Solano Transportation Authority

FINAL
Countywide Electrification Transition Plan

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Solano Transportation Authority

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Acronyms and Terms

Acronym or Term	Description
AC	Alternating Current
BAAQMD	Bay Area Air Quality Management District
BEB	Battery-Electric Bus
BESS	Battery Energy Storage System
BIL	Bipartisan Infrastructure Law
CARB	California Air Resources Board
CIG	Capital Investment Grants
CNG	Compressed Natural Gas
DAC	Disadvantaged Community
DC	Direct Current
EV	Electric Vehicle
FCEB	Fuel Cell Electric Bus
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation, and Air Conditioning
ICEB	Internal Combustion Engine Bus
kW	Kilowatt
kWh	Kilowatt-hour
LCTOP	Low Carbon Transit Operations Program
MW	Megawatt
MWh	Megawatt-hour
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas and Electric
SOC	State-of-charge
SRTP	Short Range Transportation Plan
TIRCP	Transit and Intercity Rail Capital Program
YOE	Year of Expenditure
ZE	Zero-Emission
ZEB	Zero-Emission Bus

EXECUTIVE SUMMARY

ES1 Background

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) with a gross vehicle weight rating (GVWR) exceeding 14,000 pounds to zero-emission buses (ZEBs) by 2040. The Solano Transportation Authority (STA) is developing the Countywide Electrification Transition Plan to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets. This Transition Plan is a comprehensive final plan from a series of technical analyses that are included as appendices.

STA serves as the congestion management agency for Solano County. STA is responsible for countywide transportation planning, programming transportation funds, managing and providing transportation programs and services, delivering transportation projects, and setting transportation priorities. There are five transit agencies operating in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, SolTrans, and Vacaville City Coach. It should be noted that FAST and its associated service and facilities was not analyzed in this plan. FAST developed the Fairfield Transit Fleet Electrification Final Business Plan Report (FAST Report), an independent study to develop the framework for the electrification of FAST's fleet (conducted by Willdan Energy Solutions), which was already in development when the Transition Plan was initiated. Despite the separate studies, it is important to understand FAST's transition in the context of other Solano County agencies; therefore, the Transition Plan incorporates findings from the FAST Report in some sections (vehicle procurement and costs). The FAST Report is appended to this document for reference and further context (Appendix G).

All agencies provide both fixed-route and demand response and/or paratransit services, with the exception of Dixon Readi-Ride, which only provides demand response service. Agencies in Solano County operate a wide range of vehicle types to meet service requirements, which include standard buses (35- and 40-foot), cutaways of varying lengths, vans, and motorcoaches. The current fleet is powered by several fuel types: diesel, diesel hybrid, compressed natural gas (CNG), gasoline, and battery electric. All vehicles, except the vans with GVWR lower than required by the regulation, are subject to the CARB ICT regulation.

Appendix A: *Existing Conditions Analysis* provides in-depth discussions on the agencies' existing services and facilities. Table ES1 summarizes agencies, yard locations, the number of blocks and routes served, and the total number of vehicles.

Table ES1 Solano County Service Summary

Agency	Yard Address	No. of Blocks	No. of Routes	Total Number of Vehicles
Dixon Readi-Ride	285 E. Chestnut Street, Dixon	N/A	N/A	10
Rio Vista Delta Breeze	3000 Airport Road, Rio Vista	4	2	5

Agency	Yard Address	No. of Blocks	No. of Routes	Total Number of Vehicles
SolTrans	1850 Broadway Street, Vallejo	42	14	60
Vacaville City Coach	1001 Allison Drive, Vacaville	2	2	25

Source: Each agency's Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030, and GTFS Data

ES2 Service Modeling

Lightning Bolt is a proprietary modeling tool developed by WSP to evaluate the feasibility of operating BEBs within a transit agency's existing bus schedule. The tool considers and analyzes several factors that may impact the performance of a BEB, including the specific operating conditions of an agency (topography, climate, and bus service schedule), charging and battery capacity parameters, and the extent to which all these factors would improve or reduce performance. Lightning Bolt uses these inputs to determine the percent of service that can be completed under two scenarios: "typical" and "conservative." The outputs are on a block-level scale which is a set of trips assigned to a single-vehicle during a service day.

Vehicle ranges will decline as batteries degrade over time. Additional analysis is also included to show block completion rates under end of warranted life (EWL) battery conditions.

Table ES2 summarizes the initial findings for each agency. For all the failing blocks in the fixed-route services, the following mitigation measures can be considered:

- Strategic procurement phasing to allow advancements in BEB technology
- Service changes (splitting blocks; additional pull-outs)
- Additional vehicles
- Selecting a bus model with a higher capacity than the average in the model
- Opportunity charging

The *Service Modeling Technical Analysis* (Appendix B) provides a more in-depth review of the data inputs and methodology used to conduct the analysis.

Table ES2 Summary of Modeling Results

Agency	Fixed Route		Demand Response
	Typical Scenario	Conservative Scenario	
Dixon Readi-Ride	• No fixed-route service	• No fixed-route service	Assumed BEB replacement is expected to meet the existing range of 83 to 103 miles
Rio Vista Delta Breeze	• 1 of 4 blocks failed • EWL: 1 block failed	• 1 of 4 blocks failed • EWL: 1 block failed	Assumed BEB replacement is expected to meet the existing range of 93 to 113 miles

Agency	Fixed Route		Demand Response
	Typical Scenario	Conservative Scenario	
SolTrans	• 4 out of 42 blocks failed • EWL: 15 blocks failed	• 15 failing blocks • EWL: 24 blocks failed	Assumed BEB replacement is expected to meet the existing range of 75 to 93 miles
Vacaville City Coach	• 1 out of 2 blocks failed • EWL: All blocks failed	• All blocks failed • EWL: All blocks failed	Assumed BEB replacement is expected to meet the existing range of 104 to 130 miles

Source: WSP

ES3 Facility, Power, and Energy Improvements

Electric bus charging systems require a significant amount of electrical power. Most facilities require moderate to significant upgrades to their existing electrical infrastructure, and Pacific Gas & Electric (PG&E) must also upgrade equipment to supply the necessary power to the site. The final load demand and equipment upgrades depend on the fleet size, detailed site design, number of chargers, and the electrical contractor's analysis.

The facility analysis finds that each facility can accommodate the charging infrastructure needed to support a fully electric bus fleet based on each agency's current and future fleet make-up. The facility upgrade recommendations will be refined and further evaluated in subsequent stages of design implementation.

Moreover, to ensure service delivery and energy resiliency during emergency outages, all sites can benefit by installing a permanent battery storage generator. Solar PV might be considered for Rio Vista Delta Breeze and Vacaville City Coach.

Appendix C: *Power and Energy Analysis* provides in-depth energy and resiliency analysis for each site, while Appendix D: *BEB Facility Concepts Analysis* provides the detailed facility concept for each site.

Table ES3 summarizes the facility upgrades needed for Solano County's transit agencies to accommodate the maximum number of vehicles expected in the future fleet.

Table ES3 Summary of Site Upgrades Required

Upgrade	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
New Electrical Service	Yes	Yes	Yes	Yes
Utility System Upgrades	No	No	Yes	Maybe
Charging Equipment*	• Five 150 kW DC charging cabinets • Seven cable retractors	• Four 150 kW DC charging cabinets	• Twenty-one 80 kW AC charging system • Twenty-five 150 kW DC charging cabinets • Seventy cable retractors	• Sixteen 150 kW DC charging cabinets • Thirty-one cable retractors

Upgrade	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
Charging Strategy	• Three ground-mounted plug-ins • Seven overhead-mounted plug-ins • One plug-in dispenser in maintenance area	• Eight ground-mounted plug-ins • One plug-in dispenser in maintenance area	• Forty-nine overhead-mounted plug-ins w/ option for future overhead pantograph • Twenty-one plug-in AC dispensers	• Thirty-one overhead-mounted plug-ins • Two plug-in dispensers in maintenance area
New Electrical Equipment Required	• Utility transformer • Main switchboard and meter • Underground conduit to chargers	• Utility transformer • Main switchboard and meter • Underground conduit to chargers	• Utility transformer • Main switchboard and meter • Underground conduit to chargers	• Utility transformer • Main switchboard and meter • Electrical subpanels • Large underground duct bank and conduit to chargers • Likely upgrades to utility-owned distribution equipment.

Source: WSP

ES4 ZEB Transition Plan

The following section contains an overview of the construction timelines, vehicle procurements, and costs and funding necessary for STA's ZEB transition. Detailed analyses of the construction and vehicle procurement schedules are discussed in Appendix E: *Phasing Strategy and Transition Analysis*, while detailed costs and funding analysis is provided in Appendix F: *Cost and Funding Analysis*.

Construction Schedule

Each agency's construction schedule varies based on the size of the facility, its upgrade requirements, as well as the particular goals of the agency. All agencies are anticipated to have the required infrastructure installed and constructed in advance of the CARB ICT regulation's first purchase requirements in 2026 (which requires 25% of all new purchases to be ZEB). Table ES4 provides an overview of each agency's construction schedule along with the number of proposed construction stages.

Table ES4 Construction Summary – All Agencies

Agency	No. of Stages	Timeline
Dixon Readi-Ride	1	July 2022 – Sept 2024
Rio Vista Delta Breeze	1	July 2022 – Sept 2024
Solano County Transit	2	March 2022 – May 2025
Vacaville City Coach	2	March 2022 – Feb 2024

Source: WSP

Vehicle Procurement Schedule

These procurement schedules are based on future fleet projections. The assumed delivery dates of vehicles were developed with special consideration to vehicle's useful life, construction completion dates, and reducing impacts to maintenance staff. Table ES5 shows the procurement schedule for each agency by year for all vehicle types. The table also includes FAST's proposed vehicle procurement schedule.

Table ES5 Vehicle Procurement Schedule – All Agencies

Year	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach	FAST	Total
2022	-	-	-	-	-	**-**
2023	-	-	7	10	10	**27**
2024	4	2	7	5	8	**26**
2025	4	2	10	5	6	**27**
2026	-	-	4	5	-	**9**
2027	-	-	4	-	8	**12**
2028	-	-	4	-	-	**4**
2029	-	-	-	-	4	**4**
2030	-	-	-	-	6	**6**
2031	-	-	-	-	3	**3**
2032	-	-	-	-	-	**-**
2033	-	-	-	-	15	**15**
Total	**8**	**4**	**36**	**25**	**60**	**133**

Source: WSP & Willdan

Cost and Funding

Overall, the cost analysis shows that the full lifecycle cash cost of a transition to BEBs is higher than the continued reliance on ICE vehicles, mostly due to the higher capital costs (Table ES6). However, keeping the current fleet would result in a larger emission generation over the lifecycle of the ICE fleet in comparison to the operations of a full BEB fleet. Table ES6 does not include the costs for FAST's transition. Since FAST's cost analysis was conducted under a different project, the specific output are not identical to those developed in the Transition Plan. The FAST Report analyzed the costs for maintaining an ICE fleet as well as transitioning to a BEB fleet through 2040. Meanwhile, the rest of STA's agencies were analyzed through 2030. The net expenditures for all STA agencies (including FAST) are $254M for an ICE fleet and $330M for a BEB fleet, yielding an additional $76M in costs to transition all agencies. Please refer to Appendix G for more detail regarding FAST's costs and methodology.

Table ES6 Lifecycle Costs Summary (in millions of Year of Expenditure YOE$)

Cost Categories	Dixon Readi-Ride		Rio Vista Delta Breeze		SolTrans		Vacaville City Coach		STA Countywide Costs	
	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet
Capital, O&M, and Disposal Costs	$5	$8	$3	$4	$58	$80	$33	$45	**$99**	**$137**
Environmental Costs	$0.60	$0.30	$0.30	$0.10	$4	$2	$3	$1	**$8**	**$3**
Total Lifecycle Costs	$6	$8	$3	$5	$62	$82	$36	$46	**$107**	**$141**
Total Lifecycle Costs per Mile	**$2**	**$4**	**$3**	**$4**	**$6**	**$8**	**$4**	**$5**	**N/A**	**N/A**

Source: WSP & Willdan
Notes: *Does not include FAST's cost analysis. FAST's lifecycle costs are $147M for an ICE fleet and $190M for a BEB fleet. FAST's lifecycle costs are through 2040 and do not include environmental and capital, O&M, or Disposal costs. The net expenditures for all STA agencies are $254M for existing ICE fleets and $330M for a BEB fleet, yielding an additional $76M in costs to transition all agencies
Rounded to the nearest hundred thousand when costs were less than one million dollars. Otherwise, it was rounded to the nearest million

Based on the capital costs identified in the lifecycle cost analysis and the funding analysis, it is concluded that some of these fleet electrification investments can be funded through existing capital revenues outlined in each agency's FY 2021-2030 Short Range Transit Plans (SRTP) adopted in 2020. However, STA and member agencies will also need to pursue additional funding through federal, state, regional, and other formula and discretionary grant opportunities to fill the estimated funding gap (Table ES7) to carry out the full scope of the *Solano Countywide Electrification Transition Plan*. It should also be noted that Table ES7 does not include FAST's funding surplus/gap since FAST's cost analysis was conducted under a different project and used a different methodology from this plan. As noted in the FAST Report, the cost to electrify FAST's fleet including incentives is $163.68M. The net funding gap for all STA agencies (including FAST) is -$201.79M. Please refer to Appendix G for more information regarding FAST's cost/funding analysis.

Table ES7 Estimated Funding Gap by Agency by Year (in millions of YOE$)

Agency	Funding Surplus/Gap										
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Dixon Readi-Ride	$0.29	$0.29	-$1.93	-$1.64	$0.23	$0.31	$0.20	$0.28	$0.11	$0.24	**-$1.62**
Rio Vista	$0.00	$0.98	-$1.41	-$1.05	$0.00	$0.45	$0.00	$0.12	$0.00	$0.00	**-$0.91**
SolTrans	$3.78	-$17.20	-$15.80	-$6.09	$0.58	$2.23	$0.59	$0.61	$2.13	$0.47	**-$28.70**
Vacaville City Coach	$0.15	-$11.76	-$7.12	-$4.44	-$1.49	$10.00	$4.40	$0.15	$1.00	$3.15	**-$5.96**
STA Countywide	$4.22	-$27.69	-$26.27	-$13.21	-$0.68	$12.99	$5.19	$1.16	$3.24	$3.86	**-$37.19**

Source: WSP & Willdan
Notes: *Does not include FAST's cost analysis. The cost to electrify FAST's fleet, including incentives, is $163.68M. FAST's analysis is through 2040 and does not use the same methodology as STA's other agencies. The net funding gap for all STA agencies is -$201.79M.
Rounded to the nearest ten thousand

Several federal, state, regional, and other funding opportunities have a high potential to fund Solano County's transit agencies' capital projects. The federal Bipartisan Infrastructure Law (BIL) recently passed has significantly increased funding for formula programs that can be used to fund capital projects, including procurement of ZEBs, and construction of charging/fueling infrastructure and/or associated maintenance facilities. Several available funding opportunities on the state and regional levels include CalSTA Transit and Intercity Rail Capital Program (TIRCP), Caltrans Low Carbon Transit Operations Program (LCTOP), Caltrans/State Controller's Office SB1 State of Good Repair (SGR) Program, and Bay Area Air Quality Management District Carl Moyer and Community Emission Reduction Grant Programs. Solano County transit agencies can also apply for the PG&E Electric Vehicle (EV) Fleet program.

ES5 Staffing and Training

One of the essential factors for a smooth transition to a full BEB fleet includes ensuring that the whole workforce, especially operators and technicians, is comfortable handling the new technology that can be achieved by workforce evaluation and training. Moreover, workforce evaluation is currently one of the key elements in the Zero Emission Fleet Transition Plan required for federal grants funding. A workforce evaluation tool released by FTA can be used to help identify the impact of the transition to a zero-emission fleet on the current workforce.

Based on peer transit agencies' experiences, BEB transition will not greatly disrupt current staffing and training requirements or yard management. In large, BEB maintenance follows a "bus is a bus" philosophy, indicating that many bus repairs will be standard regardless of the powertrain. However, to ensure fleet maintainers are supported throughout the life of the BEBs, it is recommended that a substantial share of the OEM training budget be reserved for the tail end of subsystem warranties to ensure maintenance staff is prepared to service components as needed.

Staff training required to support a BEB fleet will require the development of new training materials, which should be supported by BEB OEMs. Additionally, while the OEM provides training modules for both maintenance technicians and operators, some training may need to be developed for other staff. Everyone should have a high-level understanding of high voltage safety, even if that message for other job classifications is simply to be able to recognize it and stay away from it.

Just as the broader ZEB industry is in a state of constant change, so is BEB training. Educators are in the process of developing additional training curricula and resources for transit agencies. Bus manufacturers are working to improve and update their training modules, manuals, and training materials to keep up with the fast pace of product development. The lessons learned discussed in this section should be treated as "snapshots in time" of the state of the industry. It is recommended for Solano County's transit agencies to review training guidance and resources as they are developed continually.

1 INTRODUCTION

The following section provides the project overview of STA Countywide Electrification Transition Plan, the purpose and approach of the project, and the structure of the plan.

1.1 Study Overview

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040[1]. According to CARB's ICT regulation, all vehicles with a gross vehicle weight rating (GVWR) exceeding 14,000 pounds are subject to replacement. The Solano Transportation Authority (STA) is developing the Countywide Electrification Transition Plan to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

This document is a comprehensive final plan from a series of technical analyses that are included as appendices, including:

- Existing Conditions Analysis
- Service Modeling Analysis
- Power and Energy Analysis
- BEB Facility Concepts Analysis
- Phasing Strategy and Transition Analysis
- Costs and Funding Analysis

The Countywide Electrification Transition Plan captures all required elements to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of SolTrans' project elements are captured in this plan. It should be noted that FAST and its associated service and facilities was not analyzed in this plan. FAST developed the FAST Report, an independent study to develop the framework for the electrification of FAST's fleet (conducted by Willdan Energy Solutions), which was already in development when the Transition Plan was initiated. Despite the separate studies, it is important to understand FAST's transition in the context of other Solano County agencies; therefore, the Transition Plan incorporates findings from the FAST Report in some sections (vehicle procurement and costs). The FAST Report is appended to this document for reference and further context (Appendix G).

1.2 Plan Purpose and Approach

The purpose of this plan is to provide the framework for each agency's' transition to ZEBs, pursuant to the CARB's ICT regulation. The Countywide Electrification Transition Plan outlines the existing conditions,

1 CARB ICT Regulation (https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-regulation)

methodologies and analyses, BEB technology and facility upgrade needs, proposed phasing schedule, cost and funding estimations, and staffing and training recommendations. By itemizing the existing conditions, assessment, and findings by agency, this document provides a robust and comprehensive study of how ZEBs could be implemented in STA's four transit agencies.

In the initial section, the plan lays out the background information of the project and STA service area. Then, a brief overview of the market condition is discussed to give context about the current stage of BEB technology. The agency-specific sections will elaborate on the agencies' existing service and facility, electrification feasibility from service operation, facility, and utility aspects, and the complete ZEB transition plan that includes facility concept, phasing schedules, and cost analysis.

WSP assessed the viability of operating BEBs by modeling the respective agencies' transit operations with Lightning Bolt, a proprietary, formula-based tool that determines block completion. A power and energy analysis was subsequently completed to identify a shortfall in electricity and identify solutions to address it. The WSP design team then reviewed and documented each agency's existing site conditions and worked with key project representatives to develop and test a variety of alternative facility concept layouts based on various charging technologies. The preferred concepts serve as the foundation for the proposed phasing schedules and cost and funding estimations. It should be noted that due to WSP's current work with SolTrans, this plan uses the preliminary concepts and designs found in the SolTrans Zero Emission Master Plan.

1.3 Plan Structure

This plan is organized into eight main sections:

1. **Introduction** – Overview of STA Countywide Electrification Transition Plan.
2. **Background** – Overview of STA transit agencies and service area.
3. **ZEB Technology and Market Conditions** – Overview of ZEB technology as well as existing manufacturers, products, and emerging technology.
4. **Methodology and Assumptions** – Overview of the processes of service modeling, power and energy analysis, facility concept development, phasing schedule planning, and cost and funding estimation.
5. **Agency-Specific Sections** – Overview of each transit system's existing conditions, service modeling analysis results, energy and power analysis results, and complete ZEB transition plan, including facility concept, phasing schedules, and cost and funding estimations. Agency-Specific Sections include:
   a. Dixon Readi-Ride
   b. Rio Vista Delta Breeze
   c. Solano County Transit (SolTrans)
   d. Vacaville City Coach
6. **Funding Sources** – Overview of the funding sources available at the federal, regional/state, and local levels.
7. **Staffing and Training** – Overview of the impacts of full-fleet electrification on staffing and training needs related to transit operations, bus yard management, vehicle maintenance, and charging infrastructure.
8. **Conclusion** – Summarizes the findings of the plan.

2 BACKGROUND

The following section provides background on STA and its service area, including disadvantaged communities served by the agencies under STA.

2.1 Solano Transportation Authority (STA)

STA serves as the congestion management agency for Solano County. STA is responsible for countywide transportation planning, programming transportation funds, managing and providing transportation programs and services, delivering transportation projects, and setting transportation priorities. Five transit agencies are operating in Solano County, each with varying types of service and coverage (Table 2.1).

Table 2.1 Transit Agencies in Solano County

Agency	Transit Services
Dixon Readi-Ride	Demand Response Dial-a-Ride
FAST	Fixed Route Local Service ADA Paratransit (DART Service) Adult Recreation Center Taxi Program SolanoExpress Commuter Service
Rio Vista Delta Breeze	Demand Response Dial-a-Ride Fixed Route Local Service
SolTrans	Demand Response Paratransit Fixed Route Local Service SolanoExpress Commuter Service
Vacaville City Coach	Demand Response Paratransit Fixed Route Local Service

Source: Dixon Readi-Ride (2021), FAST (2021), Rio Vista Delta Breeze (2021), SolTrans (2021), Vacaville City Coach (2021)

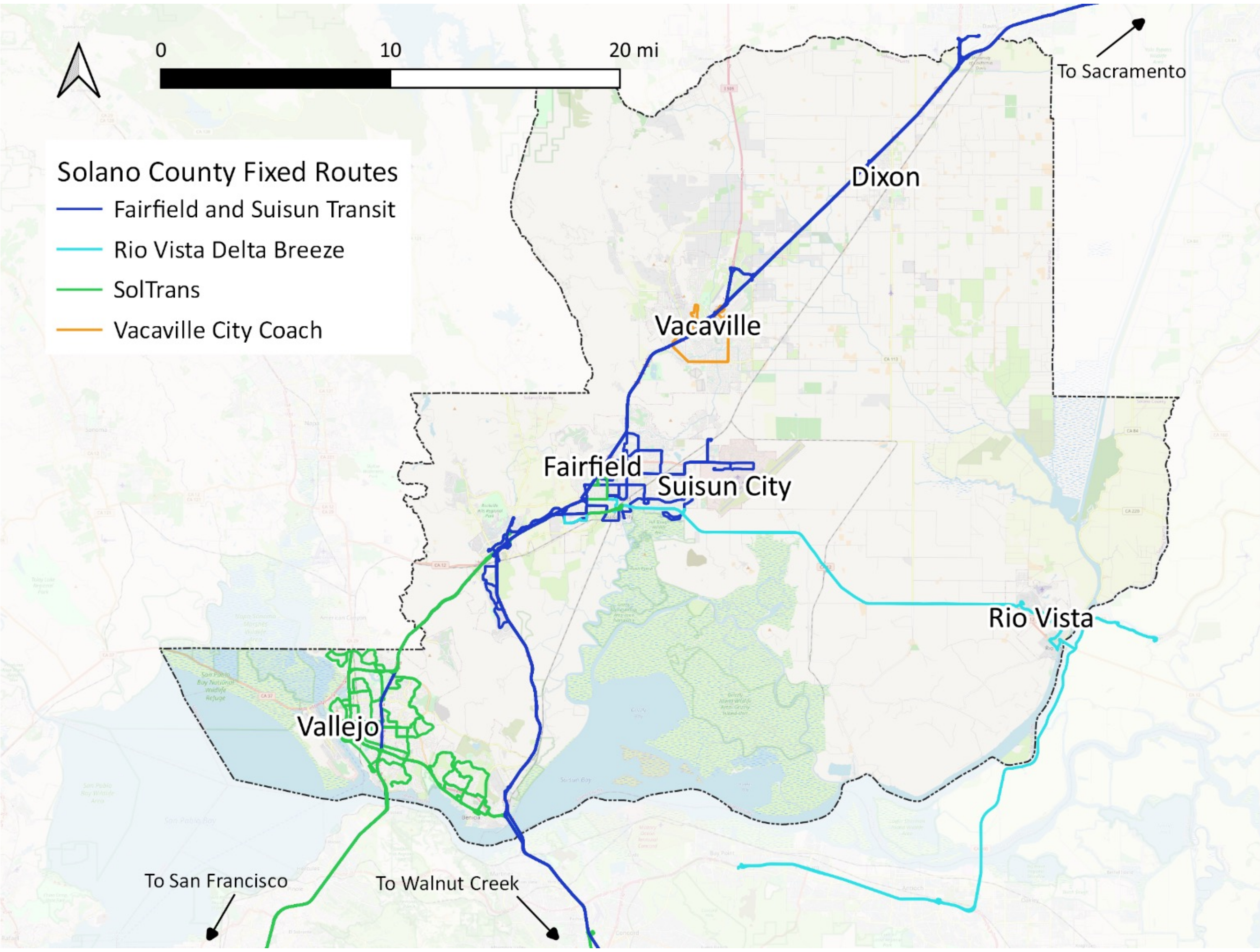
Note: "Demand Response Dial-a-Ride" includes paratransit service, while "Demand Response Paratransit" refers to service that is exclusively for ADA complementary service for disabled and senior riders.

2.2 Solano County Service Area

Solano County is approximately 822 square miles and contains the urbanized areas of Vallejo, Fairfield-Suisun City, Vacaville, Dixon, and Rio Vista. Approximately 448,000 people reside in the county, and roughly 3% of its workforce above the age of 16 use public transportation to commute to work.[2]

Agencies provide service throughout Solano County, with SolTrans and FAST also extending service into neighboring Alameda, Contra Costa, Yolo, and Sacramento Counties (Figure 2.1). All agencies provide fixed-route service (with the exception of Dixon Readi-Ride) and demand response and/or paratransit services.

Figure 2.1 STA Service Areas



Sources: State of California; OpenStreetMap Contributors

2 Solano County Census Reporter, ACS 2019

2.2.1 Weather and Topography

Solano County has a Mediterranean climate of warm, dry summers and mild, rainy winters. The average temperature can be as low as 39 degrees in the winter and as high as 89 degrees in the summer. [3] Due to its topography and landscape, Solano County experiences microclimates.[4]

Solano County has a minimum elevation of 72 feet[5] and a maximum of 2,818 feet.[6] This wide range in elevation affects the relative humidity and air circulation within the county. The average rainfall ranges between 13 inches near the coast and 22 inches inland.[7] The varied landscapes of waterfront cities to more rural and agricultural areas also relate to the creation of microclimates.

2.2.2 Utility Service

Pacific Gas & Electric (PG&E), one of the largest combined natural gas and electric energy companies in the United States, serves Solano County. As agencies in Solano County proceed with BEB transitions, they will need to coordinate with PG&E to assess infrastructure needs, explore electric vehicles (EV) incentives and programs, and install and connect power.

2.2.3 Disadvantaged Communities

Disadvantaged communities (DACs) refer to areas that suffer the most from a combination of economic, health, and environmental burdens. The California Environmental Protection Agency (CalEPA) defines a "disadvantaged" community as a community (census tract) that is located in the top 25th percentile of tracts identified by the California Communities Environmental Health Screening Tool (CalEnviroScreen). CalEnviroScreen uses environmental, health, and socioeconomic data to measure each census tract (community) in California. Each tract is assigned a score to gauge a community's pollution burden and socioeconomic vulnerability. A higher score indicates a more disadvantaged community, whereas a lower score indicates fewer disadvantages.

The replacement of conventional buses with BEBs will yield many benefits in the communities they serve, including reducing noise and harmful pollutants. Given that DACs are disproportionately exposed to these externalities, they should be considered and prioritized during the initial deployments of BEBs. Solano County's transit agencies will ensure that DACs are prioritized as buses are deployed.

Of the four analyzed agencies, two of them – Rio Vista Delta Breeze and SolTrans – operate in and serve DACs. Both agencies' bus yards are located in DACs, and 25% and 47% of fixed-route mileage are operated in DACs, respectively. The DAC-serving routes are summarized in Table 2.2 and illustrated in Figure 2.2.

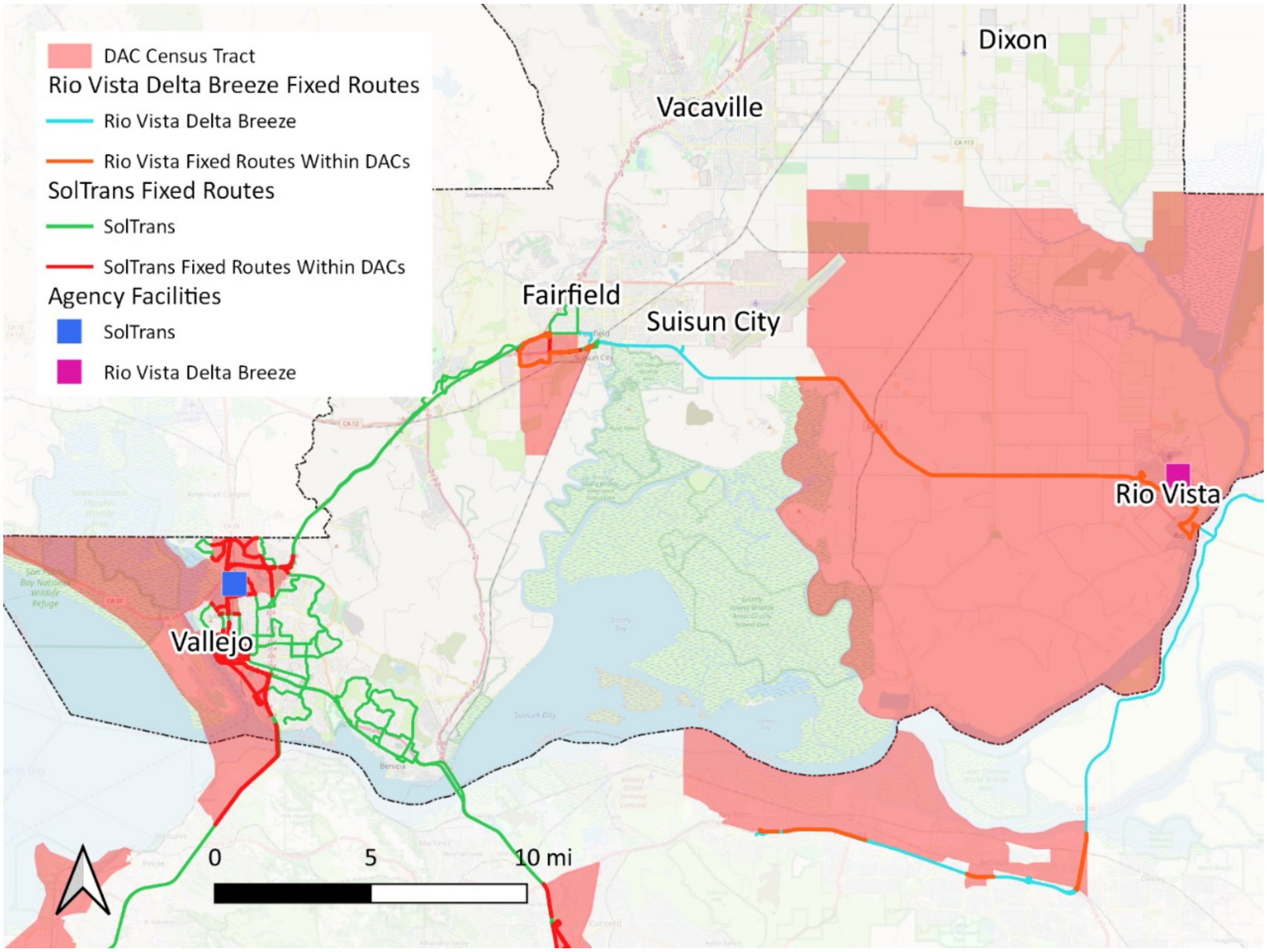
3 NOAA
4 Daily Republic
5 Any Place America
6 Peak Visor
7 BAAQMD

Table 2.2 Summary of DAC-Serving Routes

Agency	DAC-Serving Routes	% of DAC-Serving Routes
Dixon Readi-Ride	None	None
Rio Vista Delta Breeze	50 and 52	25%
SolTrans	1, 2, 3, 4, 5, 6, 7A, 7B, 8, 12, 38, 82, Red Line, and Yellow Line	47%
Vacaville City Coach	None	None

Source: CalEnviroScreen 4.0 (2021)

Figure 2.2 Disadvantaged Communities Served by Solano County Transit Agencies



Source: WSP, CalEnviroScreen 4.0 (2021), OpenStreetMap Contributors

3 ZEB TECHNOLOGY AND MARKET CONDITIONS

The following section provides an overview of ZEB technologies and the current market conditions of BEBs, and the charging infrastructure.

3.1 Battery-Electric Buses

Battery-electric buses (BEBs) use onboard batteries to store and distribute energy to power an electric motor and other onboard systems. Like many other battery-powered products, BEBs must be charged for a longer period of time to be operational.

BEBs can be charged at the yard (overnight or midday) or on-route (typically during layovers). A yard charging strategy typically consists of buses with high-capacity kilowatt-hour (kWh) battery packs that are charged overnight for four to eight hours with "slow" chargers (which have a charge rate of 150 kilowatts (kW) or less). An on-route charging strategy typically consists of buses with low-capacity battery packs that are charged with "fast" chargers – usually more than 150 kW – during bus layovers (typically five to 20 minutes).

BEBs are charged via several dispenser types (conductive and inductive) and orientations (overhead or ground-mounted). Figure 3.1 presents the methods to dispense electricity to a BEB (from left to right): plug-in, overhead inverted pantograph, and inductive.

Figure 3.1 BEB Charging Methods

Source: YorkMix, ABB (formerly ASEA Brown Boveri), and Long Beach Transit (left to right).

Under existing conditions, BEBs cannot meet the ranges of internal combustion engine buses (ICEBs). BEBs typically have a range of 125-150 miles, and this range is affected by a myriad of factors, including temperature and heating, ventilation, and air conditioning (HVAC) usage, driving behavior, and topography. For this reason, if an agency's service blocks cannot be completed with BEBs, other capital-intensive strategies must be considered to meet range requirements, including, but not limited to, additional BEBs, on-route charging infrastructure, service changes, and/or a mixed-fleet strategy with the incorporation of fuel cell electric buses (FCEBs).

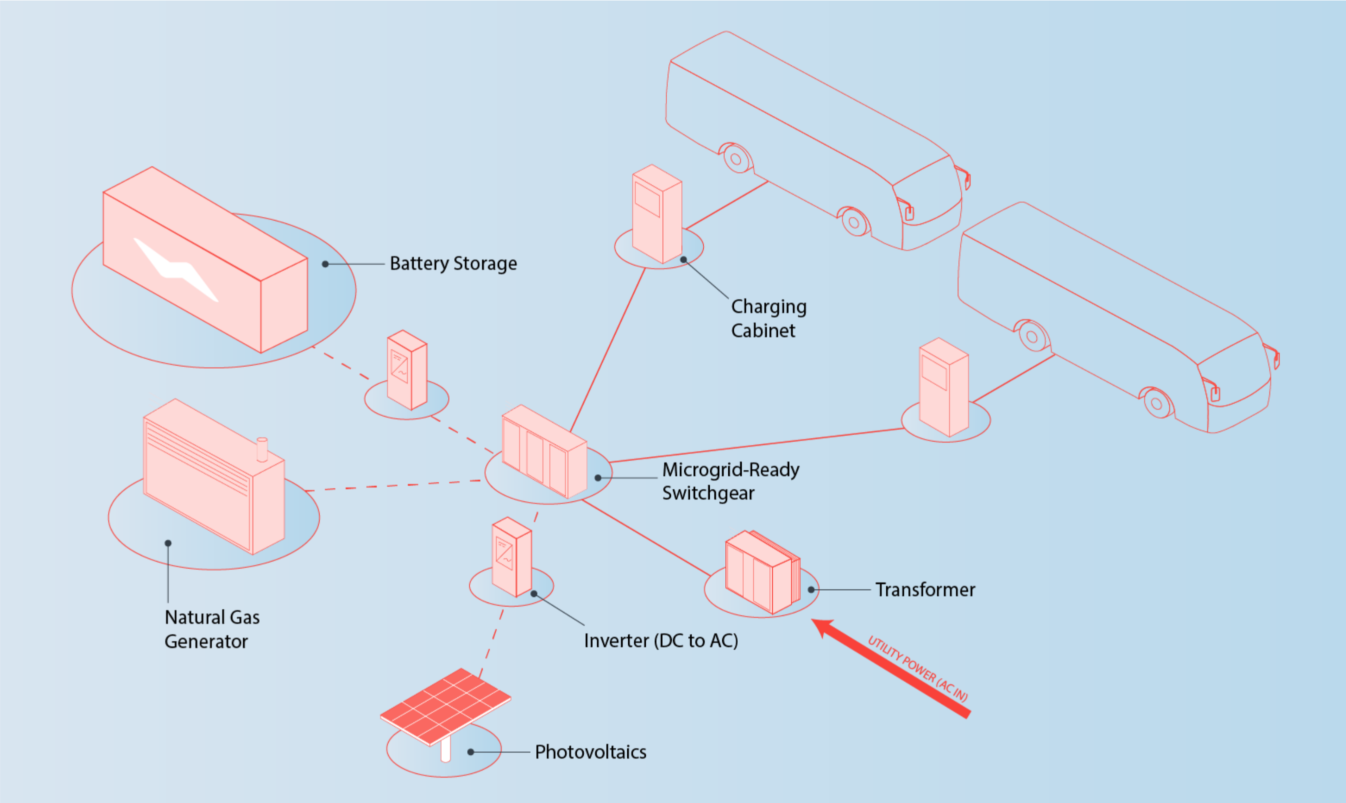
The cost of an individual BEB varies based on battery capacity, vehicle length, customizations (software/hardware, trimmings, etc.), bulk orders, and warranties. For that reason, it can be difficult to accurately estimate costs until entering a contract with an OEM. However, based on peer agencies' base BEB procurements, it is assumed that a cutaway can cost $450K, a 40-foot standard bus costs $850K, and a 40-foot motor coach costs $1.8M.

To sufficiently and safely charge BEBs, infrastructure and equipment must be in place, including:

- Charging cabinet(s) – dispense(s) power and, in most cases, converts power from alternating current (AC) to direct current (DC)
- Transformer(s) – steps down electricity to a safe and suitable limit
- Switchgear(s) – allows for the isolation of power

Other components can also be considered, such as battery storage, photovoltaics (solar panels), and backup generators. Figure 3.2 illustrates the various components of a BEB system.

Figure 3.2 Typical BEB Charging System



Source: WSP

This additional equipment can take up considerable space. Therefore, considerations to safety and reduction of impacts to existing operations must be carefully reviewed and assessed by both the agency and the utility. Due to the high electricity demand for charging a fleet of BEBs and the limited capacity available in existing grid infrastructure, expanded or new electrical service is usually required to transition fleets.

3.2 Market Conditions

3.2.1 Bus OEMs

Over the past 20 years, technological advances have made BEBs a viable and desirable alternative to ICEBs. There are a variety of bus OEMs that produce ZEBs in the United States, with many new OEMs joining the market. Table 3.1 summarizes the market-available standard, motor coach, and cutaway BEBs that best align – based on length and vehicle type – with Solano County's agencies' existing fleets (current double-decker and articulated offerings were not included).

Table 3.1 Available BEBs in the US Market (aligned with Solano County's fleets)

OEM	Vehicle Type	Length	Capacity (kWh)
ARBOC	Motor coach	30' – 35'	350 – 437
BYD	Standard	30' – 40'	215 – 352
	Motor coach	23' – 45'	141 – 446
GreenPower	Standard	30' – 40'	260 – 400
	Cutaway	25'	118
Gillig	Standard	35' – 40'	444
Lightning eMotors	Cutaways + Vans	Varies	<129
MCI	Motor coach	45'7" – 45'10"	389 – 544
New Flyer	Standard	35' – 40'	350 – 525
Nova	Standard	40'	564
Proterra	Standard	35' – 40'	450 – 675

Source: WSP

*Note: BYD is currently not in compliance with Buy America requirements

As of December 2021, approximately 3,500 ZEBs (95% of which were BEBs) are either in operation or procured in the United States – a 27% increase since 2020. Of these, approximately 1,300 ZEBs are in service. With state mandates such as CARB's ICT regulation, the demand for ZEBs is expected to increase and will certainly incentivize the launch of new OEMs and technology developments and help reduce the costs over time.

State Contracts

Bus procurements with individual OEMs can be very time-consuming and resource-intensive. The California Association for Coordinated Transportation (CalACT), a resource primarily for small, rural, and specialized transportation California-based transit providers, has several pre-approved and priced ZEBs that can be purchased to avoid lengthy bid and procurement processes. Table 3.2 presents the current ZEBs and prices that are offered via CalACT.

Table 3.2 California Bus Contract Price List

OEM	Model	Propulsion System	Length	Battery Capacity (kWh)	Cost
New Flyer	Xcelsior XE	Battery Electric	35'	311	$732,618
			40'	311	$741,768
	Xcelsior XHE	Fuel Cell	40'	100	$1,014,979
Proterra	Catalyst XR	Battery Electric	35'	220	$689,000
			40'	220	$699,000

Source: CalAct (2020)

3.2.2 Charger OEMs

Several charger OEMs have products on the market – most of which are based on Society of Automotive Engineers (SAE) standards – meaning most buses can charge with any conductive chargers that apply SAE standards. However, there are no standards for inductive charging, so adopters of one OEM (ex. WAVE) are not able to operate with other chargers (ex. Momentum). Table 3.3 summarizes the different charger OEMs and their current offerings. It should be noted that these represent DC chargers that are compatible with all bus OEMs.

Table 3.3 Available Chargers in the US Market

OEM	Charging Type	Dispenser Type	Power Output (kW)
ABB	Conductive	Plug-In and Pantograph	100-450
ChargePoint	Conductive	Plug-In and Pantograph	62.5-500
Ebus	Conductive	Pantograph	Custom
Hitachi	Conductive	Plug-In and Pantograph	Custom
Heliox	Conductive	Plug-In and Pantograph	180-450
Momentum Dynamics	Inductive		50-300
Power Electronics / Proterra	Conductive	Plug-In and Pantograph	60-600
Siemens	Conductive	Plug-In and Pantograph	150-600
Tritium	Conductive	Plug-In	50-350
WAVE	Inductive		250

Source: WSP

3.3 Emerging Technology

Several advancements and research in battery technology are aiming to improve battery energy densities and lifespans. Additional research is being conducted to reduce the cost and time required to manufacture these batteries as well as increase the cycle life.

The most significant advances are in energy density improvements resulting in reductions in battery weight. Anticipated breakthroughs within battery performance will address many of the limitations existing today in terms of range capability, weight, life expectancy, and degradation. As an example, for a bus with a 450 kWh battery, an increase of energy density from 150 Wh/kg to 300 Wh/kg could reduce bus battery weight by up to 3,000 pounds. This weight reduction would allow for additional kWh of battery capacity added or an overall reduction in bus weight.

Specific research includes:

- Lithium-air batteries are expected to exceed the conventional lithium-ion battery's charging capacity by ten times.
- Lithium-metal batteries have high specific energy and loading capabilities. They use a solid electrolyte instead of a liquid and are believed to have a higher energy density. They are also expected to have a faster charging rate, a higher voltage, and a longer cycle life.
- Semi-solid lithium batteries, rather than using a solid electrolyte, use a liquid electrolyte that prevents a gap from forming at the interface of the electrolyte and the anode-cathode separator. This ensures that access to the active material is not lost over the life of the battery.

Moreover, charger manufacturers and vehicle OEMs continue developing higher-powered charging systems, including higher powered pantographs capable of 600 kW charge rates and developing a new plug standard capable of 1 MW charging. Both of these technologies rely on changes in battery technology to develop batteries that can accept such high charging power.

4 METHODOLOGY AND ASSUMPTIONS

The following section provides an overview of the methodology and inputs used to determine the service requirements, energy and power needs, and facility concepts for each agency's ZEB transition. SolanoExpress service blocks are not included in the analysis. Two lines (Blue Line and Green Line) are part of the FAST Report (refer to Appendix G). WSP replicated the methodology to analyze the rest of the service (Yellow Line and Red Line), that can be found in Appendix H.

4.1 Service Modeling Analysis

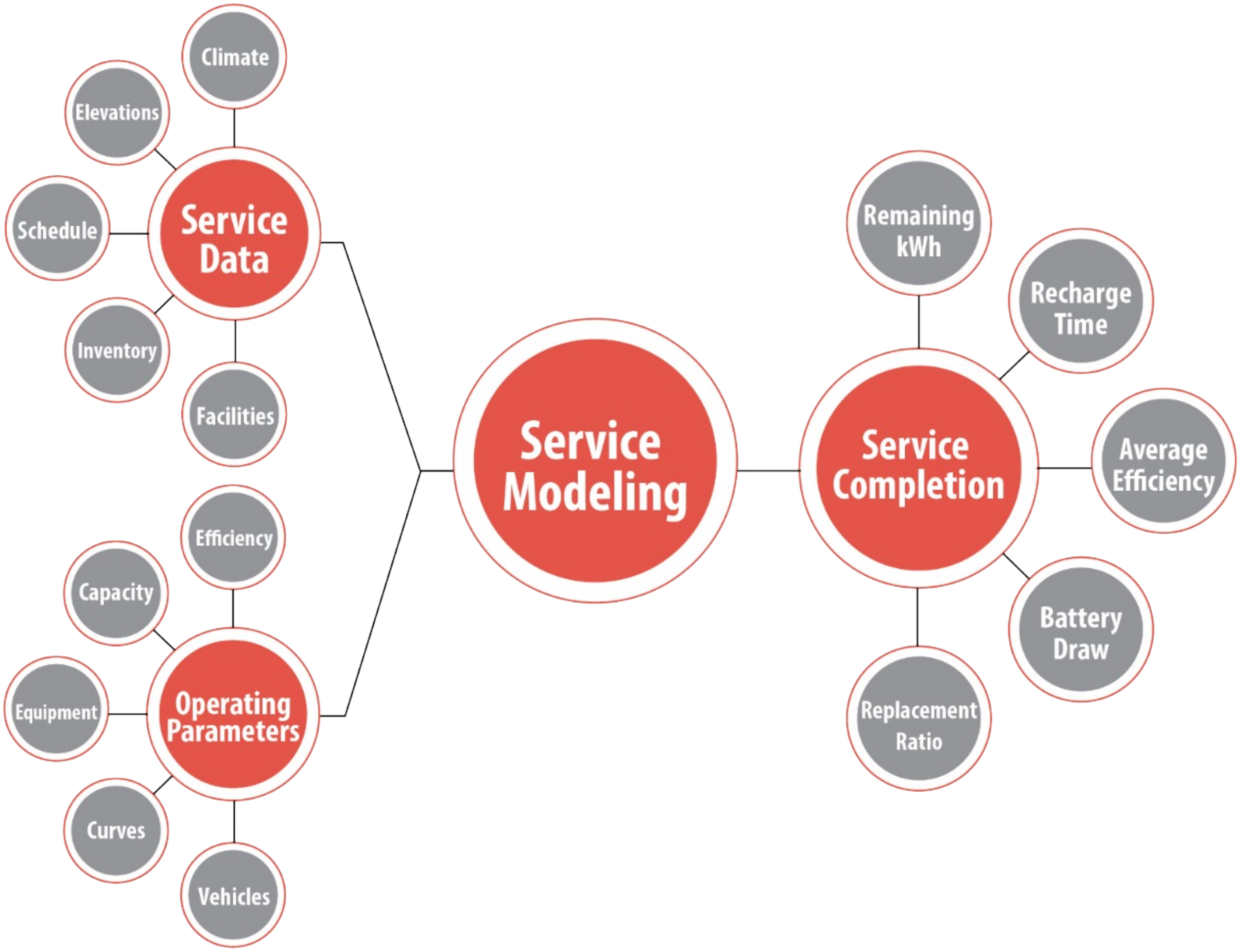
Lightning Bolt is a proprietary modeling tool developed by WSP to evaluate the feasibility of operating BEBs within a transit agency's existing bus schedule. The tool considers and analyzes several factors that may impact the performance of a BEB, including the specific operating conditions of an agency (topography, climate, and bus service schedule), charging and battery capacity parameters, and the extent to which all these factors would improve or reduce performance (Figure 4.1). Climbing hills and other landforms can negatively impact BEB performance and range – while going down a hill may help replenish the battery capacity to a lesser degree via regenerative braking. Meanwhile, ambient air temperature and the resulting HVAC usage are reported to have impacts on reducing BEB efficiency.

Lightning Bolt uses these inputs to determine the percent of service that can be completed under two scenarios: "typical" and "conservative." The two modeled scenarios – "typical" and "conservative" – demonstrate how the BEBs may perform under different conditions. The distinction between the scenarios is based on more conservative estimates for the metrics that have proven to be very impactful on energy consumption, such as ambient air temperature (using the highest or lowest average annual temperature) and elevation gain (assuming lower energy recaptured through regenerative braking).

The outputs are on a block-level scale which is a set of trips assigned to a single-vehicle during a service day. This level of analysis provides a clearer picture of the feasibility of electrifying an agency's vehicle fleet. If the modeled BEB "fails" to complete service, the output captures the degree of failure and the factors that contributed to that failure, from which WSP presents preliminary solutions (e.g., additional vehicle purchases, innovative charging solutions, and/or schedule changes). The results of modeling and this plan will be used to inform both short- and long-term operating and procurement strategies as each agency transitions its fleet.

The *Service Modeling Technical Analysis* (Appendix B) provides a more in-depth review of the data inputs and methodology used to conduct the analysis.

Figure 4.1 Lightning Bolt Model Overview



Source: WSP

Since demand response travel times and distances are variable – and each agency tracks them differently – Lightning Bolt is not a suitable tool to assess the energy required. For these services, a separate analysis was done to determine the "max" or "average" distance traveled by each vehicle to establish a baseline for assessing the energy required and making BEB feasibility recommendations.

4.1.1 Data and Assumptions

The inputs used for the model fall into two categories: service data and operating parameters. Service data includes existing bus schedules, vehicle sizes assigned to each service block, non-revenue service distances, route slope, and climate; whereas operating parameters refer to specific BEB assumptions and adjustments, such as battery capacity, vehicle efficiency, and battery safety buffers.

For the purposes of the analysis, WSP assumed that 80% of the advertised battery capacity is the operating (or usable) capacity. This accounts for an assumed 10% capacity that is deemed unusable by the OEM, as well as an additional 10% safety buffer to reduce range anxiety for operators and mitigate impacts to service.

For the end of warranted life (EWL) battery conditions, WSP assumes 80% of the operating battery capacity (approximately 64% of the advertised capacity). In practice, batteries will degrade at different rates. Table 4.1 presents the BEBs used to model service for Solano County transit agencies.

Table 4.1 Modeled BEBs

Vehicle Type	Average Capacity (kWh)	Operating Capacity (kWh)	EWL Operating Capacity (kWh)
Cutaway	118	94	76
35'	377	301	241
40'	324	259	207

Source: WSP

4.2 Power and Energy Analysis

To successfully transition to ZEB technologies, it is essential to understand the power and energy need that is required to support the fleet. These factors directly impact the capital (required number of chargers, sizing, and placement of utility infrastructure) and operating expenditures (power and energy bills).

The inputs used for calculating the required energy and power needs for each site were based on the results of the Service Modeling Analysis. The results were used to inform the development of proposed charging schedules and the value of a charge management system for the current and future fleet.

The analysis uses two scenarios, unmanaged and managed charging. The unmanaged charging scenario serves as a baseline and calculates the requirements assuming no managed charging solutions are used. This scenario provides the most flexible system but at a higher cost and potentially longer construction schedule. The managed charging scenario takes advantage of a charging station's management system (CSMS) that will allow BEB charging events to be initiated in an intelligent way to reduce the total amount of electrical power required at any given time, thus, reducing electricity demand and operational costs.

The *Power and Energy Analysis* (Appendix C) provides a more in-depth review of the data inputs and methodology used to conduct the analysis, including detailed energy resiliency and mitigation analysis discussions.

4.2.1 Data and Assumptions

WSP conducted site visits, utility bills, and PG&E databases[8] to identify circuits that feed each site. These data provide a preliminary understanding of the gap between existing and required electrical capacity. Further analysis is then conducted to assess site-specific utility upgrade recommendations.

8 The Integration Capacity Analysis (ICA) and Photovoltaic and Renewable Auction Mechanism (PVRAM) maps are designed to help contractors and developers find information on potential project sites for distributed energy resources. The information on these maps is illustrative and is likely to change or be modified over time.

Charging Rate

For the power and energy analysis, 150 kW (output) DC chargers in a 1:2 (one charger to two dispensers/ buses) were modeled and analyzed for each agency. This is a common configuration, but other options are available and should be considered during the design stage.

The maximum power provided by each charging cabinet is slightly lower than the input nameplate power suggests due to cooling system loads and other inherent inefficiencies both on the charger and battery sides. Peak charger output power often occurs between 20% and 80% of a battery's state-of-charge (SOC), with substantially reduced output power from 80% to 100% SOC. WSP assumes a constant charge rate of 90% of the advertised power of the charger to account for the variations, which equals 67.5 kW in a 1:2 configuration (Table 4.2).

Table 4.2 Modeled Charger Outputs

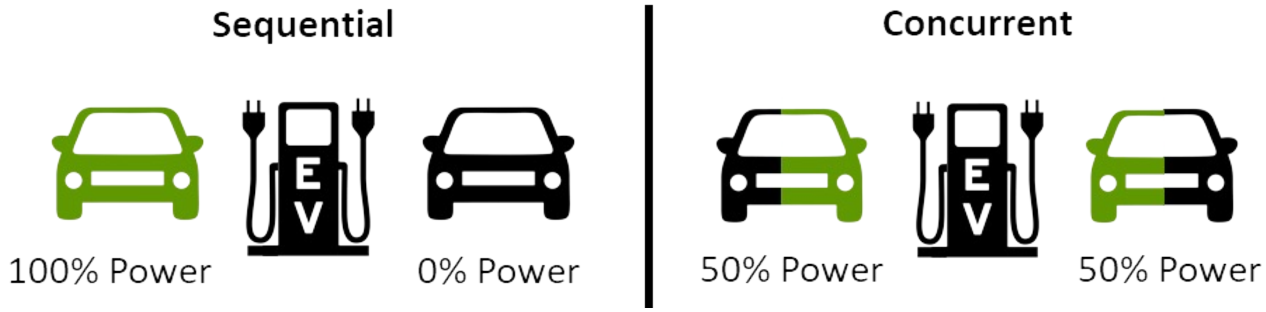
Avg Peak Output Power	Avg Modeled Charger Power	1:2 Charger to Dispensers Ratio
150 kW	135 kW	67.5 kW

Source: WSP

Charging Methods

When a charging cabinet provides power to more than a single vehicle, it can do so via two methods: sequential or concurrent charging (Figure 4.2). Sequential charging is when the charging cabinet selects which of its dispensers it provides power to, meaning it can only charge a single vehicle at a time with full power. Concurrent charging allows power to be equally split between two or more vehicles. This enables vehicles to charge at the same time, albeit at a lower rate. Depending on the amount of energy that needs to be replenished and the time spent charging, both concurrent and sequential charging configurations can be beneficial for an agency to adopt. For Dixon Readi-Ride and Vacaville City Coach, the BEBs are assumed to be charged sequentially, while at Rio Vista Delta Breeze, the BEBs are charged concurrently.

Figure 4.2 Sequential and Concurrent Charging



Source: WSP

4.3 Facility Analysis

WSP conducted site visits between June 23-24, 2021, to gather information on site conditions, circulation, vehicle inventories, electrical equipment, and other site-related items for facility operations analysis. Some agencies also provided existing facility drawings for additional context. In conjunction with the Service Modeling and Power and Energy Analyses findings, this information was used to develop conceptual drawings that provide the most viable method(s) to accommodate ZEB infrastructure on-site.

Each site's concept plan uses the existing fleet inventory and accommodates future fleet increases (as suggested by the agency). The concepts presented are not intended to reflect any fleet expansion as a method of resolving service shortcomings noted in the Service Modeling Analysis. Table 4.3 shows a breakdown of each agency's existing and future fleet inventory. Vans have been excluded from the list since they have a GVWR of less than 14,000 pounds and are therefore not required to be electrified according to the CARB ICT regulation.

A more detailed description of the assumptions used in this analysis can be found in the *BEB Facility Concepts Analysis* (Appendix D).

Table 4.3 Solano County Fleet Summary

Agency	Existing Fleet	Future Fleet
Dixon Readi-Ride	8*	10*
Rio Vista Delta Breeze	4*	8*
SolTrans	56	70
Vacaville City Coach	25	31

Source: Dixon, Rio Vista, and Vacaville Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030, and General Transit Feed Specification Data. SolTrans Zero Emission Bus Master Plan

Note: *Excludes vans

4.4 Phasing Schedule Analysis

The following section contains an overview of the methodology used to build the construction and vehicle procurements timelines.

4.4.1 Facility Construction

Facility infrastructure upgrades are planned in one or two on-site segments, or "stages," that generally represent a natural break in bus parking at the facility. This approach to construction will lead to minimal impacts on operations and no impact on riders.

Buses parked in areas that fall within each stage will be relocated for approximately six months (based on construction assumptions) to allow for the installation of the BEB charging equipment. Upon completion of each construction stage, buses can return to their parking space.

WSP and STA agencies coordinated to develop high-level assumptions for construction stages and durations based on a design-bid-build delivery method. These durations were then used to develop conceptual schedules that provide some insight into when these facilities may be ready to support ZEBs. Some stages can overlap with each other, while others rely on the completion of a previous task. The scheduling assumptions for each agency's construction process are summarized in Table 4.4, with additional details below.

The developed schedules are conceptual and may not capture some of the nuances that have the potential to prolong project delivery, including lag times, environmental clearance (CEQA/NEPA[9]), multiple build stages, materials delays, stakeholder engagement and approvals, and review times.

Table 4.4 Scheduling Assumptions

Stage	Responsibility	Description	Duration (months)
Utility Enhancements	PG&E	Plan, design, and construct off-site utility enhancements to support the power needs of each facility.	16
Design Procurement	Agency	Develop, advertise, and award contract to develop detailed designs for each facility.	4–6
Detailed Design	Designer	Take conceptual designs to 100%.	9–11
Construction Procurement	Agency	Develop, advertise, and award contract to construct infrastructure at each facility.	5–6
Construction	Contractor	Construction at each facility, including the structure, charging/fueling infrastructure, and supporting connections.	7–11

Source: WSP

4.4.2 Vehicle Procurement

All agencies in Solano County are categorized as "small transit agencies" in the regulation and, as such, must ensure that 25% of new bus deliveries between 2026 and 2028, and 100% beyond 2029, are ZEBs. During the delivery phase of procurement, buses are delivered to agencies as they come off the line at a rate specified by contract, typically two to five vehicles per week. Depending on the size of the procurement and vehicle up-fit required on-site, the delivery period may take several weeks or months.

To develop a procurement schedule, each agency must consider several requirements and constraints, such as:

- ZEBs cannot be operated unless infrastructure is in place to charge/fuel them; therefore, the delivery of ZEBs must occur after the infrastructure is constructed.
- Each agency's current vehicles must satisfy the federally mandated "useful life."
- Each agency must also satisfy the purchase requirements of CARB's ICT regulation.

Assumptions used in developing the procurement schedule include:

- Standard buses are eligible to be retired 12 years (or 500,000 miles) after their acceptance date.
- Cutaway buses are eligible to be retired five years after their acceptance date.
- Vans are eligible to be retired four years (or 150,000 miles) after their acceptance date.

9 California Environmental Quality Act / National Environmental Policy Act

- The procurement assumes a 1:1 ICEB-to-BEB replacement ratio.
- The procurement plans assume that at the end of their useful life, standard buses are immediately retired and replaced by new BEBs if there are feasible charging positions
- When necessary, to ensure there are equal or fewer BEBs to charging positions, the retirement date of some vehicles is assumed to be extended until BEB replacement is feasible.
- This analysis considers all vehicles subject to CARB ICT regulations, thus excluding vans that have a GVWR below 14,000 pounds and are not required to be electrified.

4.5 Lifecycle Cost Analysis

WSP developed a tool to assess the lifecycle costs associated with fleet electrification that will subject Solano County's transit agencies to different pricing structures and exposure to energy price volatility. The analysis consists of capital, operations, and maintenance (O&M), disposal, and environmental costs.

Agency-specific data points are preferable to inform the cost assumptions. However, industry and peer agency data are leveraged if data is unavailable. The total costs of operating a full BEB fleet ("Build" scenario) is compared to a "No Build" baseline scenario which assumes no change in the current types of vehicles in the fleet.

The following sections will briefly describe the assumptions used in the analysis. The *Cost and Funding Analysis* (Appendix F) provides a more in-depth review of the assumptions, data inputs, and methodology used to conduct the analysis. The values presented throughout this document are subject to change and are based on the most current information available at the time of this analysis.

4.5.1 Data and Assumptions

The lifecycle cost model employs a nominal discount rate of 9.5%. All cost assumptions are in 2021 dollars, while each agency's results are in year of expenditure (YOE) dollars. The model also accounts for inflation using the historical Consumer Price Index for all Urban Consumers (CPI-U) and Producer Price Index (PPI) for Bus Chassis Manufacturing.

Capital Costs – Vehicle

Vehicle purchase costs include the base purchase price (Table 4.5), additional service preparation and inspection costs, special tools and diagnostic equipment costs, and allowances for contingency. For transit buses above 35-feet, an additional $120,000 was assumed as additional options and charges. For BEBs, an additional cost for battery extended warranty over the life of the vehicle is assumed. The vehicle capital expenditure is based on the fleet procurement plan[10] and incurred one year prior to the operational start date to account for delivery lag and acceptance testing.

10 Appendix E: *Phasing Strategy and Transition Analysis*

Table 4.5 Assumed Vehicle Base Purchase Price

Bus Type	Gasoline	Hybrid	CNG	BEB
Cutaway	$132,514	-	$249,306	$263,905
35' Standard Bus	-	-	$919,576	$1,048,081
40' Standard Bus	-	$1,107,117	$833,105	$1,065,530

Source: WSP, MTC Bus Pricing, and California State Contract

Notes: Base vehicle costs for BEB are sourced from the California State Buy board. ICEBs base costs are sourced from the Metropolitan Transportation Commission (MTC) Regional Bus/Van Pricelist FY2022-23 Sheet

Capital Costs – Infrastructure

Five types of costs make up the utility improvement costs: direct cost, general conditions, contractor fee, bonds and insurances, and contingency. Direct costs are physical infrastructure and equipment costs. General conditions are 20% of the direct cost. The contractor fee percentage is 15% of direct cost and general conditions. Bonds and insurances are 3% of the total costs. Lastly, an extra 30% is added on top of the total costs for contingency.

Infrastructure capital cost was developed by a WSP estimator who assessed the facility needs at Dixon Readi-Ride, Rio Vista Delta Breeze, and Vacaville. For SolTrans, a previous estimate by a separate contractor was used for the analysis. Detailed infrastructure cost estimates are provided in the *Cost and Funding Analysis* (Appendix F).

Operation and Maintenance Costs

Vehicle O&M costs include not only time of the individual to operate the vehicle but also general vehicle maintenance, tire service, fueling infrastructure annual maintenance, fuel or energy, and bus disposal and retirement costs. Vehicle O&M costs are specific to the vehicle types and the length of the vehicles. Overall O&M costs are influenced by each vehicle's operating costs per mile and annual mileage. Table 4.6 provides the assumed average vehicle mileage and useful life for each bus type, while Table 4.7 presents the vehicles O&M costs over years of operation. The fueling infrastructure O&M costs varies for each agency, depending on the existing condition of fueling infrastructure on-site.

Table 4.6 Assumed Average Vehicle Mileage and Useful Life

Bus Type	Service Type	Useful Life	Average Vehicle Mileage (miles)			
			Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
Cutaway	Fixed Route	10 years (except. SolTrans: 7 years)	-	28,378	-	-
	Demand Response		22,956	35,595	14,031	39,273
35' Standard Bus	Fixed Route	12 years	-	-	-	27,777
40' Standard Bus	Fixed Route	12 years	-	-	36,068	-

Source: WSP

Notes: Average vehicle mileage is estimated based on the fleet age and mileage outlined in the STA 2020 Short Range Transportation Plan (SRTP)

Table 4.7 Vehicle O&M Costs by Year of Operation

Year of Operation	"No Build" Scenario			"Build" BEB Scenario		
	Cutaway	Hybrid 40'	CNG 35'/40'[11]	Cutaway[11]	35'[12]	40'[12]
Year 1 ($/mi)	0.81	0.40	0.20	0.80	1.17	1.17
Year 2 ($/mi)	0.88	0.57	0.20	0.87	1.26	1.26
Year 3 ($/mi)	0.96	0.66	0.25	0.95	1.45	1.45
Year 4 ($/mi)	1.03	0.90	0.30	1.02	1.42	1.42
Year 5 ($/mi)	1.11	1.05	0.51	1.10	1.81	1.81
Year 6 ($/mi)	1.14	1.11	0.45	1.13	1.92	2.31
Year 7 ($/mi)	1.19	1.27	0.50	1.18	2.19	2.31
Year 8 ($/mi)	1.22	1.26	0.56	1.21	2.15	2.52
Year 9 ($/mi)	1.25	1.58	0.52	1.24	2.71	2.79
Year 10 ($/mi)	1.29	1.35	0.57	1.28	2.31	2.53
Year 11 ($/mi)	N/A	1.04	0.62	N/A	1.79	2.35
Year 12($/mi)	N/A	1.03	0.65	N/A	1.76	2.25
Tires ($/mi)	0.068[13]	0.068	0.068	0.072[14]	0.072	0.072
Charger ($/year per Vehicle)	N/A	N/A	N/A	218[13]		

Source: WSP Peer Agencies

11 Based on a peer agency's experience in San Bernadino County, California

12 Based on a peer agency's experience in Washington

13 Based on a peer agency's experience in Washington

14 Based on a peer agency's experience in Washington. Assumed 10 percent higher than baseline existing vehicles to account for the heavier weight of BEBs

Fuel and energy costs for vehicles are based on MCE Clean Energy and US EIA's fuel price. Additionally, annual demand charge per electric vehicle was applied for BEB replacement scenarios using the MCE Clean Energy rates. Table 4.8 provides the summary of fuel/energy costs assumptions used in the analysis.

Table 4.8 Fuel and Energy Cost Assumptions

Category	Electricity			Diesel	Gasoline	CNG		
	25'	35'	40'	40'	25'	25'	35'	40'
Fuel/Energy Cost	$0.19/kWh[15]			$2.33/gal[16]	$2.72/gal[17]	$2.41/gal[18]		
Demand Charges ($/vehicle-year)	$3,766[19]			N/A	N/A	N/A		
Vehicle Fuel Efficiency (mpdge or kWh/mile for BEB)	0.79	1.88	2.08	6.1	8.1	5.59	3.9	3.0

Source: USEIA and MCE Tariffs for Large Businesses

Environmental Costs

Environmental costs consist of tailpipe emissions, lifecycle Greenhouse Gas (GHG) 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 annual vehicle mileage. The vehicle tailpipe emissions in g/mi were provided by the AFLEET tool, Environmental Protection Agency (EPA) MOVES 2014b model, and PG&E carbon footprint calculator. Meanwhile, lifecycle GHG emissions were gathered from CARB's All Pathways List. Table 4.9 summarizes the emissions for different fuel types.

15 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming a mix of 33% of summer rates and 67% of winter rates. Within the summer and winter rates, the analysis assumes peak, part-peak, and off-peak splits to be 20%, 40%, and 40%, respectively. This rate also includes PG&E's delivery rate, power charge indifference adjustment (PCIA) and franchise fee (FF).

16 2021 California average regular gasoline sales for resale average without tax from USEIA

17 2021 California average sales for resale No 2 Distillate without tax from USEIA

18 Five year average fuel price with tax from CNGNOW

19 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming 11% of summer peak, 22% of summer part-peak and 67% of winter peak rates. Based on 2:1 bus to charger ratio for 150 kW chargers.

Table 4.9 Tailpipe Criteria Air Pollutant (CAP) and Lifecycle GHG Emissions (g/VMT)

Emission	BEB			Diesel Hybrid	Gasoline	CNG[20]		
	25'	35'	40'	40'	Cutaway[21]	24'	35'	40'
Vehicle Tailpipe CAP								
NOX	-	-	-	2.63	0.12	0.13	0.13	0.13
SOX	-	-	-	0.01	-		-	-
PM10	0.11	0.11	0.11	0.21	0.19	0.22	0.22	0.22
VOC	-	-	-	0.50	1.50	0.44	0.44	0.44
PM2.5	0.01	0.01	0.01	0.03	0.03	0.03	0.09	0.03
Lifecycle GHG								
CO2	358[22]	853[23]	943[24]	1,997	1,704	1,397	2,481	3,259

Source: AFLEET Analysis, EPA Moves 2014 Model, CARB, and PG&E

4.6 Funding Gap Analysis

The funding gap analysis aims to identify the additional amount of funding needed to be secured by each transit agency to fully electrify their fleet. The currently planned capital budget is identified from each agency's Short Range Transportation Plan (SRTP). Since these SRTP plans were adopted in 2020, there may be some overlap between the capital costs outlined in the SRTP Capital Costs and the electrification plan capital cost analyzed. Funding resources outlined in the SRTPs to support revenue vehicle replacements, electrical charging infrastructure, and facilities-related expenses for maintenance/yards are assumed to be available to support the *Solano Countywide Electrification Transition Plan*. Other existing agency revenues that could potentially be applied to this funding gap are also included.

The Cost and Funding Analysis (Appendix F) provides a more in-depth review of the assumptions, data inputs, and methodology used to conduct the analysis.

4.7 Staffing and Training

Staffing and training impacts related to fleet electrification were analyzed by using information from peer agencies with BEB experience and document reviews related to training. High-level recommendations are given in key areas essential to full fleet electrification. The actual staffing and training needs might vary based on the specific characteristics of Solano County's transit agencies' current staffing and service operations. See Section 10 for additional analysis and discussion.

20 GHG Emissions: CARB All Pathways. CNGF204 Carbon Intensity of 80.59.

21 Used the school bus option in the AFLEET tool.

22 0.524 lbs. CO2/kWh by PG&E Carbon Footprint Calculator

23 CARB All Pathways. ULS000L00072019, carbon intensity of 100.45

24 CARB All Pathways. 90 percent of CBO000L00072019, carbon intensity of 100.82 and 10 percent of ETHC244L, carbon intensity of 76.27

DIXON READI-RIDE

5 DIXON READI-RIDE

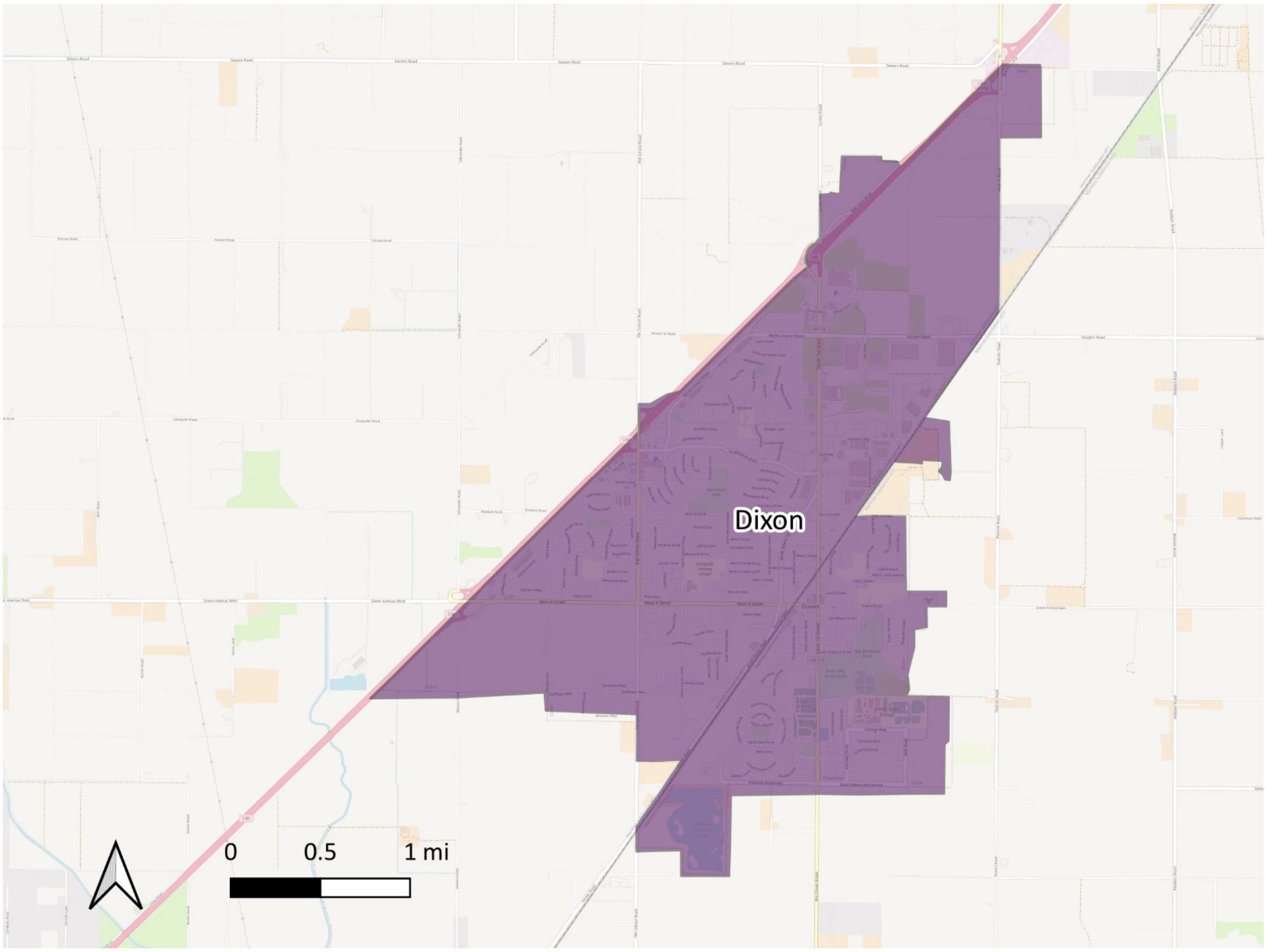
The following sections present Dixon Readi-Ride's existing conditions, service modeling results, power and energy analysis, facility concepts, phasing strategies, and cost and funding analysis to support the agency's ZEB transition.

5.1 Existing Conditions

5.1.1 Existing Service

Dixon Readi-Ride was established in 1983 as a public dial-a-ride transit system administered by the City of Dixon. It continues to provide curb-to-curb transit service within the city of Dixon (Figure 5.1). The hours of operation are Monday - Friday from 7:00 AM - 5:00 PM. The city has no fixed-route transit service.

Figure 5.1 City of Dixon



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

The service operates with two vans and eight cutaways, all powered by gasoline (Table 5.1). The vehicles were put in service between 2007 and 2019.

Table 5.1 Summary of Dixon Readi-Ride's Existing Fleet

Bus Type	Length	Fuel Type	In-Service Year	Quantity
Van	Unknown	Gasoline	2010	2
Cutaway	Unknown	Gasoline	2007-2019	8
			Total Vehicles	**10**

Source: Dixon Readi-Ride Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

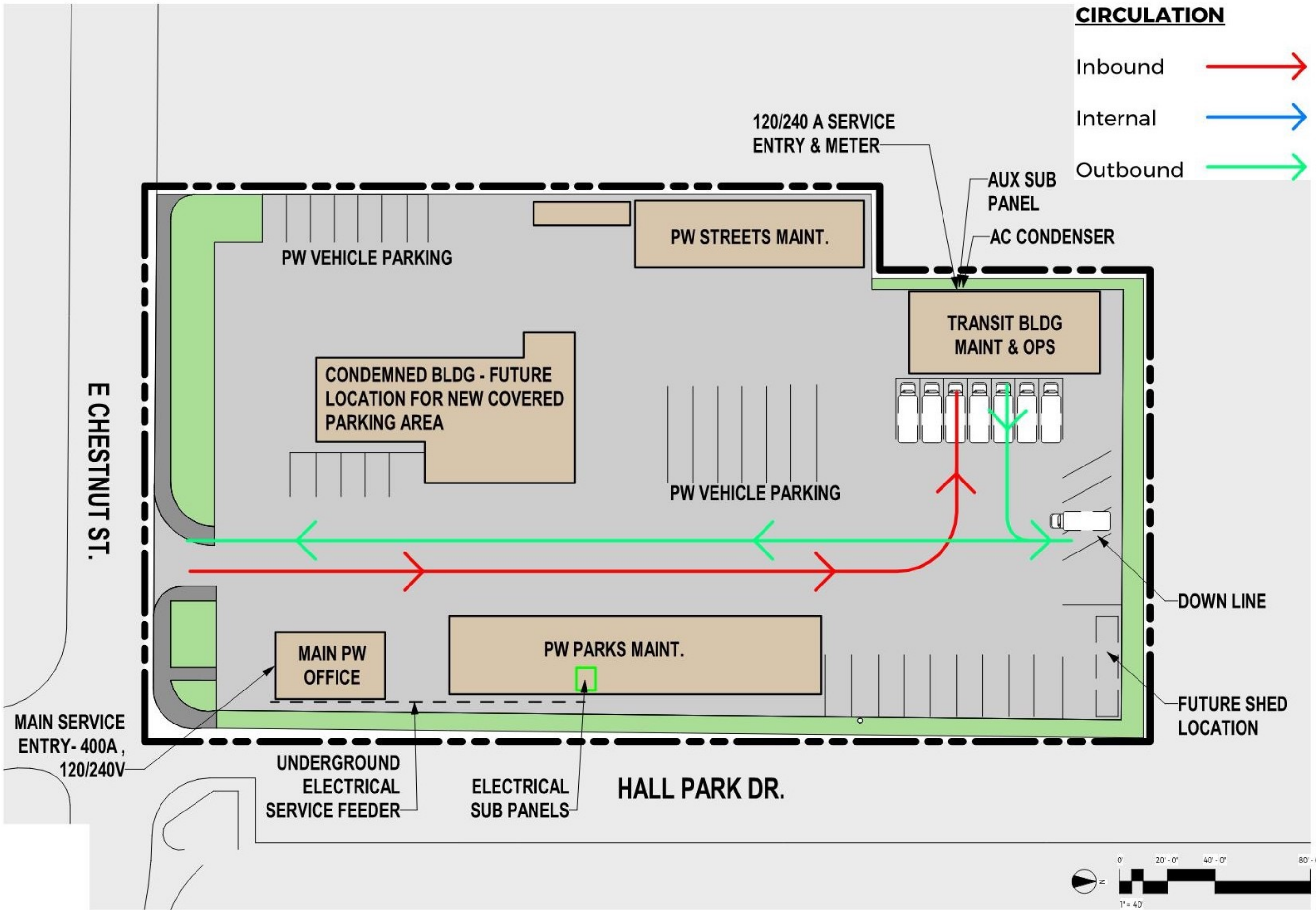
Note: A detailed list of Dixon Readi-Ride Existing Fleet is available in Appendix A: *Existing Conditions Analysis*

5.1.2 Existing Facility Conditions

The Dixon Readi-Ride facility is located at 285 East Chestnut Street (Figure 5.2). The transit operations share the site with the City of Dixon Public Works Department, and despite having a relatively small, dedicated portion of the overall site, transit operations still have adequate room to support the fleet. The transit operations consist of a parking area containing 13 parking spaces as well as a maintenance and operations building. There are also multiple single-phase electrical service entry points at the site.

There are two future site improvements planned at the facility. One is for a new storage shed that would be located in the northeast corner. The other is to demolish the condemned building in the center and replace it with a covered parking area for public works vehicles. Neither project is planned for the near future, and neither should affect the electrification implementation.

Figure 5.2 Dixon Readi-Ride Existing Facility and Site Circulation



Source: WSP

5.1.3 Existing Power and Energy Conditions

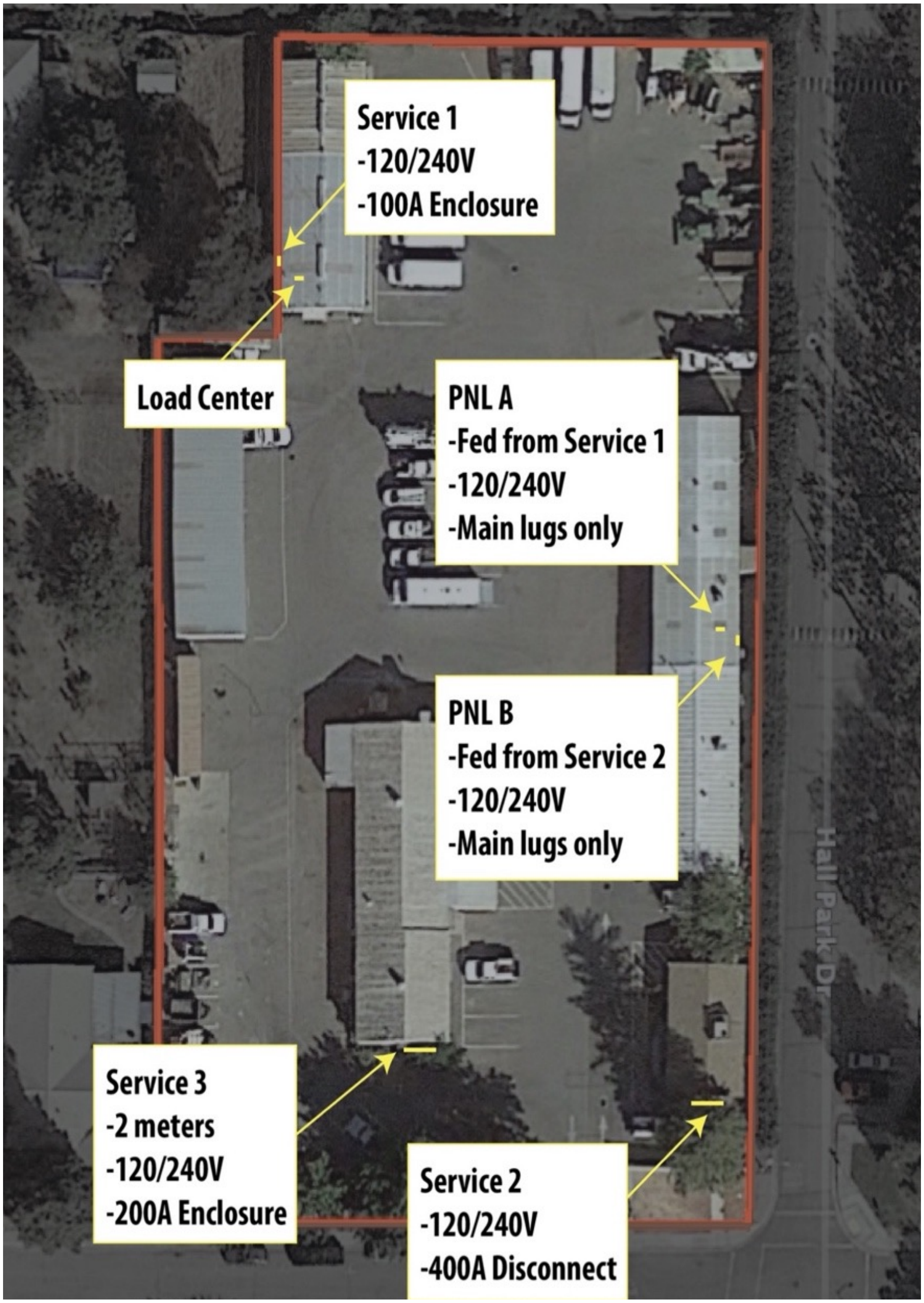
Dixon Readi-Ride's power is provided by the PG&E Dixon Substation (6206), which has a capacity of 39 megawatts (MW) on Bank 1 with a peak load of approximately 18.1 MW (based on publicly available data). The Dixon Substation feeds the Dixon 1103 feeder circuit that feeds the Dixon Readi-Ride yard. The Dixon 1103 Circuit is a 12-kilovolt (kV) circuit that has an existing capacity of 10.9 MW. PG&E estimates that the projected peak load of this circuit is 9.3 MW, leaving approximately 1.6 MW of available capacity.

If a new service is warranted from future transit upgrades, the new service could potentially be fed by the nearby Dixon 1102 Circuit if PG&E is unable to serve the required load from the existing 1103 circuit. The loads for the Dixon 1102 Circuit increase in the summer months and has peaks at 7:00 PM between June and August. BEBs on-site will most likely charge overnight, so this feeder profile should not affect Dixon Readi-Ride's electricity bill or peak demand charge.

Existing electrical service appears to be served by a 12 kV – 240/120V, single-phase, pole-mounted PG&E-owned transformer, likely shared with adjacent facilities and residential homes located approximately 0.5

miles from Dixon Substation. On-site electrical infrastructure includes two panelboards and three services (Figure 5.3). Appendix C: *Power and Energy Analysis* provides detailed information on the services.

Figure 5.3 Dixon Readi-Ride Plan View



Source: WSP

5.2 Service Modeling

Dixon Readi-Ride operates only demand response services. Since the vehicle miles traveled for demand response services are variable, the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the daily and maximum mileage traveled by the fleet. The vans were not included in the following analysis because their GVWR is below 14,000 pounds, and thus they are not subject to the CARB ICT requirements.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance for the service is between 83 and 103 miles. The GreenPower EV Star – a representative BEB replacement for Dixon Readi-Ride's existing vehicles – has an advertised range of 150 miles.

Based on the comparison between the advertised range of existing battery electric cutaways and the service's average daily vehicle distance, Dixon Readi-Ride should be able to operate its demand response service with no or minimal impact. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service. However, under EWL battery conditions (64% advertised capacity), the expected vehicle range is at or below the calculated average daily vehicle distance.

However, it should be noted that this estimate does not consider HVAC usage, slope, and other service area-specific variables that can significantly impact the vehicle's efficiency and range. For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

5.3 Power and Energy Analysis

Dixon Readi-Ride fleet currently consists of ten gas vehicles: eight cutaways and two vans. This analysis takes into consideration that in the future, the transit agency will have the capability to operate all BEB cutaways. This analysis calculated the electrical requirements for both the current and assumed future fleet.

The analysis evaluates the fleet under an unmanaged and managed charging scenario. In the unmanaged charging scenario, all vehicles will charge concurrently at the same time. Meanwhile, the managed charging scenario assumes that the vehicles will charge sequentially at a full charging rate before switching to the next vehicle. This scenario will reduce the peak demand power required but will result in a longer charging time. However, because BEBs are charging at the same rate during non-peak hours, the longer time should not affect the total energy (kWh) utility cost. The summary of the charging scenarios analysis is shown in Table 5.2.

Existing Fleet

To service the existing fleet, it is recommended that four 150 kW DC chargers be installed. The recommendation is for Dixon Readi-Ride to do managed charging. Managed charging will reduce the peak demand from 600 kW in the unmanaged scenario to 150 kW. It will reduce overall utility costs due to the lower peak demand and reduce capital costs because of the smaller equipment upgrades required. If necessary, one 150 kW DC fast charger can be used at full speed for flexible mid-day recharging.

Future Fleet

An additional 150 kW DC charger will be needed to anticipate the additional needs of two electric cutaways in the future fleet. The total peak demands are 750 kW and 300 kW for unmanaged and managed charging scenarios, respectively. Therefore, a charge management system is strongly recommended for Dixon Readi-Ride. Upgrading the electrical equipment to anticipate this load level will future-proof the site from fleet expansions.

Table 5.2 Summary of Dixon Readi-Ride Charging Scenarios

Fleet	Min. Required # of Chargers	Scenario	Charge Schedule	Charge Rate (per vehicle)	Peak Demand	Required Power Increase*
Current Fleet	Four 150 kW DC chargers	Unmanaged	All BEBs charge concurrently	67.5 kW	600 kW	660 kW
		Managed	Each BEB charges sequentially	135 kW	150 kW	165 kW
Future Fleet	Five 150 kW DC chargers	Unmanaged	All BEBs charging concurrently	67.5 kW	750 kW	825 kW
		Managed	8 BEB charge sequentially, the rest charge concurrently	135 kW	300 kW	330 kW

Source: WSP

*Note: Required power increase includes 10% buffer for ancillary loads and losses

Power and Energy Upgrades

Based on the analysis, the following facility electrical upgrades are required, assuming the worst-case scenario of unmanaged charging to accommodate the future fleet:

- 1000 kVA transformer fed by a new 12 kV underground electrical pole near Hall Park Drive
- 480V service entrance main switchboard with a minimum electrical rating of 1600 A and utility metering cabinet
- Underground electrical conductor in conduit from the new transformer to new 480V switchgear
- Vehicle charging stations with underground conduit connecting the charging stations to the new 480V switchgear

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Dixon Readi-Ride would be responsible for installing the on-site switchboard, utility metering cabinet, underground conduit, and charging stations. It is important to note that managed charging is strongly recommended, and electrical equipment properties should be determined during the design phase based on the level of electric service requested and discussions with PG&E.

Energy resiliency at the site is vital to ensure Dixon Readi-Ride has reliable service after transitioning to a full BEB fleet. One or more of the strategies below provide a suitable level of backup power after considering the possible resiliency issues that the site might experience[25]:

- 400 kW standby permanent generator
- 400 kW trailer-mounted generator and associated connection equipment
- Solar PV system paired with 1 MWh battery-electric storage system (BESS) in 20' x 8' container

A generator with an output rating of at least 400 kW can power two 150 kW DC charging cabinets simultaneously and fully recharge all vehicles overnight. A solar PV system with battery storage could provide the site with supplemental power but will not be an effective standalone backup generation source.

5.4 ZEB Transition Plan

5.4.1 Facility Concept

The Dixon Readi-Ride facility concept supports ten charging positions. Positions are planned for the zero-emission vehicles (ZEVs) that will replace the existing eight cutaway vehicles while also leaving room for two additional vehicles in the future. Five DC charging cabinets and 10 DC plug-in dispensers are needed to support the fleet. The number of dispensers required can decrease through further evaluation of the buses' charging window and end-of-the-day SOC. Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles. Of the ten plug-in dispensers, four will be ground-mounted, while seven will be overhead-mounted and require cable retractors.

These vehicles are parked outdoors, either at the east end of the maintenance building or at the north end of the facility along the fence line. Table 5.3 provides an overview of the proposed charging and utility infrastructure improvements. For additional details, refer to Appendix D: *BEB Facility Concepts Analysis*. Figure 5.4 illustrates the proposed facility concept to support the electrification transition.

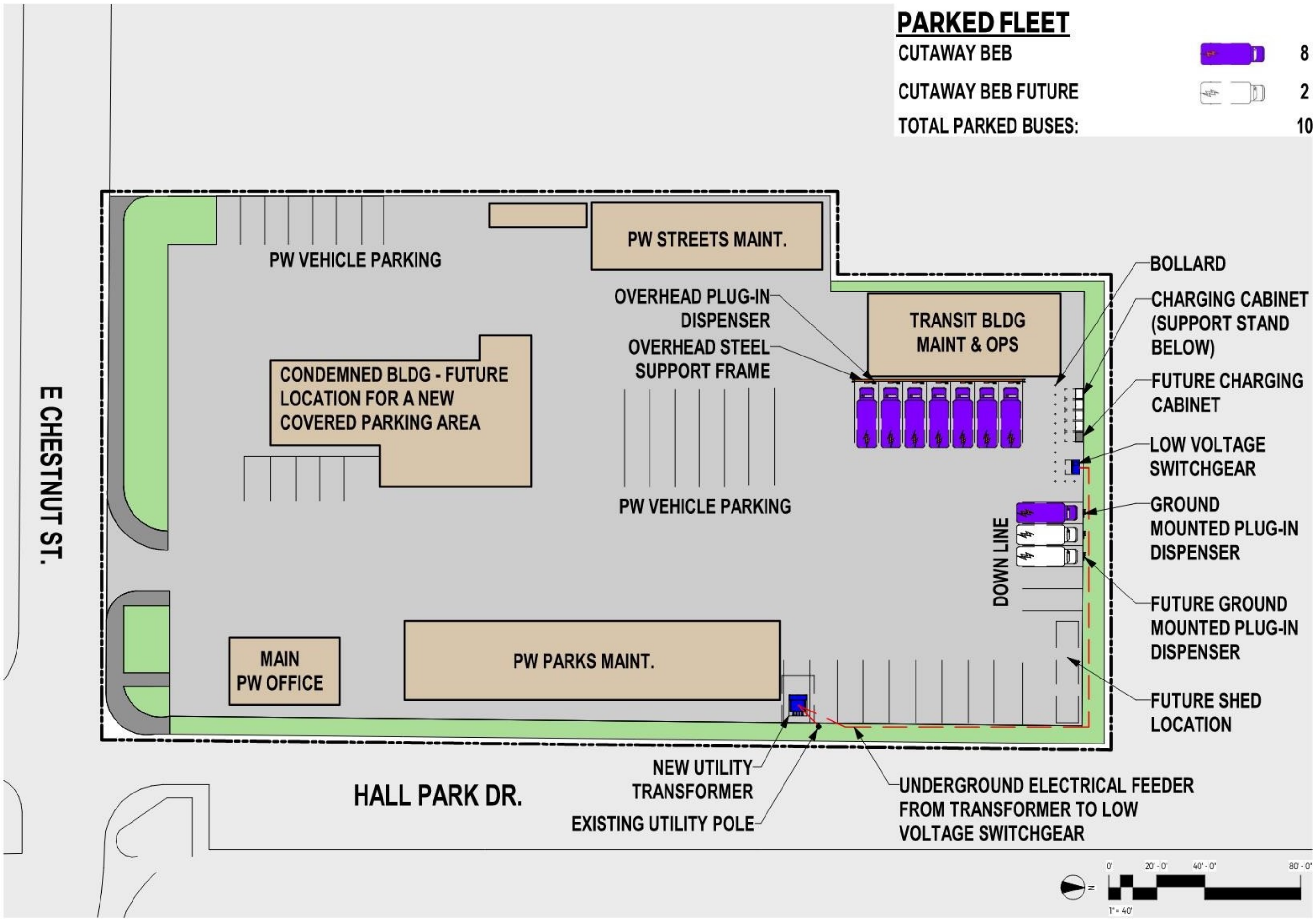
Table 5.3 Dixon Readi-Ride Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	5
Plug-in DC Dispenser	10
Cable Retractor	7
Plug-in DC Dispenser in Maintenance Area	1
Transformer	1
Switchboard	1

Source: WSP

25 Appendix C: *Power and Energy Analysis* provides in-depth resiliency analysis for the site

Figure 5.4 Dixon Readi-Ride Preliminary Facility Concept



Source: WSP

5.4.2 Construction Schedule

Due to the relatively small fleet size and the proposed configuration of the improvements, it is recommended that all on-site improvements be constructed in a single stage. The charging cabinets and associated dispensers, however, could be procured and installed in stages to better align with a desired bus procurement schedule.

The vast majority of the planned charging infrastructure and utility distribution can be done with minimum impact on current operations. However, once construction begins, vehicles that park in front of the existing maintenance building will need to be relocated. Once the frame construction is completed, the buses can resume their current parking arrangement at night while overhead electrical cabling and equipment are installed. Careful coordination between the contractor and site managers will be needed to ensure that an adequate number of maintenance bays are still accessible during construction.

Based on the assumed duration, Dixon Readi-Ride's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022. Table 5.4 illustrates the proposed schedule.

