the faults and procuring needed parts. Chrysler Technical Assistance teams were heavily involved in the repairs and they were successfully completed, but not without significant down-time. Wide technical repair experience does not yet exist on the same scale as its traditional counterparts.

Conclusion

Preliminary hybrid pilot results have shown that, in commute situations, with the ability to regularly replace the charge in the PHEV batteries, significant savings can be realized in the amount of gasoline used and the amount of greenhouse gasses emitted into the air through the use of hybrid technology.

They have also shown that the ability to charge regularly is critical to the efficiency of hybrid technology, and that the charging infrastructure is still not built out enough to allow for full efficiency. It can be expected that, as charging access improves and commute groups are able to charge with more consistency and less difficulty, we will be able to achieve greater fuel savings and emissions reductions. We intend to continue collecting and analyzing data throughout the pilot vehicles lifecycle. We will track results and publish additional pilot progress reports at key intervals.

Appendix I: King County Park and Ride Lots

Lot Status: Permanent
Owner: King County

Lot #	Name	Address	City	Zip	Owner	Lot	Max Cap.	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Avg.	Utilization	Year Open *
730	Auburn (KC)	101 5th St NE	Auburn	98001	KC	Permanent	244	133	150	142	151	144	59%	1977
754	Aurora Village Transit Center (KC)	1524 N 200th St.	Shoreline	98133	KC	Permanent	202	208	203	199	201	202.75	100%	1994
712	Bear Creek (KC)	7760 178th Pl NE	Redmond	98052	KC	Permanent	283	277	278	278	279	278	98%	1989
701	Bothell (KC)	10303 Woodinville Dr.	Bothell	98011	KC	Permanent	220	213	214	215	217	214.75	98%	1978
732	Burien TC (KC)	14900 4th Ave SW, Burien 98166	Burien	98166	KC	Permanent	488	274	310	272	299	288.75	59%	1978
759	Issaquah Highlands (KC)	1755 Highlands Dr.	Issaquah	98029	KC	Permanent	1010	1004	973	965	963	976.25	97%	2006
704	Kenmore P&R (KC)	7346 NE Bothell Way	Kenmore	98028	KC	Permanent	603	612	604	599	606	605.25	100%	1978
735	Kent / Des Moines (KC)	23405 Military Rd S	Kent	98032	KC	Permanent	404	263	200	202	218	220.75	55%	1980
734	Kent / James Street (KC)	902 W James St.	Kent	98032	KC	Permanent	713	258	243	198	221	230	32%	1978
748	Lake Meridian (KC)	26805 132 Ave SW	Kent	98042	KC	Permanent	172	27	21	26	26	25	15%	1994
753.1	Northgate TC Extension (KC)	3rd Ave NE and NE 103rd St	Seattle	98125	KC	Permanent	398	443	247	NA	NA	NA	NA	2002
753	Northgate Transit Center (KC)	10200 1st Ave NE	Seattle	98125	KC	Permanent	284	No Data	447	446	447	446.66	157%	1992
737	Ober Park (KC)	17106 Vashon Hwy SW	Vashon	98070	KC	Permanent	48	44	11	33	21	27.25	57%	1985

738	Olson Place SW / Myers Way (KC)	9000 Olson Pl SW	Seattle	98106	KC	Permanent	100	79	81	79	86	81.25	81%	1979
724	Overlake (KC)	2650 152nd Ave NE	Redmond	98052	KC	Permanent	203	119	75	75	75	86	42%	1981
726	Redmond P&R (KC)	16201 NE 83rd St.	Redmond	98052	KC	Permanent	377	374	373	371	372	372.5	99%	1978
757	Redondo Heights P&R (KC)	27454 Pacific Hwy South	Federal Way	98003	KC	Permanent	697	69	92	80	87	82	12%	2005
709	Shoreline	18821 Aurora Ave N, Shoreline 98133	Shoreline	98133	KC	Permanent	393	361	368	361	374	366	93%	1980
741	South Federal Way (KC)	901 S 348th St	Federal Way	98003	KC	Permanent	515	99	92	102	103	99	19%	1987
728	South Kirkland (KC)	3677 108th Ave NE	Bellevue	98033	KC	Permanent	840	836	801	824	820	820.25	98%	1979
761	South Sammamish (KC)	3015 228th Ave SE	Sammamish	98075	KC	Permanent	265	119	161	147	145	143	54%	2006
746	Tukwila (KC)	13445 Interurban Ave S	Tukwila	98168	KC	Permanent	267	235	254	265	264	254.5	95%	1986
747	Valley Center (KC)	20221 Vashon Hwy SW	Vashon	98070	KC	Permanent	55	35	26	23	26	27.5	50%	1985