Table 5.4 Dixon Readi-Ride Construction Schedule

<table>
<tr><th></th><th>Jul-22</th><th>Aug-22</th><th>Sep-22</th><th>Oct-22</th><th>Nov-22</th><th>Dec-22</th><th>Jan-23</th><th>Feb-23</th><th>Mar-23</th><th>Apr-23</th><th>May-23</th><th>Jun-23</th><th>Jul-23</th><th>Aug-23</th><th>Sep-23</th><th>Oct-23</th><th>Nov-23</th><th>Dec-23</th><th>Jan-24</th><th>Feb-24</th><th>Mar-24</th><th>Apr-24</th><th>May-24</th><th>Jun-24</th><th>Jul-24</th><th>Aug-24</th><th>Sep-24</th></tr>
<tr><th>Months</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th></tr>
<tr><td>Utilities</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="18">18 months</td><td></td><td></td><td></td></tr>
<tr><td>Design Procurement</td><td colspan="6">6 months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Construction</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">7 months</td></tr>
</table>

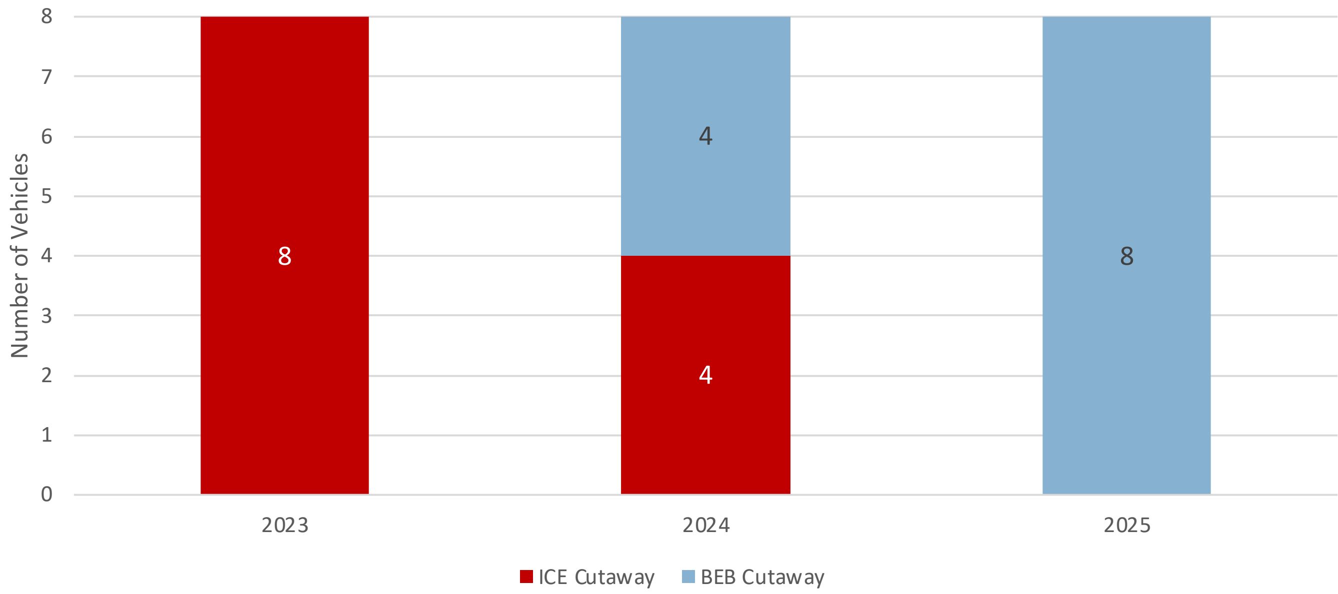
Source: WSP

5.4.3 Vehicle Procurement Schedule

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. Therefore, the first delivery of battery-electric cutaways will not occur until October 2024. The fleet will be fully electric by 2025.

The developed procurement timeline assumes that vehicles will be purchased in two sets of four vehicles. This approach will help ease the transition so that Dixon Readi-Ride has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZEVs are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Figure 5.5 illustrates Dixon Readi-Ride's fleet mix over time (between ICE and ZEB vehicles).

Figure 5.5 Dixon Readi-Ride Fleet Mix



Source: WSP

5.4.4 Lifecycle Costs Analysis

Based on the lifecycle cost analysis, the total cash cost (including capital, O&M, disposal and excluding environmental costs) of operating a full BEB fleet is approximately $8M, 56% higher than if Dixon Readi-Ride continued to operate a full gasoline fleet. This is due to the significantly higher capital costs. The total vehicle capital costs (with modification) are $2.5M for BEB compared to $1.3M for ICE vehicles. Furthermore, the total charging/fueling infrastructure capital costs are $1.8M for BEB and $0 for ICEB fleet because Dixon Readi-Ride currently does not have any fueling infrastructure on-site.

However, the lifecycle environmental costs for gasoline fleet are approximately $0.38M higher than a full BEB fleet, which will bring the total cash and non-cash costs difference between the two fuel types down to 43%. The total lifecycle cash and non-cash costs are $2.70/mile and $3.86/mile for ICE and BEB fleets, respectively.

Table 5.5 provides the summary of the lifecycle cost analysis.

Table 5.5 Lifecycle Cost (2021-2037) Analysis Results for Dixon Readi-Ride (in millions of YOE$)

Cost Categories	"No Build" Scenario	"Build" BEB Scenario
Cash Costs		
Total Capital Costs	$1.25	$4.25
Total Operating Costs	$3.78	$3.57
Total Disposal Costs	-$0.06	-$0.06
Total Cash Cost	$4.97	$7.76
Non-Cash Costs		
Total Environmental Costs	$0.64	$0.26
Total Cash and Non-Cash Costs	$5.61	$8.02
Total Cash and Non-Cash Costs per Mile	**$2.70**	**$3.86**

Source: WSP

Note: The total costs may vary due to rounding. Refer to Appendix F: *Cost and Funding Analysis* for a detailed breakdown of each item.

Note: All values are presented in and rounded to the nearest million

5.5 Findings and Next Steps

5.5.1 Service Feasibility

Based on a high-level comparison between the advertised range of existing battery electric cutaways and the service's average daily vehicle distance, Dixon Readi-Ride should be able to operate its demand response service with no or minimal impact.

However, this analysis does not consider HVAC usage, slope, and other service area-specific variables that can significantly impact the vehicle's efficiency and range. For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

5.5.2 Power and Energy Upgrades

Based on the analysis, it is recommended for Dixon Readi-Ride to install at least four 150 kW DC chargers for the current service with managed charging to keep the peak demand low. An additional charger will be needed to future-proof the site for fleet expansion. Managed charging will reduce overall utility costs due to the lower peak demand and also reduce capital costs because of the smaller equipment upgrades required.

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Dixon Readi-Ride would be responsible for installing the switchboard, utility metering cabinet, underground conduit, and charging stations.

The next immediate steps for Dixon-Readi Ride are:

1. Decide whether to invest in a charge management system.
2. Begin service application and coordination with PG&E to request new service for the calculated load
3. Determine outage mitigation methods. If a backup generator is selected, include the design and procurement in engineering and construction scope.
4. Procure long-lead items.
5. Begin construction.

5.5.3 ZEB Transition Plan

Facility Concept

The Dixon Readi-Ride facility concept supports ten charging positions. Five DC charging cabinets and 10 DC plug-in dispensers are needed to support the fleet. Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles.

Several considerations important for Dixon Readi-Ride facility improvements are:

- Due to cutaway vehicles typically being equipped with charging ports at the front of the vehicle, operators will have to pull forward into the parking spaces instead of backing into them. This will allow easier access between the dispenser and the vehicle charging port.
- The Public Works vehicles may also transition to battery-electric in the future. Therefore, the proposed infrastructure should be installed with consideration to future expansion.
- Although it is not anticipated to be an issue, the weight of the future vehicles should be specified in accordance with the existing vehicle lift capacity. If a heavier vehicle is specified, then the existing vehicle lifts will need to be upgraded.

Phasing Schedule

Due to the relatively small fleet size and the proposed configuration of the improvements, it is recommended that all on-site improvements be constructed in a single stage. The vehicle parking in front of the maintenance building will need to be relocated until the frame construction is completed.

Based on the assumed duration, Dixon Readi-Ride's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022.

To align the delivery of new vehicles with charger availability, the first round of vehicle procurement will be delivered in October 2024, after the completion of the facility's improvements. The developed procurement timeline assumes that vehicles will be purchased in two sets of four vehicles. The fleet will be fully ZE by 2025.

Cost And Funding

Based on the lifecycle cost analysis, the total cash cost of operating a full BEB fleet is approximately $8M, 56% higher than if Dixon Readi-Ride continued to operate a full gasoline fleet. This is due to the significantly higher capital costs. The costs difference goes down to 53% when considering the environmental costs of a full ICE fleet.

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in the agency's FY 2021-2030 SRTP adopted in 2020 as outlined in Table 5.6. There are also additional funding sources through federal, state, regional, and other grant opportunities that can be explored to fill the estimated funding gap. This analysis only considers the capital costs needed based on the phasing schedule developed in sections 5.4.2 and 5.4.3 (for the BEB fleet) and the potential funding sources for capital projects. Strategies for addressing the identified gaps are discussed in sections 9 and 11.5.2.

Table 5.6 Dixon Readi-Ride Estimated Costs and Funding Shortfall by Year (in millions of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Estimated Capital Costs	$0.00	$0.00	$2.38	$1.87	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$4.25**
Potential Funding Identified in SRTP	$0.00	$0.00	$0.19	$0.00	$0.00	$0.10	$0.00	$0.11	$0.00	$0.12	**$0.52**
Other Potential Existing Capital Revenues	$0.29	$0.29	$0.26	$0.23	$0.23	$0.21	$0.20	$0.17	$0.11	$0.12	**$2.11**
Surplus / Gap	$0.29	$0.29	-$1.93	-$1.64	$0.23	$0.31	$0.20	$0.28	$0.11	$0.24	**-$1.62**

Source: WSP

Note: All values are presented in and rounded to the nearest million

RIO VISTA DELTA BREEZE

6 RIO VISTA DELTA BREEZE

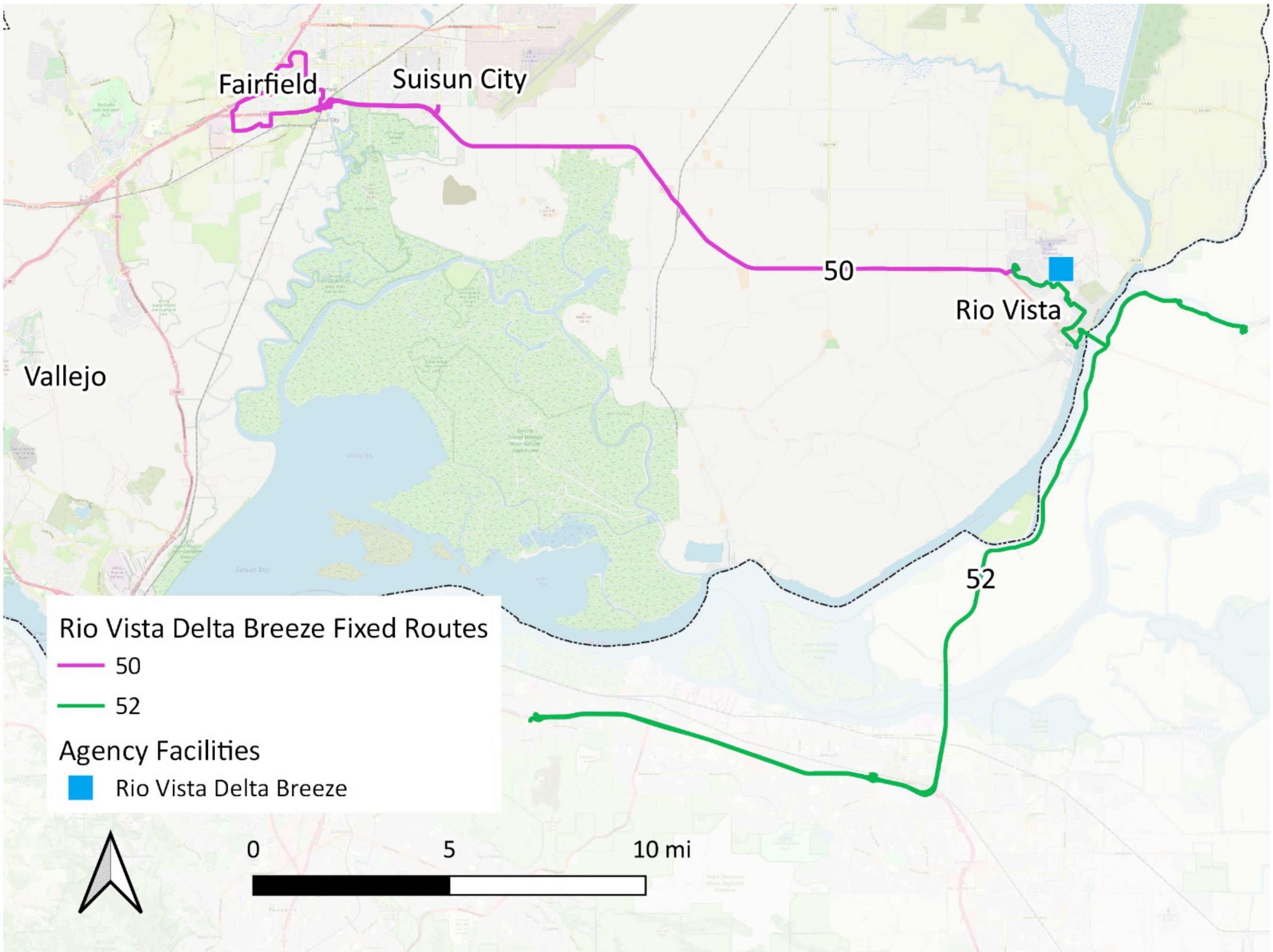
The following sections present Rio Vista Delta Breeze's existing conditions, service modeling results, power and energy analysis, facility concepts, phasing strategies, and cost and funding analysis to support the agency's ZEB transition.

6.1 Existing Conditions

6.1.1 Existing Service

Rio Vista Delta Breeze offers both demand response and deviated fixed-route services (in which actual stops on the route may vary from set designated stops) administered by the City of Rio Vista with service provided by STA in partnership with a contractor. The service area includes the City of Rio Vista and between Isleton, Rio Vista, Fairfield, Suisun City, Pittsburg/Bay Point Bay Area Rapid Transit (BART) station and Antioch with connections to Lodi (Figure 6.1). The hours of operation are generally Monday - Friday from 7:30 AM - 5:50 PM.

Figure 6.1 Rio Vista Delta Breeze Fixed Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

The Rio Vista Delta Breeze fleet consists of one gasoline-powered van and four gasoline-powered cutaways (Table 6.1). The vehicles were put into service between 2011 and 2018.

Table 6.1 Summary of Rio Vista Delta Breeze's Existing Fleet

Bus Type	Length	Fuel Type	In Service Year	Quantity
Van	12'	Gasoline	2011	1
Cutaway	22'	Gasoline	2012	1
	25'	Gasoline	2013-2018	3
			Total Vehicles	**5**

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030 Service Blocks

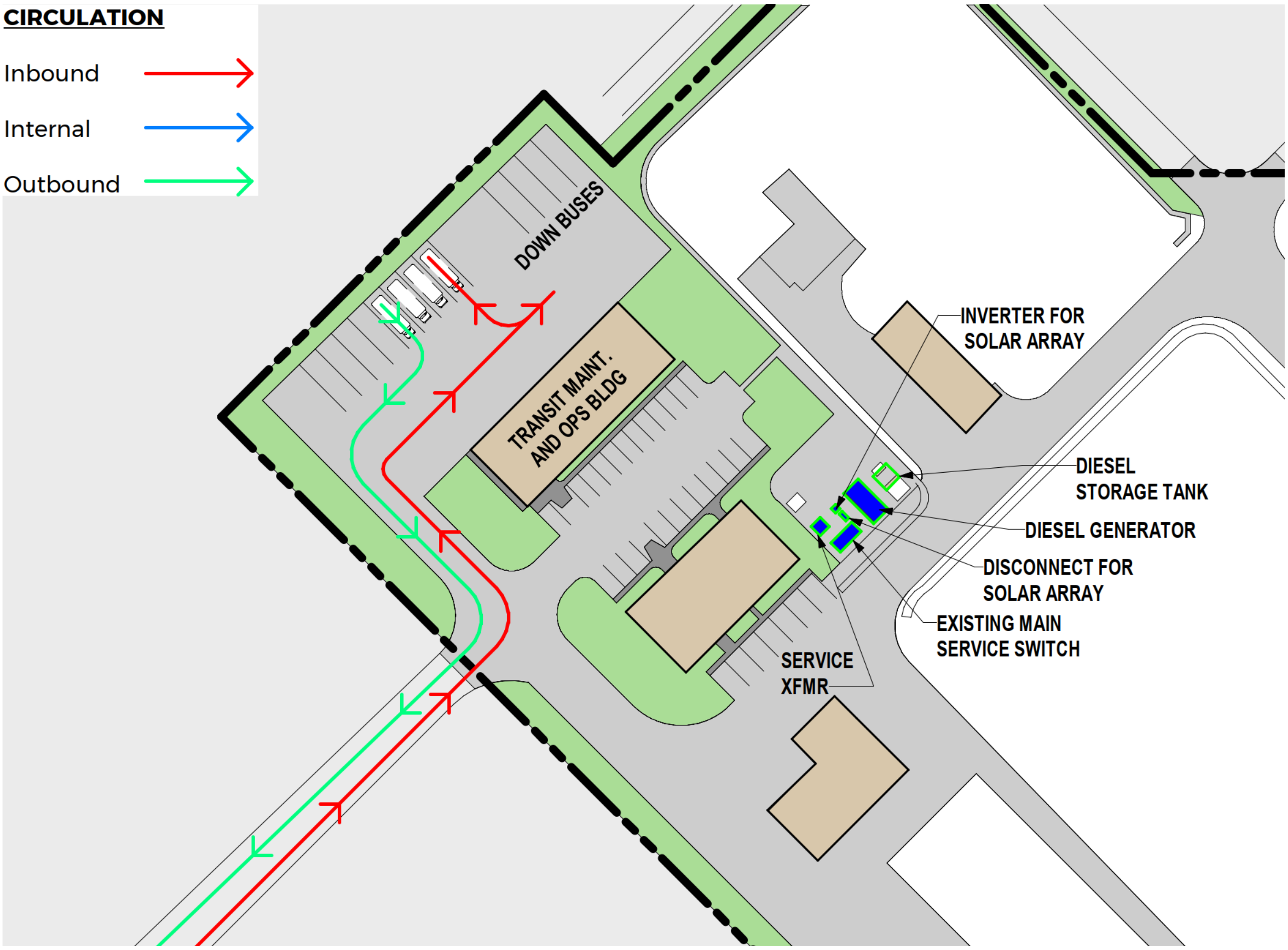
Note: A detailed list of Rio Vista Delta Breeze Existing Fleet is available in Appendix A: *Existing Conditions Analysis*

6.1.2 Existing Facility Conditions

The Rio Vista Delta Breeze facility is located at 3000 Airport Road (Figure 6.2). The transit operations share the site with the City of Rio Vista Northwest Wastewater Treatment Plant, and despite having a relatively small, dedicated portion of the overall site, transit operations still have adequate room to support the fleet. Maintenance and operations are all contained within the single building, with the maintenance bays accessed from the transit yard and the operations accessed from the employee parking on the east.

The operations could easily expand with minimal effort, and there is adequate room to accommodate electrification infrastructure. There are no planned modifications to the transit facilities at this time.

Figure 6.2 Rio Vista Delta Breeze Existing Facility and Site Circulation



Source: WSP

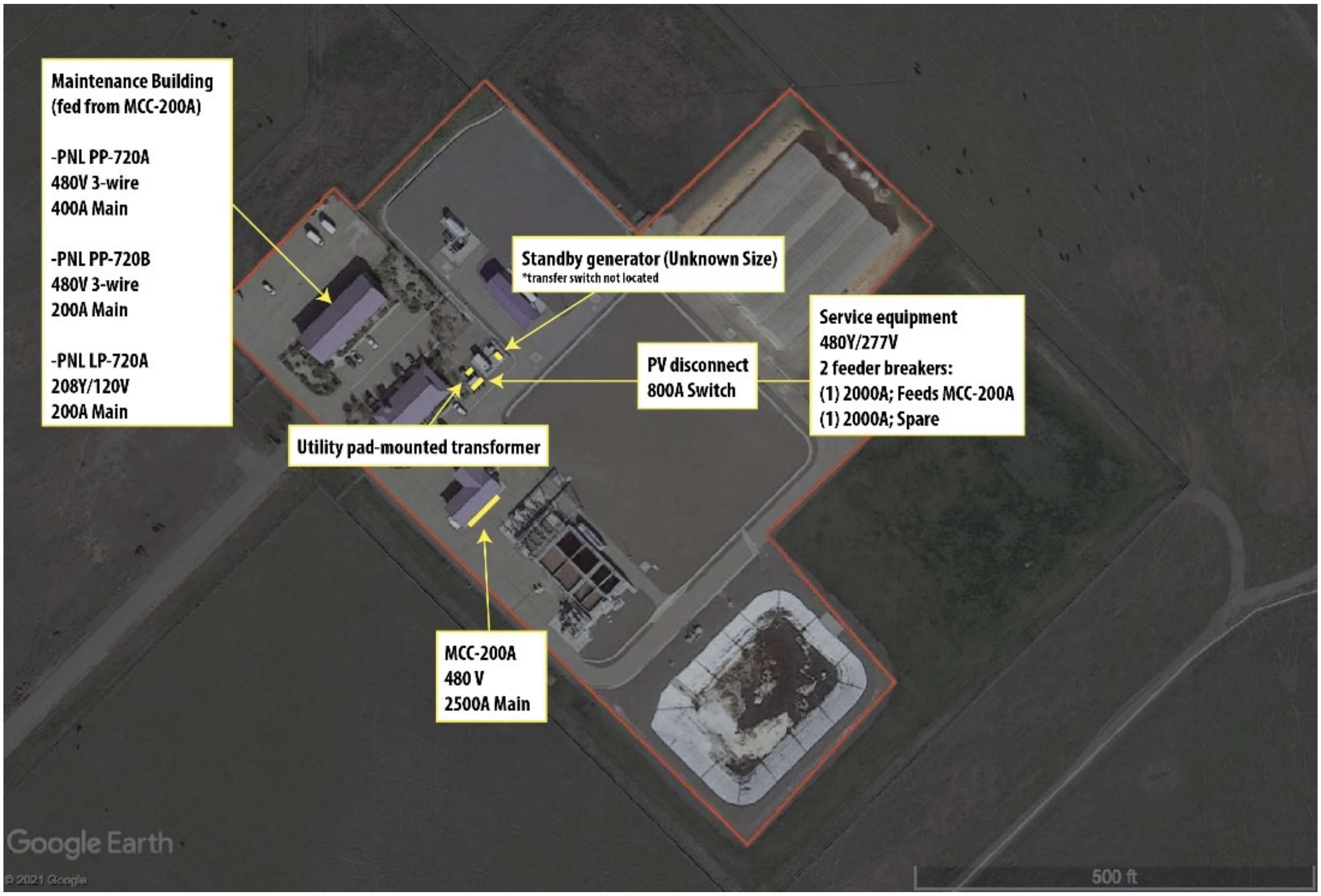
6.1.3 Existing Power and Energy Conditions

Rio Vista Delta Breeze's power is provided by the PG&E Grand Island Substation (6246), which has a capacity of 44.5 MW on Bank 3, with a peak load of approximately 14.6 MW (based on publicly available data). This substation feeds the Grand Island 2226 feeder circuit that feeds the Rio Vista Delta Breeze Yard. The Grand Island 2226 Circuit is a 21 kV circuit with an existing capacity of 18 MW. PG&E estimates that the projected peak load of this circuit is 10 MW, leaving approximately 8 MW of available capacity.

On-site electrical infrastructure includes a utility pad-mounted transformer, a small 75 kVA pad-mounted transformer, the main switchboard (labeled as MCC-200A), two feeder breakers, three panelboards, and one standby generator (Figure 6.3). Appendix C: *Power and Energy Analysis* provides detailed information on the equipment mentioned.

This site is shared with the wastewater treatment plant, whose electrical loads could be significant. Thus, future coordination with the water treatment plant on any equipment upgrades or changes will be needed.

Figure 6.3 Rio Vista Delta Breeze's Utility Plan View



Source: WSP

6.2 Service Modeling

6.2.1 Fixed-Route Service

Rio Vista Delta Breeze currently operates cutaway buses for their fixed-route services. Rio Vista Delta Breeze has two local service routes that are operated with four vehicle blocks ranging from 58 to 134 miles. The average vehicle block distance is 83 miles.

For the "typical" and "conservative" and "EWL" scenarios, three of the four blocks could be completed by a single-cutaway BEB. Table 6.2 presents a summary of the energy demands for the passing blocks. Even under worst-case scenarios reflected in the conservative scenario, the passing blocks only require 68 kWh on average (72% of the battery capacity) to complete the service.

It is assumed that each block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 0.79 kWh/mile due to the additional consumption factors (e.g., HVAC and slope). The higher efficiency change in the conservative scenario reflects the higher energy used to operate HVAC in extreme weather and the less efficient regenerative braking system.

Table 6.2 Rio Vista Delta Breeze – Summary of Passing Blocks

Scenario	Passing Blocks	Avg. Distance (miles)	Avg. Required Battery Capacity (kWh)	Avg. State of Charge Remaining	Avg. Efficiency Change (kWh/mi)
Typical	3	66	56	41% (39 kWh)	0.05
Conservative	3	66	68	28% (26 kWh)	0.23

Source: WSP

Table 6.3 presents a summary of the energy demands for the failing blocks. Block 1 is the only failing block in both scenarios (and the EWL typical and conservative scenarios). At 134 miles, Block 1 is just within the stated range of the BEB; however, due to variables such as stops, slope, and weather, the battery efficiency is only sufficient to complete 81% and 61% of the block under the typical and conservative scenario, respectively.

Table 6.3 Rio Vista Delta Breeze – Summary of Failing Blocks

Scenario	Failing Blocks	Avg. Distance (miles)	Avg. Required Battery Capacity (kWh)	Avg. % of Block Completed	Avg. Efficiency Change (kWh/mi)
Typical	1	134	117	81%	0.08
Conservative	1	134	154	61%	0.36

Source: WSP

Based on the fleet estimated charging time, strategic vehicle-to-block assignments may mitigate the need to increase the vehicle replacement ratio for the failing block. For example, one of the other three vehicles can pull out to complete the failing block's service once sufficiently charged.

6.2.2 Demand Response Service

Since the vehicle miles traveled for demand response services are variable, the Lightning Bolt model could not be used to assess block performance. In lieu of this, WSP conducted a high-level analysis of range expectations using the daily and maximum mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 90 and 113 miles. The GreenPower EV Star – a representative BEB replacement for Rio Vista Delta Breeze's existing vehicles - has an advertised range of 150 miles.

Based on the comparison between the advertised range of existing battery electric cutaways and the service's average daily vehicle distance, Rio Vista Delta Breeze should be able to operate its demand response service with no or minimal impact. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service. However, under

EWL battery conditions (64% advertised capacity), the expected vehicle range is at or below the calculated average daily vehicle distance.

However, it should be noted that this estimate does not consider HVAC usage, slope, and other service area-specific variables that can significantly impact the vehicle's efficiency and range. For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

6.3 Power and Energy Analysis

The Rio Vista Delta Breeze fleet currently consists of five gas vehicles: one van and four cutaways. The transit agency hopes to double its fleet with four additional 35-foot buses in the future. This analysis calculated the electrical requirements both with and without the addition of the four future buses.

The analysis evaluates the fleet under an unmanaged and managed charging scenario. In both scenarios, Rio Vista Delta Breeze fleet operators would begin charging all cutaways and buses at 9:00 PM. In the unmanaged charging scenario, all vehicles will charge concurrently at the same time, with half of the full charging power for each vehicle. Meanwhile, the managed charging scenario assumes that each vehicle will charge sequentially before switching to the next vehicle. This scenario will reduce the peak demand power required but will result in a longer charging time. However, because BEBs are charging at the same rate during non-peak hours, the longer time should not affect the total energy (kWh) utility cost.

Existing Fleet

To service four existing cutaways, it is recommended that two 150 kW DC chargers be installed. The recommendation is for Rio Vista Delta Breeze to do managed charging. Managed charging will reduce the peak demand from 300 kW in the unmanaged scenario to 75 kW. It will reduce overall utility costs due to the lower peak demand and reduce capital costs because of the smaller equipment upgrades required.

Future Fleet

In this scenario, the site is expected to have four 150 kW chargers to charge the four cutaways and four future 35-foot buses. The cutaways will all finish charging within 2.1 hours, and the 35-foot buses will finish charging within 7.4 hours. Managed charging will reduce the peak demand from 600 kW in the unmanaged scenario to 375 kW.

The summary of all charging scenarios for existing and future fleets is shown in Table 6.4.

Table 6.4 Summary of Rio Vista Delta Breeze Charging Scenarios

Fleet	Min. Required # of Chargers	Scenario	Charge Schedule	Charge Rate (per vehicle)	Peak Demand	Required Power Increase*
Current Fleet	Two 150 kW DC chargers	Unmanaged	All BEBs charging concurrently	67.5 kW	300 kW	330 kW
		Managed	Each BEB charges sequentially	67.5 kW	75 kW	165 kW[26]
Future Fleet	Four 150 kW DC chargers	Unmanaged	All BEBs charging concurrently	67.5 kW	600 kW	660 kW
		Managed	Each BEB charges sequentially	67.5 kW	375 kW	415 kW (suggested)

Source: WSP

*Note: Required power increase includes 10% buffer for ancillary loads and losses

Power and Energy Upgrades

Regardless of the existing or future fleet, the recommendation is to purchase a charge management system and use managed charging. The transit agency should request at least 415 kW of peak power which supports the future fleet needs, and the managed charging demand that accounts for a 10% buffer for ancillary loads and losses. If necessary, two 150 kW DC fast chargers can be used at full speed for flexible mid-day recharging. This would allow up to four cutaway vehicles and four 35-foot buses to fully recharge each night using managed charging.

Based on the analysis, the following facility electrical upgrades are required, assuming the worst-case scenario of unmanaged charging:

- 750 kVA transformer fed by new 12 kV underground conductor
- 480V service entrance main switchboard with a minimum electrical rating of 1200 A and utility metering cabinet
- Underground conduit from the location of the new transformer to the location of the new 480V switchgear
- Underground electrical conductor in conduit from the new transformer to new 480V switchgear
- Vehicle charging cabinets along with underground conduit connecting the charging stations to the new 480V switchgear

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Rio Vista Delta Breeze would be responsible for installing switchboard, utility metering cabinet, underground conduit, and charging stations. Managed charging is strongly recommended, and electrical equipment

26 Since each charger is capable of providing 150 kW, the minimum new electrical service must be capable of supplying at least this much power.

properties should be determined during the detailed engineering phase based on discussions with PG&E and the level of electric service requested.

Energy resiliency at the site is key to ensuring Rio Vista Delta Breeze service delivery once transitioning to a full BEBs fleet. One or more of the strategies below provide a suitable level of backup power after considering the possible resiliency issues that the site might experience[27]:

- 400 kW permanent standby generator
- 300 - 600 kW Solar PV system paired with 1 - 2 MWh BESS in 10' – 40' intermodal container

A generator with an output rating of at least 400 kW can power two 150 kW DC charging cabinets simultaneously and fully recharge all vehicles overnight.

6.4 ZEB Transition Plan

6.4.1 Facility Concepts

The Rio Vista Delta Breeze facility concept supports eight charging positions. Positions are planned for the ZEVs that will replace the existing four cutaway vehicles while also leaving room for four additional vehicles in the future. Four DC charging cabinets and eight DC ground-mounted plug-in dispensers will be needed to support the fleet. The number of dispensers required can decrease through further evaluation of the buses' charging window and end-of-the-day SOC. Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles.

Table 6.5 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to Appendix D: *BEB Facility Concepts Analysis*. Figure 6.4 illustrates the proposed facility concept to support the electrification transition.

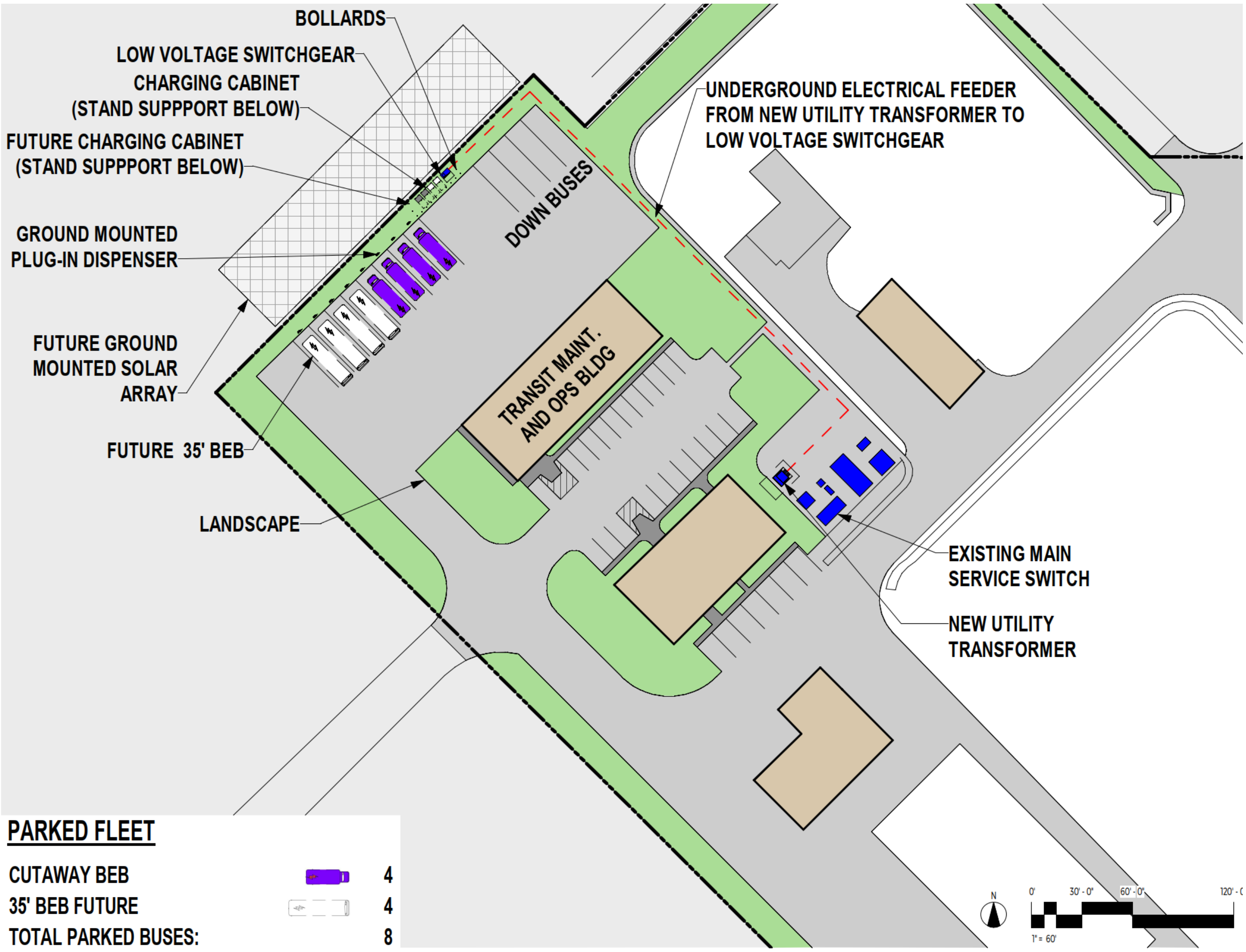
Table 6.5 Rio Vista Delta Breeze Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	4
Plug-in DC Dispenser	8
Plug-in DC Dispenser in Maintenance Area	1
Transformer	1
Switchboard	1

Source: WSP

27 Appendix C: *Power and Energy Analysis* provides in-depth resiliency analysis for the site

Figure 6.4 Rio Vista Delta Breeze Preliminary Facility Concept



Source: WSP

6.4.2 Construction Schedule

Due to the relatively small fleet size and the proposed configuration of infrastructure installation, it is recommended that all on-site improvements be constructed in a single stage. However, the charging cabinets and associated dispensers could be procured and installed in stages to better align with a desired bus procurement schedule.

The planned infrastructure improvements can occur outside the current bus parking area, ensuring that all construction activities can occur without impacting existing operations.

Based on the assumptions, Rio Vista Delta Breeze's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022. Table 6.6 illustrates the proposed schedule.

Table 6.6 Rio Vista Delta Breeze Construction Schedule

	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24
Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Utilities							18 months																				
Design Procurement	6 months																										
Design							11 months																				
Construction Procurement															6 months												
Construction																					7 months						

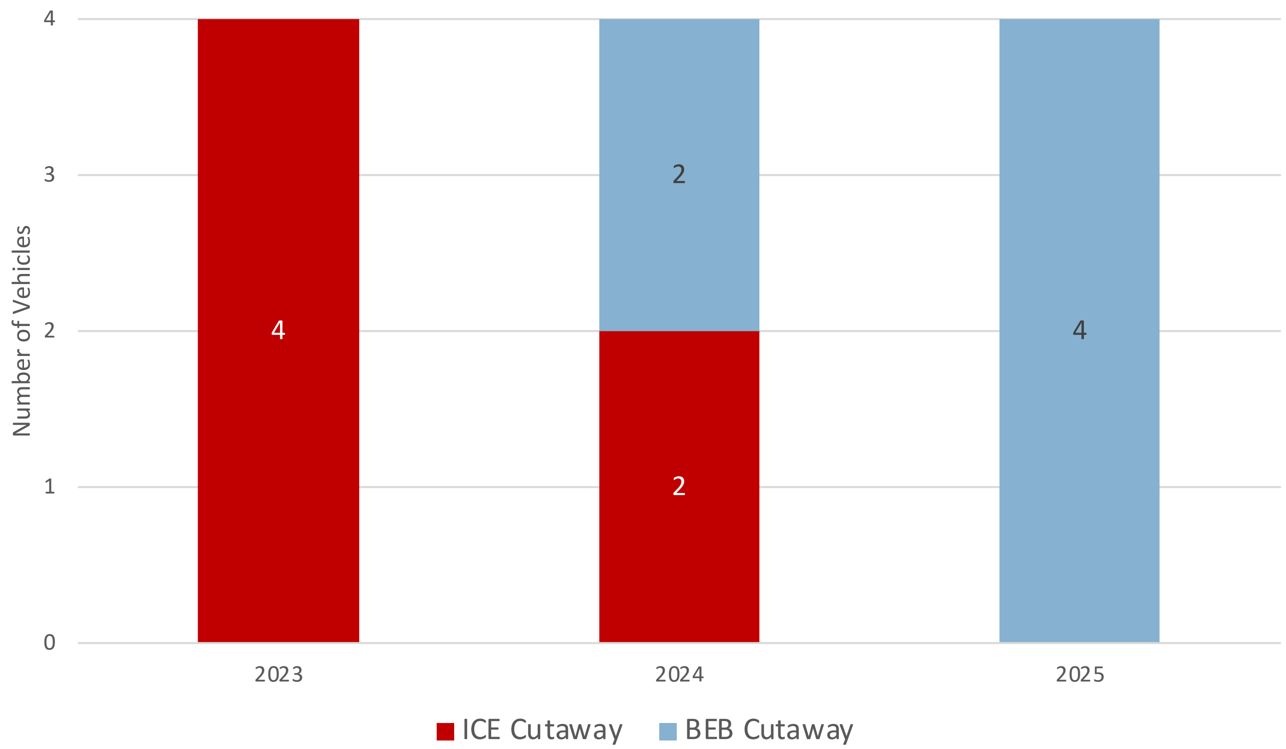
Source: WSP

6.4.3 Vehicle Procurement Schedule

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. Therefore, the first delivery of battery-electric cutaways will not occur until October 2024. The fleet will be fully electric by 2025.

The developed procurement timeline assumes that vehicles will be purchased in two sets of two vehicles. This approach will help ease the transition so that Rio Vista Delta Breeze has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Figure 6.5 illustrates Rio Vista Delta Breeze's fleet mix over time (between ICE and ZEB vehicles).

Figure 6.5 Rio Vista Delta Breeze Fleet Mix



Source: WSP

6.4.4 Lifecycle Costs Analysis

Based on the lifecycle cost analysis, the total cash cost (including capital, O&M, disposal and excluding environmental costs) of operating a full BEB fleet is approximately $4.4M, 58% higher than if Rio Vista Delta Breeze continued to operate a full gasoline fleet. This is due to the significantly higher capital costs. The total vehicle capital costs (with modification) are $1.2M for BEB compared to $0.6M for ICEB. Furthermore, the total charging/fueling infrastructure capital costs are $1.2M for BEB and $0 for ICEB fleet because Rio Vista Delta Breeze currently does not have any fueling infrastructure on-site.

However, the lifecycle environmental costs for gasoline fleet are approximately $0.2M higher than a full BEB fleet, which will bring the total cash and non-cash costs difference between the two fuel types down to 45%. The total lifecycle cash and non-cash costs are $2.73/mile and $3.96/mile for ICE and BEB fleets, respectively.

Table 6.7 provides the summary of the lifecycle cost analysis.

Table 6.7 Lifecycle Cost (2021-2037) Analysis Results for Rio Vista Delta Breeze (in millions of YOE$)

Cost Categories	"No Build" Scenario	"Build" BEB Scenario
Cash Costs		
Total Capital Costs	$0.63	$2.46
Total Operating Costs	$2.18	$1.94
Total Disposal Costs	-$0.03	-$0.03
Total Cash Cost	$2.78	$4.37
Non-Cash Costs		
Total Environmental Costs	$0.33	$0.13
Total Cash and Non-Cash Costs	$3.10	$4.50
Total Cash and Non-Cash Costs per Mile	**$3.11**	**$3.96**

Source: WSP

Note: All values are presented in and rounded to the nearest million

Note: The total costs may vary due to rounding. Refer to Appendix F: *Cost and Funding Analysis* for a detailed breakdown of each item.

6.5 Findings and Next Steps

6.5.1 Service Feasibility

Only one of the four blocks failed for fixed-route service in both the typical and the conservative scenarios (Block 1). Based on the existing service schedule and assumed charging times, there is an opportunity for Rio Vista Delta Breeze to utilize one of the available service vehicles to complete Block 1 by scheduling an additional pull-out. While this will require additional analysis and cost considerations, this would allow Rio Vista Delta Breeze to maintain a 1:1 fleet replacement ratio.

If an additional pull-out to complete Block 1 is not viable, there are several other considerations to meet the service:

- Additional service changes
- Wait for advancements in BEB technology
- Select a vehicle that has a higher battery capacity than the average used in the model
- Opportunity charging

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of Rio Vista Delta Breeze; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

It should be noted that technology is rapidly evolving, and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended in order to assess actual performance.

6.5.2 Power and Energy Upgrades

Based on the analysis, it is recommended that Rio Vista Delta Breeze purchase a charge management system and use managed charging to keep the required peak demand relatively low, depending on the future bus fleet. Managed charging will reduce overall utility costs due to the lower peak demand and also reduce capital costs because of the smaller equipment upgrades required.

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Rio Vista Delta Breeze would be responsible for installing switchboard, utility metering cabinet, underground conduit, and charging stations.

It is important to note that the Rio Vista Delta Breeze site is shared with an adjacent water treatment facility that may have spare capacity on the existing electrical service. However, the spare capacity may already be allocated to future upgrades to the water treatment facility, so this plan considered the possibility of installing a new electrical service to power the vehicle fleet.

Rio Vista Delta Breeze needs to first evaluate their options and take the next immediate steps:

1. Decide whether to invest in a charge management system or not
2. Size the site for future fleet or existing fleet
3. Request the appropriate load from PG&E
4. Begin service application and coordination with PG&E
5. Determine outage mitigation methods. If a backup generator is selected, include the design and procurement in engineering firm RFP
6. Bid out to local engineering firm for detailed design
7. Procure long-lead items
8. Begin construction to point of contact with utility

6.5.3 ZEB Transition Plan

Facility Concept

The Rio Vista Delta Breeze facility concept supports eight charging positions. Four DC charging cabinets and eight DC ground-mounted plug-in dispensers will be needed to support the fleet. Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles.

Several considerations important for Rio Vista Delta Breeze facility improvements are:

- During the detailed design phase of the charging equipment implementation, the electrical utility service enhancements to support the bus charging infrastructure will need to be carefully coordinated between Rio Vista Delta Breeze, PG&E, and the City of Rio Vista Northwest Wastewater Treatment Plant.

- Although it is not anticipated to be an issue, the weight of the future vehicles should be specified in accordance with the existing vehicle lift capacity. If a heavier vehicle is specified, then the existing vehicle lifts will need to be upgraded.

Phasing Schedule

Due to the relatively small fleet size and the proposed configuration of the improvements, it is recommended that all on-site improvements be constructed in a single stage. Construction can occur without impact on existing operations.

Based on the assumed duration, Rio Vista Delta Breeze's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022.

To align the delivery of new vehicles with charger availability, the first round of vehicle procurement will be delivered in October 2024, after the completion of the facility's improvements. The developed procurement timeline assumes that vehicles will be purchased in two sets of two vehicles. The fleet will be fully ZE by 2025.

Cost and Funding

Based on the lifecycle cost analysis, the total cash cost of operating a full BEB fleet is approximately $4.4M, 58% higher than if Rio Vista Delta Breeze continued to operate a full gasoline fleet. This is due to the significantly higher capital costs. The costs difference goes down to 45% when considering the environmental costs of a full ICE fleet.

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in the agency's FY 2021-2030 SRTP adopted in 2020 as outlined in Table 6.8. There are also additional funding sources through federal, state, regional, and other grant opportunities that can be explored to fill the estimated funding gap. This analysis only considers the capital costs needed based on the phasing schedule developed in sections 6.4.2 and 6.4.3 (for the BEB fleet) and the potential funding sources for capital projects. Strategies for addressing the identified gaps are discussed in sections 9 and 11.5.2.

Table 6.8 Rio Vista Delta Breeze Estimated Costs and Funding Shortfall by Year (in millions of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Estimated Capital Costs	$0.00	$0.00	$1.41	$1.05	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$2.46**
Potential Funding Identified in SRTP	$0.00	$0.98	$0.00	$0.00	$0.00	$0.45	$0.00	$0.12	$0.00	$0.00	**$1.55**
Other Potential Existing Capital Revenues	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$0.00**
Surplus / Gap	$0.00	$0.98	-$1.41	-$1.05	$0.00	$0.45	$0.00	$0.12	$0.00	$0.00	**-$0.91**

Source: WSP

Note: All values are presented in and rounded to the nearest million

SolTrans

7 SOLANO COUNTY TRANSIT

The following sections present SolTrans' existing conditions, service modeling results, power and energy analysis, facility concepts, phasing strategies, and cost and funding analysis to support the agency's ZEB transition.

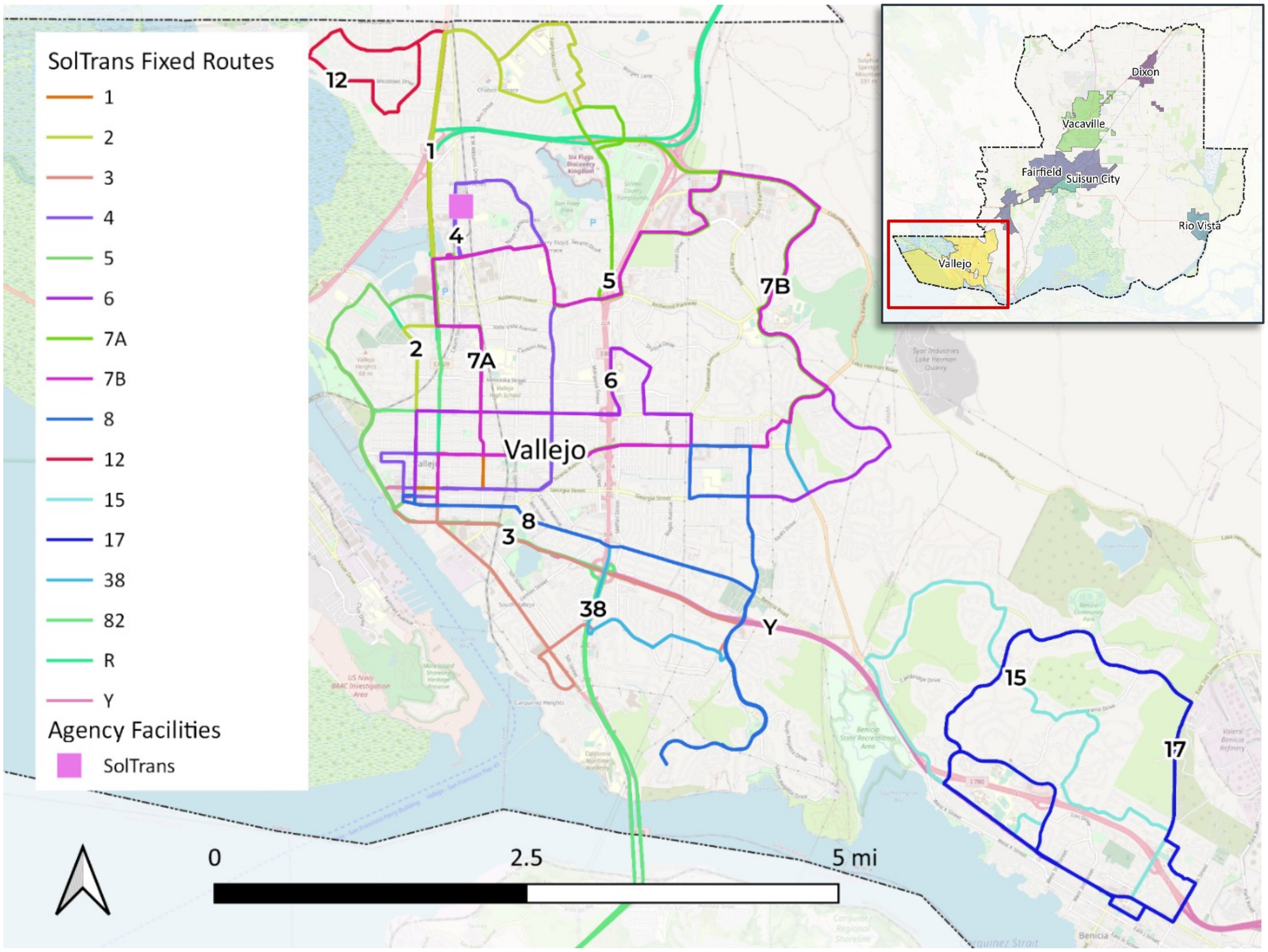
7.1 Existing Conditions

7.1.1 Existing Service

Solano County Transit (SolTrans) is a Joint Powers Authority (JPA) run by its own Board of Directors and consists of Benicia, Vallejo, and STA. It provides the highest volume of Solano County's intercity service that serves East Bay's BART stations, the San Francisco (SF) Bay ferry terminal in Vallejo, Napa Vine bus stops, and Contra Costa County transit systems (Figure 7.1). It also offers local transit to the cities of Benicia and Vallejo and connects with FAST at key locations. Local service is generally offered from 5:30 AM to 8:30 PM during the week, with limited routes and headways on weekends.

In addition to the local service, SolTrans offers two intercity services – SF Express and SolanoExpress, which FAST and SolTrans jointly manage. The SolanoExpress routes are not a part of this study as they are being evaluated under other related projects.

Figure 7.1 SolTrans Fixed Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

The SolTrans fixed-route fleet consists of 60 buses and an additional coach bus that is loaned to FAST. There are 27 standard 40-foot buses, 14 cutaways, and 19 motorcoaches (Table 7.1). One of the buses runs on diesel, 21 are diesel hybrid, four are BEBs, 20 are compressed natural gas (CNG), and 14 are gasoline-powered cutaways. The vehicles were put in service from 2001 through 2019.

Table 7.1 Summary of SolTrans Existing Fleet

Bus Type	Length	Fuel Type	In Service Year	Quantity
Cutaway	24'	Gasoline	2016	3
	26'	Gasoline	2011	6
	Unknown	Gasoline	2018-2019	5
Standard Bus	40'	Diesel	2001	1
	40'	Diesel Hybrid	2011	21
	40'	Battery Electric	2016	4
	40'	CNG	2016	1
Coach	45'	CNG	2003-2019	19
			Total Vehicles	**60**

Source: 2020 Revenue Fleet Listing

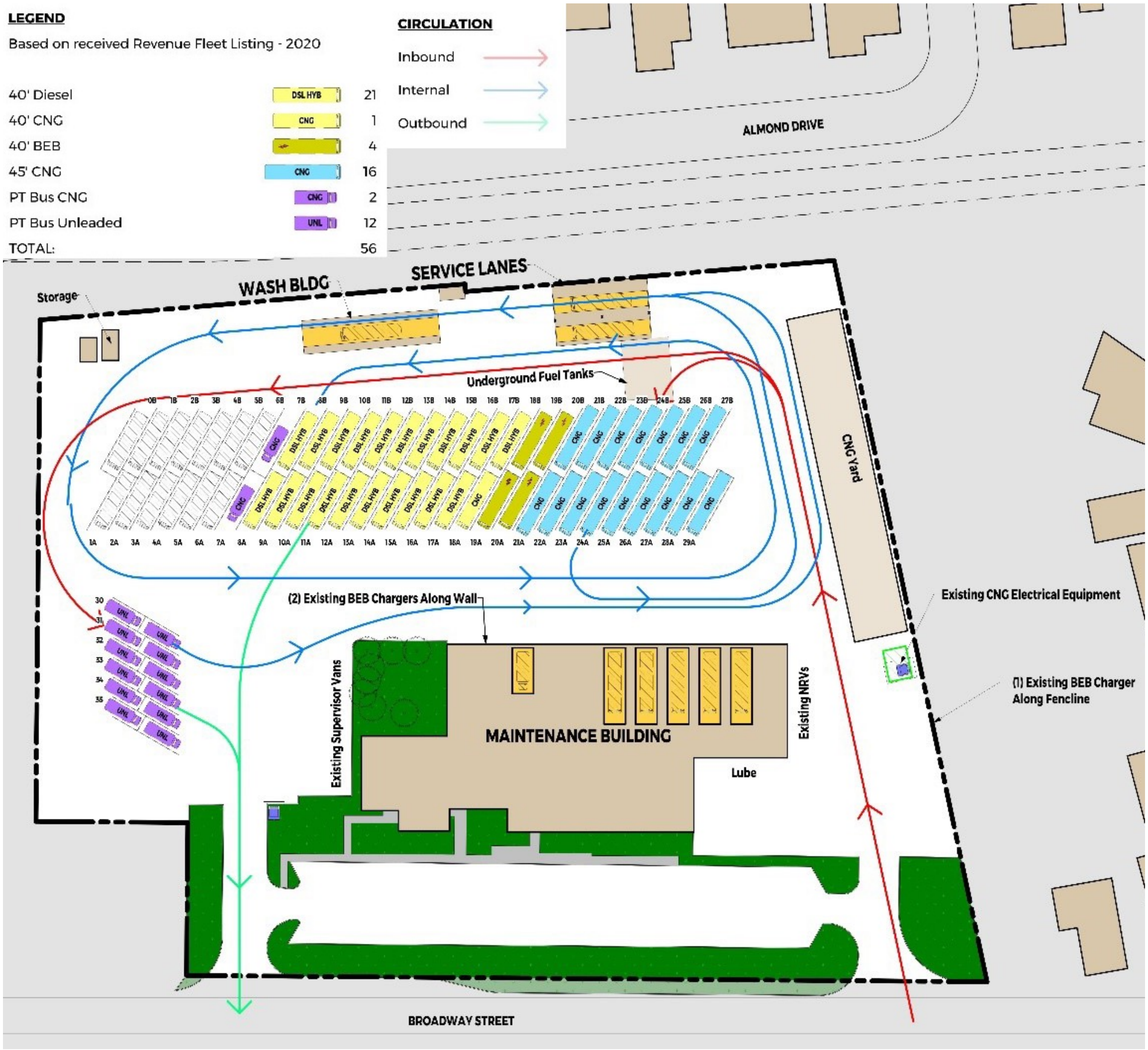
Note: A detailed list of SolTrans Existing Fleet is available in Appendix A: *Existing Conditions Analysis*

7.1.2 Existing Facility Conditions

The SolTrans facility is located at 1850 Broadway Street in Vallejo. The site consists of a joint maintenance and operations facility with five maintenance bays for buses and one for paratransit vehicles; a fuel island with two fuel lanes supplying diesel and CNG to buses and unleaded to non-revenue vehicles (NRVs) and paratransit buses; an associated CNG compression and storage yard; underground fuel tanks; a backup generator; BEB charging equipment area; employee parking; and bus parking (Figure 7.2). The site has four 80 kW AC BEB dispensers to charge SolTrans four existing BYD 40-foot BEBs.

SolTrans has developed a master plan for a full-BEB retrofit of the existing facility and is currently in the process of implementing Phase 1 of that plan.

Figure 7.2 SolTrans Existing Facility and Site Circulation



Source: WSP

7.1.3 Existing Power And Energy Conditions

SolTrans' power is provided by the PG&E Highway Substation (4265), which has a capacity of 44.6 MW on Bank 1, with a peak load of approximately 22.4 MW (based on publicly available data). This substation feeds the Highway 1106 feeder circuit that feeds the SolTrans yard. The Highway 1106 Circuit is a 12 kV circuit that has an existing capacity of 12.8 MW. PG&E estimates that the projected peak load of this circuit is 9.9 MW, leaving approximately 3 MW of available capacity.

Two electrical services serve the site. Appendix C: *Power and Energy Analysis* provides detailed information on the transformers, meters, switchboards, and generators associated with each service.

7.2 Service Modeling

7.2.1 Fixed-Route Service

SolTrans currently operates 40-foot buses for their fixed-route services. SolTrans' local service consists of 42 vehicle blocks ranging from eight to 201 miles. All but one block operates under 150 miles, the general range for existing BEBs. The average vehicle block miles traveled is 74 miles.

A single 40-foot BEB could complete 38 and 27 of the 42 blocks in the typical and conservative scenario, respectively. Table 7.2 summarizes the energy demands for the passing blocks. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 2.08 kWh/mile due to the additional consumption factors. The higher efficiency change in the conservative scenario reflects the higher energy used to operate HVAC in extreme weather and the less efficient regenerative braking system.

Table 7.2 SolTrans – Summary of Passing Blocks

Scenario	Passing Blocks	Avg. Distance (miles)	Avg. Required Battery Capacity (kWh)	Avg. State of Charge Remaining	Avg. Efficiency Change (kWh/mi)
Typical	38	67	165	36% (94 kWh)	0.38
Conservative	27	55	160	37% (97 kWh)	0.81

Source: WSP

Four blocks fail to complete the service block in the typical scenario. The failing blocks are some of the longest, both in distance and time. Meanwhile, 15 blocks fail in the conservative scenario. Table 7.3 presents a summary of the energy demands for the failing blocks. The average distances of the failing blocks in the typical and conservative scenarios are lower than the BEB's advertised range of 156 miles. However, due to variables such as stops, slope, and weather, the battery efficiency is insufficient to complete the whole block.

Table 7.3 SolTrans – Summary of Failing Blocks

Scenario	Failing Blocks	Avg. Distance (miles)	Average Block Duration (hours)	Avg. Required Battery Capacity (kWh)	Avg. % of Block Completed	Avg. Efficiency Change (kWh/mi)
Typical	4	137	11:50	341	81%	0.41
Conservative	15	107	9:48	317	85%	0.89

Source: WSP

Three blocks in the typical scenario and 12 blocks in the conservative scenarios fail after completing more than 80% of the blocks. These blocks can likely achieve completion with minor service changes or advancements in BEB technology. Moreover, based on the fleet charging analysis, strategic vehicle-to-block assignments may mitigate the need to increase the vehicle replacement ratio for the failing blocks, especially in the typical scenario.

When calculating the EWL scenario, more blocks cannot be completed with a 1:1 vehicle replacement using existing technology due to battery capacity degradation. Table 7.4 shows the number of completed and uncompleted blocks for typical and conservative EWL scenarios. There would be 11 fewer blocks that could be completed in the typical scenario, while nine fewer blocks would be completed in the conservative scenario. Thus, at the end of battery warranted life, the percentage of completed blocks compared to the total number of blocks are 64% and 43% for typical and conservative scenarios, respectively.

Table 7.4 SolTrans – Summary of EWL Scenarios

Scenario	Passing Blocks	Failing Blocks	Percent Passing
EWL Typical	27	15	64%
EWL Conservative	18	24	43%

Source: WSP

7.2.2 Demand Response Service

Since the vehicle miles traveled for demand response services are variable, the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the daily and maximum mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 75 and 90 miles. The GreenPower EV Star – a representative BEB replacement for SolTrans' existing vehicles – has an advertised range of 150 miles.

Based on the comparison between the advertised range of existing battery electric cutaways and the service's average daily vehicle distance, SolTrans should be able to operate its demand response service with no or minimal impact. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service. However, under EWL battery conditions (64% advertised capacity), the expected vehicle range is just barely greater than the calculated average daily vehicle distance.

However, it should be noted that this estimate does not consider HVAC usage, slope, and other service area-specific variables that can significantly impact the vehicle's efficiency and range. For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

7.3 Power and Energy Analysis

This site has been analyzed previously in a separate study of SolTrans' Phase 1 BEB transition and is currently in the design and bid phase. All information in this section is based on the previous report, with no additional analysis performed. Additionally, technical information presented in this section does not depict the SolTrans requirements as designed or as constructed. Requirements and specifications may have changed during the design & construction process and may not be reflected in this section.

7.3.1 Maintenance Facility Site Electrical Components

The SolTrans maintenance facility detailed design & engineering for phase 1 was completed in 2021. A summary of the electrical scope of work for phase 1 is elaborated below. Future phases will accommodate additional buses.

- Install new 480V electric service
- Install new main meter switchboard
- Construct approximately 50' of new underground electrical duct bank
- Construct approximately 300' of conduit
- Install four new 800A electric distribution panels
- Install one new 400A auxiliary electrical panel
- Install one new 100 kVA auxiliary transformer for lighting and control
- Install 21 new BEB charging cabinets with retractable plugs
- Add/Alternate: install a solar PV system
- Add/Alternate: install battery energy storage system

In terms of energy resiliency, SolTrans' needs to maintain the ability to operate from the maintenance facility site in the event of utility failure. The SolTrans conceptual design includes an add-alternate option to install up to two 2-megawatt hour batteries on the site, for a total of four megawatt-hours of battery storage. In addition to photovoltaic panels, the backup batteries will generate and store back up power for standard duration power failures (two hours).

7.3.2 Curtola Electrical Components

Phase 1 will include:

- New 12 kV service
- One new 500 kVA transformer
- One new site meter
- One new 750-amp switchboard
- One 300 kW ground-mounted induction charger pad and associated charging cabinet
- All required conduit and connections to distribute phase 1 power needs

7.3.3 Vallejo Transit Center Electrical Components

Phase 1 will include:

- New 12 kV service
- One new 1,500 kVA transformer to replace 750 kVA transformer (replacing the existing transformer)

- One new site meter
- One new 1,500-amp switchboard
- One new 45 kVA 480V/120V AUX transformer (one per switchgear)
- Two 300 kW ground-mounted induction charger pads and associated charging cabinets
- All required conduit and connections to distribute phase 1 power needs

The final phase will include the following in addition to the Phase 1 equipment:

- One 300 kW ground-mounted induction charger pad and associated charging cabinet
- One new 45 kVA 480V/120V AUX transformer (one per switchgear)
- All required conduit and connections to distribute ultimate phase power needs

7.4 ZEB Transition Plan

7.4.1 Facility Concept

The SolTrans facility concept supports 70 charging positions: 26 for 40-foot buses, 16 for coach buses, 14 for ZE cutaways, and 14 additional positions for future expansion. The number of dispensers required can decrease through further evaluation of the buses' charging window and end-of-the-day SOC. Overhead plug-in dispensers are shown in the masterplan drawing; however, this plan can also support the application of pantographs.

Table 7.5 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to Appendix D: *BEB Facility Concepts Analysis*. Figure 7.3 illustrates the proposed facility concept to support the electrification transition.

Table 7.5 SolTrans Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	25
80 kW AC Charging System	21
Plug-in DC Dispenser	49
Plug-in AC Dispenser	21
Cable Retractor	70
Transformer	4
Switchboard	3
2-Megawatt hour (MWh) Battery Backup	2

Source: WSP

Figure 7.3 SolTrans Preliminary Facility Concept

Source: WSP

7.4.2 Construction Schedule

The available funding is insufficient to support the installation of an entire overhead support structure, battery backup containers, and solar panels at the initial stage of implementation. As such, it was deemed most appropriate to develop the site in two separate stages.

Based on the assumed duration, SolTrans' electrification transition will take 39 months (over two stages), with an estimated completion date in May 2025. The first construction stage's design procurement and design steps have already been completed. Thus, the first step in this timeline is construction procurement. In order to sync up to the first construction stage, the utility upgrade request should be initiated in March 2022. Table 7.5 illustrates the proposed schedule. Appendix E: *Phasing Strategy and Transition Analysis* provide details for each construction stage.

Table 7.6 SolTrans Construction Schedule

	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25
Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Utilities	10 Months																																						
Stage 1 Construction Procurement		5 Months																																					
Stage 1 Construction (22 charging positions)							8 Months																																
Stage 2 Design Procurement															6 Months																								
Stage 2 Design (charging positions and infrastructure)																					9 Months																		
Stage 2 Construction Procurement																											6 Months												
Stage 2 Construction																																	7 Months						

Source: WSP

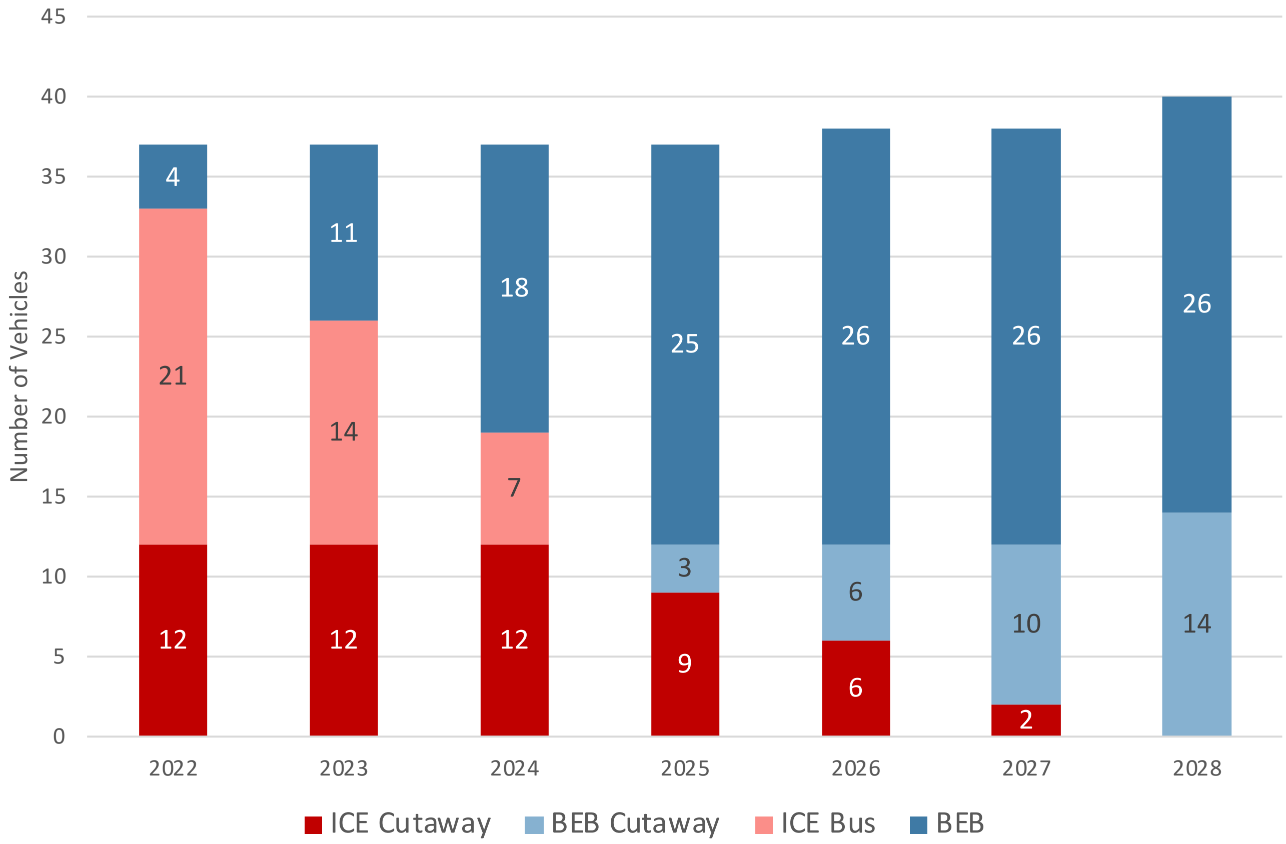
7.4.3 Vehicle Procurement Schedule

The delivery of new vehicles must align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. The developed procurement timeline assumes that vehicles will be purchased in staggered sets of vehicles. This approach will help ease the transition so that SolTrans has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time.

The Stage 2 construction will add chargers for ZE cutaways (as well as coach buses). The ZE cutaways are shown in the procurement timeline to be purchased over the course of four years, with the transition completed by 2028.

Figure 7.4 illustrates SolTrans' fleet mix over time (between ICE and ZEB vehicles).

Figure 7.4 SolTrans Fleet Mix



Source: WSP

7.4.4 Lifecycle Costs Analysis

Based on the lifecycle cost analysis, the total cash cost (including capital, O&M, disposal, and excluding environmental costs) of operating a full BEB fleet is approximately $80M, 39% higher than if SolTrans continued to operate the current fleet. The total vehicle capital costs (with modification) are comparable between BEB and ICEB. Based on the cost estimates developed by M Lee Corporation, the total charging/fueling infrastructure capital costs are $19M for BEB and $7M for ICEB fleet. The fueling infrastructure costs for ICEB fleet assume that the CNG tank installed in 2016 will be replaced in 2036, the three diesel storage tanks of unknown age are assumed to be replaced in 2025, and the above ground storage tank installed in 2010 will be replaced in 2040.

However, the lifecycle environmental costs for the current ICEB fleet are approximately $2M higher than a full BEB fleet, which will bring the total cash and non-cash costs difference between the two fuel types down to 33%. The total lifecycle cash and non-cash costs are $6/mile and $7.96/mile for ICE and BEB fleets, respectively.

Table 7.7 provides the summary of the lifecycle cost analysis.

Table 7.7 Lifecycle Cost (2021-2037) Analysis Results for SolTrans (in millions of YOE$)

Cost Categories	"No Build" Scenario	"Build" BEB Scenario
Cash Costs		
Total Capital Costs	$37	$49
Total Operating Costs	$21	$31
Total Disposal Costs	-$0.2	-$0.2
Total Cash Cost	$58	$80
Non-Cash Costs		
Total Environmental Costs	$4	$2
Total Cash and Non-Cash Costs	$62	$82
Total Cash and Non-Cash Costs per Mile	**$6**	**$7.96**

Source: WSP and M Lee Corporation for Infrastructure Costs Estimate

Note: All values are presented in and rounded to the nearest million

Note: The total costs may vary due to rounding. Refer to Appendix F: *Cost and Funding Analysis* for a detailed breakdown of each item.

7.5 Findings and Next Steps

7.5.1 Service Feasibility

Only four blocks failed under the typical scenario for fixed-route service; while 15 blocks failed under the conservative scenario. Although additional analysis and cost considerations are required, it is possible that

SolTrans can make service changes to have additional vehicles pull out by using one of the available service vehicles to help reduce the percentage of incomplete blocks.

There are various mitigation measures to consider for the failing blocks:

- Additional service changes
- Wait for advancements in BEB technology
- Select a vehicle that has a higher battery capacity than the average used in the model
- On-route charging

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of SolTrans; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

It should be noted that technology is rapidly evolving, and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended in order to assess actual performance.

7.5.2 Power and Energy Upgrades

The SolTrans portion of the project includes three sites: the maintenance facility, the Curtola Park-and-Ride, and the Vallejo Park-and-Ride. Currently, all three sites have gone through detailed design and are undergoing the bidding process for engineering, procurement, and construction. Therefore, the next steps for SolTrans are outside the scope of this plan.

7.5.3 ZEB Transition Plan

Facility Concept

The SolTrans facility concept supports 70 charging positions. Both overhead plug-in dispensers or pantographs can be implemented at the facility.

Several considerations important for SolTrans facility improvements are:

- This plan is based on the plan developed by SolTrans and reflects a hybrid charging strategy. The proposed infrastructure allows SolTrans the flexibility to adopt different charging strategies as the fleet is transitioned.
- The existing CNG-supporting electrical service will ultimately be transitioned to support BEB charging infrastructure in the final configuration when CNG vehicles are phased out. Managing the phasing for this process will be crucial to ensure that CNG is available until all vehicles are able to be transitioned.

Phasing Schedule

It was deemed most appropriate to develop the site in two separate stages. Based on the assumed duration, SolTrans' electrification transition will take 39 months (over two stages), with an estimated completion date in May 2025. The first construction stage's design procurement and design steps have already been completed.

To align the delivery of new vehicles with chargers availability, the first round of vehicle procurement will be delivered in October 2024, after the completion of the facility's improvements. The developed procurement timeline assumes that vehicles will be purchased in staggered sets of vehicles, and the fleet will be fully ZE by 2028.

Cost And Funding

Based on the lifecycle cost analysis, the total cash cost of operating a full BEB fleet is approximately $80M, 39% higher than if SolTrans continued operating the current fleet. This is due to the significantly higher capital costs. The costs difference goes down to 33% when considering the environmental costs of a full ICE fleet.

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in the agency's FY 2021-2030 SRTP adopted in 2020 as outlined in Table 7.8. There are also additional funding sources through federal, state, regional, and other grant opportunities that can be explored to fill the estimated funding gap. This analysis only considers the capital costs needed based on the phasing schedule developed in sections 7.4.2 and 7.4.3 (for the BEB fleet) and the potential funding sources for capital projects. Strategies for addressing the identified gaps are discussed in sections 9 and 11.5.2.

Table 7.8 SolTrans Estimated Costs and Funding Shortfall by Year (in millions of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Estimated Capital Costs	$0.00	$18.66	$17.26	$10.05	$2.33	$0.68	$0.00	$0.00	$0.00	$0.00	**$48.98**
Potential Funding Identified in SRTP	$3.78	$1.46	$1.46	$3.96	$2.91	$2.91	$0.59	$0.61	$2.13	$0.47	**$20.28**
Other Potential Existing Capital Revenues	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$0.00**
Surplus / Gap	$3.78	**-$17.20**	**-$15.80**	**-$6.09**	$0.58	$2.23	$0.59	$0.61	$2.13	$0.47	**-$28.70**

Source: WSP

CITY COACH

8 VACAVILLE CITY COACH

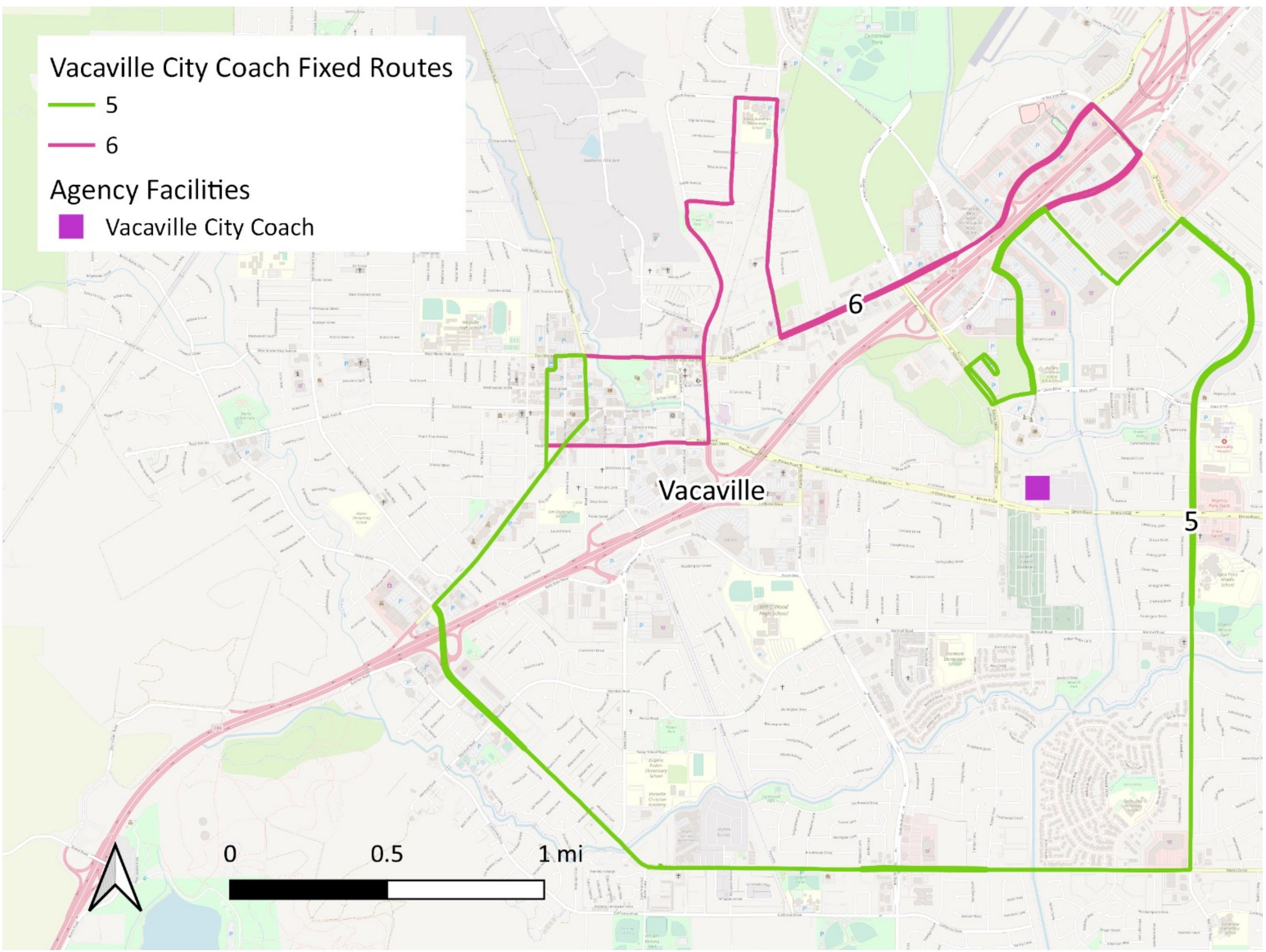
The following sections present Vacaville City Coach's existing conditions, service modeling results, power and energy analysis, facility concepts, phasing strategies, and cost and funding analysis to support the agency's ZEB transition.

8.1 Existing Conditions

8.1.1 Existing Service

Vacaville City Coach operates under the Public Works Department through its General Services Division. Previously, Vacaville City Coach operated six fixedroutes that provide coverage throughout the city but has since implemented COVID-19-related service cuts (Figure 8.1) and plans to operate a much more scaled-down version closer to the pandemic service. Weekday service runs from 6:00 AM to 6:30 PM on 30-minute headways throughout the day, Monday through Friday. Reduced service is provided from 8:00 AM to 6:15 PM on Saturday.

Figure 8.1 Vacaville City Coach Fixed Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

The fixed-route fleet consists of 18 standard 35-foot buses, and the demand response fleet consists of seven cutaways (although there are additional cutaway vehicles that have been procured) (Table 8.1). The 35-foot buses all run on CNG, while the cutaways run on gasoline. The vehicles were first put in service between 2008 and 2015.

Table 8.1 Summary of Vacaville City Coach Existing Fleet

Bus Type	Length	Fuel Type	In Service Year	Quantity
Cutaway	24'	Gasoline	2008-2015	7
Standard Bus	35'	CNG	2009-2013	18
			Total Vehicles	**25**

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Note: A detailed list of Vacaville City Coach Existing Fleet is available in Appendix A: *Existing Conditions Analysis*

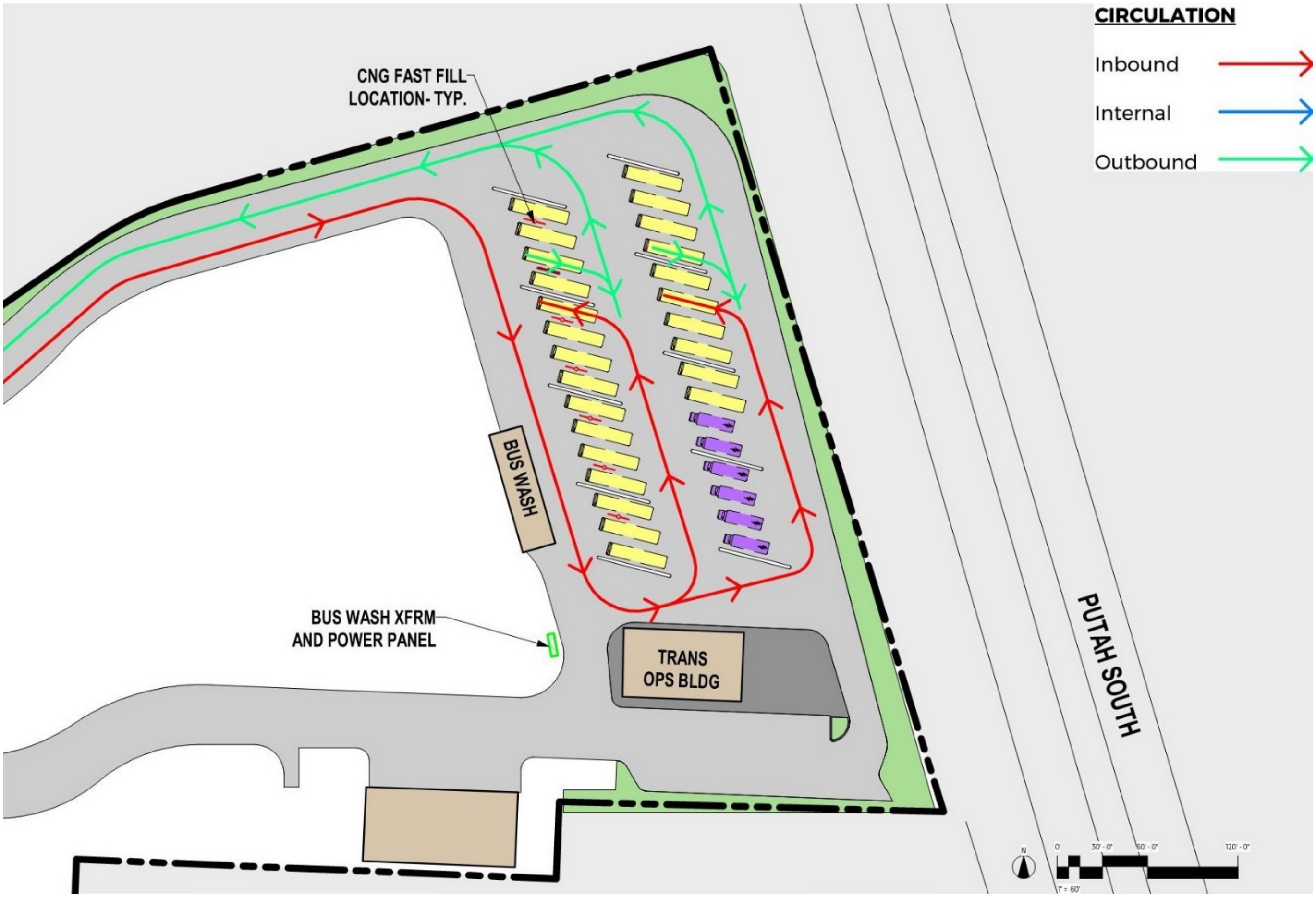
8.1.2 Existing Facility Conditions

The Vacaville City Coach facility is located at 1001 Allison Drive (Figure 8.2). The transit operations share the site with the City of Vacaville Public Works Department.

The maintenance building is located at the site's northwest corner and services both transit vehicles and public works vehicles. The bus parking area is outfitted with seven fast-fill CNG dispensers. There is also a fueling station near the facility's entrance that provides fast-fill CNG, diesel, and unleaded fuel and is used by both transit and public works vehicles. A bus wash is located adjacent to the bus parking area and services only transit vehicles.

The transit operations portion of this site has an additional transit bus parking capacity. There are currently no new planned projects that would affect the transit area operations or negatively affect the electrification efforts. When transitioning to ZEB, the existing fast-fill locations in the bus parking area will require special coordination to ensure that CNG fueling is not negatively impacted during transition phases.

Figure 8.2 Vacaville City Coach Existing Facility and Site Circulation



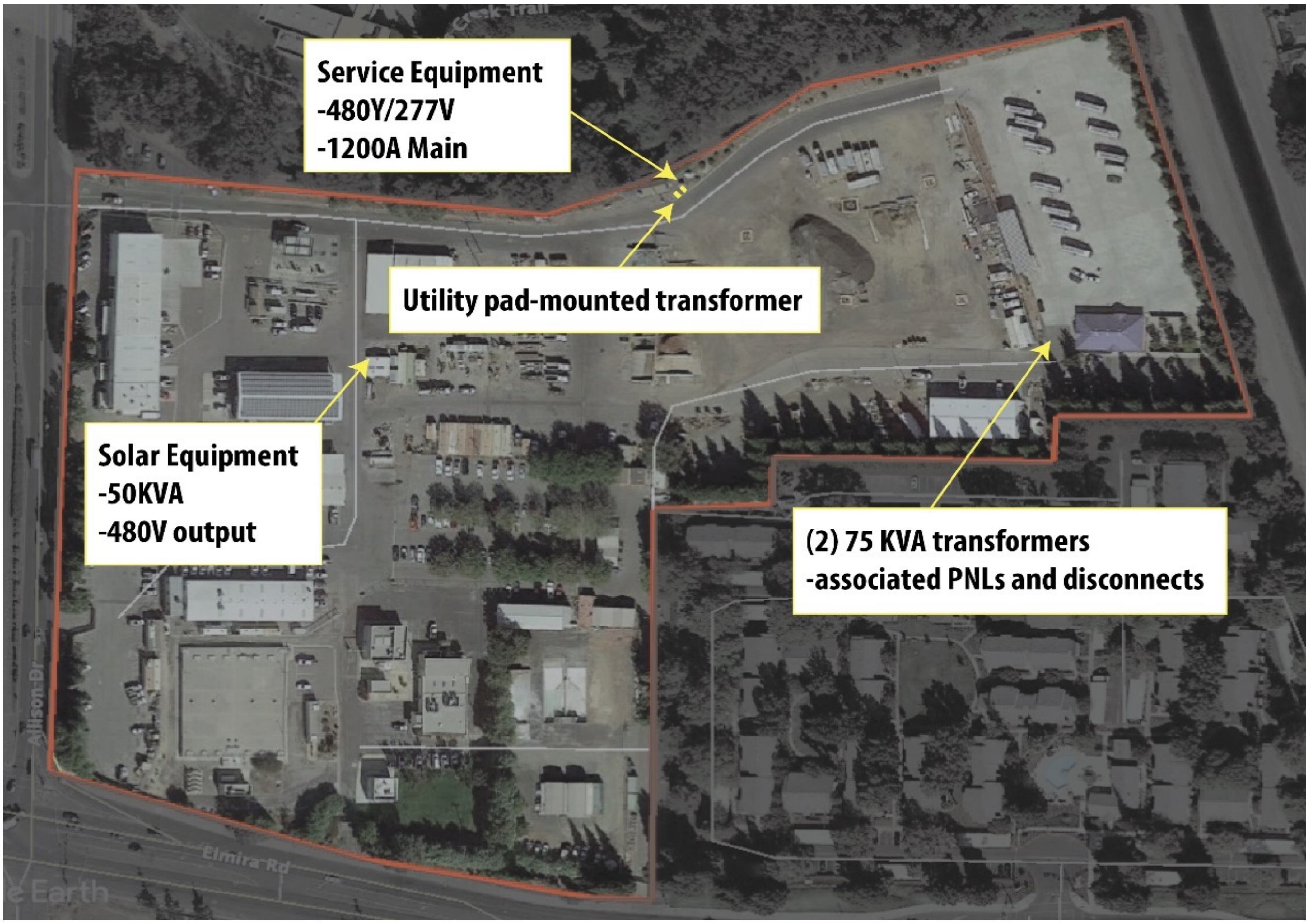
Source: WSP

8.1.3 Existing Power and Energy Conditions

Vacaville City Coach's power is provided by the PG&E Vacaville Substation (6360), which has a capacity of 44.6 MW on Bank 2, with a peak load of approximately 37.8 MW (based on publicly available data). This substation feeds the Vacaville 1105 circuit that feeds the Vacaville City Coach yard. The 12 kV Vacaville 1105 Circuit has an existing capacity of 10.9 MW. PG&E estimates the projected peak load of this circuit as 9.2 MW, leaving approximately 1.7 MW of available capacity.

The site has a utility pad-mounted transformer, two 75 kVA transformers and their associated panelboards and disconnects, one main switchboard with an estimate of three spare breakers, a solar panel, and a generator (Figure 8.3). If necessary, the existing electrical infrastructure can power a small number of bus chargers while awaiting new utility service upgrades or outage restoration from PG&E.

Figure 8.3 Vacaville City Coach Utility Plan View



Source: WSP

8.2 Service Modeling

8.2.1 Fixed-Route Service

Vacaville City Coach currently operates 35-foot buses for their fixed-route services. Vacaville City Coach's local service is operated with two-vehicle blocks. One service block is approximately 125 miles, while the other is 172 miles.

Based on the service modeling analysis, a single BEB cannot complete one of the blocks in the typical scenario. Furthermore, both blocks will fail in the conservative scenario. While both blocks are within the average stated range of the replacement BEBs, due to variables such as slope and weather, the battery efficiency is not sufficient to complete the block. Table 8.2 summarizes the energy demands for the passing block. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 1.88 kWh/mile due to the additional consumption factors. In the typical and conservative EWL scenarios, neither block can be completed by a single vehicle.

Table 8.2 Vacaville City Coach – Summary of Passing Blocks

Scenario	Passing Blocks	Avg. Distance (miles)	Avg. Required Battery Capacity (kWh)	Avg. State of Charge Remaining	Avg. Efficiency Change (kWh/mi)
Typical	1	125	293	3% (8 kWh)	0.46
Conservative	-	-	-	-	-

Source: WSP

Table 8.3 presents a summary of the energy demands for the failing blocks. On average, 75-76% of the blocks could be completed by a single 35-foot BEB in typical and conservative scenarios. The higher efficiency change in the conservative scenario reflects the higher energy used to operate HVAC in extreme weather and the less efficient regenerative braking system.

Table 8.3 Vacaville City Coach – Summary of Failing Blocks

Scenario	Failing Blocks	Avg. Distance (miles)	Avg. Required Battery Capacity (kWh)	Avg. % of Block Completed	Avg. Efficiency Change (kWh/mi)
Typical	1	172	399	75%	0.44
Conservative	2	149	404	76%	0.85

Source: WSP

8.2.2 Demand Response Service

Since the vehicle miles traveled for demand response services are variable, the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the daily and maximum mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 104 and 130 miles. The GreenPower EV Star – a representative BEB replacement for Vacaville City Coach's existing vehicles - has an advertised range of 150 miles.

Based on the comparison between the advertised range of existing battery electric cutaways and the service's average daily vehicle distance, Vacaville City Coach should be able to operate its demand response service with no or minimal impact. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service. However, under EWL battery conditions (64% advertised capacity), the expected vehicle range is below the calculated average daily vehicle distance.

However, it should be noted that this estimate does not consider HVAC usage, slope, and other service area-specific variables that can significantly impact the vehicle's efficiency and range. For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

8.3 Power and Energy Improvements

Vacaville City Coach fleet currently consists of seven gas cutaways and eighteen CNG 35-foot buses. This analysis considers that the transit agency can add up to five 35-foot buses and an electric cutaway at the site in the future. This analysis calculated the electrical requirements for both the current and assumed future fleet.

The analysis evaluates the fleet under an unmanaged and managed charging scenario. In the unmanaged charging scenario, all vehicles will charge concurrently at the same time. Meanwhile, the managed charging scenario assumes that the vehicles will charge sequentially at a full charging rate before switching to the next vehicle. This scenario will reduce the peak demand power required but will result in a longer charging time. However, because BEBs are charging at the same rate during non-peak hours, the longer time should not affect the total utility cost. It is important to note that the managed charging scenario showed in this analysis is only one example of many charging profile optimizations that can be performed to demonstrate the benefits of managed charging

Existing Fleet

To service the existing fleet, thirteen 150 kW DC chargers are recommended to be installed. The recommendation is for Vacaville City Coach to do managed charging. Managed charging will reduce the peak demand from 1875 kW in the unmanaged scenario to 900 kW. It will reduce overall utility costs due to the lower peak demand and reduce capital costs because of the smaller equipment upgrades required. If necessary, five 150 kW DC fast chargers can be used at full speed for flexible mid-day recharging.

Future Fleet

Three additional 150 kW DC chargers will be needed to anticipate the additional needs of the future fleet. The total peak demands are 1,875 kW and 1,050 kW for unmanaged and managed charging scenarios, respectively. Therefore, a charge management system is strongly recommended for Vacaville City Coach. Upgrading the electrical equipment to anticipate this load level will futureproof the site from fleet expansions.

The summary of the charging scenarios analysis is shown in Table 8.4.

Table 8.4 Summary of Vacaville City Coach Charging Scenarios

Fleet	Min. Required # of Chargers	Scenario	Charge Schedule	Charge Rate (per vehicle)	Peak Demand	Required Power Increase*
Current Fleet	Thirteen 150 kW DC chargers	Unmanaged	All BEBs charge concurrently	67.5 kW	1,875 kW	2,063 kW
		Managed	Each BEB charges sequentially	135 kW	900 kW	990 kW
Future Fleet	Sixteen 150 kW DC chargers	Unmanaged	All BEBs charge concurrently	67.5 kW	1,875 kW	2,063 kW
		Managed	Each BEB charges sequentially	135 kW	1,050 kW	1,155 kW

Source: WSP

*Note: Required power increase includes 10% buffer for ancillary loads and losses

Power and Energy Upgrades

It is highly advised for Vacaville City Coach to invest in a CSMS because the existing PG&E feeder, Vacaville 1105 Circuit, serving the site, only has a free peak capacity of 1.7 MW. The peak times for the feeder may or may not coincide with the projected peak times Vacaville City Coach wants to charge, nor can it support the potential 1.88 MW peak load Vacaville City Coach can potentially incur with unmanaged charging.

Based on the analysis, the following facility electrical upgrades are required, assuming the worst-case scenario of unmanaged charging:

- 3000 kVA transformer near the north end of site fed by new 12kV underground electrical service
- 480V service entrance main switchboard with a minimum electrical rating of 5000 A and utility metering cabinet
- Underground electrical conductor in conduit from the new transformer to new 480V switchboard
- Vehicle charging stations with underground conduit connecting the charging stations to the new 480V switchgear.

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Vacaville City Coach would be responsible for installing the switchboard, utility metering cabinet, underground conduit, and charging stations. Managed charging is strongly recommended, and electrical equipment properties should be determined during the design phase based on discussions with PG&E and the level of electric service requested.

Energy resiliency at the site is key to ensure Vacaville City Coach service delivery once transitioning to a full BEBs fleet. One or more of the strategies below provide a suitable level of backup power after considering the possible resiliency issues that the site might experience[28]:

- 500 kW permanent standby generator
- Solar PV system paired with 1 - 2 MWh BESS in 10' – 40' intermodal container

A generator with an output rating of at least 500 kW generator would be capable of recharging every vehicle in a 24-hour period but may require some vehicles to charge during the day if the outage duration is long

8.4 ZEB Transition Plan

8.4.1 Facility Concept

The Vacaville City Coach facility concept supports 31 charging positions. This will support the planned 10 ZEBs and 15 ZE cutaway vehicles/vans, while also leaving room for additional vehicles in the future. Sixteen DC charging cabinets and 31 dispensers are recommended to support the fleet. The number of dispensers required can decrease through further evaluation of the buses' charging window and end-of-the-day SOC.

To maximize the usage of the parking area and limit the amount of trenching required at the existing parking area, overhead charging was determined to be the preferred solution, with overhead plug-in being the preference over pantograph dispensers. It should be noted that while the 35-foot buses can be served by either overhead pantograph or overhead-mounted plug-in dispensers, the cutaway vehicles can only support plug-in charging.

Table 8.5 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to Appendix D: *BEB Facility Concepts Analysis*. Figure 8.4 illustrates the proposed facility concept to support the electrification transition.