Lot Status: Permanent
Owner: Other

Lot #	Name	Address	City	Zip	Owner	Lot	Max. Cap.	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Avg.	Utilization
731	Duvall	SR 203 & Woodinville/Duvall Rd, Duvall 98019	Duvall	98019	City	Permanent	49	20	27	17	19	20.75	42%
720	Kirkland Way	I-405/NE 85th St, Kirkland 98033	Kirkland	98033	City	Permanent	20	7	6	4	5	5.5	28%
762	North Bend	W North Bend Way & Sydney Ave, North Bend 98045	North Bend	98045	City	Permanent	80	7	8	13	13	10.25	13%
744	SW Spokane	3599 26th Ave SW, Seattle 98126	Seattle	98126	City	Permanent	55	0	0	0	7	1.75	3%
755	Tibbetts Lot	1675 Newport Way NW, Issaquah 98027	Issaquah	98027	City	Permanent	170	105	118	101	110	108.5	64%
758	Northgate Mall Garage	300 NE 103rd St, Seattle 98125	Seattle	98125	Private	Permanent	280	269	278	278	280	276.25	99%
756	Renton P&R (Metropolitan Place Apts)	232 Burnett Ave S, Renton 98055	Renton	98055	Private	Permanent	150	152	148	147	148	148.75	99%
760	Thornton Place Garage	3rd Ave NE and NE 100th St	Seattle	98125	Private	Permanent	350	270	276	325	330	300.25	86%
891	Angle Lake Station	19908 27th Ave S	Seatac	98188	ST	Permanent	1120	1122	1100		NA	NA	NA
873	Auburn Garage at Auburn Station	23 "A" St SW, Auburn 98001	Auburn	98001	ST	Permanent	520	519	513		NA	NA	NA
873.1	Auburn Surface Lot at Auburn Station	23 "A" St SW, Auburn 98001	Auburn	98001	ST	Permanent	113	114	113		NA	NA	NA

877	Federal Way TC	31261 - 23rd Avenue S, Federal Way 98003	Federal Way	98003	ST	Permanent	1190	1170	1176		NA	NA	NA
818	Issaquah TC	1050 17th Ave NW, Issaquah 98027	Issaquah	98027	ST	Permanent	819	772	798		NA	NA	NA
872	Kent Garage at Kent Station	301 Railroad Avenue N, Kent 98032	Kent	98032	ST	Permanent	877	853	853		NA	NA	NA
872.1	Kent Surface Lot at Kent Station	301 Railroad Avenue N, Kent 98032	Kent	98032	ST	Permanent	119	125	124		NA	NA	NA
830	Mercer Island	7800 N Mercer Wy, Mercer Island 98040	Mercer Island	98040	ST	Permanent	447	450	444		NA	NA	NA
890	Tukwila International Blvd Station	International & Southcenter Blvds, Tukwila 98188	Tukwila	98188	ST	Permanent	600	589	597		NA	NA	NA
871.1	Tukwila Surface Lot at Tukwila Station	7301 S Longacres Way, Tukwila 98188	Tukwila	98188	ST	Permanent	390	354	356		NA	NA	NA
702	Brickyard Rd	15530 Juanita-Woodinville Wy NE, Bothell 98011	Bothell	98011	WSDOT	Permanent	443	421	394	395	415	406.25	92%
713	Eastgate P&R	14200 SE Eastgate Way, Bellevue 98007	Bellevue	98007	WSDOT	Permanent	1614	1465	1600	1617	1610	1573	97%
715	Evergreen Point Bridge	SR 520/76th Ave NE, Medina 98039	Medina	98039	WSDOT	Permanent	38	52	52	50	47	50.25	132%

733	Federal Way / S 320th Street P&R	32320 23rd Ave S Federal Way 98003	Federal Way	98003	WSDOT	Permanent	877	254	304	245	251	263.5	30%
703	Greenlake / I-5 & 65th St.	6601 8th Ave NE Seattle 98115	Seattle	98115	WSDOT	Permanent	411	413	411	401	410	408.75	99%
717	Houghton P&R	7024 116th Ave NE, Kirkland 98033	Kirkland	98033	WSDOT	Permanent	470	76	75	77	77	76.25	16%
719	Kingsgate P&R (WSDOT)	13001 116th Wy NE, Kirkland 98034	Kirkland	98034	WSDOT	Permanent	502	492	494	490	488	491	98%
736	Maple Valley P&R	23033 Maple Valley Hwy, Maple Valley 98038	Maple Valley	98038	WSDOT	Permanent	122	0	61	56	59	44	36%
722	Newport Hills	5115 113th Pl SE, Bellevue 98006	Bellevue	98006	WSDOT	Permanent	275	252	264	239	250	251.25	91%
725	Preston P&R	30303 SE High Point Way, Issaquah 98027	Issaquah	98027	WSDOT	Permanent	53	33	37	27	32	32.25	61%
743	South Renton P&R	205 S 7th St. Renton 98055	Renton	98055	WSDOT	Permanent	385	290	378	383	382	358.25	93%
749	Spokane/Airport	Spokane St & Airport Wy, Seattle 98134	Seattle	98134	WSDOT	Permanent	25	10	12	18	16	14	56%
745	Star Lake P&R	27015 26th Ave S Kent 98032	Kent	98032	WSDOT	Permanent	540	270	244	245	250	252.25	47%
752	Tahlequah	north of Tahlequah Rd, Vashon Island 98070	Vashon	98070	WSDOT	Permanent	36	40	39	29	39	36.75	102%
742	Twin Lakes	21st Ave SW & SW 344th St,	Federal Way	98023	WSDOT	Permanent	600	74	76	86	89	81.25	14%

		Federal Way 98023											
729	Wilburton P&R	720 114th Ave SE, Bellevue 98005	Bellevue	98005	WSDOT	Permanent	186	165	182	177	185	177.25	95%
711	Woodinville P&R	17800 140th Ave NE, Woodinville 98072	Woodinville	98072	WSDOT	Permanent	438	259	264	240	255	254.5	58%
739	Peasley Canyon Rd/West Valley Highway					No transit service	54	No Data	No Data	No Data	No Data	No Data	No Data
751	SR 18/Auburn-Black Diamond Rd					No transit service	26	0	No Data	No Data	No Data	No Data	No Data

Lot Status: Leased/Donated

Lot #	Name	Address	City	Zip	Owner	Lot	Cap	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Avg.	Utilization
542	All Saints Lutheran Church	27225 Military Road S, Auburn 98001	Auburn	98001	Church	Leased	75	47	40	42	43	43	57%
576	Aurora Church of the Nazarene	1900 N 175th Street, Shoreline 98133	Shoreline	98133	Church	Leased	116	130	133	124	116	125.75	108%
538	Bellevue Christian Reformed Church	1221 - 148th NE, Bellevue 98007	Bellevue	98007	Church	Leased	20	0	2	9	7	4.5	23%
550	Beverly Park First Baptist Church	11659 1st Avenue South, Seattle 98168	Seattle	98168	Church	Leased	12	5	4	6	6	5.25	44%
502	Buddha Jewel Monastery	17418 8th Ave NE, Shoreline 98155	Shoreline	98125	Church	Leased	40	27	24	27	34	28	70%
598	Burien Church of God	16640 1st Avenue South, Burien 98148	Burien	98148	Church	Leased	20	1	0	0	0	0.25	1%
524	City View Church	255 Hardie Ave SW, Renton 98055	Renton	98055	Church	Leased	96	52	27	31	31	35.25	37%
591	Community Bible Fellowship	11227 Renton Avenue South, Seattle 98178	Seattle	98178	Church	Leased	29	4	0	1	1	1.5	5%
634	Congregational Church of Mercer Island	4545 Island Crest Way, Mercer Island 98040	Mercer Island	98040	Church	Leased	28	3	2	2	3	2.5	9%