Table 8.5 Vacaville City Coach Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	16
Plug-in DC Dispenser	31
Cable Retractor	31
Transformer	1
Switchboard	1

Source: WSP

28 Appendix C: *Power and Energy Analysis* provides in-depth resiliency analysis for the site

Figure 8.4 Vacaville City Coach Preliminary Facility Concept

Source: WSP

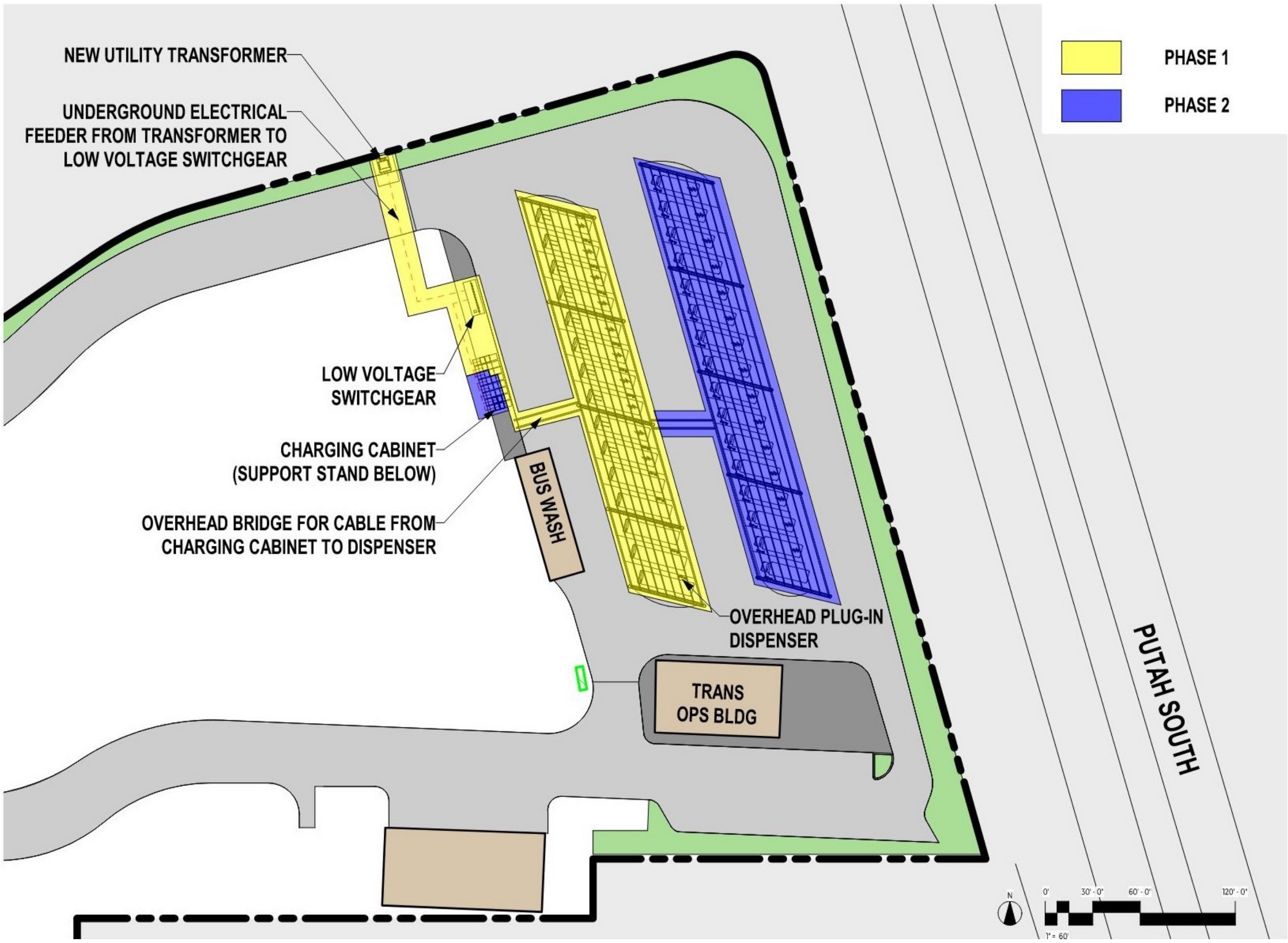
8.4.2 Construction Phasing

The Vacaville City Coach schedule is shortened due to Vacaville City Coach's goal to electrify ten vehicles by November 2023. In order to relieve some of the constraints, the transition has been split into two stages. The first stage is intended to install the needed support for the first procurement of 10 35-foot BEBs. The second stage is for the ZE cutaway fleet that does not need to meet the November 2023 goal (per the CARB ICT regulation, cutaways do not need to transition until 2026). Appendix E: *Phasing Strategy and Transition Analysis* details each construction stage.

During the first stage, the CNG fast-fill dispensers located at the bus parking positions will need to be decommissioned and removed from service. Existing CNG buses will need to be fueled through the fueling island.

Vacaville City Coach has procured a design firm to perform a 30% design. The 30% design work is scheduled to commence in March 2022. Meanwhile, the procurement for 100% design is planned to start in April 2022, with the actual design work starting in August 2022. The construction phases will be completed in February 2024. Figure 8.5 illustrates the construction phasing, and Table 8.6 illustrates the proposed schedule.

Figure 8.5 Vacaville City Coach Preliminary Staging Concept



Source: WSP

Table 8.6 Vacaville City Coach Construction Schedule

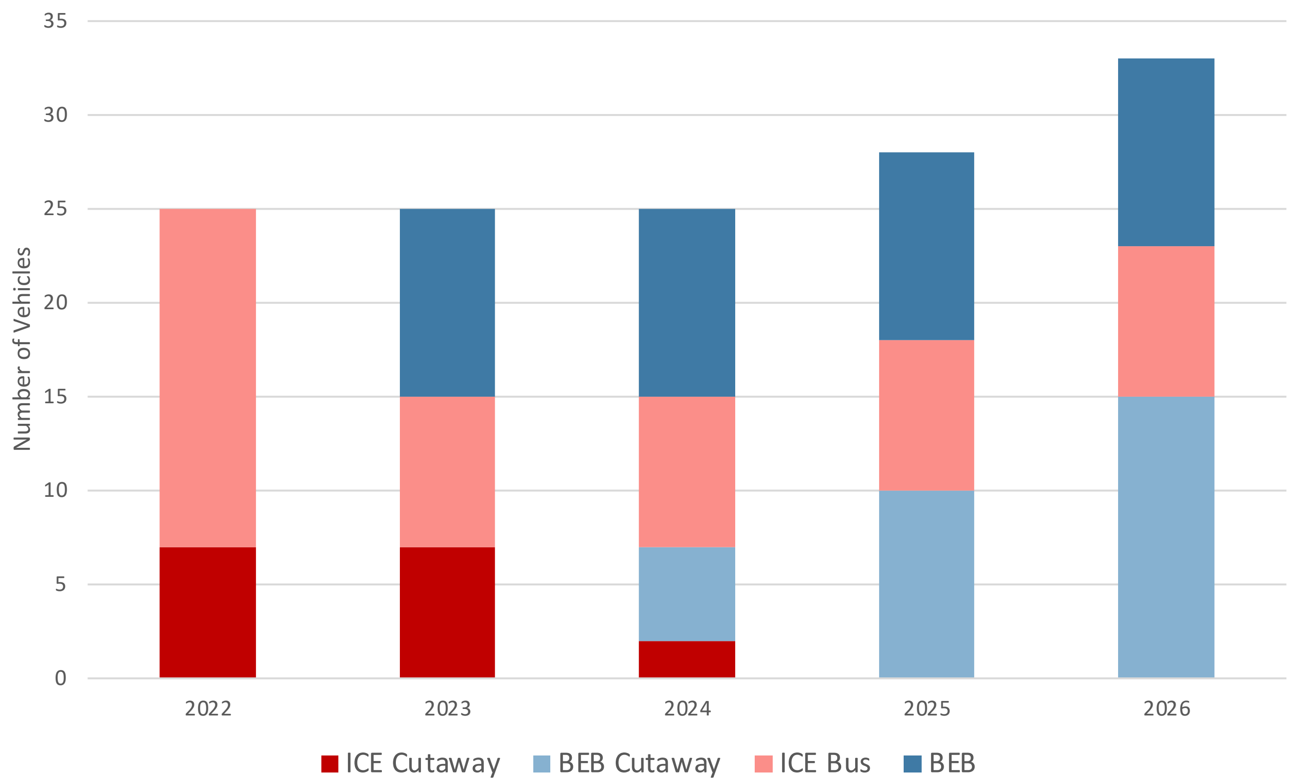
	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24
Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Utilities	18 Months																							
100% Design Procurement		4 Months																						
30% Design	5 Months																							
100% Design						5 Months																		
Construction Procurement									5 Months															
Stage 1 Construction														7 Months										
Stage 2 Construction																					4 Months			

Source: WSP

8.4.3 Vehicle Procurement Schedule

The delivery of new vehicles must align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. Vacaville City Coach aims to procure ten 35-foot vehicles to align with the completion of Stage 1; subsequent procurements will align with Stage 2, with five ZE cutaways arriving in 2024. Additional cutaways will be procured in sets of five in 2025 and 2026. This approach will help ease the transition so that Vacaville City Coach has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Vacaville City Coach can choose to speed up the procurement of the cutaways, given that the dispensers will be available by April 2024. Figure 8.6 illustrates Vacaville City Coach's fleet mix over time (between ICE and ZEB vehicles).

Figure 8.6 Vacaville City Coach Fleet Mix



Source: WSP

8.4.4 Lifecycle Costs Analysis

Based on the lifecycle cost analysis, the total cash cost (including capital, O&M, disposal and excluding environmental costs) of operating a full BEB fleet is approximately $45M, 36% higher than if Vacaville City Coach continued to operate the current fleet. This is due to the significantly higher capital costs. The total vehicle capital costs (with modification) are $17M for BEB compared to $12M for ICEB. Furthermore, the total charging/fueling infrastructure capital costs are $9M for BEB and $5M for ICEB fleet. The fueling infrastructure costs for ICEB fleet assume that one CNG tank will be replaced in 2031 and another will be upgraded in 2039, while a diesel tank replacement was assumed to occur in 2022.

However, the lifecycle environmental costs for the current ICEB fleet are approximately $2M higher than a full BEB fleet, which will bring the total cash and non-cash costs difference between the two fuel types down to 28%. The total lifecycle cash and non-cash costs are $3.92/mile and $5.03/mile for ICE and BEB fleets, respectively.

Table 8.7 provides the summary of the lifecycle cost analysis.

Table 8.7 Lifecycle Cost (2021-2037) Analysis Results for Vacaville City Coach (in millions of YOE$)

Cost Categories	"No Build" Scenario	"Build" BEB Scenario
	Cash Costs	
Total Capital Costs	$18	$26
Total Operating Costs	$15	$19
Total Disposal Costs	-$0.20	-$0.20
Total Cash Cost	$33.00	$45
	Non-Cash Costs	
Total Environmental Costs	$3	$1
Total Cash and Non-Cash Costs	$36	$46
Total Cash and Non-Cash Costs per Mile	**$3.92**	**$5.03**

Source: WSP

Note: All values are presented in and rounded to the nearest million

Note: The total costs may vary due to rounding. Refer to Appendix F: *Cost and Funding Analysis* for a detailed breakdown of each item.

8.5 Findings and Next Steps

8.5.1 Service Feasibility

One service block in the typical scenario failed, and both failed in the conservative scenario. Under both scenarios, additional pull-outs from spares at the facility could support the service, while small advancements in battery technology could reduce the additional vehicles required to meet the service.

If additional pull-outs to complete service are not viable, there are several other considerations to meet the service:

- Additional service changes
- Wait for advancements in BEB technology
- Select a vehicle that has a higher battery capacity than the average used in the model
- On-route charging

It should be noted that technology is rapidly evolving and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended to assess actual performance.

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of Vacaville City Coach; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

8.5.2 Power and Energy Upgrades

Based on the analysis, it is recommended for Vacaville City Coach to install at least thirteen 150 kW DC chargers with managed charging to keep the required power increase to 990 kW. Managed charging will reduce overall utility costs due to the lower peak demand and reduce capital costs because of the smaller equipment upgrades required.

PG&E would be responsible for installing the new transformer and underground electrical conductor, while Vacaville City Coach would be responsible for installing the switchboard, utility metering cabinet, underground conduit, and charging stations.

The next immediate steps for Vacaville City Coach are:

1. Decide whether to invest in a charge management system
2. Begin service application and coordination with PG&E for the appropriate load from PG&E
3. Determine outage mitigation methods. If a backup generator is selected, including the design and procurement in engineering firm RFP
4. Begin detailed engineering design
5. Procure long-lead items
6. Begin construction to point of contact with utility

8.5.3 ZEB Transition Plan

Facility Concept

The Vacaville City Couch facility concept supports 31 charging positions. Sixteen DC charging cabinets and 31 dispensers are recommended to support the fleet. Overhead charging was determined to be the preferred solution, with overhead plug-in being the preference over pantograph dispensers.

Several considerations important for Vacaville City Coach facility improvements are:

- Currently, vehicles can pull into some spaces in either direction. With charging equipment requiring a fixed location, the orientation of each parking space will not be flexible. However, with overhead-mounted equipment, it is much easier to reconfigure if parking direction preferences change in the future.
- As the charging infrastructure is phased in, the CNG fast-fill infrastructure in the parking area will need to be removed to facilitate the proposed charging strategy.

Phasing Schedule

The Vacaville City Coach schedule is shortened due to Vacaville City Coach's goal to electrify ten vehicles by November 2023. In order to relieve some constraints, the transition has been split into two stages. Vacaville

City Coach has procured a design firm to perform a 30% design. The 30% design work is scheduled to commence in March 2022. Meanwhile, the procurement for 100% design is planned to start in April 2022, with the actual design work starting in August 2022. The construction phases will be completed in February 2024.

The delivery of new vehicles must align with the completion of construction, given that the vehicles cannot be operated until chargers are installed. Ten 35-foot BEBs are going to be delivered in 2023 to align with the completion of Stage 1. Then, five ZE cutaways will be delivered each year from 2024 to 2026. The procurement of the cutaways can be sped up, given that the dispensers will be available by April 2024.

Cost And Funding

Based on the lifecycle cost analysis, the total cash cost of operating a full BEB fleet is approximately $45M, 36% higher than if Vacaville City Coach continued operating the current fleet. This is due to the significantly higher capital costs. The costs difference goes down to 28% when considering the environmental costs of a full ICE fleet.

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in the agency's FY 2021-2030 SRTP adopted in 2020 as outlined in Table 8.8. There are also additional funding sources through federal, state, regional, and other grant opportunities that can be explored to fill the estimated funding gap. This analysis only considers the capital costs needed based on the phasing schedule developed in sections 8.4.2 and 8.4.3 (for the BEB fleet) and the potential funding sources for capital projects. Strategies for addressing the identified gaps are discussed in sections 9 and 11.5.2.

Table 8.8 Vacaville City Coach Estimated Costs and Funding Shortfall by Year (in millions of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Estimated Capital Costs	$0.00	$11.91	$7.54	$4.77	$1.64	$0.00	$0.00	$0.00	$0.00	$0.00	**$25.86**
Potential Funding Identified in SRTP	$0.15	$0.15	$0.42	$0.33	$0.15	$10.00	$4.40	$0.15	$1.00	$3.15	**$19.90**
Other Potential Existing Capital Revenues	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$0.00**
Surplus/ Gap	$0.15	-$11.76	-$7.12	-$4.44	-$1.49	$10.00	$4.40	$0.15	$1.00	$3.15	**-$5.96**

Source: WSP

Note: All values are presented in and rounded to the nearest million

9 FUNDING SOURCES

This section identifies and evaluates the funding sources that may potentially be available to support STA and its member transit agencies to fund the transitions to all battery-electric bus (BEB) fleets. Options considered include federal, state, and regional/local/other funding sources. Refer to Appendix F: *Cost and Funding Analysis* for in-depth descriptions and comparison of the funding sources.

The sources listed in this section are based on what is available during the time this plan is being written. In the future, more funding sources might be available for electrification projects considering the increasing concerns to reduce the emissions from the transportation sector. Some of the grants and projects listed might also expire and are not continued. Therefore, STA and the related transit agencies must periodically update the list to ensure the accuracy of the list moving forward.

9.1 Federal Funding

The Infrastructure Investment and Jobs Act (IIJA), signed into law in November 2021 as the Bipartisan Infrastructure Law (BIL), provides for the lion's share of transportation-related formula and discretionary grant assistance that comes from the U.S. federal government. This legislation included a reauthorization of the programs included in the Fixing America's Surface Transportation (FAST) Act, along with the creation of new ones. Overall, the BIL authorizes more funding opportunities to accommodate the country's transition to a more climate-friendly transportation system. Existing and new formula funding and discretionary grant programs will receive a historic investment of federal funds that will be eligible for fleet electrification and associated infrastructure projects.

The BIL also amends other programs and funding sources that could potentially be used for BEB purchases or other projects stipulated in the *Solano Countywide Electrification Transition Plan*. These include:

- Federal Highway Administration (FHWA) Surface Transportation Block Grant (STBG) Funding eligible uses expanded to include installation of EV charging infrastructure.
- FHWA Congestion Mitigation and Air Quality (CMAQ) funding eligible use expanded to include the purchase of medium- or heavy-duty ZE vehicles and related charging equipment.

Note that CMAQ and STBG funding in the nine-county Bay Area Region is distributed via the regional Metropolitan Transportation Commission (MTC) One Bay Area Grant (OBAG) program.

Table 9.1 provides a high-level summary of each funding source's key characteristics and considerations evaluated in this section. Appendix F: *Cost and Funding Analysis*.

Table 9.1 Potential Federal Funding Sources Overview

Federal Funding Program	Administering Agency	Eligibility			Funding Potential
		Maintenance Facility	Charging Infrastructure	BEB Purchase	
RAISE	USDOT	✓	✓	✓	Moderate to Low
Capital Investment Grants (CIG) Small Starts	Federal Transit Administration (FTA)		✓	✓	Low
Section 5307: Urbanized Area Formula Grants	FTA	✓	✓	✓	High to Moderate
Section 5311: Formula Grants for Rural Areas	FTA	✓	✓	✓	High
Section 5339: Bus and Bus Facilities Formula Funds Grant	FTA	✓	✓	✓	High
Section 5339 (c): Low or No Emission Vehicle Program	FTA	✓	✓	✓	Moderate
Carbon Reduction Program	FHWA		✓		Moderate
Charging and Fueling Infrastructure Grant Program[29]	FHWA		✓		Low
Alternative Fuel Tax Credit	USDOE		✓		Moderate to High
New Market Tax Credits	USDOT	✓	✓		Moderate
Opportunity Zones	USDOT	✓	✓		Low to Moderate

Source: WSP

9.2 State Funding

A variety of funding programs within the State of California supports transit fleet electrification efforts. Table 9.2 provides a high-level summary of each funding source's key characteristics and considerations evaluated in this section. Appendix F: *Cost and Funding Analysis* provides more elaborate discussions on each funding source.

Additionally, STA and its member agencies can benefit from tax exemptions in California to aid in the fleet electrification transition. BEB purchases are exempt from California sales and use taxes when purchased by a transit agency. Moreover, the electricity that local agencies or public transit operators use as a motor vehicle fuel to operate public transit services is exempt from applicable user taxes imposed by California counties.

29 Refer to The National Electric Vehicle Infrastructure (NEVI) Formula Program Guidance

Table 9.2 Potential State Funding Sources Overview

State Funding Program	Administering Agency	Eligibility			Funding Potential
		Maintenance Facility	Charging Infrastructure	BEB Purchase	
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)	CARB		✓	✓	Moderate
State Volkswagen Settlement Mitigation	CARB		✓	✓	Moderate to Low
Transit and Intercity Rail Capital Program (TIRCP)	CalSTA		✓	✓	High
Solutions for Congested Corridor Programs	CTC			✓	Low to Moderate
Low Carbon Transit Operations Program (LCTOP)	CalTrans	✓	✓	✓	High
Transportation Development Act: Local Transportation Fund (LTF)	Caltrans/ State Board of Equalization	✓	✓	✓	High
Transportation Development Act: State Transit Assistance Fund (STAF)	Caltrans/State Controllers' Office (SCO)	✓	✓	✓	High
SB 1 State of Good Repair Program (SGR)	Caltrans/SCO	✓	✓	✓	High
Clean Mobility Options (CMO)	CALSTART		✓	✓	Moderate
Clean Transportation Program	CEC	TBD	TBD	TBD	Moderate to High

Source: WSP

9.3 Regional & Local Funding

In addition to the regionally administered state funding discussed in the previous sections, a few regional entities also disperse funding that could potentially be used for fleet electrification projects.

Table 9.3 provides a high-level summary of each funding source's key characteristics and considerations evaluated in this section. Appendix F: *Cost and Funding Analysis* provides more elaborate discussions on each funding source.

Table 9.3 Potential Regional / Local Funding Sources Overview

Regional/Local Funding Program	Administering Agency	Eligibility			Funding Potential
		Maintenance Facility	Charging Infrastructure	BEB Purchase	
One Bay Area Grant (OBAG)	MTC	✓	✓		Moderate to High
Transportation Funds for Clean Air (TFCA)	Bay Area Air Quality Management District (BAAQMD) & STA		✓	✓	Moderate to High
Carl Moyer Program	BAAQMD		✓	✓	Moderate to High
Community Emission Reduction Grant Program	BAAQMD		✓	✓	Moderate
Regional Traffic Impact Fee (RTIF)	STA				Low
EV Charge Network	PG&E		✓		Low
EV Fleet Program	PG&E			✓	High

Source: WSP

10 STAFFING AND TRAINING

One of the essential factors for a smooth transition to a full BEB fleet includes ensuring that the whole workforce, especially operators and technicians, is comfortable handling the new technology, which can be achieved by workforce evaluation and training. Moreover, workforce evaluation is one of the key elements in the Zero Emission Fleet Transition Plan required for federal grants funding.

The following sections discuss the impacts of full-fleet electrification on staffing needs and training. Recommendations are summarized from peer agencies that have experience in operating BEBs.

10.1 Staffing

Based on the data gathered from peer transit agencies, the prevailing approach for those that have deployed BEBs is to see BEB as simply another type of fleet vehicle which agency operators and technicians need to be prepared to drive, maintain, and repair like any other, regardless of its different propulsion and fueling systems. Most peer transit agencies emphasize the need to train existing staff on the newer BEB technology without increasing staffing levels. Unions have generally reacted positively to the implementation of BEBs, particularly because it allows their members to learn and work with new technology. The key is ensuring the staff is trained with proper procedures and safety measures regardless of the propulsion system.

The following sections will outline the high-level lessons learned from peer transit agencies in key areas essential for the transition process to a full BEB fleet. The actual staffing needs might vary based on the specific characteristics of Solano County's transit agencies' current staffing and service operations. A workforce evaluation tool released by FTA can be used to help identify the impact of the transition to a zero-emission fleet on the current workforce[30].

10.1.1 Transit Operations

One of the biggest challenges unique to BEBs is ensuring that the bus state-of-charge will be sufficient to complete the daily bus block. Peer transit agencies had established efforts to ensure an accurate performance monitoring system, such as actively relaying real-time state-of-charge data to dispatchers or establishing a separate division to provide direct support to ZEV-related issues. In some cases, very long vehicle blocks may need to be divided into smaller segments due to BEB range limitations, affecting operators' hours.

- Service Schedulers or Planners have to have the flexibility to adjust the schedule to fit the decreased range of a BEB. Scheduling might need to occur in advance of BEB delivery to anticipate for the shorter range.
- There would not be a need to add operator staff positions assuming a 1:1 ICEB to BEB bus replacement ratio
- Additional operator hours might be needed if the service changed to adapt to BEB's shorter range. The additional hours account for the deadheads to swap BEBs to and from the bus divisions.
- BEBs may require operators and dispatchers to be more cognizant of the remaining vehicle range and should use existing protocols to report issues to the transportation management center (TMC).

30 Refer to FTA Workforce Evaluation Tool

- Operators must be trained on the operation and charging of the BEBs, and how functions, such as HVAC and regenerative braking, will have a significant impact on battery performance.
- For potential on-road BEB breakdowns, it is recommended for road call crews to have two staff members per bus to provide a buddy system for high-voltage safety. The agency should work with third-party towing companies to ensure they have the proper training on how to tow a BEB safely.
- BEBs would not impact staffing levels for staff in the TMC and dispatchers.

10.1.2 Bus Yard Management

- BEBs will require modifications to the roles of service workers, yard starters (yard dispatchers), and maintenance controllers.
  - When the service workers receive the bus from transit operators, the bus needs to be parked in the charging position (instead of fueling).
  - Service workers have to ensure that the buses are connected to the chargers and charging as scheduled.
- Facility technicians will be trained on all (non-bus) equipment applicable to the mechanic's grade.
- In the event that long blocks are cut due to BEB range limitations, more transit cleaners will be needed to provide midday cleaning for buses that are returned after serving a morning block.
- Since they will be working in the proximity of high voltage, Cleaners also have to be trained and understand the the safety elements of the vehicles and chargers.
- If the overall fleet size increases due to BEBs, the number of service workers and transit cleaners should be increased proportionally because their workload is based on the number of buses they can process within a limited amount of time.

10.1.3 Vehicle Maintenance

- All mechanics should receive PPE and high-voltage training, training for maintenance and troubleshooting vehicles and charging infrastructure.
- The staffing level impacts for the Fleet Maintenance department are largely dependent on the replacement ratio. If more than one BEB is required to replace one conventional bus, the number of mechanics may need to increase incrementally.
- On the other hand, BEBs do not have diesel engines, so preventive maintenance should be simpler to perform. It is recommended that the transit agencies continually monitor and assess mechanic staffing needs throughout the BEB rollout to satisfy the need for running repair and preventive maintenance. Once a BEB has been safely de-energized, the repair functions are the same as current diesel or CNG equipment.
- Mechanics will also be needed on the Quality Assurance and Vehicle Acceptance teams. Quality Assurance staffing may increase incrementally with an increase in fleet size. Vehicle Acceptance staffing will need to accommodate the large fleet turnover due to BEBs.
- BEB mileage should be reported to maintenance controllers upon pull-in every day in order to help them schedule preventive maintenance. The number of maintenance controllers may not need to increase. Some agencies might be able to take advantage of automatic mileage reporting from vehicle telemetry if their current ITS architecture allows for it.

10.1.4 Charge Management and Infrastructure Maintenance

Ensuring that BEBs are properly charged with electricity will be a new responsibility for the staff of the transit agencies. Charge management is complex because of competing priorities, including energy cost, electricity supply and capacity at individual facilities, BEB charging capability, and charging infrastructure capability. Charge management software is critical for managing the charging of large fleets to properly balance on-site electricity loads, schedule, monitor, and control each bus's charging process, and identify and help diagnose problems.

It is important to note that the complexity of the charge management process increases as the fleet size increases. Therefore, smaller transit agencies might not require as many resources as agencies with a bigger fleet. In general, a centralized charge management platform capable of remote operation is recommended for all transit agencies. These assumptions are used as a basis for the following staffing recommendations:

- A new SOP will need to be developed around the oversight of charge management and emergency response procedures.
- Fleet Maintenance mechanic shift supervisors should be responsible for using the charge management system to control and monitor BEB charging at the facility, maintaining coverage 24 hours a day, seven days a week. Because Fleet Maintenance is ultimately responsible for ensuring buses are available for revenue service, which currently includes fueling, Fleet Maintenance should set the parameters for BEB charging. Staffing changes are not likely necessary solely for charge management.
- Fleet Maintenance supervisors and staff should also have first-line responsibility for diagnosing bus charging problems. They may need assistance from the team assigned to do charging maintenance to diagnose problems.
- Most peer transit agencies primarily rely on in-warranty servicing and service contracts with bus OEMs, charger OEMs, or third-party electricians for their charging infrastructure maintenance.

10.2 Training

This section presents findings on BEB training best practices gleaned from peer transit agencies with BEB experiences as well as published reports.

10.2.1 Curriculum/Training Models

- Some reports and training curricula focus on the BEB propulsion system and associated electrical safety, since this sets BEBs apart from buses with conventional fuel sources. The California Transit Training Consortium (formerly known as the Southern California Regional Transit Training Consortium) is set up to provide BEB and advanced electronics training to current transit technicians, mechanics, and supervisors.
- OEM-provided training packages for BEBs are comprehensive and address all bus subsystems and components, even if there is a substantial commonality with conventionally fueled buses. At the same time, they are also very specific to the bus model and the installed systems and components being purchased by the transit agency. Training needs to be provided at this detailed level for each bus make/model purchased.

- There is significantly less material on charging infrastructure and equipment training. However, some transit agencies indicated that training is provided by charging equipment OEMs and software providers much the same way as bus OEMs.
- Generally, BEB-specific training is made available to all relevant staff and not limited to a subgroup of people (e.g., a handful of fleet mechanics or supervisors). However, training is still primarily subject to operational needs.
- While not prevalent now, supervisors will need to learn how to operate charge management software and provide an initial diagnosis of charging issues. Supervisors also require training for general high-voltage electrical safety, scaffolding, and Personal Protective Equipment (PPE).
- Mechanics require in-depth training for all new buses to understand manufacturer-specific and model-specific maintenance procedures.
- Operators' specific training varies by the transit agency. All agencies provide basic familiarization training. However, one suburban transit agency has additionally focused on operator driving behavior and feedback to increase energy efficiency and improve BEB range by taking advantage of regenerative braking. Other agencies operating in more urban environments acknowledged some benefits of "eco-driving" but made it a higher priority to train operators in defensive driving/driving safely.

Table 10.1 provides an example of training modules and the estimated hours based off of a peer agency's estimated requirements.

Table 10.1 BEB Training Modules (Sample)

Module	Hours
General Vehicle Orientation	8
Multiplex System	32
Entrance and Exit Doors	8
Wheelchair Ramp	4
Brake Systems and Axles	16 (8 per axle)
Air System and ABS	8
Front and Rear Suspension, Steering, and Kneeling	8
Body and structure	4
Propulsion & ESS Fam/HV Safety	24
Charging Equipment	4
Electric HVAC, AC Maintenance (Vendor Specific)	24
Propulsion & ESS Troubleshooting	16
Operator Orientation	8
Towing and Recovery	4

Source: SFMTA, 2019

10.2.2 Training Providers

- Most transit agencies interviewed use OEM training packages as a starting point for training. Typically, the agency selects which modules it wants to be taught at a particular time and schedules an on-site visit by the OEM and/or relevant subsystem suppliers to provide the selected training modules to agency staff. The transit agency is responsible for assigning staff to each training module. Some agencies also use OEM trainers to supplement their own training programs.
- In one typical pattern, OEM and subsystem suppliers are used in a "train-the-trainer" role, wherein the agency's staff trainers attend OEM/supplier training modules along with the other agency staff being trained. The staff trainers also receive the supplier's training materials, then use the materials and knowledge to train additional agency staff. In this manner, fewer OEM/supplier training hours are expended, and staff trainers can train more staff in multiple courses over time. This pattern is particularly useful when equipment warranties expire, and operator staff must take over full responsibility for maintenance.
- Third-party providers, including professional training companies, may also be contracted to provide on-site training in areas such as general electrical system safety. Additionally, with the growing interest in ZEV across all vehicle types, agencies may be able to partner with local technical colleges for workforce recruitment and training.
- Given the regional approach, there may be opportunities to create shared workforce development training centers and resources based on interest.

10.2.3 Training Procurement

Transit agencies typically procure training by including it as a budget item within capital purchase contracts, such as for new buses, software systems, or charging equipment. This training budget is used to pay OEM and system suppliers to provide in-person training for selected training modules.

11 CONCLUSION

11.1 Existing Conditions

Table 11.1 summarizes the initial findings for each Solano County transit agency as they pertain to: 1) service requirements; 2) facility operations and layout; and 3) energy usage and availability. Appendix A: *Existing Conditions Analysis* provides in-depth discussions on the agencies' existing services and facilities.

Table 11.1 Summary of Existing Conditions

Agency	Service	Facility	Utilities
Dixon Readi-Ride	• Operates 10 cutaways and vans for demand response service (only) • Daily range of 83-103 miles	• Shares facility with City of Dixon Public Works Dept.	• Existing circuit (Dixon 1103) is estimated to have 1.3 MW of available capacity • Dixon 1102 (circuit) may also be utilized.
Rio Vista Delta Breeze	• Operates 5 cutaways and vans • Fixed route daily average range of 83 miles • Demand response range daily range of 90-113 miles	• Shares facility with City of Rio Vista Northwest Wastewater Treatment Plant	• Existing circuit (Grand Island 2226) is estimated to have 8 MW of available capacity
SolTrans	• Operates 59 standard buses, cutaways, and coaches • All but 1 fixed-route service block are under 150 miles (average of 74 miles) • Demand response range daily range of 75-93 miles	• SolTrans has developed a Master Plan for a full-BEB retrofit of its existing facility and is currently in the process of implementing Phase 1 of that plan.	
Vacaville City Coach	• Operates 25 standard buses and cutaways • Fixed route daily range is 129 and 173 miles • Demand response range daily range between 104 and 130 miles	• Shares facility with City of Vacaville Public Works Department • Special coordination is required to ensure that CNG fueling is not negatively impacted during transition phases	• Existing circuit (1105) is estimated to have 1.7 MW of available capacity

Source: WSP

11.1.1 FAST Report

Based on the FAST Report, it is expected that electrifying FAST's fleet will be more expensive than continuing to operate its diesel fleet, primarily due to the initial capital costs – however, operating costs are expected to decrease overall.

Aside from costs, several other changes were proposed to successfully operate an electric transit fleet such as retrofitting the maintenance facility, splitting up the Blue Line into two routes (this service is now operated by SolTrans), and incorporating maintenance and repair work within gaps in bus charging schedules. Fairfield may need to train or hire specialized mechanics that service electric buses, and drivers will need to be trained on how to drive the buses most efficiently and how to properly use the chargers.

11.2 Service Modeling Results

The Service Modeling Analysis is based on existing vehicle specifications, and with technology rapidly evolving, the results are subject to change.

The analysis calculated the average baseline battery efficiencies for each agency's vehicle types and then modeled those vehicles on the blocks while accounting for additional consumption factors. The results were provided as "typical" and "conservative" scenarios; however, the typical scenario may be considered rather conservative and should be supplemented and confirmed with actual pilot projects. While operating battery capacity was factored into these analyses, the battery conditions should be considered "new." To simulate vehicle ranges under a degraded battery, block completion rates with 64% of operating battery capacity (EWL conditions) were also presented.

The demand response analysis was much simpler, based on average daily mileage ranges. More precise data is required for a more nuanced model.

Table 11.1 summarizes the initial findings for each agency. For all of the failing blocks in the fixed-route services, the following mitigation measures can be considered:

- Service changes (splitting blocks; additional pull-outs)
- Additional vehicles
- Wait for advancements in BEB technology
- Selecting a bus that has higher capacity than the average in the model
- Opportunity charging

The *Service Modeling Technical Analysis* (Appendix B) provides a more in-depth review of the data inputs and methodology used to conduct the analysis.

Table 11.2 Summary of Modeling Results

Agency	Fixed Route		Demand Response*
	Typical Scenario	Conservative Scenario	
Dixon Readi-Ride	• No fixed-route service	• No fixed-route service	• Assumed BEB replacement is expected to meet the existing range of 83 to 103 miles
Rio Vista Delta Breeze	• 1 of 4 blocks failed • EWL: 1 block failed	• 1 of 4 blocks failed • EWL: 1 block failed	• Assumed BEB replacement is expected to meet the existing range of 93 to 113 miles

Agency	Fixed Route		Demand Response*
	Typical Scenario	Conservative Scenario	
SolTrans	• 4 out of 42 blocks failed • EWL: 15 blocks failed	• 15 failing blocks • EWL: 24 blocks failed	• Assumed BEB replacement is expected to meet the existing range of 75 to 93 miles
Vacaville City Coach	• 1 out of 2 blocks failed • EWL: All blocks failed	• •All blocks failed • EWL: All blocks failed	• Assumed BEB replacement is expected to meet the existing range of 104 to 130 miles

Source: WSP

*Note: Assuming battery-electric cutaway replacement with 150 miles range

11.3 Facility, Power, and Energy Improvements

Electric bus charging systems require a significant amount of electrical power. Most facilities require moderate to significant upgrades to their existing electrical infrastructure, and PG&E must also upgrade equipment to supply the necessary power to the site. The final load demand and equipment upgrades depend on the fleet size, detailed site design, number of chargers, and the electrical contractor's analysis.

The facility analysis finds that each facility can accommodate the charging infrastructure needed to support a fully electric bus fleet. The facility upgrade recommendations will be refined and further evaluated in subsequent stages of design implementation.

Moreover, to ensure service delivery and energy resiliency during emergency outages, all sites can benefit by installing a permanent battery storage generator. Solar PV might be considered for Rio Vista Delta Breeze and Vacaville City Coach.

Appendix C: *Power and Energy Analysis* provides in-depth energy and resiliency analysis for each site, while Appendix D: *BEB Facility Concepts Analysis* provides the detailed facility concept for each site.

Table 11.3 summarizes the facility upgrades needed for Solano County's transit agencies to accommodate the maximum number of vehicles expected in the future fleet.

Table 11.3 Summary of Site Upgrades Required (Assuming Future Fleet Capacity)

	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
New Electrical Service	Yes	Yes	Yes	Yes
Utility System Upgrades	No	No	Yes	Maybe
Charging Equipment*	• Five 150 kW DC charging cabinets • Seven cable retractors	• Four 150 kW DC charging cabinets	• Twenty-one 80 kW AC charging system • Twenty-five 150 kW DC charging cabinets • Seventy cable retractors	• Sixteen 150 kW DC charging cabinets • Thirty-one cable retractors
Charging Strategy	• Three ground-mounted plug-ins • Seven overhead-mounted plug-ins • One plug-in dispenser in maintenance area	• Eight ground-mounted plug-ins • One plug-in dispenser in maintenance area	• Forty-nine overhead-mounted plug-ins w/ option for future overhead pantograph • Twenty-one plug-in AC dispensers**	• Thirty-one overhead-mounted plug-ins • Two plug-In dispensers in maintenance area
New Electrical Equipment Required	• Utility transformer • Main switchboard and meter • Underground conduit to chargers	• Utility transformer • Main switchboard and meter • Underground conduit to chargers	• Utility transformer • Main switchboard • Underground conduit to chargers	• Utility transformer • Main switchboard and meter • Electrical subpanels Large underground duct bank and conduit to chargers • Likely upgrades to utility-owned distribution equipment.

Source: WSP

*Note: Assuming 1:2 charger to dispensers ratio

**Note: Phase 1 will utilize 21 AC chargers and subsequent phases are programmed to accept either DC or AC systems depending on SolTrans' vehicle procurement decisions

11.4 Phasing Schedule

11.4.1 Construction Schedules

Each agency's construction schedule varies based on the size of the facility, its upgrade requirements, and the particular goals of the agency. All agencies are anticipated to have all required infrastructure installed and constructed in advance of the CARB ICT regulation's first purchase requirements in 2026 (25% of new purchases are required to be ZEB).

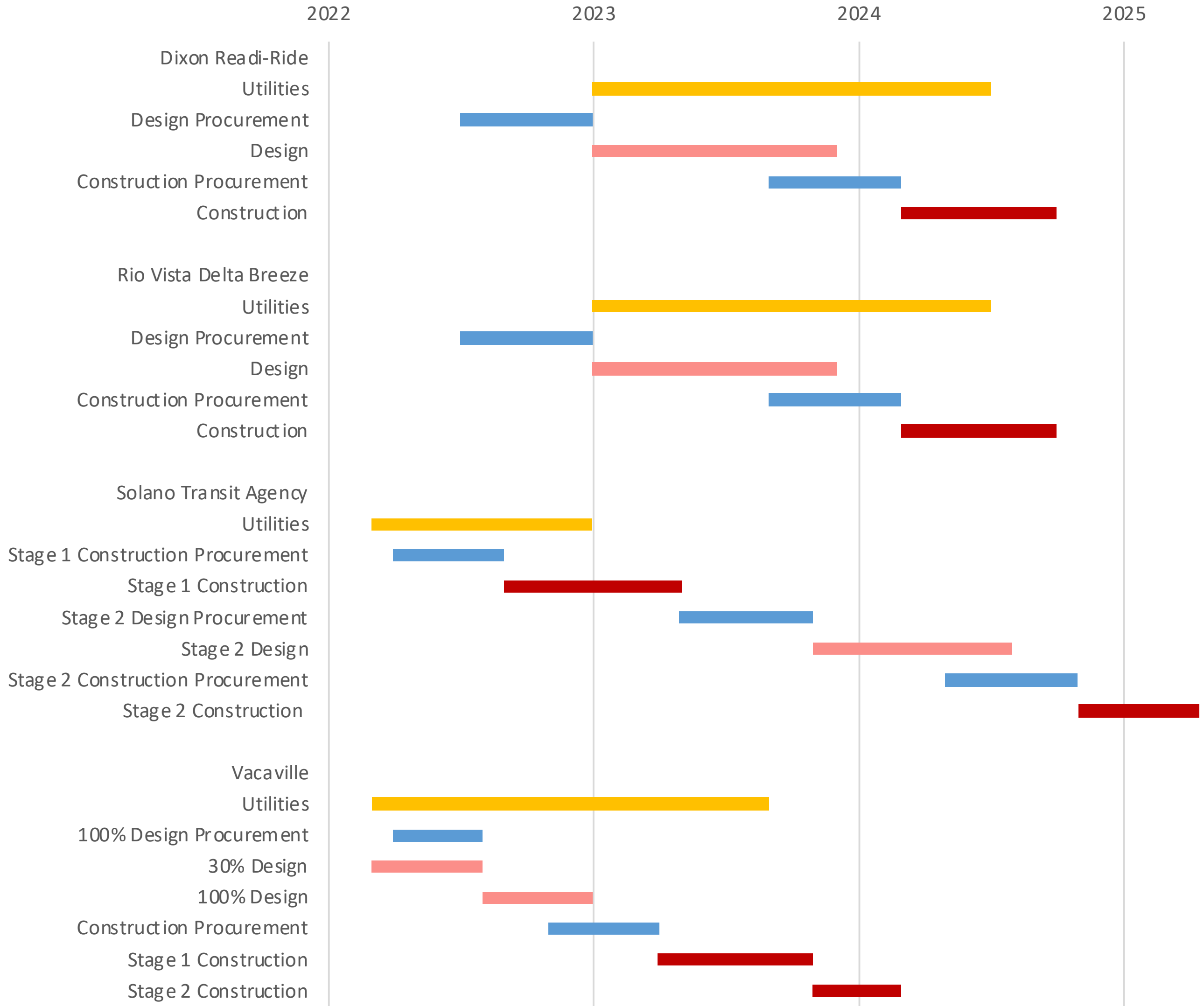
Table 11.4 provides an overview of each agency's construction schedule along with the number of proposed construction stages. Figure 11.1 presents the schedules for each agency's facility, broken up into the major steps of the transition. Detailed construction schedules are provided in Appendix E: *Phasing Strategy and Transition Analysis*.

Table 11.4 Construction Summary – All Agencies

Agency	No. of Stages	Timeline
Dixon Readi-Ride	1	July 2022 – Sept 2024
Rio Vista Delta Breeze	1	July 2022 – Sept 2024
Solano County Transit	2	March 2022 – May 2025
Vacaville City Coach	2	March 2022 – Feb 2024

Source: WSP

Figure 11.1 Construction Schedule – All Agencies



Source: WSP

11.4.2 Vehicle Procurement Schedules

The developed procurement schedules are based on future fleet projections. The assumed delivery dates of vehicles were developed with special consideration to vehicles' useful life, construction completion dates, and reducing impacts to maintenance staff. Table 11.5 shows the procurement schedule for each agency by year, by vehicle type. Detailed construction schedules are provided in Appendix E: *Phasing Strategy and Transition Analysis*. The table also includes FAST's proposed vehicle procurement schedule. Please refer to Appendix G: FAST Report for more detail.

Table 11.5 Vehicle Procurement Schedule – All Agencies

Year	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans		Vacaville City Coach		FAST		Total
	Cutaway	Cutaway	Cutaway	Bus	Cutaway	Bus	Cutaway	Bus	
2022	-	-	-	-	-	-	-	-	-
2023	-	-	-	7	10	-	1	9	**27**
2024	4	2	-	7	-	5	3	5	**26**
2025	4	2	3	7	-	5	3	5	**27**
2026	-	-	3	1	-	5	-	-	**9**
2027	-	-	4	-	-	-	-	8	**12**
2028	-	-	4	-	-	-	-	-	**4**
2029	-	-	-	-	-	-	-	4	**4**
2030	-	-	-	-	-	-	-	-	**-**
2031	-	-	-	-	-	-	-	3	**3**
2032	-	-	-	-	-	-	-	-	**-**
2033	-	-	-	-	-	-	-	15	**15**
Total	**8**	**4**	**14**	**22**	**10**	**15**	**12**	**48**	**133**

Source: WSP

11.4.3 Transition Considerations

In determining the path forward towards its transition goals, agencies must consider, address, and mitigate a variety of factors and risks, such as:

- **Service Completion:** Solano County agencies will have to align their procured vehicles with any needed service changes to accommodate the failing blocks identified in the Service Modeling Analysis. The gradual transitions as outlined in this plan will help ease the process by giving the agencies time to analyze performance data and fall back on ICE vehicles while they are still in the fleet.
- **Fleet Replacement Ratio:** The number of BEBs needed to complete service should be regularly re-assessed based on actual performance gathered during the incremental rollout of BEBs outlined in the phasing analysis.
- **Capital Improvement Plans:** The schedules in this plan do not account for delays that might occur from capital improvement plans that are not directly related to fleet electrification (if any).
- **Service Growth:** The expanded fleets for Dixon Readi-Ride and Rio Vista Delta Breeze are not included in the procurement analyses due to the lack of information regarding future timelines.
- **RFPs and Utility Applications:** In most cases, the RFPs for design/construction packages should commence soon (as of this plan). Additionally, utility applications must be submitted to PG&E up to 16 months in advance of each facility.

- **Charge Management:** Charge management is a necessary component for operating a BEB fleet. A charge management software system can track each bus's SOC while they are at the facility and in service and intelligently charge and dispatch buses based on the estimated energy needs of the upcoming service blocks. Therefore, it can reduce the number of BEBs and chargers needed.
- **Workforce Training and Impacts:** Training for the operation, maintenance, and handling of BEBs will be conducted after bus procurement and in advance of delivery. It is expected that all relevant personnel will be sufficiently trained before buses arrive. If other OEM-provided buses are procured in the future and/or if new components, software, or protocols are implemented, it is expected that staff will be trained well in advance of the commissioning of these additions.

11.5 Cost and Funding

11.5.1 Lifecycle Cost

Overall, the cost-benefit analysis shows that the full lifecycle cash cost of a transition to battery-electric buses is higher than the continued reliance on ICE vehicles for all transit agencies (Table 11.6). While the initial capital and operating costs are higher for BEBs, there are opportunities for some savings in fuel costs. Additionally, operating cost benefits depend on continually evolving factors as BEBs deploy in-transit services.

The analysis also shows that keeping the current fleet would result in a large emission generation over the ICEB operations' lifecycle compared to a full BEB fleet. The large vehicle emission difference between the two replacement scenarios was expected, as the technology in the BEBs is aimed to reduce GHG emissions, particularly for carbon emissions.

Detailed lifecycle cost analysis is provided in Appendix F: *Cost and Funding Analysis*.

The table below does not include the costs for FAST's transition. Since FAST's cost analysis was conducted under a different project, the specific output is not identical to those developed in the Transition Plan. The FAST Report analyzed the costs for maintaining an ICE fleet as well as transitioning to a BEB fleet through 2040. Meanwhile, the rest of STA's agencies were analyzed through 2030. The net expenditures for all STA agencies (including FAST) are $254M for an ICE fleet and $330M for a BEB fleet, yielding an additional $76M in costs to transition all agencies. Please refer to Appendix G for more detail regarding FAST's costs and methodology.

Table 11.6 Summary of Lifecycle Costs Analysis (in million of YOE$)

Cost Categories	Dixon Readi-Ride		Rio Vista Delta Breeze		SolTrans		Vacaville City Coach		STA Countywide Costs	
	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet
Cash Costs										
Total Capital Costs	$1	$4	$0.60	$2	$37	$49	$18	$26	$57	$82
Total Operating Costs	$4	$4	$2	$2	$21	$31	$15	$19	$42	$56

Cost Categories	Dixon Readi-Ride		Rio Vista Delta Breeze		SolTrans		Vacaville City Coach		STA Countywide Costs	
	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet	Current Fleet	BEB Fleet
Total Disposal Costs	-$0.10	-$0.10	-$0.00	-$0.00	-$0.20	-$0.20	-$0.20	-$0.20	-$0.5	-$0.5
Total Cash Cost	$5	$8	$3	$4	$58	$80	$33	$45	$99	$137
Non-Cash Costs										
Total Environmental Costs	$0.60	$0.30	$0.30	$0.10	$4	$2	$3	$1	$8	$3
Total Cash and Non-Cash Costs	$6	$8	$3	$5	$62	$82	$36	$46	$107	$141
Total Cash and Non-Cash Costs per Mile*	**$2**	**$4**	**$3**	**$4**	**$6**	**$8**	**$4**	**$5**	**N/A**	**N/A**

Source: WSP & Willan

Notes: *Does not include FAST's cost analysis. FAST's lifecycle costs are $147M for an ICE fleet and $190M for a BEB fleet. FAST's lifecycle costs are through 2040 and do not include environmental and capital, O&M, or Disposal costs. The net expenditures for all STA agencies are $254M for existing ICE fleets and $330M for a BEB fleet, yielding an additional $76M in costs to transition all agencies
Rounded to the nearest hundred thousand when costs were less than one million dollars. Otherwise, it was rounded to the nearest million.

11.5.2 Funding Gap

A funding gap analysis was conducted by comparing the annual capital costs analyzed in the lifecycle costs analysis with the identified potential funding in SRTP and other existing capital revenues. This analysis only considers the capital costs needed based on the BEB phasing schedule developed in this plan (refer to section 11.4) and the potential funding sources for capital projects.

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in each agency's FY 2021-2030 SRTP adopted in 2020. However, STA and member agencies will also need to pursue additional funding through federal, state, regional, and other grant opportunities to fill the estimated funding gap to carry out the full scope of the *Solano Countywide Electrification Transition Plan*.

Table 11.7 summarizes the estimated capital costs and the funding surplus/gap per year by agency. Detailed funding gap analysis is provided in Appendix F: *Cost and Funding Analysis*.

It should be noted that the table below does not include FAST's funding surplus/gap since FAST's cost analysis was conducted under a different project and used a different methodology from this plan. As noted in the FAST Report, the cost to electrify FAST's fleet including incentives is $163.68M. The net funding gap for all STA agencies (including FAST) is -$201.79M. Please refer to Appendix G for more information regarding FAST's cost/funding analysis.

Table 11.7 Estimated Capital Costs and Funding Gap by Agency by Year (in million of YOE$)

Agency		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Dixon Readi-Ride	Estimated Capital Cost	$0.00	$0.00	$2.38	$1.87	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$4.25**
	Funding Surplus / Gap	$0.29	$0.29	-$1.93	-$1.64	$0.23	$0.31	$0.20	$0.28	$0.11	$0.24	**-$1.62**
Rio Vista	Estimated Capital Cost	$0.00	$0.00	$1.41	$1.05	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$2.46**
	Funding Surplus / Gap	$0.00	$0.98	-$1.41	-$1.05	$0.00	$0.45	$0.00	$0.12	$0.00	$0.00	**-$0.91**
SolTrans	Estimated Capital Cost	$0.00	$18.66	$17.26	$10.05	$2.33	$0.68	$0.00	$0.00	$0.00	$0.00	**$48.98**
	Funding Surplus / Gap	$3.78	-$17.20	-$15.80	-$6.09	$0.58	$2.23	$0.59	$0.61	$2.13	$0.47	**-$28.70**
Vacaville City Coach	Estimated Capital Cost	$0.00	$11.91	$7.54	$4.77	$1.64	$0.00	$0.00	$0.00	$0.00	$0.00	**$25.87**
	Funding Surplus / Gap	$0.15	-$11.76	-$7.12	-$4.44	-$1.49	$10.00	$4.40	$0.15	$1.00	$3.15	**-$5.96**
STA Countywide	Estimated Capital Cost	$0.00	$30.57	$28.59	$17.74	$3.97	$0.68	$0.00	$0.00	$0.00	$0.00	**$81.56**
	Funding Surplus / Gap	$4.22	-$27.69	-$26.27	-$13.21	-$0.68	$12.99	$5.19	$1.16	$3.24	$3.86	**-$37.19**

Source: WSP & Willdan

Note: All values are presented in and rounded to the nearest million

Notes: *Does not include FAST's cost analysis. The cost to electrify FAST's fleet, including incentives, is $163.68M. FAST's analysis is through 2040 and does not use the same methodology as STA's other agencies. The net funding gap for all STA agencies is -$201.79M. Rounded to the nearest ten thousand

11.5.3 Funding Recommendations

For federal funding programs, the BIL has significantly increased funding for formula programs like FTA Section 5307, 5311, and 5339. These sources of formula funding are fairly flexible and can be leveraged at an 80% federal / 20% local match to fund capital projects, including procurement of ZEBs, and construction of charging/fueling infrastructure and/or associated maintenance facilities. STA and transit agencies in Solano County could consider allocating a portion of these additional formula funds above those amounts needed for operations to fund capital projects like ZEB purchases and charging infrastructure. In addition to these formula funding programs, the FTA Section 5339(c) Low or No Emissions competitive grant program also received a big boost through the BIL – increasing in size from $182 M/year in FY 2021 to $1.1 B/year in awards starting in FY 2022 through FY 2026.

For state and regional funding programs, transit agencies in Solano County show a projected surplus of Caltrans TDA LTF funding in their SRTPs that could be used for electrification investments. Similarly, STA controls the allocation of TDA STAF funding, a portion of BAAQMD TFCA funds and controls the prioritization of local projects that may receive MTC OBAG funding, all of which could be leveraged. In addition, STA and member agencies should pursue the following opportunities as fleet electrification projects are well aligned with program objectives (and have previous success in obtaining funds to support ZEB infrastructure investments in some cases):

- CalSTA's TIRCP
- Caltrans' LCTOP
- Caltrans/State Controller's Office SB1 SGR Program
- Bay Area Air Quality Management District Carl Moyer and Community Emission Reduction Grant Programs

Other newer state transportation opportunities that STA and member agencies should monitor for funding and forthcoming procedural/eligibility requirements include the CALSTART CMO program as well as the CEC Clean Transportation Program.

Finally, with respect to other funding opportunities, STA and member agencies can apply for the PG&E EV fleet program, which can be used to support the purchase of ZEBs and charging infrastructure for PG&E customers.

Detailed funding analysis is provided in Appendix F: *Cost and Funding Analysis*.

11.6 Staffing And Training

One of the essential factors for a smooth transition to a full BEB fleet includes ensuring that the whole workforce, especially operators and technicians, is comfortable handling the new technology that can be achieved by workforce evaluation and training. Moreover, workforce evaluation is currently one of the key elements in the Zero Emission Fleet Transition Plan required for federal grants funding. A workforce evaluation tool released by FTA can be used to help identify the impact of transition to a zero-emission fleet on the current workforce[31].

31 Refer to FTA Workforce Evaluation Tool

Based on peer transit agencies' experiences, BEB transition will not greatly disrupt current staffing and training requirements or yard management. In large, BEB maintenance follows a "bus is a bus" philosophy, indicating that many bus repairs will be standard regardless of the powertrain. However, to ensure fleet maintainers are supported throughout the life of the BEBs, it is recommended that a substantial share of the OEM training budget be reserved for the tail end of subsystem warranties to ensure maintenance staff is prepared to service components as needed.

Staff training required to support a BEB fleet will require the development of new training materials, which should be supported by BEB OEMs. Additionally, while the OEM provides training modules for both maintenance technicians and operators, some training may need to be developed for other staff. Everyone should have a high-level understanding of high voltage safety, even if that message for other job classifications is simply to be able to recognize it and stay away from it.

Just as the broader ZEB industry is in a state of constant change, so is BEB training. Educators are in the process of developing additional training curricula and resources for transit agencies. Bus manufacturers are working to improve and update their training modules, manuals, and training materials to keep up with the fast pace of product development. The lessons learned discussed in this section should be treated as "snapshots in time" of the state of the industry. It is recommended for Solano County's transit agencies to review training guidance and resources as they are developed continually.

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX A: EXISTING CONDITIONS ANALYSIS

Solano Transportation Authority

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 1: EXISTING CONDITIONS ANALYSIS

Final — July 2021

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Solano Transportation Authority

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Acronyms and Terms

Term	Description
BART	Bay Area Rapid Transit
BEB	Battery-Electric Bus
Blocks	The work assignment for a single vehicle during a service workday
CARB	California Air Resources Board
CNG	Compressed Natural Gas
Efficiency	A measure of a vehicle's performance, expressed in kilowatt-hours per mile throughout this report
FAST	Fairfield and Suisun Transit
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GTFS	General Transit Feed Specification
ICEB	Internal Combustion Engine Bus
ICT	Innovative Clean Transit
kW	Kilowatt
MW	Megawatt
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas & Electric
SolTrans	Solano County Transit
STA	Solano Transportation Authority
ZE	Zero-Emission
ZEB	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040[1]. The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Plan* includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- **Task 1: Existing Conditions Analysis (this report)**
- Task 2: Service Modeling Analysis
- Task 3: BEB Facility Concepts
- Task 4: Power and Energy Analysis
- Task 5: Costs and Funding Analysis
- Task 6: Phasing Strategy and Transition Analysis
- Task 7: Countywide Electrification Transition Plan

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of this project's elements are incorporated in this project. FAST is currently developing the *Fairfield Transition Electrification Transition Model Project,* an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the *Countywide Electrification Transition Plan;* however, FAST's final report (expected in Summer 2021) will be incorporated into the final *Countywide Electrification Transition Plan,* which is anticipated to be completed by Q1 2022.

1 CARB ICT Regulation (https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-regulation)

1.2 Report Purpose and Approach

The purpose of the Existing Conditions Analysis is to identify and establish the baseline conditions that will serve as the basis of analysis for subsequent technical reports within the *Countywide Electrification Transition Plan.* To establish the baseline, it is essential to understand the existing conditions for each agency as they pertain to: 1) service requirements (range of vehicles); 2) facility operations and layout; and 3) energy usage and availability. WSP coordinated with both STA and the county's transit agencies to collect and validate data to document and analyze these elements.

Agencies should have no problem with meeting service requirements with the transition if the range of existing service is less than or equal to the performance capabilities of existing BEBs (generally 150 miles). To determine fixed-route service requirements, Solano County's agencies' general transit feed specification (GTFS) scheduling data – in conjunction with non-revenue trip information – was analyzed to estimate the range requirements of each service block[2]. For demand response services, the average vehicle miles traveled per day was not available at the time of the report, so an estimate was based on the vehicle hours and miles identified in agencies' respective SRTPs to establish the travel speed based on an 8- or 10-hour shift. These data will be further evaluated in the service modeling phase of the *Countywide Electrification Transition Plan*.

For facility operations and layouts, WSP conducted site visits between April 12-16, 2021 to gather information on site conditions, circulation, vehicle inventories, electrical equipment, and other site-related items. As-builts and other documentation was also provided by some agencies for context. This information was used to develop drawings that will be used to assess the most viable method(s) to accommodate BEB infrastructure on-site during the facility concept phase of the *Countywide Electrification Transition Plan.*

BEBs typically require more energy and power than what is provided at existing bus facilities. For that reason, it is important to understand if there is a shortfall in electricity and the solutions to address it. WSP used utility bills, site visits, and Pacific Gas & Electric (PG&E) databases, such as the Integration Capacity Analysis (ICA) and Solar Photovoltaic and Renewable Auction Mechanism (PVRAM) maps[3] to identify circuits that feed each site. These data provide a preliminary understanding of the delta between existing and required, which will be further explored in subsequent phases of the project.

1.3 Report Structure

This report is organized into six main sections:

1. **Introduction –** Overview of *Countywide Electrification Transition Plan* and Existing Conditions Analysis.
2. **Background –** Overview of STA, the Solano County service area, and Solano County's transit agencies.
3. **Market Conditions –** Overview of existing manufacturers, products, and emerging technology.

2 Service blocks are the group of daily assignments (or trips) for an individual bus. Blocks include both non-revenue (deadheads) and revenue trips and may serve one or multiple routes. A bus may also operate multiple blocks in a day. In order to properly assess battery-electric bus (BEB) performance, it is necessary to understand the block assignments of each of its buses, in particular the range (miles) that is required of each block.

3 The ICA and PVRAM maps are designed to help contractors and developers find information on potential project sites for distributed energy resources. The information on these maps is illustrative and is likely to change or be modified over time.

4. **Agency-Specific Sections –** Presents each agency's existing conditions with consideration to service, operations, facilities, and utilities:
    a. Dixon Readi-Ride
    b. Rio Vista Delta Breeze
    c. SolTrans
    d. Vacaville City Coach
5. **Conclusion and Next Steps –** Summarizes the findings of the report and outlines next steps

2 BACKGROUND

The following section provides background on STA, the Solano County service area, and Solano County's transit agencies.

2.1 Solano Transportation Authority

STA serves as the congestion management agency for Solano County. STA is responsible for countywide transportation planning, programming transportation funds, managing and providing transportation programs and services, delivering transportation projects, and setting transportation priorities. There are five transit agencies operating in Solano County, each with varying types of service and coverage (Table 2.1).

Table 2.1 Transit Agencies in Solano County

Agency	Transit Services
Dixon Readi-Ride	Demand Response Dial-a-Ride
FAST	Fixed-Route Local Service ADA Paratransit (through DART) Adult Recreation Center Taxi Program SolanoExpress Commuter Service
Rio Vista Delta Breeze	Demand Response Dial-a-Ride Fixed-Route Local Service
SolTrans	Demand Response Paratransit Fixed-Route Local Service SolanoExpress Commuter Service
Vacaville City Coach	Demand Response Paratransit Fixed-Route Local Service

Source: Dixon Readi-Ride (2021), FAST (2021), Rio Vista Delta Breeze (2021), SolTrans (2021), Vacaville City Coach (2021)

Note: "Demand Response Dial-a-Ride" includes paratransit service, while "Demand Response Paratransit" refers to service that is exclusively for ADA complementary service for disabled and senior riders.

2.2 Solano County Service Area

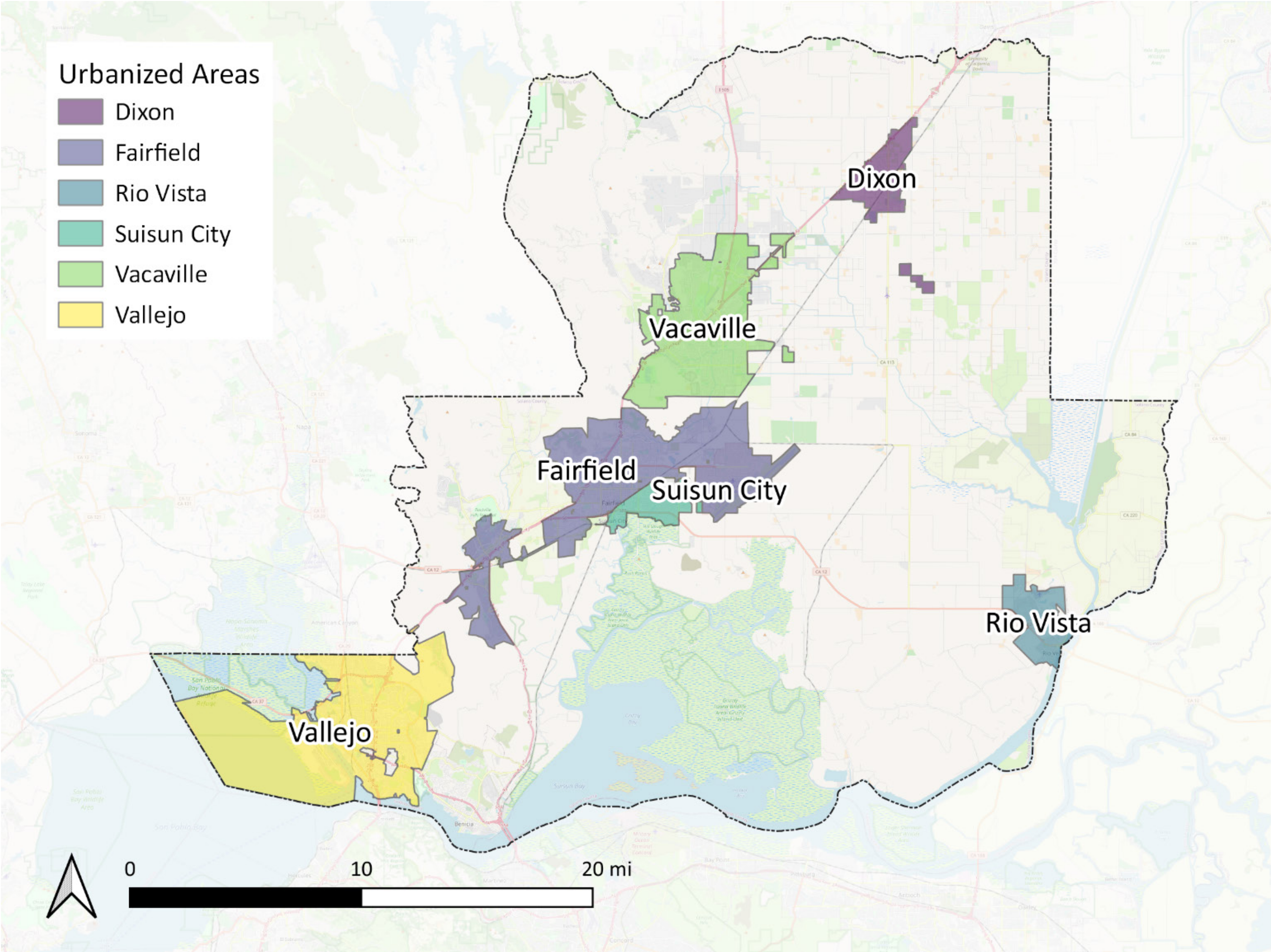
2.2.1 URBANIZED AREAS AND TRANSIT USE

Solano County is approximately 822 square miles and contains the urbanized areas of Vallejo, Fairfield-Suisun City, Vacaville, Dixon, and Rio Vista (Figure 2.1).

Approximately 448,000 people reside in the county, and roughly 3% of its workforce above the age of 16 use public transportation to commute to work, which is lower than both the state and national averages of 5%.[4] Table 2.2 summarizes the population, size, and percentage of transit commuters for each of Solano County's urbanized areas.

4 Solano County Census Reporter, ACS 2019

Figure 2.1 Solano County Urbanized Areas



Sources: State of California; OpenStreetMap Contributors

Table 2.2 Solano County Urbanized Areas

Urbanized Areas	Population	Size (Square Miles)	Percentage Commuting by Transit
Vallejo	151,557	69	6%
Fairfield-Suisun City	149,892	210	3%
Vacaville	106,828	139	1%
Dixon	22,876	181	<1%
Rio Vista	10,676	223	4%

Sources: American Community Survey 2019, 5-year estimates

2.2.2 WEATHER AND TOPOGRAPHY

Solano County has a Mediterranean climate of warm, dry summers and mild, rainy winters. The average temperature can be as low as 39 degrees in the winter and as high as 89 degrees in the summer.[5] Due to its topography and landscape, Solano County experiences microclimates.[6]

Solano County has a minimum elevation of 72 feet[7] and a maximum of 2,818 feet.[8] This wide range in elevation affects the relative humidity and air circulation within the county. The average rainfall ranges between 13 inches near the coast and 22 inches inland.[9] The varied landscapes of waterfront cities to more rural and agricultural areas also relate to the creation of microclimates.

The operating conditions of a BEB, including temperature and elevation can drastically impact battery performance. It will be essential to consider Solano County's unique operating conditions in subsequent modeling analysis.

2.2.3 UTILITY SERVICE

PG&E, one of the largest combined natural gas and electric energy companies in the United States, services Solano County. As agencies in Solano County proceed with BEB transitions, they will need to coordinate with PG&E to assess infrastructure needs, explore EV incentives and programs, and install and connect power.

2.3 Solano County Agencies

2.3.1 SERVICE

Agencies provide service throughout Solano County, with SolTrans and FAST also extending service into neighboring Alameda, Contra Costa, Yolo, and Sacramento Counties (Figure 2.2). All agencies provide fixed-route (with the exception of Dixon Readi-Ride) and demand response and/or paratransit services. Of the agencies that operate fixed-route service, SolTrans has the most routes (14) and Rio Vista Delta Breeze and Vacaville City Coach offer the fewest (two).

To better analyze BEB feasibility with existing service, it is important to know the movements of each vehicle throughout the day – more commonly referred to as "service blocks." Service blocks are defined as the group of daily assignments (or trips) for an individual bus. Blocks include both non-revenue (deadheads) and revenue trips and may include one or multiple routes. A bus may also operate multiple blocks in a day. For example, buses that operate peak-only service may be assigned to both AM- and PM-serving blocks. In order to properly assess BEB performance on Solano County's existing routes, it is necessary to understand the block assignments of each of its buses, in particular the range (miles) that is required of each block. The range serves as the foundation for determining whether a battery will meet service requirements. While BEB performance will vary based on a myriad of factors, it is assumed that a 40-foot BEB should have a range between 125-150 miles with existing technology.

5 NOAA
6 Daily Republic
7 Any Place America
8 Peak Visor
9 BAAQMD

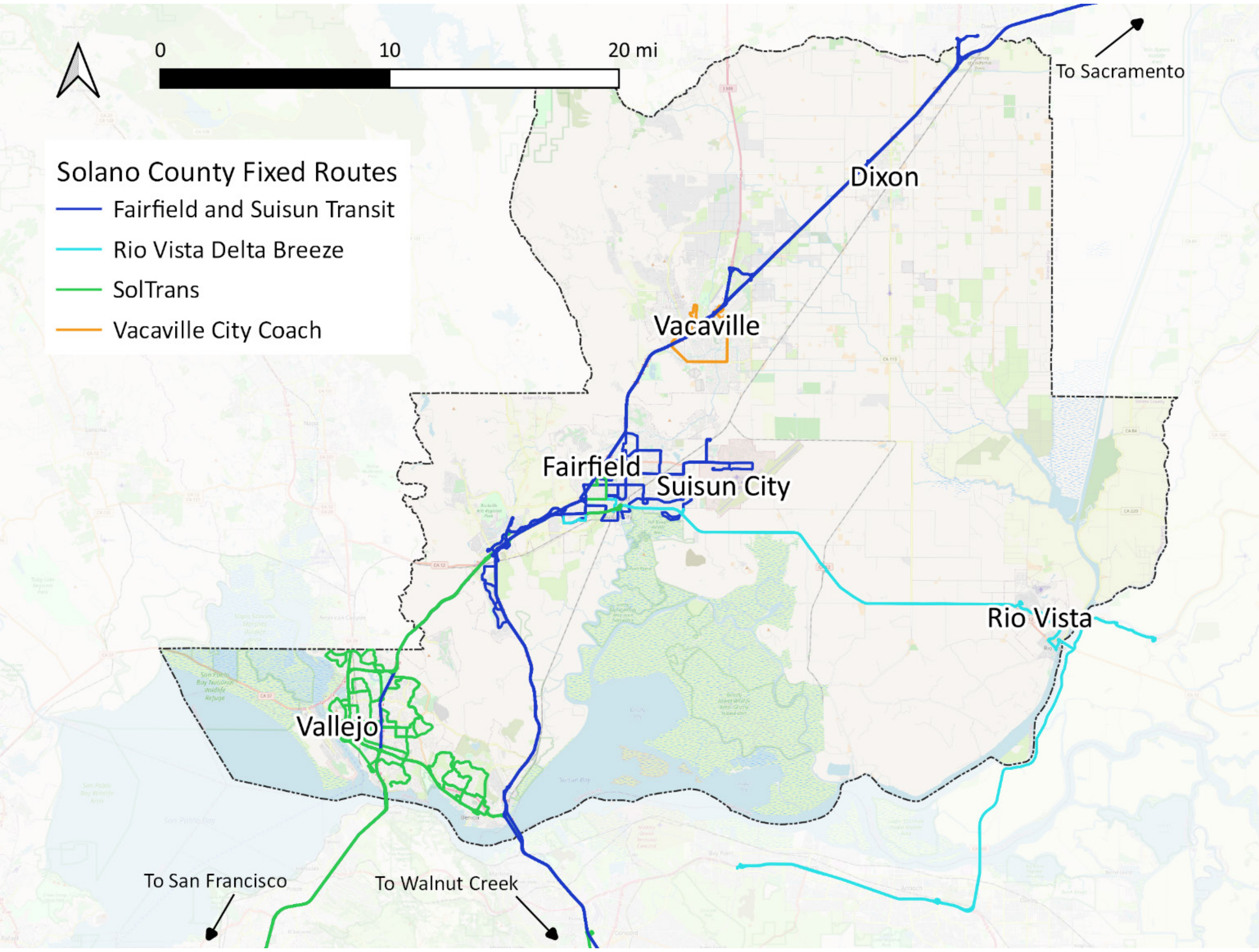
Table 2.3 summarizes agencies, yard locations, and the number of blocks and routes served.

Table 2.3 Solano County Service Summary

Agency	Yard Address	No. of Blocks	No. of Routes
Dixon Readi-Ride	285 E. Chestnut Street, Dixon	N/A	N/A
Rio Vista Delta Breeze	3000 Airport Road, Rio Vista	4	2
SolTrans	1850 Broadway Street, Vallejo	42	14
Vacaville City Coach	1001 Allison Drive, Vacaville	2	2

Source: Each agency's Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030, and GTFS Data

Figure 2.2 Solano County Fixed-Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

2.3.2 VEHICLE FLEET

Agencies in Solano County operate a wide range of vehicle types to meet service requirements. These include standard buses (35- and 40-foot), cutaways of varying lengths, vans, and motorcoaches. Vehicle fleets are also comprised of and powered by several fuel types, including diesel, diesel hybrid, compressed natural gas (CNG), gasoline, and battery-electric. According to CARB's ICT regulation, all vehicles with a gross vehicle weight rating (GVWR) that exceeds 14,000 pounds are subject to replacement. Almost all Solano County transit agencies' vehicles are above this threshold.

Table 2.4 summarizes the number and type of vehicle by agency.

Table 2.4 Solano County Vehicle Summary

Agency	Vans	Cutaways	Standards	Coaches	Total
Dixon Readi-Ride	2	8	-	-	10
Rio Vista Delta Breeze	1	4	-	-	5
SolTrans	-	15	25	19	59
Vacaville City Coach	-	7	18	-	25

Source: Each agency's Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030, and GTFS Data

2.3.3 DISADVANTAGED COMMUNITIES

Disadvantaged communities (DACs) refer to areas that suffer the most from a combination of economic, health, and environmental burdens. The California Environmental Protection Agency (CalEPA) defines a "disadvantaged" community as a community (census tract) that is located in the top 25th percentile of tracts identified by the California Communities Environmental Health Screening Tool (CalEnviroScreen). CalEnviroScreen uses environmental, health, and socioeconomic data to measure each census tract (community) in California. Each tract is assigned a score to gauge a community's pollution burden and socioeconomic vulnerability. A higher score indicates a more disadvantaged community, whereas a lower score indicates fewer disadvantages.

The replacement of conventional buses with BEBs will yield many benefits in the communities they serve, including a reduction of noise and harmful pollutants. Given that DACs are disproportionately exposed to these externalities, they should be considered and prioritized during initial deployments of BEBs. Solano County's transit agencies will ensure that DACs are prioritized as buses are deployed.

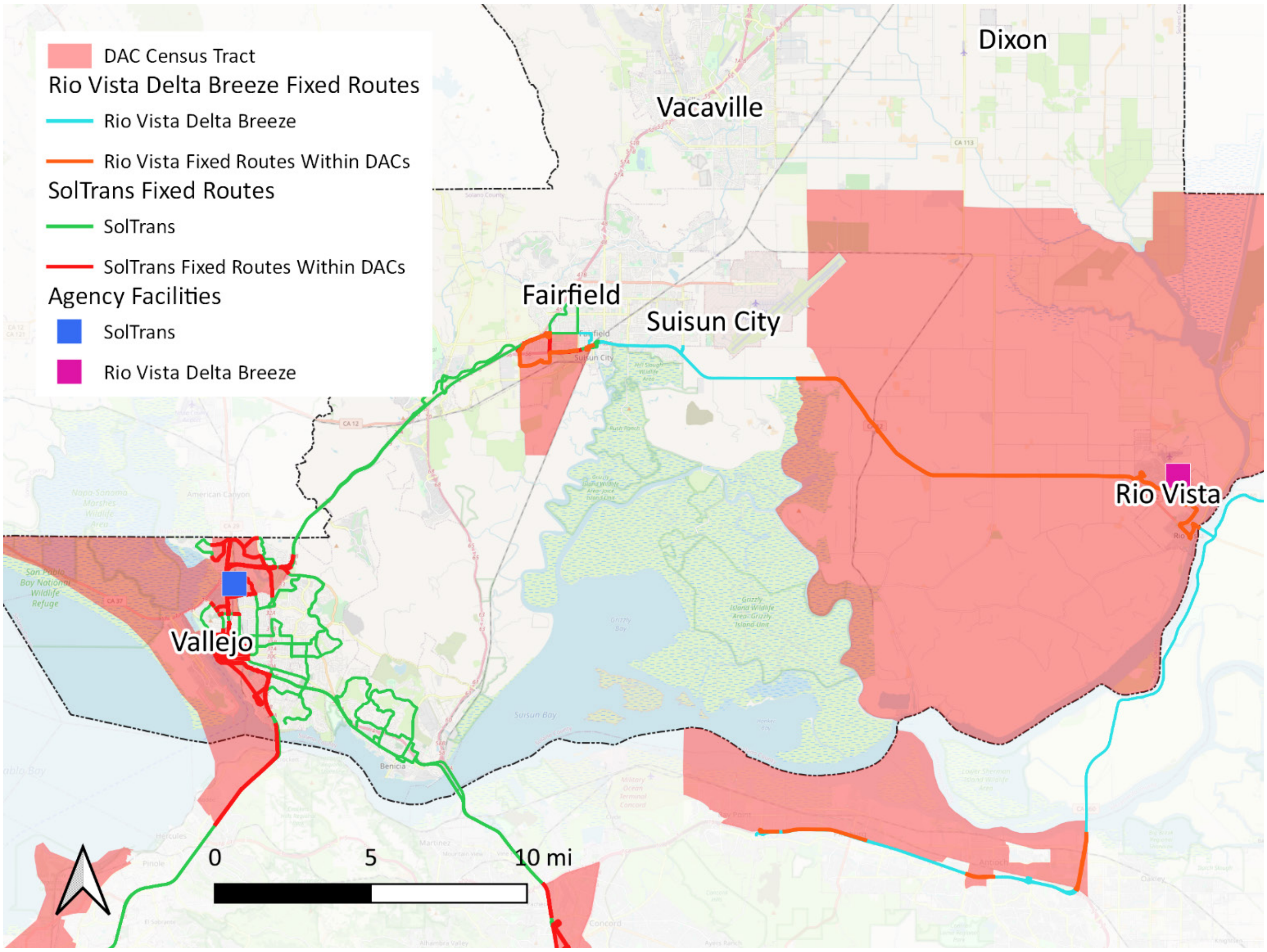
Of the four analyzed agencies, two of them - Rio Vista Delta Breeze and SolTrans - operate in and serve DACs. Both agencies' bus yards are located in DACs and 25% and 47% of Fixed-Route mileage are operated in DACs, respectively. The DAC-serving routes are summarized in Table 2.5 and illustrated in Figure 2.3.

Table 2.5 Summary of DAC-Serving Routes

Agency	DAC-Serving Routes
Dixon Readi-Ride	None
Rio Vista Delta Breeze	50 and 52
SolTrans	1, 2, 3, 4, 5, 6, 7A, 7B, 8, 12, 38, 82, Red Line, and Yellow Line
Vacaville City Coach	None

Source: CalEnviroScreen 4.0 (2021)

Figure 2.3 Disadvantaged Communities Served by Solano County Transit Agencies



Source: WSP, CalEnviroScreen 4.0 (2021), OpenStreetMap Contributors

2.4 Battery-Electric Buses

BEBs use onboard batteries to store and distribute energy to power an electric motor and other onboard systems. Similar to many other battery-powered products, BEBs must be charged for a period of time to be operational.

Currently, BEBs can be charged at the yard, overnight or midday, or on-route (typically during layovers). A yard charging strategy typically consists of buses with high-capacity (kilowatt-hour or kWh) battery packs that are charged for four to eight hours with "slow" chargers - usually less than 100 kilowatts (kW) – while being stored overnight. An on-route charging strategy typically consists of buses with low-capacity battery packs that are charged with "fast" chargers – usually in excess of 100 kW – during bus layovers (typically 5-20 minutes).

BEBs are charged via several dispenser types (conductive and inductive) and orientations (overhead or ground-mounted). Figure 2.4 presents the methods to dispense electricity to a BEB (from left to right): plug-in, overhead pantograph, and inductive.

Figure 2.4 BEB Charging Methods

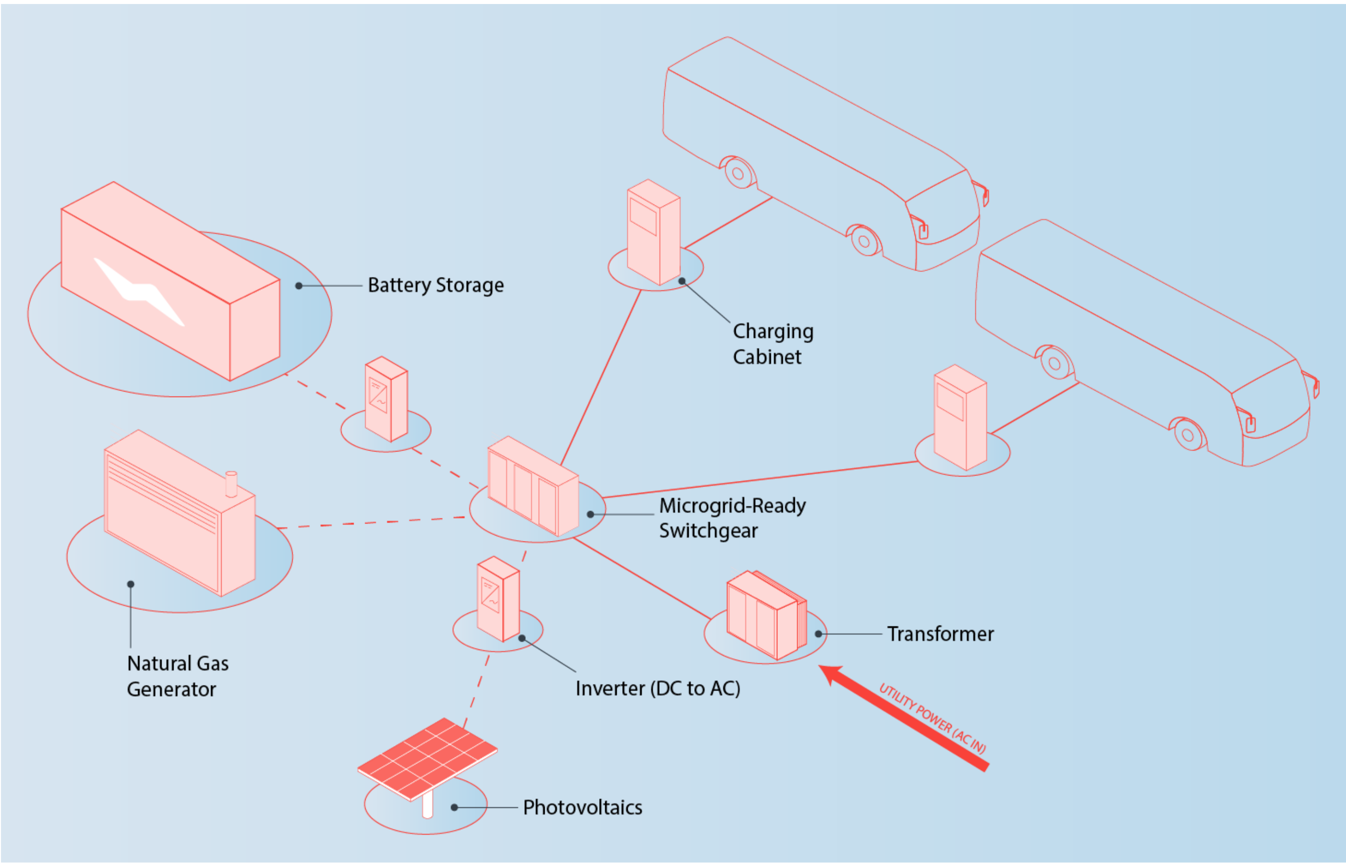
Source: YorkMix, ABB (formerly ASEA Brown Boveri), and Long Beach Transit (left to right).

Under existing conditions, BEBs cannot meet the ranges that ICEBs can. BEBs typically have a range of 125-150 miles, and this range is affected by a myriad of factors, including temperature and HVAC usage, driving behavior, and topography. For this reason, if an agency's service blocks cannot be completed with BEBs, other capital-intensive strategies must be considered to meet range requirements, including, but not limited to, additional BEBs, on-route charging infrastructure, service changes, and/or a mixed-fleet strategy with the incorporation of fuel cell electric buses.

2.4.1 GRID CONNECTIVITY

To sufficiently and safely charge a BEB (or fleet of BEBs), infrastructure and equipment must be in place, including: charging cabinet(s) – dispenses power and in most cases converts power from AC to DC; transformer(s) – steps down electricity to a safe and suitable limit; and switchgear(s) – allows for the isolation of power. Other components can also be considered, such as battery storage, photovoltaics (solar panels), and backup generators. Figure 2.5 illustrates the various components of a BEB system.

Figure 2.5 Typical BEB Charging System



Source: WSP

This additional equipment can take up considerable space, so considerations to safety and reduction of impacts to existing operations must be carefully reviewed and assessed by both the agency and PG&E. Due to the high power demand for charging a fleet of BEBs and the limited spare capacity available in existing circuits, expanded or new electrical service is usually required to transition fleets.

3 MARKET CONDITIONS

The following section provides an overview of BEBs and chargers that are currently available on the market as well as emerging technologies.

3.1 Battery-Electric Buses OEMs

Technological advances over the past 20 years have made BEBs a viable and desirable alternative to traditional diesel and natural gas fueled buses. There are a variety of bus original equipment manufacturers (OEMs) that produce ZEBs (both BEBs and fuel cell electric buses) in the United States with many new OEMs joining the market (Arrival, Van Hool, etc.).

Table 3.1 summarizes the available standard, motorcoach, and cutaway BEBs on the market that best align - based on length and vehicle type - with Solano County's agencies' existing fleet (i.e., current double-decker and articulated offerings were not included).

Table 3.1 Available BEBs in the US Market (aligned with Solano County's fleets)

OEM	Vehicle Type	Length	Capacity (kWh)
ARBOC	Motorcoach	30'	350
		35'	437
BYD	Standard	30'	215
		35'	266
		40'	313 – 352
	Motorcoach	23'	141
		35'	313
		40'	352
		45'	446
GreenPower	Standard	30'	260
		40'	400
	Cutaway	25'	118
Gillig	Standard	40'	444
Lightning eMotors	Cutaways + Vans	Varies	<129

OEM	Vehicle Type	Length	Capacity (kWh)
MCI	Motorcoach	45'7"	544
		45'10"	389
New Flyer	Standard	35'	350/440
		40'	350/440/525
Nova	Standard	40'	564
Proterra	Standard	35'	450
		40'	675

Source: WSP

As of December 2020, there were approximately 2,700 ZEBs either in operation or procured in the United States – a 24% increase since 2019. Of these, approximately 1,000 are in service. With state mandates such as CARB's ICT regulation, the demand for ZEBs is expected to increase, and will certainly launch new OEMs, technologies, and help reduce the costs over time.

3.2 Charger OEMs

There are several BEB charger OEMs that have products on the market – most of which are based on Society of Automotive Engineers (SAE) standards. Currently, there are no standards for inductive charging, so adopters of one OEM (ex. Wave) are not able to operate on other inductive infrastructure (Momentum). Table 3.2 summarizes the different charger manufacturers and their current offerings. It should be noted that these represent DC chargers that are compatible with all bus OEMs. Proterra also offers chargers; however, these typically are purchased in conjunction with Proterra buses.

Table 3.2 Available Chargers in the US Market

OEM	Charging Type	Dispenser Type	Power (kW)
ABB	Conductive	Plug-In and Pantograph	100-450
ChargePoint	Conductive	Plug-In and Pantograph	62.5-500
Ebus	Conductive	Pantograph	Custom
Hitachi	Conductive	Plug-In and Pantograph	Custom
Heliox	Conductive	Plug-In and Pantograph	180-450
Momentum Dynamics	Inductive		50-300
Siemens	Conductive	Plug-In and Pantograph	150-600

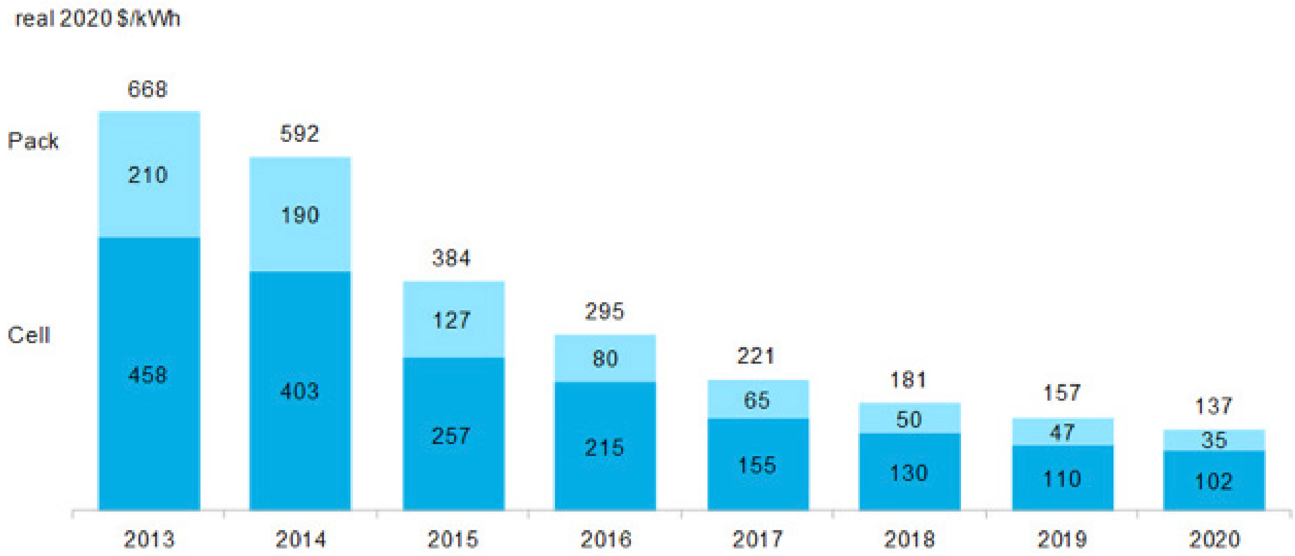
OEM	Charging Type	Dispenser Type	Power (kW)
Tritium	Conductive	Plug-In	50-350
Wave	Inductive		250

Source: WSP

3.2.1 COSTS

The cost of an individual BEB varies based on a myriad of factors, including battery capacity, vehicle length, customizations (software/hardware, trimmings, etc.), bulk orders, and warranties. For that reason, it can be difficult to accurately estimate cost until entering a contract with an OEM. However, based on peer agencies' base BEB procurements, it is assumed that a cutaway can cost $450K, a 40-foot standard bus costs $850K, and a 40-foot motorcoach costs $1.8M. While these vehicles are substantially more costly than their internal combustion engine counterparts, the price for batteries (per kWh) has dramatically decreased every year (Figure 3.1). In 2010, the price per kWh was $1,100; in 2020 the price was $137/kWh; and by 2023, prices are expected to drop to $100/kWh.

Figure 3.1 Volume-Weighted Average Battery Cost



Source: BloombergNEF (2020)

3.2.2 PROCUREMENT

Bus procurements can be very time consuming and resource intensive. CalACT, a resource primarily for small, rural, and specialized transportation California-based transit providers, has several pre-approved and priced BEBs that can be purchased to avoid lengthy bid and procurement processes. Table 3.3 presents the current vehicles and prices that are offered via CalACT.

Table 3.3 California Bus Contract Price List

OEM	Model	Length	Battery Capacity (kWh)	Cost
New Flyer	Xcelsior XE 35'	35'	311	$732,618
Proterra	Catalyst XR	35'	220	$689,000
New Flyer	Xcelsior XE 40'	40'	311	$741,768
Proterra	Catalyst XR	40'	220	$699,000

Source: CalAct (2020)

3.3 Emerging Technology

There are a several advancements in battery technology being researched that aim to improve energy densities, lifespans, and reduce weight. Additional research is being conducted to reduce the cost and time required to manufacture these batteries as well as increase the cycle life.

The most significant advances are in energy density improvements resulting in reductions in battery weight. Anticipated breakthroughs within battery performance will address many of the limitations existing today in terms of range capability, weight, life expectancy and degradation. As an example, for a bus with a 450 kWh battery, an increase of energy density from 150 Wh/kg to 300 Wh/kg could reduce bus battery weight by up to 3000 pounds. This weight reduction would allow for additional kWh of battery capacity added or an overall reduction in bus weight.

Specific research includes:

- Lithium air batteries are expected to exceed the conventional lithium-ion battery's charging capacity by 10 times.
- Lithium-metal batteries have high specific energy and loading capabilities. They use a solid electrolyte instead of a liquid and are believed to have a higher energy density. They are also expected to have a faster charging rate, a higher voltage, and a longer cycle life.
- Semi-solid lithium batteries, rather than using a solid electrolyte, use a liquid electrolyte that prevents a gap from forming at the interface of the electrolyte and the anode-cathode separator. This ensures that access to the active material is not lost over the life of the battery.

DIXON READI-RIDE

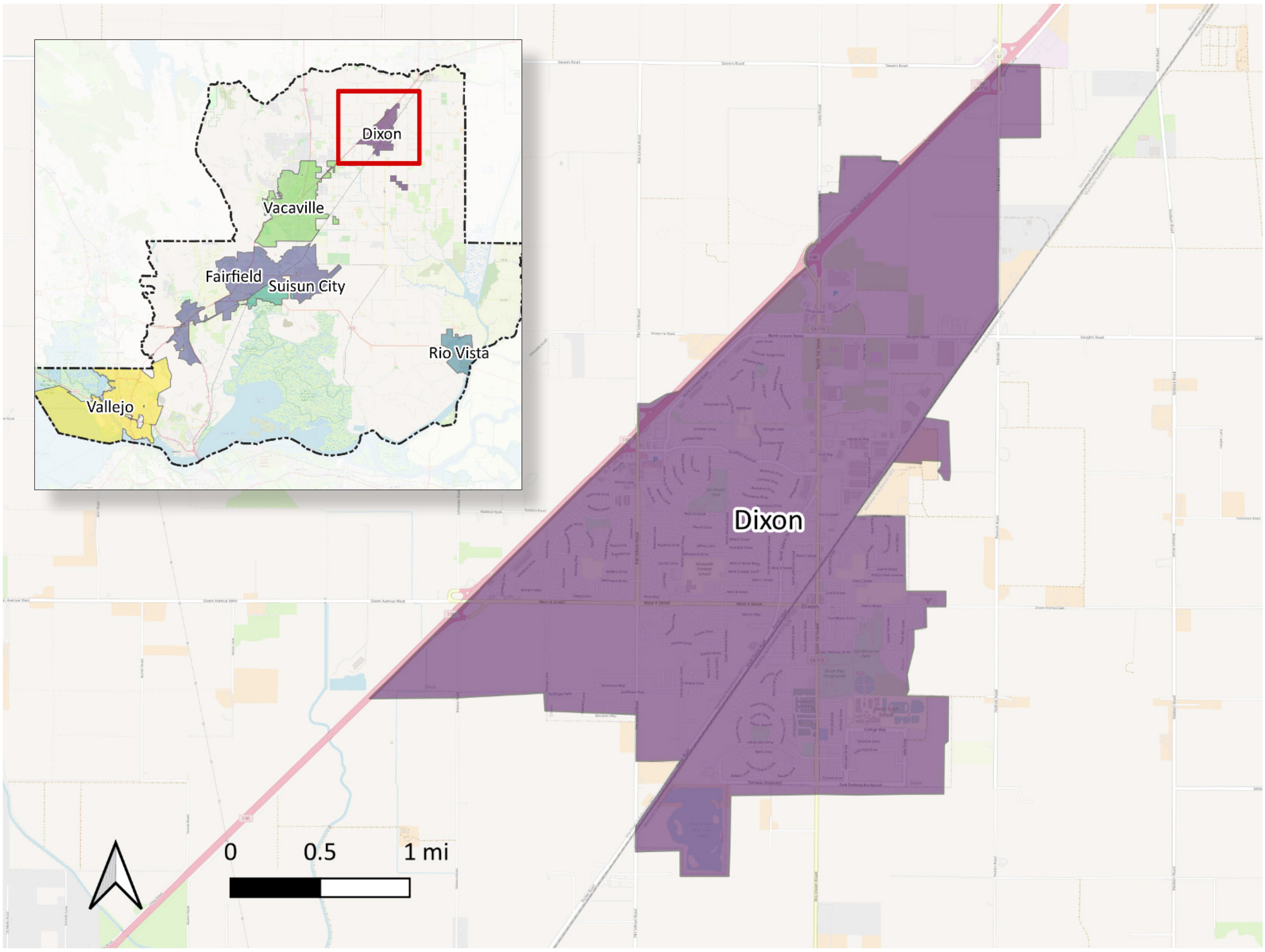
4 DIXON READI-RIDE

The following sections provide an overview of Dixon Readi-Ride, its existing vehicle portfolio, bus service, and facility conditions (including maintenance yard layouts and utility conditions).

4.1 Overview

Dixon Readi-Ride was established in 1983 as a public dial-a-ride transit system (administered by the City of Dixon) and continues to provide curb-to-curb transit service within the city of Dixon. The service operates 10 vehicles, and the hours of operation are Monday - Friday from 7:00 AM - 5:00 PM. The city has no fixed-route transit service.

Figure 4.1 City of Dixon



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

4.2 Vehicle Portfolio

The Dixon Readi-Ride fleet consists of 10 vehicles: two vans and eight cutaways, all powered by gasoline (Table 4.1). The vehicles were put in service between 2007 and 2019.

Table 4.1 Summary of Dixon Readi-Ride's Existing Fleet

Make/Model	Fuel Type	Length	In Service Year	Bus Type	Quantity
Dodge Caravan Van	Gasoline	Unknown	2010	Van	2
Starcraft E450	Gasoline	Unknown	2007	Cutaway	1
Ford E450 Elkhart	Gasoline	Unknown	2011	Cutaway	4
Ford 450	Gasoline	Unknown	2015 and 2017	Cutaway	2
Glavel 450	Gasoline	Unknown	2019	Cutaway	1
				Total Buses	10

Source: Dixon Readi-Ride Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

4.3 Bus Service

With demand response service, the fleet use can vary greatly from day to day, based on the demand of customers, their pick-up and drop-off locations, and the capacity for Dixon Readi-Ride to provide the service. Based on available data, the average daily distance traveled by a fleet vehicle is between 83 and 103 miles (Table 4.2). This range was calculated using the average reported speeds in the *Dixon Readi-Ride Short Range Transit Plan FY 2021 – FY 2030* (Dixon SRTP) and an assumed vehicle operator's shift of eight or 10 hours.

Current (similarly sized) BEBs on the market advertised range capabilities that exceed Dixon Readi-Ride's, meaning it is possible that the existing service may be suitable to operate BEBs. Further analysis of BEB performance and suitability for Dixon Readi-Ride's service will be conducted with service modeling (Task 2).

Table 4.2 Dixon Readi-Ride Demand Response Estimated Vehicle Service Statistics

Metric	Statistic
Annual Miles	96,675 miles
Annual Hours	9,372 hours
Average Daily Speed	10 mph
8-Hour Shift Distance	83 miles
10-Hour Shift Distance	103 miles

Source: Dixon Readi-Ride Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

4.4 Facility Conditions

4.4.1 OPERATIONS AND MAINTENANCE

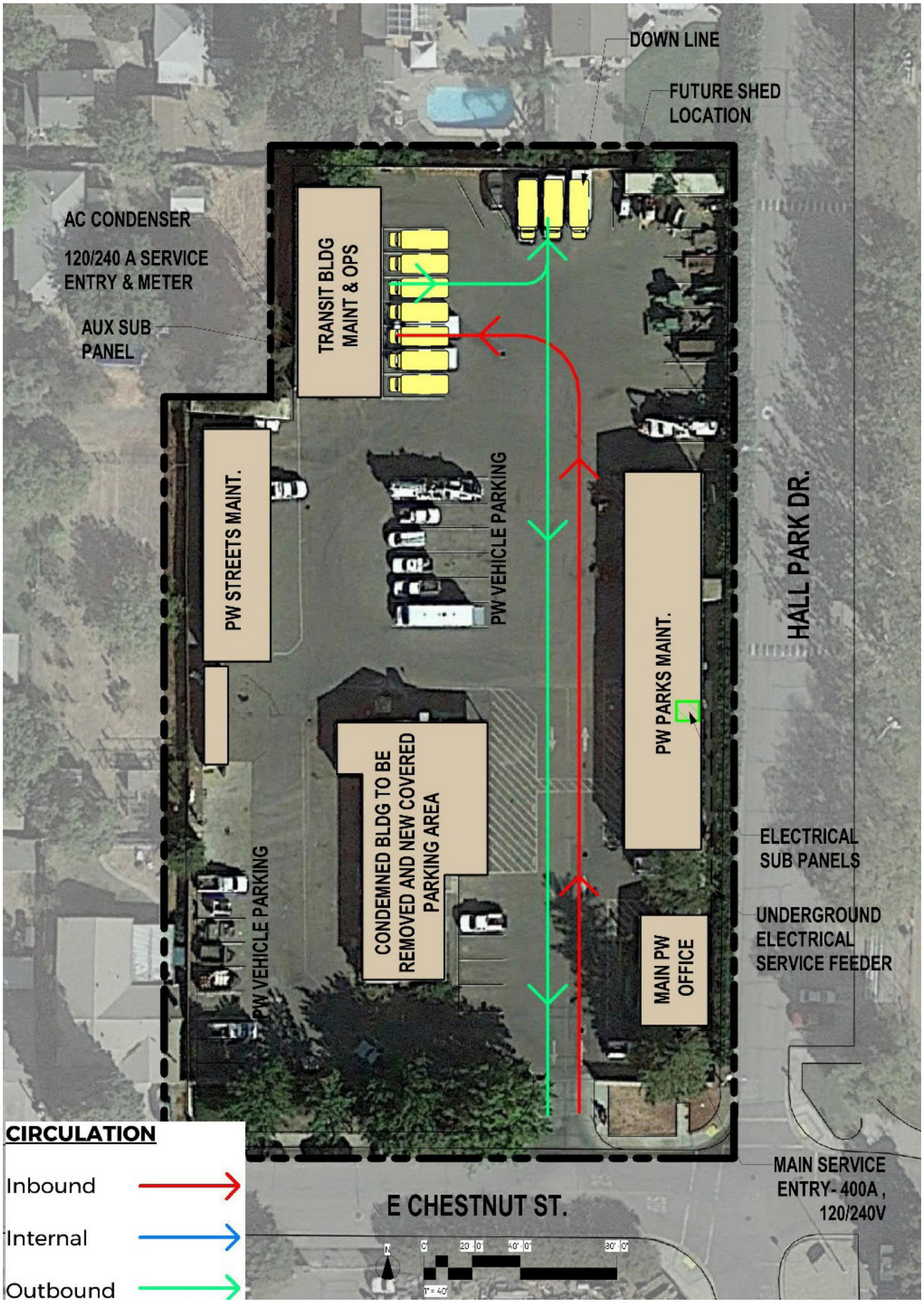
The Dixon Readi-Ride facility is located at 285 East Chestnut Street. The transit operations share the site with the City of Dixon Public Works Department and despite having a relatively small dedicated portion of the overall site, transit operations still have adequate room to support the fleet.

There are two future site improvements planned at the facility. One is for a new storage shed that would be located in the northeast corner. The other is to demolish the condemned building in the center and replace it with a covered parking area for public works vehicles. Neither project is planned for the near future and neither should affect the electrification implementation.

Circulation

Transit vehicles enter the site from the main road along East Chestnut Street at the south end of the site. Buses continue to the rear of the site and are parked (nose-in) in front of the transit operations and maintenance building in the northwest corner of the site. Buses that are not within the active fleet are backed into the spaces along the north property line to await servicing. There is no fueling onsite. The fleet is fueled by operators prior to returning to the facility. During pull-out, buses back out of the active fleet parking stalls and exit at the southern end of the site to East Chestnut Street (Figure 4.2).

Figure 4.2 Dixon Readi-Ride Site Circulation



Source: WSP

4.4.2 UTILITY CONDITIONS

Substation & Circuit

Dixon Readi-Ride's power is provided by the PG&E Dixon Substation (6206) that is located at 369 West A Street, approximately one mile from the yard. The Dixon Substation has a capacity of 39 megawatts (MW) on Bank 1 with a peak load of approximately 18.1 MW based on publicly available data. This feeds the Dixon 1103 feeder circuit that feeds the Dixon Readi-Ride yard.

The Dixon 1103 Circuit is a 12-kilovolt (kV) circuit that enters the yard from South 3rd Street. It has an existing capacity of 10.9 MW and PG&E estimates that the projected peak load of this circuit is 9.3 MW, leaving approximately 1.6 MW of available capacity. If new service is warranted from future transit upgrades, the new service could potentially be fed by the nearby Dixon 1102 Circuit if PG&E is unable to serve the required load from the existing 1103 circuit.

Peak loads for the Dixon 1102 Circuit are monitored by PG&E and published on their ICA Map. Based on the ICA map, the load increases in summer months and has peaks at 7:00 PM between June and August. The usage is at its minimum at 2:00 PM in the spring months between March and May. BEBs on-site will most likely charge overnight, so this feeder profile should not affect Dixon Readi-Ride's electricity bill or peak demand charge.

Transformer & Switchboard

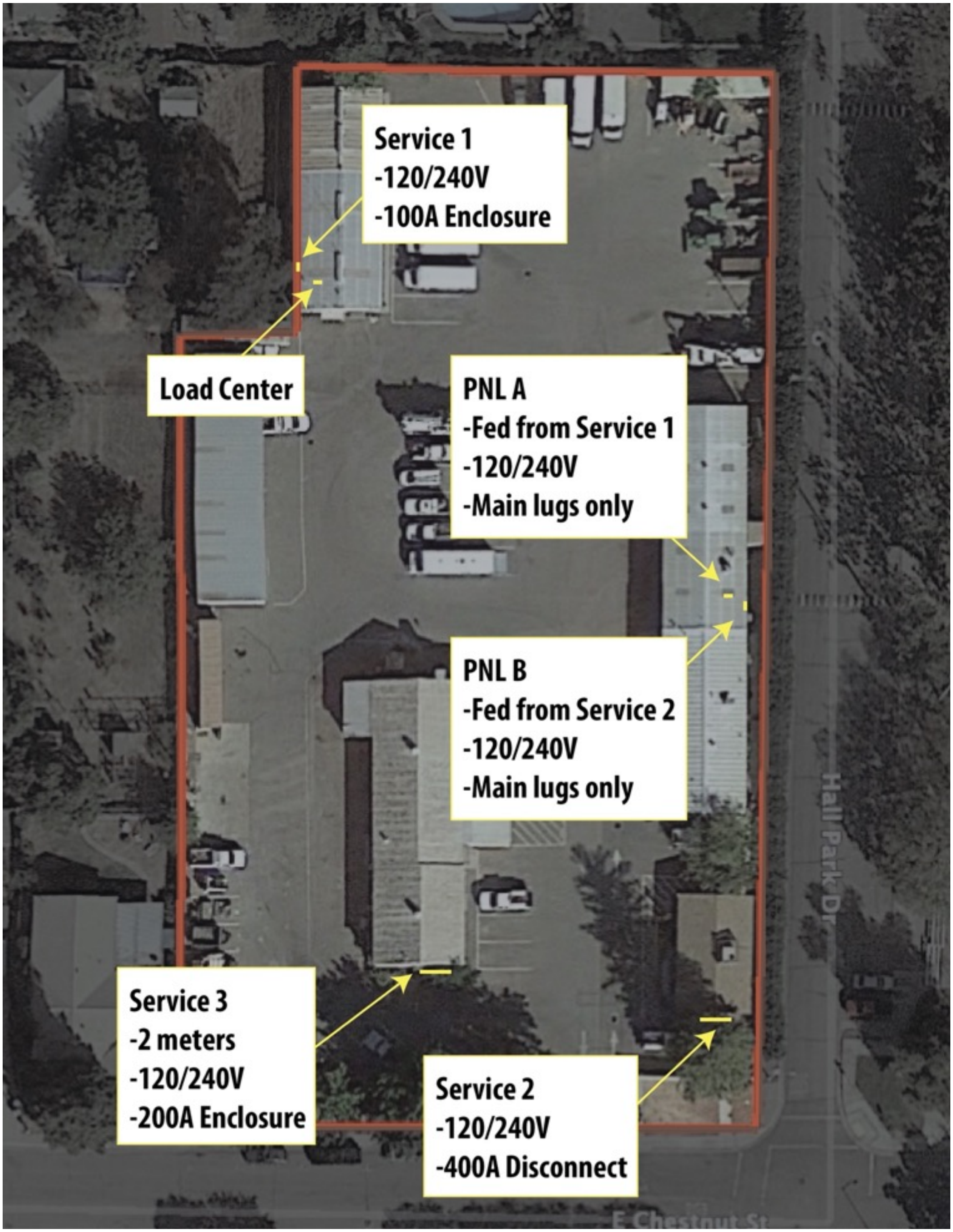
Existing electrical service appears to be served by a 12 kV – 240/120 V, single-phase, pole mounted PG&E owned transformer, likely shared with adjacent facilities and residential homes (Figure 4.3) located approximately 0.5 miles from Dixon Substation. Given the use of overhead electrical lines and a shared transformer, this only provides a low level of resiliency against distribution-related outages.

Figure 4.3 Dixon-Readi-Ride Transformer

Source: Google Maps

On-site electrical infrastructure, as shown in Figure 4.4, includes two panelboards and three services. Service 1 is a 100A switchboard that feeds the load center and panelboard A. Service 2 is a 400 A switchboard that feeds panelboard B. Service 3 is a 200 A switchboard and has two different meters. At Service 2, eight out of 30 breaker positions are free. As an estimate, this switchboard can likely feed up to four Level 2 AC vehicle chargers, assuming existing loads are 15 A. For Service 1 and 2, the number of free breakers and load profile cannot be verified at this time.

Figure 4.4 Dixon Readi-Ride Utility Plan View



Source: WSP

Potential Enhancements

It is unlikely that the utility will need a new feeder or significant upgrades to existing feeders, but the Dixon site will likely need a new PG&E service line pulled from PG&E circuit 1102 on West Chestnut Street if it is determined that all 10 vehicles must be charged simultaneously. Alternatively, it may be possible to upgrade existing electrical service served from PG&E circuit 1103 on South 3rd Street if PG&E determines that the existing infrastructure can support the additional load. This assessment will be updated at later phases based on operational needs. If a new service is required, PG&E may need to perform a detailed load study on the feeders.

RIO VISTA

DELTA BREEZE

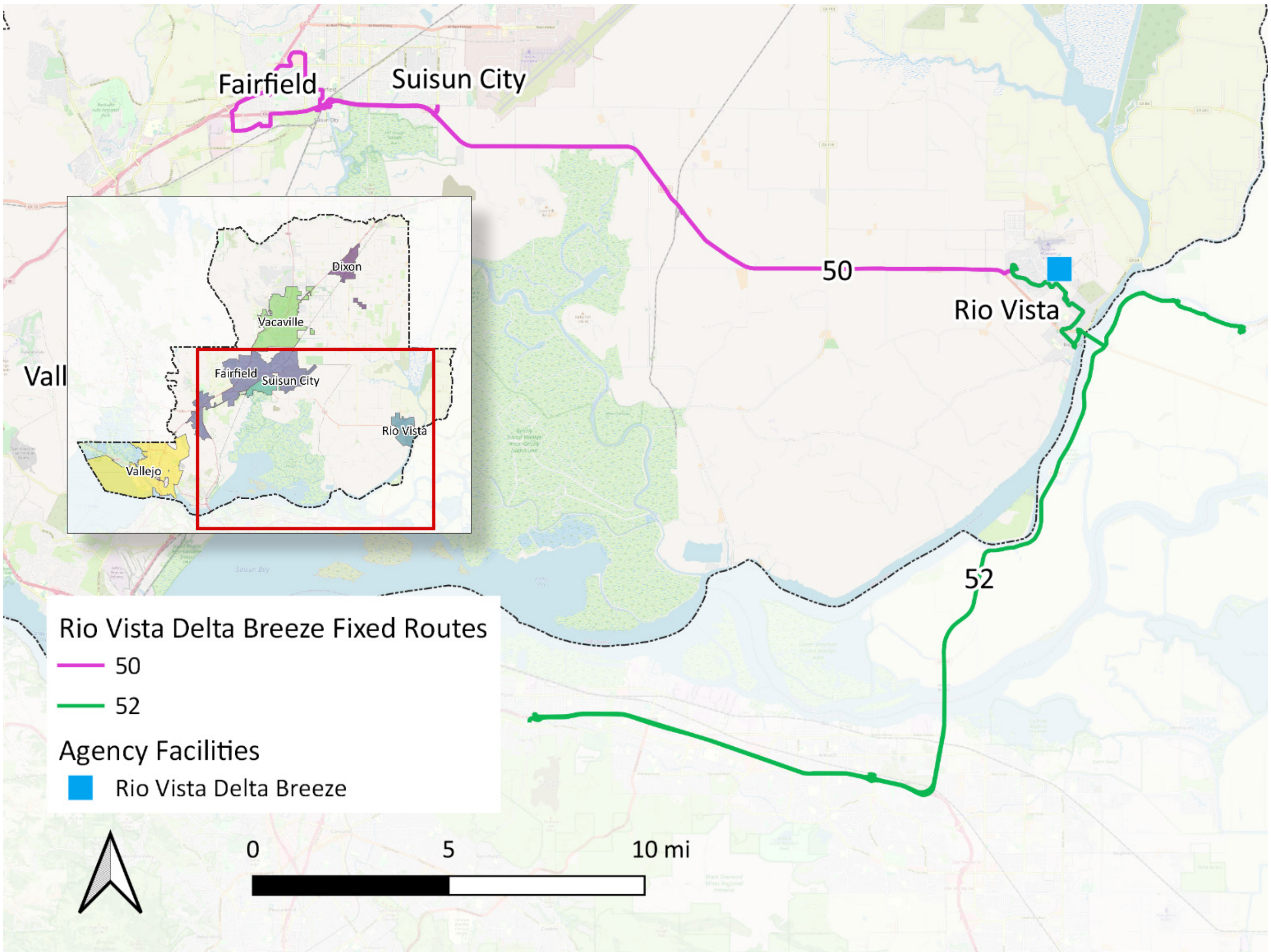
5 RIO VISTA DELTA BREEZE

The following sections provide an overview of Rio Vista Delta Breeze, its existing vehicle portfolio, bus service, and facility conditions (including maintenance yard layouts and utility conditions).

5.1 Overview

Rio Vista Delta Breeze began as Rio Vista Transit, in 1980, offering only demand response service. In 2006, deviated fixed-route service was added and the agency evolved into Rio Vista Delta Breeze. Service is provided within the City of Rio Vista and between Isleton, Rio Vista, Fairfield, Suisun City, Pittsburg/Bay Point Bay Area Rapid Transit (BART) station and Antioch with connections to Lodi. The system is administered by the City of Rio Vista with service provided by STA in partnership with a contractor. The service operates five vehicles, and the hours of operation are generally Monday - Friday from 7:30 AM - 5:50 PM.

Figure 5.1 Rio Vista Delta Breeze Fixed-Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

5.2 Vehicle Portfolio

The Rio Vista Delta Breeze fleet consists of one gasoline powered van and four gasoline powered cutaways (Table 5.1). The vehicles were put into service between 2011 and 2018.

Table 5.1 Summary of Rio Vista Delta Breeze's Existing Fleet

Make/Model	Fuel Type	Length	In Service Year	Bus Type	Quantity
El Dorado Van	Gasoline	12'	2011	Van	1
Ford E450	Gasoline	22'	2012	Cutaway	1
Ford E450	Gasoline	25'	2013	Cutaway	1
Ford Glavel	Gasoline	25'	2016	Cutaway	1
Ford Glavel	Gasoline	25'	2018	Cutaway	1
				Total Buses	5

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030 Service Blocks

5.3 Bus Service

Rio Vista Delta Breeze operates two local deviated fixed-routes and a dial-a-ride service (Table 5.2). The fleet consists of five buses - four cutaways and one van. Based in Rio Vista, the fixed-route service extends south to Bay Point and west to Fairfield and Suisun City (Figure 5.1).

Table 5.2 Rio Vista Delta Breeze Service by Service Type

Service Category	Description	Avg. Distance (mi.)	Avg. No. of Trips	Avg. Speed (mph)	No. of Routes
Local	Deviated fixed-route service	24	5	23	2
Dial-A-Ride	Demand response	90 – 113	N/A	11	1

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030 and Rio Vista November 2019 GTFS Files

5.3.1 FIXED-ROUTE

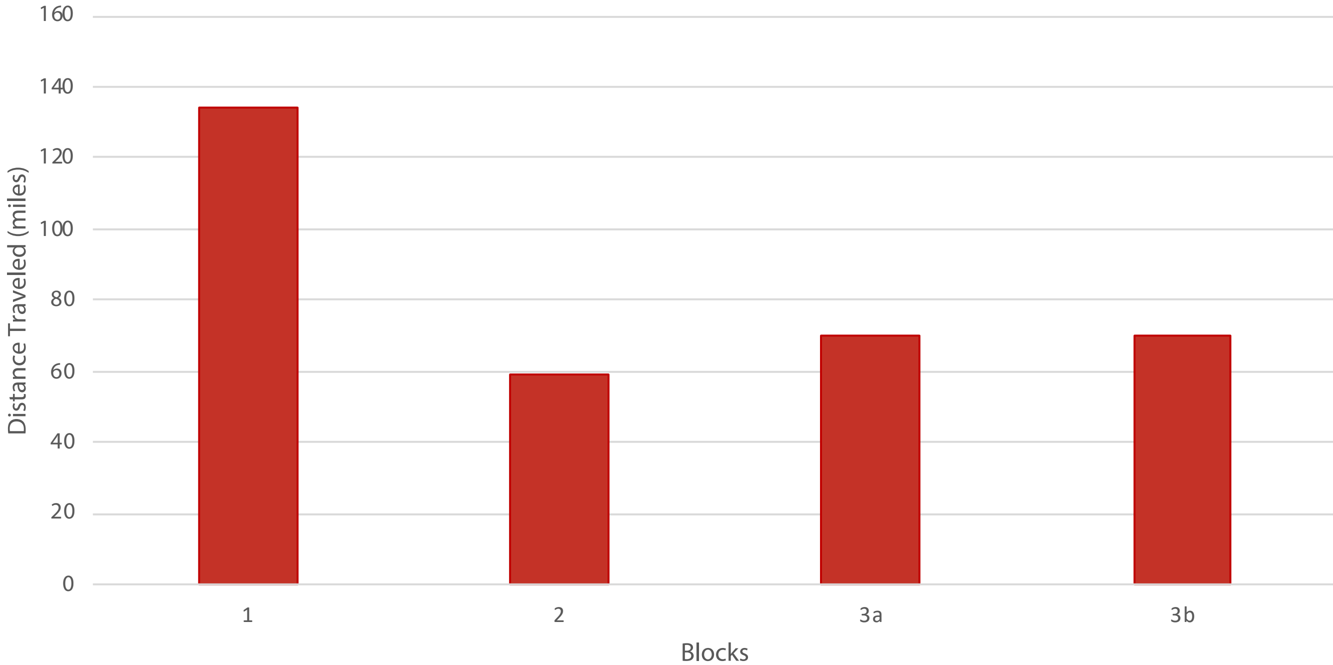
Rio Vista Delta Breeze has two local service routes that are operated with four vehicle blocks ranging from 59 to 134 miles. The average vehicle block has a distance of 83 miles. An overview of routes is presented in Table 5.3 and vehicle block ranges are shown in Figure 5.2.

Table 5.3 Rio Vista Deviated Fixed-Routes

Route	Area Served	Days/Week	Frequency
Route 50 Hwy 12 Express	Downtown Rio Vista, Fairfield Transportation Center, Homecoming Park, Trilogy Vista Clubhouse, Solano Town Center, Solano County Government Center, and Suisun City Train Depot	5	Four AM trips Four PM trips
Route 52 Hwy 160 Express	Pittsburg/Bay Point BART Station connects to Central Contra Costa Transit Authority (The County Connection) and Eastern Contra Costa Transit Authority (Tri Delta Transit)	5	One SB AM trip One NB PM trip

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Figure 5.2 Rio Vista Delta Breeze Weekday Block Ranges



Source: Rio Vista GTFS November 2019

5.3.2 DEMAND RESPONSE

With demand response service, the fleet use can vary greatly from day to day, based on the demand of customers, their pick-up and drop-off locations, and the capacity for Rio Vista Delta Breeze to provide the service. Based on available data, the average daily distance traveled by a fleet vehicle is between 90 and 113 miles (Table 5.4).This range was calculated using the average reported speeds in the *Rio Vista Delta Breeze Short Range Transit Plan FY 2021 – FY 2030* (Rio Vista SRTP) and an assumed vehicle operator's shift of eight or 10 hours.

Current (similarly sized) BEBs on the market advertised range capabilities that exceed Rio Vista Delta Breeze's, meaning it is possible that the existing service may be suitable to operate BEBs. Further analysis of BEB performance and suitability for Rio Vista Delta Breeze service will be conducted with service modeling (Task 2).

Table 5.4 Rio Vista Paratransit Estimated Vehicle Service Statistics

Metric	Statistic
Annual Miles	11,318 miles
Annual Hours	1,003 hours
Average Daily Speed	11 mph
8-Hour Shift Distance	90 miles
10-Hour Shift Distance	113 miles

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

5.4 Facility Conditions

5.4.1 OPERATIONS AND MAINTENANCE

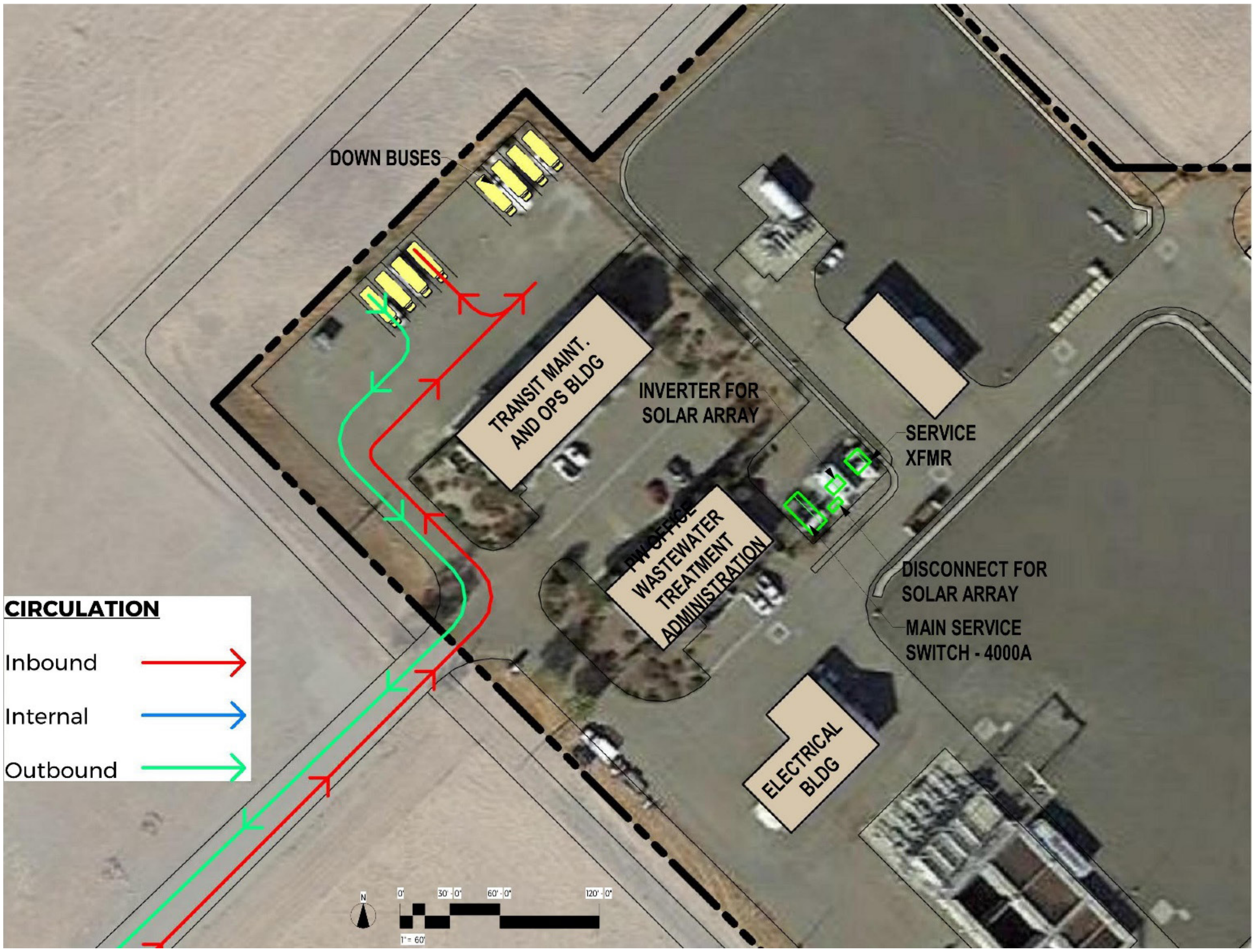
The Rio Vista Delta Breeze facility is located at 3000 Airport Road. The transit operations share the site with the City of Rio Vista Northwest Wastewater Treatment Plant, and despite having a relatively small, dedicated portion of the overall site, transit operations still have adequate room to support the fleet. Maintenance and operations are all contained within the single building, with the maintenance bays accessed from the transit yard and the operations accessed from the employee parking on the east.

The operations could easily expand with minimal effort and there is adequate room to accommodate electrification infrastructure. There are no planned modifications to the transit facilities at this time.

Circulation

Transit vehicles enter the site from the main road along Airport Road at the west end of the site. Buses enter the site turn into the gated transit area and back into spaces along the northern edge of the pavement. Buses that are not within the active fleet park nose-in at the spaces to the furthest north to await servicing. There is no fueling onsite. The fleet is fueled by operators prior to returning to the base. During pull-out, buses pull from the active fleet parking stalls, exit the transit area, and then use the access road to Airport Road (Figure 5.3).

Figure 5.3 Rio Vista Delta Breeze Site Circulation



Source: WSP

5.4.2 UTILITY CONDITIONS

Substation & Circuit

Rio Vista Delta Breeze's power is provided by the PG&E Grand Island Substation (6246), located approximately 17 miles from the yard. The Grand Island Substation has a capacity of 44.5 MW on Bank 3 with a peak load of approximately 14.6 MW based on publicly available data. This feeds the Grand Island 2226 feeder circuit that feeds the Rio Vista Delta Breeze Yard.

The Grand Island 2226 Circuit is a 21 kV circuit with an existing capacity of 18 MW. PG&E estimates that the projected peak load of this circuit is 10 MW, leaving approximately 8 MW of available capacity. The overhead portion of circuit 2226 follows Airport Road and enters an access road towards the Rio Vista Delta Breeze facility. The overhead portion dead-ends at the adjacent industrial site along the access road and enters the yard through an underground conduit for the last quarter mile.

Peak loads for the Grand Island 2226 are monitored by PG&E and published on their ICA Map. Based on the ICA map, the load increases in summer months and has peaks at 8:00 PM from June to September.

Transformer & Switchboard

The site has a utility pad-mounted transformer (T12665) fed by the underground Grand Island 2226 Circuit described above. There is also a small 75 kVA Eaton pad-mounted transformer next to the panelboards in the maintenance building. This site is shared with the wastewater treatment plant, whose electrical loads could be significant. There will be a need to request the site's single line diagram, utility invoices, load data, meter readings, and other utility information from the treatment plant to identify the amount of spare capacity and equipment connections. This site will also need to coordinate with the water treatment plant on any equipment upgrades or changes since the plant could have its own reliability requirements or planned upgrades.

There is a 4000 A 480 Y/277 V main switchboard next to the utility transformer, with two feeder breakers: (1) spare 2000 A breaker and (2) 2000 A breaker that feeds MCA-200 A. The MCA-200 A in turn feeds the shop/maintenance building located on the other side of the site. Lastly, there are three panelboards located in one building on the left side of the entry road as summarized below:

Table 5.5 Rio Vista Delta Breeze Panelboards

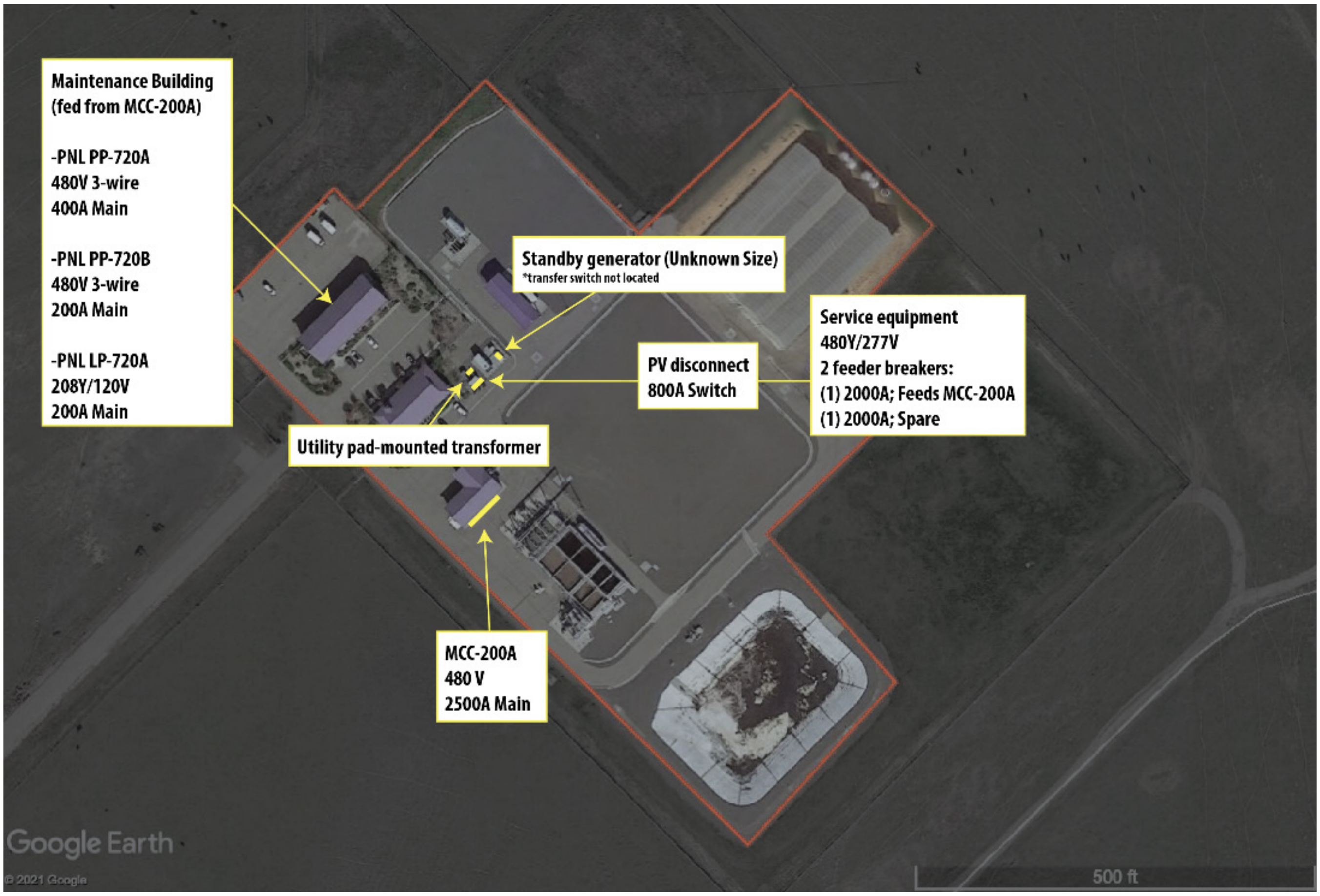
Panelboard	Voltage	Main Breaker
PNL LP-720A *	208 Y/120 V	200 A
PNL PP-720A	480 V, 3 wire	400 A
PNL PP-720B	480 V, 3 wire	200 A

Source: PG&E

* Has integral surge protective device

There is one generator (unknown size) onsite for resiliency purposes. It is unknown where the transfer switch is. The onsite PV 800 A disconnect switch and negative feeder load implies that there are PV panels nearby but could not be verified to be onsite. These panels may or may not provide power to the site during normal operations depending on the panel verification.

Figure 5.4 Rio Vista Delta Breeze's Utility Plan View



Source: WSP

Potential Enhancements

Rio Vista Delta Breeze only hosts five upgradable buses and has an existing spare 2000 A breaker on the service switchboard, so it is highly unlikely that the site will need any electrical infrastructure upgrades even with a 1:1 charging configuration (one vehicle to one charger). This will be further evaluated at later phases based on operational needs. However, early coordination is necessary with the wastewater treatment plant. If a new service is required, PG&E would need to perform a detailed load study on the feeder before adding the service.

SolTrans

6 SOLANO COUNTY TRANSIT

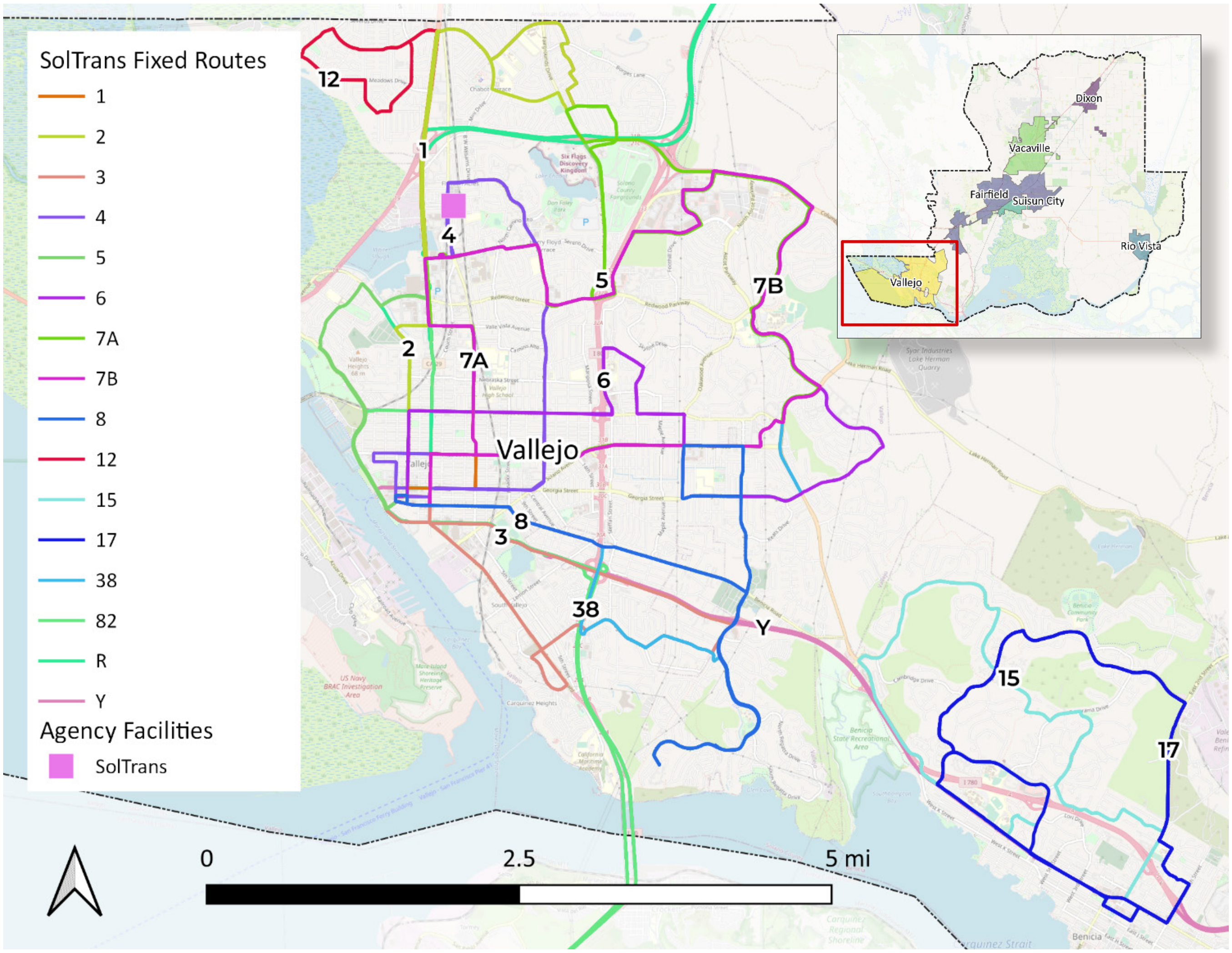
The following sections provide an overview of SolTrans, its existing vehicle portfolio, bus service, and facility conditions (including maintenance yard layouts and utility conditions).

6.1 Overview

Solano County Transit (SolTrans) is a Joint Powers Authority (JPA) run by its own Board of Directors and consists of Benicia, Vallejo, and STA. It was formed in 2011 when two local providers, Benicia Breeze and Vallejo Transit, consolidated their programs in partnership with STA. It provides the highest volume of Solano County's intercity bus passengers primarily to/from East Bay's BART stations, but also the San Francisco (SF) Bay ferry terminal in Vallejo, Napa Vine bus stops, and Contra Costa County transit systems. It also offers local transit to the cities of Benicia and Vallejo and connects with FAST at key locations. Local service is generally offered from 5:30 AM to 8:30 PM during the week, with limited routes and headways on weekends.

In addition to the local service, SolTrans offers two intercity services – SF Express (Route 82) and SolanoExpress (two routes), which is jointly managed by FAST and SolTrans. It should be noted that the SolanoExpress routes are not a part of the scope of the *Countywide Electrification Transition Plan* as they are being evaluated under the scope of other related projects.

Figure 6.1 SolTrans Fixed-Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

6.2 Vehicle Portfolio

The SolTrans fixed-route fleet consists of 59 buses, as well as an additional coach bus that is loaned to FAST. There are 27 standard 40-foot buses, 14 cutaways, and 19 motorcoaches (Table 6.1). One of the buses runs on diesel, 21 are diesel hybrid, two are BEBs, 20 are CNG, and 15 are gasoline-powered cutaways. The vehicles were put in service from 2001 through 2019.

Table 6.1 Summary of SolTrans Existing Fleet

Make/Model	Fuel Type	Length	In Service Year	Bus Type	Quantity
Orion	Diesel	40'	2001	Standard	1
Gillig Corp	Diesel Hybrid	40'	2011	Standard	21
BYD	Battery Electric	40'	2016	Standard	4
Nova	CNG	40'	2016	Standard	1
MCI	CNG	45'	2003	Coach	3
MCI	CNG	45'	2017	Coach	6
MCI	CNG	45'	2018	Coach	4
MCI	CNG	45'	2019	Coach	6
Starcraft	Gasoline	26'	2011	Cutaway	6
El Dorado	Gasoline	24'	2016	Cutaway	3
Glaval	Gasoline	Unknown	2018	Cutaway	3
Arboc	Gasoline	Unknown	2019	Cutaway	2
				Total Buses	60

Source: 2020 Revenue Fleet Listing

6.3 Bus Service

SolTrans operates 14 local fixed-routes (including five limited school routes in Benicia and Vallejo), two SolanoExpress routes, one intercity SF Express route, and paratransit service (Table 6.2).

Table 6.2 SolTrans Service by Service Type

Service Category	Description	Avg. Distance (mi.)	Avg. No. of Trips	Avg. Speed (mph)	No. of Routes
Local	Fixed-route service.	7	28	11	14
Paratransit	Demand response	75 – 93	N/A	9	1

Source: SolTrans Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030 and SolTrans December 2019 GTFS Files

6.3.1 FIXED-ROUTE

SolTrans operates 16 routes. The two SolanoExpress routes – Red and Yellow Lines – extend to Walnut Creek and Fairfield and Suisun City, while SolTrans Route 82 extends to San Francisco. Otherwise, the fixed-route services operate within Vallejo city limits (Table 6.3).

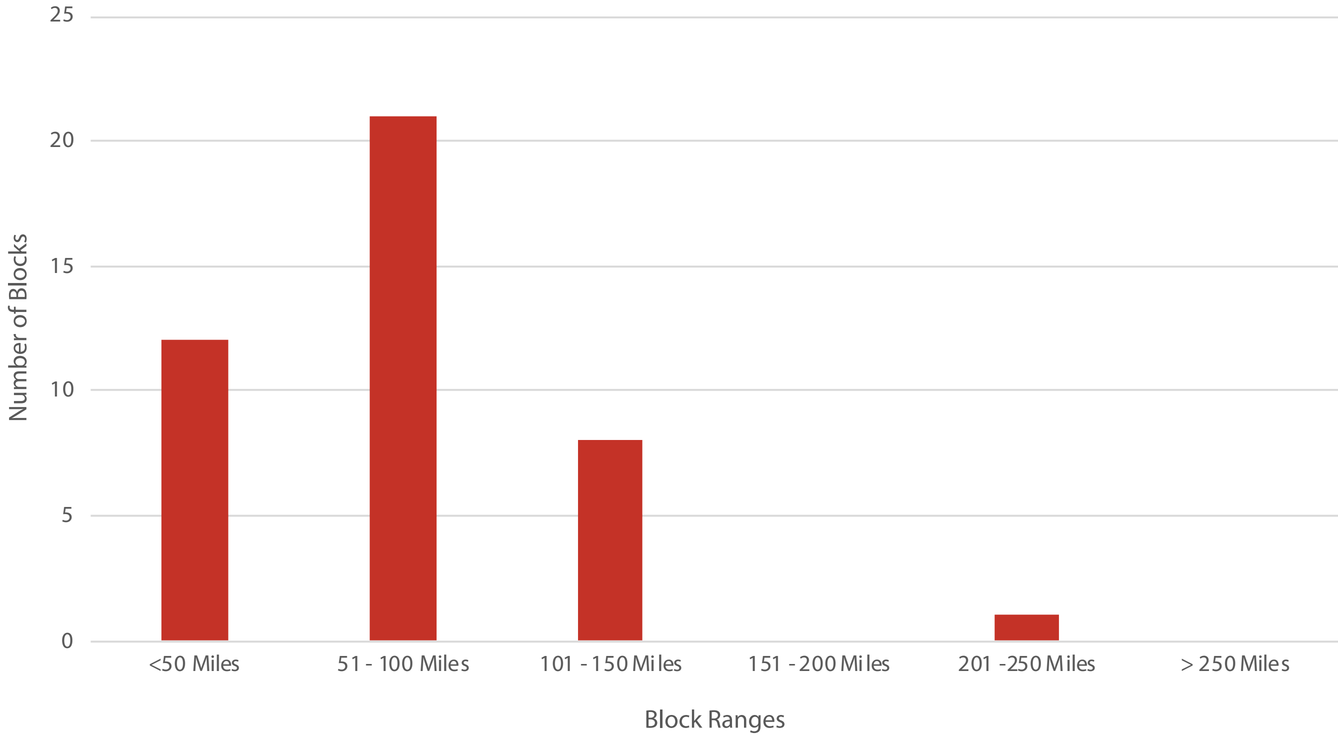
SolTrans' local service is operated with 42 vehicle blocks ranging from eight to 201 miles. All but one block operates under 150 miles, the general range for existing BEBs. The average vehicle block miles traveled is 74. A breakdown of vehicle block ranges is shown in Figure 6.2.

Table 6.3 SolTrans Fixed-Routes

Route	Area Served	Days/Week	Weekday Frequency
1	Northwest Vallejo	7	30 minutes
2	North Vallejo	6	30 minutes
3	South Vallejo	6	30 minutes
4	Tuolumne Street	6	30 minutes
5	Six Flags Discovery Kingdom	6	30 minutes
6	Hogan Middle School & Springhill Shopping Center	6	1 hour
7A & 7B	Gateway Plaza and Springs Road	7	30 minutes
8	Hogan Middle School, Glen Cove Elementary School, Springhill Shopping Center	6	1 hour
12	Rancho Square, Mini & Sonoma, Solano Middle School, and Gateway & Fairgrounds	5	1 morning run
15 & 17	Mary Farmar Elementary, Benicia High School, Benicia Middle School, Joe Henderson Elementary, Matthew Turner Elementary School, Robert Semple Elementary, and Southampton Shopping Center	5	1 morning run 2 afternoon runs
38	Glen Cove Elementary, Hogan Middle School, Vallejo Charter School, Jesse Bethel High School, Solano Community College's Vallejo Campus, and Gateway Shopping Plaza	5	1 morning run
Yellow Line	From Vallejo and Benicia to the Pleasant Hill and Walnut Creek BART stations	7	30 to 60 minutes
Red Line	From Vallejo to the El Cerrito del Norte BART station	7	15 to 30 minutes
Route 82	From Vallejo to the San Francisco Ferry Building	5	1 weekday evening run

Source: SolTrans Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Figure 6.2 SolTrans Weekday Block Ranges



Source: SolTrans GTFS December 2019

6.3.2 DEMAND RESPONSE

With demand response service, the fleet use can vary greatly from day to day, based on the demand of customers, their pick-up and drop-off locations, and the capacity for SolTrans to provide the service. Based on available data, the average daily distance traveled by a fleet vehicle is between 75 and 93 miles (Table 6.4). This range was estimated calculated using the average reported speeds in the *SolTrans Short Range Transit Plan FY 2021 – FY 2030* (SolTrans SRTP) and an assumed vehicle operator's shift of 8 or 10 hours.

Current (similarly sized) BEBs on the market advertised range capabilities that exceed SolTrans, meaning it is possible that the existing service may be suitable to operate BEBs. Further analysis of BEB performance and suitability for SolTrans service will be conducted with service modeling (Task 2).

Table 6.4 SolTrans Paratransit Estimated Vehicle Service Statistics

Metric	Statistic
Annual Miles	146,685 miles
Annual Hours	15,762 hours
Average Daily Speed	9 mph
8-Hour Shift Distance	75 miles
10-Hour Shift Distance	93 miles

Source: SolTrans Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

6.4 Facility Conditions

6.4.1 OPERATIONS AND MAINTENANCE

The SolTrans facility is located at 1850 Broadway Street in Vallejo. The site consists of a joint maintenance and operations facility with five maintenance bays for buses and one for paratransit vehicles, a fuel island with two fuel lanes supplying diesel and compressed natural gas (CNG) to buses and unleaded to non-revenue vehicles and paratransit buses, an associated CNG compression and storage yard, underground fuel tanks, a backup generator, BEB charging equipment area, employee parking, and bus parking (Figure 6.3).

The existing bus parking layout consists of 59 transit buses (40- and 45-foot buses) parked at an angle, nose-to-tail, east of the maintenance building and 14 cutaways parked at an angle nose-to-tail north of the maintenance building.

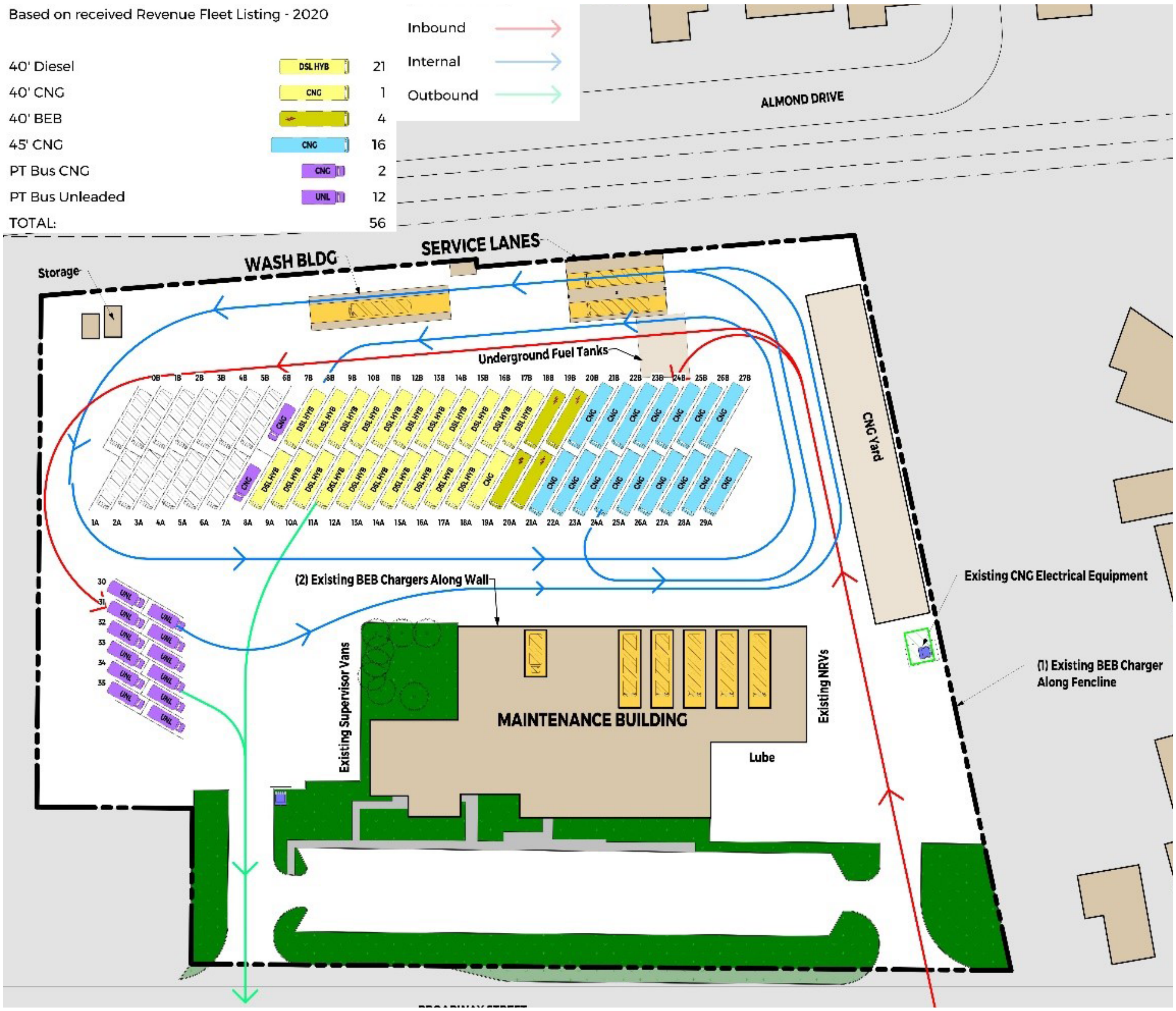
The site also has four 80 kW AC BEB dispensers for charging SolTrans' four existing BYD 40-foot BEB's. Two chargers are located along the maintenance facility wall and the other two chargers are located along the fence line at the south west corner of the site near the CNG power transformer. After the BEBs are charged they are moved back into the main parking spaces in the center of the bus yard.

SolTrans has developed a master plan for a full-BEB retrofit of the existing facility and is currently in the process of implementing Phase 1 of that plan.

Circulation

Transit vehicles enter the site from the main road along Broadway Street at the southeast corner of the site. Buses are parked nose-to-tail in two-deep angled parking rows. During nightly servicing, the buses are cycled thru fueling at the CNG station along the east of the site and through the servicing and wash along the north of the site before re-parking. During pull-out, buses exit to Broadway Street via the driveway at the southwest corner of the site (Figure 6.3).

Figure 6.3 SolTrans Site Circulation



Source: WSP

6.4.2 UTILITY CONDITIONS

To assess utility conditions, WSP utilized existing drawings that were produced (also by WSP USA) in a separate project, the *SolTrans Zero Emission Bus Plan* (2020). The analysis in this plan was based on data collected from site visits and multiple conversations with SolTrans staff. The existing site conditions, in addition to the project goals and criteria, provide the framework of the options and alternatives that were considered by WSP for transitioning the SolTrans fleet and facilities to BEB operations.

Substation & Circuit

Soltrans' power is provided by the PG&E Highway Substation (4265), located at 3331 CA-29, American Canyon, CA - approximately three miles from the yard. The Highway Substation has a capacity of 44.6 MW on Bank 1 with a peak load of approximately 22.4 MW based on publicly available data. This feeds the Highway 1106 feeder circuit that feeds the SolTrans yard.

The Highway 1106 Circuit is a 12 kV circuit that is fed from the Highway Substation. The Highway 1106 circuit has an existing capacity of 12.8 MW. PG&E estimates that the projected peak load of this circuit is 9.9 MW, leaving approximately 3 MW of available capacity. The circuit enters the yard from Lincoln Highway.

Transformers & Switchboards

The site is served by two electrical services. The below table summarizes the transformers, meters, switchboards, and generators associated with each service.

Table 6.5 SolTrans Electrical Services

Service	Transformer	Meters + Switchboards	Generator
Electrical Service 1	225 kVA (480 Y/277 V)	2500A Meter (480 Y/277 V) Main switchboard breaker: 800 A	250 kW/312.5 kVA (480 Y/277 V) w/ 400 A main breaker
Electrical Service 2	1500 kVA 21/12 kV (480 Y/277 V)	2500 A Meter (480 Y/277 V) Main switchboard breaker: 1200 A	850 kW (480 Y/277) w/ 1200 A main breaker

Source: PG&E

Given the use of overhead electrical lines, a shared transformer, and onsite generation, this site should have a moderate level of resiliency against distributed-related outages.

CITY COACH

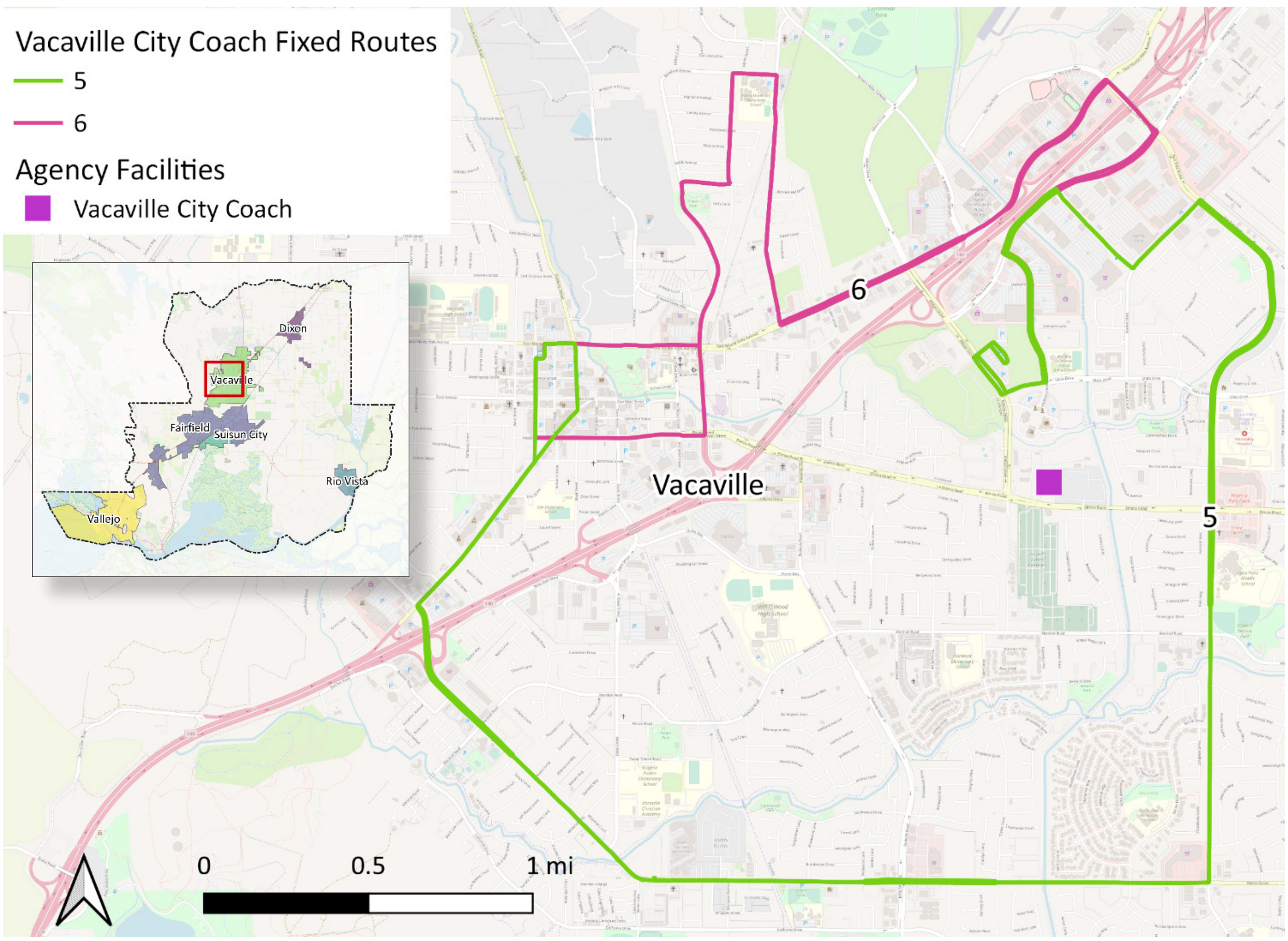
7 VACAVILLE CITY COACH

The following sections provide an overview of Vacaville City Coach, its existing vehicle portfolio, bus service, and facility conditions (including maintenance yard layouts and utility conditions).

7.1 Overview

Vacaville was incorporated in 1892 as a general law city. Founded in 1981, Vacaville City Coach operates under the Public Works Department through its General Services Division. Previously, Vacaville City Coach operated six fixed-routes that provide coverage throughout the city, but has since implemented COVID-19-related service cuts (Figure 7.1) and plans to operate a much more scaled down version closer to the pandemic related service. The Fixed-Routes are supported by 18 buses. The agency also utilizes seven cutaways for their paratransit service. Weekday service operates from 6:00 AM to 6:30 PM on 30-minute headways throughout the day, Monday through Friday. Reduced service is provided from 8:00 AM to 6:15 PM on Saturday.

Figure 7.1 Vacaville City Coach Fixed-Routes



Source: Metropolitan Transportation Commission, OpenStreetMap Contributors

7.2 Vehicle Portfolio

The fixed-route fleet consists of 18 standard 35-foot buses and the demand response fleet consists of seven cutaways (although there are additional cutaway vehicles that have been procured) (Table 7.1). The 35-foot buses all run on CNG, while the cutaways run on gasoline. The vehicles were first put in service between 2008 and 2015.

Table 7.1 Summary of Vacaville City Coach Existing Fleet

Make/Model	Fuel Type	Length	In Service Year	Bus Type	Quantity
New Flyer	CNG	35'	2009	Standard	10
New Flyer	CNG	35'	2010	Standard	5
New Flyer	CNG	35'	2013	Standard	3
Bus West	Gasoline	24'	2008	Cutaway	2
ARBOC	Gasoline	24'	2014	Cutaway	3
Chevrolet	Gasoline	24'	2015	Cutaway	2
				Total Buses	25

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

7.3 Bus Service

The fleet consists of 25 vehicles: 18 35-foot buses and seven cutaways. The two fixed-routes operate entirely within Vacaville (Table 7.2).

Table 7.2 Vacaville City Coach Service by Service Type

Service Category	Description	Avg. Distance	Avg. No. of Trips	Avg. Speed	No. of Routes
Local	Fixed-route service.	7	42	15	2
Paratransit	Demand response	104 – 130	N/A	13	1

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030 and Vacaville City Coach March 2020 GTFS Files

7.3.1 FIXED-ROUTE

Vacaville City Coach currently operates two routes. This has been reduced from six due to a loss of demand due to the COVID-19 pandemic (Table 7.3).

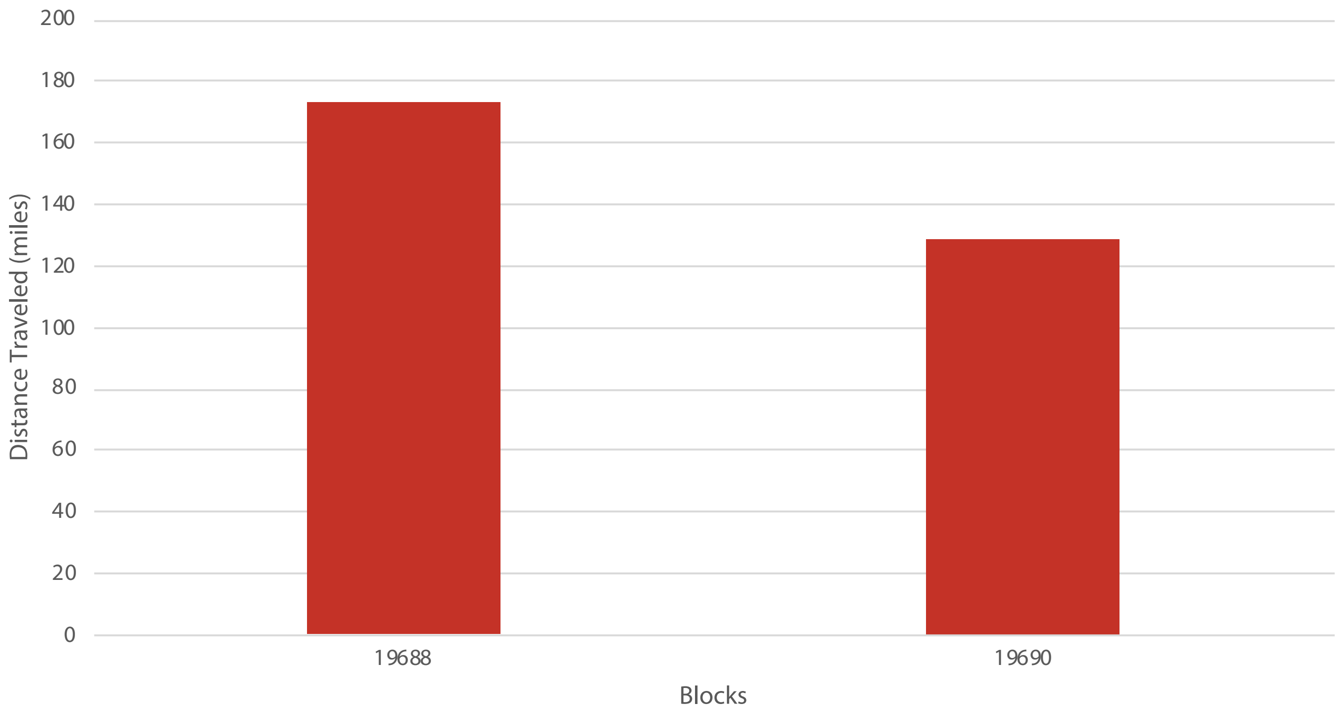
Vacaville's local service is operated with two vehicle blocks. One service block is approximately 129 miles, while the other is 173 miles – a distance that may be challenging to meet with existing BEBs. A breakdown of vehicle block ranges is shown in Figure 7.2.

Table 7.3 Vacaville City Coach Fixed-Routes

Route	Area Served	Days/Week	Weekday Frequency
5	Southern Vacaville	6	30 minutes
6	Central Vacaville	6	30 minutes

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030
Note: Routes 1, 2, 3, and 4 were indefinitely removed from service due to the COVID-19 pandemic.

Figure 7.2 Vacaville City Coach Weekday Block Ranges



Source: Vacaville GTFS March 2020

7.3.2 DEMAND RESPONSE

With demand response service, the fleet use can vary greatly from day to day, based on the demand of customers, their pick-up and drop-off locations, and the capacity for Vacaville City Coach to provide the service. Based on available data, the average daily distance traveled by a fleet vehicle is between 104 and 130 miles (Table 7.4). This range was calculated using the average reported speeds in the *Vacaville City Coach's Short Range Transit Plan FY 2021 – FY 2030* (Vacaville SRTP) and an assumed vehicle operator's shift of eight or 10 hours.

Current (similarly sized) BEBs on the market advertised range capabilities that exceed Vacaville City Coach, meaning it is possible that the existing service may be suitable to operate BEBs. Further analysis of BEB performance and suitability for Vacaville City Coach service will be conducted with service modeling (Task 2).

Table 7.4 Vacaville City Coach Demand Response Estimated Vehicle Service Statistics

Metric	Statistic
Annual Miles	83,331 miles
Annual Hours	6,422 hours
Average Daily Speed	13 mph
8-Hour Shift Distance	104 miles
10-Hour Shift Distance	130 miles

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

7.4 Facility Conditions

7.4.1 OPERATIONS AND MAINTENANCE

The Vacaville City Coach facility is located at 1001 Allison Drive. The transit operations share the site with the City of Vacaville Public Works Department.

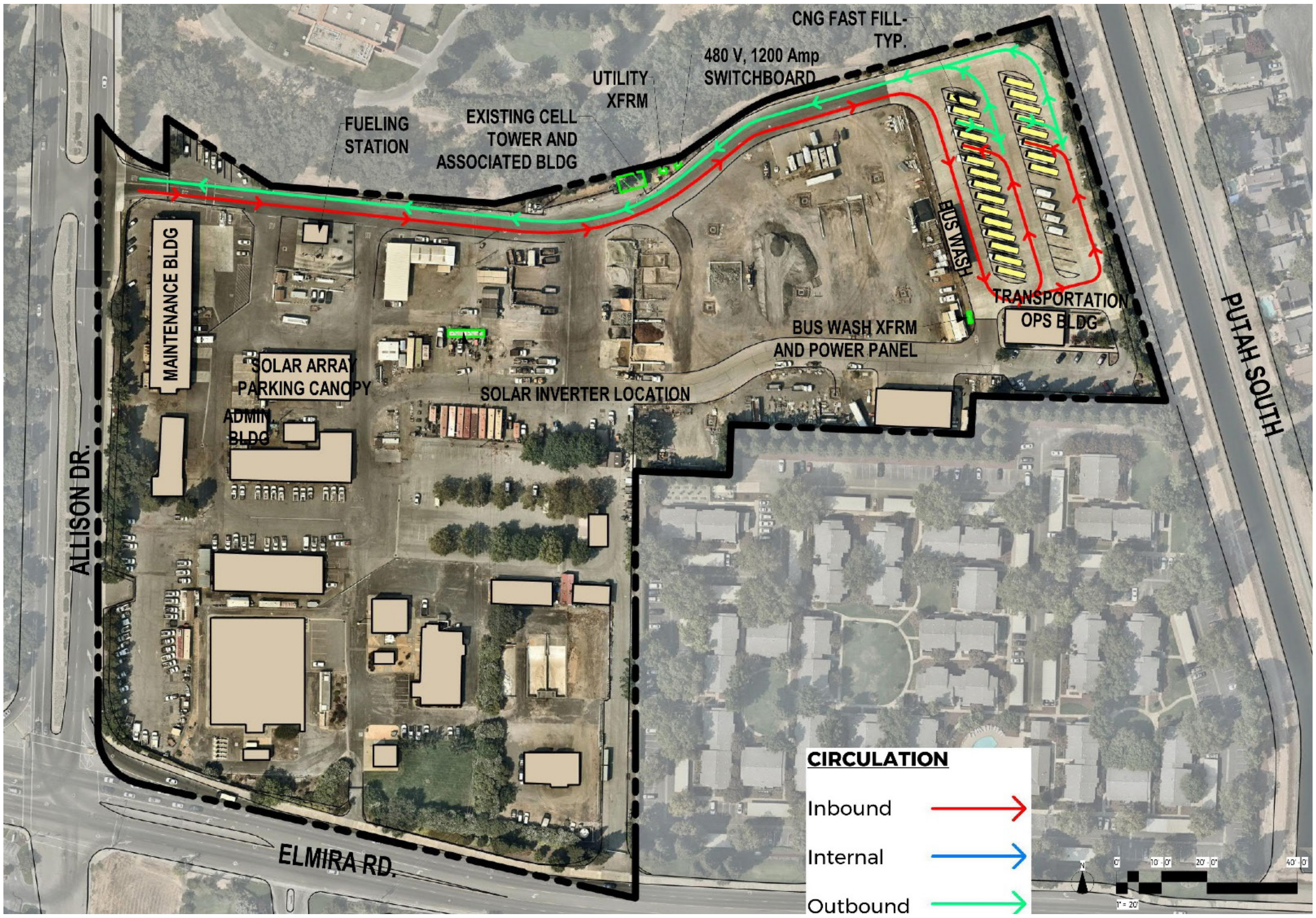
The maintenance building is located at the northwest corner of the site and services both transit vehicles and public works vehicles. The bus parking area is outfitted with seven fast fill CNG dispensers. There is also a fueling station near the facility's entrance that is equipped to provide fast fill CNG, diesel, and unleaded fuel, and is used by both transit and public works vehicles. A bus wash is located adjacent to the bus parking area and services only transit vehicles.

The transit operations portion of this site has the ability to support additional transit bus parking capacity. There are currently no new planned projects that would affect the transit area operations or negatively affect the electrification efforts. When transitioning to ZEB, the existing fast fill locations in the bus parking area will require special coordination to ensure that CNG fueling is not negatively impacted during transition phases.

Circulation

Transit vehicles enter the site from the main road along Allison Drive (Figure 7.3). Buses continue to the transit operations area at the far east end of the site and park into a stall of one of two pull-through parking rows. The western most row contains seven remote fast fill CNG dispensers that are used to fuel the bulk of the larger buses in their parking stalls. All other buses are fueled at the main public works shared fuel island at the west end of the site upon their return from their service and prior to proceeding to the parking area. A bus wash is located adjacent to the bus parking area and bus are periodically cycled through it. During pull-out, the buses exit via the main drive back to the exit at Allison Drive.

Figure 7.3 Vacaville City Coach Circulation Plan



Source: WSP

7.4.2 UTILITY CONDITIONS

Substation & Circuit

Vacaville City Coach's power is provided by the PG&E Vacaville Substation (6360), located approximately 2.4 miles from the transit yard. The substation has a capacity of 44.6 MW on Bank 2 with a peak load of approximately 37.8 MW based on publicly available data. This feeds the Vacaville 1105 circuit that feeds the Vacaville City Coach yard.

The 12 kV Vacaville 1105 Circuit has an existing capacity of 10.9 MW. PG&E estimates the projected peak load of this circuit as 9.2 MW, leaving approximately 1.7 MW of available capacity. The circuit enters the yard from Elmira Road along an unnamed street to the property.

Peak loads for the Vacaville 1105 feeder are monitored by PG&E and published on their ICA Map. Based on the ICA map, the load increases in summer months and has peaks at 6:00 PM to 7:00 PM from June to September. Once the fleet is electrified, the ZEBs on the site will most likely charge overnight, so this feeder profile should not affect Vacaville City Coach's electricity bill or peak demand charge.

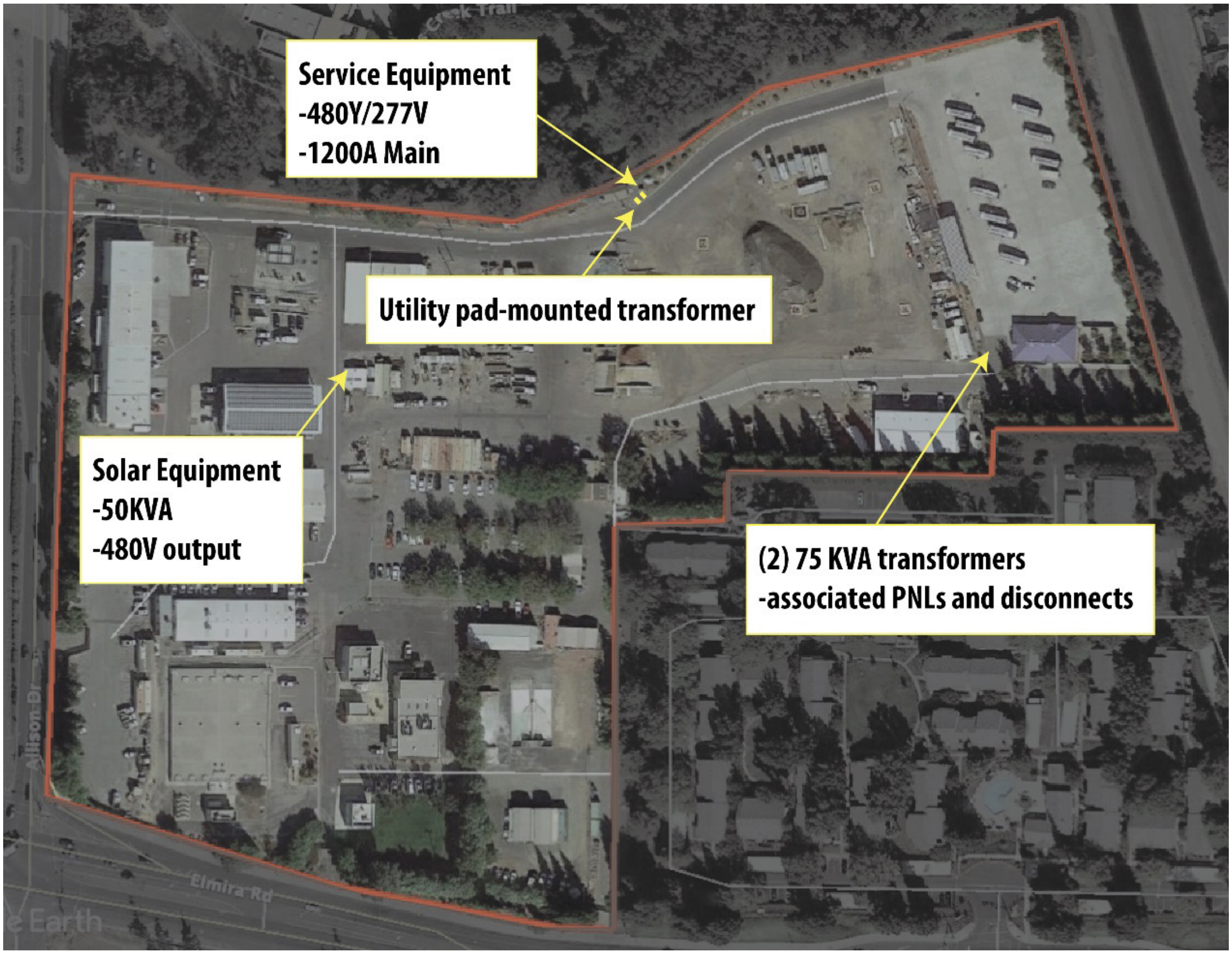
Transformers & Switchboard

The site has a utility pad-mounted transformer (T18142) in the site center (Figure 7.4). On the east side of the site, there are two 75 kVA transformers and their associated panelboards and disconnects. Onsite connections cannot be verified at this time.

There is one 1200 A 480 Y/277 V main switchboard service equipment with an estimate of three spare breakers. The switchboard schedule could not be verified at this time.

There is 50 kVA solar power with 480 V output and a Satcon 480 V DC-AC generator onsite. The 50 kVA solar panel's disconnect switch could not be verified, so it is assumed to always be connected and providing power to the site. As for the generator, its purpose and operations schedule are unknown. For the fleet size and the available onsite resources, resiliency is moderate to low. If necessary, the existing electrical infrastructure can power a small number of bus chargers while awaiting new utility service upgrades or outage restoration from PG&E.

Figure 7.4 Vacaville City Coach Utility Plan View



Source: WSP

Potential Enhancements

Due to the current low available circuit capacity and the expected energy demands after fleet electrification, it is highly likely that PG&E will need to perform significant upgrades to the 1105 circuit. It is advised to engage with PG&E as early as possible in this process. The facility might choose to phase in the ZEV transition as opposed to a mass fleet replacement since this will avoid waiting for PG&E to finish their feeder upgrade. This recommendation will be updated at later phases based on operational needs.

8 CONCLUSION AND NEXT STEPS

The Existing Conditions Analysis identified and established the baseline conditions for each Solano County transit agency as they pertain to: 1) service requirements; 2) facility operations and layout; and 3) energy usage and availability. It should be noted that the general findings of this analysis will be refined and further evaluated in subsequent tasks. Table 8.1 summarizes the initial findings for each agency.

Table 8.1 Summary of Existing Conditions

Agency	Service	Facility	Utilities
Dixon ReadiRide	• Operates (10) cutaways and vans for demand response service (only) • Daily range of 83103 miles • Range is within performance capabilities of existing ZE technology	• Shares facility with City of Dixon Public Works Dept. • Appears to have adequate space for charging infrastructure	• Existing circuit (Dixon 1103) estimated to have 1.3 MW of available capacity • Dixon 1102 (circuit) may also be utilized. • Utility upgrades are likely needed
Rio Vista Delta Breeze	• Operates (5) cutaways and vans for both fixedroute and demand response service • Fixed-Route daily average range of 83 miles; demand response range daily range of 90113 miles • Range is within performance capabilities of existing ZE technology	• Shares facility with City of Rio Vista Northwest Wastewater Treatment Plant • Appears to have adequate space for charging infrastructure	• Existing circuit (Grand Island 2226) estimated to have 8 MW of available capacity • Utility upgrades are likely not needed
SolTrans	• Operates (59) standard buses, cutaways, and coaches for both fixedroute and demand response service • Fixed-Route daily range of eight and 201 miles (average of 74) • All but one service block is under 150 miles • Demand response range daily range of 7593 miles • Range is within performance capabilities of existing ZE technology	• SolTrans has developed a Master Plan for a fullBEB retrofit of its existing facility and is currently in the process of implementing Phase 1 of that plan.	

Agency	Service	Facility	Utilities
Vacaville City Coach	• Operates (25) standard buses and cutaways for both fixedroute and demand response service • Fixed-Route daily range is 129 and 173 miles • Demand response range daily range between 104 and 130 miles • Range for all vehicles with the exception of 173mile blocks appears to be within performance capabilities of existing ZE technology	• Shares facility with City of Vacaville Public Works Department • Appears to have adequate space for charging infrastructure • Special coordination is required to ensure that CNG fueling is not negatively impacted during transition phases	• Existing circuit (1105) estimated to have 1.7 MW of available capacity • Utility upgrades are likely needed

Source: WSP

The findings of this report will be used to inform subsequent reports and analysis. The service data will be used for the Task 2: Service Modeling Analysis, the facility data will be used to develop concepts in Task 3: BEB Facility Concepts Analysis, and the utilities data will be used to develop solutions in Task 4: Power and Energy Analysis. All of this information will be used to estimates costs and generate transition strategies, Task 5 and 6, respectively. After coordination and collaboration with each agency, the findings and solutions proposed in Task 1-6 will be compiled into the *Countywide Electrification Transition Plan.*

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX B: SERVICE MODELING ANALYSIS

Solano Transportation Authority

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 2: SERVICE MODELING ANALYSIS

Final — September 2021

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Solano Transportation Authority

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Acronyms and Terms

Acronym or Term	Description
BEB	Battery-Electric Bus
Block	The work assignment for a single vehicle during a service workday
CARB	California Air Resources Board
CNG	Compressed Natural Gas
Efficiency	A measure of a vehicle's performance, expressed in kilowatt-hours per mile throughout this report
FAST	Fairfield and Suisun Transit
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GTFS	General Transit Feed Specification
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
MW	Megawatt
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas & Electric
SolTrans	Solano County Transit
STA	Solano Transportation Authority
ZE	Zero-Emission
ZEB	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040[1]. The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Plan* includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- Task 1: Existing Conditions Analysis
- **Task 2: Service Modeling Analysis (this report)**
- Task 3: BEB Facility Concepts
- Task 4: Power and Energy Analysis
- Task 5: Costs and Funding Analysis
- Task 6: Phasing Strategy and Transition Analysis
- Task 7: Countywide Electrification Transition Plan

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of this project's elements are incorporated in this project. FAST is currently developing the Fairfield Transition Electrification Transition Model Project, an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the Countywide Electrification Transition Plan; however, FAST's final report (expected in Summer 2021) will be incorporated into the final Countywide Electrification Transition Plan, which is anticipated to be completed by Q1 2022.

1.2 Report Purpose and Approach

The purpose of the Service Modeling Analysis is to determine the viability of operating Solano County's transit agencies' bus service and schedules with BEBs.

1 . CARB ICT Regulation (https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-regulation)

Currently, Solano County's transit agencies operate conventionally-fueled vehicles (compressed natural gas (CNG), gasoline, and diesel). These vehicles have ranges in excess of 300 miles, which is suitable for service blocks in Solano County. BEBs on the other hand, are unable to achieve these ranges. It is typically assumed that a 40-foot BEB has a range of approximately 150 miles, though this can vary based on specific route (block) characteristics and other consumption factors. The variation in performance makes it essential that the planning stages of BEB implementation include performance modeling of BEBs within existing (or planned) service to develop strategies that will reduce or eliminate negative impacts to service. When a service block cannot be completed with a BEB, agencies can consider making service adjustments, purchasing additional vehicles, incorporating opportunity charging (charging at stops while the bus is in service), procuring fuel cell electric buses (FCEBs) (FCEBs have ranges that align to conventionally-fueled vehicles), or delaying BEB integration until the technological advances meet range requirements.

WSP assessed the viability of operating BEBs by modeling Solano County transit agencies with Lightning Bolt, a proprietary, formula-based tool that determines the percentage of service that can be completed based on provided scheduling information, regional characteristics (elevations and climate), and various BEB-related vehicle and charging assumptions (battery capacities, charger types, etc.).

It should be noted that modeling results are contingent on both conservative and high-level inputs and assumptions (detailed in Section 2.2). Considering the rapid advancement of technology and the uncertainty of service schedules and trends in the future, it is recommended that these results be used for planning and informative purposes only. It is likely that results will be drastically different when agencies proceed with detailed design and implementation/procurement.

1.3 Report Structure

This report is organized into four main sections:

1. **Introduction –** Overview of *Countywide Electrification Transition Plan* and the Service Modeling Analysis
2. **Inputs and Methodology –** Overview of the modeling process, including inputs, assumptions, and approach
3. **Agency-Specific Sections –** Presents each agency's service modeling analysis results
   a. Dixon Readi-Ride
   b. Rio Vista Delta Breeze
   c. SolTrans
   d. Vacaville City Coach
4. **Conclusion and Next Steps –** Summarizes the findings of the report and outlines next steps

2 INPUTS AND METHODOLOGY

The following section provides an overview of the inputs (data and assumptions), methodology, and outputs used to determine the viability of operating BEBs with Solano County transit agencies' existing service schedules.

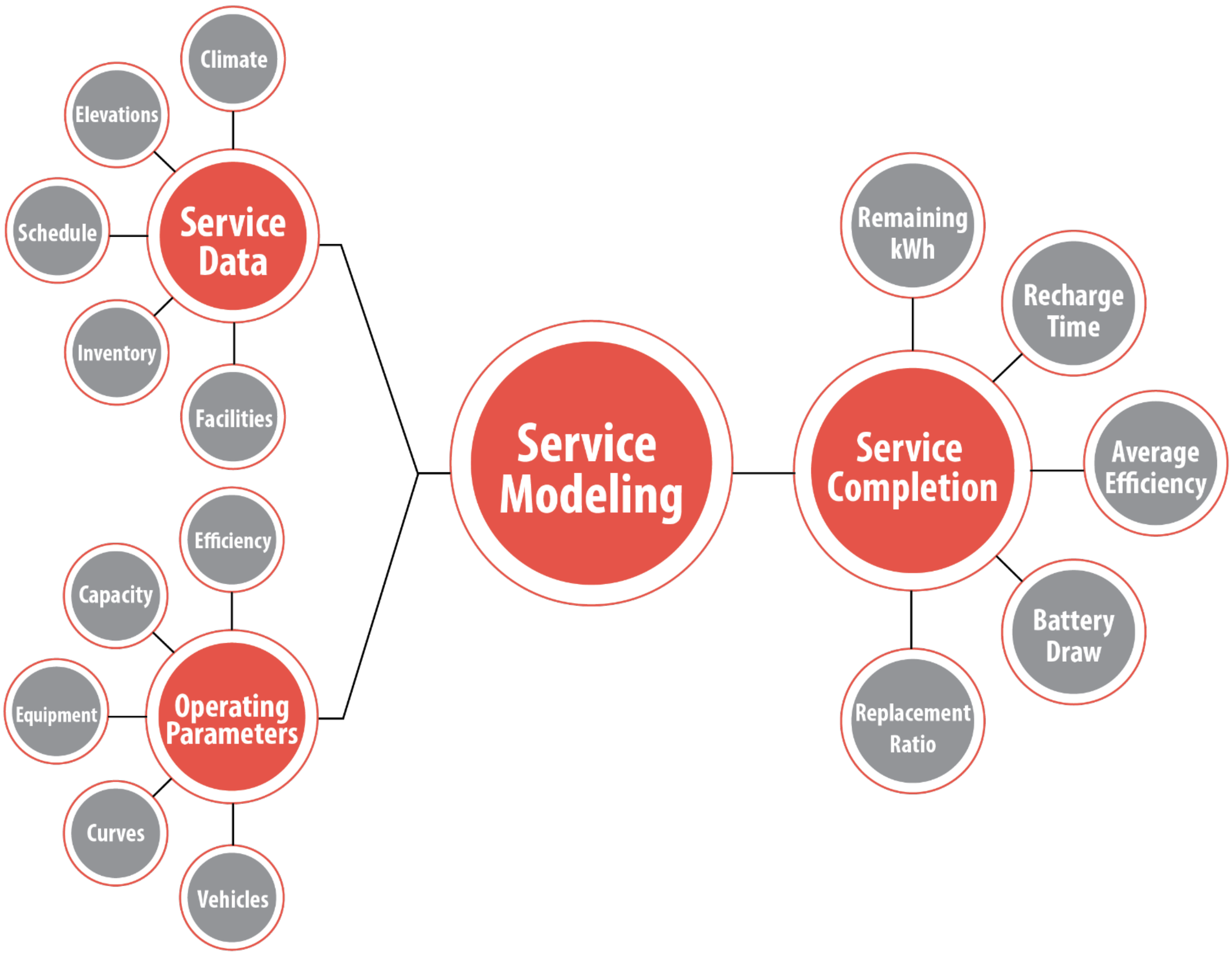
2.1 Modeling Overview

Lightning Bolt is a proprietary modeling tool developed by WSP to evaluate the feasibility of operating BEBs within a transit agency's existing bus schedule. The tool considers and analyzes several factors that may impact the performance of a BEB, including the specific operating conditions of an agency (topography, climate, and bus service schedule), charging and battery capacity parameters, and the extent to which all of these factors would improve or reduce performance (Figure 2.1).

Lightning Bolt uses these inputs to determine the percent of service that can be completed under two scenarios: "typical" and "conservative." The outputs are on a block-level scale and provide a clearer picture of the feasibility of electrifying an agency's vehicle fleet. If the modeled BEB "fails" to complete service, the output captures the degree of failure and the factors that contributed to that failure, from which WSP presents preliminary solutions (ex. additional vehicle purchases, innovative charging solutions, and/or schedule changes). Although range is currently a challenge for existing BEB technology, recent trends have indicated a 6% improvement in range and capacity every year.[2] The results of modeling and this report will be used to inform both short- and long-term operating and procurement strategies as the agency transitions its fleet.

2 https://rmi.org/insight/breakthrough-batteries/

Figure 2.1 Lightning Bolt Model Overview



Source: WSP

2.2 Data and Assumptions

The inputs used for the model fall into two categories: service data and operating parameters. Service data generally includes existing bus schedules, vehicle inventories, facility locations, elevations, and climate; whereas operating parameters refer to specific BEB assumptions and adjustments, including information on vehicles, charging, and batteries (power and capacity considerations). The following section details the service data and operating parameters established in the model.

2.2.1 SERVICE DATA

Schedules

Bus schedules are the foundation for modeling. Although schedules and service change over time, it is essential that an agency-preferred schedule is provided to establish a baseline for the modeling process.

For fixed-route bus services, this data is provided in the form of general transit feed specification (GTFS) files, automatic vehicle location (AVL) outputs, or other outputs that clearly identify characteristics of all trips and/or blocks. If not included in the scheduling data, the distance of non-revenue service trips is also necessary to fully account for all vehicle movements. While data may be provided for all service days, only weekday service is typically modeled. Most agencies elect this approach because weekdays typically have the highest peak vehicle requirements. While some blocks may be longer on the weekend, there usually are more vehicles available for service.

Since demand response travel times and distances are variable – and each agency tracks them differently – Lightning Bolt is not a suitable tool to assess the energy required. For these services, it is important to determine the "max" or "average" distance traveled by each vehicle to establish a baseline for assessing the energy required and making EV recommendations.

WSP coordinated with STA and each individual agency to confirm both fixed-route and demand response service schedules. Below is a summary of the fixed-route schedules used for each agency's baseline:

- Dixon Readi-Ride:
  a. No fixed-route service
  b. Demand response data extracted from FY 2021-2030 SRTP
- Rio Vista Delta Breeze:
  a. November 2019 GTFS
  b. Demand response data extracted from FY 2021-2030 SRTP
- SolTrans:
  a. December 2019 GTFS
  b. Demand response data extracted from FY 2021-2030 SRTP
- Vacaville City Coach:
  a. March 2020 GTFS
  b. Demand response data extracted from FY 2021-2030 SRTP

For demand response services, WSP extracted the annual revenue miles and operating hours from each agency's SRTP to calculate the average travel speed. This was then multiplied by an assumed eight- or 10-hour shift to establish the estimated range that demand response vehicles travel (per day).

Vehicle Inventory

There are many different types of BEBs available on the market, such as cutaway shuttles, 35-foot buses, 40-foot buses, double-decker buses, etc. Unless an agency specifies otherwise, the agency's existing vehicle inventory determines which types of BEBs are modeled for each service block. The vehicle inventory should list the OEM, length, gross vehicle weight rating (GVWR), the block and/or route that the vehicle operates on, and the facility that it operates from.

In this analysis, vehicle inventories for Dixon Readi-Ride, Rio Vista Delta Breeze, and Vacaville City Coach were sourced from each agency's 2021-2030 short range transit plan. The SolTrans vehicle inventory was sourced from its *2020 Revenue Fleet Listing* document. The different types of vehicles for each agency are presented in Table 21.

Table 2.1 Solano County Vehicle Summary

Agency	Vans	Cutaways	35-Foot Bus	40-Foot Bus	Coaches	Total
Dixon Readi-Ride	2	8	-	-	-	10
Rio Vista Delta Breeze	1	4	-	-	-	5
SolTrans	-	12	-	26	16	54
Vacaville City Coach	-	7	18	-	-	25

Source: Each agency's Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030, and GTFS Data

Facility Locations

The location/address of each facility is essential in 1) establishing non-revenue distances (if not provided), and 2) grouping blocks to establish summaries of service completion and energy usage.

The address and/or coordinates of each agency's facility was provided via email.

Elevations

Climbing hills and other landforms can negatively impact BEB performance and range – while going down a hill may help with replenishing the battery capacity via regenerative braking. For this reason, it is important to capture the topography that a service block traverses to account for the impacts to a BEB's range. To do so, WSP uses the United States Geological Survey (USGS) digital elevation profile.

USGS data was downloaded for the Solano County service area.

Climate

Ambient air temperature and the resulting HVAC usage is reported to have one of the greatest impacts on BEB efficiency. To ensure that the model is adequately addressing energy usage, weather data is gathered to gauge both low and high temperatures for a given service area; this informs the extent to which HVAC will be used in different operating conditions.

Climate data for Solano County was captured from the National Oceanic and Atmospheric Administration (NOAA). In this study, the annual average high (89° F) and low temperature (39° F) for the City of Fairfield were used to capture extreme conditions, while 73° F was used as the typical daytime temperature.

2.2.2 OPERATING PARAMETERS

Efficiency and Range

A BEB's performance is typically measured by its range (miles). This is a direct factor of its "efficiency," as expressed in kilowatt-hours per mile (kWh/mi.). A vehicle with a higher numerical efficiency has a shorter range, whereas a vehicle with a lower numerical efficiency has a longer range. Efficiencies can vary based on several factors, including:

- Battery health and state-of-charge (SOC)
- Operator driving behavior
- Temperature (HVAC usage)
- Speed traveled
- Vehicle weight / passenger load
- Route topography

Lightning Bolt analyzes the range using two scenarios – "typical" and "conservative" – to demonstrate how the BEBs may perform under different conditions. The distinction between the scenarios is based on more conservative estimates for three metrics that have proven to be very impactful on energy consumption: ambient air temperature, elevation gain, and number of stops. While the elevation gain or number of stops for each block remains the same in both, various factors (such as passenger load, weather, and driver behavior) impacts how much energy is consumed by those three metrics.

The model tailors these metrics using an agency's unique operating conditions and builds upon a baseline efficiency provided by Altoona reports (if available) or OEM specifications (which do not account for factors that impact BEB performance). These adjustments are made using data garnered from existing performance evaluations, research, and physics-based calculations. Though this analysis aims to capture significant influences on BEB performance, the applied metrics are not exhaustive and are limited to current published data and the methodologies used therein. The metrics and methodologies used in this analysis are outlined below.

Ambient air temperature: The model bases its calculations on average daytime as well as annual high and low temperatures in order to capture the area's typical and extreme climate conditions. Drawing upon existing research, the model estimates the power needs of HVAC under typical daytime operating conditions, as well as extreme high or low (whichever is most extreme) conditions.

Elevation gain: WSP applies an estimate for the additional energy required to move a loaded bus over each individual segment based on the degree of the slope and the bus weight with maximum occupancy (maximum gross vehicle weight, or MGVW). The accumulative slope energy required for each segment is assigned to each vehicle block's trips. Recaptured energy is also included in estimates for typical and conservative scenarios.

Stops: Energy consumption from stops throughout the block are accounted for using physics-based formulas to provide a tailored efficiency adjustment to every trip within a service block. The number of stops are calculated for each trip using GTFS data. The acceleration force (work) draws upon MGVW.