583	Cornerstone United Methodist Church	20730 SE 272nd Street, Covington 98042	Covington	98042	Church	Leased	20	11	14	15	10	12.5	63%
560	Cottage Lake Assembly of God	15737 Avondale Road, Woodinville 98072	Woodinvill e	98072	Church	Leased	20	2	6	8	7	5.75	29%
551	Eastgate Congregational Church	15318 SE Newport Way, Bellevue 98006	Bellevue	98006	Church	Leased	20	8	15	12	11	11.5	58%
570	Fairwood Assembly of God	13120 SE 192nd St, Renton 98058	Renton	98058	Church	Leased	25	0	9	3	6	4.5	18%
565	Family Life Center-Church of God	116 Lakeland Hills Way SE, Auburn 98092	Auburn	98092	Church	Leased	27	18	19	16	14	16.7 5	62%
562	Holy Family Church	9641 20th Ave SW, Seattle 98106	Seattle	98106	Church	Leased	23	8	6	4	4	5.5	24%
509	Holy Spirit Lutheran Church	10021 NE 124th St, Kirkland 98034	Kirkland	98034	Church	Leased	40	32	29	25	27	28.2 5	71%
557	Kenmore Community Church	7504 NE Bothell Wy, Kenmore 98028	Kenmore	98028	Church	Leased	15	0	11	13	13	9.25	62%
579	Kennydale United Methodist	3005 Park Avenue North, Renton 98056	Renton	98056	Church	Leased	50	69	63	58	72	65.5	131%

521	Kent Covenant Church	12010 SE 240th St, Kent 98031	Kent	98031	Church	Leased	20	13	11	12	12	12	60%
527	Kent United Methodist Church	11010 SE 248th St, Kent 98031	Kent	98031	Church	Leased	23	0	15	20	18	13.25	58%
597	Korean Covenant Church	14220 Juanita/Woodinville Way NE, Kirkland 98034	Kirkland	98034	Church	Leased	30	5	8	8	8	7.25	24%
504	Korean Zion Presbyterian Church	17920 Meridian Ave N, Shoreline 98155	Shoreline	98155	Church	Leased	25	22	24	22	25	23.25	93%
505	Lamb of God Lutheran Church	12509 27th NE, Seattle 98125	Seattle	98125	Church	Leased	21	7	25	20	26	19.5	93%
511	Mercer Island Presbyterian Church	3605 84th Ave SE, Mercer Island 98040	Mercer Island	98040	Church	Leased	30	9	11	4	9	8.25	28%
512	Mercer Island United Methodist Church	7070 SE 24th St, Mercer Island 98040	Mercer Island	98040	Church	Leased	18	13	18	17	18	16.5	92%
530	Nativity Lutheran Church	17707 140th Ave SE, Renton 98058	Renton	98058	Church	Leased	49	0	15	13	14	10.5	21%
536	New Life Church @ Renton	15711 152nd Ave SE, Renton 98059	Renton	98059	Church	Leased	25	16	14	21	18	17.25	69%
514	Newport Covenant Church	12800 SE Coal Creek Pkwy, Bellevue 98006	Bellevue	98006	Church	Leased	75	38	27	38	27	32.5	43%

581	Normandy Park Congregational	19247 1st Avenue South, Normandy Park 98166	Normandy Park	98166	Church	Leased	10	1	1	2	3	1.75	18%
531	Our Savior's Baptist Church	701 S 320th St, Federal Way 98003	Federal Way	98003	Church	Leased	24	0	2	3	3	2	8%
544	Prince of Peace Lutheran Church	14514 - 20th Ave NE, Shoreline 98155	Shoreline	98125	Church	Leased	20	14	16	15	18	15.75	79%
599	Redwood Family Church	11500 Redmond-Woodinville Rd NE, Redmond 98052	Redmond	98052	Church	Leased	10	0	No Data	#N/A	#N/A	#N/A	#N/A
578	Sacred Heart Church of Enumclaw	1614 Farrelly St, Enumclaw 98022	Enumclaw	98022	Church	Leased	40	11	12	8	9	10	25%
588	Sammamish Hills Lutheran Church	22818 SE 8th St, Sammamish 98074	Sammamish	98074	Church	Leased	54	31	15	13	18	19.25	36%
566	Shoreline United Methodist Church	14511 25th Ave NE, Shoreline 98155	Shoreline	98125	Church	Leased	20	19	18	18	18	18.25	91%
553	Sonrise Evangelical Free Church	610 SW Roxbury St, Seattle 98108	Seattle	98108	Church	Leased	10	5	1	1	2	2.25	23%
543	St Columba's Episcopal Church	26715 Military Road S, Kent 98032	Kent	98032	Church	Leased	15	4	4	5	4	4.25	28%