Battery Capacity

The *advertised capacity* of a battery differs from the *operating* (or usable) capacity that a battery offers. Thus, it is essential to clarify and establish the operating capacity of a battery to accurately assess range and performance. Generally, 10% or more of a battery's advertised capacity is deemed unusable by the OEM in order to support the health of the battery. Additional percentages may also be added to this safety buffer by the agency to reduce range anxiety for operators and mitigate impacts to service. Another benefit of providing a *safety buffer* is that the battery (while charging) can maximize the usage of a charger and reduce charging times (batteries typically receive peak power between 20% and 80% SOC). For the purposes of the analysis, WSP assumed that 80% of the advertised battery capacity is the operating (or usable) capacity of each battery.

It should be noted that batteries do degrade over time, effectively reducing the range. The rate of degradation varies based on usage, charge cycles, and battery state-of-charge. For this reason, degradation was not included in this analysis; however, the included safety buffer may support some of the lost range from battery degradation as the BEB enters the end of its warranty period. It is recommended that agencies ensure that battery degradation safeguards are incorporated into vehicle warranties and bus specifications to mitigate impacts to range. WSP can evaluate degradation impacts upon request.

Charging and Dispenser Specifications

There are several options for chargers, dispensers, and associated specifications at each agency's disposal. The power (kW), dispenser type (pantograph, plug-in, etc.), charging ratio (one charger to two dispensers, etc.), and how vehicles are charged (concurrently, sequentially, etc.) will be dictated by each agency's needs and will provide various outcomes for vehicle availability, service completion, and facility operations. All of these options are discussed with agencies and factored into the model.

Table 2.2 provides the assumptions in the model for each agency. These assumptions determine the time it takes to recharge the vehicles.

Table 2.2 Modeled Charger Scenarios

Agency	Charger kW (Advertised/ Modeled)	Dispenser Type	Charger Ratio	Charge Sequencing
Dixon-Readi Ride	150/135	Plug-In	1:2	Sequential
Rio Vista Delta Breeze	150/135	Plug-In & Pantograph	1:2	Sequential
SolTrans	80/72	Plug-In	1:1	Sequential
Vacaville City Coach	150/135	Plug-In & Pantograph	1:2	Sequential

Source: WSP

Note: On-route induction charging is being constructed for SolTrans's SolanoExpress. SolanoExpress is not modeled in this report.

Charging Curves

Each battery on a BEB has a "charge curve" that demonstrates the variations of power (kW) or acceptance rate that can be received over time while charging based on the vehicle's SOC. For instance, if a charger can provide a maximum of 150 kW, but the electric vehicle has an acceptance rate at 75 kW, then the vehicle will be charged at approximately 75 kW regardless of the charger's rated power.

The acceptance rate is dictated by a battery's chemistry – not the charger itself. Peak power draw often occurs between roughly 30% and 80% of a battery's SOC, with substantially reduced peak power draw from 80% to 100% (and especially reduced during the last 10% when the battery system is doing cell balancing). For instance, if a vehicle is connected to a 150 kW charger, it may receive a maximum charge rate close to 150 kW between 30% to 80% SOC, but a substantial lower power draw of around 30-50 kW during the last 10% of replenishment.

The charge curve is often OEM-specific and can vary by technology – making it difficult to forecast specific power outputs and thus, charging cycles. To account for varying charge curves and inefficiencies when calculating the time needed to recharge, WSP assumes a constant charge rate of 90% of the advertised power of the charger. Meaning, 150 kW chargers will provide 135 kW of power throughout the charge cycle.

Vehicles and Battery Capacities

Battery capacity and vehicle weight - and thus the range - vary by OEM and vehicle length. The battery assumptions in Lightning Bolt use an average from available vehicle models for each vehicle length. This approach captures an estimation of the current state of the technology and provides flexibility when selecting vehicle models (a level of OEM-agnosticism). It is important to note that BEB technology is rapidly advancing, thus larger battery capacities and improvements in performance may be available by the release of this report.

Table 2.3 shows all three types of BEBs used to model service for Solano County transit agencies. This list is not exhaustive: some available models were excluded because their stated range was below the respective agency's service block lengths

Table 2.3 Replacement BEB Inventory Used In Lightning Bolt

<table>
<tr><th>Vehicle Type</th><th>EV Replacement</th><th>Range (mi.)</th><th>Battery Capacity (kWh)</th><th>Average Capacity / Operating Capacity (kWh)</th></tr>
<tr><td>Cutaway</td><td>GreenPower EV Star</td><td>150</td><td>118</td><td>118 / 94</td></tr>
<tr><td rowspan="4">35'</td><td>BYD K9S</td><td>157</td><td>266</td><td rowspan="4">377 / 301</td></tr>
<tr><td>Proterra ZX5+</td><td>240</td><td>450</td></tr>
<tr><td>New Flyer Charge NG</td><td>175</td><td>350</td></tr>
<tr><td>New Flyer Charge NG</td><td>220</td><td>440</td></tr>
<tr><td>40'</td><td>BYD K9M</td><td>156</td><td>324</td><td>324 / 259</td></tr>
</table>

Source: WSP

2.3 Analysis and Outputs

Once service data is collected, a database of trips/blocks is developed to catalog and consolidate an agency's service schedule. Lightning Bolt then incorporates the operating parameters (as defined above) to each trip/block in the database and calculates the energy required to complete service. The outcomes show whether or not – and to what extent – the service can be completed with a 1:1 vehicle replacement using existing technology.

Lightning Bolt outputs the percentage of each service block that can be completed based on the assumed operating parameters. Based on this information, several other metrics and data can be extracted from the results, such as: the remaining kWh at the end of each block (if applicable), the amount of time it would take to recharge the battery, the average efficiency of the block, bus replacement ratios, and the determination of what factors are the largest impacts on battery consumption (distance, elevation, HVAC usage, etc.).

Using the Lightning Bolt results, WSP can provide preliminary recommendations on how to complete the service. If the block barely fails to complete service, slight service changes or minor advancements in technology may be the solution. For more severe shortfalls, additional buses or pull-outs may be necessary. Modeling results are a function of the inputs and should not be used to guide purchasing decisions. It is recommended that demonstration or pilot projects be implemented to support procurement decisions.

Although there are multiple mitigation options for failed blocks, the output includes a vehicle replacement ratio that assumes no measures are taken. For example, if a service block can be 90% completed by a single BEB, then a second bus is needed, resulting in a replacement ratio of 1:2. If a service block can only be 45% completed, then the replacement ratio will be 1:3. The following sections summarize the modeling results for each Solano County agency.

DIXON READI-RIDE

3 DIXON READI-RIDE

Dixon Readi-Ride operates demand response service. The fleet consists of 10 vehicles: two vans and eight cutaways.

The following section presents an overview of Dixon Readi-Ride's modeling results. The vans were not included in the following analysis because their GVWR is below 14,000 pounds, and thus they are not subject to the CARB ICT requirements.

3.1 Demand Response

As discussed in Section 2.2.1, the vehicle miles traveled for demand response services are variable, so the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the estimated daily mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 83 and 103 miles (Table 3.1).

Table 3.1 Dixon Readi-Ride – Demand Response Estimated Vehicle Service Statistics

Metric	Existing Daily Range	Advertised BEB Range
8-Hour Shift Distance	83 miles	150 miles
10-Hour Shift Distance	103 miles	150 miles

Source: Dixon Readi-Ride Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Based on the advertised range of existing battery electric cutaways (presented in Table 2.3), Dixon Readi-Ride should be able to operate its demand response service with no or minimal impact. The GreenPower EV Star – a representative BEB replacement for Dixon Readi-Ride's existing vehicles - has an advertised range of 150 miles. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service.

However, it should be noted that this estimate is based on the advertised range and assumed travel distances. It does not consider HVAC usage, slope, and other service area-specific variables. For example, the GreenPower EV Star has been modeled with Lighting Bolt on fixed-routes for other Solano County transit agencies. The characteristics of the route have resulted in the range being greatly reduced, in some cases lower than what is required of Dixon Readi-Ride's 103-mile threshold.

For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

RIO VISTA

DELTA BREEZE

4 RIO VISTA DELTA BREEZE

Rio Vista Delta Breeze operates two types of service: demand response, and fixed-routes. The demand response service is run with one cutaway bus, while the fixed-route service consists of four service blocks across two routes and uses three cutaway buses.

The following section presents an overview of Rio Vista Delta Breeze's modeling results.

4.1 Fixed-Route Service

Rio Vista Delta Breeze currently operates cutaway buses for their fixed-route services. The representative BEB replacement that was modeled is the GreenPower EV Star, which has a 118 kWh battery (94 kWh is usable) and a stated range of 150 miles (resulting in a battery efficiency of 0.79 kWh/mile). Rio Vista Delta Breeze's four service blocks range in distance from 58 to 134 miles.

4.1.1 BLOCK COMPLETION

Typical Scenario

Based on a "typical" scenario, it is expected that three of the four blocks could be completed by a single cutaway BEB. Block 1 is the only failing block in this scenario. At 134 miles, Block 1 is just within the stated range of the BEB, however due to variables such as slope and weather, the battery efficiency is only sufficient to complete 81% of the block. Table 4.1 presents a summary of the energy demands for each block. It is assumed that each block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 0.79 kWh/mile due to the additional consumption factors. A further breakdown of these consumption factors is detailed below in Figure 4.1.

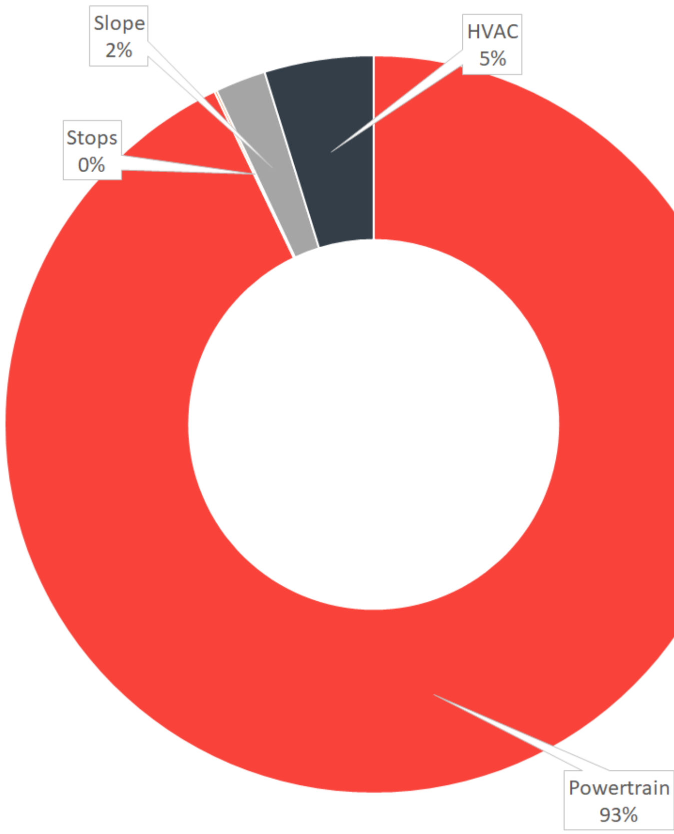
Table 4.1 Rio Vista Delta Breeze – Summary of Blocks – Typical Scenario

Block ID	Distance (miles)	Required Battery Capacity (kWh)	% of Block Completed	State of Charge Remaining	Efficiency Change (kWh/mi)
1	134	117	81%	N/A	0.08
2	59	50	100%	47% (44 kWh)	0.06
3A	70	58	100%	38% (36 kWh)	0.04
3B	70	59	100%	38% (36 kWh)	0.05

Source: WSP

Figure 4.1 provides a breakdown of the impact that each consumption factor has on Rio Vista's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and averages 93% of the total energy consumption. HVAC usage for this scenario reflects a fair-weather day, and accounts for 5% of the total energy consumption per block. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

Figure 4.1 Rio Vista Delta Breeze – Block Consumption Factors – Typical Scenario



Source: WSP

Table 4.2 summarizes the amount of time it would take to recharge vehicles that have completed blocks based on two charging scenarios. The first, represents a 1:1 (charger to dispenser) configuration – which would maximize power and reduce charging times (with potentially higher operational costs), and the second represents a 1:2 configuration that has slightly longer charging times, but with potential lower operational costs. For the Block 1 bus that depletes its battery, it will take 42 minutes to recharge the usable battery with a 1:1 configuration, and 84 minutes with a 1:2 configuration.

Table 4.2 Rio Vista Delta Breeze – Time Needed to Recharge Completed Blocks – Typical Scenario

Block ID	Required Battery Capacity (kWh)	State of Charge Remaining	Charging time at 135 kW (mins)	Charging time at 67.5 kW (mins)
2	50	47% (44 kWh)	22	45
3A	58	38% (36 kWh)	26	52
3B	59	38% (36 kWh)	26	52

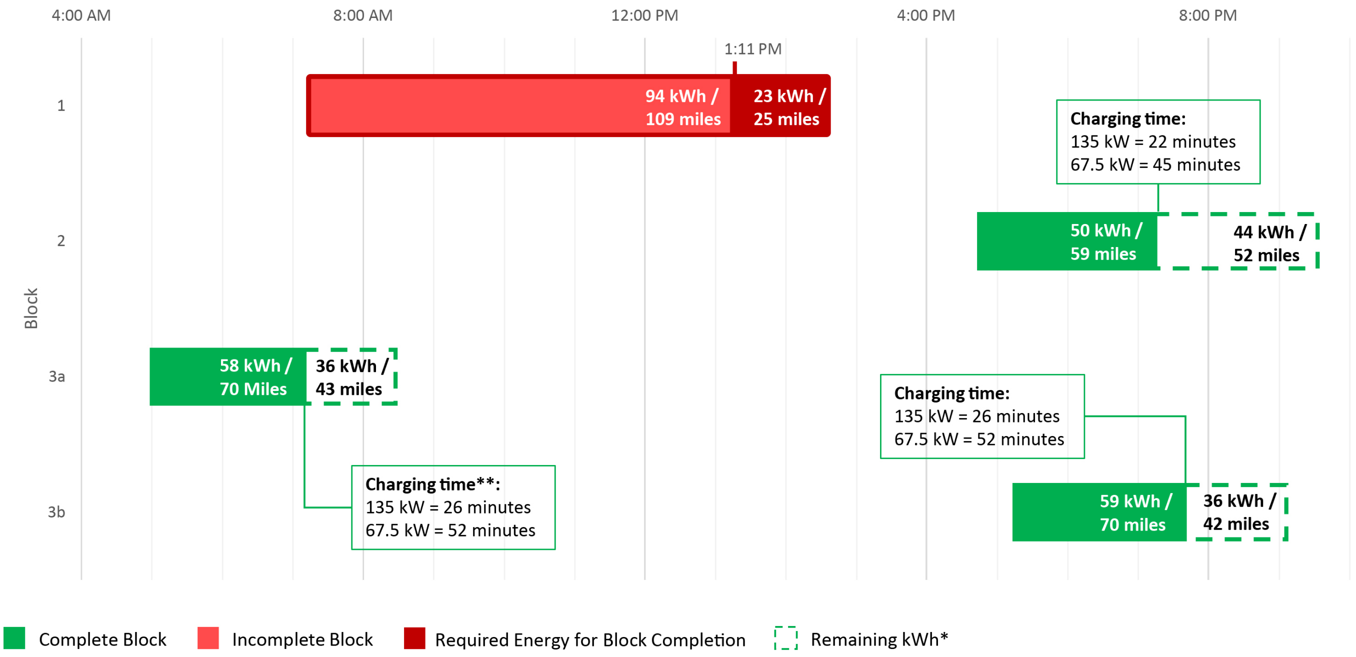
Source: WSP

Note: Charging is based on 150 kW charger at 90% efficiency.

Figure 4.2 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period. This information provides insight into charging infrastructure requirements and opportunities to optimize service planning.

Based on the fleet charging analysis, strategic vehicle-to-block assignments may mitigate the need to increase the vehicle replacement ratio for the failing block (Block 1). Block 1 is estimated to run out of battery at around 1:11 PM, and one of the other three vehicles can pull-out to complete the service. Even Block 3A, which completes at 7:15 AM, could complete Block 1 since it can fully recharge before 1:11 PM.

Figure 4.2 Rio Vista Delta Breeze – Blocks by Start and End Times – Typical Scenario



* Service end-time is based on a hypothetical scenario of 100% energy capacity use and does not reflect actual service hours
** The 135 kW and 67.5 kW charging rates are based on 1:1 and 1:2 charger: dispenser ratios, respectively

Source: WSP

Conservative Scenario

The conservative scenario does not reflect typical conditions, but instead is aimed at reflecting worst-case scenarios (for example, during extreme weather) and accounts for greater energy impacts from HVAC usage, elevation gain, and number of stops.

It is expected that three of the four blocks could be completed by a single vehicle. Block 1 is still the only failing block in this scenario. Table 4.3 presents a summary of the energy demands for each block. It is assumed that each block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 0.79 kWh/mile due to the additional consumption factors. A further breakdown of these consumption factors is detailed below in Figure 4.3.

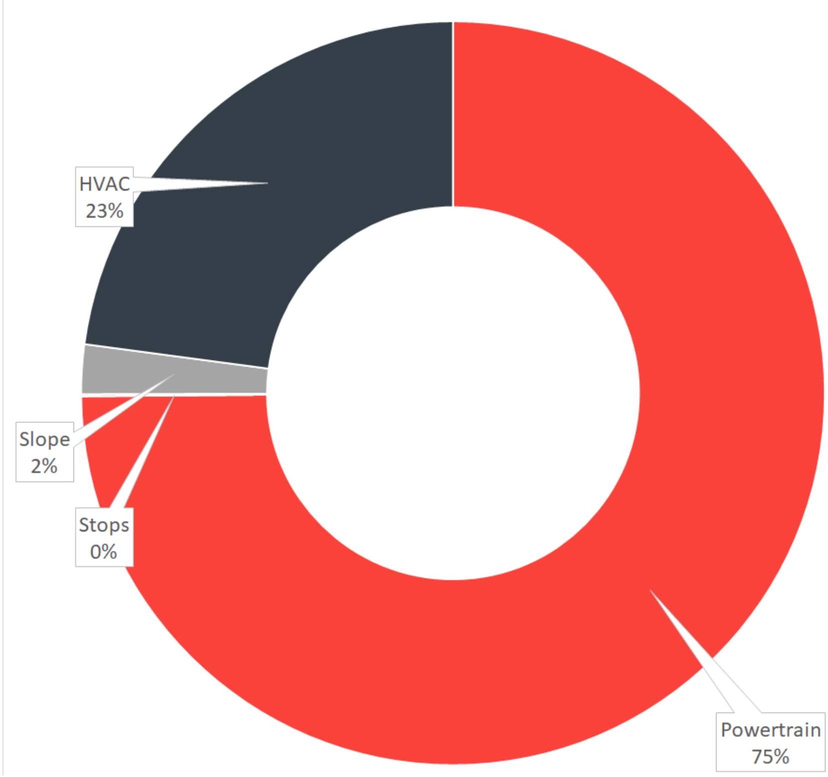
Table 4.3 Rio Vista Delta Breeze – Summary of Blocks – Conservative Scenario

Block ID	Distance (miles)	Battery Capacity Needed (kWh)	% of Block Completed	State of Charge Remaining	Average Change (kWh/mi)
1	134	154	61%	N/A	.0.36
2	59	63	100%	34% (32 kWh)	0.27
3A	70	69	100%	26% (25 kWh)	0.20
3B	70	71	100%	25% (23 kWh)	0.23

Source: WSP

Figure 4.3 provides a breakdown of the impact that each consumption factor has on Rio Vista's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and averages 75% of the total energy use per block.HVAC usage for this scenario reflects extreme weather conditions, and accounts for 23% of the total energy consumption. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

Figure 4.3 Rio Vista Delta Breeze – Block Consumption Factors – Conservative Scenario



Source: WSP

Table 4.4 summarizes the amount of time it would take to recharge vehicles that have *completed* blocks based on two charging scenarios. The first, represents a 1:1 (charger to dispenser) configuration – which would maximize power and reduce charging times (with potentially higher operational costs), and the second represents a 1:2 configuration that has slightly longer charging times, but with potentially lower operational costs.

Table 4.4 Rio Vista Delta Breeze – Time Needed to Recharge Completed Blocks – Conservative Scenario

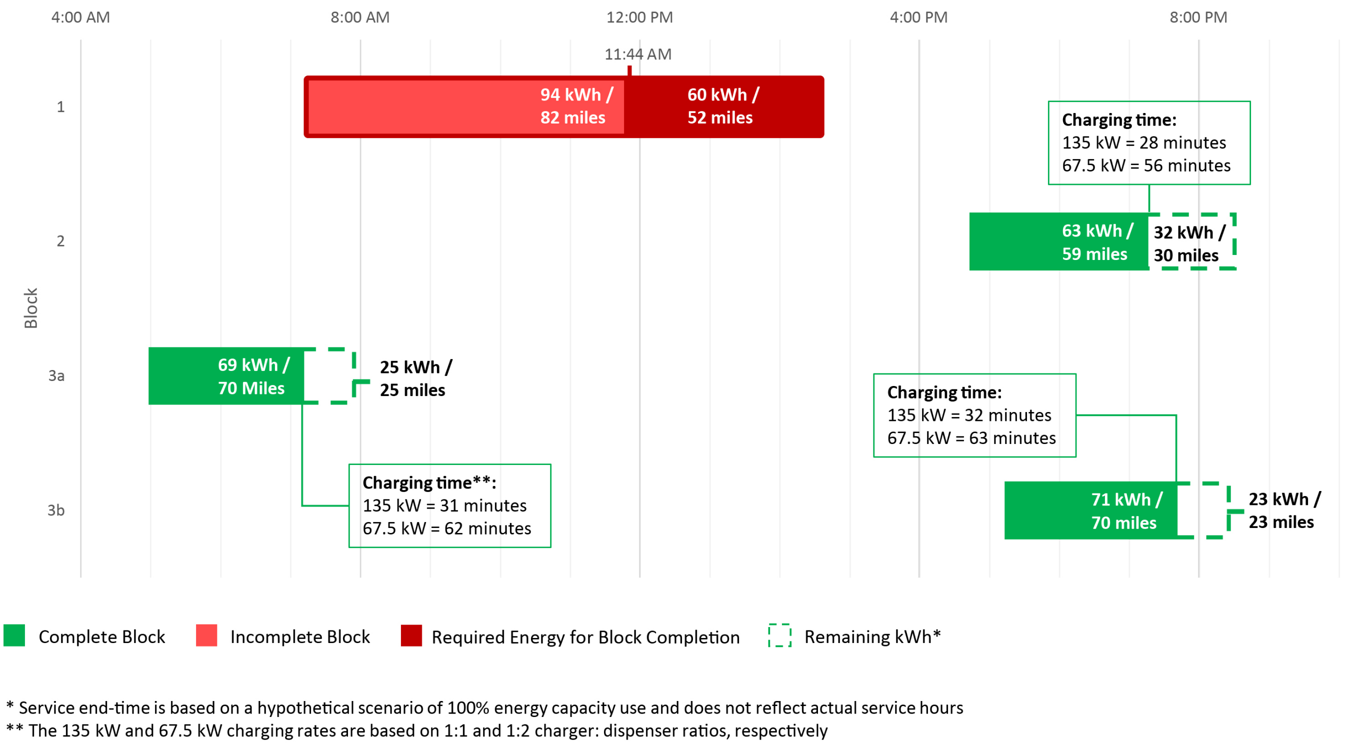
Block ID	Battery Capacity Needed (kWh)	State of Charge Remaining	Charging time at 67.5 kW (mins)	Charging time at 135 kW (mins)
2	63	34% (32 kWh)	56	28
3A	69	26% (25 kWh)	62	31
3B	71	25% (23 kWh)	63	32

Source: WSP

Figure 4.4 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period. This information provides insight into charging infrastructure requirements and opportunities to optimize service planning.

Based on the fleet charging analysis, strategic vehicle-to-block assignments may mitigate the need to increase the vehicle replacement ratio for the failing block (Block 1). Block 1 is estimated to run out of battery at around 11:44 AM, one of the other three vehicles can pull-out to complete the service. Even Block 3A, which completes at 7:15 AM, could complete Block 1 since it can fully recharge before 11:44 AM.

Figure 4.4 Rio Vista Delta Breeze – Blocks by Start and End Times – Conservative Scenario



Source: WSP

4.2 Demand Response

As discussed in Section 2.2.1, the vehicle miles traveled for demand response services are variable, so the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the estimated daily mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 90 and 113 miles (Table 4.5).

Table 4.5 Rio Vista Delta Breeze – Demand Response Estimated Vehicle Service Statistics

Metric	Existing Daily Range	Advertised BEB Range
8-Hour Shift Distance	90 miles	150 miles
10-Hour Shift Distance	113 miles	150 miles

Source: Rio Vista Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Based on the advertised range of existing BEBs (presented in Table 2.3), Rio Vista Delta Breeze should be able to operate its demand response service with no or minimal impact. The GreenPower EV Star – a representative BEB replacement for Rio Vista Delta Breeze's existing vehicles - has an advertised range of 150 miles. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service.

However, it should be noted that this estimate is based on the advertised range and assumed travel distances. It does not consider HVAC usage, slope, and other service area-specific variables. For example, the GreenPower EV Star has been modeled with Lighting Bolt on fixed-routes for Rio Vista Delta Breeze. The characteristics of the route, in some cases, have resulted in the range being greatly reduced, in some cases, to lower than what is required of Rio Vista Delta Breeze's 113-mile threshold.

For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

4.3 Summary

For fixed-route service in both the typical and the conservative scenarios, only one of the four blocks failed (Block 1). Based on the existing service schedule and assumed charging times, Block 1 can be completed by pulling out an additional vehicle. While this will require additional analysis and cost considerations, this would allow Rio Vista Delta Breeze to maintain a 1:1 fleet replacement ratio.

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of Rio Vista Delta Breeze; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

If an additional pull-out to complete Block 1 isn't viable, there are several other considerations to meet the service:

- Additional Service changes
- Wait for advancements in BEB technology
- Select a vehicle that has higher battery capacity than the average used in the model
- On-route charging

It should be noted that technology is rapidly evolving and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended in order to assess actual performance.

5 SOLANO COUNTY TRANSIT

Solano County Transit (SolTrans) operates four types of service: demand response, local fixed-routes, SolanoExpress, and the intercity SF Express. The demand response service is run with 12 cutaways, while the fixed-route service consists of 42 service blocks across 16 routes and uses 26 40-foot buses. The SolanoExpress service uses 16 45-foot coach buses; however, the service is excluded from the scope of this study.

5.1 Fixed-Route Service

SolTrans currently operates 40-foot buses for their fixed-route services. The BEB currently being procured is a BYD K9M, which has a 324 kWh battery and a stated range of 156 miles (resulting in an average battery efficiency of 2.08 kWh/mile). This is the vehicle that is modeled in this analysis. SolTrans's 42 service blocks range in distance from eight to 201 miles.

5.1.1 BLOCK COMPLETION

Typical Scenario

Based on a "typical" scenario, it is expected that 38 of the 42 blocks could be completed by a single 40-foot BEB, while four blocks fail to complete the service block. The four failing blocks are some of the longest, both in distance and time. Table 5.1 presents a summary of the energy demands for the failing blocks (see Appendix A for a summary of all blocks). It is assumed that the block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 2.08 kWh/mile due to the additional consumption factors. A further breakdown of these consumption factors is detailed below in Figure 5.1.

Table 5.1 SolTrans – Summary of Failed Blocks – Typical Scenario

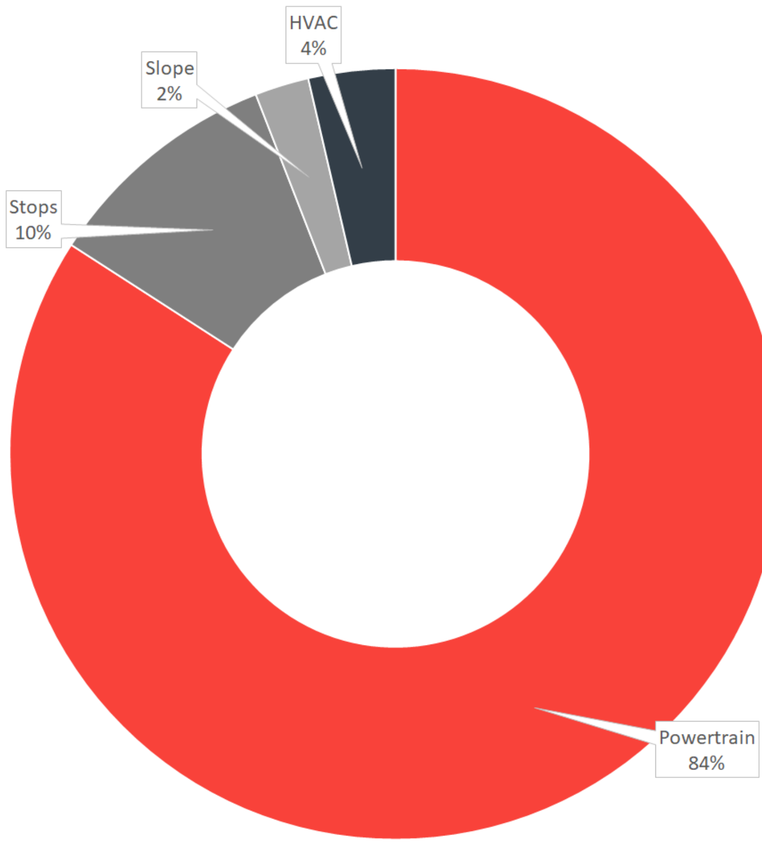
Block ID	Distance (Miles)	Time (Hours)	Battery Capacity Needed (kWh)	% of Block Completed	Efficiency Change (kWh/mi)
1	201	15:28	505	51%	0.43
118017	129	11:24	314	83%	0.35
118023	106	10:48	269	96%	0.46
118049	111	9:41	274	95%	0.39

Source: WSP

Two of the failed blocks are 95% & 96% complete, and one is 86% complete. With minor service changes or advancements in BEB technology, these blocks can likely achieve completion. However, without service changes, on-route charging, or other range-extending strategies, the fleet size would likely need to be increased.

In terms of accounting for the energy consumption of different variables, there was very little variation between the completed and failed blocks. Thus, Figure 5.1 provides a breakdown of the impact that each consumption factor has on SolTrans's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and represents an average of 84% of the total energy per block. HVAC usage for this scenario reflects a fair-weather day, and accounts for 4% of the total energy consumption. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

Figure 5.1 SolTrans – Overall Consumption Factors – Typical Scenario

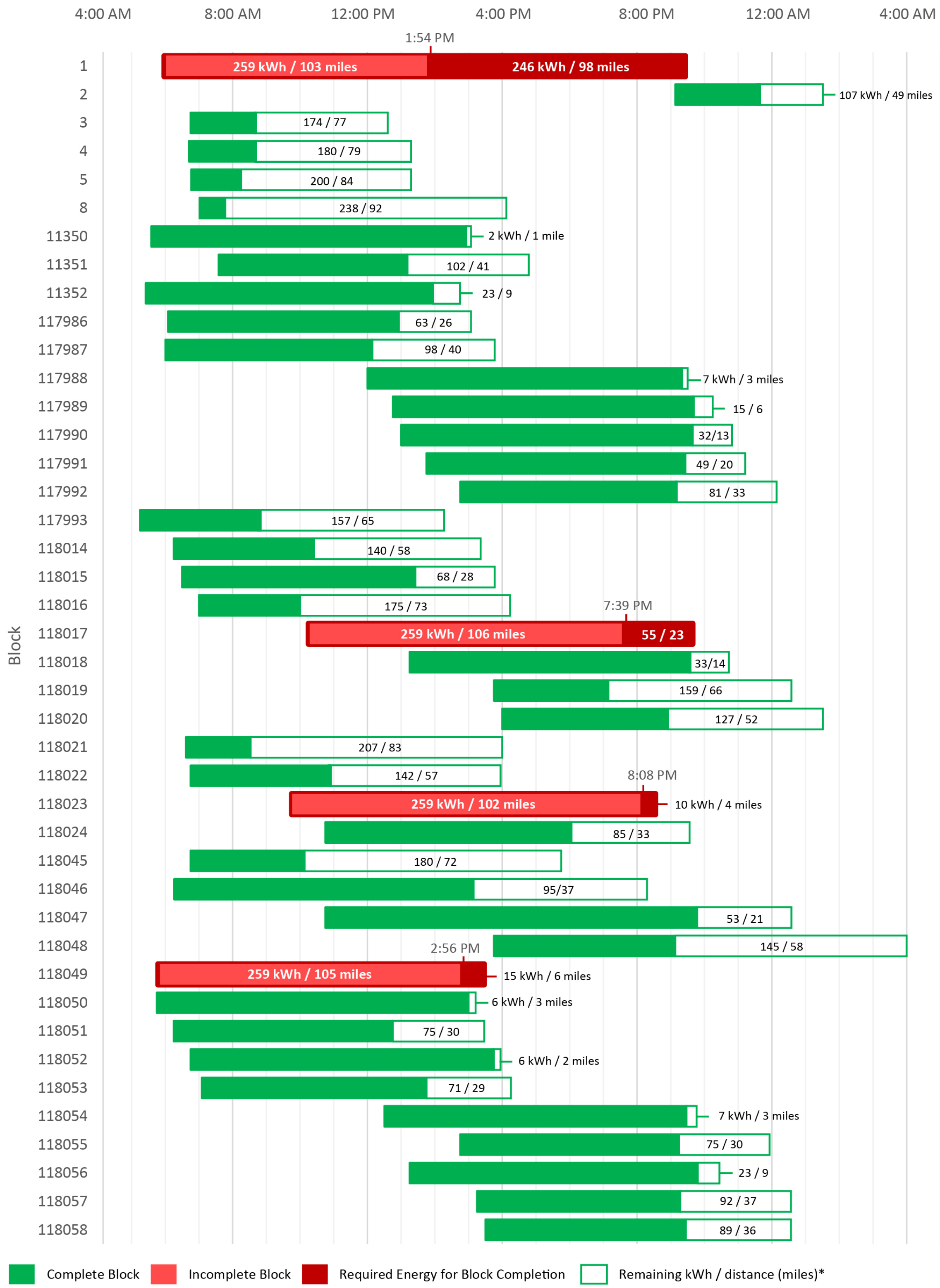


Source: WSP

Figure 5.2 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period (see the Appendix for a summary of charging times for each block). This information provides insight into charging infrastructure requirements and opportunities to optimize service planning.

Based on the fleet charging analysis, strategic vehicle-to-block assignments may mitigate the need to increase the vehicle replacement ratio for the failing blocks. For example, Block 1 is estimated to run out of battery at around 1:54 PM – with 98 miles remaining in the block. Based on the analysis, there are several vehicles/blocks that may make an additional pull-out to complete Block 1's service, including Block 5 and Block 8.

Figure 5.2 SolTrans – Blocks by Start and End Times – Typical Scenario



* Service end-time is based on a hypothetical scenario of 100% energy capacity use and does not reflect actual service hours

Source: WSP

Conservative Scenario

The conservative scenario does not reflect typical conditions, but instead is aimed at reflecting worst-case scenarios (for example, during extreme weather) and accounts for greater energy impacts from HVAC usage, elevation gain, and number of stops. It is expected that 27 of the 42 blocks could be completed by a single 40-foot BEB, with 15 blocks failing.

Table 5.2 presents a summary of the energy demands for the 15 blocks that failed (see Appendix A for a summary of all blocks). It is assumed that each block is operated by a single vehicle.

Table 5.2 SolTrans – Summary of Failed Blocks – Conservative Scenario

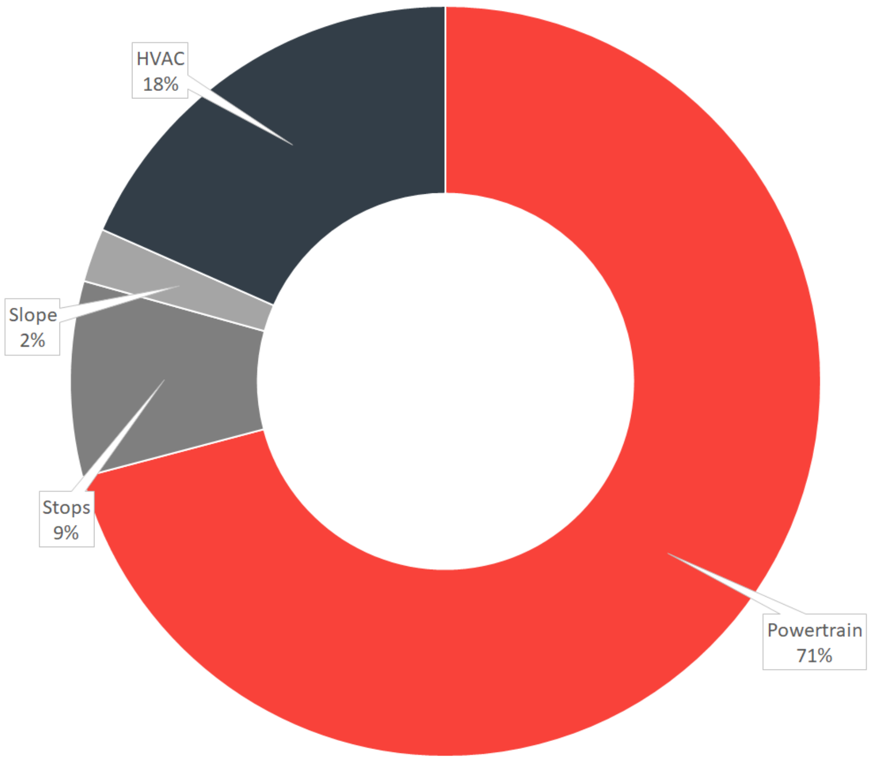
Block ID	Distance (Miles)	Time (Hours)	Battery Capacity Needed (kWh)	Efficiency Change (kWh/mi)	% of Block Completed
1	201	15:28	584	0.83	44%
11350	103	9:21	305	0.89	85%
11352	95	8:31	280	0.87	93%
117988	101	9:20	300	0.89	86%
117989	98	8:56	290	0.88	89%
117990	91	8:39	271	0.90	96%
118017	129	11:24	373	0.81	70%
118018	93	8:20	269	0.81	96%
118023	106	10:48	325	0.99	80%
118047	81	11:01	262	1.16	99%
118049	111	9:41	323	0.84	80%
118050	102	9:13	300	0.87	86%
118052	102	9:00	299	0.86	87%
118054	102	8:58	299	0.85	87%
118056	96	8:32	280	0.84	93%

Source: WSP

Five of the failed blocks are between 90-99% complete, and seven blocks are between 80-90%. With minor service changes or advancements in BEB technology, these blocks can likely achieve completion. However, without service changes, on-route charging, or other range-extending strategies, the fleet size would likely need to be increased.

Figure 5.3 provides a breakdown of the impact that each consumption factor has on SolTrans's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and represents an average of 71% of the total energy per block. HVAC usage for this scenario reflects extreme weather conditions, and accounts for 18% of the total energy consumption. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

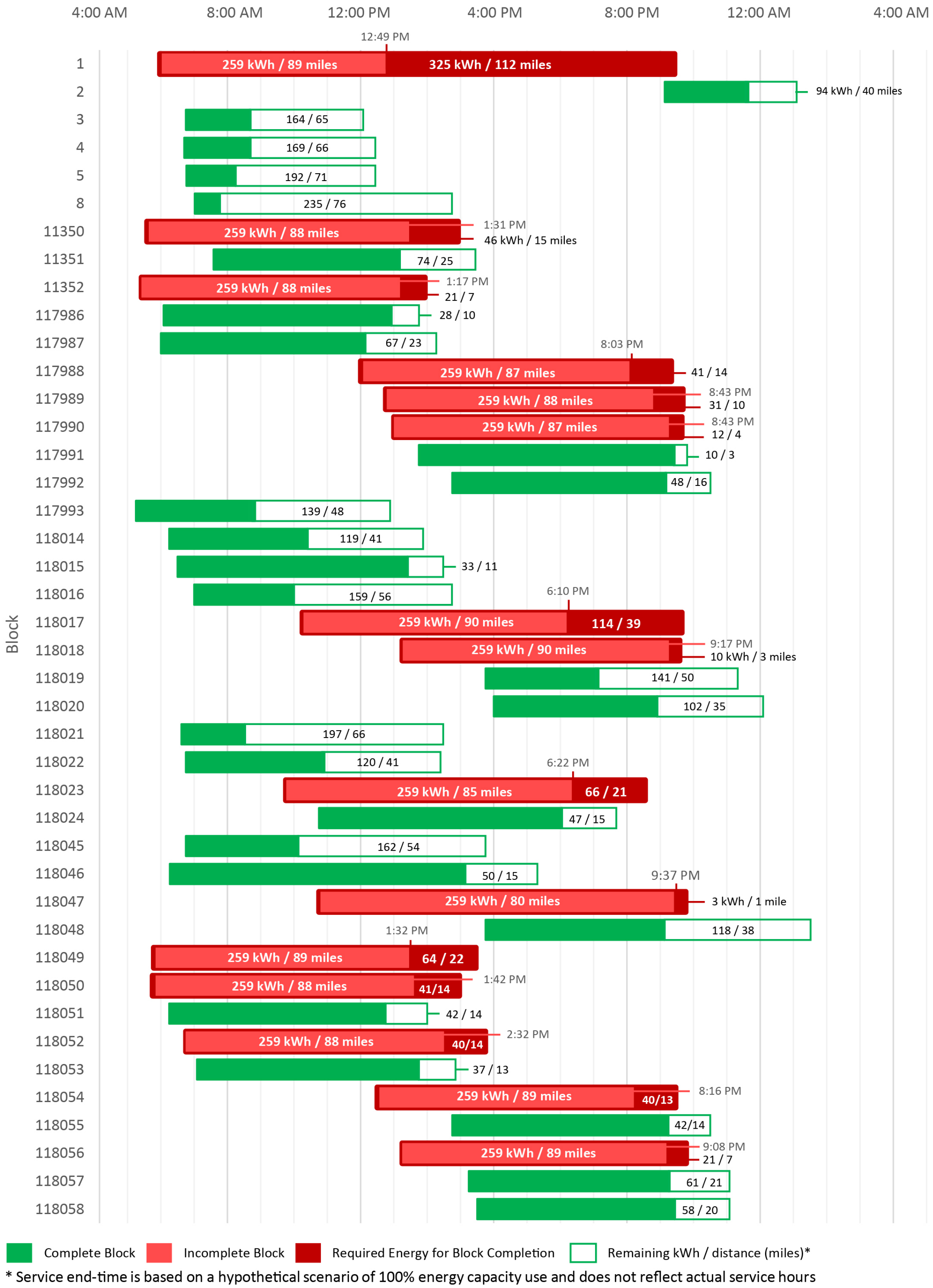
Figure 5.3 SolTrans – Overall Consumption Factors – Conservative Scenario



Source: WSP

Figure 5.4 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period. This information provides insight into charging infrastructure requirements and opportunities to optimize service planning.

Figure 5.4 SolTrans – Blocks by Start and End Times – Conservative Scenario



Source: WSP

5.2 Demand Response

As discussed in Section 2.2.1, the vehicle miles traveled for demand response services are variable, so the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the estimated daily mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 75 and 90 miles (Table 5.3).

Table 5.3 SolTrans – Demand Response Estimated Vehicle Service Statistics

Metric	Existing Daily Range	Advertised BEB Range
8-Hour Shift Distance	75 miles	150 miles
10-Hour Shift Distance	93 miles	150 miles

Source: SolTrans Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Based on the advertised range of existing BEBs (presented in Table 2.3), SolTrans should be able to operate its demand response service with no or minimal impact. The GreenPower EV Star – a representative BEB replacement for SolTrans's existing vehicles - has an advertised range of 150 miles. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service.

However, it should be noted that this estimate is based on the advertised range and assumed travel distances. It does not consider HVAC usage, slope, and other service area-specific variables. For example, the GreenPower EV Star has been modeled with Lighting Bolt on fixed-routes for other Solano County transit agencies. The characteristics of the route have resulted in the range being greatly reduced, in some cases, to lower than what is required of SolTrans's 93-mile threshold.

For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

5.3 Summary

For fixed-route service, only four blocks failed under the typical scenario, while 15 blocks failed under the conservative scenario. While additional analysis and cost considerations are required, it is possible that SolTrans can make service changes to have additional vehicles pull-out to help reduce the percentage of incomplete blocks.

There are various mitigation measures to consider for the failing blocks:

- Additional Service changes
- Wait for advancements in BEB technology
- Select a vehicle that has higher battery capacity than the average used in the model
- On-route charging

It should be noted that technology is rapidly evolving and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended in order to assess actual performance.

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of SolTrans; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

CITY COACH

6 VACAVILLE CITY COACH

Vacaville City Coach operates two types of service: demand response, and fixed-routes. The demand response service is run with seven cutaways, while the fixed-route service consists of two service blocks across two routes and has 18 35-foot buses (the 18 buses were previously used across six fixed-use routes). The following section presents the results of the simulation model for Vacaville City Coach's service blocks, showing blocks completed and fleet requirements.

The following section presents an overview of Vacaville City Coach's modeling results.

6.1 Fixed-Route Service

Vacaville City Coach currently operates 35-foot buses for their fixed-route services. The EV alternatives to these vehicles average a 376 kWh battery and a stated range of 199 miles (resulting in an average battery efficiency of 1.88 kWh/mile). Assuming that 80% of the battery is usable, this amounts to 301 kWh. Vacaville City Coach's two service blocks are 125 miles (Block ID 19690) and 172 miles (Block ID 19688).

6.1.1 BLOCK COMPLETION

Typical Scenario

Based on the service analysis running a "typical" scenario, it is expected that Block 19688 cannot be completed by a single BEB, while Block 19690 can be completed. While both blocks are within the average stated range of the replacement BEBs, due to variables such as slope and weather, the battery efficiency is not sufficient to complete the block. Table 6.1 presents a summary of the energy demands for each block. It is assumed that each block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 1.88 kWh/mile due to the additional consumption factors. A further breakdown of these consumption factors is detailed below Figure 6.1.

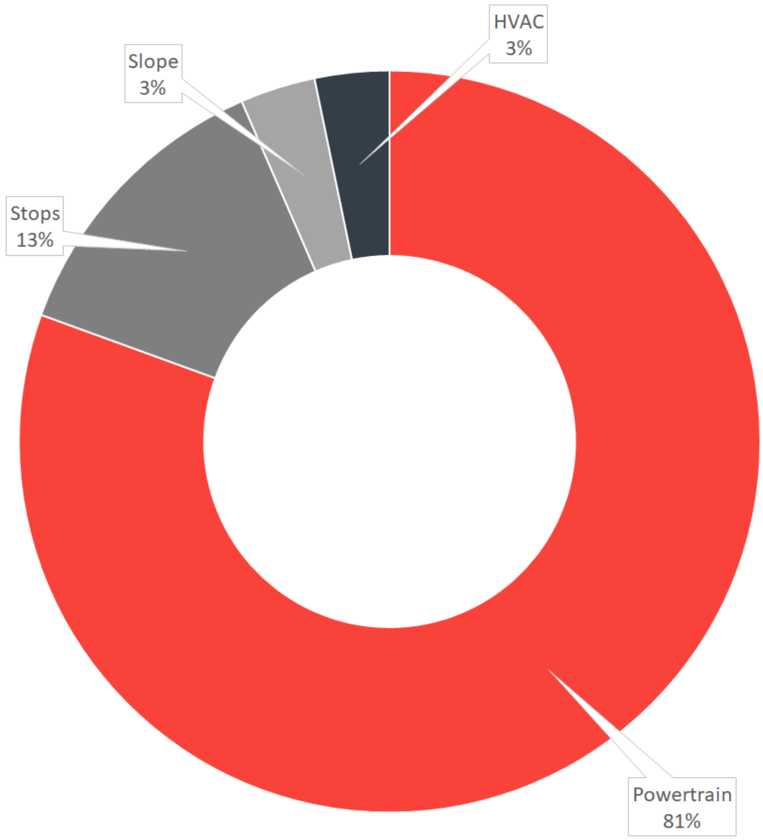
Table 6.1 Vacaville City Coach – Summary of Blocks – Typical Scenario

Block ID	Distance (miles)	Required Battery Capacity (kWh)	% of Block Completed	State of Charge Remaining	Efficiency Change (kWh/mi)
19688	172	399	75%	N/A	0.44
19690	125	293	100%	3% (8 kWh)	0.46

Source: WSP

Figure 6.1 provides a breakdown of the impact that each consumption factor has on Vacaville City Coach's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and averages 81% of the total energy consumption. HVAC usage for this scenario reflects a fair-weather day, and accounts for 3% of the total energy consumption per block. Stops accounts for 13% of total energy consumption. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

Figure 6.1 Vacaville City Coach – Block Consumption Factors – Typical Scenario



Source: WSP

Table 6.2 summarizes the amount of time it would take to recharge vehicles that have completed blocks based on two charging scenarios. The first, represents a 1:1 (charger to dispenser) configuration – which would maximize power and reduce charging times (with potentially higher operational costs), and the second represents a 1:2 configuration that has slightly longer charging times, but with potentially lower operational costs. For the Block 19688 bus that depletes its battery, it will take 2:14 hours to recharge the usable battery with a 1:1 configuration, and 4:28 hours with a 1:2 configuration.

Table 6.2 Vacaville City Coach – Time Needed to Recharge Completed Blocks – Typical Scenario

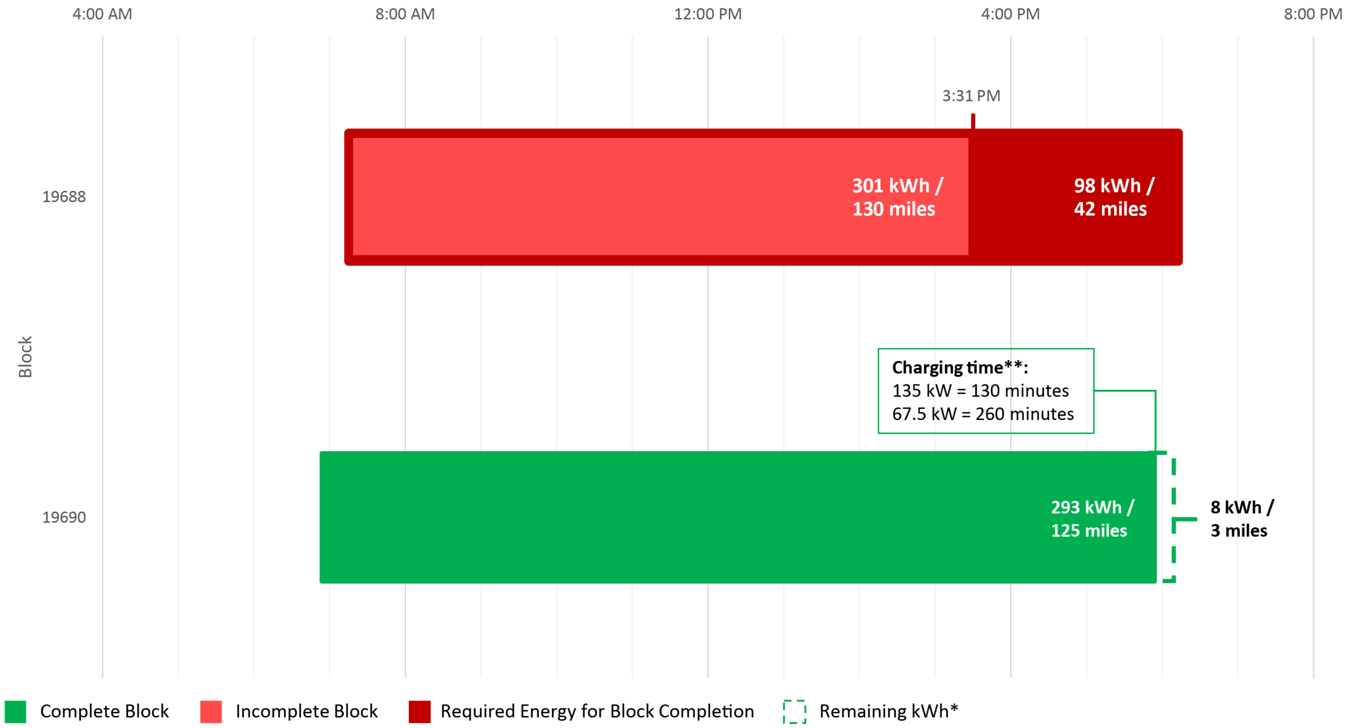
Block ID	Battery Capacity Needed (kWh)	State of Charge Remaining	Charging time at 67.5 kW (hours)	Charging time at 135 kW (hours)
19690	293	3% (8 kWh)	4:20	2:10

Source: WSP

Figure 6.2 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period. This information provides insight into charging infrastructure requirements and opportunities to optimize service planning.

Based on the fleet charging analysis, one additional vehicle would be required for Block 19688 to meet service.

Figure 6.2 Vacaville City Coach – Blocks by Start and End Times – Typical Scenario



* Service end-time is based on a hypothetical scenario of 100% energy capacity use and does not reflect actual service hours
** The 135 kW and 67.5 kW charging rates are based on 1:1 and 1:2 charger: dispenser ratios, respectively

Source: WSP

Conservative Scenario

The conservative scenario does not reflect typical conditions, but instead is aimed at reflecting worst-case scenarios (for example, during extreme weather) and accounts for greater energy impacts from HVAC usage, elevation gain, and number of stops.

It is expected that 66% (Block ID 19688) and 86% (Block ID 19690) of each block could be completed by a single 35-foot BEB based on current BEB technology (Table 6.3). Similar to the typical scenario, solutions for achieving completion would include pulling additional vehicles out or on-route charging at route termini.

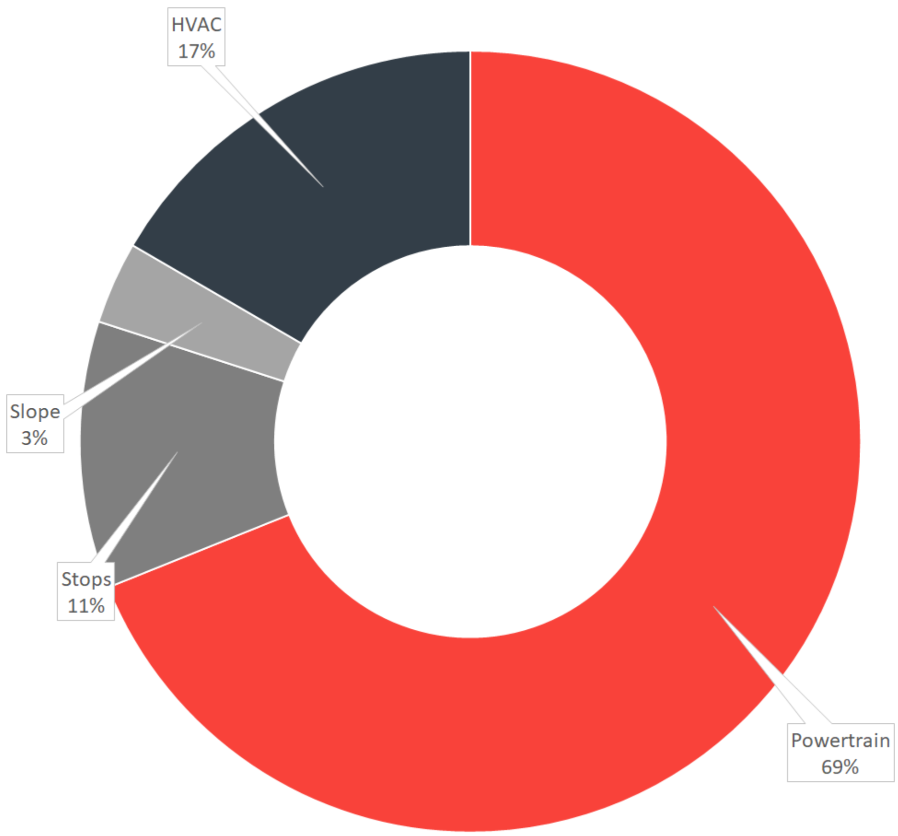
Table 6.3 Vacaville City Coach – Summary of Blocks – Conservative Scenario

Block ID	Distance (miles)	Time (Hours)	Battery Capacity Needed (kWh)	% of Block Completed	Efficiency Change (kWh/mi)
19688	172	10:58	457	66%	0.77
19690	125	11:00	350	86%	0.92

Source: WSP

Figure 6.3 provides a breakdown of the impact that each consumption factor has on Vacaville City Coach's average efficiency. The "powertrain" factor is based on the time and distance traveled on the block, and represents an average of 69% of energy per block. HVAC usage for this scenario reflects a fair-weather day, and accounts for 17% of the total energy consumption. Some of the additional energy depleted due to climbing inclines is recaptured through regenerative braking while going downhill.

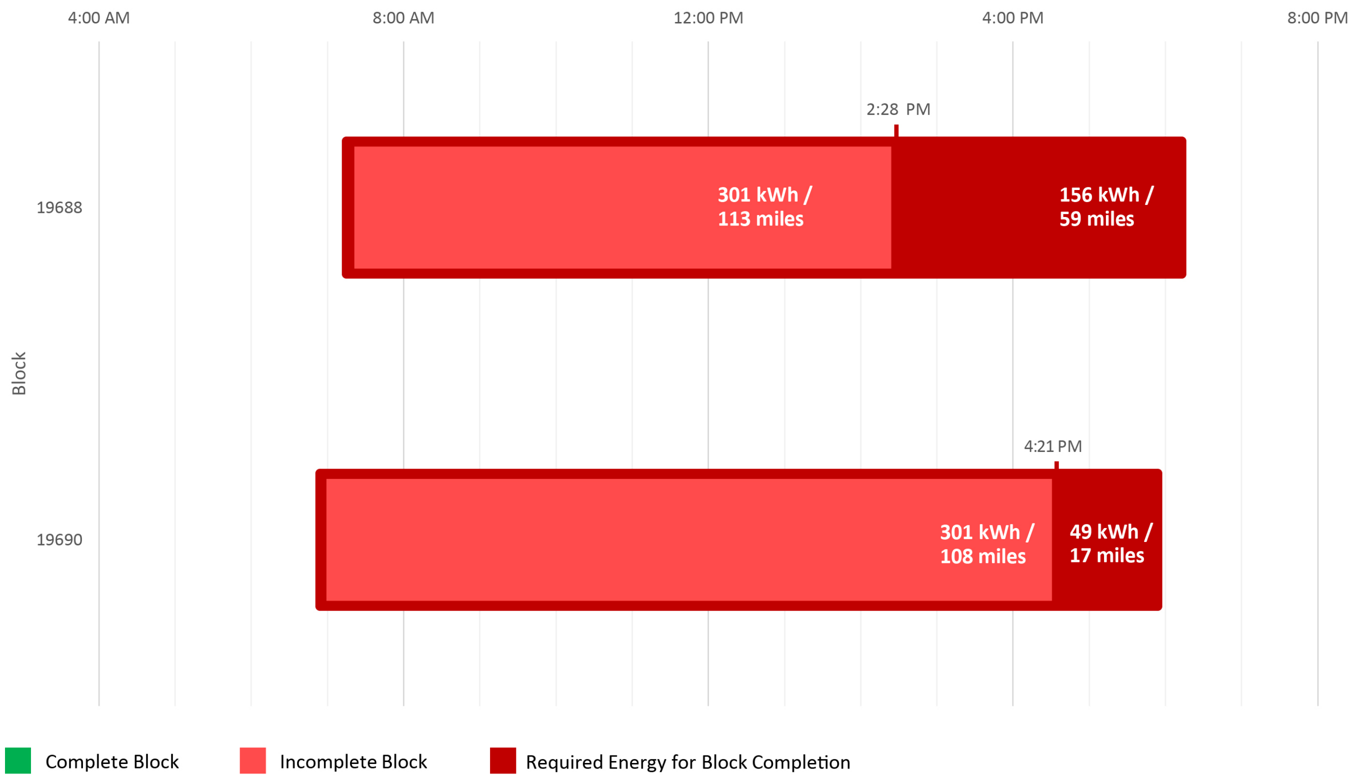
Figure 6.3 Vacaville City Coach – Block Consumption Factors – Conservative Scenario



Source: WSP

Figure 6.4 illustrates the timespan of each service block, the estimated energy used on each block, and when each vehicle will pull back into the facility at the end of the service period. This information provides insight into charging infrastructure requirements and opportunities to optimize service planning. In this scenario, each block would require an additional vehicle to meet service.

Figure 6.4 Vacaville City Coach – Blocks by Start and End Times – Conservative Scenario



Source: WSP

6.2 Demand Response

As discussed in Section 2.2.1, the vehicle miles traveled for demand response services are variable, so the Lightning Bolt model could not be used. In lieu of this, WSP conducted a high-level analysis of range expectations using the estimated daily mileage traveled by the fleet.

Based on the average travel speeds (calculated from data provided in the SRTP and an assumed eight or 10-hour vehicle operator shift), the average daily vehicle distance is between 104 and 130 miles (Table 6.4).

Table 6.4 Vacaville City Coach – Demand Response Estimated Vehicle Service Statistics

Metric	Existing Daily Range	Advertised BEB Range
8-Hour Shift Distance	104 miles	150 miles
10-Hour Shift Distance	130 miles	150 miles

Source: Vacaville City Coach Short Range Transit Plan Fiscal Year 2021 – Fiscal Year 2030

Based on the advertised range of existing BEBs (presented in Table 2.3), Vacaville City Coach should be able to operate its demand response service with no or minimal impact. The GreenPower EV Star – a representative BEB replacement for Vacaville City Coach's existing vehicles - has an advertised range of 150 miles. Even with consideration to a 20% safety buffer, the advertised range of the BEB still exceeds the average distance traveled for its demand response service.

However, it should be noted that this estimate is based on the advertised range and assumed travel distances. It does not consider HVAC usage, slope, and other service area-specific variables. For example, the GreenPower EV Star has been modeled with Lighting Bolt on fixed-routes for other Solano County transit agencies. The characteristics of the route, in some cases, have resulted in the range being greatly reduced, in some cases, lower than what is required of Vacaville City Coach's 130-mile threshold.

For this reason, it is recommended that more specific vehicle travel information be analyzed and/or a demonstration pilot be conducted to gauge real-world performance.

6.3 Summary

One service block in the typical scenario failed, and both failed in the conservative scenario. Under both scenarios, additional pull-outs from spares at the facility could support the service, while small advancements in battery technology could reduce the additional vehicles required to meet the service.

If additional pull-outs to complete service aren't viable, there are several other considerations to meet the service:

- Additional Service changes
- Wait for advancements in BEB technology
- Select a vehicle that has higher battery capacity than the average used in the model
- On-route charging

It should be noted that technology is rapidly evolving and modeling may not reflect actual performance – especially when it is time to procure vehicles. Demonstration pilots and real-world applications are recommended in order to assess actual performance.

For demand response, existing technology appears to be sufficient to meet the average daily range requirements of Vacaville City Coach; however, it is difficult to forecast specific consumption factors due to the variability of vehicle travel on a daily basis.

7 CONCLUSION AND NEXT STEPS

The Service Modeling Analysis is based on existing vehicle specifications, and with technology rapidly evolving, the results are subject to change.

This report calculated the average baseline battery efficiencies for each agency's vehicle types, and then modeled those vehicles on the blocks while accounting for additional consumption factors. The results were provided as "typical" and "conservative" scenarios. Even then, the typical scenario may be considered rather conservative, and should be supplemented and confirmed with actual pilot projects.

The demand response analysis was much simpler, based on average daily mileage ranges. More precise data is required for a more nuanced model.

Table 7.1 summarizes the initial findings for each agency. For all of the failing blocks in the fixed-route services, the following mitigation measures can be considered:

- Service changes
- Additional pull-outs
- Wait for advancements in BEB technology
- Selecting a bus that has higher capacity than the average in the model
- On-route charging

Table 7.1 Summary of Modeling Results

Agency	Fixed-Route – Typical Scenario	Fixed-Route – Conservative Scenario	Demand Response
Dixon Readi-Ride	No fixed-route service	No fixed-route service	• Assumed BEB replacement has an advertised range of 150 miles, which is expected to meet existing range of 83 to 103 miles
Rio Vista Delta Breeze	• One of four blocks failed • Additional pull-out and/or vehicle	• One of four blocks failed • Additional pull-out and/or vehicle	• Assumed BEB replacement has an advertised range of 150 miles, which is expected to meet existing range of 93 to 113 miles
SolTrans	• Four failing blocks • Additional pull-out and/or additional vehicles required	• 15 failing blocks • Additional pull-outs and/or additional vehicle(s) required	• Assumed BEB replacement has an advertised range of 150 miles, which is expected to meet existing range of 75 to 93 miles
Vacaville City Coach	• One failing block • Additional pull-outs and/or additional vehicle required	• Two failing blocks • Additional pull-outs and/or additional vehicle(s) required	• Assumed BEB replacement has an advertised range of 150 miles, which is expected to meet existing range of 104 to 130 miles

Source: WSP

APPENDIX A

SolTrans Block Summary

APPENDIX A – SOLTRANS BLOCK SUMMARY

The following tables contain the summaries of blocks for SolTrans, for both the typical and conservative scenarios. Each summary table is followed by a summary of charging times for the completed blocks.

Typical Scenario

Based on a "typical" scenario, it is expected that 38 of the 42 blocks could be completed by a single 40-foot BEB. The following table presents a summary of the energy demands for each block. It is assumed that each block is operated by a single vehicle. The "Efficiency Change" column shows how much the efficiency has declined from the baseline of 2.08 kWh/mile due to the additional consumption factors.

The table also estimates the amount of time it would take to recharge vehicles that have *completed* blocks. The charger in this calculation is an 80 kW charger at 90% efficiency – reflecting the actual chargers that SolTrans has procured for its BEB fleet. For failing blocks, it will take 3:36 hours to recharge a fully depleted battery.

SolTrans – Summary of Blocks – Typical Scenario

Block ID	Distance (miles)	Required Battery Capacity (kWh)	% of Block Completed	State of Charge Remaining	kWh of Battery Remaining	Efficiency Change (kWh/mi)	Charging Time at 72 kW (hours)
1	201	505	51%	0%	0	0.43	N/A
2	70	152	100%	41%	107	0.09	2:06
3	38	85	100%	67%	174	0.17	1:11
4	35	79	100%	69%	180	0.19	1:06
5	25	60	100%	77%	200	0.31	0:49
8	8	21	100%	92%	238	0.52	0:17
11350	103	257	100%	1%	2	0.42	3:34
11351	63	157	100%	40%	102	0.41	2:10
11352	95	236	100%	9%	23	0.41	3:16
117986	79	196	100%	24%	63	0.40	2:43
117987	65	161	100%	38%	98	0.40	2:14
117988	101	252	100%	3%	7	0.42	3:29
117989	98	244	100%	6%	15	0.41	3:23
117990	91	227	100%	13%	32	0.41	3:08
117991	84	210	100%	19%	49	0.42	2:54
117992	72	178	100%	31%	81	0.40	2:28
117993	42	102	100%	61%	157	0.36	1:25
118014	49	119	100%	54%	140	0.35	1:39

118015	79	191	100%	26%	68	0.34	2:39
118016	35	84	100%	67%	175	0.33	1:10
118017	129	314	83%	0%	0	0.36	N/A
118018	93	226	100%	13%	33	0.35	3:08
118019	42	100	100%	61%	159	0.31	1:23
118020	54	132	100%	49%	127	0.37	1:50
118021	21	53	100%	80%	207	0.43	0:43
118022	47	118	100%	55%	142	0.43	1:38
118023	106	269	96%	0%	0	0.46	N/A
118024	68	174	100%	33%	85	0.49	2:25
118045	32	80	100%	69%	180	0.41	1:06
118046	65	165	100%	36%	95	0.46	2:17
118047	81	207	100%	20%	53	0.47	2:52
118048	45	114	100%	56%	145	0.45	1:34
118049	111	274	95%	0%	0	0.39	N/A
118050	102	253	100%	2%	6	0.40	3:30
118051	75	184	100%	29%	75	0.38	2:33
118052	102	253	100%	2%	6	0.40	3:30
118053	76	188	100%	28%	71	0.39	2:36
118054	102	253	100%	3%	7	0.40	3:30
118055	75	184	100%	29%	75	0.38	2:33
118056	96	236	100%	9%	23	0.39	3:16
118057	68	168	100%	35%	92	0.39	2:19
118058	69	171	100%	34%	89	0.40	2:22

Source: WSP

Note: Charging time is based on 80 kW charger at 90% efficiency.

Conservative Scenario

Based on a "conservative" scenario, it is expected that 27 of the 42 blocks could be completed by a single BEB, with 15 blocks failing. The following table presents a summary of the energy demands for each block. It is assumed that each block is operated by a single vehicle. The "Average Efficiency" column shows how the efficiency has declined from the baseline of 2.08 kWh/mile due to the additional consumption factors.

The table also estimates the amount of time it would take to recharge vehicles that have *completed* blocks. The charger in this calculation is an 80 kW charger at 90% efficiency – reflecting the actual chargers that SolTrans has procured for its BEB fleet. For failing blocks, it will take 3:36 hours to recharge a fully depleted battery.

SolTrans – Summary of Blocks – Conservative Scenario

Block ID	Distance (miles)	Required Battery Capacity (kWh)	% of Block Completed	State of Charge Remaining	Efficiency Change (kWh/mi)	Charging Time at 72 kW (hours)
1	201	584	44%	0%	0.83	N/A
2	70	165	100%	36%	0.29	2:17
3	38	95	100%	63%	0.43	1:19
4	35	90	100%	65%	0.49	1:14
5	25	67	100%	74%	0.61	0:56
8	8	25	100%	91%	0.99	0:20
11350	103	305	85%	0%	0.89	N/A
11351	63	186	100%	28%	0.87	2:34
11352	95	280	93%	0%	0.87	N/A
117986	79	231	100%	11%	0.85	3:12
117987	65	193	100%	26%	0.88	2:40
117988	101	300	86%	0%	0.89	N/A
117989	98	290	89%	0%	0.88	N/A
117990	91	271	96%	0%	0.90	N/A
117991	84	250	100%	4%	0.89	3:27
117992	72	211	100%	18%	0.86	2:56
117993	42	121	100%	53%	0.79	1:40
118014	49	140	100%	46%	0.79	1:57
118015	79	227	100%	13%	0.79	3:08
118016	35	100	100%	62%	0.77	1:23
118017	129	373	70%	0%	0.81	N/A
118018	93	269	96%	0%	0.81	N/A
118019	42	118	100%	55%	0.73	1:38
118020	54	157	100%	39%	0.84	2:11

118021	21	62	100%	76%	0.89	0:51
118022	47	139	100%	46%	0.88	1:55
118023	106	325	80%	0%	0.99	N/A
118024	68	212	100%	18%	1.04	2:56
118045	32	97	100%	63%	0.95	1:20
118046	65	210	100%	19%	1.15	2:54
118047	81	262	99%	0%	1.16	N/A
118048	45	141	100%	46%	1.06	1:57
118049	111	323	80%	0%	0.84	N/A
118050	102	300	86%	0%	0.87	N/A
118051	75	218	100%	16%	0.82	3:01
118052	102	299	87%	0%	0.86	N/A
118053	76	222	100%	14%	0.84	3:05
118054	102	299	87%	0%	0.85	N/A
118055	75	218	100%	16%	0.82	3:01
118056	96	280	93%	0%	0.84	N/A
118057	68	199	100%	23%	0.84	2:45
118058	69	201	100%	22%	0.84	2:47

Source: WSP

Note: Charging time is based on 80 kW charger at 90% efficiency.

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX C: POWER AND ENERGY ANALYSIS

Solano Transportation Authority

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 4: POWER AND ENERGY ANALYSIS

Final — December 2021

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APPENDICES

APPENDIX A - RESILIENCY BACKGROUND INFORMATION

Acronyms and Terms

Term	Description
BEB	Battery-Electric Bus
BESS	Battery Energy Storage Systems
CAISO	California Independent System Operator
CARB	California Air Resources Board
CPUC	California Public Utilities Commission
CSMS	Charger Station Management System
EV	Electric Vehicle
FAST	Fairfield and Suisun Transit
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation, and Air Conditioning
ICA	Integration Capacity Analysis
ICEB	Internal Combustion Engine Buses
ICT	Innovative Clean Transit
ISO	Independent System Operator
kV	Kilovolt
kVA	Kilovolt-Ampere
kW(h)	Kilowatt (hour)
MW(h)	Megawatt (hour)
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas & Electric
PV	Photovoltaic
PUC	Public Utilities Commission
PVRAM	Photovoltaic and Renewable Auction Mechanism
SOC	State of Charge
SolTrans	Solano County Transit
STA	Solano Transportation Authority
ZEB	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040[1] The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Plan* includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- Task 1: Existing Conditions Analysis
- Task 2: Service Modeling Analysis
- Task 3: BEB Facility Concepts
- **Task 4: Power and Energy Analysis (this report)**
- Task 5: Costs and Funding Analysis
- Task 6: Phasing Strategy and Transition Analysis
- Task 7: Countywide Electrification Transition Plan

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of this project's elements are incorporated in this project. FAST is currently developing the *Fairfield Transition Electrification Transition Model Project,* an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the *Countywide Electrification Transition Plan;* however, FAST's final report (expected in Summer 2021) will be incorporated into the final *Countywide Electrification Transition Plan,* which is anticipated to be completed by Q1 2022.

1.2 Report Purpose

The purpose of the Power and Energy Analysis is to identify and establish the power and energy availability and needs of Solano County's transit agencies: Dixon Readi-Ride, Rio Vista Delta Breeze, SolTrans, and Vacaville City Coach, and serve as the basis of analysis for subsequent scheduling and financial technical reports within the Countywide Electrification Transition Plan. All information included in this report for SolTrans is sourced from the 2020 SolTrans Zero Emissions Bus Master Plan as well as design documents issued for

1 . CARB ICT Regulation (https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-regulation)

bid in Spring of 2021. No additional analysis was performed for the preparation of this report. WSP coordinated with all Solano County's transit agencies to collect and validate data to document and analyze these elements. Additionally, this report analyzes factors impacting the resiliency of each facility's electrical service to various types of outages and presents possible solutions for mitigating the impacts of these outages.

BEBs typically require more energy and power than what is provided at existing bus facilities. For that reason, it is important to understand if there is a shortfall in electricity and identify solutions to address it. WSP conducted site visits, and used utility bills, Pacific Gas & Electric (PG&E) databases, such as the Integration Capacity Analysis (ICA) and Solar Photovoltaic and Renewable Auction Mechanism (PVRAM) maps[2] to identify circuits that feed each site. These data provide a preliminary understanding of the delta between existing and required energy, which will be further explored in subsequent phases of the project. In this report, each site's section will discuss proposed charger station configurations, the necessary electrical infrastructure upgrades to meet the demand requirements, resiliency strategies, next steps, and other recommendations.

1.3 Report Structure

This report is organized into four main sections:

1. **Introduction** – Overview of Countywide Electrification Transition Plan and the Energy and Power Analysis
2. **Inputs and Methodology –** Overview of the energy and power analysis process, including inputs, assumptions, and approach
3. **Agency-Specific Sections –** Presents each agency's service energy and power analysis results, a summary of facility upgrades, and analysis of electrical outage resiliency factors and recommended mitigation strategies.
    a. Dixon Readi-Ride
    b. Rio Vista Delta Breeze
    c. SolTrans
    d. Vacaville City Coach
4. **Conclusion and Next Steps –** Summarizes the findings of the report and outlines next steps

2 The Integration Capacity Analysis (ICA) and Photovoltaic and Renewable Auction Mechanism (PVRAM) maps are designed to help contractors and developers find information on potential project sites for distributed energy resources. The information on these maps is illustrative and is likely to change or be modified over time.

2 ELECTRIC UTILITY OVERVIEW

The following section provides an overview of the PG&E application process for new electrical service and a summary of PG&E's new electric vehicle (EV) fleet tariff rates. This informs the transit agencies of the steps required for new meter installations and the expected daily costs an agency may incur from charging an EV fleet. This section assumes that the projects in this report qualify for PG&E's EV Fleet program.

PG&E, one of the largest combined natural gas and electric energy companies in the United States, services Solano County. Based in San Francisco, PG&E delivers energy to nearly 16 million people in Northern and Central California. Coordination with PG&E will be essential to successfully transition each of Solano County's transit agencies to BEB operations.

2.1 Utility and Service Applications

As outlined in Task 1: Existing Conditions Analysis, PG&E requires commercial customers to apply for upgraded service through their web portal, PG&E Connect. A summary of the different tasks and responsible parties in PG&E's application process is outlined in Table 2.1.

Table 2.1 Summary of PG&E Application Process

Task Item	Description	Responsible Party
Site Plan	Shows the existing and proposed physical upgrades to the site's plot of land	Transit Agency
Improvement Plans	Demonstrates to PG&E the planned number of chargers to be installed and the estimated total electric load	Transit Agency
Architectural Plans	Design of the facility layout, site equipment placement, and other architectural needs (ex. elevation plans)	Transit Agency
Permitting	Project approval and permit conditions that need to be incorporated in utility design and construction activities	Transit Agency with County specific Planning or Building Departments
Additional Load Details	Current electrical kW load request with clarifying details, type of electrical equipment, and potential future loads if known for PG&E planning purposes	Transit Agency
Electrical and Mechanical Plans	Detailed electrical and mechanical engineering drawings that illustrate new construction, equipment, safety features, and interconnection between all parts	Transit Agency with Utility

Source: WSP

An application should be submitted to PG&E as soon as possible during the preliminary design phase. However, PG&E cannot complete their portion of the design work until the facility design is completed and equipment vendors are selected and provided to PG&E. After the facility and utility designs are complete and a contract is signed with PG&E, the pre-construction tasks generally take 2-4 months, with construction taking another 3-4 months. However, upgrades to utility infrastructure can delay these timelines significantly. This may include upgrades to substations, distribution lines, and power poles. PG&E must perform a detailed study to determine what equipment may need to be upgraded. The scope and associated costs are identified after a customer applies.

2.2 EV Fleet Program

PG&E offers a program specifically for EV fleets, known as the "EV Fleet Program". The general requirements include the following:[3]

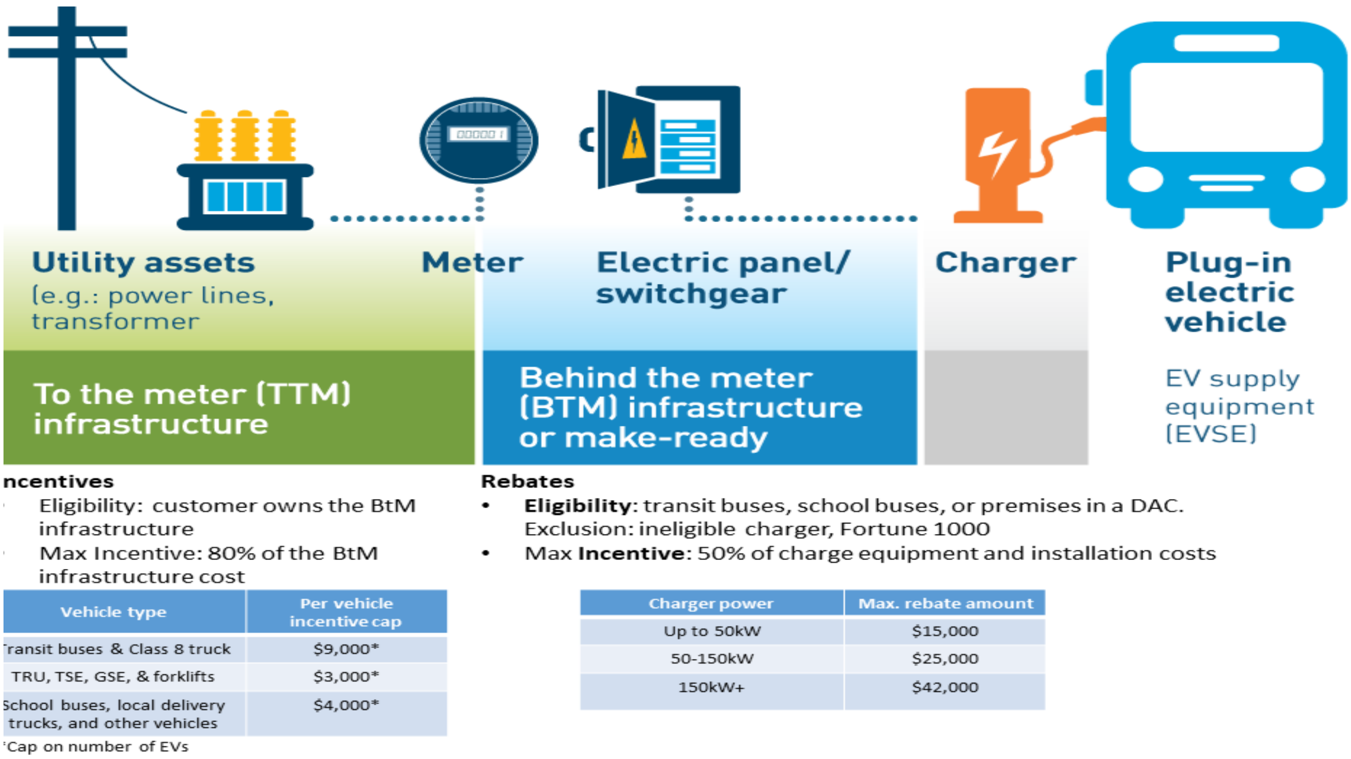
- Be a PG&E electric customer
- Own or lease the property
- Acquire at least two EVs by 2024
- Agree to all requirements

All Solano County transit agencies are likely eligible for PG&E's EV Fleet program. If a Solano County's transit agency's site is selected for the EV Fleet Program, PG&E will construct, own, and maintain all electrical infrastructure from the transformer to the customer's meter. From the site's program description, it is implied PG&E will pay for the utility costs, but this needs to be clarified during the EV Fleet application process. In select instances, the program will also cover behind-the-meter infrastructure. Fleet operators will design, build, own, operate, and maintain the electrical infrastructure from the meter to the EV charger.

As summarized in Figure 2.1, PG&E may provide infrastructure incentives up to $9,000 per transit bus, up to $15,000 for 50% of the cost of Level 2 Chargers (50 kilowatts (kW) and below), and up to $42,000 to offset initial capital costs for 50% of the cost of DC chargers of 150 kW and above. However, in return, the agencies are required to provide EV usage data to PG&E for at least five years after the chargers are installed and operated for 10 years. There are different PG&E rate plans available to EV owners, but this report assumes all Solano County transit agencies will utilize the BEV2 rate plan described below.

3 The full terms & conditions may be reviewed here: https://www.pge.com/pge_global/common/pdfs/solar-and-vehicles/your-options/clean-vehicles/charging-stations/ev-fleet-program/PGE-EV-Fleet-Program-Terms-Conditions-Contract.pdf

Figure 2.1 Summary of PG&E's Incentives and Rebates



Vehicle type	Per vehicle incentive cap
'ransit buses & Class 8 truck	$9,000*
TRU, TSE, GSE, & forklifts	$3,000*
School buses, local delivery trucks, and other vehicles	$4,000*

'Cap on number of EVs

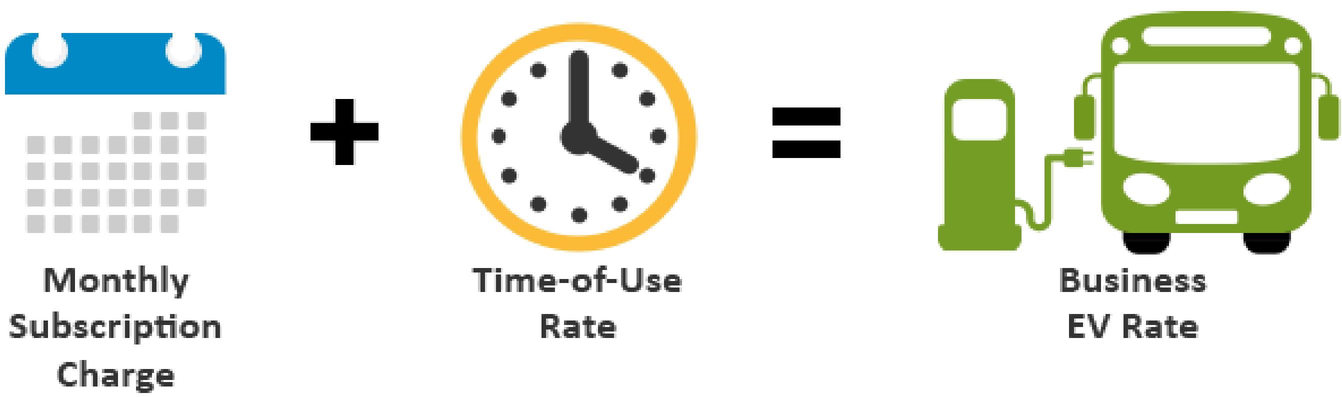
Charger power	Max. rebate amount
Up to 50kW	$15,000
50-150kW	$25,000
150kW+	$42,000

Source: PG&E

2.3 PG&E EV Rate Structure

This report assumes that all transit agencies will use the PG&E Business High Use EV Rate BEV-2-S.[4] This rate schedule assesses a monthly subscription demand charge and a time-of-use energy charge, as shown in Figure 2.2 and described below.

Figure 2.2 PG&E Business EV Rate Overview



Source: PG&E[5]

4 https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDS_BEV.pdf

5 https://www.pge.com/en_US/small-medium-business/energy-alternatives/clean-vehicles/ev-charge-network/electric-vehicle-rate-plans.page

- Monthly Subscription Demand Charge: selected by transit agency and uses the highest calculated charging load based on 50 kW blocks.
- Overage Fee ($ per kW of peak power): charged if the peak power use at any point in the month was higher than the amount selected in the monthly subscription charge. For example, if a 100-kW subscription was selected, and the transit facility used 110 kW one day in the month, an overage fee will be assessed on 10 kW.
- Time-of-Use Rate ($ per kW hour (kWh) of energy): charged based on the actual amount of energy consumed, with rates varying throughout the day according to seasonal time-of-use pricing.

Instead of paying a set dollar amount per kW of peak demand, the customer selects a monthly subscription charge plan. The monthly subscription charge is based on 50 kW increments at $95.56. Any additional power is $1.91 per kW. If the customer overuses the subscribed demand, the overage charge is $3.82 per kW. For example, if the site has an estimated 106 kW peak demand, then the site will subscribe for 106 kW and pay a total of $202.58 per month since they're choosing to subscribe to two blocks of 50 kW and six extra kW. In terms of energy use, each agency will be charged with time of use rates (summarized in Table 2.2). A more refined and detailed cost comparison between the agency's current electricity rate and the Business EV rate will need to be conducted in coordination with PG&E once an application is formally submitted.

Table 2.2 Summary of PG&E Business EV Rate Plan (BEV-2-S)

Section Category	Time of Use Period	Energy Cost ($/kWh)	Monthly Subscription Charge
Peak	4:00 PM to 9:00 PM (daily)	$0.33994	$95.56 per 50 kW block plus $1.91 per additional kW
Off-peak	2:00 PM to 4:00 PM and 9:00 PM to 9:00 AM (daily)	$0.12671	
Super Off-peak	9:00 AM to 2:00 PM (daily)	$0.10344	

Source: WSP and PG&E

3 INPUTS AND METHODOLOGY

The following section provides an overview of the inputs and methodology used to determine the energy and power needs of each facility, as well as the methodology for evaluating the resiliency of each facility against various types of electrical outages.

The inputs used for calculating the required energy and power needs for each site are the results determined in the Task 2: Service Modeling Analysis Report. These results provide the number and type of buses, along with the daily schedules and energy use based on duty cycles. The Task 2 results were used to develop suggested charging schedules for each facility, including whether a particular site requires a charger station management system (CSMS).

3.1 Charging Assumptions

The installed power (in kW), original equipment manufacturer (OEM), and dispenser type (pantograph, plug-in, etc.) will be dictated by each agency's service needs and desired charging strategy. For this analysis, 150 kW DC chargers were modeled and analyzed for each agency. The 150 kW is the nameplate rating of each charger and refers to maximum power supplied to the vehicle. The maximum power provided by each charger will be lower due to cooling system loads and other inefficiencies. This report assumes the facility will install 150 kW chargers in a 2:1 configuration, meaning one charger supports two vehicles. This is a common configuration, but other options are available and should be considered during the design stage. For Dixon Readi-Ride and Vacaville City Coach, the BEBs are assumed to be charged sequentially, while at Rio Vista Delta Breeze, the BEBs are charged concurrently.

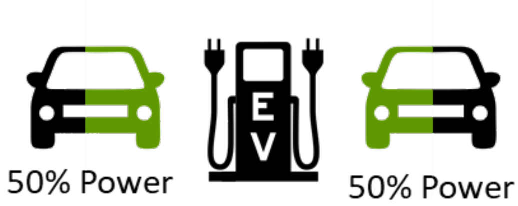
When a charging cabinet provides power to more than a single vehicle, it can do so via two methods: sequential or concurrent charging. Sequential charging is when the charging cabinet selects which of its dispensers it provides power to, depending on its settings, as shown in Figure 3.1. It can either charge Bus A at 150 kW or Bus B at 150 kW, but it cannot charge both at once. If Bus B is plugged into the same charging station after Bus A, the charging station will not charge Bus B until Bus A has completed its necessary charge.

Figure 3.1 Sequential Mode

Source: WSP

A concurrent charging configuration allows power to be equally split between two or more vehicles. This enables vehicles to charge at the same time, albeit at a lower rate as shown in Figure 3.2. When one vehicle is plugged in to the dispenser, this vehicle will only receive half of full charging rate, regardless of whether the other dispenser is being used. For example, Bus A may arrive before Bus B, but each vehicle's charge peaks at 75 kW. Depending on the amount of energy that needs to be replenished and time connected to the chargers, both concurrent and sequential charging configurations can be beneficial for an agency to adopt.

Figure 3.2 Concurrent Mode



Source: WSP

In addition to charging infrastructure, each facility is evaluated to determine whether a CSMS is appropriate. A CSMS allows BEB charging sessions to be distributed to reduce the total amount of electrical power required at any given time, thus, reducing an agency's demand and operational costs. For certain facilities, the calculated power requirements assume the use of a CSMS, while others may not. This is discussed in detail in the respective agency sections of this report.

3.2 Battery-Electric Bus Assumptions

3.2.1 BATTERY CAPACITY

The *advertised* capacity of a battery differs from the *operating* (or usable) capacity that a battery offers. Thus, it is essential to clarify and establish the operating capacity of a battery to accurately assess range and performance. Generally, 10% or more of a battery's advertised capacity is deemed unusable by the OEM in order to support the health of the battery. Additional percentages may also be added to this *safety buffer* by the agency to reduce range anxiety for operators and mitigate impacts to service. Another benefit of providing a safety buffer is that the battery (while charging) can maximize the usage of a charger and reduce charging times (batteries typically receive peak power between 20% and 80% state of charge (SOC). For the purposes of the analysis, WSP assumed that 80% of the advertised battery capacity is the operating (or usable) capacity of each battery.

The vehicles analyzed in this report include cutaways (vehicle designed to transport passengers with gross vehicle weight rating (GVWR) greater than 14,000 pounds but less than 26,000 pounds), 35-foot buses, and 40-foot buses with nominal and usable battery capacities, as shown in Table 3.1 below.

Table 3.1 Summary of Battery Capacities

	Cutaways	35-foot buses	40-foot buses
Nominal Battery Capacity	142 kWh	502 kWh	613 kWh
Usable Battery Capacity	114 kWh	402 kWh	490 kWh

Source: WSP

3.2.2 CHARGING AND DISPENSER SPECIFICATIONS

There are several options for chargers, dispensers, and associated specifications at each agency's disposal. The power (kW), dispenser type (pantograph, plug-in, etc.), charging ratio (one charger to two dispensers, etc.), and how vehicles are charged (concurrently, sequentially, etc.) will be dictated by each agency's needs and will provide various outcomes for vehicle availability, service completion, and facility operations.

In this report, BEBs are assumed to have acceptance rates of 150 kW or above, equal to the advertised power rate of the charger. The acceptance rate is the maximum charging rate a BEB can electrically handle. For instance, if a charger can provide a maximum of 150 kW, but the battery has an acceptance rate at 75 kW, then the vehicle will be charged at 75 kW regardless of what the charger can provide.

The vehicles analyzed in this report include cutaways, 35-foot buses, and 40-foot buses with nominal battery capacities of at least 142 kWh, 502 kWh, and 613 kWh, respectively. It is assumed that usable capacity is equal to 80% of the nominal capacity, which is enough to complete the service routes as outlined in Task 2: Service Modeling Analysis. Vans are not considered in this analysis because their GVWR is below 14,000 pounds and are not subject to the CARB ICT requirements.

3.2.3 CHARGING CURVES

Each battery on a BEB has a "charge curve" that demonstrates the variations of power (kW) or acceptance rate that can be received over time while charging based on the vehicle's SOC.

The acceptance rate is dictated by a battery's chemistry – not the charger itself. Peak power draw often occurs between roughly 20% and 80% of a battery's SOC, with substantially reduced peak power draw from 80% to 100% (and especially reduced during the last 10% when the battery system is doing cell balancing). For instance, if a vehicle is connected to a 150-kW charger, it may receive a maximum charge rate close to 150 kW between 20% to 80% SOC, but a substantial lower power draw of around 30-50 kW during the last 10% of replenishment.

The charge curve is often OEM-specific and can vary by technology – making it difficult to forecast specific power outputs and thus, charging cycles. To account for varying charge curves and inefficiencies when calculating the time needed to recharge, WSP assumes a constant charge rate of 90% of the advertised power of the charger, meaning, 150 kW chargers will provide 135 kW of power throughout the charge cycle. If the BEBs are in a 2:1 configuration, WSP assumes the 150 kW chargers will provide 67.5 kW instead of 75 kW as summarized in Table 3.2.

Table 3.2 Modeled Charger Outputs

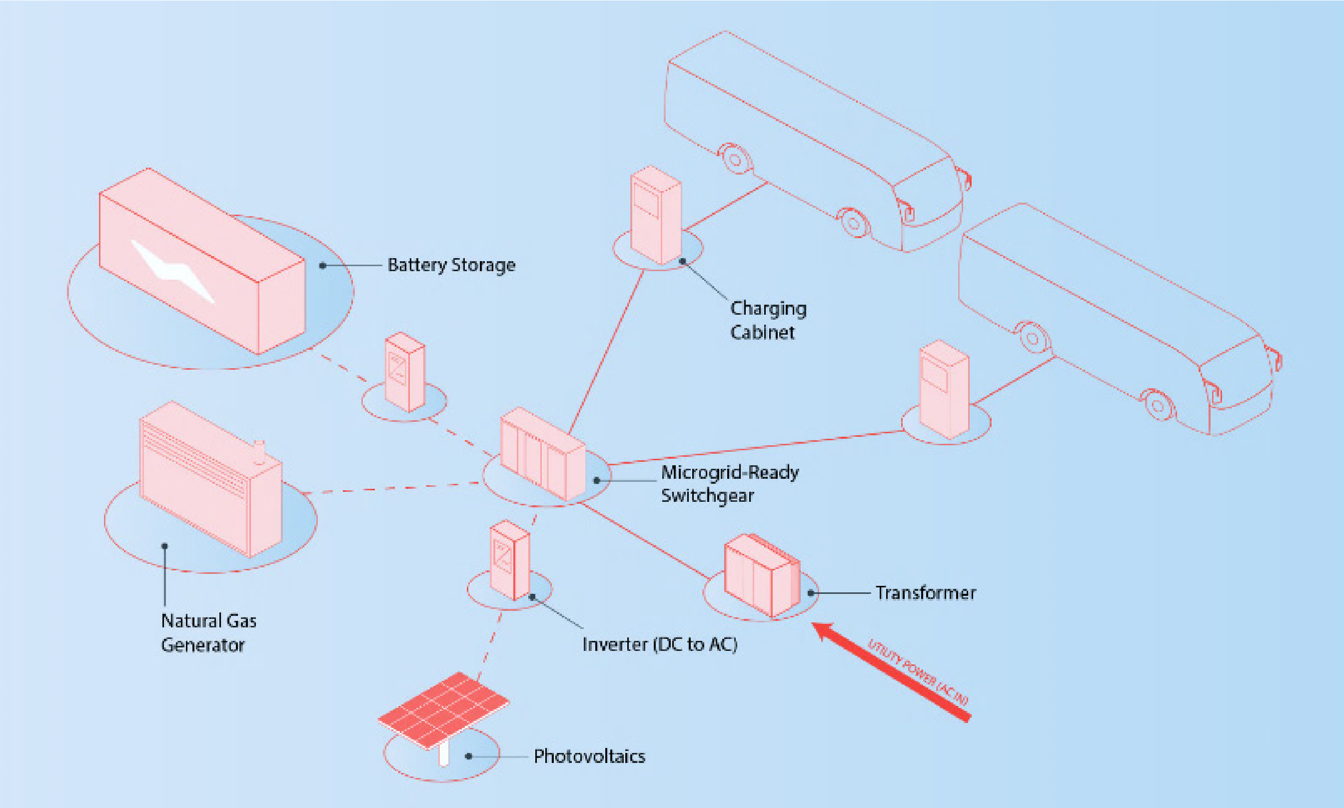
Advertised Charger	Modeled Charger	2:1 Charging
150 kW	135 kW	67.5 kW

Source: WSP

3.3 Energy Infrastructure Upgrades

Before each transit agency can transition their fleets to BEBs, electrical infrastructure upgrades and enhancements may be required. A utility transformer and switchboard are necessary to supply electricity to chargers. The operating specifications of each piece of equipment depends on the amount of power it needs to supply. Figure 3.3 demonstrates the relationship between common BEB infrastructure.

Figure 3.3 Utility Equipment for Charging Stations



Source: WSP

3.4 Resiliency Methodology

It is important to design resilient BEB charging infrastructure to minimize disruptions to operations and service. The likelihood of occurrence, impact to transit operations, and optimal mitigation strategy varies. However, most electrical outages can be grouped into the four categories below. Additional considerations and background information for each type of outage is provided in Appendix A.

- Distribution-related utility outages
- Transmission-related utility outages
- Utility energy supply shortages
- Onsite facility equipment outages

The resiliency analysis looked at each of these four types of electrical outages. The inputs to the analysis are shown as *Factors Impacting Resiliency* and were used to determine a *Resiliency Rating* (described below). Various methods of addressing these outages are described as mitigation strategies considered and include both technical and procedural strategies that are useful for that particular type of outage at the specific facility being discussed. Finally, specific types of backup power systems are recommended for each facility, along with a discussion of further analysis that should be completed during the project design phase.

3.4.1 RESILIENCY RATING

For each type of outage, a qualitative rating is assigned for each transit facility. The rating considers the various factors that were investigated and represents the relative risk and potential impact of that particular type of outage compared to other similar facilities for that same type of outage. It is not meant to represent the relative probability compared to other types of outages. For example, a facility may be assigned a resiliency score of *low* for transmission-related outages. However, transmission related outages are extremely rare for all types of facilities. A facility with a resiliency score of *high* for distribution-related outages may experience a distribution-related outage more frequently than a *low* transmission-related outage, because overall the electrical transmission grid is designed to be more robust than the distribution grid.

3.5 Facility Upgrades

Concepts for the facility upgrades consider multiple facets of the existing sites to best locate equipment and provide for the conceptual strategy for locating charging equipment on the site. Items such as facility capacity, existing yard circulation, bus parking orientation, available site area, and planned future projects are all considered to identify the best fit strategy and are documented in the Task 3: BEB Facility Concepts Report. The locations of new electrical service equipment such as transformers and switchboards, routing for new power conductors, locations of charging equipment, and number and type of charging equipment were a coordinated effort between what worked best for each site from a power and utility perspective as well as a functional facility planning perspective.

DIXON READI-RIDE

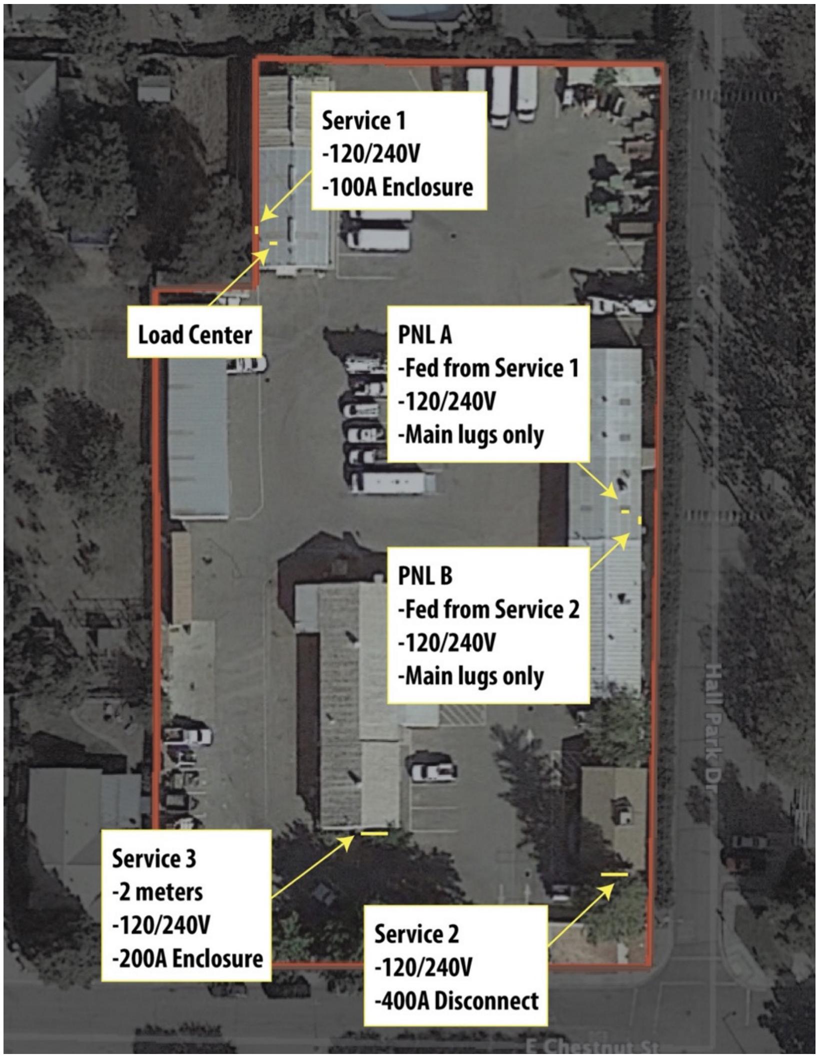
4 DIXON READI-RIDE

The following section presents an overview of Dixon Readi-Ride's energy and power analysis results, facility electrical upgrades, and suggested resiliency methods.

4.1 Existing Conditions

Dixon Readi-Ride's power is provided by the PG&E Dixon Substation (6206) that is located at 369 W A St, Dixon, CA 95620, approximately one mile from the yard. Based on the information presented in Task 1: Existing Conditions, it was determined that PG&E should install a new electrical service to the Dixon Readi-Ride facility, along with associated electrical equipment, such as meters, panels, switches, and circuit breakers. The locations of the existing facility electrical equipment are shown in Figure 4.1 for reference.

Figure 4.1 Dixon Readi-Ride Plan View



Source: WSP

4.2 Energy and Power Analysis

4.2.1 VEHICLE FLEET

There are 10 total vehicles in the Dixon Readi-Ride fleet. Eight of which (cutaways) are considered in this analysis, the two vans are not included and will not be replaced with BEBs. The eight cutaways have a max charge rate of 150 kW and will use an average of 70-87 kWh per day. The total fleet's energy use is 1.14 megawatt hour (MWh) assuming the whole fleet fully charges all vehicles. The peak unmanaged charging demand with 10% buffer is 660 kW.

4.2.2 CHARGING SCENARIOS CONSIDERED

This report analyzes two scenarios, unmanaged and managed charging. The unmanaged charging scenario serves as a baseline and calculates the requirements assuming no managed charging solutions are used. This scenario provides the most flexible system, but at a higher cost and potentially longer construction schedule. The managed charging scenario takes advantage of a charge management system to provide flexibility while minimizing capital costs, energy costs, and demand charges.

To service eight cutaways, it is recommended that four 150 kW DC chargers be installed. The recommendation is for Dixon to invest in a CSMS and plan to use managed charging. If managed charging is selected, the new utility electrical service should be requested to provide at least 165 kW of peak power, which supports the managed charging demand plus a 10% buffer for ancillary loads and losses. Up to eight cutaway vehicles can fully recharge each night using managed charging. One 150 kW DC fast charger can be used at full-speed for flexible mid-day recharging, if necessary.

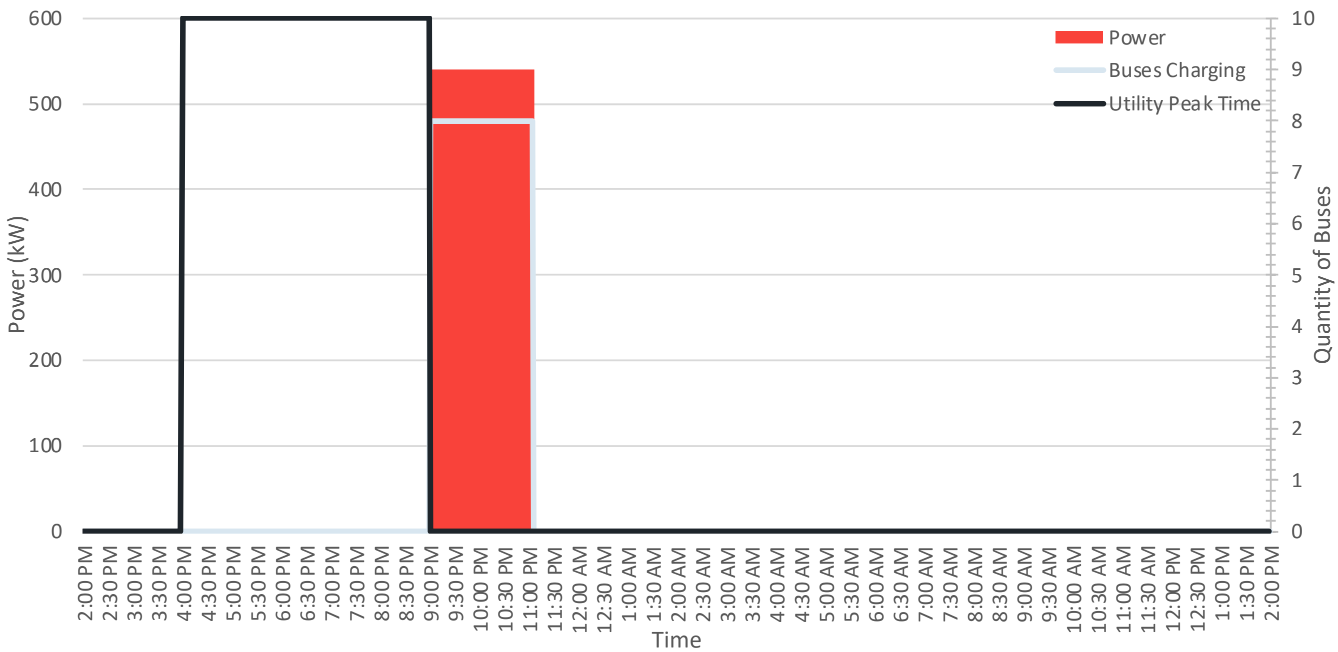
Unmanaged Charging

Dixon Readi-Ride vehicles operate a demand-response service which inhibits precise predictions for daily energy. The results of Task 2: Service Modeling Analysis for Dixon Readi-Ride presented a high-level estimate of the daily range but did not calculate exact energy depletion of each vehicle's battery. To ensure fleet availability and to provide recommendations for the worst-case scenario, this report will assume a full charge is necessary each day for each cutaway vehicle.

Figure 4.2 demonstrates fleet charge time and power requirements, the primary vertical axis shows the average power demand the fleet will incur throughout the night at the particular timestamp shown on the horizontal axis. The red bar graph is the fleet's cumulative amount of power demand at that timestamp. The secondary vertical axis showcases the quantity of buses with the grey line measuring the number of BEBs charging currently at that timestamp. The black line shows the blackout times that the fleet should not charge at to avoid PG&E's peak energy rates.

With eight vehicles starting to charge at 9:00 PM at an average rate of 67.5 kW per vehicle, the cutaways will finish charging within approximately two hours. This incurs a charging demand of 660 kW including losses and ancillary loads. The total energy usage would be approximately 1.1 MWh per day.

Figure 4.2 Dixon Readi-Ride Unmanaged Charging Scenario

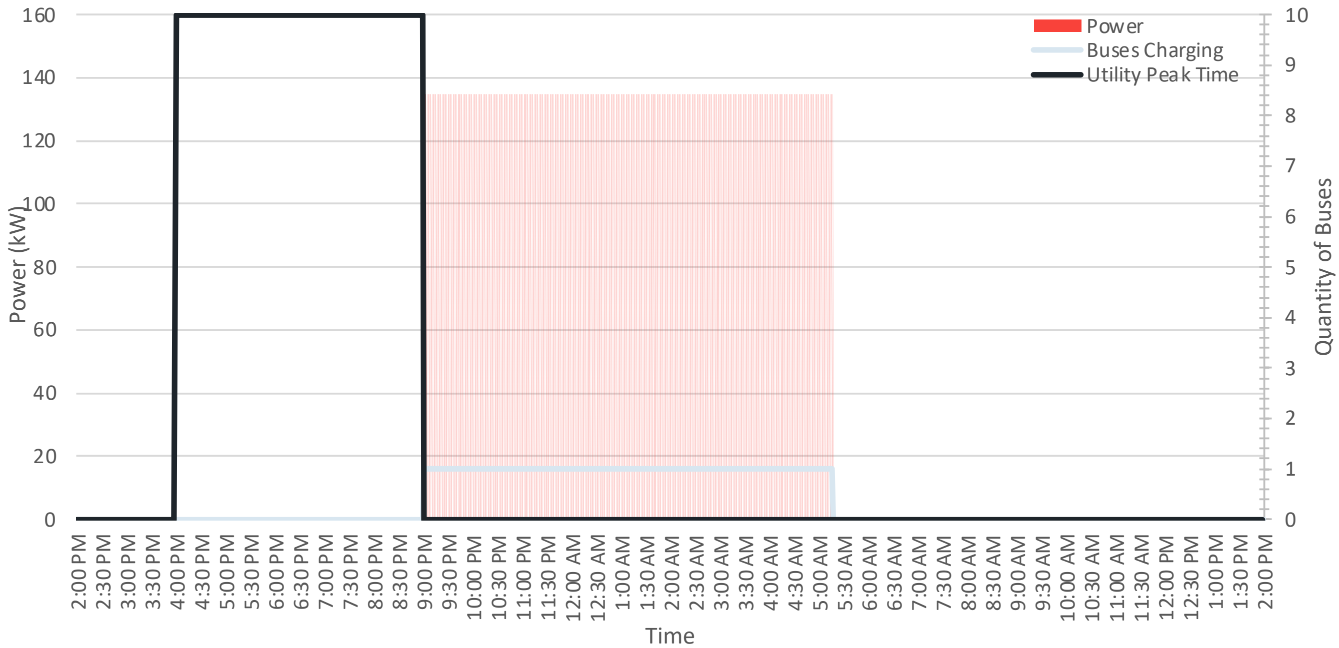


Source: WSP

Managed Charging

In this scenario, the Dixon Readi-Ride site invests in a CSMS, which spreads the vehicle charging throughout the night. This allows a pair of vehicles to charge every two hours. The CSMS would sequentially charge vehicles at an average rate of 135 kW for 62.4 minutes before switching to the next vehicle, as summarized in Figure 4.3. Through managed charging, the fleet will incur a peak demand of approximately 150 kW including losses. The overall energy usage will be approximately 1.1 megawatt (MW) for the entire fleet regardless of charger configuration.

Figure 4.3 Dixon Readi-Ride Managed Charging Scenario



Source: WSP

Impacts of Unmanaged Charging Compared to Managed Charging

- **Higher utility subscription charges:**[6] These charges will cost four times more in peak demand charges in a given month. For Dixon Readi-Ride, this would be approximately $946 difference per month in demand subscription charges with unmanaged vs managed charging.
- **Higher utility energy prices:** If vehicles charge as soon as they are plugged in, they may be charging during times of peak energy prices, which ranges from 4 PM – 9 PM each day as highlighted by the black box in Figure 5.4. Peak energy prices are approximately $0.21 more per kWh than off-peak prices. For Dixon Readi-Ride, with an operation of five days a week, this could result in monthly energy costs up to $5,329 if they do not schedule their charging during off-peak hours.[7] The ability for the operator to schedule the charger's charging start time is guaranteed in managed charging, but it is highly dependent on the charger manufacturer and model in unmanaged charging.
- **Higher capital costs:** A higher peak power requires more capable equipment, which can increase equipment cost and extend the project schedule both for the transit facility and the electric utility.

4.2.3 RECOMMENDED NEW ELECTRICAL SERVICE

Based on the analysis, it is recommended that Dixon Readi-Ride implement a CSMS. The new utility electrical service load would decrease from 660 kW to 165 kW, greatly reducing the physical size and electrical rating of the switchboard and transformer necessary to support the BEB charging equipment. The utility upgrade

6 Refer to Section 3.2.1.

7 This assumes all eight vehicles are fully recharged each day, peak energy costs of 0.33994 per kWh and off-peak costs of 0.12671 per kWh.

could be less involved and could likely be completed sooner, but this depends on the results of a detailed study performed by PG&E.

Further Analysis

While a 114-kWh usable battery capacity is theoretically sufficient to support Dixon Readi-Ride's service, other factors like heating, air conditioning, or driving style may impact the rate of energy depletion. If necessary, the cutaways may return to the facility for a midday charge before continuing the service. Ideally, the cutaways will charge during PG&E's off-peak period (between 9:00 AM to 2:00 PM). If it is determined that mid-day charging is not necessary, the transit agency should consider whether lower power charging cabinets would meet the fleet's needs at a lower initial cost.

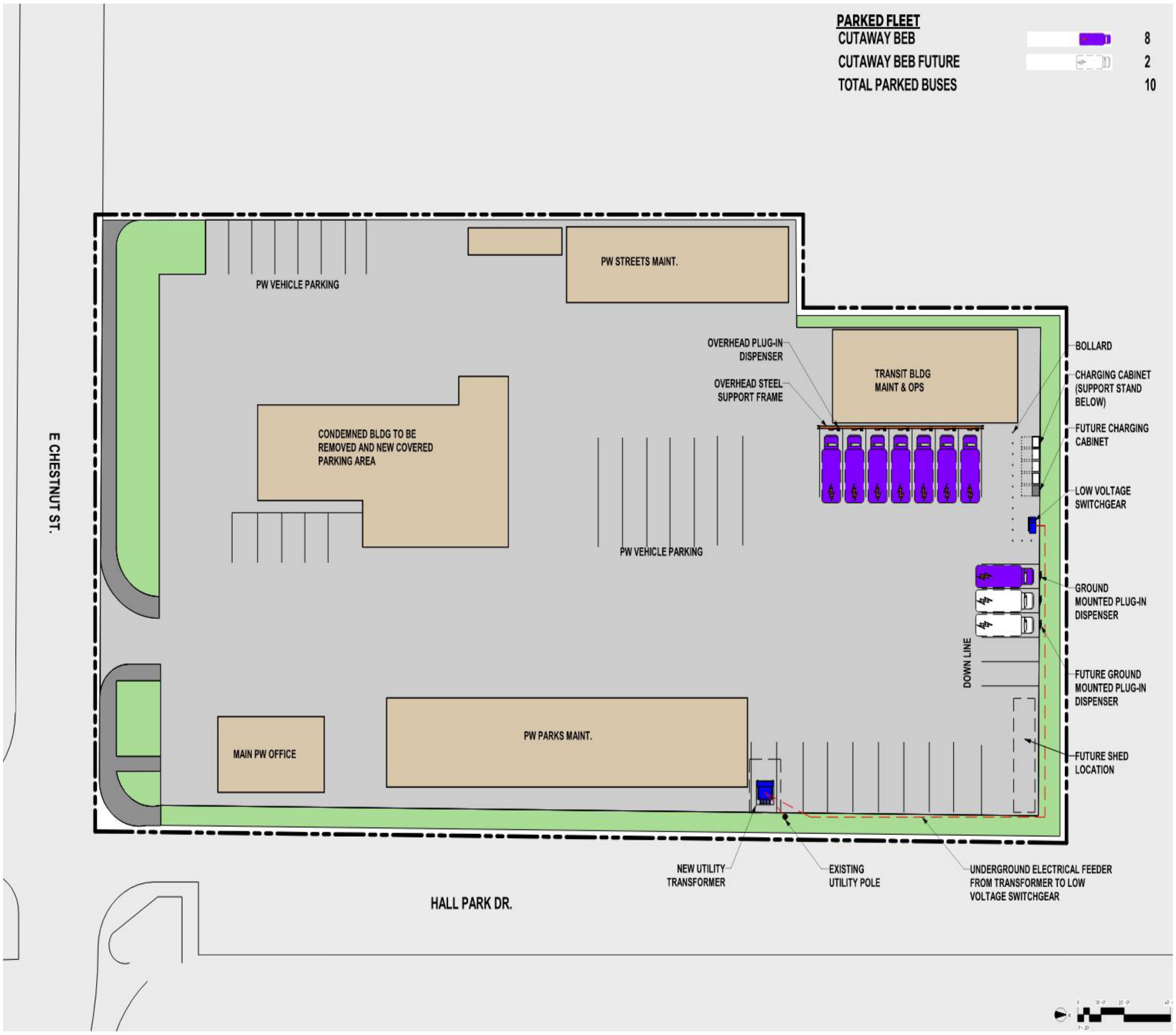
4.3 Facility Upgrades

Based on the analysis, the following facility electrical upgrades are required as described below and illustrated in Figure 4.4:

- PG&E to install new 750 kilovolt-ampere (kVA) transformer near Hall Park Dr, fed by new 12 kilovolt (kV) underground electrical pole on Hall Park Dr.
- Dixon Readi-Ride to install new 480 V switchboard and utility metering cabinet at north end of site with minimum electrical rating of 1200 A.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchgear at north end of site. Underground conduit will need to be installed by Dixon Readi-Ride, but PG&E will install the electrical conductor.
- Dixon Readi-Ride to install new vehicle charging stations where indicated, with underground conduit connecting the charging stations to the new 480 V switchgear.

The two charging scenarios discussed above inform the requirements for new electrical equipment. For the purposes of this report, the assumed sizing of on-site electrical equipment presented is based on the unmanaged charging scenario to provide for worst-case analysis of equipment ratings and physical size. However, managed charging is recommended, and electrical equipment properties should be determined during the design phase based on discussions with PG&E and the level of electric service requested.

Figure 4.4 Proposed Dixon Readi-Ride Facility Upgrades



Source: WSP

4.4 Resiliency Analysis

The following section provides an overview of the site's conditions that impact the resiliency rating for the specified outage type, the assigned resiliency rating, and potential mitigation strategies to consider.

4.4.1 DISTRIBUTION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Type of construction:** 100% overhead with primarily wood-poles

- **Distance from substation:** The PG&E Dixon substation is only 0.8 miles from the Dixon Readi-Ride facility, which is considered close. A short distance like this lowers the chances of an adverse event taking the distribution line out of service.
- **Distribution line route:** The PG&E feeder line primarily follows suburban public roadways, with adjacent trees along less than 5% of the line, so there is a low chance of a vegetation-induced outage during a weather event.
- **Utility substation transformer:** The Dixon substation has two step-down transformers, which then feed the 12 kV Dixon distribution line. This provides a high level of redundancy against adverse transformer events.

Resiliency rating: Moderate

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Dixon Readi-Ride facility has a moderate level of resiliency against distribution-related outages. This rating is driven primarily by the distribution line being overhead construction. An underground distribution line would provide a higher level of resiliency.

Mitigation Strategies Considered

- **Dedicated, pad-mounted utility transformer:** The Dixon Readi-Ride facility will be supplied by a new utility transformer, which will be located on-site in a protective enclosure at ground-level, rather than mounted on a distribution pole and shared with adjacent commercial and residential buildings.
- **Backup generator:** The Dixon Readi-Ride fleet only has eight electric vehicles, which allows for significant flexibility when choosing a backup generator. The facility could utilize either a permanently installed diesel or natural gas backup generator or a mobile, trailer-mounted backup generator that could be stored elsewhere and connected during extended outages. A trailer-mounted generator could also be shared with other facilities, which reduces the up-front capital cost but increases operational complexity.

4.4.2 TRANSMISSION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Redundant transmission lines:** The Dixon substation is fed by tapping two 60 kV transmission lines which supply two step-down transformers, which then feed the 12 kV Dixon distribution line. This provides a moderate level of redundancy against adverse events at the utility substation, and one redundant source of power for the outage of a 60 kV transmission line.
- **California Public Utilities Commission (CPUC) wildfire risk category:** The Dixon area is classified as tier 1 according to the CPUC FireMap, with tier 1 being the lowest risk of wildfire-related utility events and tier 3 being the highest risk.

Resiliency rating: High

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Dixon Readi-Ride facility has a high level of resiliency against this type of outage. It is important to note that transmission-related outages are extremely rare, even for facilities assigned a rating of "low." This rating is intended to compare the level of resiliency against other commercial and industrial facilities in the United States.

Mitigation Strategies Considered

- **Offsite vehicle charging:** Designate use of an alternate charging site during an outage or charge from a public charging site if possible. The nearest public charger site currently is 10 - 11.6 miles away.
- **Backup generator:** A backup generator may also minimize the impacts of rolling blackouts caused by transmission-related utility outages.

4.4.3 UTILITY ENERGY SUPPLY SHORTAGES

Factors Impacting Resiliency

- **Grid generation shortages:** Stage 3 emergencies are declared by the independent system operator (ISO) in California when the grid operators are unable to meet minimum contingency reserve requirements, and load interruption is imminent or in progress. Overall, California independent system operator (CAISO) has recorded 41 Stage 3 emergencies over a 23-year period between 1998 to 2021[8]. One important caveat is 38 out of the 41 (roughly 93%) Stage 3 emergencies happened in 2001, with none reported until 2020.

Resiliency rating: High

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Dixon Readi-Ride facility has a high level of resiliency against this type of outage. However, changes in the California generation mix along with frequent extreme weather events, including the shutdown of a nuclear power plant, mean that Stage 3 emergencies could happen more frequently in the near-term than they did 10-15 years ago. While in 2021, the chances of a utility energy supply shortage are rare, the resiliency does depend on the prevention actions taken by PG&E and CAISO.

Mitigation Strategies Considered

- **Qualify as an Essential Use Customer:** The transit agency should consider applying to PG&E for Essential Use Customer Classification[9] under the CPUC, especially if other forms of onsite backup generation are not present or do not meet the full needs of the Dixon Readi-ride facility. BEB fleets in California are still relatively new, so it is unclear if BEBs qualify under the current CPUC categories for Essential Use Customers.
- **Off-peak charging:** By using charge management system to intelligently shift charging to off-peak times of day, the Dixon Readi-Ride facility will be less susceptible to blackouts caused by energy-supply shortages.
- **Backup generator:** A backup generator may also minimize the impacts of rolling blackouts caused by energy supply shortages. However, given that these type of outages tend to be shorter in duration but occur more frequently over the course of days or weeks, a permanent generator is better suited than a mobile generator that is shared with other facilities, since the shared facilities may also need the mobile generator at different times of day if the rolling blackouts are impacting the entire geographic area.

8 http://www.caiso.com/Documents/AWE-Grid-History-Report-1998-Present.pdf
9 https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_FORMS_79-1038.pdf

4.4.4 ONSITE FACILITY EQUIPMENT OUTAGES

Factors Impacting Resiliency

- **Lack of redundant equipment:** Since the Dixon Readi-Ride facility only requires eight electric vehicles, it is not cost-effective to install multiple transformers and switchboards. However, it is proposed that multiple DC vehicle chargers be installed, which provides redundancy against a common point of failure.

Resiliency rating: Moderate

While the preliminary electrical design for the Dixon Readi-Ride site does not include redundant transformers or switchboards, the vehicles will be powered by a dedicated electrical system that is separate from the rest of the Dixon Readi-Ride facility. This minimizes the risk of equipment downtime due to failures caused by nonvehicular equipment. Additionally, all proposed electrical equipment and systems will be brand new and utilize modern technology, which greatly reduces the likelihood of major equipment failures in the next 10-15 years when compared to retrofitting an existing system.

Mitigation Strategies Considered

- **Onsite spare equipment:** Spare parts should be kept onsite at the Dixon Readi-Ride facility for equipment that is most likely to experience a failure. This includes fuses, circuit breakers and terminals/ lugs. If possible, spare parts should be provided by the manufacturer for the electric vehicle DC chargers since these devices tend to use proprietary electronic components that may not be easily obtained in the future. Onsite personnel should be trained to troubleshoot common issues and simple failures.
- **Offsite vehicle charging:** Designate use of an alternate charging site during an outage or charge from a public charging site if possible. The nearest public charger site currently is 10 - 11.6 miles away
- **Routine equipment inspection:** Electrical equipment and vehicle charging equipment should be inspected, tested and cleaned on a regular basis according to manufacturer's recommendations. An inspection schedule and testing procedure should be developed and incorporated into the facility's routine maintenance plans.
- **Warranty & service contracts:** Electric vehicle charging equipment may require specialized parts and manufacturer-trained technicians to repair. Dixon Readi-Ride should determine who will be responsible for repairs both during and after the initial warranty period and should identify the manufacturer's point-of-contact for repair and the local firm that is capable of performing the repair.

4.4.5 BACKUP POWER SYSTEMS

One or more of the backup power strategies below provide a suitable level of backup power for most of the scenarios described above at the Dixon Readi-Ride facility. The selection of a resiliency strategy during the design phase should consider the likelihood of a given outage scenario, the risk tolerance and operational flexibility of the transit agency, and the project budget.

1. **Permanent standby generator:** A 400 kW generator would fully power two 150 kW DC chargers simultaneously, and fully recharge all vehicles overnight. However, a smaller generator could be used to charge the vehicles overnight using a charge management system.

2. **Trailer-mounted mobile generator:** A 400 kW trailer-mounted generator would fully power two 150 kW DC chargers, and fully recharge all vehicles overnight. It may be a good fit for the Dixon Readi-Ride facility if there are no ideal locations on site to install a permanent generator.

Other Types of Backup Power Systems Considered

- **Solar photovoltaic (PV) system:**[10] A solar photovoltaic system can be an effective way of supplementing energy supplied by a utility. However, due to its intermittent nature along with utility interconnection rules, it is not effective on its own as a source of backup power. There is also not adequate rooftop space or facility ground space that allows for a large solar photovoltaic system at Dixon Readi-Ride.
- **Battery energy storage system (BESS):** A 1 MWh battery energy storage system installed in a 20 foot by eight foot container would provide backup power to all eight cutaways for an outage lasting up to one day. The high cost and small output of these systems currently makes them a suboptimal choice as a standalone backup system.

4.5 Summary and Next Steps

The following section summarizes the energy and power analysis, facility upgrades recommendation, and resiliency discussion from the previous sections. The recommendations will inform the immediate next steps for Dixon Readi-Ride electrification.

4.5.1 SUMMARY

The summary of the two different charging scenarios for Dixon Readi-Ride is mentioned in Table 4.1. The recommendation is for Dixon to invest in a CSMS and use managed charging to keep the required power increase to 165 kW.

10 This section only analyzed a solar PV system as a means of resiliency and did not consider reduced energy costs. When installed to meet renewable energy goals or to offset the cost of utility-provided energy, a solar PV system can be a good supplement to other forms of backup power, especially when combined with a battery energy storage system.

Table 4.1 Summary of Dixon Readi-Ride Charging Scenarios

Recommended Charger	Scenario	Charge Schedule	Peak Demand	Upgrades Necessary	Est. Monthly Cost
Four 150 kW DC chargers	**Unmanaged**	All eight BEBs charge concurrently and simultaneously at 9:00 PM	600 kW	660 kW	$3,482
	Managed*	Each BEB charges sequentially at charger's full power	150 kW	165 kW	$4,428

*Preferred scenario

Source: WSP

Table 4.2 summarizes the needed facility upgrade for Dixon Readi-Ride's facility. PG&E would be responsible in installing the new transformer and underground electrical conductor, while Dixon Readi-Ride would be responsible in installing switchboard, utility metering cabinet, underground conduit, and charging stations.

Table 4.2 Summary of Dixon Readi-Ride's Facility Upgrade

Responsible Stakeholder	Item to Install	Location	Note
PG&E	750 kVA transformer	Near Hall Park Dr.	Fed by new 12 kV underground electrical pole on Hall Park Dr.
	Underground electrical conductor	Along Dixon 1102 or 1103 Circuit, depends on utility capacity	Connecting transformer installed by PG&E to the switchboard installed by Dixon Readi-Ride
Dixon Readi-Ride	480 V switchboard and utility metering cabinet	North end of site	Min. electrical rating of 1200A
	Underground conduit	Decision based on engineering design	Connecting new transformer to the new switchboard
	Charging stations and underground conduit	As indicated	Connected to the 480 V switchboard

Source: WSP

Table 4.3 summarizes the contributing factors, resiliency rating, and mitigation method for different types of outages.

Table 4.3 Summary of Resiliency Analysis for Dixon Readi-Ride

Summary of Dixon Readi-Ride Charging Scenarios	Distribution-Related Outages	Transmission-Related Outages	Energy Supply Shortages	Facility Equipment Failures
Contributing Factors	• Short feeder distance to substation • Distribution route is 100% overhead with primarily wood-poles through suburban neighborhood	• Redundant transmission lines • Low risk area for wildfires	• Two grid generation shortages in the last 19 years • Increase in wildfires over CA	• Lack of redundant equipment
Resiliency Rating	Moderate	High	High	Moderate
Mitigation Method	• Dedicated, pad-mounted utility transformer • Backup generator	• Offsite vehicle charging • Backup generator	• Become Essential Use Customer • Off-peak charging • Backup generator	• Onsite spare equipment and repair people • Offsite vehicle charging • Routine equipment inspection
Backup Power Options	• 400 kW standby permanent generator • 400 kW trailer-mounted generator • Solar PV system paired with 1 MWh BESS in 20' x 8' container A generator with an output rating of at least 400 kW can power two 150 kW DC charging cabinets simultaneously and fully recharge all vehicles overnight. A solar PV system with battery storage would provide supplemental backup power.			

Source: WSP

4.5.1 NEXT STEPS

The next immediate steps for Dixon-Readi Ride are:

1. Decide whether to invest in a charge management system
2. Begin service application and coordination with PG&E to request new service for the calculated load (165 kW for managed, 660 kW for unmanaged)
3. Determine outage mitigation methods. If a backup generator is selected, include the design and procurement in engineering and construction scope
4. Procure long-lead items
5. Begin construction

RIO VISTA DELTA BREEZE

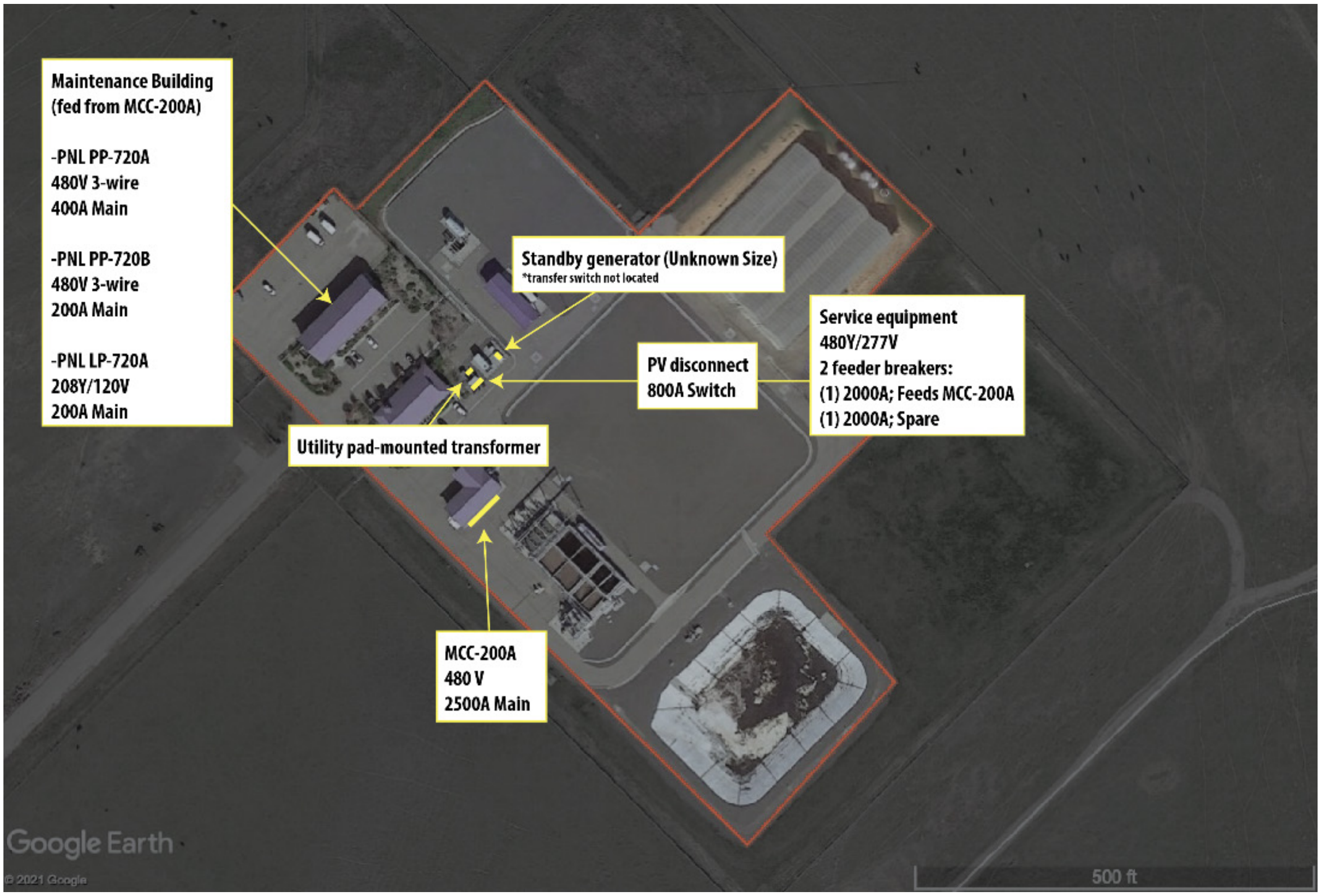
5 RIO VISTA DELTA BREEZE

The following section presents an overview of the Rio Vista Delta Breeze energy and power analysis results, facility electrical upgrades, and suggested resiliency methods.

5.1 Existing Conditions

The Rio Vista Delta Breeze operations are currently located at 3000 Airport Rd, Rio Vista, CA. The transit operations share their site with a City of Rio Vista's Northwest Wastewater Treatment Plant. They currently operate a fleet of four cutaway buses and one van performing primarily dial-a-ride and deviated fixed-route service. Rio Vista Delta Breeze's power is provided by the PG&E Grand Island Substation (6246), located at 38.231524, -121.590142, approximately 17 miles from the yard. The Grand Island Substation has a capacity of CPUC kV circuit with an existing capacity of 18 MW. PG&E estimates that the projected peak load of this circuit is 10 MW, leaving approximately 8 MW of available capacity. The overhead portion of circuit 2226 follows Airport Road and enters an access road towards the Rio Vista Delta Breeze facility. The overhead portion dead-ends at the adjacent industrial site along the access road and enters the yard through an underground conduit for the last quarter mile.

Figure 5.1 Rio Vista Delta Breeze Plan View



Source: WSP

Onsite, Service 1 is a 100 A switchboard that feeds the Load Center and Panelboard A. Service 2 is a 400 A switchboard that feeds Panelboard B. Service 3 is a 200 A switchboard and has two different meters fed by PG&E. At Service 2, eight out of 30 breaker positions are free. As an estimate, this switchboard can feed four maximum chargers assuming existing loads are 15 A. For Service 1 and 2, the number of free breakers and current load profile cannot be verified at this time nor can the onsite transformer. There is one generator (unknown size) onsite for resiliency purposes as shown in Figure 5.1. It is unknown where the transfer switch is. There is an onsite PV 800 A disconnect switch for the PV arrays on the southeast side of the wastewater treatment center. These panels provide power to the site during normal operations but belong to the wastewater treatment center.

5.2 Energy and Power Analysis

5.2.1 VEHICLE FLEET

The Rio Vista Delta Breeze fleet consists of five gas vehicles: one van and four cutaways. In the future, the transit agency hopes to double their fleet with four additional 35-foot buses. This report calculated the electrical requirements both with and without the addition of the four future buses. When taking into account the future buses, it is assumed that the usable battery capacity is fully depleted each day. The van was not included.

5.2.2 CHARGING SCENARIOS CONSIDERED

This report analyzes two scenarios, unmanaged and managed charging. The unmanaged charging scenario serves as a baseline and calculates the requirements assuming no managed charging solutions are used. This scenario provides the most flexible system, but at a higher cost and potentially longer construction schedule. The managed charging scenario takes advantage of a charge management system to provide flexibility while minimizing capital costs, energy costs, and demand charges.

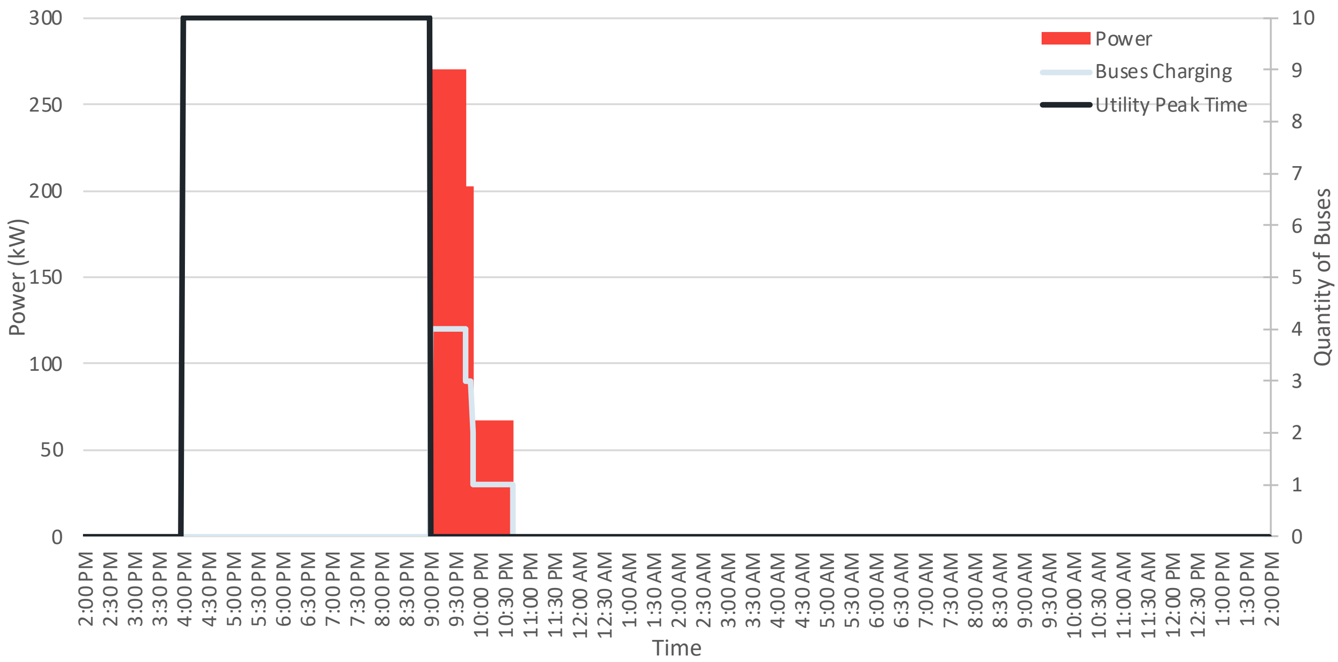
From Task 2: Service Modeling Analysis, the cutaway's battery capacity of 142 kWh is typically enough to service the longest distance of 134 miles. With a 2:1 dispenser to charger configuration, the four existing cutaways will require installation of two 150 kW DC chargers. If operating simultaneously at their full power, the maximum power draw would be over 300 kW. This report recommends installing new electrical service capable of supplying at least 415 kW of power in combination with a charge management system. Two 150 kW DC chargers could also be used simultaneously at full-speed for flexible mid-day recharging when necessary. This would allow up to four cutaway vehicles and four 35-foot buses to fully recharge each night using managed charging.

Unmanaged Charging

CURRENT FLEET

The site is expected to have two 150 kW DC chargers to charge the four existing cutaways. The unmanaged charging option is to charge all the cutaways concurrently at an average rate of 67.5 kW for 1.5 hours, totaling a peak demand of 300 kW and 280 kWh energy used as shown in Figure 5.2.

Figure 5.2 Rio Vista Delta Breeze Existing Fleet Unmanaged Charging Scenario: Four Cutaways

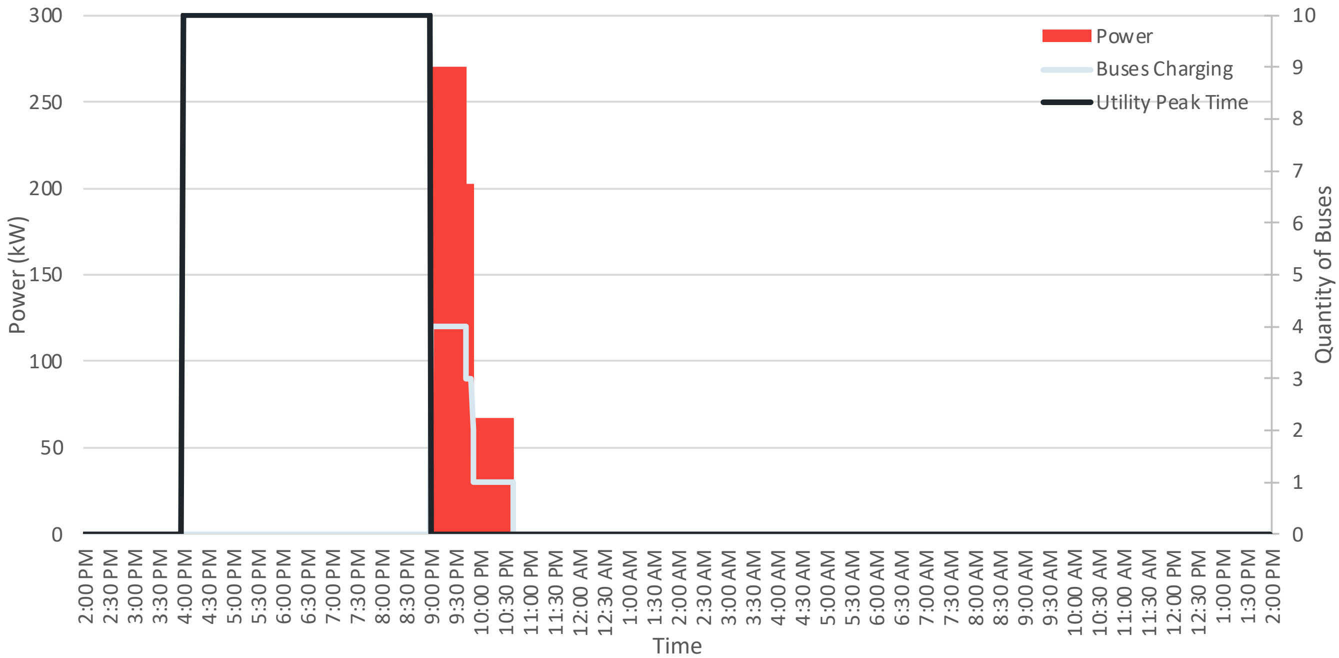


Source: WSP

FUTURE BUSES

The unmanaged charging analysis also looked at the impact of adding an additional four 35-foot battery electric buses in the future. In this scenario, the site is expected to have four 150 kW chargers to charge the four cutaways and four future 35-foot buses. With the chargers set to charge concurrently, the average charge rate of each vehicle is 67.5 kW. The 142 kWh cutaways will all finish charging within 2.1 hours and the 502 kWh 35-foot buses will finish within 7.4 hours as shown in Figure 5.3. In this scenario, the fleet's peak charging demand is 600 kW and total energy would be 2.44 MWh.

Figure 5.3 Rio Vista Unmanaged Charging Scenario: Four Cutaways and Four Future Buses

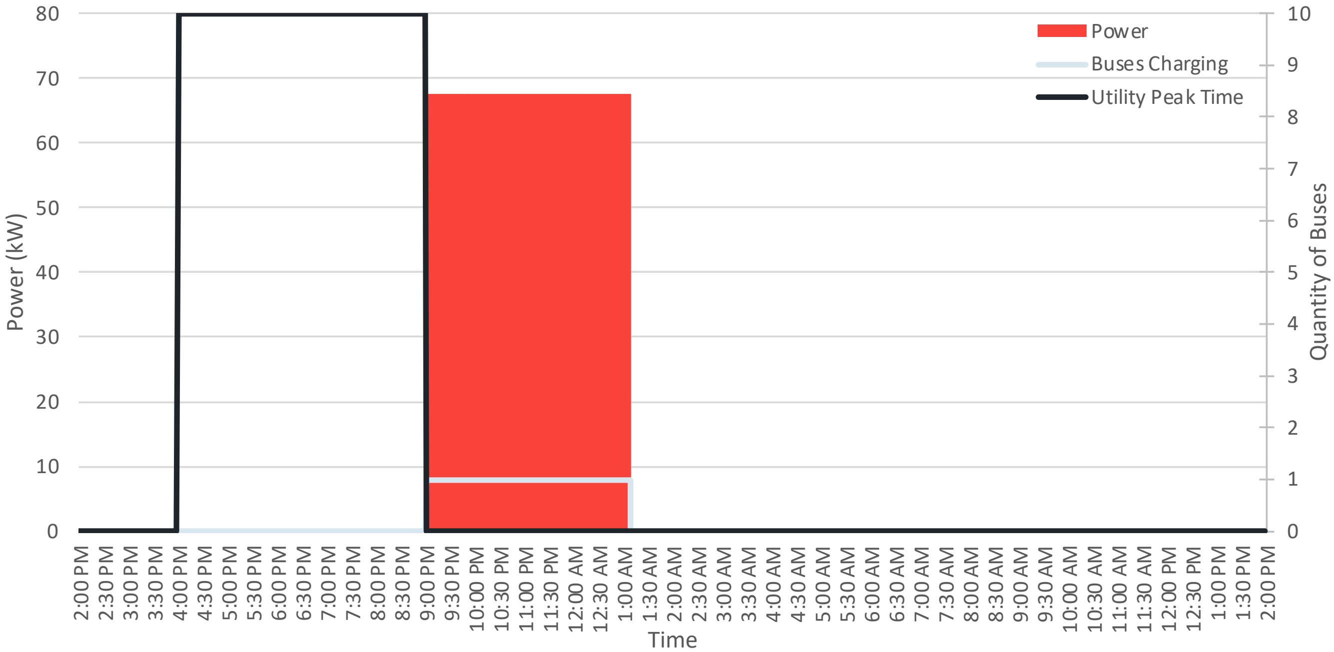


Source: WSP

Managed Charging

Another option to decrease peak demand is to have the charge management sequentially stagger the charger stations by turning one dispenser on after the other is done. This will result in each cutaway charging at an average rate of 67.5 kW until the batteries hit the necessary state of charge for its service route. This will decrease the site's peak demand to 67.5 kW, but the fleet charging completion time would increase to four hours as shown in Figure 5.4. The total energy remains at 280 kWh.

Figure 5.4 Rio Vista Delta Breeze Existing Fleet Managed Charging Scenario: Four Cutaways



Source: WSP

Impacts of Unmanaged Charging Compared to Managed Charging (current fleet)

- **Higher Utility Subscription Charges:**[11] For Rio Vista Delta Breeze, subscription charges would be approximately $473 higher per month.
- **Higher Utility Energy Prices:** If vehicles charge as soon as they are plugged in, they may be charging during times of peak energy prices, which ranges from 4 PM – 9 PM each day. Peak energy prices are approximately $0.21 more per kWh than off-peak prices. For Rio Vista Delta Breeze, this could cause monthly energy costs to be up to $1,313 more expensive if they do not charge during off-peak hours.[12] The ability for the operator to schedule the charger's charging start time is guaranteed in managed charging, but it is highly dependent on the charger manufacturer and model in unmanaged charging.

In terms of electrical equipment upgrade for the unmanaged charging option, the site will potentially require a 750 kVA transformer and a 600 A switchboard (if the transit agency cannot use the 2000 A spare breaker on the existing 4000 A switchboard shared with the wastewater treatment plant). However, the final electrical infrastructure sizing is determined by Rio Vista Delta Breeze's decision on load management and conversations with PG&E.

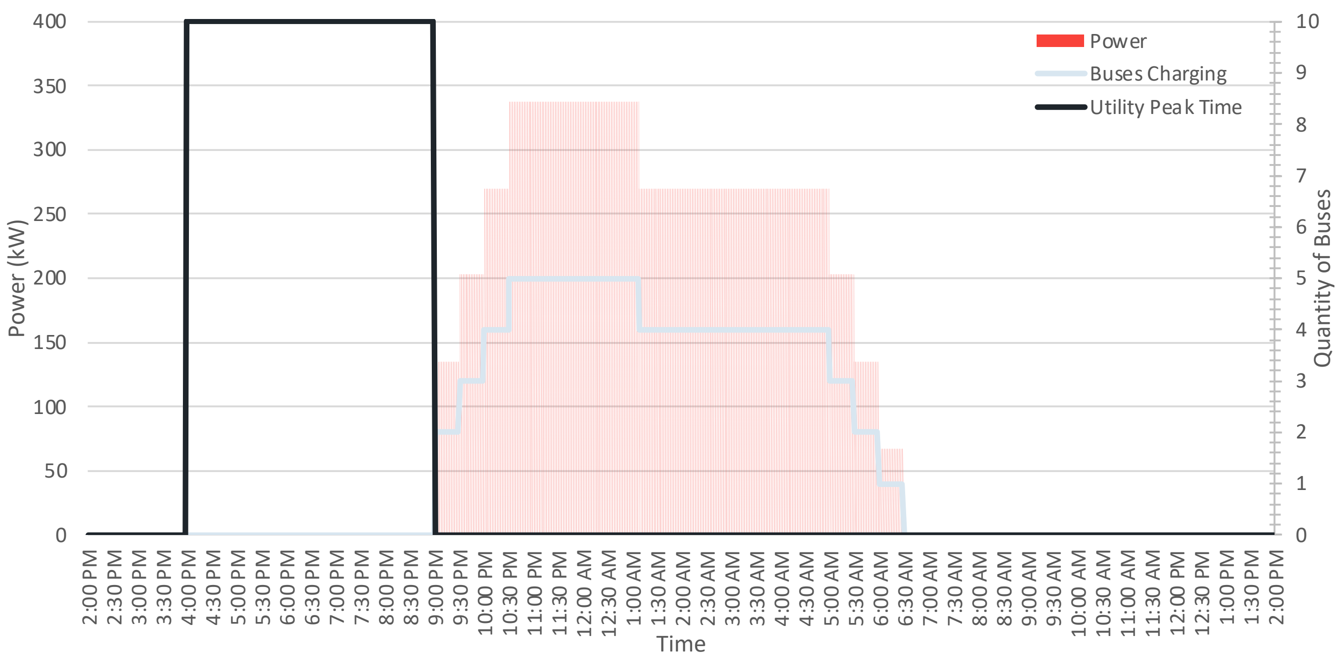
11 PG&E may use a monthly subscription charge in lieu of a demand charge, which is charged in 50kW blocks.

12 This assumes all four vehicles are fully recharged each day, peak energy costs of 0.33994 per kWh, off-peak costs of 0.12671 per kWh and 30 days per month.

The spare 2000 A breaker can also be used as the temporary solution in case PG&E's timeline is longer than the transit agency's timeline in rolling out these new BEBs. However, this will require negotiation with the wastewater treatment plant since they have expressed a future need for the spare 2000 A breaker.

To lower peak charging power, the agency can employ a CSMS to charge one cutaway and 35-foot bus pair starting at 9:00 PM with an average rate of 67.5 kW. Then as the cutaways finish charging, the CSMS will turn on the next cutaway charger dispenser. For the 35-foot buses, the CSMS starts charging a 35-foot bus 30 minutes after the previous one's charging start time. This creates an overlap of peak demand starting at 10:30 PM and 1:00 AM, but it allows all the vehicles to finish charging by 6:30 AM, within the hours of non-peak times and meets the earliest known check-in time of 6:45 AM. The summary of the fleet charging is shown in Figure 5.5. In this scenario, the fleet's peak charging demand is 375 kW and total energy would be 2.44 MWh.

Figure 5.5 Rio Vista Managed Charging Scenario: Four Cutaways and Four Future Buses



Source: WSP

Impacts of Unmanaged Charging Compared to Managed Charging (future buses included)

- **Higher Utility Subscription Charges:**[13] For Rio Vista Delta Breeze subscription charges would be approximately $468 higher per month.
- **Higher Utility Energy Prices:** Peak energy prices are approximately $0.21 more per kWh than off-peak prices. For Rio Vista Delta Breeze this could cause monthly energy costs to be up to $11,446 more expensive if they do not schedule their charging during off-peak hours.[14] The ability for the operator to schedule the charger's charging start time is guaranteed in managed charging, but it is highly dependent on the charger manufacturer and model in unmanaged charging.

13 PG&E may use a monthly subscription charge in lieu of a demand charge, which is charged in 50kW blocks.
14 This assumes all four vehicles are fully recharged each day, peak energy costs of 0.33994 per kWh, off-peak costs of 0.12671 per kWh and 30 days per month.

5.2.3 RECOMMENDED NEW ELECTRICAL SERVICE

Regardless of the existing or future fleet, the recommendation is to purchase a charge management system and use managed charging. The new utility electrical service load would decrease from 330 kW or 660 kW to 75 kW or 375 kW respectively. This greatly decreases the size of switchboard and transformer necessary to support the fleet chargers. The transit agency should request at least 415 kW of peak power which supports the future fleet needs and the managed charging demand that accounts for a 10% buffer for ancillary loads and losses.

While the 35-foot buses and cutaways should theoretically have enough capacity to service the Rio Vista Delta Breeze routes, other factors like heating, ventilation, and air conditioning (HVAC) or driving style may impact the battery capacity. Thus, if necessary, the BEBs can return to the bus depot for a midday charge before continuing their route. The CSMS can be remotely set to prepare for the incoming BEBs to dynamically charge midway. Ideally, the BEBs will charge for 30 minutes to an hour any time during off-peak time between 9:00 AM to 2:00 PM. The CSMS can reset these chargers back to the advertised 150 kW charge rate and provide a full charge for the cutaways in 56 minutes and 30% of the battery to the 35-foot buses. This will provide more than three times enough mileage for the cutaway to complete the conservative scenario of Block ID 1 as discussed in Task 2: Service Modeling Analysis. The buses should not have any problems completing the existing routes on an overnight charge unless Rio Vista Delta plans to add longer bus routes.

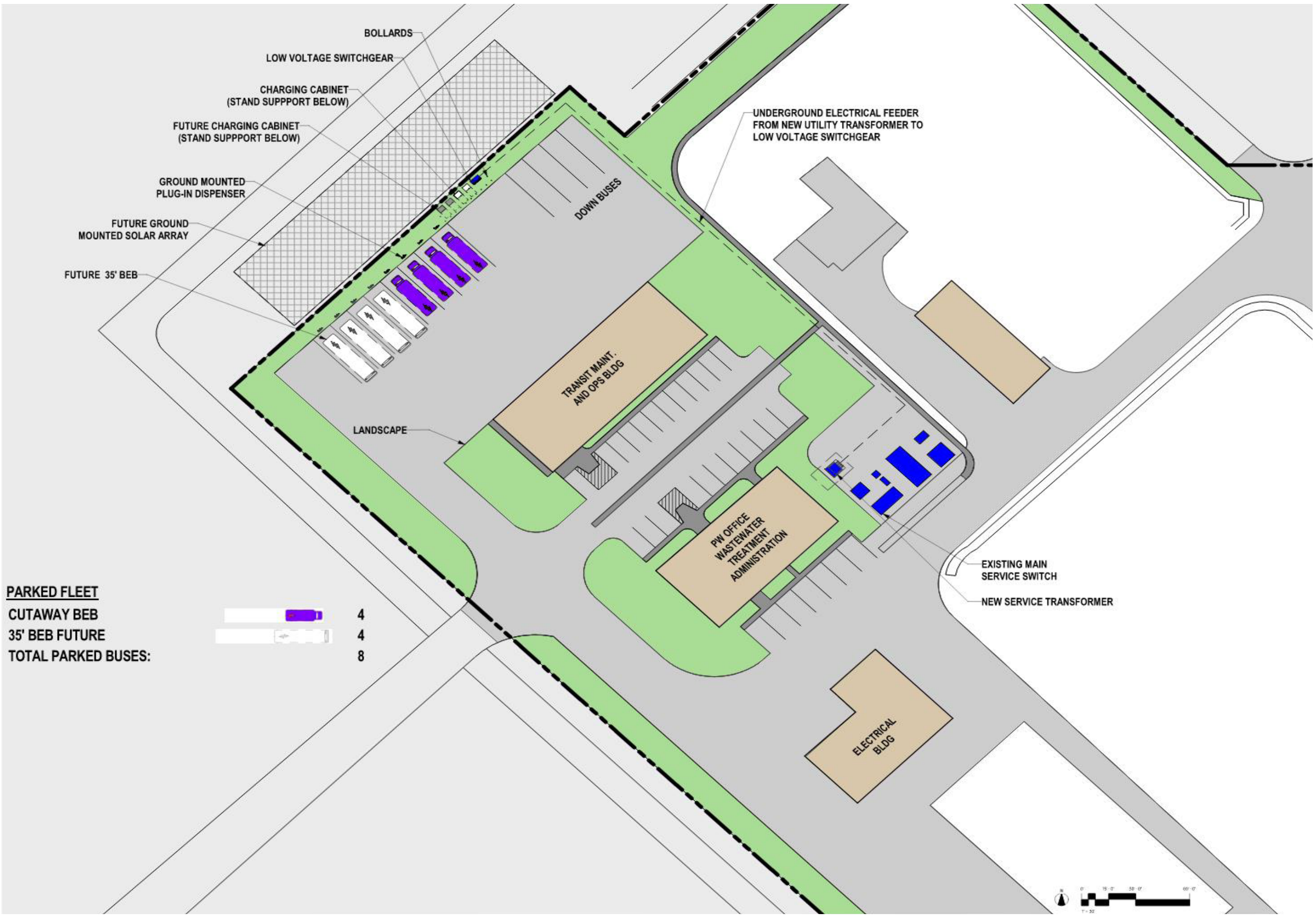
5.3 Facility Upgrades

Based on the analysis in this report, the following facility electrical upgrades are required as described below and illustrated in Figure 5.6:

- PG&E to install new 750 kVA transformer near site entrance, fed by new 12 kV underground conductor entering southwest end of site.
- Rio Vista Delta Breeze to install new 480 V switchboard and utility metering cabinet at northwest end of site with minimum electrical rating of 1200 A.
- Rio Vista Delta Breeze to install underground conduit from location of new transformer to location of new 480 V switchgear. This will require saw cutting and excavating existing paved areas.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchgear at north end of site. Underground conduit will need to be installed by Rio Vista Delta Breeze as described above, but PG&E will install the electrical conductor.
- Rio Vista Delta Breeze to install new vehicle charging cabinets where indicated, along with underground conduit connecting the charging stations to the new 480 V switchgear on the northwest end of the site.

The two charging scenarios discussed above inform the requirements for new electrical equipment. For the purposes of this report, the assumed sizing of on-site electrical equipment presented above is based on the unmanaged charging scenario to provide for worst-case analysis of equipment ratings and physical size. However, managed charging is recommended, and electrical equipment properties should be determined during the detailed engineering phase based on discussions with PG&E and the level of electric service requested.

Figure 5.6 Proposed Rio Vista Facility Upgrades



Source: WSP

5.4 Resiliency Analysis

The following section provides an overview of the site's existing conditions that impact the resiliency rating for the specified outage type, the resulting resiliency rating, and potential mitigation strategies to consider.

5.4.1 DISTRIBUTION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Type of construction:** 21 kV, primarily overhead wood-poles
- **Distance from substation:** The PG&E Grand Island 2226 substation is 17 miles from the Rio Vista Delta Breeze facility, which is considered far. A long distance like this increases the chances of an adverse event taking the distribution line out of service.
- **Distribution line route:** The PG&E Grand Island 2226 line primarily follows rural public roadways, with adjacent trees along a small section of the line, so there is a low chance of a vegetation-induced outage during a weather event. Additionally, the line crosses a river.

- **Shared-use:** The PG&E Grand Island 2226 line supplies power to rural customers, suburban residential customers, commercial customers, and industrial customers.

Resiliency rating: Low

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Rio Vista Delta Breeze facility has a low level of resiliency against distribution-related outages. This rating is driven primarily by the distribution line being overhead construction and the distance from the nearest substation. However, most of the line is easily accessible by utility maintenance crews and the line supplies power to many customers, so issues would likely be repaired quickly.

Mitigation Strategies Considered

- Backup Generator
- Solar Photovoltaic System
- Battery Energy Storage System

5.4.2 TRANSMISSION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Redundant transmission lines:** The PG&E Grand Island substation is fed by one double-circuit 115 kV transmission line. This means there are two sets of high voltage power lines that share the same towers. This provides a low level of redundancy against certain transmission outages, such as maintenance events, but does not provide any redundancy against an outage caused by loss of a transmission tower, such as wildfire or extreme weather.
- **Utility substation configuration:** The 115 kV transmission lines supply two step-down transformers, which then supply the 21 kV Grand Island 2226 distribution line that feeds the Rio Vista Delta Breeze facility. This provides a moderate level of redundancy against adverse events at the utility substation.
- **CPUC wildfire risk category:** The geographic area near Rio Vista Delta Breeze is classified as tier 1 according to the CPUC FireMap,[15] with tier 1 being the lowest risk of wildfire-related utility events and tier 3 being the highest risk.

Resiliency rating: Moderate

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Rio Vista Delta Breeze facility has a moderate level of resiliency against transmission-related outages. It is important to note that transmission-related outages are extremely rare compared to other types of outages, even for facilities assigned a rating of "low." However, when they do happen, they may impact a wider geographic area and take longer to repair. This rating is intended to compare the level of resiliency against other commercial and industrial facilities in the United States.

Mitigation Strategies Considered

- Backup Generator
- Solar Photovoltaic System
- Battery Energy Storage System

15 https://ia.cpuc.ca.gov/firemap/

5.4.3 UTILITY ENERGY SUPPLY SHORTAGES

Factors Impacting Resiliency

- **Grid generation shortages:** Stage 3 emergencies are declared by the CAISO when the grid operators are unable to meet minimum contingency reserve requirements, and load interruption is imminent or in progress. Overall, CAISO has recorded 41 Stage 3 emergencies over a 23-year period between 1998 to 2021.[16] One important caveat is 38 out of the 41 (roughly 93%) Stage 3 emergencies happened in 2001, with none reported until 2020.

Resiliency rating: High

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Rio Vista Delta Breeze facility has a high level of resiliency against this type of outage. However, changes in the California generation mix along with frequent extreme weather events, including the shutdown of a nuclear power plant, mean that Stage 3 emergencies could happen more frequently in the near-term than they did 10-15 years ago. While in 2021, the chances of a utility energy supply shortage are rare, the resiliency does depend on the prevention actions taken by PG&E and CAISO.

Mitigation Strategies Considered

- **Qualify as an Essential Use Customer:** The transit agency should consider applying to PG&E for Essential Use Customer Classification[17] under the CPUC, especially if other forms of onsite backup generation are not present or do not meet the full needs of the Rio Vista Delta Breeze facility. BEB fleets in California are still relatively new, so it is unclear if BEBs qualify under the current CPUC categories for Essential Use Customers.
- **Off-peak charging:** By using charge management system to intelligently shift charging to off-peak times of day, the Rio Vista Delta Breeze facility will be less susceptible to blackouts caused by energy-supply shortages.
- **Backup generator:** A backup generator may also minimize the impacts of rolling blackouts caused by energy supply shortages. However, given that these types of outages tend to be shorter in duration but occur more frequently over the course of days or weeks, a permanent generator is better suited than a mobile generator that may take time to connect and ramp-up. It is likely that the adjacent water treatment facility already has a sizable backup generator, which could be utilized or upgraded to provide backup power to both portions of the facility.
- **Solar photovoltaic system:** A solar photovoltaic system can be an effective way of responding to rolling blackouts caused by utility energy supply shortages when combined with a battery energy storage system. However, given the large amount of solar PV in California, energy supply shortages may also be more likely to occur on cloudy days when Rio Vista onsite solar may also be constrained.
- **Battery energy storage system:** A battery energy storage system may provide backup power immediately to a limited number of electric vehicle chargers for a short duration, typically on the order of hours. This makes it a good fit for short-duration outages caused by utility energy shortages.

16 http://www.caiso.com/Documents/AWE-Grid-History-Report-1998-Present.pdf
17 https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_FORMS_79-1038.pdf

5.4.4 ONSITE FACILITY EQUIPMENT OUTAGES

Factors Impacting Resiliency

- **Lack of redundant equipment:** Since the Rio Vista Delta Breeze facility only requires eight electric vehicles, it is not cost-effective to install multiple transformers and switchboards. However, it is proposed that multiple DC vehicle chargers be installed, which provides redundancy against a common point of failure.
- **Lack of public charger nearby:** Due to the remote location of the transit agency, the nearest public charger is 23 miles away and there are no nearby charger maintenance centers nearby.

Resiliency rating: Moderate

If the Rio Vista Delta Breeze facility can use the spare capacity of the existing onsite transformer, there would not be a redundant transformer or main switchboard. However, if a second transformer is installed by PG&E to serve the electric vehicle charging equipment, then it may be possible to design the system in a way that provides redundancy for both the electric vehicle chargers and the water treatment facility. Regardless, the uptime requirements of the water treatment facility are likely high, and the existing electrical infrastructure is likely to be reliable and designed for minimal downtime. The remote location of the facility will require the site to operate on more of a self-service model or have a long waiting time for outside repairs since the town is quite small.

Mitigation Strategies Considered

- **Onsite spare equipment:** Spare parts should be kept onsite at the Rio Vista Delta Breeze facility for equipment that is most likely to experience a failure. This includes fuses, circuit breakers and terminals/lugs. If possible, spare parts should be provided by the manufacturer for the electric vehicle DC chargers since these devices tend to use proprietary electronic components that may not be easily obtained in the future.
- **Routine equipment inspection:** Electrical equipment and vehicle charging equipment should be inspected, tested, and cleaned on a regular basis according to manufacturer's recommendations. An inspection schedule and testing procedure should be developed and incorporated into the facility's routine maintenance plans.
- **Warranty & service contracts:** Electric vehicle charging equipment may require specialized parts and manufacturer-trained technicians to repair. The transit agency should determine who will be responsible for repairs both during and after the initial warranty period and should identity the manufacturer point-of-contact for repair and the local firm that can perform the repair.

5.4.5 BACKUP POWER SYSTEMS

One or more of the backup power strategies below provide a suitable level of backup power for most of the scenarios described above at the Rio Vista Delta Breeze facility. The selection of a resiliency strategy during the design phase should consider the likelihood of a given outage scenario, the risk tolerance and operational flexibility of the transit agency, and the project budget.

1. **Permanent Standby Generator**
   The Rio Vista Delta Breeze facility should consider installing a permanent standby generator, powered by either diesel or natural gas, and connect it to the main switchboard using a manual or automatic transfer switch. This allows the facility to switch between the utility feed and generator power and isolates the generator from the utility feed to prevent back feeding the utility system. It is likely that the adjacent water treatment facility already has a backup generator, which could be utilized or upgraded to provide backup power to both portions of the facility. This should be investigated during the project design phase. If a new generator is necessary, a 400 kW generator would fully power two 150 kW DC chargers simultaneously, and fully recharge the existing vehicles overnight or 75% of the future fleet (all cutaways and two buses). The generator will run as long as there is fuel, so the run time of the generator can mitigate many types of outages. In California, all newly purchased generators need to meet certain CARB emissions rules, which can vary depending on how the generator is used.
2. **Solar Photovoltaic System [300 - 600 kW]**
   A solar PV system is not suitable as a source of backup power on its own and should be combined with a battery energy storage system or generator. The decision to install a solar PV system should also incorporate renewable energy goals and potential energy cost savings. The Rio Vista Delta Breeze site has adequate space to install a sizable solar PV system.
3. **Battery Energy Storage System [1 - 2 MWh]**
   A battery energy storage system may be able to provide a good source of backup power to a significant portion of the Rio Vista Delta Breeze fleet. These systems are modular and are available in 10 to 40-foot standard intermodal containers. Capital costs tend to be higher than a backup generator, and a battery storage system may not be sufficient for all types of outages as discussed above. These tradeoffs should be investigated during the project design phase. A 1 – 2 MWh system could provide backup power for approximately one day, while optimizing a solar PV system.

Other Types of Backup Power Systems Considered

- **Trailer-mounted mobile generator -** A mobile generator is less beneficial since the Rio Vista facility is shared with the water treatment facility, and the facility has ample space to install a permanent standby generator. The transit agency also does not have other nearby facilities that might benefit from sharing a single mobile generator.

5.5 Summary and Next Steps

The following section summarizes the energy and power analysis, facility upgrades recommendation, and resiliency discussion from the previous sections. The recommendations will inform the immediate next steps for Rio Vista Delta Breeze electrification.

5.5.1 SUMMARY

The summary of the different charging scenarios for Rio Vista Delta Breeze is mentioned in Table 5.1. The recommendation is to purchase a charge management system and use managed charging to keep the new electrical service load to 75 kW or 375 kW, depending on the future bus fleet.

Table 5.1 Summary of Rio Vista Charging Scenarios

Recommended Charger	Scenario	Charge Schedule	Peak Demand	Upgrade Necessary	Est. Monthly Cost
Two or four 150 kW DC chargers *(depending on future bus fleet)*	**Unmanaged - without future buses**	All eight BEBs charge concurrently and simultaneously at 9:00 PM	300 kW	330 kW	$1,411
	Unmanaged - with future buses		600 kW	660 kW	$8,063
	Managed – without future buses*	Vehicle charging is sequentially scheduled throughout the night to smooth out power demand, BEBs charge concurrently at average rate of 67.5 kW	75 kW	165 kW[18]	$938
	Managed – with future buses*		375 kW	415 kW (suggested)	$7,595

*Preferred scenarios

Source: WSP

Table 5.2 summarizes the needed facility upgrade for Rio Vista Delta Breeze's facility. PG&E would be responsible in installing the new transformer and underground electrical conductor, while Rio Vista Delta Breeze would be responsible in installing switchboard, utility metering cabinet, underground conduit, and charging stations.

Table 5.2 Summary of Rio Vista's Facility Upgrade

Responsible Stakeholder	Item to Install	Location	Note
PG&E	750 kVA transformer	Near site entrance	Fed by new 12 kV underground conductor entering southwest end of site
	Underground electrical conductor	Along Grand Island 2226 circuit	Connecting transformer installed by PG&E to the switchboard installed by Rio Vista Delta Breeze
Rio Vista Delta Breeze	480 V switchboard and utility metering cabinet	Northwest end of site	Min. electrical rating of 1200A
	Underground conduit	Decision based on engineering design	Connecting new transformer to the new switchboard
	Charging stations and underground conduit	As indicated	Connected to the 480 V switchboard

Source: WSP

Table 5.3 summarizes the contributing factors, resiliency rating, and mitigation method for different types of outages.

18 Since each charger is capable of providing 150 kW, the minimum new electrical service must be capable of supplying at least this much power.

Table 5.3 Summary of Resiliency Analysis for Rio Vista Delta Breeze

Summary of Dixon Readi-Ride Charging Scenarios	Distribution-Related Outages	Transmission-Related Outages	Energy Supply Shortages	Facility Equipment Failures
Contributing Factors	• 17 miles to substation • 21 kV feeder is 100% overhead with primarily wood-poles through rural, desert neighborhood	• Redundant transmission lines • Low risk area for wildfires • Two step-down transformers at substation	• Two grid generation shortages in the last 19 years • Increase in wildfires	• Remote area • Lack of redundant equipment
Resiliency Rating	Low	Moderate	High	Moderate
Mitigation Method	• Backup generator • PV and BESS	• Backup generator • PV and BESS	• Become Essential Use Customer • Off-peak charging • Backup generator	• Onsite spare equipment and repair people • Routine equipment inspection • Warranty & service contracts
Backup Power Options	• 400 kW permanent standby generator • 300 - 600 kW Solar PV system paired with 1 - 2 MWh BESS in 10' – 40' intermodal container A generator with an output rating of at least 400 kW can power two 150 kW DC charging cabinets simultaneously and fully recharge all vehicles overnight.			

Source: WSP

5.5.2 NEXT STEPS

Rio Vista Delta Breeze needs to first evaluate their options and take the next immediate steps:

1. Decide whether to invest in a charge management system or not
2. Size the site for future fleet or existing fleet
3. Request the appropriate load from PG&E
4. Future Fleet: 415 kW for managed, 660 kW for unmanaged
5. Existing Fleet: 165 kW for managed, 330 kW for unmanaged
6. Begin service application and coordination with PG&E
7. Determine outage mitigation methods. If a backup generator is selected, include the design and procurement in engineering firm RFP
8. Bid out to local engineering firm for detailed design
9. Procure long-lead items
10. Begin construction to point of contact with utility

SolTrans

6 SOLTRANS

6.1 Background

This site has been analyzed previously in separate study of Soltrans' Phase 1 BEB transition and currently is in the design and bid phase. All information in this report is based on the previous report. No additional analysis was performed, so the report structure does not match the other sections in this report. Additionally, technical information presented in this report does not depict the SolTrans requirements as designed or as constructed. Requirements and specifications may have changed during the design & construction process and may not be reflected in this report.

6.2 Energy and Power Analysis

6.2.1 MAINTENANCE FACILITY SITE ELECTRICAL COMPONENTS

The SolTrans maintenance facility detailed design & engineering for phase 1 was completed in 2021. Refer to construction documents for details. A summary of the electrical scope of work for phase 1 is below. Future phases will accommodate additional buses.

- Install new 480 V electric service (by PG&E)
- Install new main meter switchboard near PG&E transformer
- Construct approximately 50 feet of new underground electrical duct bank
- Construct approximately 300 feet of conduit up the side of existing building, across roof, across utility bridge, terminating on top of new steel canopy structure
- Install four new 800 A electric distribution panels
- Install one new 400 A auxiliary electrical panel
- Install one new 100 kVA auxiliary transformer for lighting and control
- Install 21 new BEB charging cabinets with retractable plugs
- Add/Alternate: install solar PV system
- Add/Alternate: install battery energy storage system

6.2.2 CURTOLA ELECTRICAL COMPONENTS

Phase 1 will include:

- New 12 kV service
- One new 500 kVA transformer
- One new site meter
- One new 750-amp switchboard
- One 300 kW ground-mounted induction charger pad and associated charging cabinet
- All required conduit and connections to distribute phase 1 power needs

6.2.3 VALLEJO TRANSIT CENTER ELECTRICAL COMPONENTS

Phase 1 will include:

- New 12 kV service

- One new 1,500 kVA transformer to replace 750 kVA transformer (replacing the existing transformer)
- One new site meter
- One new 1,500-amp switchboard
- One new 45 kVA 480V/120V Aux transformers (one per switchgear)
- Two 300 kW ground-mounted induction charger pads and associated charging cabinets
- All required conduit and connections to distribute phase 1 power needs

Final Phase will include the following in addition to the Phase 1 equipment:

- One 300 kW ground-mounted induction charger pad and associated charging cabinet
- One new 45 kVA 480V/120V Aux transformers (one per switchgear)
- All required conduit and connections to distribute ultimate phase power needs

6.3 Resiliency Analysis

In the event of utility failure, SolTrans' needs to maintain the ability to operate from the maintenance facility site. The existing backup generator is not adequately sized to provide charging operations for the incoming BEB's, so the SolTrans conceptual design includes an add-alternate option to install up to two 2-megawatt hour batteries on the site, for a total of four megawatt hours of battery storage. The backup batteries in addition to photovoltaic panels mounted to the new overhead support structure will generate and store backup power for standard duration power failures at the maintenance facility site via their connection to a "microgrid ready" switchgear at the heart of the electrical system. A standard duration outage is assumed to be two hours.

6.4 Summary and Next Steps

The SolTrans portion of the project includes three sites: the maintenance facility, the Curtola Park and Ride, and the Vallejo Park and Ride. Currently, all three sites have gone through detailed design and are currently undergoing the bidding process for engineering, procurement, and construction. Therefore, next steps for SolTrans are outside the scope of this report.

CITY COACH

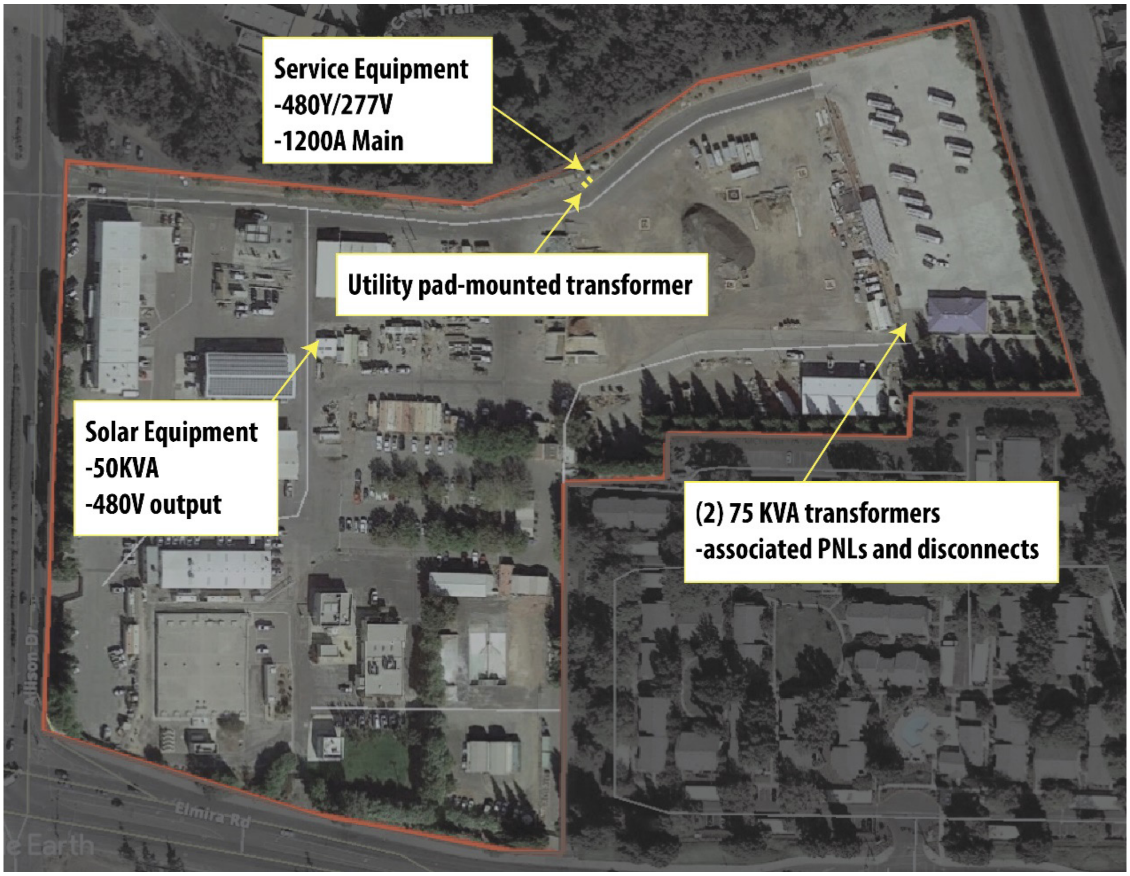
7 VACAVILLE CITY COACH

The following section presents an overview of the Vacaville City Coach energy and power analysis results, facility electrical upgrades, and suggested resiliency methods.

7.1 Existing Conditions

The Vacaville City Coach operations are currently located at 1001 Allison Dr, Vacaville, CA 95687. The transit agency currently operates 18 standard 35-foot buses and the demand response fleet consists of seven cutaways. The 35-foot buses all run on compressed natural gas, while the cutaways run on gasoline. Vacaville City Coach's power is provided by the PG&E Vacaville Substation (6360) at 38.356532, -121.980470, located approximately 2.4 miles from the transit yard. The substation has a capacity of 44.6 MW on Bank 2 with a peak load of approximately 37.8 MW based on publicly available data. This feeds the Vacaville 1105 circuit that feeds the Vacaville City Coach yard. The 12 kV Vacaville 1105 Circuit has an existing capacity of 10.9 MW. PG&E estimates the projected peak load of this circuit as 9.2 MW, leaving approximately 1.7 MW of available capacity. The circuit enters the yard from Elmira Road.

Figure 7.1 Vacaville City Coach Plan View



Source: WSP

The site has a utility pad-mounted transformer (T18142) in the site center as shown on Figure 7.1. On the east side of the site, there are two 75 kVA transformers and their associated panelboards and disconnects. Onsite connections cannot be verified at this time. There is one 1200A 480Y/277V main switchboard service equipment with an estimate of three spare breakers. The switchboard schedule could not be verified at this time. There is 50 kVA solar power with 480 V output and a Satcon 480 V transformer onsite. The 50 kVA solar panel disconnect switch could not be verified, so it is assumed to always be connected and providing power to the site.

7.2 Energy and Power Analysis

7.2.1 VEHICLE FLEET

The Vacaville City Coach fleet consists of 25 gas vehicles, 18 35-foot buses and seven cutaways.

7.2.2 CHARGING SCENARIOS CONSIDERED

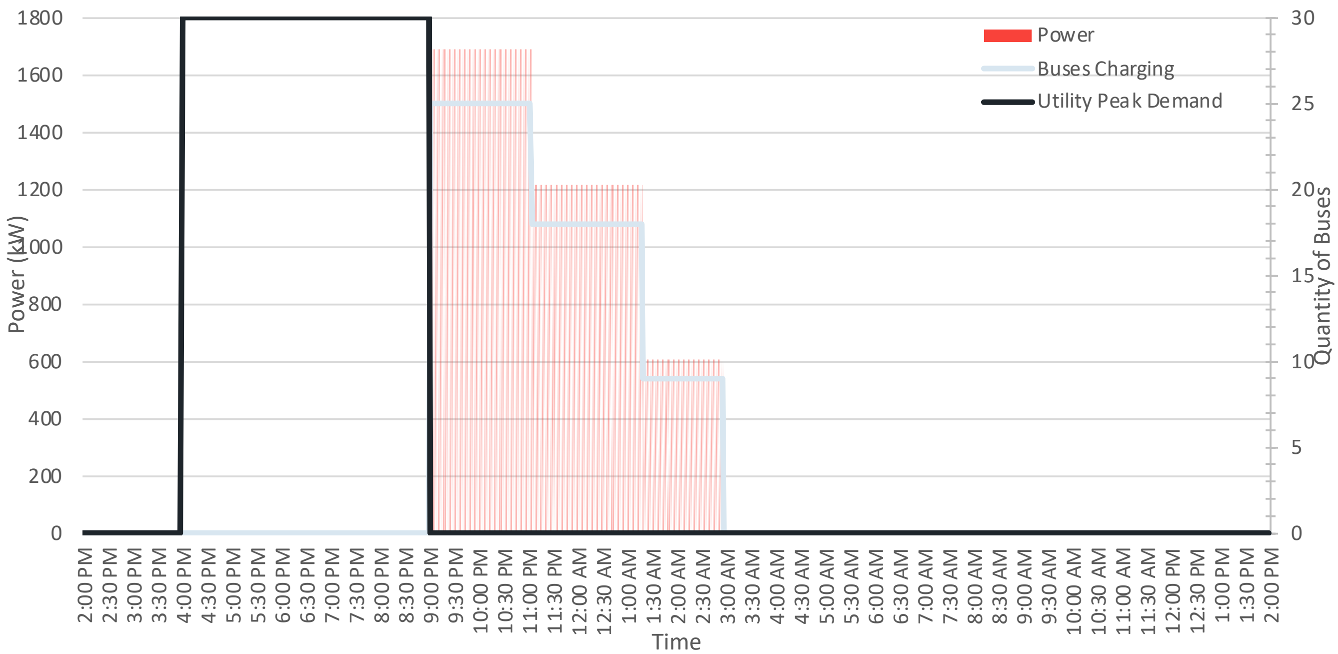
This report analyzes two scenarios, unmanaged and managed charging. The unmanaged charging scenario serves as a baseline and calculates the requirements assuming no managed charging solutions are used. This scenario provides the most flexible system, but at a higher cost and potentially longer construction schedule. The managed charging scenario takes advantage of a charge management system to provide flexibility while minimizing capital costs, energy costs, and demand charges.

This report recommends installation of new electrical service capable of supplying at least 990 kW of power in combination with a charge management system. The total recommended number is 13 150 kW DC chargers. This would allow up to seven cutaways and 18 35-foot buses to fully recharge each night using managed charging. Also, five out of the 13 DC chargers could be used simultaneously at full-speed for flexible mid-day recharging if necessary, or to charge other vehicles that were not included as part of this analysis.

Unmanaged Charging

The site is expected to have thirteen 150 kW DC chargers to charge the entire fleet. The unmanaged charging option assumes all the BEBs charge concurrently at an average rate of 67.5 kW beginning at 9:00 PM. The 502 kWh 35-foot buses will all finish charging within six hours while the cutaways will finish charging within 2.1 hours, ensuring all BEBs are ready for the earliest roll-out time of 6:45 AM, as shown in Figure 7.2. The peak demand is 1.88 MW and will occur for the first two hours of charging. The total energy demand is 7.2 MWh.

Figure 7.2 Vacaville City Coach Unmanaged Charging Scenario

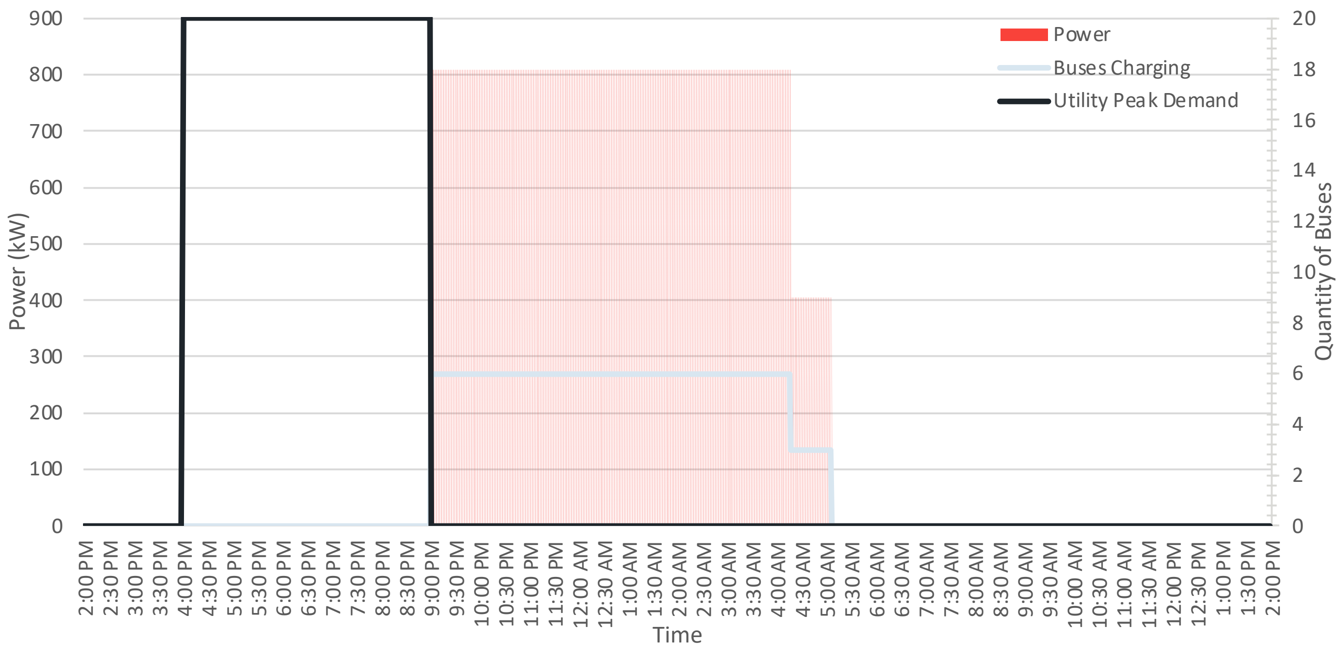


Source: WSP

Managed Charging

In this scenario, Vacaville City Coach invests in a CSMS which spreads the vehicle charging throughout the night. There are many variations in the fleet's charging profile that the CSMS can perform, but for the simplicity of this report, the discussion will use one example on the benefits of managed charging. Instead of charging all the vehicles at once, the CSMS can be programmed to charge the vehicles with the earliest pull-out times first at an average rate of 135 kW before moving onto the next batch of vehicles with a later pull-out time or lower priorities. The assumed nine 35-foot buses that serve Block ID 19690 have an earlier pull-out time of 6:24 AM while the other nine buses that service Block ID 19688 have a later pull-out time of 6:45 AM. The cutaways have the last priority since they are demand response vehicles. In this example, the CSMS continually charges six BEBs at a time according to charge priority and moves on to the next BEB once the initial charging BEB is done as shown in Figure 7.3. The site has a peak demand of 900 kW and a total energy of 7.2 MWh consumed, not accounting for internal charger losses.

Figure 7.3 Vacaville City Coach Managed Charging Scenario



Source: WSP

Impacts of Unmanaged Charging Compared to Managed Charging

- **Higher Utility Subscription Charges:**[19] For Vacaville City Coach, this would be approximately $2,050 more per month in PG&E's demand subscription charges, detailed in Section 3.2.1, with unmanaged versus managed charging.
- **Higher Utility Energy Prices:** If vehicles charge as soon as they are plugged in, they may be charging during times of peak energy prices, which ranges from 4 PM – 9 PM each day. Peak energy prices are approximately $0.21 more per kWh than off-peak prices. For Vacaville City Coach, which operates six days a week, this could cause monthly energy costs to be up to $41,452 more expensive if they do not charger during off-peak hours.[20] The ability for the operator to schedule the charger's charging start time is guaranteed in managed charging, but it is highly dependent on the charger manufacturer and model in unmanaged charging.

The cost and financial impacts are discussed in detail in the Costs and Funding Analysis report.

7.2.3 RECOMMENDED NEW ELECTRICAL SERVICE

Between the two charger scenarios, the recommendation is to purchase a CSMS and use managed charging. The new utility electrical service load would decrease from 2063 kW to 990 kW, greatly decreasing the size of switchboard and transformer necessary to support the fleet chargers. It is highly advised for Vacaville City Coach to invest in a CSMS because the existing PG&E feeder, Vacaville 1105 Circuit, serving the site only has a

19 Refer to Section 3.2 for an overview of the utility rate structure.

20 This assumes all four vehicles are fully recharged each day, peak energy costs of 0.33994 per kWh, off-peak costs of 0.12671 per kWh and 30 days per month.

free peak capacity of 1.7 MW. The peak times for the feeder may or may not coincide with the projected peak times Vacaville City Coach wants to charge nor can it support the potential 1.88 MW peak load Vacaville City Coach can potentially incur with unmanaged charging.

While the 35-foot bus's 502 kWh battery capacity is theoretically enough to run Vacaville City Coach's routes, other factors like HVAC or driving style may drain the battery quicker. In the Task 2: Service Modeling Analysis's conservative scenario for Vacaville City Coach, there is an average of 57.3 kWh more battery capacity needed to finish the transit routes. Addressing this shortfall is outside the scope of this report but should be investigated further.