547	St Luke's Lutheran Church - Federal Way	515 S 312th St, Federal Way 98003	Federal Way	98003	Church	Leased	20	10	0	1	1	3	15%
640	St Matthew Lutheran Church	2516 NE 16th St, Renton 98056	Renton	98056	Church	Leased	128	72	79	84	83	79.5	62%
541	Sunrise United Methodist Church	150 S 356th St, Federal Way 98003	Federal Way	98003	Church	Leased	25	1	1	2	2	1.5	6%
501	The Vine Church (formerly Bethany Bible)	6214 Bothell Way NE, Kenmore 98028	Kenmore	98028	Church	Leased	75	74	72	73	75	73.5	98%
589	Vashon Episcopal Church of the Holy Spirit	15420 Vashon Highway SW, Vashon 98070	Vashon	98070	Church	Leased	23	12	6	5	11	8.5	37%
559	Woodinville Unitarian Universalist Church	19020 Woodinville/Duvall Rd, Woodinville 98072	Woodinville	98072	Church	Leased	30	3	3	4	5	3.75	13%
523	Farmer's Park	SE 436th St & 228th Ave SE, Enumclaw 98022	Enumclaw	98022	City	Leased	25	3	1	1	1	1.5	6%
569	Renton Municipal Garage P&R	655 S 2nd St, Renton 98055	Renton	98055	City	Leased	150	116	105	103	103	106.75	71%
564	Sunset Park	1306 69th Street SE, Auburn 98092	Auburn	98092	City	Leased	10	4	5	7	8	6	60%

533	Fred Meyer, Renton	365 Renton Center Way SW, Renton 98056	Renton	98056	Private	Leased	21	18	21	20	20	19.75	94%
516	South Mercer Center, LLC @ Mercer Island QFC	84 Ave SE & SE 68th St, Mercer Island 98040	Mercer Island	98040	Private	Leased	21	6	8	9	6	7.25	35%
906	North Seattle Interim	402 NE 103rd Street, Seattle 98125	Seattle	98125	ST	Leased	155	No Data	No Data		#N/A	#N/A	#N/A
903	SeaTac Center Garage (Sound Transit)	15247 International Boulevard, SeaTac 98188	SeaTac	98188	ST	Leased	62	53	0		#N/A	#N/A	#N/A
737.1	Ober Park Annex (Vashon Parks Department)	17130 Vashon Hwy SW, Vashon 98070	Vashon	98070	City	Donated	9	0	0	4	6	2.5	28%
631	Snoqualmie Community Park	35016 SE Ridge Street, Snoqualmie 98065	Snoqualmie	98065	City	Donated	20	5	6	20	10	10.25	51%
540	Tibbetts Valley Park	965 - 12th Ave NW, Issaquah 98027	Issaquah	98027	City	Donated	27	1	3	1	2	1.75	6%
510	Klahanie #1	SE Klahanie Blvd & 244th Pl SE, Issaquah 98027	Issaquah	98027	Private	Donated	30	10	14	17	13	13.5	45%
515	Klahanie #3	Klahanie Dr SE & SE 40th St,	Issaquah	98045	Private	Donated	30	2	1	7	12	5.5	18%

		Issaquah 98045											
652	Maple Valley Town Square	26520 Maple Valley Highway, Maple Valley 98038	Maple Valley	98038	Private	Donated	97	65	62	75	71	68.25	70%
632	Redmond Ridge P&R	NE Cedar Park Crescent & Redmond Ridge Dr NE	Redmond	98053	Private	Donated	52	24	31	15	27	24.25	47%
851	Overlake TC at NE 40th					Closed for Link Construction	222	Closed	Closed		#N/A	#N/A	#N/A
539	St Andrew's Lutheran Church	2650 - 148th Ave SE, Bellevue 98007	Bellevue	98007	Church	Leased - ST	20	0	No Data	#N/A	#N/A	#N/A	#N/A