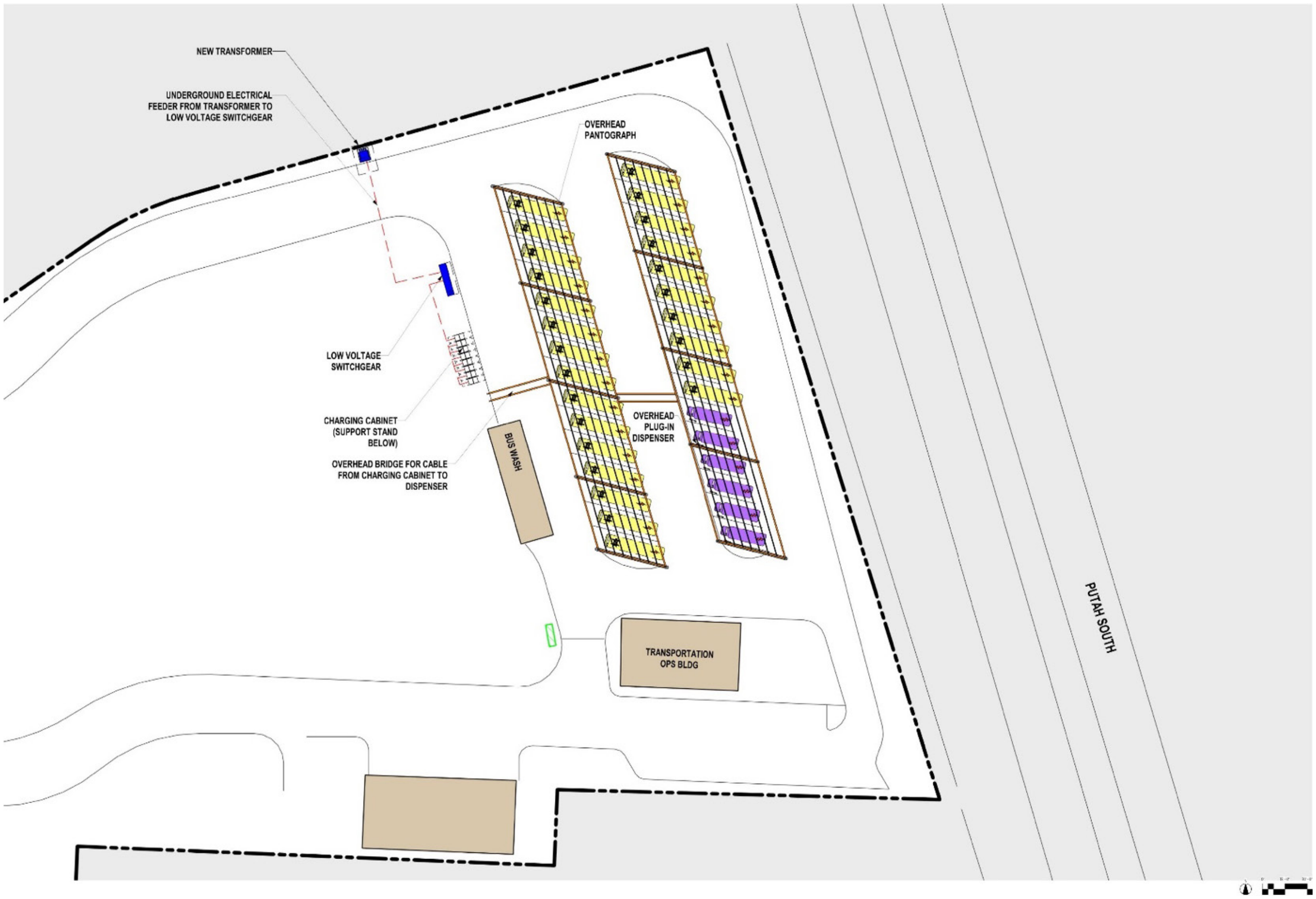
7.3 Facility Upgrades

Based on the analysis in this report, the following facility electrical upgrades are required as described below and illustrated in Figure 7.4:

- PG&E to install new 3000 kVA transformer near north end of site, fed by new 12kV underground electrical service that enters the site from the west.
- Vacaville City Coach to install new 480 V switchboard and utility metering cabinet to the north of the bus wash building with minimum electrical rating of 4000 A.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchboard. Underground conduit will need to be installed by Vacaville City Coach, but PG&E will install the electrical conductor.
- Vacaville City Coach to install new vehicle charging stations where indicated, with underground conduit connecting the charging stations to the new 480 V switchgear.

The two charging scenarios discussed above inform the requirements for new electrical equipment. For the purposes of this report, the assumed sizing of on-site electrical equipment presented is based on the unmanaged charging scenario to provide for worst-case analysis of equipment ratings and physical size. However, managed charging is recommended, and electrical equipment properties should be determined during the design phase based on discussions with PG&E and the level of electric service requested.

Figure 7.4 Vacaville City Coach Facility Upgrades



Source: WSP

The onsite utility 75 kVA transformers and existing 1200 A switchboards are not large enough to power the new fleet electrical needs. The proposed location for the new transformers and switchboards is near the parking location of the buses. PG&E would need to tap into the existing overhead 12 kV Vacaville 1105 circuit and run the new underground conduit to the new transformer and switchboard. From the new low voltage switchboard, the conductors for the chargers will run along an underground trench to the charging cabinet located at the western edge of the concrete pad of the fleet's existing parking spot as shown in Figure 7.4. The charging cabinets then connect to the 150 kW overhead pantographs with 2:1 plug-in dispenser.

7.4 Resiliency Analysis

The following section provides an overview of the site's conditions that impact the resiliency rating for the specified outage type, the assigned resiliency rating, and potential mitigation strategies to consider.

7.4.1 DISTRIBUTION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Type of construction:** 100% overhead with primarily wood-poles.
- **Distance from substation:** The PG&E Vacaville substation is only 2.4 miles from the Vacaville City Coach facility, which is considered close. A short distance like this lowers the chances of an adverse event taking the distribution line out of service.
- **Distribution line route:** The PG&E Vacaville 1105 feeder line primarily follows city public roadways, with adjacent landscaped trees along the line, so there is a low to moderate chance of a vegetation-induced outage during a weather event.
- **Utility substation transformer:** The PG&E Vacaville substation has three step-down transformers, which then feed the 12 kV Vacaville 1105 distribution line. This provides a high level of redundancy against adverse transformer events.

Resiliency rating: Moderate

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Vacaville City Coach facility has a moderate level of resiliency against distribution-related outages. This rating is driven primarily by the distribution line being overhead construction and the presence of adjacent trees along the route. An underground distribution line would provide a higher level of resiliency.

Mitigation Strategies Considered

- **Dedicated, pad-mounted utility transformer:** The Vacaville City Coach facility will be supplied by a new utility transformer, which will be located on site in a protective enclosure at ground-level.
- **Permanently installed standby generator:** An extended distribution-related outage is best mitigated by a permanent diesel or natural gas generator rather than a mobile generator.
- **Battery energy storage system:** Since the Vacaville City Coach facility has 25 vehicles, a battery storage system may not be an effective backup solution on its own for providing backup power during an extended distribution-related outage. It can provide enhanced capabilities when paired with a standby generator and an onsite solar PV system.

7.4.2 TRANSMISSION-RELATED UTILITY OUTAGES

Factors Impacting Resiliency

- **Redundant transmission lines:** The PG&E Vacaville substation is fed by two 115 kV transmission lines which supply two three-down transformers, which then feed the 12 kV Vacaville 1105 distribution line. This provides a moderate level of redundancy against adverse events at the utility substation, and one redundant source of power for the outage of a 115 kV transmission line.
- **CPUC wildfire risk category:** The Vacaville area is classified as tier 1 according to the CPUC FireMap,[21] with tier 1 being the lowest risk of wildfire-related utility events and tier 3 being the highest risk. However, Vacaville is within several miles of an area that is rated tier 2, which is at elevated risk.

Resiliency rating: High

21 https://ia.cpuc.ca.gov/firemap/

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Vacaville City Coach facility has a high level of resiliency against this type of outage. It is important to note that transmission-related outages are extremely rare, even for facilities assigned a rating of "low." This rating is intended to compare the level of resiliency against other commercial and industrial facilities in the United States.

Mitigation Strategies Considered

- **Permanently installed standby generator:** The Vacaville City Coach facility requires 25 electric vehicles, 18 of which are buses with large capacity batteries. Though rare, transmission-related outages may be longer in duration, especially if due to a public safety power shutoff. A permanent backup generator provides the runtime needed to continue operations for a multi-day transmission outage.
- **Battery energy storage system:** A battery energy storage system may be a good solution to supplement a permanently installed standby generator, especially during peak charging times.

7.4.3 UTILITY ENERGY SUPPLY SHORTAGES

Factors Impacting Resiliency

- **Grid generation shortages:** Stage 3 emergencies are declared by the California ISO when the grid operators are unable to meet minimum contingency reserve requirements, and load interruption is imminent or in progress. Overall, CAISO has recorded 41 Stage 3 emergencies over a 23-year period between 1998 to 2021.[22] One important caveat is 38 out of the 41 (roughly 93%) Stage 3 emergencies happened in 2001, with none reported again until 2020.

Resiliency rating: High

Based on a qualitative analysis of the risk factors described above, the utility feed supplying the Vacaville City Coach facility has a high level of resiliency against this type of outage. However, changes in the California generation mix along with frequent extreme weather events, including the shutdown of a nuclear power plant, mean that Stage 3 emergencies could happen more frequently in the near-term than they did 10-15 years ago. While in 2021, the chances of a utility energy supply shortage are rare, the resiliency does depend on the prevention actions by PG&E and CAISO.

Mitigation Strategies Considered

- **Qualify as an Essential Use Customer:** The transit agency should consider applying to PG&E for Essential Use Customer Classification[23] under the CPUC, especially if other forms of onsite backup generation are not present or do not meet the full needs of the Vacaville City Coach facility. BEB fleets in California are still relatively new, so it is unclear if BEBs qualify under the current CPUC categories for Essential Use Customers.
- **Off-peak charging:** By using charge management system to intelligently shift charging to off-peak times of day, the Vacaville City Coach facility will be less susceptible to blackouts caused by energy-supply shortages.

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22 http://www.caiso.com/Documents/AWE-Grid-History-Report-1998-Present.pdf
23 https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_FORMS_79-1038.pdf

- **Backup generator:** A backup generator may also minimize the impacts of rolling blackouts caused by energy supply shortages. However, many generators require up to an hour to ramp-up to their full output, making them suboptimal for rolling short-duration outages.

7.4.4 ONSITE FACILITY EQUIPMENT OUTAGES

Factors Impacting Resiliency

- **Lack of redundant equipment:** Since the Vacaville City Coach facility has 25 electric vehicles, it may not be cost-effective to install multiple transformers and main switchboards to provide additional redundancy. However, it is proposed that multiple DC vehicle chargers be installed, which provides redundancy against a common point of failure.

Resiliency rating: Moderate

While the preliminary electrical design for the Vacaville City Coach facility does not include redundant transformers or switchboards, the vehicles will be powered by a dedicated electrical system that is separate from the rest of the Vacaville City Coach facility. This minimizes the risk of equipment downtime due to failures caused by nonvehicular equipment. Additionally, all proposed electrical equipment and systems will be brand new and utilize modern technology, which greatly reduces the likelihood of major equipment failures in the next 10-15 years when compared to retrofitting an existing system. Also, a local firm that can quickly service the equipment is more probable since the city of Vacaville is larger than the other sites considered in this report as evidenced by the close proximity to other DC chargers.

Mitigation Strategies Considered

- **On site spare equipment:** Spare parts should be kept onsite at the Vacaville City Coach facility for equipment that is most likely to experience a failure. This includes fuses, circuit breakers & terminals/lugs. If possible, spare parts should be provided by the manufacturer for the electric vehicle DC chargers since these devices tend to use proprietary electronic components that may not be easily obtained in the future.
- **Routine equipment inspection:** Electrical equipment and vehicle charging equipment should be inspected, tested and cleaned on a regular basis according to manufacturer's recommendations. An inspection schedule and testing procedure should be developed and incorporated into the facility's routine maintenance plans.
- **Warranty & service contracts:** Electric vehicle charging equipment may require specialized parts and manufacturer-trained technicians to repair. Vacaville City Coach should determine who will be responsible for repairs both during and after the initial warranty period and should identity the manufacturer point-of-contact for repair and the local firm that can perform the repair.
- **Offsite vehicle charging:** Designate use of an alternate charging site during an outage or charge from a public charging site if possible. The nearest public charger site currently is 1.5 miles away from the Vacaville City Coach site. It is unexpected for all 35-buses to charge at a public charging site, but if emergencies arise, the transit agency can potentially strike a deal with public DC charger vendors to have priority charging for a few buses or cutaways.

7.4.5 BACKUP POWER SYSTEMS

One or more of the backup power strategies below provide a suitable level of backup power for most of the scenarios described above at the Vacaville City Coach facility. The selection of a resiliency strategy during the design phase should consider the likelihood of a given outage scenario, the risk tolerance and operational flexibility of the transit agency, and the project budget.

1. **Permanent Standby Generator**
   A permanent generator can be powered by diesel or natural gas and is permanently connected to the main switchboard using a manual or automatic transfer switch. This allows the facility to switch between the utility feed and generator power and isolates the generator from the utility feed to prevent back feeding the utility system.

   The Vacaville City Coach site requires a peak load of over 1 MW. It may not be practical to install a generator with such a large capacity. It may be necessary to size the generator to charge only a portion of the fleet simultaneously, based on an analysis of essential service and other operating obligations.

   A 500-kW generator would be capable of recharging every vehicle in a 24 hour period but may require some vehicles to charge during the day if the outage duration is long. In California, all newly purchased generators need to meet certain CARB emissions rules, which can vary depending on how the generator is used. A smaller generator could also be supplemented with a battery storage and/or solar PV system.

2. **Battery Energy Storage System [1 – 2 MWh]**
   A battery energy storage system may be able to provide a good supplemental source of backup power to a portion of the Vacaville City Coach fleet in combination with a generator. These systems are modular and are available in 10 to 40-foot standard intermodal containers. Capital costs and physical size tend to be higher than a backup generator, and a battery storage system may not be sufficient for all types of outages as discussed above. These tradeoffs should be investigated during the project design phase. Also, if there is any extra unused power generated by the existing onsite 50 kVA PV system, the battery storage system can capture the extra generation.

3. **Solar Photovoltaic System**
   An additional small solar PV system could be installed over a new rooftop canopy at the Vacaville City Coach site. A solar PV system is not suitable as a source of backup power on its own for a fleet of this size and should be combined with a battery energy storage system or generator. The decision to install a solar PV system should also incorporate renewable energy goals and potential energy cost savings.

7.5 Summary and Next Steps

The following section summarizes the energy and power analysis, facility upgrades recommendation, and resiliency discussion from the previous sections. The recommendations will inform the immediate next steps for Vacaville City Coach electrification. A more detailed analysis of the financial implications is included in the Task 5: Costs and Funding Analysis report.

7.5.1 SUMMARY

The summary of the different charging scenarios for Vacaville City Coach is mentioned in Table 7.1. The recommendation is to purchase a CSMS and use managed charging to keep the new utility electrical service load to 990 kW, greatly decreasing the size of switchboard and transformer necessary to support the fleet chargers.

Table 7.1 Summary of Vacaville City Coach Charging Scenarios

Recommended Chargers	Scenario	Charge Schedule	Peak Demand	Upgrade Necessary	Est. Monthly Cost
13 150 kW DC chargers	**Unmanaged**	All 25 vehicles charge simultaneously beginning at 9:00 PM	1875 kW	2063 kW	$28,574
	Managed*	Vehicle charging is scheduled throughout the night to smooth out power demand, beginning at 9:00 PM	900 kW	990 kW	$26,524

*Preferred scenarios

Source: WSP

Table 7.2 summarizes the needed facility upgrade for Vacaville City Coach's facility. PG&E would be responsible in installing the new transformer and underground electrical conductor, while Vacaville City Coach would be responsible in installing switchboard, utility metering cabinet, underground conduit, and charging stations.

Table 7.2 Summary of Vacaville City Coach's Facility Upgrade

Responsible Stakeholder	Item to Install	Location	Note
PG&E	3000 kVA transformer	Near north end of site	Fed by new 12 kV underground electrical service entering west end of site
	Underground electrical conductor	Along Vacaville 1105 circuit	Connecting transformer installed by PG&E to the switchboard installed by Vacaville City Coach
Vacaville City Coach	480 V switchboard and utility metering cabinet	North of the bus wash building	Min. electrical rating of 4000 A
	Underground conduit	Decision based on engineering design	Connecting new transformer to the new switchboard
	Charging stations and underground conduit	As indicated	Connected to the 480 V switchboard

Source: WSP

Table 7.3 summarizes the contributing factors, resiliency rating, and mitigation method for different types of outages.

Table 7.3 Summary of Resiliency Analysis for Vacaville City Coach

Summary of Dixon Readi-Ride Charging Scenarios	Distribution-Related Outages	Transmission-Related Outages	Energy Supply Shortages	Facility Equipment Failures
Contributing Factors	• 2.4 miles to substation • 12 kV feeder is 100% overhead with primarily wood-poles through public roadways	• Redundant transmission lines • Adjacent to high risk area for wildfires	• Two grid generation shortages in the last 19 years • Increase in wildfires over CA	• Proximity to public chargers • Lack of redundant equipment • Large fleet size
Resiliency Rating	Low	High	High	Moderate
Mitigation Method	• Dedicated, pad-mounted utility transformer • Backup generator • BESS	• Permanent standby generator • PV and BESS	• Become essential use Customer • Off-peak charging • Backup generator	• Onsite spare equipment and repair people • Routine equipment inspection • Warranty & service contracts
Backup Power Options	• 500 kW permanent standby generator • Solar PV system paired with 1 - 2 MWh BESS in 10' – 40' intermodal container A generator with an output rating of at least 500-kW generator would be capable of recharging every vehicle in a 24-hour period but may require some vehicles to charge during the day if the outage duration is long			

Source: WSP

7.5.2 NEXT STEPS

Vacaville City Coach needs to first evaluate their options, determine their desired course of action, and propose whether use load management. The next immediate steps for Vacaville City Coach are:

1. Decide whether to invest in a charge management system
2. Begin service application and coordination with PG&E for the appropriate load from PG&E (2,063 kW for managed, 990 kW for unmanaged
3. Determine outage mitigation methods. If a backup generator is selected, include the design and procurement in engineering firm RFP
4. Begin detailed engineering design
5. Procure long-lead items
6. Begin construction to point of contact with utility

8 CONCLUSION AND NEXT STEPS

The Power and Energy Analysis identified and established the power and energy needs for each Solano County transit agency as they pertain to: 1) service requirements; 2) facility operations and layout; 3) energy usage and availability; and 4) resiliency. It should be noted that the findings of this analysis will be refined and further evaluated in subsequent tasks.

8.1 Summary of Power and Energy Needs

Electric bus charging systems require a significant amount of electrical power. Most facilities require moderate to significant upgrades to their existing electrical infrastructure, and PG&E must also upgrade equipment to supply the necessary power to the site. The worst-case maximum electrical power needs for each transit site were calculated and are summarized in Table 8.1. The site's specific electrical requirements should be explored in detail during the project design phase and will likely change from what is presented in this report.

Table 8.1 Summary of Site Electrical Upgrades

Upgrades	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans[24]	Vacaville City Coach
New Electrical Service Required	Yes	Yes[25]	Yes	Yes
Utility System Upgrades Required	No	No	Yes	Maybe
Number of Proposed Chargers	4	2 or 4	22 (Phase 1)	13
Calculated Peak Charging Load[26]	660 kW	330 or 660 kW	1500 kVA (phase 1)[27]	2100 kW[28]

24 All information included in this report for SolTrans is taken from 2020 SolTrans Zero Emissions Bus Master Plan as well as design documents issued for bid in Spring of 2021. No additional analysis was performed for the preparation of this report.

25 The Rio Vista Delta Breeze site is shared with an adjacent water treatment facility that may have spare capacity on the existing electrical service. However, the spare capacity may already be allocated to future upgrades to the water treatment facility, so this report considered the possibility of installing new electrical service to power the vehicle fleet.

26 Peak charging load shown here is based on unmanaged charging with 10% buffer. The transit agency's requested load will depend on the facility and includes losses. Refer to each transit agency section for details.

27 Proposed transformer size for SolTrans phase 1

28 Highly advised for Vacaville City Coach to invest in a CSMS because the existing PG&E feeder, Vacaville 1105 Circuit, serving the site only has a free peak capacity of 1.7 MW. The managed peak load will only be 990 kW with the 10% buffer included.

Upgrades	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans[24]	Vacaville City Coach
New Electrical Equipment Required	• New utility transformer • New main switchboard and meter Underground conduit to vehicle chargers	• New utility transformer • New main switchboard and meter Underground conduit to vehicle chargers	• New utility transformer • New main switchboard	• New utility transformer • New main switchboard and meter • New electrical subpanels • Large underground duct bank and conduit to vehicle chargers • Likely upgrades to utility-owned distribution equipment.

Source: WSP

8.2 Summary of Resiliency Analysis

The resiliency of each site was analyzed according to the four types of electrical distribution outages and associated mitigation strategies discussed in section 3.4.1. For each type of outage, mitigation strategies are considered, and a qualitative rating is assigned ranging from low to high as summarized in Table 8.2. The qualitative metrics were assigned based on how resilient the site is against the specified outage type. For more information, refer to Appendix A - Resiliency Background Information.

Table 8.2 Summary of Solano County's Transit Agencies Sites Resiliency Analysis

Electrical Outage Types	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
Distribution-related Outages	Moderate	Low	Not Analyzed	Moderate
Transmission-related Outages	High	Moderate	Not Analyzed	High
Energy Supply Shortages	High	High	Not Analyzed	High
Facility Equipment Failures	Moderate	Moderate	Not Analyzed	Moderate

Electrical Outage Types	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans	Vacaville City Coach
Suggested Backup Power System(s)	• Permanent Generator • Mobile Generator	• Permanent Generator • Battery Storage System • Solar PV System	Not Analyzed	• Permanent Generator • Battery Storage System • Solar PV System

Source WSP

The findings of this report will be used to inform subsequent reports and analysis. The utility and power equipment data will be used for the Task 5: Cost and Funding Analysis; the power data will be used to develop concepts in Task 6: Phasing and Transition. All this information will be used to estimates costs and generate transition strategies, Tasks 5 and 6, respectively. After coordination and collaboration with each agency, the findings and solutions proposed in Tasks 1-6 will be compiled into the *Countywide Electrification Transition Plan.*

8.3 Summary of Facility Upgrades

8.3.1 DIXON READI-RIDE

- PG&E to install new 750 kVA transformer near Hall Park Dr, fed by new 12 kV underground electrical pole on Hall Park Dr.
- Dixon Readi-Ride to install new 480 V switchboard and utility metering cabinet at north end of site with minimum electrical rating of 1200 A.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchgear at north end of site. Underground conduit will need to be installed by Dixon Readi-Ride, but PG&E will install the electrical conductor.
- Dixon Readi-Ride to install new vehicle charging stations where indicated, with underground conduit connecting the charging stations to the new 480 V switchgear.

8.3.2 RIO VISTA DELTA BREEZE

- PG&E to install new 750 kVA transformer near site entrance, fed by new 12 kV underground conductor entering southwest end of site.
- Rio Vista Delta Breeze to install new 480 V switchboard and utility metering cabinet at northwest end of site with minimum electrical rating of 1200 A.
- Rio Vista Delta Breeze to install underground conduit from location of new transformer to location of new 480 V switchgear. This will require saw cutting and excavating existing paved areas.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchgear at north end of site. Underground conduit will need to be installed by Rio Vista Delta Breeze as described above, but PG&E will install the electrical conductor.
- Rio Vista Delta Breeze to install new vehicle charging cabinets where indicated, along with underground conduit connecting the charging stations to the new 480 V switchgear on the northwest end of the site.

8.3.3 SOLTRANS

The SolTrans maintenance facility detailed design & engineering was completed in 2021. Refer to construction documents for details. A summary of the electrical scope of work is below:

- Install new 480 V electric service (by PG&E)
  - New service will require PG&E to upgrade utility distribution/substation equipment
- Install new main meter switchboard near PG&E transformer
- Construct approximately 50 feet of new underground electrical duct bank
- Construct approximately 300 feet of conduit up the side of existing building, across roof, across utility bridge, terminating on top of new steel canopy structure
- Install four new 800 A electric distribution panels
- Install one new 400 A auxiliary electrical panel
- Install one new 100 kVA auxiliary transformer for lighting and control
- Install 21 new BEB charging cabinets with retractable plugs
- Add/Alternate: install solar PV system
- Add/Alternate: install battery energy storage system

8.3.4 VACAVILLE CITY COACH

- PG&E to install new 3000 kVA transformer near north end of site, fed by new 12 kV underground electrical service that enters the site from the west.
- Vacaville City Coach to install new 480 V switchboard and utility metering cabinet to the north of the bus wash building with minimum electrical rating of 4000 A.
- PG&E to install new underground electrical conductor in conduit from new transformer to new 480 V switchboard. Underground conduit will need to be installed by Vacaville City Coach, but PG&E will install the electrical conductor.
- Vacaville City Coach to install new vehicle charging stations where indicated, with underground conduit connecting the charging stations to the new 480 V switchgear.

APPENDIX A

Resiliency Background Information

APPENDIX A – RESILIENCY BACKGROUND INFORMATION

RESILIENCY METHODOLOGY

It is important to design resilient BEB charging infrastructure to minimize disruptions to operations and service. The likelihood of occurrence, impact to transit operations, and optimal mitigation strategy varies. However, most electrical outages can be grouped into the four categories below. Regardless of the outage type and mitigation strategies chosen, it is important for transit agencies to develop standard operating procedures for emergency electrical outages ahead of time.

DISTRIBUTION-RELATED UTILITY OUTAGES

How are they typically experienced?

- Unplanned, local outages related to weather or other unplanned events causing physical damage to a distribution line or local substation that serves the transit facility.
- In California they may be experienced as public safety power shutoffs to a particular geographic area when distribution lines are intentionally disconnected to lower the risk of wildfire.

What facilities have the highest likelihood of this type of outage?

- Facilities served by long overhead distribution lines on wood poles, especially those near tall trees, and that regularly experience extreme weather events such as thunderstorms, hurricanes, and snow.

What is the operational impact?

- This type of outage could last hours or days depending on the cause and level of difficulty for the utility to repair.
- Damage to a line near a major public roadway with easy access will likely be fixed quickly, while damage to a line that runs through a remote forested area could take far longer to repair.

What are some mitigation strategies to ensure essential BEBs can be charged?

- Redundant utility feeders: It may be possible for the utility to provide two feeders to the transit site, each served from a different substation. The viability and cost of this option depends on the local utility performing a detailed study.
- Trailer-mounted mobile backup generators: Cost-effective for smaller transit sites and for transit operators that wish to be able to move the generator between multiple sites to lower the capital cost for each site.
- Permanently installed natural gas or diesel backup generators: May be activated automatically or manually and are typically sized to provide backup power to a percentage of BEBs at a given facility. Transit facilities with many buses may not be able to cost-effectively provide backup power for every BEB charger simultaneously. However, generators may be combined with charge management systems, onsite solar generation, and alternative operating procedures to adequately charge essential BEBs during long distribution outages.
- Battery Energy Storage Systems (BESS): May provide backup power immediately to a limited number of BEBs in the event of an outage that only lasts several hours, which may be extended when combined with an onsite solar PV system.
- Offsite vehicle charging: For transit sites that have a small number of vehicles, it may be more cost-effective to designate use of an alternate charging site during an outage.

TRANSMISSION-RELATED UTILITY OUTAGES

How are they typically experienced?

- This type of outage is extremely rare due to redundancy in the electric transmission grid and are typically only experienced during weather events with extreme wind such as hurricanes and tornadoes. However, they may be experienced in California as public safety power shutoffs (PSPS) to a particular geographic area when transmission lines are intentionally disconnected to lower the risk of wildfire.
- The CPUC assigns categories to regions according to their wildfire risk. Transit agency facilities in Tier 2 (elevated) or Tier 3 (extreme) have a higher chance of being impacted by a public safety power shutoff.

What is the operational impact?

- Public safety power shutoffs could last several days depending on the wildfire threat and weather conditions.
- A PSPS to the area may alter the transit agency's normal bus service in a way that could either increase or decrease the load on the bus charging system at a particular time of day. Transit agencies should consider abnormal operations when selecting the optimal resiliency strategies for a particular transit site.

What are some mitigation strategies to ensure essential BEBs can be charged?

- Trailer-mounted mobile backup generators: Cost-effective for smaller transit sites and for transit operators that wish to be able to move the generator between multiple sites to lower the capital cost for each site.
- Permanently installed natural gas or diesel backup generators: May be activated automatically or manually and are typically sized to provide backup power to a percentage of BEBs at a given facility. Transit facilities with many buses may not be able to cost-effectively provide backup power for every BEB charger simultaneously. However, generators may be combined with charge management systems, onsite solar generation, and alternative operating procedures to adequately charge essential BEBs during long distribution outages.
- BESS: May provide backup power immediately to a limited number of BEBs in the event of an outage that only lasts several hours, which may be extended when combined with an onsite solar photovoltaic system.
- Offsite vehicle charging: For transit sites that have a small number of vehicles, it may be more cost-effective to designate use of an alternate charging site during an outage.

UTILITY ENERGY SUPPLY SHORTAGES

How are they typically experienced?

- These are usually experienced as rolling blackouts on hot summer days or cold winter days when energy resources are unable to meet peak demand.
- Since the power shutoffs are initiated by the utility, each customer is usually only disconnected for a few hours at a time.

What is the operational impact?

- Outages are usually planned and communicated in advance by the utility, so impacts to service operations should be minimal when compared to other types of outages.
- It is important for transit site operators to pay close attention to local utility announcements, and preferably have a direct point of contact with the local utility. The CPUC created a priority system in which certain customers who provide essential public health, safety, and security services should normally be exempt from rotating outages.

What are some mitigation strategies to ensure essential BEBs can be charged?

- Qualify as an Essential Use Customer: The transit agency should consider applying to their local utility for Essential Use Customer Classification under the CPUC, especially if other forms of onsite backup generation are not present or do not meet the full needs of the transit facility.
- Shift charging to off-peak times: If not already done using a charge management system, shift bus charging to off peak times that are less likely to be impacted by rolling blackouts.
- BESS: May provide backup power immediately to a limited number of essential BEBs in the event of a rolling blackout that only lasts several hours, which may be extended when combined with an onsite solar photovoltaic system.

- Onsite backup generation: may be engaged if installed to mitigate other types of outages discussed above. Note that mobile trailer-mounted units may be less suitable for rolling blackouts, as transit agencies may experience short blackouts at multiple facilities in a given day, which would require moving the generator between facilities several times per day. Large, permanent generators may also require up to an hour to ramp-up to their full power output, so may not be ideal for short-duration outages.

ONSITE FACILITY EQUIPMENT OUTAGE

How are they typically experienced?

- Typically, all electric vehicle charging equipment at a transit facility downstream of the utility meter is owned and maintained by the transit agency. Switchboards, transformers, cables, and circuit breakers may all be disconnected intentionally (for planned maintenance) or unintentionally (in the case of a failure).

What is the operational impact?

- Onsite equipment outages may impact power to some or all the vehicle chargers at the facility, and the duration depends on how long it takes for transit agency or third-party maintenance personnel to repair the affected equipment.
- Most common equipment failures can be repaired same day, but specialized equipment such as transformers or battery electric bus DC fast chargers may take longer to repair.
- During most outages, some electric vehicle chargers would be unavailable. This may require temporarily modifying the normal parking and charging routine of certain vehicles.

What are some mitigation strategies to ensure essential BEBs can be charged?

- Electrical system with redundancy: The design of the facility electric distribution system should employ a level of redundancy, such as redundant transformers, coordinated circuit breakers, or multiple utility feeds connected in a main-tie-main configuration. However, added redundancy comes at the expense of increased capital cost, increased complexity, and increased footprint on the site. The transit agency should discuss redundancy options with the facility design engineer during the preliminary design phase of the project.
- Onsite spare equipment: The transit agency should procure spare parts for less reliable equipment up-front, such as electric vehicle DC chargers. DC chargers typically employ proprietary electronics and computer chips, making them more likely to experience failures than other equipment. They may also have a longer lead-time from the manufacturer.
- Offsite vehicle charging: For transit sites that have a small number of vehicles, it may be more cost-effective to designate use of an alternate charging site during an outage.
- Warranty and service contracts: Electric vehicle charging equipment may require specialized parts and manufacturer-trained technicians to repair. The transit agency should determine who will be responsible for repairs both during and after the initial warranty period and should identify the manufacturer point of contact for repair and the local firm that can perform the repair.

RESILIENCY RATING

For each type of outage, a qualitative rating is assigned for each transit facility. The rating considers the various factors that were investigated and represents the relative risk and potential impact of that particular type of outage compared to other similar facilities for that same type of outage. It is not meant to represent the relative probability compared to other types of outages. For example, a facility may be assigned a resiliency score of *low* for transmission-related outages. However, transmission related outages are extremely rare for all types of facilities. A facility with a resiliency score of *high* for distribution-related outages may experience a distribution-related outage more frequently than a *low* transmission-related outage, because overall the electrical transmission grid is designed to be more robust than the distribution grid.

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX D: BEB FACILITY CONCEPTS ANALYSIS

Solano Transportation Authority

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 3: BEB FACILITY CONCEPTS ANALYSIS

Final — December 2021

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Acronyms and Terms

Acronym/Term	Description
BEB	Battery-Electric Bus
CARB	California Air Resources Board
CNG	Compressed Natural Gas
FAST	Fairfield and Suisun Transit
GVWR	Gross Vehicle Weight Rating
ICEB	Internal Combustion Engine Bus
ICT	Innovative Clean Transit
kW	Kilowatt
MW(h)	Megawatt (hour)
PG&E	Pacific Gas & Electric
SolTrans	Solano County Transit
STA	Solano Transportation Authority
SOC	State of Charge
ZE(B)	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040.[1] The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Pla*n includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- Task 1: Existing Conditions Analysis
- Task 2: Service Modeling Analysis
- **Task 3: BEB Facility Concepts Analysis (this report)**
- Task 4: Power and Energy Analysis
- Task 5: Costs and Funding Analysis
- Task 6: Phasing Strategy and Transition Analysis
- Task 7: Countywide Electrification Transition Plan

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of this project's elements found in the SolTrans Zero Emission Master Plan are incorporated in this project. FAST is currently developing the *Fairfield Transition Electrification Transition Model Project*, an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the *Countywide Electrification Transition Plan*; however, FAST's final report (expected in Summer 2021) will be incorporated into the final *Countywide Electrification Transition Plan*, which is anticipated to be completed by Q1 2022.

1 . CARB ICT Regulation (https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-regulation)

1.2 Report Purpose and Approach

The purpose of the *BEB Facilities Concepts Analysis* Report is to present preliminary design concepts of charging infrastructure that will support each agency's full transition to BEBs.

The design team reviewed and documented each agency's existing site conditions and worked with key project representatives to develop and test a variety of alternative facility concept layouts based on various charging technologies. It should be noted that due to WSP's current work with SolTrans, this report uses the preliminary concepts and designs found in the *SolTrans Zero Emission Master Plan*. The preferred concepts are described and presented within this report and will serve as the foundation for subsequent technical reports within the *Countywide Electrification Transition Plan*. This report includes the unique characteristics of each agency's current operations, fleet makeup, and spatial constraints. Where requested, considerations for future fleet expansion are also implemented.

1.3 Report Structure

This report is organized into four main sections:

1. **Introduction –** Overview of the Countywide Electrification Transition Plan and the BEB Facilities Concepts Analysis Report
2. **Inputs and Methodology –** Overview of the methodology, including inputs, assumptions, and approach
3. **Transit System-Specific Sections –** Presents each transit agency's BEB facility concepts with consideration to current operation, fleet makeup, and spatial constraints:
    a. Dixon Readi-Ride
    b. Rio Vista Delta Breeze
    c. SolTrans
    d. Vacaville City Coach
4. **Conclusion and Next Steps –** Summarizes the findings of the report and outlines next steps

2 INPUTS AND METHODOLOGY

The following section provides background on the site visits, data provided (as-builts), and the approach for assumptions (i.e., charging ratio, etc.).

2.1 Data

Facilities

For facility operations and layouts, WSP conducted site visits between April 12-16, 2021 to gather information on site conditions, circulation, vehicle inventories, electrical equipment, and other site-related items. As-builts and other documentation were also provided by some agencies for additional context. A more detailed analysis of these documents can be found in the Existing Conditions Analysis Report. This information was used to assess the most viable method(s) to integrate the BEB infrastructure at each site.

Vehicles

Each site's concept plan uses the existing fleet inventory (as established in the Existing Conditions Analysis Report) and accommodates future fleet increases (as suggested by the agency). The concepts presented in this report are not intended to reflect any fleet expansion as a method of resolving service shortcomings noted in the Service Modeling Analysis Report. Table 2.1 shows a breakdown of each agency's existing and future fleet inventory. Vans have been excluded from the list since they have a gross vehicle weight rating (GVWR) of less than 14,000 pounds and are therefore not required to be electrified according to the CARB ICT regulation.

Table 2.1 Solano County Fleet Summary

Agency	Existing Fleet	Future Fleet
Dixon-Readi Ride	8*	10*
Rio Vista Delta Breeze	4*	8*
SolTrans	56	70
Vacaville City Coach	25	31

Source: Dixon, Rio Vista, and Vacaville Short Range Transit Plan Fiscal Year 2021 - Fiscal Year 2030, and General Transit Feed Specification Data. SolTrans Zero Emission Bus Master Plan

Note: *Excludes vans

Utility Service

Utility service data from the electrical utility, Pacific Gas & Electric (PG&E), were analyzed to determine the existing available electrical service in each site. The detailed documentation of this analysis is reported in the Power & Energy Analysis Report.

2.2 Assumptions

Charger output and utility tie-in locations were key assumptions that were made for each site to conceptualize the best implementation method of charging equipment and infrastructure. In most cases the ideal location for new electrical service is assumed to be close in proximity to an existing electrical service.

The nominal output capacity for each charging cabinet is assumed to be 150 kilowatt (kW) since it is currently the most widely available size in the market from various original equipment manufacturers with individual charger cabinet models ranging from 125 kW to 180 kW. It was also assumed that a charging ratio of two dispensers served by a single charging cabinet is utilized in all cases. This charging ratio allows two buses to be charged concurrently at a reduced output (up to approximately 75 kW to each bus) or sequentially at full output (up to approximately 150 kW to a single bus). Sharing a charging cabinet between two dispensers allows for a reduction in overall electrical and charging infrastructure required to support the fleet and helps distribute the charging load more evenly over the course of the available charging window. Several of the fleets covered in this study include cutaway vehicles, which typically have smaller battery capacities than standard buses. The cutaway fleets could be candidates to either utilize lower output capacity chargers (sub 125 kW and typically 60-75 kW) or higher charger ratios (such as one charger to three or four-plus dispensers) to further reduce the amount of charging equipment and the peak energy demand. For the purposes of this study, conservative assumptions are made to allow the agency the flexibility to make those reductions at a later time.

Additional site-specific assumptions are addressed within the descriptions of each agency's section.

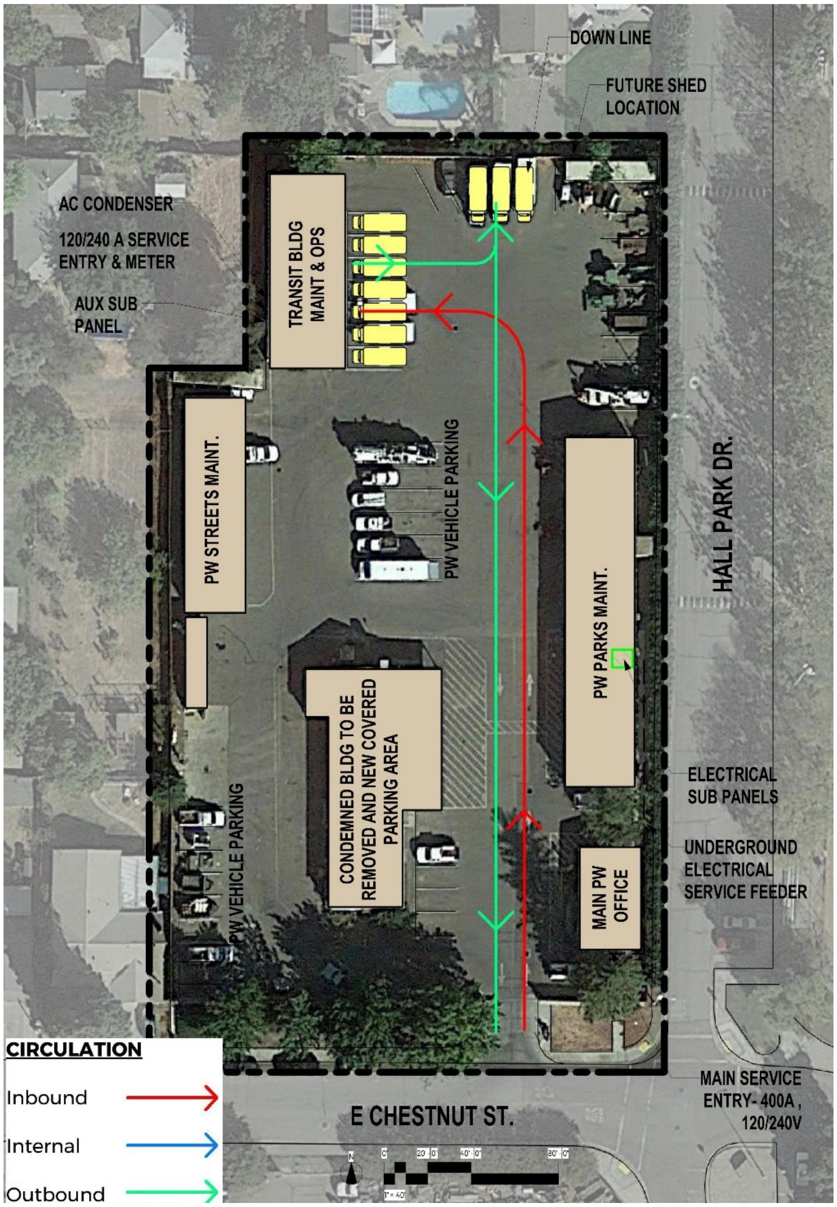
DIXON READI-RIDE

3 DIXON READI-RIDE

3.1 Existing Conditions

The Dixon Readi-Ride facility is located at 285 East Chestnut Street and shares the site with the City of Dixon Public Works Department (Figure 3.1). The transit operations consist of a parking area containing 13 parking spaces as well as a maintenance and operations building. There are also multiple single-phase electrical service entry points at the site. The existing vehicle inventory includes eight cutaway vehicles and two minivans.

Figure 3.1 Dixon Readi-Ride Site Circulation



Source: WSP

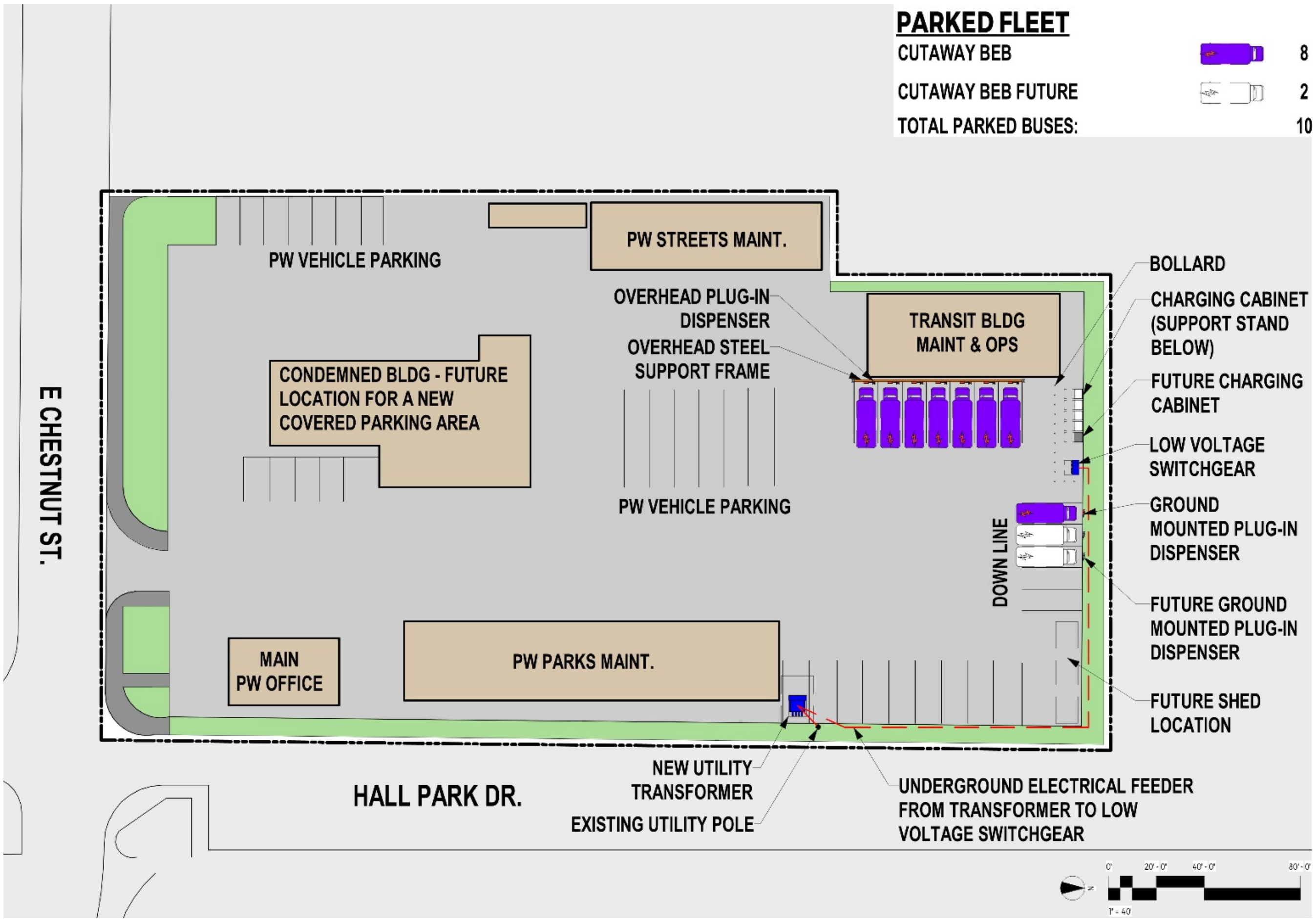
3.2 Preliminary Concept

Plug-in charging was determined to be the most suitable method of charging since the fleet consists of solely cutaway vehicles. These vehicles are parked outdoors either east of the maintenance building or at the north end of the facility along the fence line. Both ground-mounted and overhead-mounted DC plug-in dispensers were conceptually tested on these two parking locations.

Installing permanent charging infrastructure in the parking spaces east of the maintenance building poses an operational challenge since the building's façade consists of operable openings (four overhead doors and one personnel door). To maintain existing access to the already limited area along the maintenance bays, overhead-mounted DC plug-in dispensers with retractors are proposed. Ground-mounted and wall-mounted dispensers were deemed a less viable solution since they would require additional ground-level space that is not available under existing conditions without blocking overhead door access. The overhead-mounted plug-in dispensers would require a lightweight structural frame spanning the width of the bus parking area away from any of the overhead door openings. The lightweight dispensers can then be placed onto the overhead frame and be optimally positioned for the buses charging below. The charging cords would utilize a retractor system that can be lowered for bus charging and raised when not in use. Each retractor would be controlled by a switch located on the exterior wall of the existing maintenance building.

For the parking spaces at the north end of the facility, ground-mounted dispensers can be installed north of the parking space making it the most viable charging solution. With ground mounted remote plug-in dispensers, no retraction system is needed due to the available cord hook/reel on the dispenser. The area adjacent to these parking spaces, are ideal for placing switchgear and DC charging cabinets as it allows close proximity between the equipment and dispensers. Figure 3.2 illustrates the proposed facility concept to support the electrification transition.

Figure 3.2 Dixon Readi-Ride Preliminary Facility Concept



Source: WSP

3.2.1 CHARGING INFRASTRUCTURE

Five DC charging cabinets and 10 DC plug-in dispensers are needed to support the eight existing and two future fleet vehicles as shown in Table 3.1. Of the 10 plug-in dispensers, four will be ground-mounted while seven will be overhead-mounted and require cable retractors. The number of dispensers required can decrease through further evaluation of the buses' charging window and end of the day state of charge (SOC). Although limited in number, DC charging cabinets with lower power output can also be considered a possible solution. However, the use of at least one 150 kW charging cabinet is still recommended to provide additional flexibility for midday fast charging if any bus was unable to complete its service route. An additional plug-in dispenser should also be installed in the maintenance area to provide any charging needed to support maintenance functions for the electric fleet. This dispenser can potentially be energized from an initially installed charging cabinet if the unit is able to support three-plus dispenser connections. It can also potentially provide charging for two maintenance bays if positioned between them and if it utilizes an optional longer (15+ foot) cord.

Table 3.1 Dixon Readi-Ride Recommended Charging Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	5
Plug-in DC Dispenser	10
Cable Retractor	7
Plug-in DC Dispenser in Maintenance Area	1

Source: WSP

3.2.2 UTILITY INFRASTRUCTURE

Currently this site is equipped with multiple single-phase electrical service points. Since all major charging equipment runs on 3-phase power, a new 3-phase electrical service will need to be provided by PG&E. Table 3.2 lists the required utility infrastructure to support fleet electrification. Based on available PG&E information, this power will most likely be routed via a drop from the existing power pole along Hall Park Drive to a ground-mounted transformer adjacent to the Dixon Public Works Parks' maintenance building. Power will then be routed underground to the proposed switchgear location near the transit maintenance building.

Table 3.2 Dixon Readi-Ride Recommended Utility Infrastructure

Item	Quantity
Transformer	1
Switchboard	1

Source: WSP

3.3 Considerations/Potential Impacts

- Due to cutaway vehicles typically being equipped with charging ports at the front of the vehicle, operators will have to pull forward into the parking spaces instead of backing into them. This will allow easier access between the dispenser and the vehicle charging port.
- The Public Works vehicles may also transition to battery-electric in the future. Therefore, the proposed infrastructure should be installed with consideration to future expansion.
- Although it is not anticipated to be an issue, the weight of the future vehicles should be specified in accordance with the existing vehicle lift capacity. If a heavier vehicle is specified, then the existing vehicle lifts will need to be upgraded.

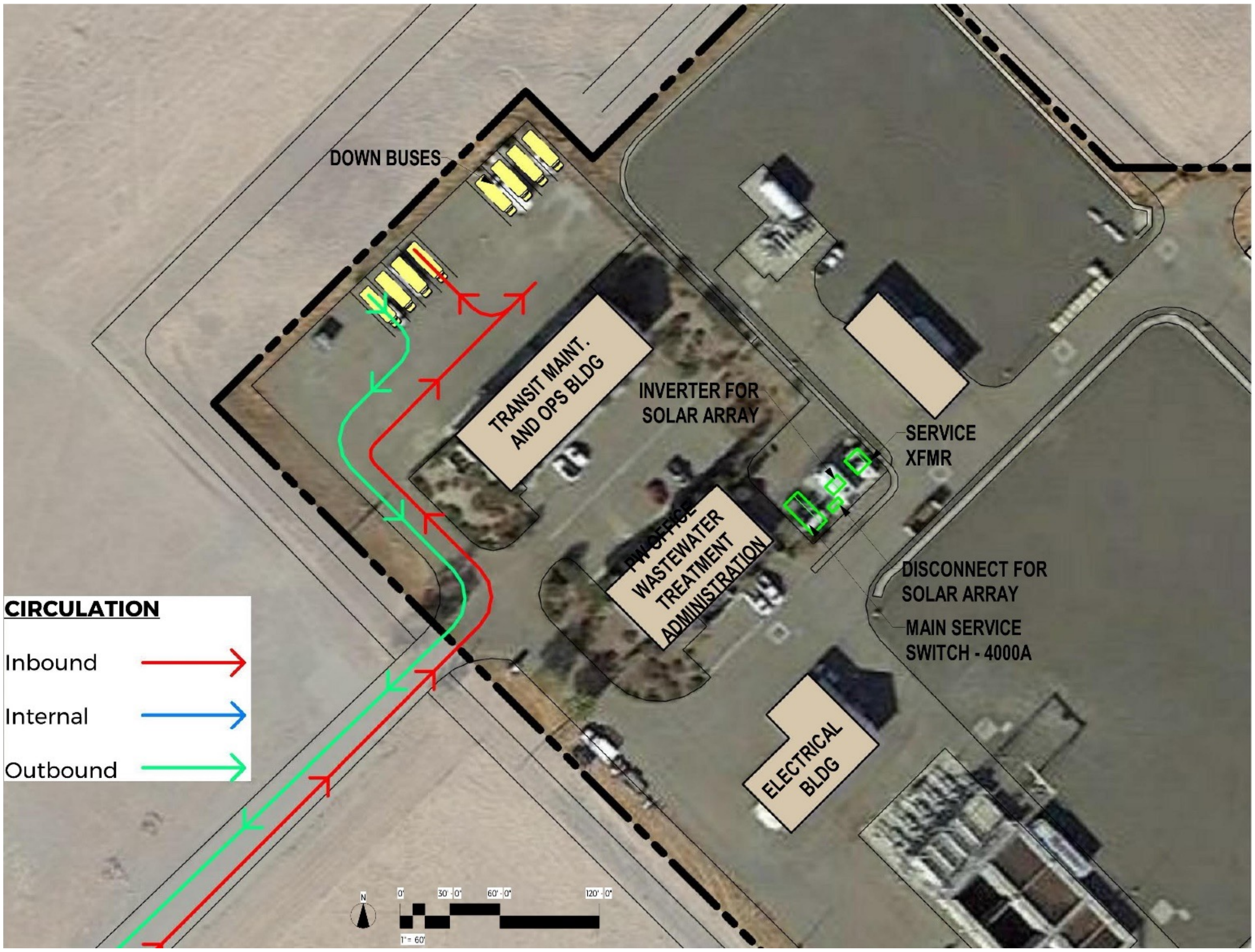
RIO VISTA DELTA BREEZE

4 RIO VISTA DELTA BREEZE

4.1 Existing Conditions

The Rio Vista Delta Breeze facility is located at 3000 Airport Road. As shown in Figure 4.1 the transit operations share the site with the City of Rio Vista Northwest Wastewater Treatment Plant. Maintenance and operations are both contained within a single building on the site, with the maintenance bays accessed from the transit yard. The operations areas are accessed from the employee parking on the east. The existing fleet consists of four cutaway vehicles and one minivan. Power for the transit operation is currently served from the existing Wastewater Treatment Plant's primary electrical service.

Figure 4.1 Rio Vista Delta Breeze Site Circulation



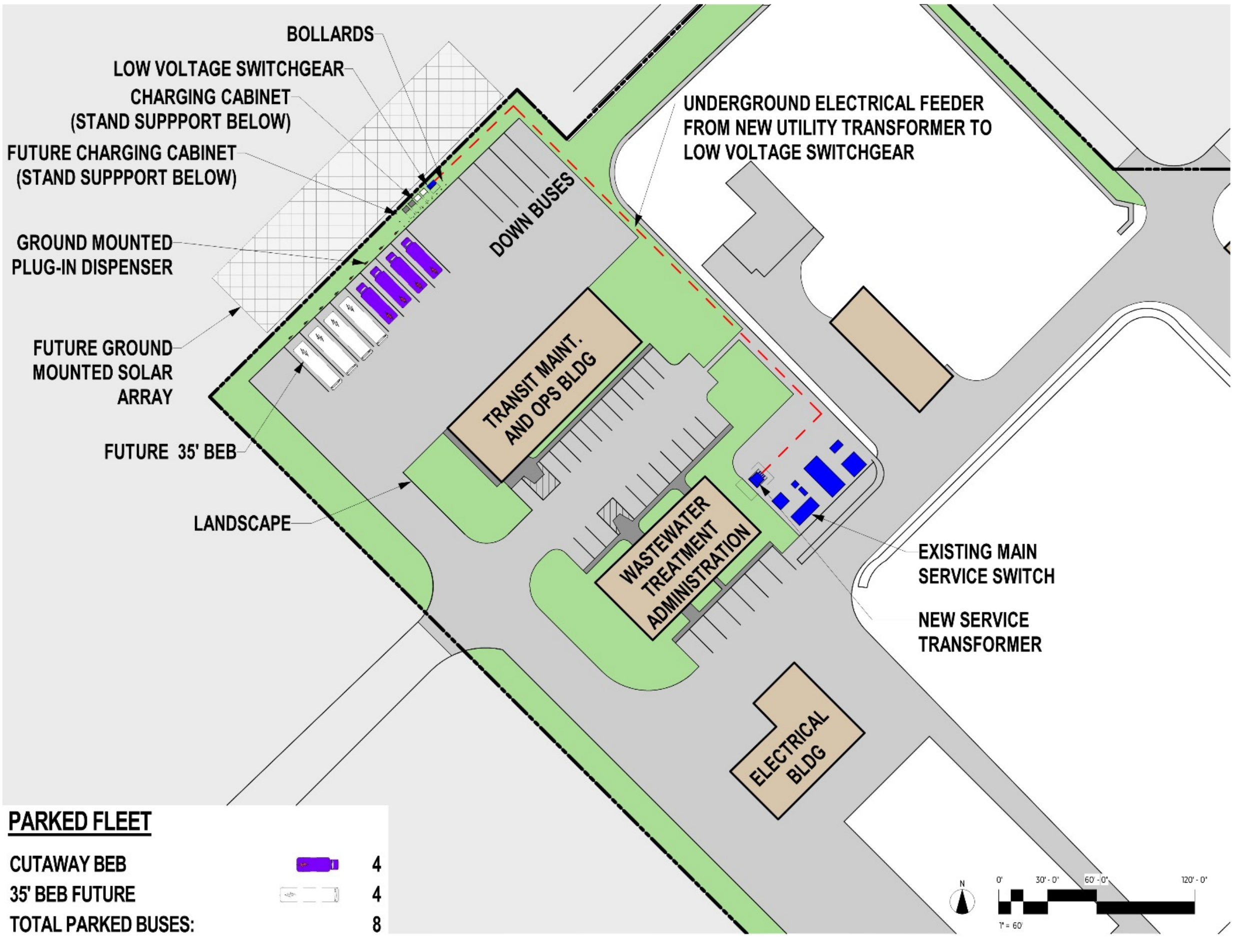
Source: WSP

4.2 Preliminary Concept

Since the fleet consists of four cutaway vehicles and the site has plenty of undeveloped space, ground-mounted plug-in charging was determined to be the most viable and cost-effective solution. Based on conversations with the agency, an additional four future 35-foot buses should be anticipated and planned for future service expansion. Due to the existing parking configuration with adjacent available space, a new switchgear, four charging cabinets, and eight plug-in dispensers are all proposed to be located at the northwest perimeter of the bus parking area (Figure 4.2). This will limit the power routing distance between the switchboard, charging cabinets, and plug-in dispensers. Cutaway buses will be parked head-in and future larger buses will be backed in for easy access to the dispensers and limit the required cord reach. Pipe bollards should also be installed to protect all charging equipment infrastructure from vehicle collisions.

Rio Vista has expressed interest in pursuing a ground-mounted solar array (similar to the existing one southeast of the site) to help offset some energy usage costs during the day. This can also be tied to a future resiliency strategy using the solar to support an on-site battery storage system. With the property extending significantly to the northwest, there is plenty of available site area to accommodate both a ground-mounted solar array and battery storage if desired.

Figure 4.2 Rio Vista Delta Breeze Preliminary Facility Concept



Source: WSP

4.2.1 CHARGING INFRASTRUCTURE

To support the four existing cutaways and four future 35-foot buses, four DC charging cabinets and eight DC ground-mounted plug-in dispensers will be needed (Table 4.1). The number of dispensers required can decrease through further evaluation of the buses' charging window and end of the day SOC. Although limited in availability, DC charging cabinets with lower power output can also be considered a possible solution. However, the use of at least one 150 kW charging cabinet is still recommended to provide additional flexibility for midday fast charging if any bus was unable to complete its service route. The 150-kW charging cabinet solution also allows additional flexibility in the future if larger buses are utilized to accommodate expanded service demands. It should be noted that if larger vehicles are considered in the future, the existing vehicle maintenance building would need to be expanded to support the larger vehicle size. An additional plug-in dispenser should also be installed in the maintenance area to provide any charging needed to support maintenance functions for the electric fleet. This dispenser can potentially be energized from an initially installed charging cabinet if the unit is able to support three-plus dispenser connections. It can also potentially provide charging for two maintenance bays if positioned between them and if it utilizes an optional longer (15+ foot) cord.

Table 4.1 Rio Vista Delta Breeze Recommended Charging Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	4
Plug-in DC Dispenser	8
Plug-in DC Dispenser in Maintenance Area	1

Source: WSP

4.2.2 UTILITY INFRASTRUCTURE

While reviewing the existing site's service, it was determined that there is additional capacity available that could potentially be utilized for addressing the power needs of the BEB infrastructure. However, the Wastewater Treatment Plant has confirmed that they have plans to utilize at least some of that capacity in the future, although the amount is undetermined at this time. For the purposes of planning, at the direction of STA, the concept plans have been developed with the assumption that a new electrical service will be requested and implemented at the site to support the new charging infrastructure (Table 4.2).

Table 4.2 Rio Vista Delta Breeze Recommended Utility Infrastructure

Item	Quantity
Transformer	1
Switchboard	1

Source: WSP

4.3 Considerations/Potential Impacts

- During the detailed design phase of the charging equipment implementation, the electrical utility service enhancements to support the bus charging infrastructure will need to be carefully coordinated between Rio Vista Delta Breeze, PG&E, and the City of Rio Vista Northwest Wastewater Treatment Plant.
- Although it is not anticipated to be an issue, the weight of the future vehicles should be specified in accordance with the existing vehicle lift capacity. If a heavier vehicle is specified, then the existing vehicle lifts will need to be upgraded.

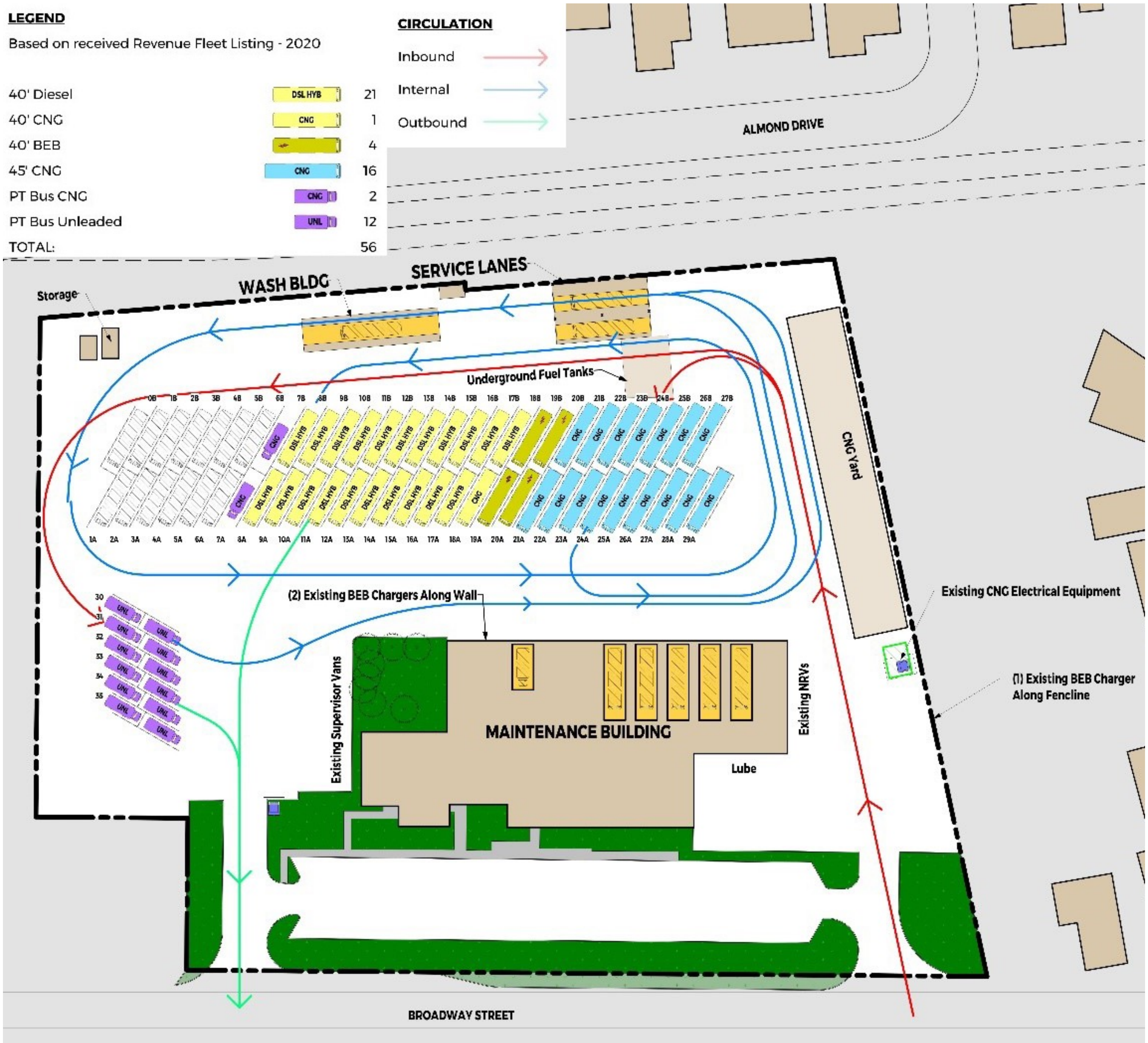
SolTrans

5 SOLTRANS

5.1 Existing Conditions

The SolTrans facility is located at 1850 Broadway Street in Vallejo. As shown in Figure 5.1, the existing bus parking layout consists of 56 transit buses (40-foot buses and 45-foot coaches) parked at an angle, nose-to-tail, east of the maintenance building and 12 cutaways parked at an angle nose-to-tail north of the maintenance building.

Figure 5.1 SolTrans Site Circulation



Source: WSP

5.2 Preliminary Concept

Overhead pantograph and overhead plug-in concepts were similar in their requirements. While the overhead plug-in option is detailed here, an overhead pantograph layout could also be utilized if SolTrans decides to pursue this option in the future.

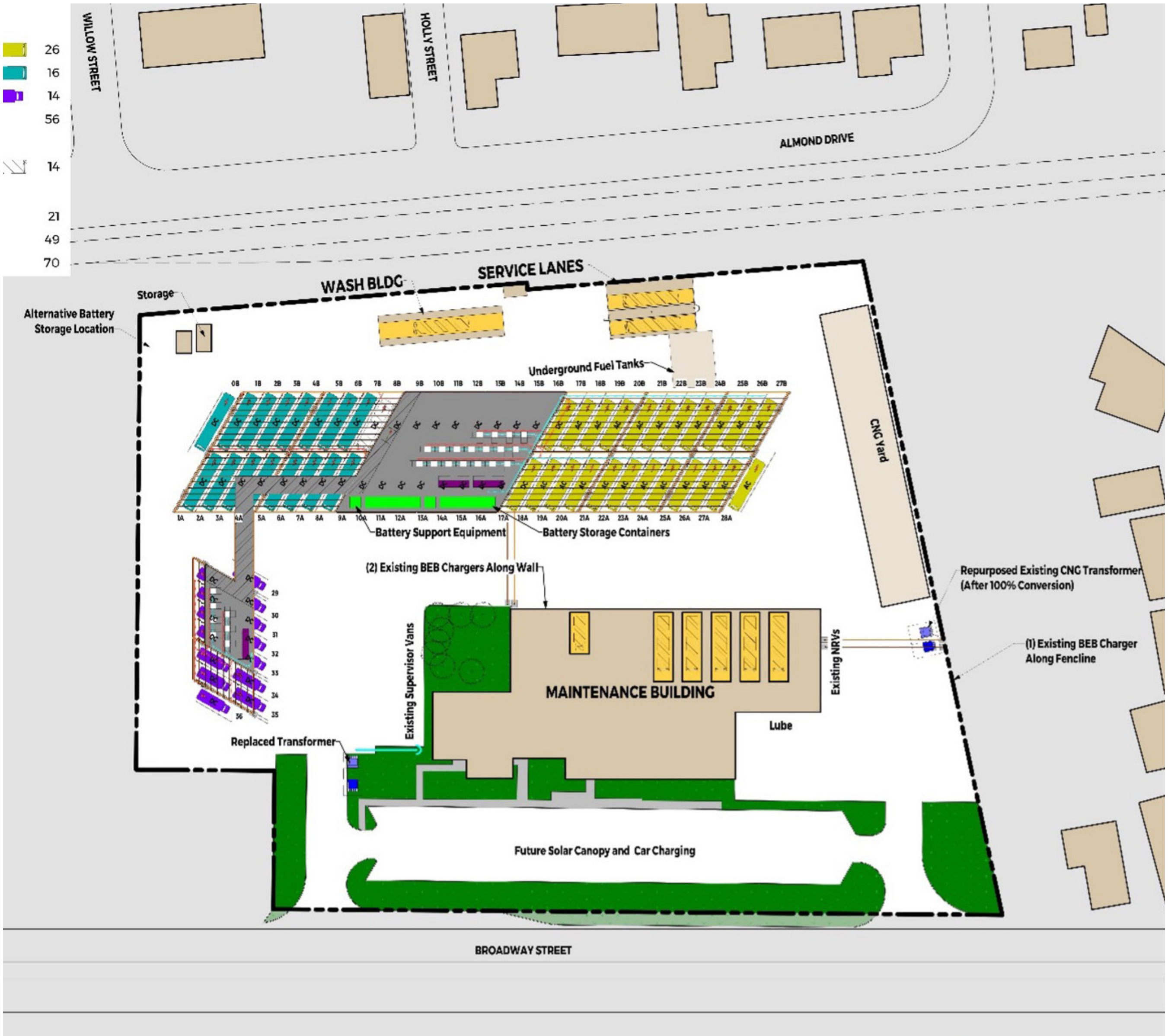
The main goal of the selected overhead plug-in option, shown in Figure 5.2, was to maintain the existing site flow, while also providing a high level of flexibility given the rate at which battery electric technology has been evolving. The site will maintain the existing parking configuration and circulation patterns. It will also preserve the pull through parking and will not introduce or require bus reversing as part of standard on-site bus circulation.

To keep the electrical equipment off the ground and maximize the usable space on the site, an overhead support structure is required. This overhead support structure will include the overhead plug-in dispenser and cord retractor pairs, as well as the client-owned electrical equipment (Figure 5.3). There are two main portions of the overhead structure:

- **Open Structure:** This portion is open and has less supporting steel, since there will be no heavy equipment mounted above it. This allows for the lighter plug-in dispensers and retractors to be suspended from it. There are other items that can be supported by this frame, such as a canopy or solar panel array. The spacing of the joists allow for a dispenser and retractor pair to be quickly relocated to accommodate various bus sizes and positions.
- **In-Filled Structure:** This portion will be designed to hold the heavy equipment such as the charging cabinets and switchboards. This area also provides a surface for personnel to walk on and perform maintenance on the charging equipment. Like the Open Structure, the spacing of the supporting beams allows for the dispenser and retractor pair to be relocated as needed.

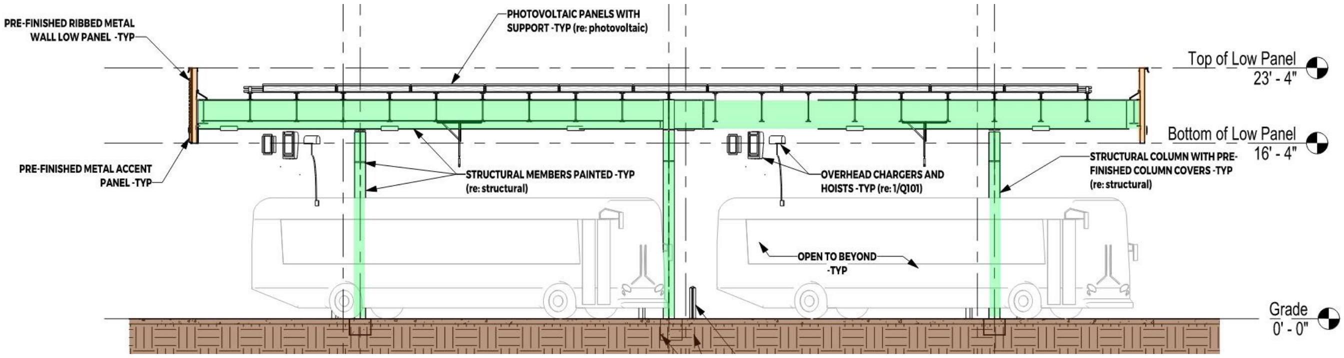
In order to minimize the interruptions to operations on the site and allow for SolTrans to implement new BEBs via either AC or DC charging as funding becomes available, the entire overhead support structure, battery backup containers, and solar panels are programmed to be completed during Phase 1. Once the support structure is in place any future BEB charging positions will simply need to have their associated equipment mounted to the frame above and have their required power routed to them via wireways on the support frame. By completing the entire structure as part of Phase 1, SolTrans will have flexibility to complete the entire site's transition and fleet expansion to 70 vehicles without major operational interruptions.

Figure 5.2 SolTrans Preliminary Facility Concept



Source: WSP

Figure 5.3 SolTrans Preliminary Facility Concept Section View



Source: WSP

5.2.1 CHARGING INFRASTRUCTURE

Based on SolTrans' initial Phase 1 strategy of bringing in 21 AC chargers to support their initial fleet of BEB buses, the infrastructure is designed to accommodate either additional AC chargers or 150 kW DC charging cabinets with a 1:2 charging ratio. The current concept plan shows the 150 kW chargers being utilized for all future deployments leaving 25 charging cabinets to support 49 overhead-mounted plug-in dispensers. Should DC charging be utilized in a future implementation as shown, the infrastructure will support either overhead-mounted plug-in dispensers or pantograph dispensers, giving SolTrans considerable flexibility for future phases of implementation. A summary of charging infrastructure is provided in Table 5.2.

Table 5.1 SolTrans Recommended Charging Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	25
80 kW AC Charging System	21
Plug-in DC Dispenser	49
Plug-in AC Dispenser	21*
Cable Retractor	70

Source: WSP

Note: * Phase 1 will utilize 21 AC chargers and subsequent phases are programmed to accept either DC or AC systems depending on SolTrans' vehicle procurement decisions

5.2.2 UTILITY INFRASTRUCTURE

The PG&E supplied transformers will be mounted on the ground, with one new transformer to be installed near the north exit which is close to the existing installed transformer, and one more new transformer proposed to be installed near the south entrance, adjacent to the compressed natural gas (CNG) yard existing transformer. The existing electrical infrastructure being utilized for the CNG yard will be repurposed for BEB charging upon 100% BEB conversion in the ultimate phase of the site. Phase 1 will only require one of the new transformers to serve the 21 initial 80 kW AC chargers. A summary of the recommended utility infrastructure is shown in Table 5.2.

The power will come from the PG&E power supply to both pairs of transformers. Conduit routed from the transformers next to the CNG yard will carry the conductors from the transformers over a bridge elevated above the entry drive aisle to the roof of the maintenance building, where it will continue and then turn towards the charging equipment platform. Conduit routed from the transformers located near the exit will be run underground to the side of the maintenance building, where it will turn up to run along the roof and turn towards the charging equipment platform. Another bridge will carry these two sets of conduits from the roof of the maintenance building to the overhead structure, where it will connect to the switchboards. These overhead bridges will utilize the roof of the existing maintenance facility for power distribution and will limit the need for on-site trenching and allow for easier access to conduits and wiring for future upgrades and additions. From the switchboards, a cable tray will carry the individual conductors to each charging cabinet and or dispenser.

Table 5.2 SolTrans Recommended Utility Infrastructure

Item	Quantity
Transformer	4*
Switchboard	3
2-Megawatt hour (MWh) Battery Backup	2

Source: WSP

Note: *Two existing transformers are being repurposed

5.3 Considerations/Potential Impacts

- This report is based on the plan developed by SolTrans and reflects a hybrid charging strategy. The proposed infrastructure allows SolTrans the flexibility to adopt different charging strategies as the fleet is transitioned.
- The existing CNG-supporting electrical service will ultimately be transitioned to support BEB charging infrastructure in the final configuration when CNG vehicles are phased out. Managing the phasing for this process will be crucial to ensure that CNG is available until all vehicles are able to be transitioned.

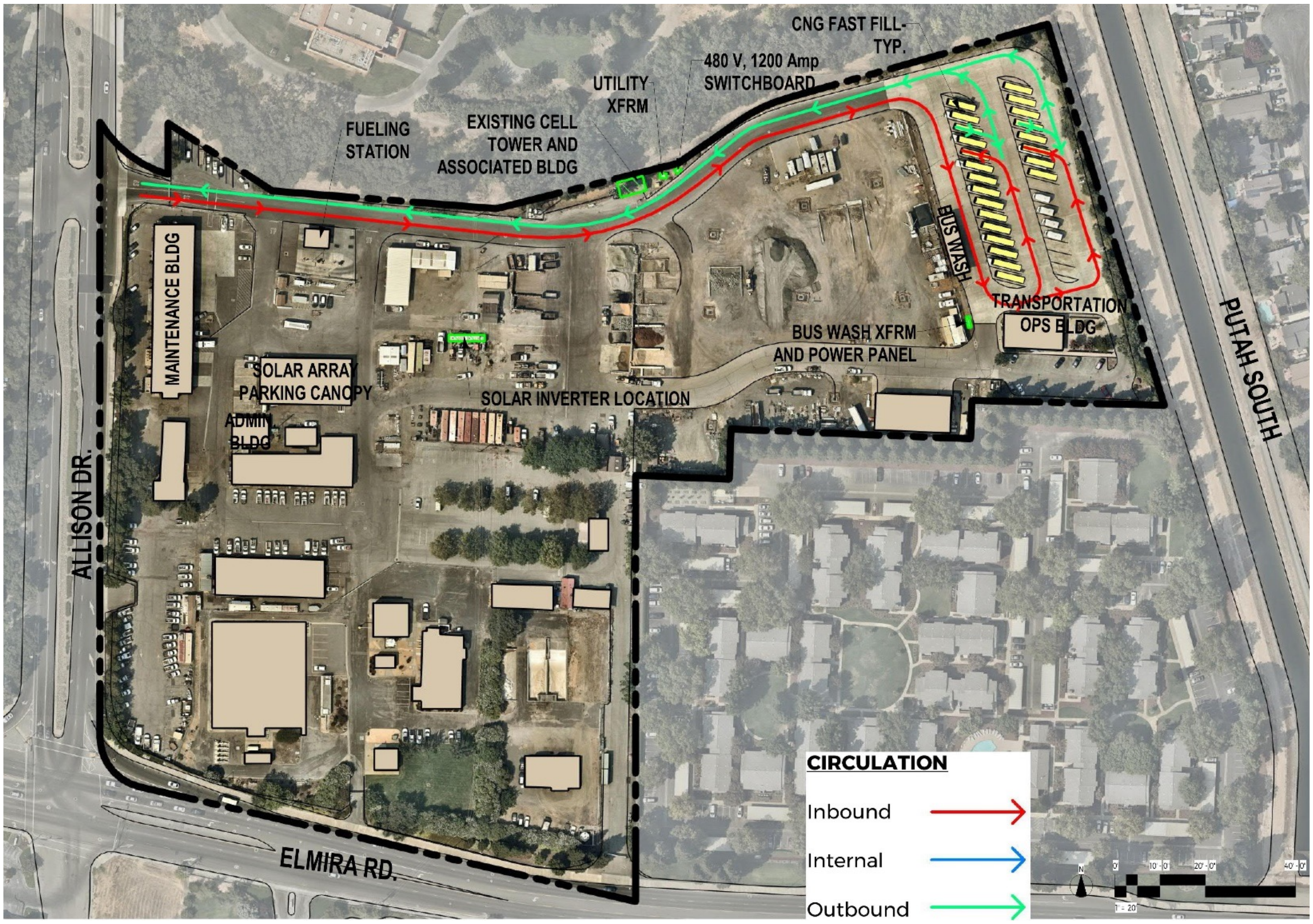
CITY COACH

6 VACAVILLE CITY COACH

6.1 Existing Conditions

The Vacaville City Coach facility is located at 1001 Allison Drive. The transit operations share the site with the City of Vacaville Public Works Department with the transit operations located in the northeast corner of the site (Figure 6.1). The fleet consists of 18 35-foot buses and seven cutaway vehicles utilized for paratransit services while there is currently parking available for future growth. The primary electrical service for the site is located along the north property line near the middle of the site.

Figure 6.1 Vacaville City Coach Site Circulation

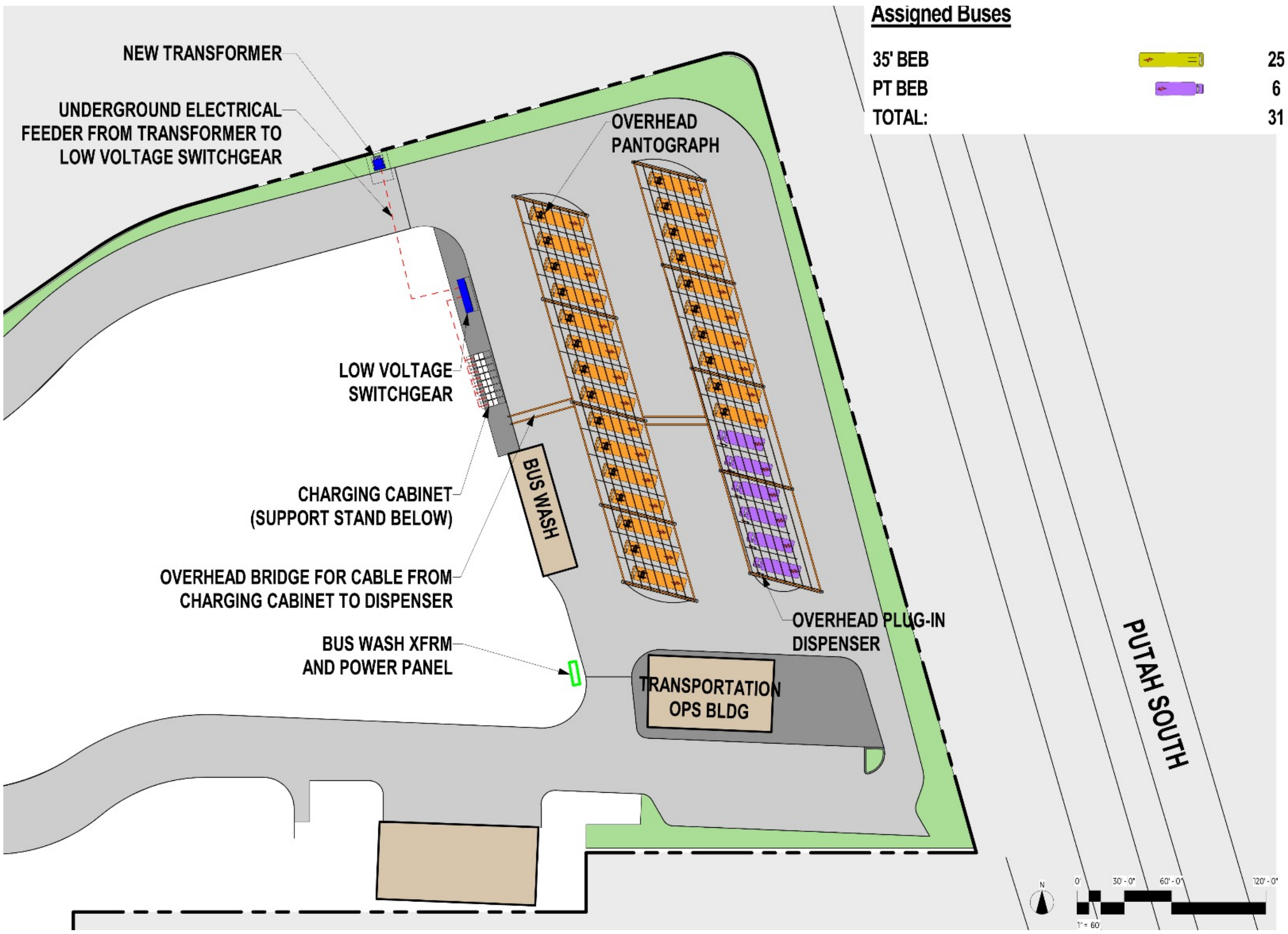


Source: WSP

6.2 Preliminary Concept

For this site, concepts were studied for ground-mounted plug-in charging and overhead-mounted charging via either pantograph or overhead plug-in dispenser. To maximize the usage of the parking area and limit the amount of trenching required at the existing parking area, overhead charging was determined to be the preferred solution with overhead plug-in being the preference over pantograph dispensers. This concept places new switchgear and charging cabinets along the western fence line that separates the transit operations from the main public works site (Figure 6.2). This area is currently unpaved, making a less intrusive location to route new underground conduit without impacting operations. A new structural steel frame is proposed over the two existing bus parking areas. From this new overhead framing, overhead plug-in dispensers will be suspended to support the 35-foot buses and the cutaway paratransit vehicles. Because the dispenser power feeds are distributed from an overhead cable tray suspended from the new overhead framing, the overhead-mounted plug-in cords could be changed to pantographs over time without requiring concrete trenching in the agency preference changes. Thus, because of the dispenser power feeds set-up with the overhead cable tray, minimal construction impacts to the on-going site transit operations are expected. The overhead frames will be connected across the drive aisles to each other and to the charging equipment area via overhead bridges. These bridges will support the routing of all cabling via conduit and cable tray from the DC charging cabinets to the dispensers at each bus parking space. The overhead frame also is intended to support a photovoltaic solar array that will be used to help offset some energy usage costs during the day and potentially be tied to a future resiliency strategy using the solar to power on-site battery storage.

Figure 6.2 Vacaville City Coach Preliminary Facility Concept



Source: WSP

6.2.1 CHARGING INFRASTRUCTURE

To support the existing 18 35-foot buses and seven paratransit cutaway buses plus a future expansion up to a total of 31 buses, 16 DC charging cabinets and 31 dispensers are recommended (Table 6.1). The number of dispensers required can decrease through further evaluation of the buses' charging window and end of the day SOC. While it is possible that the cutaway vehicles could be supported by smaller capacity chargers, at this time it is anticipated that a uniform solution will be implemented across the site. It should be noted that while the 35-foot buses can be served by either overhead pantograph or overhead-mounted plug-in dispensers, the cutaway vehicles can only support plug-in charging. An additional plug-in dispenser should be in the maintenance area to provide any charging needed to support maintenance functions for the electric fleet. The agency preference is to include two dispensers within the maintenance area (one at each dedicated transit bay) however a single remote plug-in dispenser could be positioned between the two maintenance bays with an optional longer (15+ foot) cord to support both bays from a single dispenser if desired.

Table 6.1 Vacaville City Coach Recommended Charging Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	16
Plug-in DC Dispenser	31
Cable Retractor	31
Plug-in DC Dispenser in Maintenance Area	2

Source: WSP

6.2.2 UTILITY INFRASTRUCTURE

Currently this site is equipped with multiple electrical service points along the north property line that are not currently adequate to support the additional electrical demand of the proposed charging infrastructure. An additional utility service transformer is proposed along the north property line but closer to the transit operations on the eastern portion of the site. This proposed location would maximize the run for high voltage cable thus reducing the run of lower voltage cabling. The proposed utility infrastructure requirements are outlined in Table 6.2.

Table 6.2 Vacaville City Coach Recommended Utility Infrastructure

Item	Quantity
Transformer	1
Switchboard	1

Source: WSP

6.3 Considerations/Potential Impacts

- Currently vehicles can pull into some spaces in either direction. With charging equipment requiring a fixed location, the orientation of each parking space will not be flexible. However, with overhead-mounted equipment it is much easier to reconfigure if parking direction preferences change in the future.
- As the charging infrastructure is phased in, the CNG fast fill infrastructure in the parking area will need to be removed to facilitate the proposed charging strategy.

7 CONCLUSION AND NEXT STEPS

The BEB Facility Concepts Analysis Report finds that each facility can accommodate the charging infrastructure needed to support a fully electric bus fleet and identified the improvements necessary to support the proposed infrastructure. The general findings of this analysis including charging strategy, charging equipment/ratio, resiliency considerations, and potential impacts for each agency are summarized in Table 7.1. The recommended charging strategy and charging equipment/ratio considers the future electrified fleet inventory and current parking layout of each agency. The resiliency considerations and potential impacts have also been noted for each agency to assist with future planning. It should be noted that these findings will be refined and further evaluated in subsequent stages of design implementation.

Table 7.1 Summary of BEB Facility Concepts

Agency	Charging Strategy	Charging Equipment / Ratio	Resiliency Considerations	Considerations/Potential Impacts
Dixon Readi-Ride	• Ground-Mounted Plug-In (3) • Overhead-Mounted Plug-In (7) • Plug-In dispenser in maintenance area (1)	• 150 kW DC (5) charging cabinets • 1:2 cabinet to dispenser ratio • Cable retractors (7)	• Portable or permanent generator connection	• Change in parking operations • Future electrification of Public Works vehicles • Verify future vehicle weight is in accordance to the existing vehicle lift capacity
Rio Vista Delta Breeze	• Ground-Mounted Plug-In (8) • Plug-In dispenser in maintenance area (1)	• 150 kW DC charging cabinets (4) • 1:2 cabinet to dispenser ratio	• Future ground-mounted solar array w/ battery storage system • Portable or permanent generator connection.	• Coordination required with PG&E, and the Wastewater Treatment Plant for utility enhancements • Verify future vehicle weight is in accordance to the existing vehicle lift capacity
SolTrans	• Overhead-Mounted Plug-in w/ option for future Overhead Pantograph (49) • Plug-In AC Dispenser (21*)	• 80 kW AC charging system (21) • 150 kW DC charging cabinets (25) • 1:2 cabinet to dispenser ratio • Cable retractors (70)	• Frame-mounted solar array with battery storage system.	• Report reflects a hybrid charging strategy • The existing CNG-supporting electrical service will be transitioned to support BEB charging infrastructure
Vacaville City Coach	• Overhead-Mounted Plug-in (31) • Plug-In dispenser in maintenance area (2)	• 150 kW DC charging cabinets (16) • 1:2 cabinet to dispenser ratio • Cable retractors (31)	• Future frame-mounted solar array w/ battery storage system • Portable or permanent generator connection.	• Change in parking operations • The CNG fast fill infrastructure will need to be removed

Source: WSP

Note: * Phase 1 will utilize 21 AC chargers and subsequent phases are programmed to accept either DC or AC systems depending on SolTrans' vehicle procurement decisions

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX E: PHASING STRATEGY AND TRANSITION ANALYSIS

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 6: PHASING STRATEGY AND TRANSITION ANALYSIS

Final — April 2022

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Solano Transportation Authority

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Acronyms and Terms

Acronym or Term	Description
BEB	Battery-Electric Bus
Block	The work assignment for a single vehicle during a service workday
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CNG	Compressed Natural Gas
Efficiency	A measure of a vehicle's performance, expressed in kilowatt-hours per mile throughout this report
FAST	Fairfield and Suisun Transit
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GTFS	General Transit Feed Specification
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
MW	Megawatt
NEPA	National Environmental Protection Act
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas & Electric
PUC	Public Utilities Commission
PVRAM	Photovoltaic and Renewable Auction Mechanism
SOC	State of Charge
SolTrans	Solano County Transit
STA	Solano Transportation Authority
ZE	Zero-Emission
ZEB	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resources Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040. The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Plan* includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- Task 1: Existing Conditions Analysis
- Task 2: Service Modeling Analysis
- Task 3: BEB Facility Concepts
- Task 4: Power and Energy Analysis
- Task 5: Costs and Funding Analysis
- **Task 6: Phasing Strategy and Transition Analysis (this report)**
- Task 7: Countywide Electrification Transition Plan

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and eight off-site locations – many of this project's elements are incorporated in this project. FAST is currently developing the Fairfield Transition Electrification Transition Model Project, an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the Countywide Electrification Transition Plan; however, FAST's final report will be incorporated into the final Countywide Electrification Transition Plan, which is anticipated to be completed by Q1 2022.

1.2 Report Purpose and Approach

The Task 3: *BEB Facility Concepts* report that preceded this analysis included preliminary facility design concepts, projected fleet sizes, and other assumptions and data points. This report builds off those analyses to establish construction and vehicle procurement schedules.

1.3 Report Structure

This report is organized into four main sections:

1. **Introduction** – Overview of *Countywide Electrification Transition Plan* and the Phasing Strategy and Transition Analysis.
2. **Inputs and Methodology** – Overview of inputs and methodology used to develop construction and procurement schedules.
3. **Agency-Specific Sections** – Presents each agency's facility improvements and transition timeline.
   a. Dixon Readi-Ride
   b. Rio Vista Delta Breeze
   c. SolTrans
   d. Vacaville City Coach
4. **Conclusion** – Summarizes the construction and procurement schedules and discusses specific transition considerations.

2 INPUTS AND METHODOLOGY

The following section provides an overview of the inputs and methodologies used to develop facility construction and vehicle procurement schedules for each agency.

2.1 Facility Construction

Facility infrastructure upgrades are planned in one or two on-site segments, or "stages", that generally represent a natural break in bus parking at the facility. This approach to construction will lead to minimal impacts to operations and no impact to riders.

Buses that fall within each stage will be relocated for approximately six months (based on construction assumptions) to allow for the installation of the BEB charging equipment at each stage. Upon completion of the staged construction, buses can return to their parking space(s).

WSP and the respective agencies coordinated to develop high-level assumptions for construction stages and durations based on a design-bid-build delivery method. These durations were then used to develop conceptual schedules that provides some insight into when these facilities may be ready to support ZEBs. The scheduling assumptions for each agency's construction process are summarized in Table 2.1, with additional details below.

Table 2.1 Scheduling Assumptions

Responsibility	Stage	Description	Duration (months)
PG&E	Utility Enhancements	Plan, design, and construct off-site utility enhancements to support the power needs of each facility.	16
Agency	Design Procurement	Develop, advertise, and award contract to develop detailed designs for each facility.	4 - 6
Designer	Detailed Design	Take conceptual designs to 100%.	9 - 11
Agency	Construction Procurement	Develop, advertise, and award contract to construct infrastructure at each facility.	5 - 6
Contractor	Construction	Construction at each facility, including the structure, charging/fueling infrastructure, and supporting connections.	7 - 11

Source: WSP

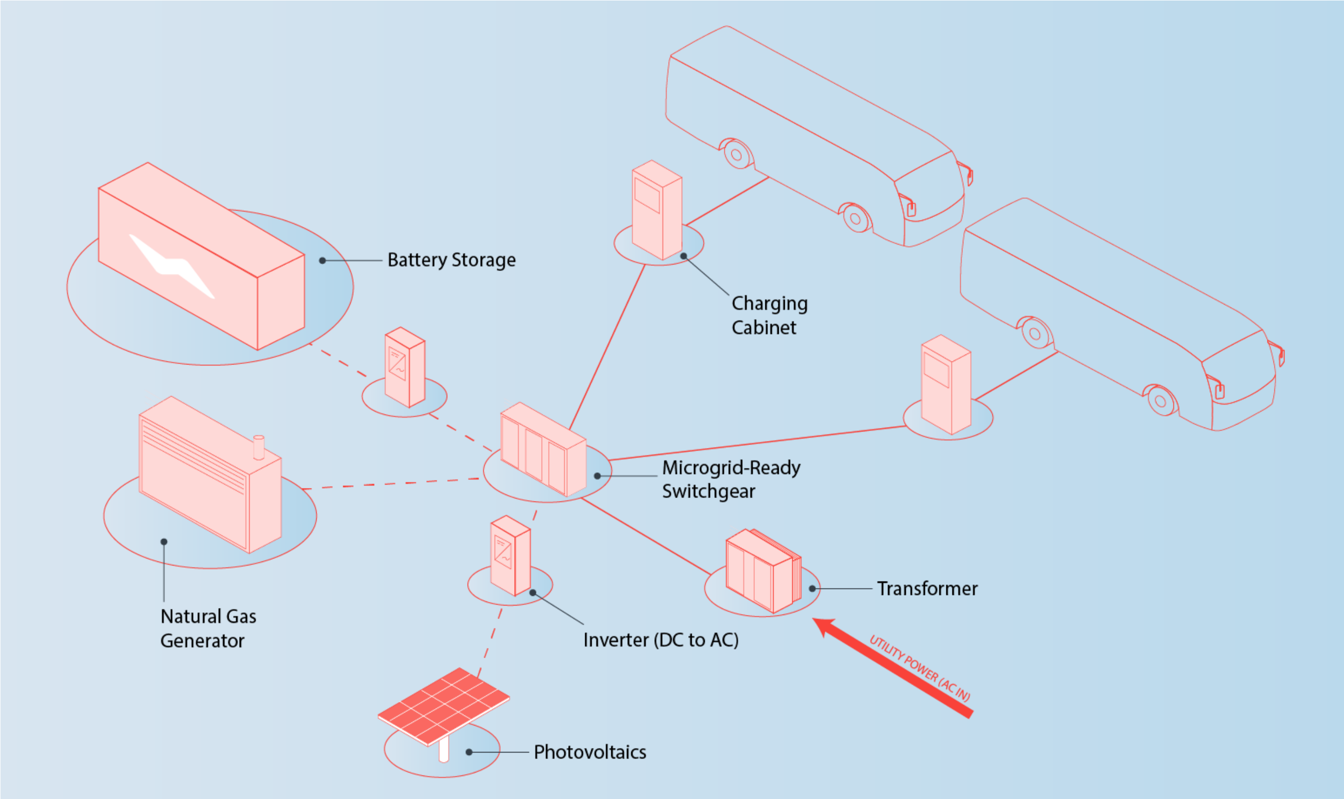
Some stages can overlap with each other, while others rely on the completion of a previous task. Utility enhancements, for example, are expected to take approximately 16 months and can occur concurrently with other stages. The completion of the utility enhancements should align with the construction stage. The detailed design stage cannot proceed until the design procurement is developed, advertised, and awarded; and the construction stage cannot proceed until the construction procurement stage is complete.

The following parameters were considered or assumed during each construction stage:

- Utility Enhancements
    - 13-month timeline based on PG&E's EV Fleet Program, with three additional months for contingency
    - The EV Fleet Program consists of permitting, preliminary design, final design, and construction
    - Aligned completion date with the conclusion of construction
- Design Procurement
    - Development of requirements
    - Advertise the request for proposal
    - Accept bids and interview candidates
    - Award contract to develop detailed designs for each facility
- Design Phase
    - Detailed design (100%)
    - Environmental clearance
    - Permitting
- Construction Procurement
    - Development of requirements
    - Advertise the request for proposal
    - Accept bids and interview candidates
    - Award contract to construct infrastructure at each facility
- Construction Stage(s)
    - General contractor mobilizes off-site
    - Submittal development, review, and revisions
    - Arrival of switchgear, charging cabinets, pantographs, and necessary materials
    - Relocation of buses on site
    - Installation of piers, overhead structure, and charging infrastructure (distribution can be conduit, ductbanks (trenches), cable trays, etc.)
    - Demobilization and reoccupying parking tracks

Figure 2.1 illustrates the general BEB infrastructure. Not all of these elements (such as photovoltaics) are present in all configurations, but this illustration demonstrates how components relate to one another.

Figure 2.1 BEB Infrastructure Overview



Source: WSP

The developed schedules are conceptual and in many ways may not capture some of the nuances that have the potential to prolong project delivery, including lag times, environmental clearance (CEQA/NEPA), multiple build stages, materials delays, stakeholder engagement and approvals, and review times. On the other hand, as previously mentioned, there are several optimizations that can be considered and applied to reduce durations and overall schedules. For instance, utility enhancements can begin immediately and occur concurrently for all facilities, and design periods can also occur earlier – and potentially at a single time - leading to early construction bids. Design-bid-build is also not the only project delivery method, each agency may also consider design-build, alternative delivery, or other strategies.

The 7.3 Transition Considerations section summarizes additional considerations, such as workforce training, emergency response, and resilience.

2.2 Vehicle Procurement

To develop a procurement schedule, each agency must consider several requirements and constraints. First, ZEBs cannot be operated unless infrastructure is in place to charge/fuel them; therefore, it is essential that the delivery of ZEBs occurs after infrastructure is constructed. Second, each agency's current vehicles have several requirements that must be considered – such as the federally mandated "useful life." Lastly, each agency must also satisfy the purchase requirements of CARB's ICT regulation. All agencies in Solano County are categorized as “small transit agencies” in the regulation, and as such must ensure that 25% of new bus deliveries between 2026 and 2028, and 100% beyond 2029, are ZEBs. Mid-life overhauls require vehicles to be removed from commission for a period of time. Thus, vehicles are assumed to be procured over a period of time rather than all procured at once, even if the infrastructure is ready for all of them. This staggered purchasing schedule is also reflected in the procurement timeline.

That said, developing a procurement schedule for Solano County’s agencies’ transitions was a complex process that is formulated based on many assumptions. The WSP team’s conceptual procurement schedule aligns with the conceptual schedules, but also applies many other assumptions:

- Standard buses are eligible to be retired 12 years (or 500,000 miles) after their acceptance date.
- Cutaway buses are eligible to be retired five years after their acceptance date.
- Vans are eligible to be retired four years (or 150,000 miles) after their acceptance date.
- The procurement assumes a 1:1 internal combustion engine bus (ICEB)-to-BEB replacement ratio.
- Except where necessary to ensure that there are equal or fewer BEBs than charging positions, the procurement plans assume that at the end of their useful life, standard buses are immediately retired and replaced by new BEBs, depending on available charging positions.
- When necessary to ensure there are equal or fewer BEBs to charging positions, the retirement date of some vehicles is assumed to be extended until BEB replacement is feasible.
- This analysis considers all the fleet vehicles that are subject to CARB ICT regulations. Both Dixon Readi-Ride and Rio Vista Delta Breeze currently operate vans, which are below a gross vehicle weight rating (GVWR) of 14,000 pounds. These vehicles are not required to be electrified under CARB ICT and are thus excluded from this analysis. However, it is assumed they will still be supported by new charging infrastructure as these vehicles can charge when transit vehicles are out for service.

The Short Range Transit Plans (SRTPs) for each agency demonstrates that they generally retain cutaways and vans beyond their useful life, with replacements shown to occur approximately 10 to 11 years from the date of purchase (and sometimes longer). For every agency, the vehicles will be at or beyond their useful life by the time chargers are scheduled to be available according to this report’s timeline (with the exception of the SolanoExpress coach buses, which are not a part of this study). Based on this end of useful life schedule, all of the existing ICE vehicles that are under the purview of the CARB ICT regulations and are a part of this study will have reached the end of their useful life by the end of 2025.

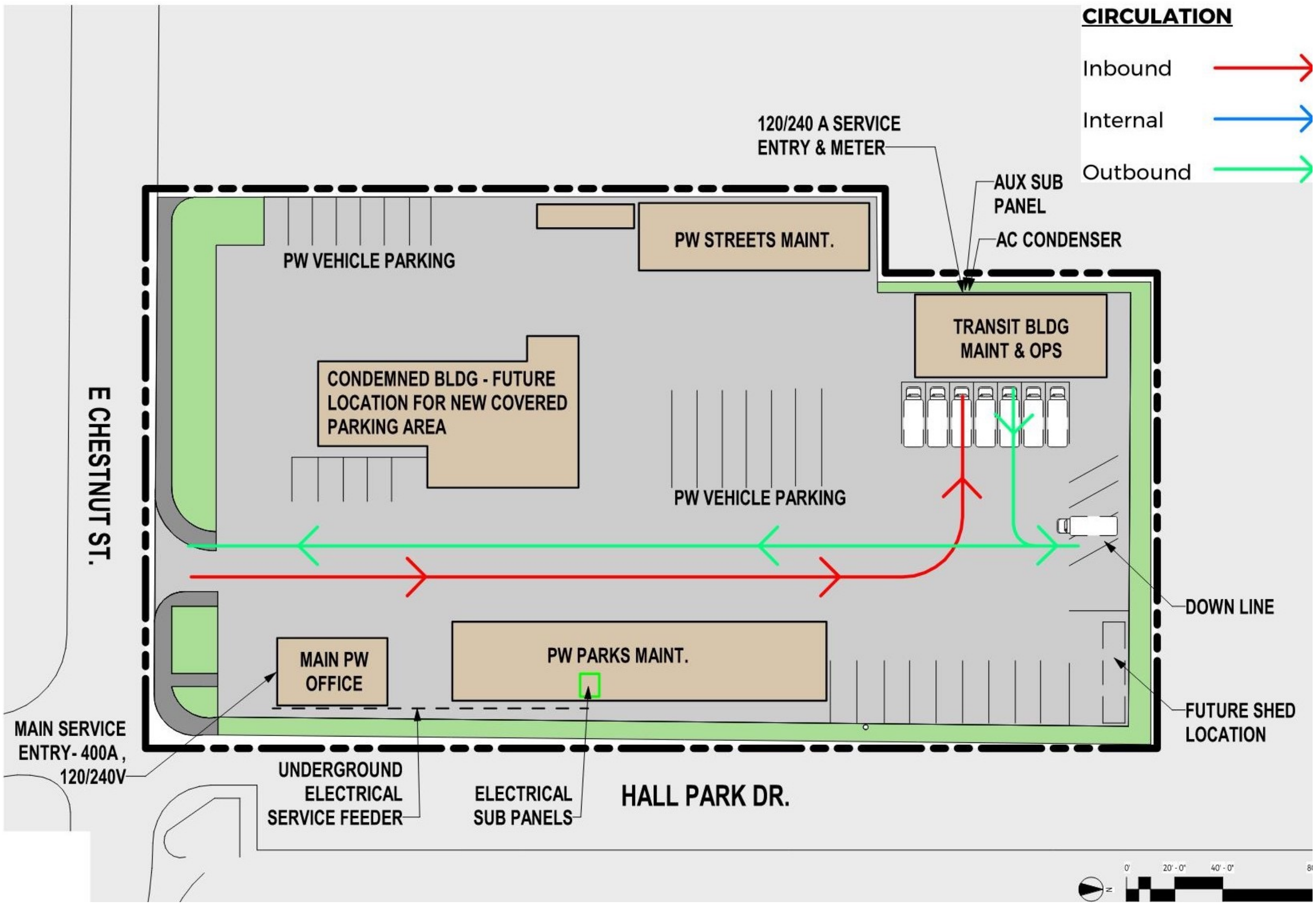
DIXON READI-RIDE

3 DIXON READI-RIDE

3.1 Existing Conditions

The Dixon Readi-Ride facility is located at 285 East Chestnut Street and shares the site with the City of Dixon Public Works Department. The transit operations consist of a parking area containing 13 parking spaces as well as a maintenance and operations building. There are also multiple single-phase electrical service entry points at the site. The existing vehicle inventory includes eight cutaway vehicles and two minivans. Figure 3.1 illustrates the existing conditions and site circulation.

Figure 3.1 Dixon Readi-Ride Existing Conditions



Source: WSP

3.2 Proposed Zeb Facility Improvements

The Dixon Readi-Ride facility concept supports 10 charging positions. Positions are planned for the future ZEs that will replace the existing eight cutaway vehicles, while also leaving room for two additional vehicles in the future.

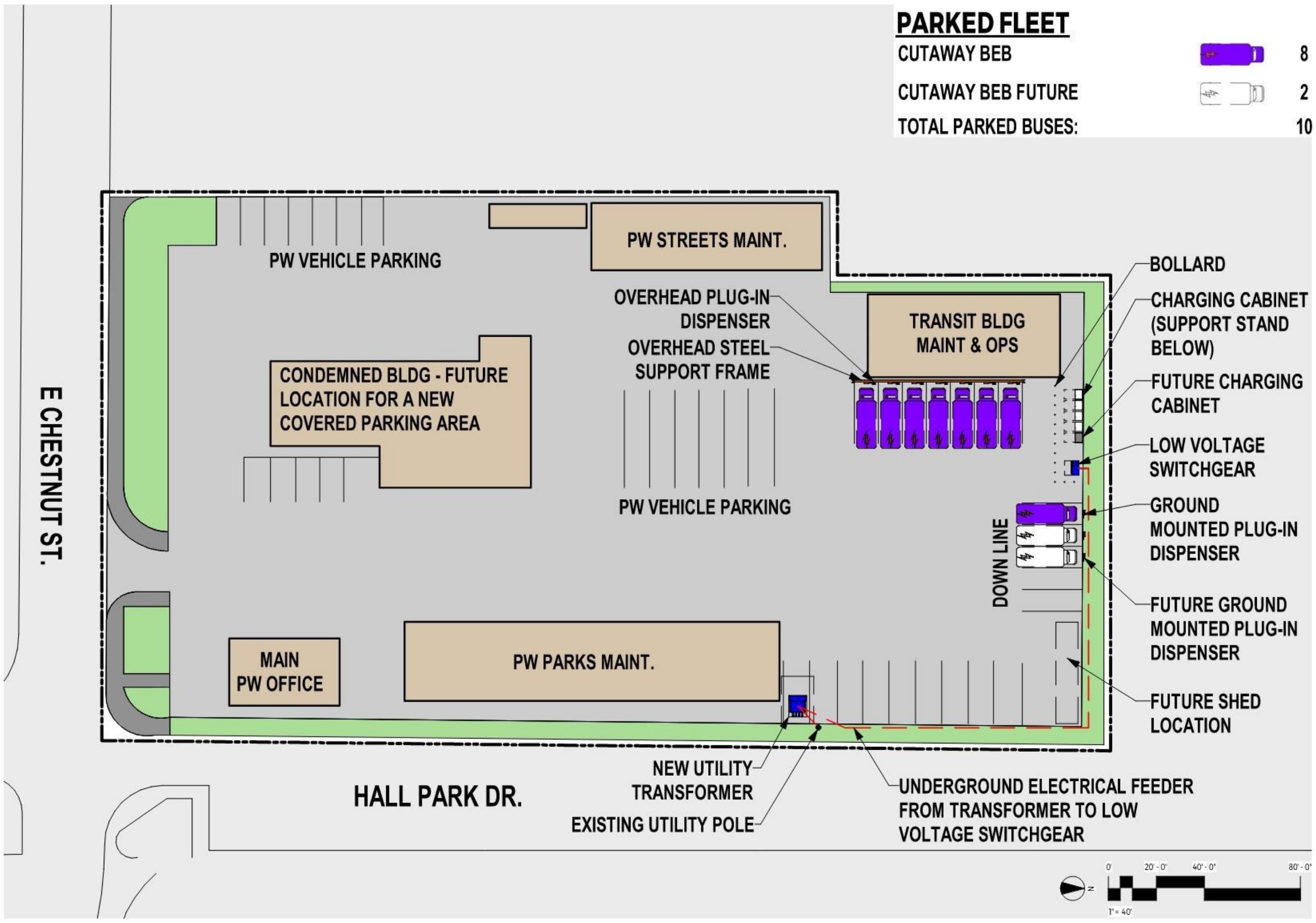
Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles. These vehicles are parked outdoors either east of the maintenance building or at the north end of the facility along the fence line. Table 3.1 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to the Task 3: *BEB Facility Concepts* report. Figure 3.2 illustrates the proposed facility concept to support the electrification transition.

Table 3.1 Dixon Readi-Ride Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	5
Plug-in DC Dispenser	10
Cable Retractor	7
Plug-in DC Dispenser in Maintenance Area	1
Transformer	1
Switchboard	1

Source: WSP

Figure 3.2 Dixon Readi-Ride Preliminary Facility Concept



Source: WSP

3.3 Implementation Strategy

Due to the relatively small fleet size and the proposed configuration of the improvements, it is recommended that all on-site improvements be constructed in a single stage.

The vast majority of the planned charging infrastructure and utility distribution can be accommodated in unpaved areas or along the edge of paved areas, minimizing the impact on current operations. However, once construction begins on the areas in front of the existing maintenance building, vehicles parking in these positions will need to be relocated elsewhere, either on site or another location.

Careful coordination between the contractor and site managers will be needed to ensure that an adequate number of maintenance bays are still accessible while the framing and associated foundations are installed in this area. Once the framing is completed, however, the buses should be able to resume their current parking arrangement at night while overhead electrical cabling and equipment are installed.

It should be noted that while the infrastructure makes the most sense to be installed in a single stage, the charging cabinets and associated dispensers could be procured and installed in additional stages to better align with a desired bus procurement schedule.

3.3.1 CONSTRUCTION SCHEDULE

Based on the assumed durations, Dixon Readi-Ride's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022.

The first step is design procurement, which involves issuing an RFP for the design, receiving proposals, and accepting a bid. At the end of this six month phase, the actual design phase will commence. The design phase is estimated to take 11 months, ending in November 2023. In order to sync up to the construction phase, the utility upgrade process should begin in January 2023, at the same time that the design procurement phase is completed. When there are still three months remaining in the design phase, the construction procurement can begin. At that point the design will be far enough along that the overall scope of the construction can be written into an RFP. Like the design procurement phase, the construction phase should take six months. Once that phase is completed, in February 2024, the actual construction can begin. That step is estimated to take seven months.

Table 3.2 summarizes the number of stages and schedule for Dixon Readi-Ride and Table 3.3 illustrates the proposed schedule.

Table 3.2 Dixon Readi-Ride Construction Summary

Agency	No. of Stages	Timeline
Dixon Readi-Ride	1	July 2022 – September 2024

Source: WSP

Table 3.3 Dixon Readi-Ride Construction Schedule

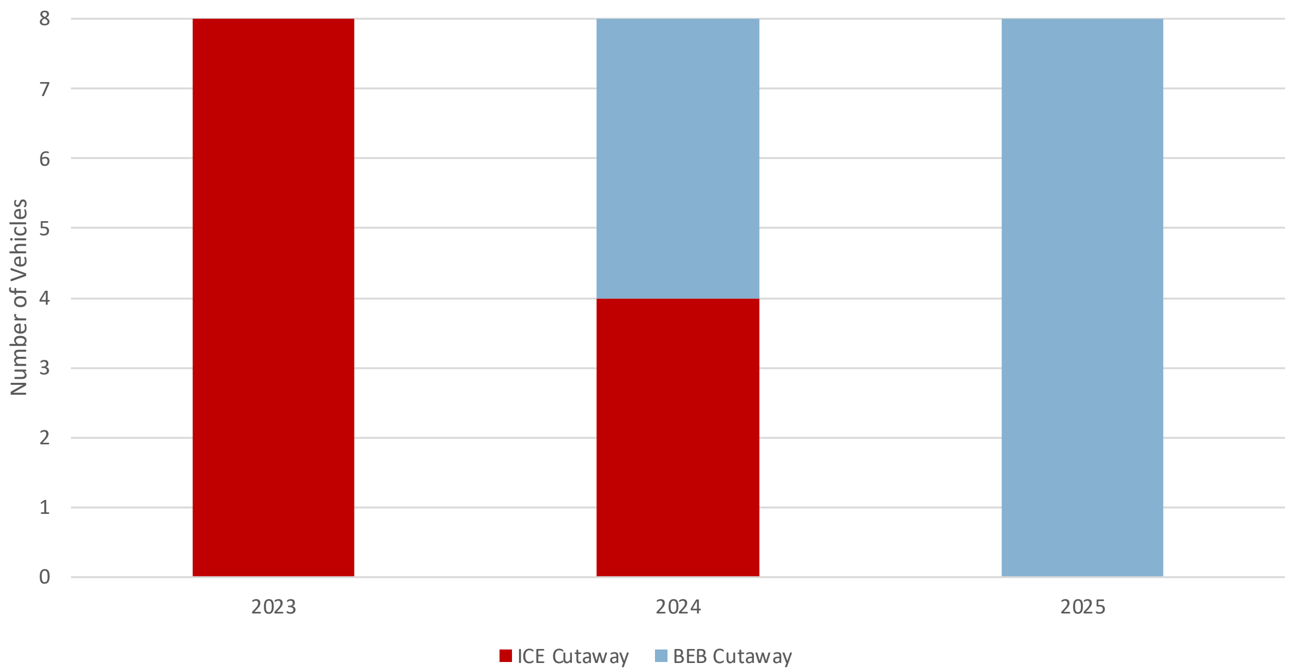
<table>
<tr><th></th><th>Jul-22</th><th>Aug-22</th><th>Sep-22</th><th>Oct-22</th><th>Nov-22</th><th>Dec-22</th><th>Jan-23</th><th>Feb-23</th><th>Mar-23</th><th>Apr-23</th><th>May-23</th><th>Jun-23</th><th>Jul-23</th><th>Aug-23</th><th>Sep-23</th><th>Oct-23</th><th>Nov-23</th><th>Dec-23</th><th>Jan-24</th><th>Feb-24</th><th>Mar-24</th><th>Apr-24</th><th>May-24</th><th>Jun-24</th><th>Jul-24</th><th>Aug-24</th><th>Sep-24</th></tr>
<tr><td>Months</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td></tr>
<tr><td>Utilities</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="18">18 Months</td><td></td><td></td><td></td></tr>
<tr><td>Design Procurement</td><td colspan="6">6 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Design</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="11">11 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Construction Procurement</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">6 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Construction</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">7 Months</td></tr>
</table>

Source: WSP

3.3.2 PROCUREMENT SCHEDULE

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. The developed procurement timeline assumes that vehicles will be purchased in two sets of four vehicles. This approach will help ease the transition so that Dixon Readi-Ride has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Figure 3.3 illustrates Dixon Readi-Ride's fleet mix over time (between ICE and ZEB vehicles) and Table 3.4 presents a conceptual procurement schedule that aligns with the construction schedule and design concept.

Figure 3.3 Dixon Readi-Ride Fleet Mix



Source: WSP

Table 3.4 Dixon Readi-Ride Procurement Schedule

	2022	2023	2024 (Oct)	2025
Total Available Charging Positions	-	-	10*	10*
Delivered Cutaways	-	-	4	4

Source: WSP

Note: *Planned for eight vehicles; allowing for an expansion of two additional vehicles.

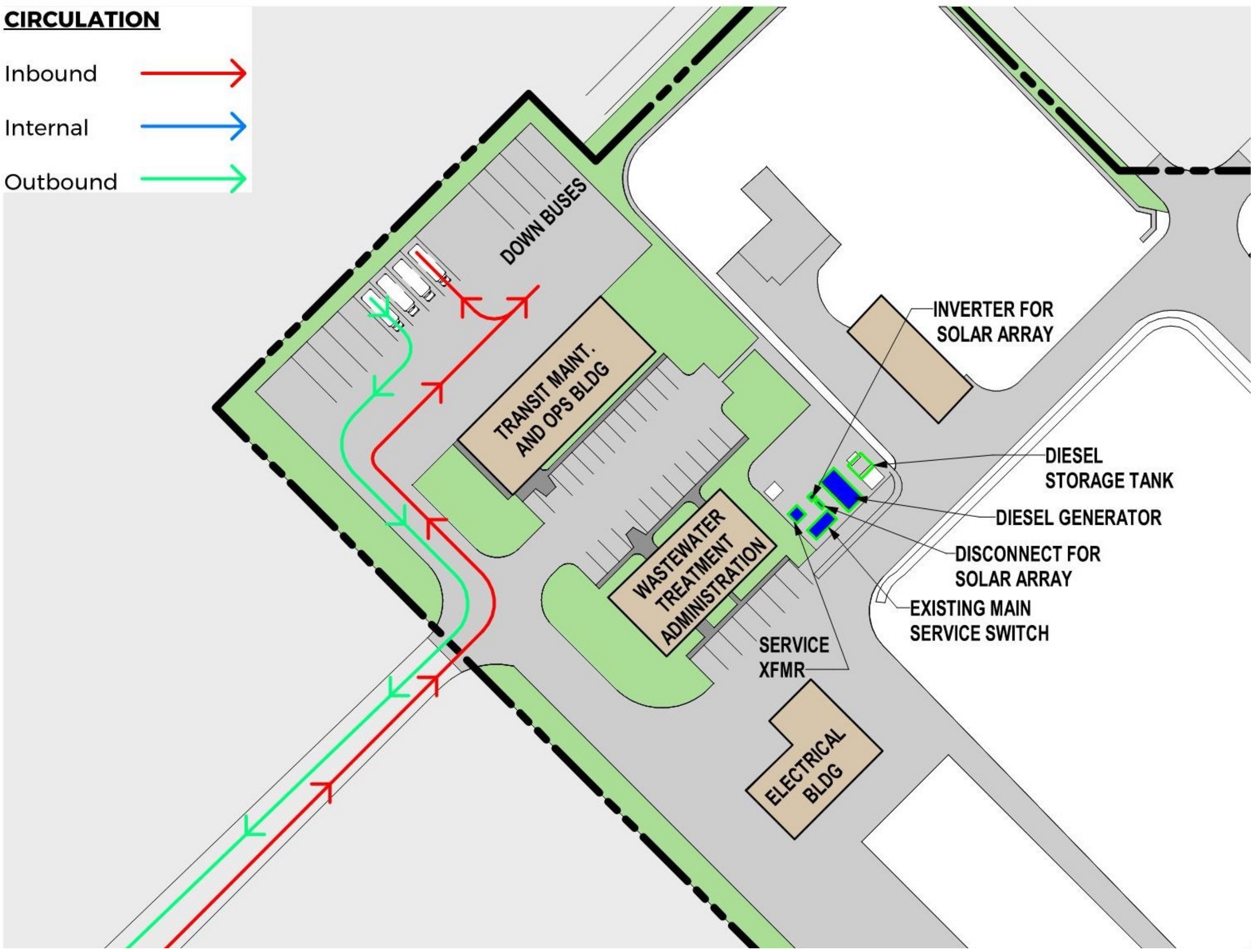
RIO VISTA
DELTA BREEZE

4 RIO VISTA DELTA BREEZE

4.1 Existing Conditions

The Rio Vista Delta Breeze facility is located at 3000 Airport Road and shares the site with the City of Rio Vista Northwest Wastewater Treatment Plant. Maintenance and operations are both contained within a single building on the site, with the maintenance bays accessed from the transit yard. The operations areas are accessed from the employee parking on the east. The existing fleet consists of four cutaway vehicles and one minivan. Power for the transit operation is currently served from the existing Wastewater Treatment Plant's primary electrical service. Figure 4.1 illustrates the existing conditions and site circulation.

Figure 4.1 Rio Vista Delta Breeze Existing Conditions



Source: WSP

4.2 Proposed Zeb Facility Improvements

The Rio Vista Delta Breeze facility concept supports eight charging positions. Positions are planned for the future ZEs that will replace the existing four cutaway vehicles, while also leaving room for four additional vehicles in the future.

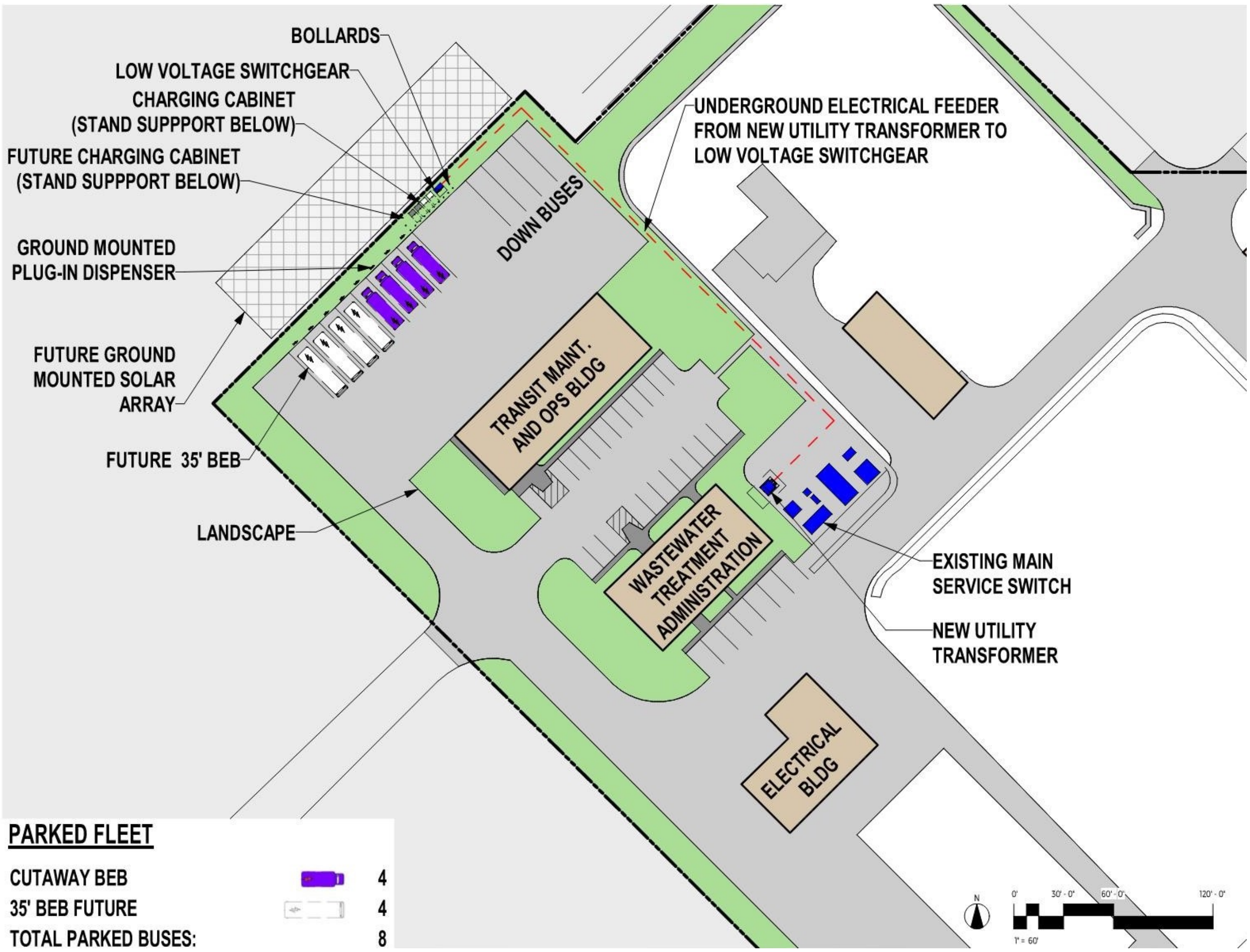
Plug-in charging was determined to be the most suitable method of charging since the fleet solely consists of cutaway vehicles. Table 4.1 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to the Task 3: *BEB Facility Concepts* report. Figure 4.2 illustrates the proposed facility concept to support the electrification transition.

Table 4.1 Rio Vista Delta Breeze Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	4
Plug-in DC Dispenser	8
Plug-in DC Dispenser in Maintenance Area	1
Transformer	1
Switchboard	1

Source: WSP

Figure 4.2 Rio Vista Delta Breeze Preliminary Facility Concept



Source: WSP

4.3 Implementation Strategy

Due to the relatively small fleet size and the proposed configuration of the improvements, it is recommended that all on-site improvements be constructed in a single stage.

The planned infrastructure improvements are able to occur outside the current bus parking area, ensuring that all construction activities can occur without any impacts to existing operations.

It should be noted that while the infrastructure makes the most sense to be installed in a single procurement stage, the charging cabinets and associated dispensers themselves could be procured and installed in additional stages to better coordinate with a desired bus procurement schedule.

4.3.1 CONSTRUCTION SCHEDULE

Based on the assumed durations, Rio Vista Delta Breeze's electrification transition will take 27 months, with an estimated completion date in September 2024 – assuming that the development of the design procurement begins in July 2022.

The first step is design procurement, which involves issuing an RFP for the design, receiving proposals, and accepting a bid. At the end of this six month phase, the actual design phase will commence. The design phase is estimated to take 11 months, ending in November 2023. In order to sync up to the construction phase, the utility upgrade request should start in January 2023, at the same time that the design procurement phase is completed. When there are still three months remaining in the design phase, the construction procurement can begin. At that point the design will be far enough along that the overall scope of the construction can be written into an RFP. Like the design procurement phase, the construction phase should take six months. Once that phase is completed, in February 2024, the actual construction can begin. That step is estimated to take seven months.

Table 4.2 summarizes the number of stages and schedule for Rio Vista Delta Breeze and Table 4.3 illustrates the proposed schedule.

Table 4.2 Rio Vista Delta Breeze Construction Summary

Agency	No. of Stages	Timeline
Rio Vista Delta Breeze	1	July 2022 – September 2024

Source: WSP

Table 4.3 Rio Vista Delta Breeze Construction Schedule

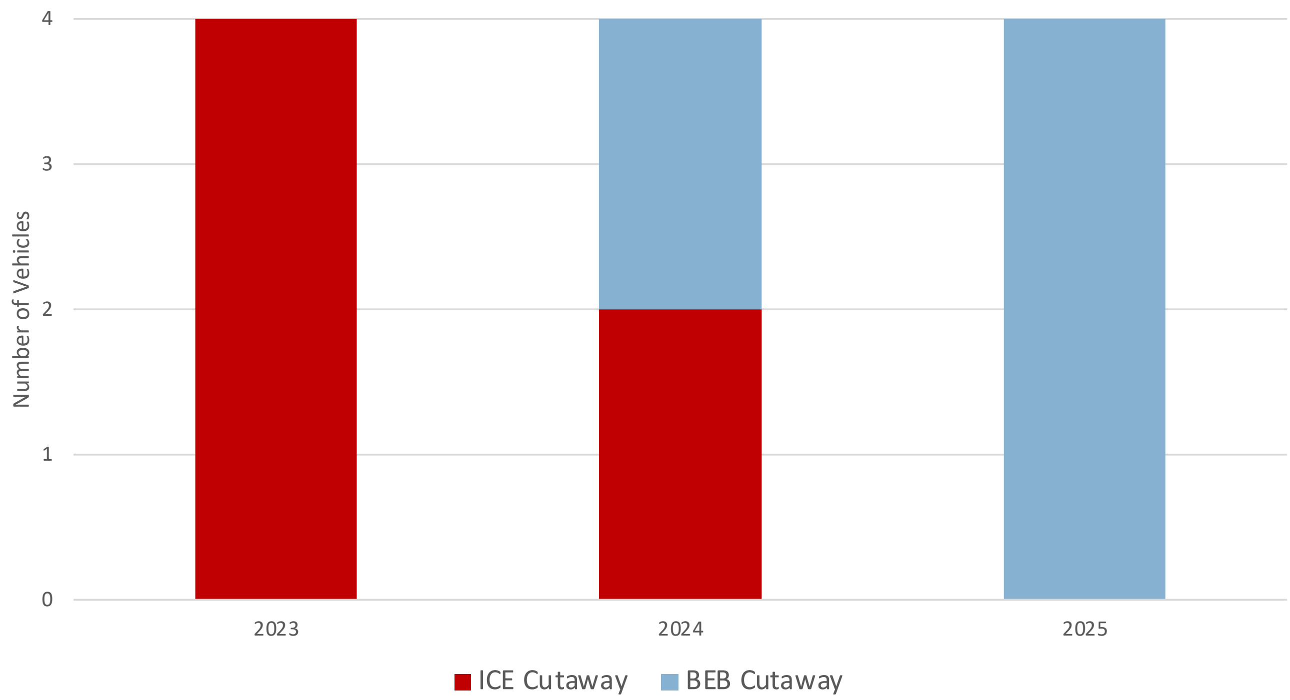
	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24
Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Utilities							18 Months																				
Design Procurement	6 Months																										
Design							11 Months																				
Construction Procurement															6 Months												
Construction																					7 Months						

Source: WSP

4.3.2 PROCUREMENT SCHEDULE

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. The developed procurement timeline assumes that vehicles will be purchased in two sets of two vehicles. This approach will help ease the transition so that Rio Vista Delta Breeze has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Figure 4.3 illustrates Rio Vista Delta Breeze's fleet mix over time (between ICE and ZEB vehicles) and Table 4.4 presents a conceptual procurement schedule that aligns with the construction schedule and design concept.

Figure 4.3 Rio Vista Delta Breeze Fleet Mix



Source: WSP

Table 4.4 Rio Vista Delta Breeze Procurement Schedule

	2022	2023	2024 (Oct)	2025
Total Available Charging Positions	-	-	8*	8*
Delivered Cutaways	-	-	2	2

Source: WSP

Note: *Planned for four vehicles; allowing for an expansion of four additional vehicles.

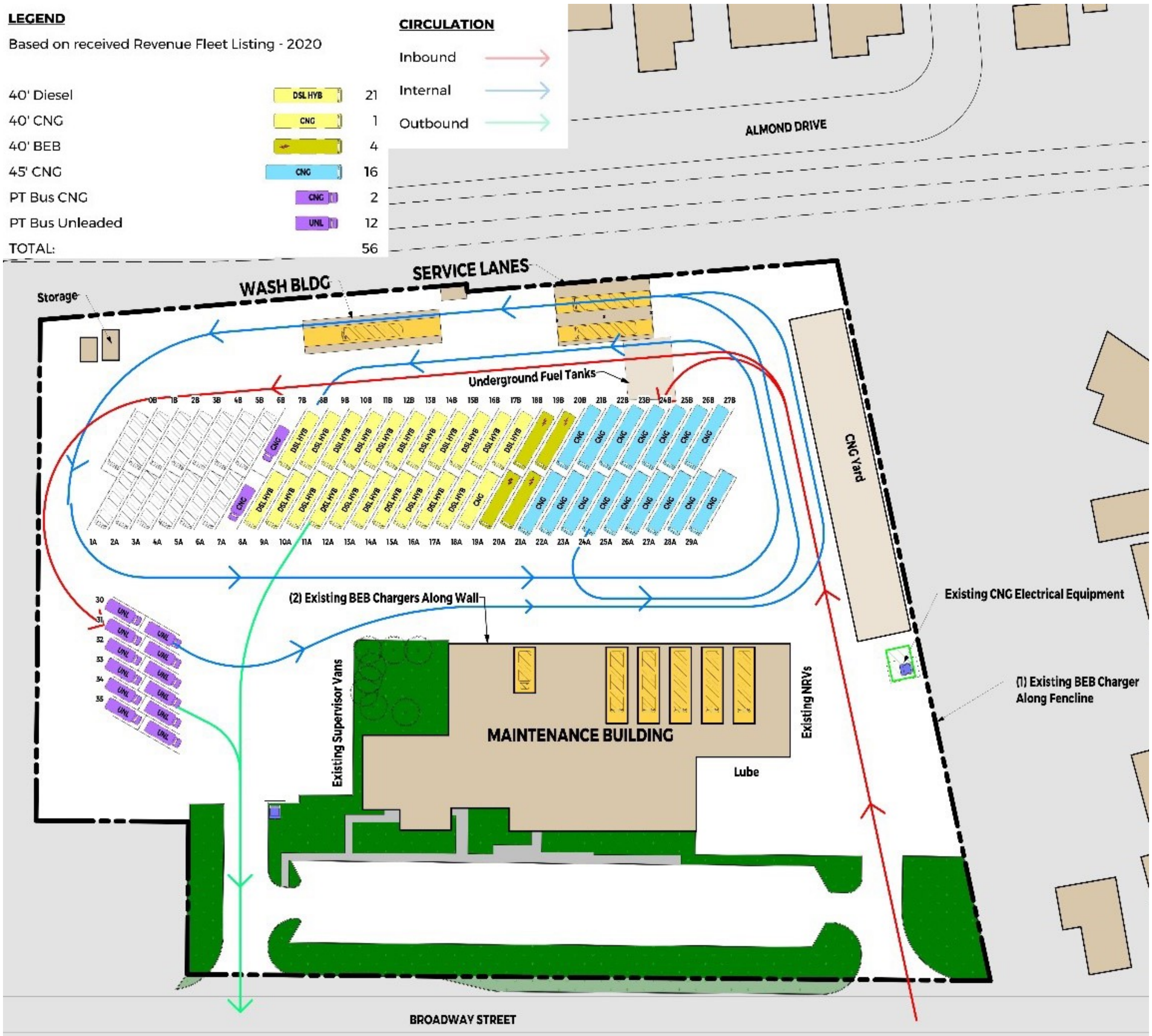
SolTrans

5 SOLANO COUNTY TRANSIT

5.1 Existing Conditions

The SolTrans facility is located at 1850 Broadway Street in Vallejo. The existing bus parking layout consists of 56 transit buses (40-foot buses and 45-foot coaches) parked at an angle, nose-to-tail, east of the maintenance building, and 12 cutaways parked at an angle nose-to-tail north of the maintenance building. Figure 5.1 illustrates the existing conditions and site circulation.

Figure 5.1 SolTrans Existing Site Conditions



Source: WSP

5.2 Proposed Zeb Facility Improvements

The SolTrans facility concept supports 70 charging positions: 26 for 40-foot buses; 16 for coach buses; 14 for ZE cutaways; and 14 additional positions for future expansion. Overhead plug-in dispensers are shown in the masterplan drawing; however, this plan can also support the application of pantographs.

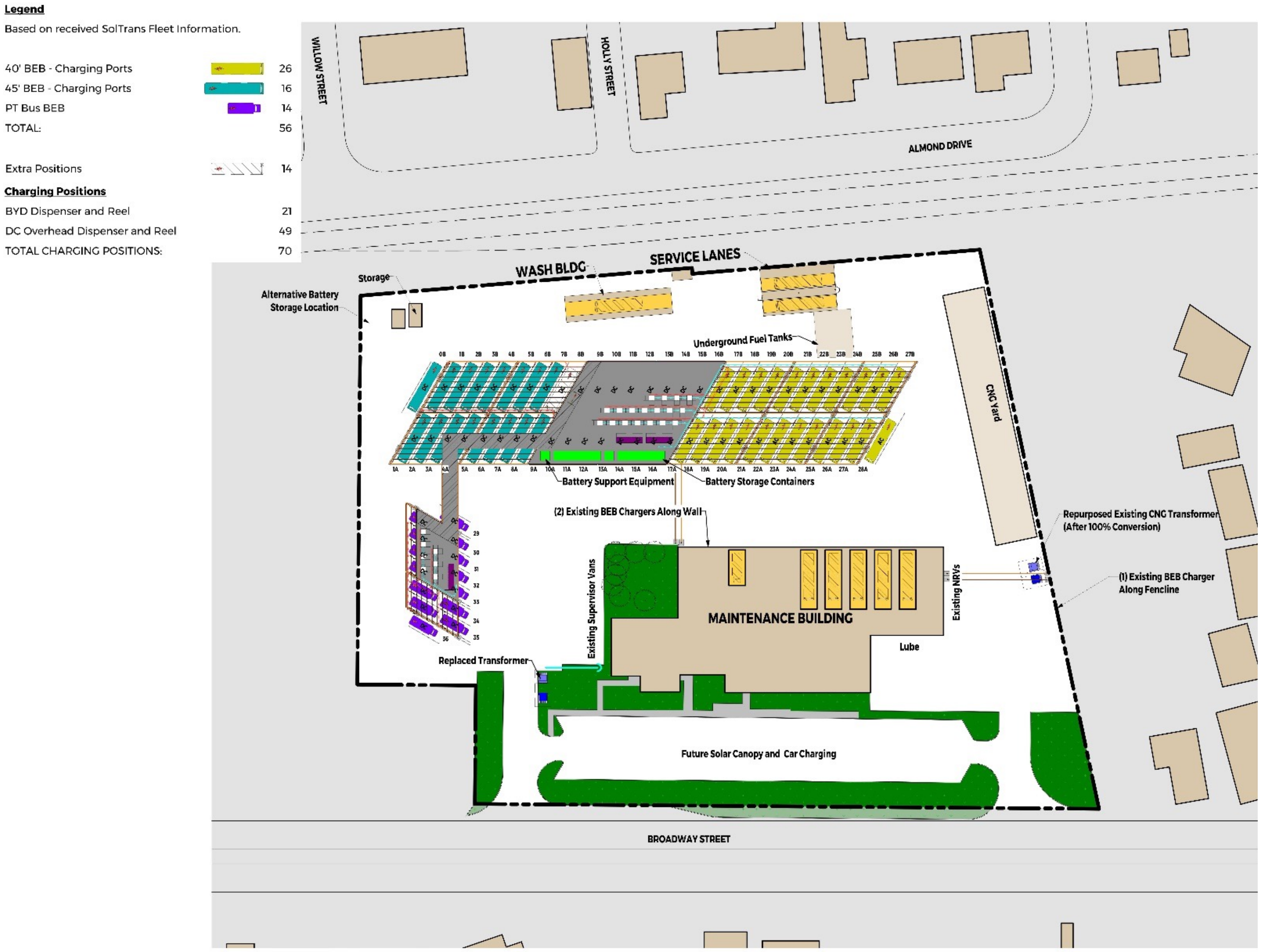
Table 5.1 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to the Task 3: *BEB Facility Concepts* report. Figure 5.2 illustrates the proposed facility concept to support the electrification transition.

Table 5.1 SolTrans Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	25
80 kW AC Charging System	21
Plug-in DC Dispenser	49
Plug-in AC Dispenser	21
Cable Retractor	70
Transformer	4
Switchboard	3
2-Megawatt hour (MWh) Battery Backup	2

Source: WSP

Figure 5.2 SolTrans Preliminary Facility Concept



Source: WSP

5.3 Implementation Strategy

In order to minimize interruptions to operations and allow for SolTrans to implement new BEBs via either AC or DC charging as funding becomes available, the entire overhead support structure, battery backup containers, and solar panels were originally anticipated to be completed as part of the initial stage of implementation. However, the funding available to support the initial deployment was found to be insufficient to support the complete build-out. As such, it was deemed most appropriate to develop the site in two separate stages.

5.3.1 CONSTRUCTION SCHEDULE

Based on the assumed durations, SolTrans' electrification transition will take 39 months (over two stages), with an estimated completion date in May 2025 – assuming that the development of the design procurement begins in July 2022. In order to sync up to the first construction stage, the utility upgrade request should be initiated in March 2022. The design procurement and design steps for the first construction stage has already been completed. Thus, the first step in this timeline is construction procurement. At the end of this six month phase, the actual construction phase will commence.

STAGE 1

Stage 1 shall include the installation of the new utility service transformer, the low voltage switchboard, the five easternmost structural frame bays and 21 overhead mounted AC plug-in dispensers. This stage will be intended to support the first procurement of 21 BEBs, although the design and infrastructure shall be designed to allow for support up to the first 39 BEBs. The transformer and primary charging equipment switchboard shall be sized and designed to support the full masterplan. Additional charging equipment, battery backup containers and solar panels can be added to the built condition as funds become available.

The Stage 1 construction procurement phase should take five months. Once that phase is completed, in August 2022, the actual Stage 1 construction phase can begin. That phase is estimated to take eight months and result in 22 new charging positions to accommodate 40-foot buses.

STAGE 2

Stage 2 shall include the completion of the overhead structural framing and remaining charging equipment needed to support the remaining bus positions. Once the overhead structural framing is complete, the charging equipment can be phased in as needed to best align with vehicle procurements. The addition of battery backup containers and solar panels can be added to the scope or in the future as funds become available.

When Phase 1 is completed, in May 2023, then the Stage 2 design procurement can begin. That process will be six months in duration and will be followed by the design stage. The design step is estimated to take nine months and be completed in July 2024. In May 2024, three months before the design step is completed, the Stage 2 construction procurement phase can begin. That step will be six months long and be completed in October 2024. After that, the seven month long construction phase can commence, with completion in May 2025.

Table 5.1 summarizes the number of stages and schedule for SolTrans and Figure 5.3 illustrates the proposed schedule.

Table 5.2 SolTrans Construction Summary

Agency	No. of Stages	Timeline
Solano County Transit	2	March 2022 – May 2025

Source: WSP

Table 5.3 SolTrans Construction Schedule

<table>
<tr><th></th><th>Mar-22</th><th>Apr-22</th><th>May-22</th><th>Jun-22</th><th>Jul-22</th><th>Aug-22</th><th>Sep-22</th><th>Oct-22</th><th>Nov-22</th><th>Dec-22</th><th>Jan-23</th><th>Feb-23</th><th>Mar-23</th><th>Apr-23</th><th>May-23</th><th>Jun-23</th><th>Jul-23</th><th>Aug-23</th><th>Sep-23</th><th>Oct-23</th><th>Nov-23</th><th>Dec-23</th><th>Jan-24</th><th>Feb-24</th><th>Mar-24</th><th>Apr-24</th><th>May-24</th><th>Jun-24</th><th>Jul-24</th><th>Aug-24</th><th>Sep-24</th><th>Oct-24</th><th>Nov-24</th><th>Dec-24</th><th>Jan-25</th><th>Feb-25</th><th>Mar-25</th><th>Apr-25</th><th>May-25</th></tr>
<tr><td>Months</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td></tr>
<tr><td>Utilities</td><td colspan="10">10 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 1 Construction Procurement</td><td></td><td colspan="5">5 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 1 Construction (22 charging positions)</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="8">8 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 2 Design Procurement</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">6 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 2 Design (charging positions and infrastructure)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="9">9 Months</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Stage 2 Construction</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">6 Months</td></tr>
</table>

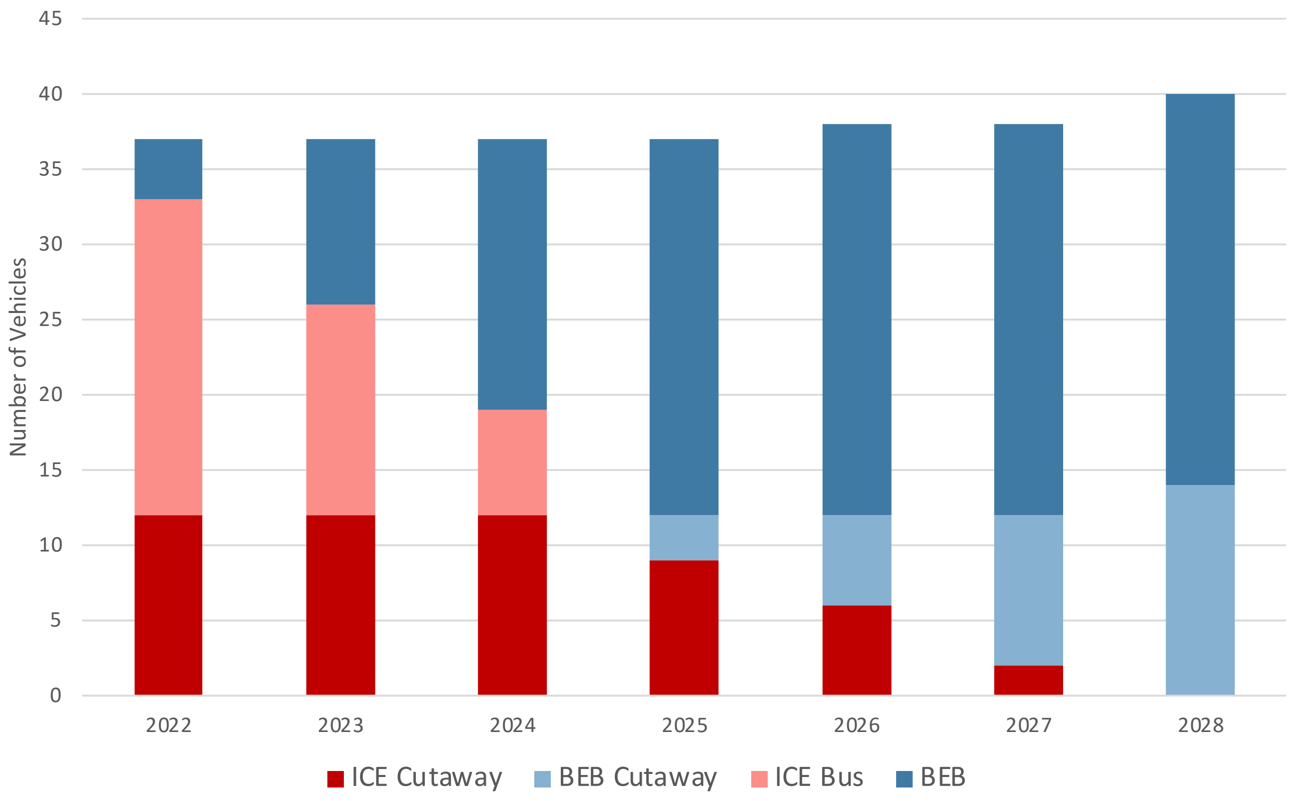
Source: WSP

5.3.2 PROCUREMENT SCHEDULE

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. The developed procurement timeline assumes that vehicles will be purchased in three sets of seven vehicles. This approach will help ease the transition so that SolTrans has the flexibility of continuing to operate ICE vehicles for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. The Stage 2 construction will add chargers for ZE cutaways (as well as coach buses). The ZE cutaways are shown in the procurement timeline to be purchased over the course of four years, with the transition completed by 2028.

Figure 5.3 illustrates SolTrans' fleet mix over time (between ICE and ZEB vehicles) and Table 5.4 presents a conceptual procurement schedule that aligns with the construction schedule and design concept.

Figure 5.3 SolTrans Fleet Mix



Source: WSP

Table 5.4 SolTrans Procurement Schedule

	2022	2023 (May)	2024	2025 (June)	2026	2027	2028
Total Available Charging Positions	-	26	26	70**	70**	70**	70**
Delivered ZE Cutaway	-	-	-	3	3	4	4
Delivered ZE Buses	-	7	7	7	1	-	-
Delivered Coach Buses*	1	4	4	4	-	-	-

Source: WSP

Note: *Coach buses (Solano Express) is not part of this study. Assumed procurement is shown here for context.

**Planned for 56 vehicles; allowing for an expansion of 14 additional vehicles.

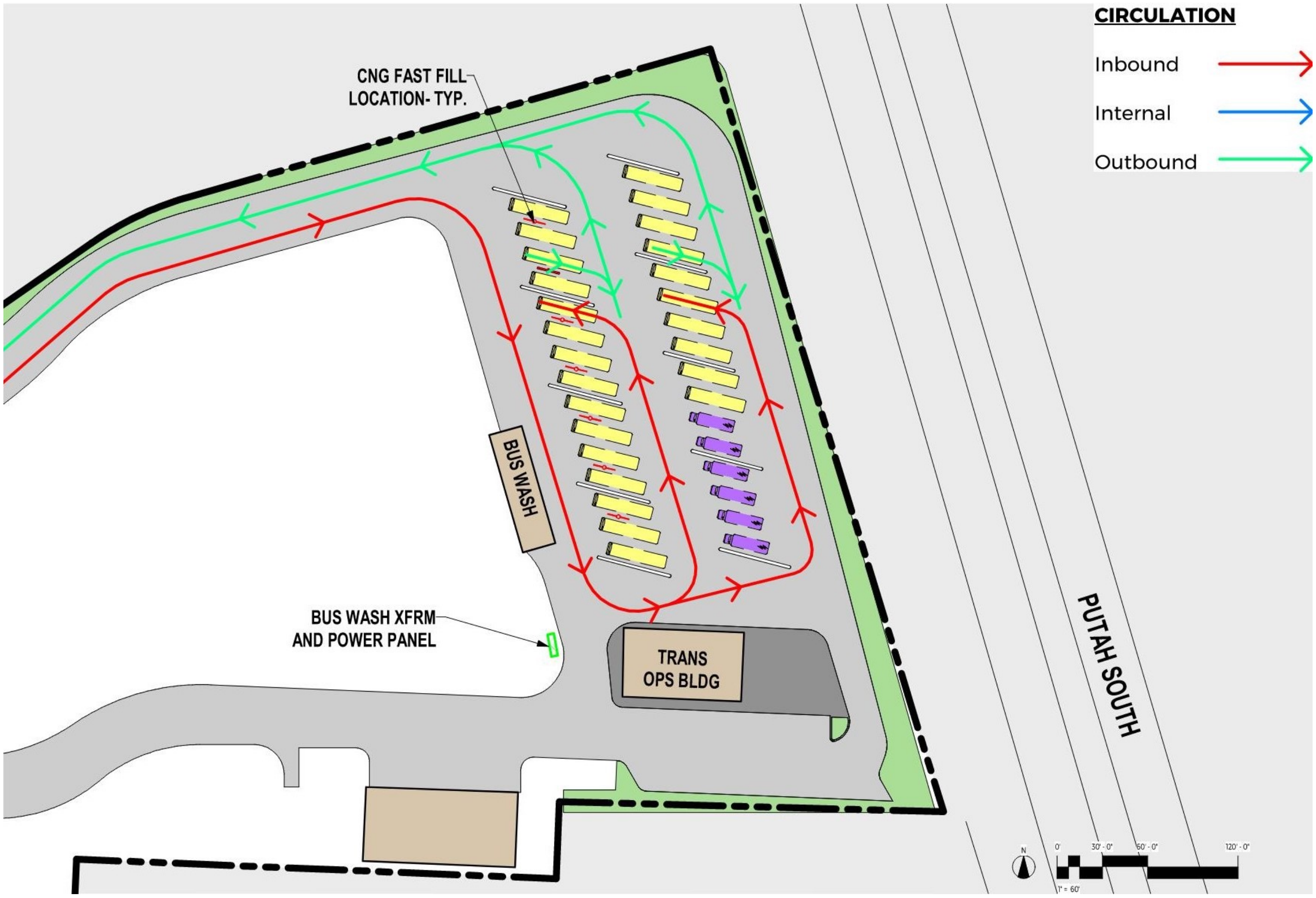
CITY COACH

6 VACAVILLE CITY COACH

6.1 Existing Conditions

The Vacaville City Coach facility is located at 1001 Allison Drive. The transit operations share the site with the City of Vacaville Public Works Department with the transit operations located in the northeast corner of the site. The fleet consists of 18 35-foot buses and seven cutaway vehicles utilized for paratransit services while there is currently parking available for future growth. The primary electrical service for the site is located along the north property line near the middle of the site. Figure 6.1 illustrates the existing conditions and site circulation.

Figure 6.1 Vacaville City Coach Existing Conditions



Source: WSP

6.2 Proposed Zeb Facility Improvements

The Vacaville City Coach facility concept supports 31 charging positions: 10 for 35-foot buses, and 21 for ZE cutaways. This will support the planned 10 ZEBs and 15 ZE cutaway vehicles/vans, while also leaving room for additional vehicles in the future. To maximize the usage of the parking area and limit the amount of trenching required at the existing parking area, overhead charging was determined to be the preferred solution with overhead plug-in being the preference over pantograph dispensers. Table 6.2 provides an overview of the proposed charging and utility infrastructure. For additional details, refer to the Task 3: *BEB Facility Concepts* report. Figure 6.2 illustrates the proposed facility concept to support the electrification transition.

Table 6.1 Vacaville City Coach Recommended Infrastructure

Item	Quantity
150 kW DC Charging Cabinet	16
Plug-in DC Dispenser	31
Cable Retractor	31
Transformer	1
Switchboard	1

Source: WSP

Figure 6.2 Vacaville City Coach Preliminary Facility Concept

Source: WSP

6.3 Implementation Strategy

Due to the proposed configuration of the improvements, it is recommended that the construction efforts be split into two separate stages. The improvements could be installed within a single procurement or within two separate construction procurements depending on Vacaville City Coach's preference. It should be noted that while two stages are presented, the charging cabinets and associated dispensers could also be installed in additional stages to better coordinate with a desired bus delivery schedule.

6.3.1 CONSTRUCTION SCHEDULE

The Vacaville City Coach schedule is shortened due to Vacaville City Coach's goal to electrify 10 vehicles by November 2023. In order to relieve some of the constraints, the transition has been split into two stages, with the second stage being for the cutaway fleet that does not need to meet the November 2023 goal (per the CARB ICT regulation, cutaways do not need to transition until 2026).

The design procurement for 30% design has already commenced as of this report, with the actual 30% design work scheduled to begin in March 2022. Shortly after that, in April 2022, the design procurement for 100% should take place. This procurement process will last four months, with a design team selected by July 2022, at the same time that the 30% design is completed. The 100% design process will then begin and will last five months, ending in December 2022. Meanwhile, the utility upgrade request should begin in March 2022 so that it can be completed by August 2023, just prior to the completion of the Stage 1 construction.

The construction procurement will select a single team that will implement the designs for both construction stages. Construction procurement should begin just prior to the completion of the 100% design, in November 2022, and will last five months, ending in March 2023. The Stage 1 construction will take place from April to October 2023. At that point the facility will be able to accept the 10 35-foot BEBs on order. The Stage 2 construction can begin right after Stage 1 is completed. Stage 2 is estimated to take four months, with the construction finishing in April 2024.

STAGE 1

Stage 1 shall include the installation of the new utility service transformer, the low voltage switchboard, five charging cabinets, the western structural frame and bridge and ten overhead mounted plug-in dispensers. This stage will be intended to support the first procurement of ten 35-foot BEBs, although the design and infrastructure shall be designed to allow for support of another five 35-foot BEBs in the future. During this initial stage the CNG fast fill dispensers located at the bus parking positions will need to be decommissioned and removed from service.

During the construction of Stage 1, the buses parking in the affected positions will need to be temporarily relocated while the CNG dispensers are decommissioned and the overhead framing system installed. During this time, these CNG buses will not be able to be refueled in their parking position and will need to be cycled through the fueling island. It is recommended that during this stage the affected 35-foot buses be moved to the eastern parking row and the smaller cutaway and van vehicles be moved to another open area of the site.

STAGE 2

Stage 2 shall include the construction of the overhead framing system over the eastern parking positions as well as the bridge that extends between the two framing units. At this time any additional charging cabinets and dispensers desired to support the smaller fleet vehicles (vans or cutaways if desired) shall be installed. During this stage the 35-foot BEBs would be located back in their preferred positions upgraded during Stage 1 and the smaller vehicles would remain in their temporary locations elsewhere on the site.

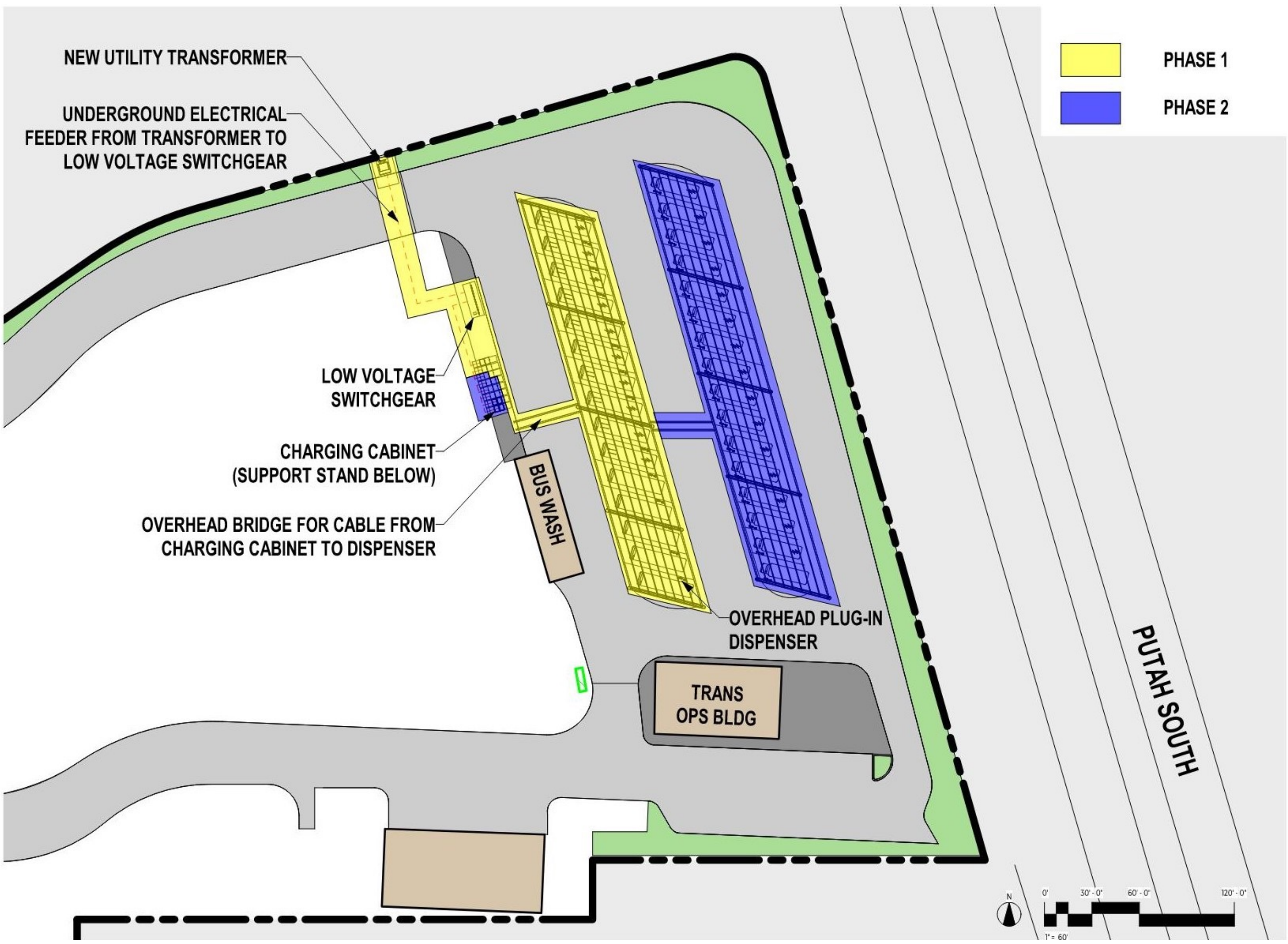
Table 6.2 and Figure 6.3 summarize and illustrate the number of stages, respectively, and Table 6.3 illustrates the proposed schedule.

Table 6.2 Vacaville City Coach Construction Summary

Agency	No. of Stages	Timeline
Vacaville City Coach	2	March 2022 – February 2024

Source: WSP

Figure 6.3 Vacaville City Coach Preliminary Staging Concept



Source: WSP

Table 6.3 Vacaville City Coach Construction Schedule

<table>
<tr><th></th><th>Mar-22</th><th>Apr-22</th><th>May-22</th><th>Jun-22</th><th>Jul-22</th><th>Aug-22</th><th>Sep-22</th><th>Oct-22</th><th>Nov-22</th><th>Dec-22</th><th>Jan-23</th><th>Feb-23</th><th>Mar-23</th><th>Apr-23</th><th>May-23</th><th>Jun-23</th><th>Jul-23</th><th>Aug-23</th><th>Sep-23</th><th>Oct-23</th><th>Nov-23</th><th>Dec-23</th><th>Jan-24</th><th>Feb-24</th></tr>
<tr><td>Months</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td></tr>
<tr><td>Utilities</td><td colspan="18">18 Months</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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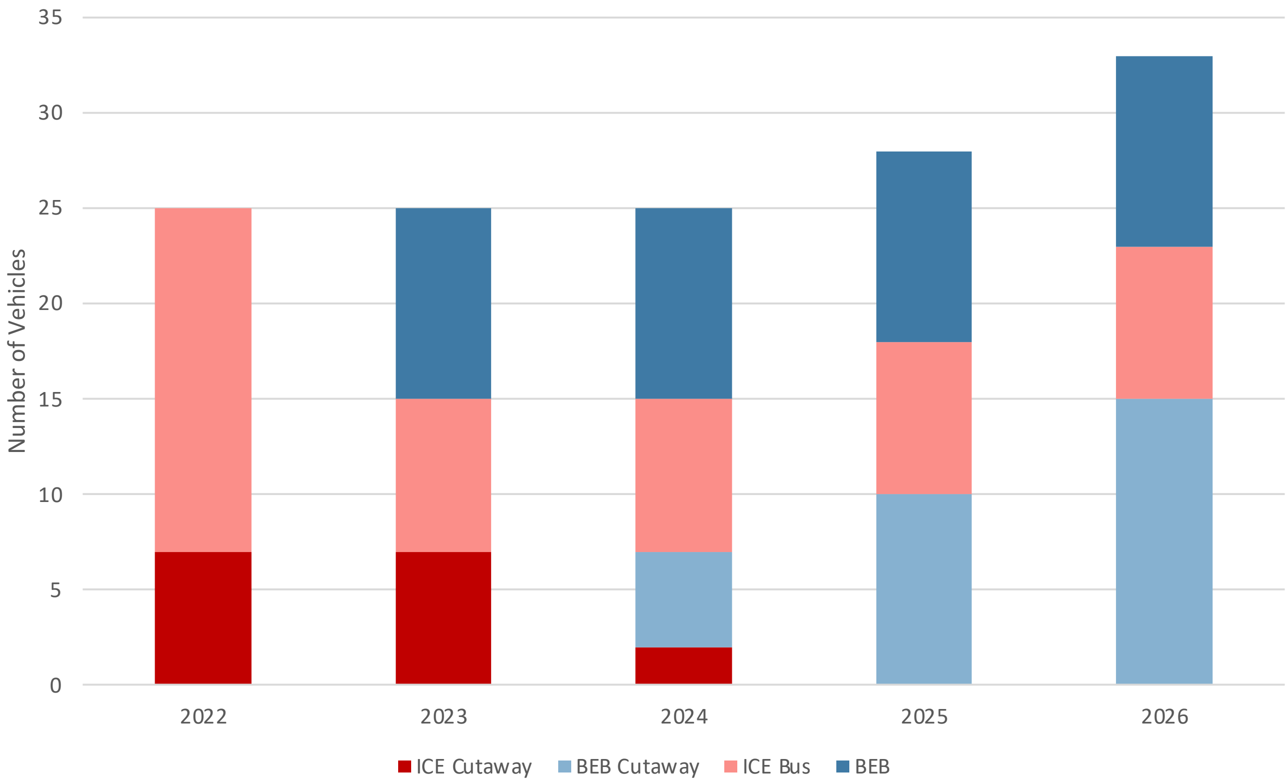
<tr><td>Stage 1 Construction</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">7 Months</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Stage 2 Construction</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">4 Months</td></tr>
</table>

Source: WSP

6.3.2 PROCUREMENT SCHEDULE

It is essential that the delivery of new vehicles align with or after the completion of construction, given that the vehicles cannot be operated until chargers are installed. Vacaville City Coach has a goal of procuring 10 35-foot vehicles to align with the completion of Stage 1, subsequent procurements will align with Stage 2, with five ZE cutaways arriving in 2024. Additional cutaways will be procured in sets of five in 2025 and 2026. This approach will help ease the transition so that Vacaville City Coach has the flexibility of continuing to operate ICE cutaways for a short period of time while the new ZE vehicles are delivered. This approach will also help ensure that any mid-life maintenance will not occur for the entire fleet at the same time. Vacaville City Coach can choose to speed up the procurement of the cutaways, given that the dispensers will be available by April 2024. Figure 6.4 illustrates Vacaville City Coach's fleet mix over time (between ICE and ZEB vehicles) and Table 6.4 presents a conceptual procurement schedule that aligns with the construction schedule and design concept.

Figure 6.4 Vacaville City Coach BEB Procurement Transition



Source: WSP

Table 6.4 Vacaville City Coach Procurement Schedule

	2022	2023 (Nov)	2024 (March)	2025	2026
Total Available Charging Positions	-	10	31*	31*	31*
Delivered ZE Cutaways	-	-	5	5	5
Delivered ZE Buses	-	10	-	-	-

Source: WSP

Note: *Planned for 25 vehicles; allowing for an expansion of six additional vehicles.

7 CONCLUSION

This Phasing Strategy and Transition Analysis presents construction and procurement schedules that can serve as the framework for each agency to meet CARB ICT regulation requirements. The following sections provide an overview of the construction and procurement schedules for each agency and details some of the considerations that each agency will need to address or mitigate during its transition.

7.1 Construction Schedules

Each agency's construction schedule varies based on the size of the facility, its upgrade requirements, as well as the particular goals of the agency. All agencies are anticipated to have all required infrastructure installed and constructed in advance of the CARB ICT regulation's first purchase requirements in 2026 (25% of new purchases required to be ZEB).

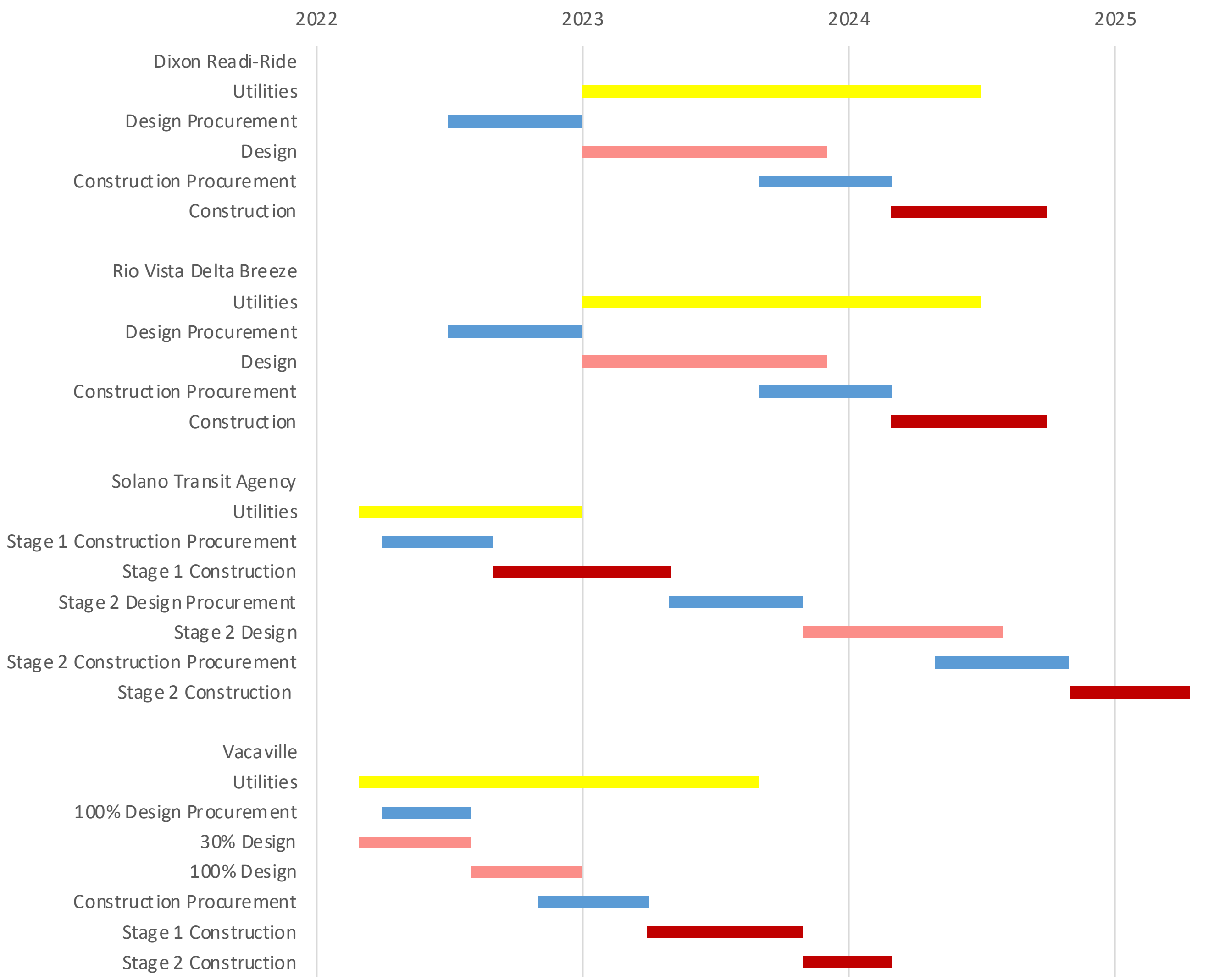
Table 7.1 provides an overview of each agency's construction schedule along with the number of proposed construction stages. Figure 7.1 presents the schedules for each agency's facility, broken up into the major steps of the transition.

Table 7.1 Construction Summary – All Agencies

Agency	No. of Stages	Timeline
Dixon Readi-Ride	1	July 2022 – September 2024
Rio Vista Delta Breeze	1	July 2022 – September 2024
Solano County Transit	2	March 2022 – May 2025
Vacaville City Coach	2	March 2022 – February 2024

Source: WSP

Figure 7.1 Construction Schedule – All Agencies



Source: WSP

7.2 Procurement Schedules

The developed procurement schedules are based on future fleet projections. The assumed delivery dates of vehicles were developed with special consideration to vehicles' useful life, construction completion dates, and reducing impacts to maintenance staff. Table 7.2 shows the procurement schedule for each agency by year, by vehicle type.

Table 7.2 Procurement Schedule – All Agencies

Year	Dixon Readi-Ride	Rio Vista Delta Breeze	SolTrans		Vacaville City Coach		Total
	Cutaway	Cutaway	Cutaway	Bus	Cutaway	Bus	
2022	-	-	-	-	-	-	-
2023	-	-	-	7	10	-	17
2024	4	2	-	7	-	5	18
2025	4	2	3	7	-	5	21
2026	-	-	3	1	-	5	9
2027	-	-	4	-	-	-	4
2028	-	-	4	-	-	-	4
Total	8	4	14	22	10	15	73

Source: WSP

Dixon Readi-Ride plans to replace its existing eight ICE cutaways with ZE cutaways. The proposed procurement schedule assumes four cutaways arriving in October 2024, with the remaining four ZE cutaways arriving in the following year.

Rio Vista Delta Breeze plans to replace its existing two ICE cutaways with ZE cutaways. The proposed procurement schedule assumes two cutaways arriving in October 2024, with the remaining two ZE cutaways arriving in the following year.

SolTrans currently has 12 ICE cutaway vehicles, 21 40-foot buses, 16 45-foot coach buses, and four BEBs. The agency plans to replace the ICE cutaways with 14 ZE cutaways, and the 40-foot ICE buses with 22 BEBs. The current procurement schedule has the BEBs arriving first, seven per year, starting in May 2023 to align with the 22 new charging dispensers from Stage 1. When the Stage 2 construction is complete, in June 2025, the ZE cutaways will begin their arrival.

Vacaville City Coach currently has seven ICE cutaway vehicles and 18 35-foot buses. The agency plans to replace the ICE cutaways with 15 ZE cutaways, and the 35-foot ICE buses with 10 BEBs. The proposed procurement schedule assumes the delivery of the 10 BEBs in November 2023 to align with the 10 new charging dispensers from Stage 1. When the Stage 2 construction is complete, in March 2024, the ZE cutaways will begin their arrival at the rate of five per year.

7.3 Transition Considerations

In determining the path forward towards its transition goals, agencies must consider, address, and mitigate a variety of factors and risks. The following sections provide an overview of some of these.

7.3.1 SERVICE COMPLETION

The service modeling analysis found that some existing blocks are too long to be served with battery-electric technology. Furthermore, the demand response daily mileage data was estimated and may need refining. Solano County agencies will have to align their procured vehicles with any needed service changes. The gradual transitions as outlined in this plan will help ease the process by giving the agencies time to analyze performance data and fall back on ICE vehicles while they are still in the fleet.

7.3.2 FLEET REPLACEMENT RATIO

The previous Task 2: *Service Modeling Analysis* estimated the energy needs of current service blocks. It should be re-emphasized that that replacement ratio was modeled not only on current service, but also on current technology, and should be regularly re-assessed based on actual performance. The incremental rollout of BEBs will provide ongoing up-to-date examples of actual BEB performance, which can inform how many BEBs are needed to meet service, as well as their charging needs.

7.3.3 CAPITAL IMPROVEMENT PLANS

As facilities age, STA agencies may be planning retrofits or rebuilds irrespective of fleet electrification. This may result in a delay to fleet transition due to a desire to align the transition with the planned construction. The schedules in this report do not account for capital improvement plans that are not directly related to fleet electrification.

7.3.4 SERVICE GROWTH

The Task 3: *BEB Facility Concepts* report included accommodations for expanded fleets at Dixon Readi-Ride, Rio Vista Delta Breeze, and Vacaville City Coach. For Dixon Readi-Ride (two additional cutaways) and Rio Vista Delta Breeze (four additional vehicles – either cutaways or 35-foot buses), there are currently no timelines for the expanded fleet, nor confirmation that they are needed. At this point there are simply spaces for them in the design plans. As such, the expanded fleet for those agencies are not included in the procurement analyses in this report. For Vacaville City Coach, the future fleet has been revised since the *BEB Facility Concepts* report. At this point, the cutaway fleet is planned to expand from seven to 15, while the 35-foot bus fleet is going to be reduced from 18 to 10.

7.3.5 RFPS AND UTILITY APPLICATIONS

Careful planning is needed in order to stay on schedule. For example, in most cases the RFPs for design/construction packages should commence soon (as of this report). Additionally, utility applications must be submitted to PG&E up to 16 months in advance of each facility.

7.3.6 CHARGE MANAGEMENT

Charge management is a necessary component for operating a BEB fleet. A charge management software system can track each bus' SOC while they are at the facility and in service and will intelligently charge and dispatch buses based on the estimated energy needs of the upcoming service blocks. They can also account for utility tariffs in order to minimize charging during peak demand hours. There are many vendors offering charge management services that are compatible with most charger vendors.

7.3.7 WORKFORCE TRAINING AND IMPACTS

The transition to an all-ZEB fleet will significantly alter agency's service and operations. Converting to BEBs from existing ICE vehicles is logistically complicated and will impact all ranks of the organization.

Training for the operation, maintenance, and handling of BEBs will be conducted after bus procurement and in advance of delivery. Training conditions and schedules will be included in procurement documents, as they are with all existing procurements. It is expected that all relevant personnel will be sufficiently trained before buses arrive. If other OEM-provided buses are procured in the future and/or if new components, software, or protocols are implemented, it is expected that staff will be trained well in advance of the commissioning of these additions.

For operations staff, buses will take longer than ICE vehicles to be prepared for dispatch, due to longer recharging times. In addition, the battery SOC will always have to be considered (if the facility has parking lanes with multiple spaces in it), dispatch will not always be as simple as pulling out the bus that is at the front of the line. On-site traffic flows may change, as well, though one of the goals of workforce training will be to smoothly integrate BEBs into operations.

For maintenance staff, they will need to understand BEB propulsion systems, repair, and troubleshooting, as well as the charge management system.

Operator training should focus on operator driving behavior to increase energy efficiency and improve BEB range by taking advantage of regenerative braking.

7.3.8 EMERGENCY RESPONSE

The use and storage of BEBs require updated safety procedures. Along with upgraded facilities to accommodate the vehicles, enhanced safety procedures include modified emergency response plans and firefighting techniques. There are currently no building codes or recommendations for constructing or modifying maintenance facilities to guide transit agencies for the introduction of BEBs. There are codes and regulations for stationary energy storage systems, but none are specific to commercial nor private maintenance, parking, or service of electric vehicles. This process is ongoing and will evolve as technology expands, more vehicles are placed in service, and lessons are learned.

Battery fires require different strategies and techniques due to the thermodynamic factors that affect their combustion process. The batteries themselves are the ignition source and the electrolyte inside the individual battery cells is what is burning. Once the fire is put out, if there is still a cell or battery pack that is damaged and has a short circuit, they can get hot enough again and spontaneously reignite. This cycle has been known to repeat itself for many hours on small batteries. Larger energy storage systems have been known to remain a hazard for days.

If a fire does occur, the most widely accepted technique will be to use large volumes of water to cool the ESS in order to control and reduce temperatures and reduce further hazards. Neither dry chemicals nor foam suppressants provide the needed reduction in temperatures to control the spread of the fires.

7.3.9 RESILIENCE

With the transition, there is going to be a renewed reliance on the electrical grid. It is going to be essential that agencies protect their infrastructure by investing and applying several strategies to ensure that service can continue to be operated in the face of emergencies.

For example, an auxiliary battery storage system can be integrated to reduce the effect of unexpected power outages on operations. Other considerations include redundant feeds and dispatchable generators. PG&E reliability data can show the frequency and durations of power outages every year, and thus provide an estimate of how much backup power is needed. Backup power will generally come in the form of on-site battery storage system in order to provide a minimum viable backup. A minimum viable backup power assumption can be made, such as a reserve system accounting for 75% of the entire fleet's usable battery capacity. The size of the storage, and the costs, should be considered during the analysis.

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX F: COST AND FUNDING ANALYSIS

Solano Transportation Authority

Solano Transportation Authority

Countywide Electrification Transition Plan

TASK 5: COST AND FUNDING ANALYSIS

Final — May 2022

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Acronyms and Terms

Acronym or Term	Description
BEB	Battery-Electric Bus
Block	The work assignment for a single vehicle during a service workday
CARB	California Air Resources Board
CNG	Compressed Natural Gas
CPI-U	Consumer Price Index
Efficiency	A measure of a vehicle's performance, expressed in kilowatt-hours per mile throughout this report
FAST	Fairfield and Suisun Transit
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GTFS	General Transit Feed Specification
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
MW	Megawatt
OEM	Original Equipment Manufacturer
PG&E	Pacific Gas & Electric
PPI	Producer Price Index
SolTrans	Solano County Transit
STA	Solano Transportation Authority
ZEB	Zero-Emission Bus

1 INTRODUCTION

1.1 Study Overview

The California Air Resources Board's (CARB) Innovative Clean Transit (ICT) regulation has mandated that all transit agencies in California must transition internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs) by 2040. The Solano Transportation Authority (STA) is developing the *Countywide Electrification Transition Plan* to guide Solano County transit agencies in their transitions to all battery-electric bus (BEB) fleets.

The *Countywide Electrification Transition Plan* includes a series of technical analyses and reports that will support the transition and be combined into the comprehensive final report. The following provides an overview of these reports and tasks:

- Task 1: Existing Conditions Analysis
- Task 2: Service Modeling Analysis
- Task 3: BEB Facility Concepts
- Task 4: Power and Energy Analysis
- **Task 5: Costs and Funding Analysis (this report)**
- Task 6: Phasing Strategy and Transition Analysis
- Task 7: *Countywide Electrification Transition Plan*

The *Countywide Electrification Transition Plan* captures all required elements that need to be analyzed and reported for a CARB-approved ICT Rollout Plan. Rollout Plans are state-mandated documents that Solano County agencies – along with many other "small" transit agencies – will need to submit to CARB by July 2023.

There are five agencies that operate in Solano County: Dixon Readi-Ride, Fairfield, and Suisun Transit (FAST), Rio Vista Delta Breeze, Solano County Transit (SolTrans), and Vacaville City Coach. SolTrans and FAST have already taken steps to achieve their respective transitions. SolTrans is currently working with WSP on engineering and design services to bring both power and charging infrastructure to its facilities and two off-site locations – many of this project's elements are incorporated in this project. FAST is currently developing the Fairfield Transition Electrification Transition Model Project, an independent study to develop a framework for the electrification of FAST's fleet (being conducted by Willdan Energy Solutions). For this reason, FAST is not analyzed in any technical memoranda or reports under the *Countywide Electrification Transition Plan*.

1.2 Report Purpose and Approach

The purpose of the Cost and Funding report is to provide in-depth analyses on the lifecycle costs and available funding sources to support Solano County's agencies' fleet electrification effort. The lifecycle cost estimation included cash and non-cash costs. Cash costs consisted of vehicle and infrastructure capital costs, operating and maintenance costs, and disposal costs. Meanwhile, non-cash costs consisted of environmental costs and benefits.

The list of available funding sources is provided on the federal, state, and regional/local levels. Lastly, a funding gap analysis was conducted to identify opportunities and strategies for future financial planning efforts for the fleet electrification program.

1.3 Report Structure

This report is organized into five main sections:

1. **Introduction** – Overview of *Countywide Electrification Transition Plan* and the Cost and Funding Analysis.
2. **Methodology** – Overview of the lifecycle cost analysis, including inputs, assumptions, and limitations.
3. **Agency-Specific Sections** – Presents each agency's lifecycle costs analysis results.
    a. Dixon Readi-Ride
    b. Rio Vista Delta Breeze
    c. SolTrans
    d. Vacaville City Coach
4. **Funding Sources**
    a. Federal
    b. State
    c. Regional/Local
5. **Conclusion** – Provide summaries on total project costs, funding gaps, and key takeaways of the analyses.

2 METHODOLOGY

The following section provides an overview of the inputs (data and assumptions), methodology, and outputs used to determine the costs of transitioning Solano County transit agencies to BEBs.

2.1 Introduction

The WSP team is actively engaged with agencies that operate zero-emission vehicle fleets, fuel providers, and vehicle manufacturers to understand trends in the industry. This information is utilized to inform assumptions on energy availability and pricing, and vehicle performance and costs. The values presented throughout this document are subject to change and are based on the most current information available at the time of this analysis.

Compared to internal combustion engine vehicles, zero-emission vehicles, specifically electric vehicles, incur different capital and operating costs, which vary based on the type of vehicles operated and their operating environments. For example, the cost to install and maintain utility infrastructure and charging stations will differ in both the magnitude and the types of resources required in comparison to the replacement and maintenance of a diesel storage and fueling facility. Other examples include battery replacement schedules, mid-life overhaul, and disposal value.

Electric buses and facilities may offer the opportunity for Solano County's agencies to reduce operations and maintenance costs, while others will increase. Similar to conventionally fueled vehicles, electric vehicle operations and maintenance costs are highly dependent on the size and complexity of the vehicle fleet. Additionally, an electrification strategy would shift Solano County's agencies' primary fuel source for core bus operations from diesel, compressed natural gas (CNG), or gasoline fuel with electric power, which would subject the agencies to very different energy pricing structures and exposure to energy price volatility.

Table 2.1 outlines the major cost categories associated with bus electrification. Estimated costs in each of these categories were developed for electrification scenarios, as well as a "No-Build" baseline scenario which assumes no change in the current types of vehicles in the fleet.

The total cost of Solano County's agencies' transition will be contingent upon their specific fleet size, bus acquisition plan, facility sizes, charging strategy, construction schedule, pursuit of applicable grant and funding programs, among other details.

Table 2.1 Primary Cost Categories

Type	Cost Components Attributed to Lifecycle Analysis
Capital	Vehicle Purchase Price
	Modifications & Contingency
	Charging or Fueling Infrastructure
Operating	Vehicle Maintenance, Vehicle Tools, Training and Equipment
	Vehicle Fuel/Energy Costs
	Tire Replacement Costs
	Battery Replacement Costs
	Fueling or Charging Operational Costs
Disposal	Battery Disposal Cost or Salvage Value
	Bus Disposal Cost or Salvage Value
Environmental	Vehicle Emissions
	Upstream Emissions
	Noise

Source: WSP

2.2 LifeCycle Cost Analysis

The analysis provided in this report was developed to adhere to California Air Resources Board (CARB) mandate to transition all transit fleets to zero-emission. In support of the mandate, WSP developed a lifecycle cost analysis tool applying data specific to Solano County's agencies' operations, up-to-date industry data, and region-specific indicators. Where data specific to STA operations are not available, WSP leveraged aggregated information collected from peer agencies.

The structure of the lifecycle cost modeling includes the assessment of capital, operating, disposal, and monetized environmental costs associated with the transition of Solano County's agencies' existing vehicles under a No-Build and Build Scenarios, defined as:

- **No-Build Scenario** - Continued operation of Solano County's agencies' current clean diesel/CNG/ unleaded-fueled vehicles with replacement by similar models at the end of the assumed vehicle service life
- **Build Scenario** - Replacement of Solano County's agencies' current clean diesel/CNG/unleaded-fueled vehicles with zero emission vehicles at the end of the assumed vehicle service life

The lifecycle costs are assessed over the vehicles' operating years to account for their full operating costs over 12 or 10 years.

2.3 General Data, Assumptions, and Limitations

The following section details the data inputs and sources, and operational assumptions underlying the lifecycle cost analysis and modeling for all the fleet operators.

2.3.1 GENERAL DATA SOURCES

The lifecycle cost modeling utilizes various capital, operating, disposal, and environmental assumptions. Wherever possible, agency-specific datapoints are used to inform the cost assumptions. For unavailable datapoints, this analysis leverages peer agency data and WSP assumptions based on previous experience with other agencies.

2.3.2 CAPITAL COSTS OF VEHICLES

Capital costs of vehicles are sourced from the base vehicle prices provided through the California State Buy board for battery electric buses, the Metropolitan Transportation Commission (MTC) Regional Bus/Van Pricelist FY2022-23 Sheet for ICE vehicles. The additional cost of battery extended warranties were applied to the capital cost of BEB vehicles. Vehicle costs represent the cost of replacing the existing vehicle fleet and do not consider incremental vehicle requirements due to potential range reductions from the transition to BEBs. Vehicle purchase costs includes the standard purchase price, additional costs for service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price). For battery electric buses, an additional cost for battery extended warranty over the life of the vehicle is assumed. All values are rounded to the nearest thousands.

Capital costs of vehicles are incurred based on the procurement timeline from the Task 7: Phasing Strategy and Transition Analysis, and are subject to considerations such as the useful life of the current vehicles fleet and any established procurement goals. There are two main factors considered with vehicle procurement: timing and quantity. The number of vehicles being procured is determined by how many vehicles can be accommodated at each facility and the quantity needed to maintain services. The lifecycle model assumes that standard buses can be retired after their useful life benchmark.

The fleet replacement plan is based on the current operations of Solano County's agencies, with the assumption that BEB infrastructure will be constructed during the 2023-2024 timeframe. Vehicle purchases for BEB conversion may not fully align with the current vehicle fleet due to other operational considerations. Additionally, capital costs of vehicles are incurred one year prior to operational start date to account for delivery lag and acceptance testing.

Infrastructure capital costs for charging and fueling infrastructure are based on recent experiences of peer agencies to replace their existing fueling tanks for the no build scenario, while for the build scenario, infrastructure cost estimates represent the cost to procure, design, and installation of BEB chargers and update underlying infrastructure. Cost assumptions were developed by a WSP cost estimator, or in the case of comparable cost estimates, by a contractor (SolTrans only). The facility cost estimates prepared by WSP are based on a combination of facility improvements, vehicle charger units, and supporting utility infrastructure upgrades. Current costs for BEB chargers were used and applied to each facility based on the number of anticipated BEBs in operation. Facility improvements and utility upgrades are based on unit estimates and corresponding unit costs values. The analysis does not amortize the capital costs and assume costs will be incurred during the specified fleet replacement years or assumed construction period.

2.3.3 CHARGING INFRASTRUCTURE COSTS

Charging and fueling infrastructure includes the supporting equipment and facility construction to support the operations and maintenance of buses. Charging infrastructure conceptual estimates are developed by a WSP cost estimator based on the equipment and construction needs to host the battery electric buses at each facility.

There are five types of costs that make up the utility improvement costs – direct cost, general conditions, contractor fee, bonds and insurances and contingency. Direct costs are physical infrastructure and equipment costs. General conditions are applied to the direct cost. Contractor fee percentage is applied to sum of direct cost and general conditions. Bonds and insurances percentage is applied to sum of direct cost, general conditions, and contractor fee.

2.3.4 OPERATING AND MAINTENANCE COSTS

Operating and maintenance costs are evaluated on a cost per mile basis and applied to the average vehicle mileage over the 12-,10-, or 7- year lifecycle of BEBs and ICE vehicles. Average mileage of each vehicle type is determined based on the fleet odometer reading presented in the 2020 Short Range Transportation Plan (SRTP) for each agency, vehicle mileage data provided by the agency and considers refinements from the calculation of bus blocks by WSP. Values on operating costs per mile are sourced from the operating experience of peer agencies. Fuel costs, including diesel compressed natural gas (CNG) and gasoline are based on current California wholesale prices excluding taxes. Energy costs (electricity) are based on the utility tariffs of a local, California green energy provider, MCE and Pacific Gas & Electric (PG&E). Fuel cost projections are based on the five-year historical trends from US Energy Information Administration (US EIA) and US EIA Annual Energy Outlook projections. Disposal costs are based on the current Federal Transit Administration guidance and the operating experience of the agencies. Lastly, the environmental assumptions for tailpipe and lifecycle GHG emissions are based on Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool, Fuel Pathways by CARB, and the EPA Moves 2014b model.

2.3.5 DISCOUNT RATES

The lifecycle cost model employs nominal discount rate of 9.5%. The rate accounts for the typical 7% discount rate required by United States Department of Transportation (USDOT) on federal grant applications and an addition of average escalation of approximately 2.5%. All cost assumptions are in 2021 dollars. All agency combined lifecycle cost analysis results are shown in discounted 2021 dollars and in year of expenditure (YOE) dollars. Each agency's results are in YOE dollars.

2.3.6 GENERAL INFLATION

The lifecycle cost model accounts for inflation using the historical Consumer Price Index for all Urban Consumers (CPI-U) and Producer Price Index (PPI) for Bus Chassis Manufacturing. The model accounts for the historic differential in growth rates off of the regional CPI-U. Table 2.2 is an overview of CPI-U values from 2020 – 2024 provided by Bureau of Labor Statistics and PPI for Bus Chassis Manufacturing. After 2024 annual growth rates are held constant with the 2024 values.

Table 2.2 National Consumer Price Index for All Urban Consumers (CPI-U) and National PPI for Bus Chassis Manufacturing Based on Historic Ratio

Year	2020	2021	2022	2023	2024
CPI-U	1.25%	2.79%	2.33%	2.30%	2.30%
PPI Bus Chassis Manufacturing	2.55%	4.09%	3.63%	3.60%	3.60%

Source: Bureau of Labor Statistics

2.4 Funding Sources

The section identifies and evaluates funding sources that potentially may be available to support STA and its member transit agencies to fund their transitions to, pursuant to the Solano *Countywide Electrification Transition Plan*. Funding sources outlined in this section are applicable for funding BEB vehicle purchases and/or associated facility enhancements or charging infrastructure to accommodate BEBs.

This section evaluates funding sources at the federal, state, and regional or local levels. Each respective funding section begins with a summary table comparing key components of the funding option, including an explanation of the likelihood that the option would provide funding to the program of projects outlined in the *Countywide Electrification Transition Plan*. A comprehensive description of each option can be found in Appendix B.

2.4.1 FEDERAL FUNDING

The Infrastructure Investment and Jobs Act, signed into law in November 2021 as the Bipartisan Infrastructure Law (BIL), provides for the lion's share of transportation-related formula and discretionary grant assistance that comes from the U.S. federal government. This legislation included a reauthorization of the programs included in the Fixing America's Surface Transportation (FAST) Act along with the creation of new ones. Overall, the BIL authorizes more funding opportunities to accommodate the country's transition to a more climate-friendly transportation system. Existing and new formula funding and discretionary grant programs will receive an historic investment of federal funds that will be eligible for fleet electrification and associated infrastructure projects.

The federal funding options described and evaluated in this section include the following:

- US Department of Transportation (USDOT) Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Program;
- Federal Transit Administration (FTA) Capital Investment Grants (CIG) – Small Starts;
- FTA Section 5307: Urbanized Area Formula Grants;
- FTA Section 5311: Formula Grants for Rural Areas;
- FTA Section 5339: Bus and Bus Facilities Program, both formula and competitive;
- FTA Low or No Emission Vehicle Program – Section 5539 (C);
- Federal Highway Administration (FHWA) Carbon Reduction Program;
- FHWA Electric Vehicle (EV) Charging Formula Funding and Grant Program;
- US Department of Energy (USDOE) Alternative Fuel Tax Credit;
- US Department of Treasury (USDT) New Markets Tax Credit (NMTC) Program; and,
- USDT Opportunity Zones.

Appendix B provides a high-level summary of the key characteristics and considerations of each funding sources evaluated in this section, followed by a comprehensive description of each option.

Other Federal Funding Opportunities

The BIL amends other programs and funding sources that could potentially be used for BEB purchases or other projects stipulated in the Solano *Countywide Electrification Transition Plan*. These include:

- FHWA Surface Transportation Block Grant (STBG) Funding eligible uses expanded to include installation of EV charging infrastructure.
- FHWA Congestion Mitigation and Air Quality (CMAQ) funding eligible uses expanded to include the purchase of medium- or heavy-duty zero emission vehicles and related charging equipment.

Note that CMAQ and STBG funding in the 9-county Bay Area Region are distributed via the regional Metropolitan Transportation Commission (MTC) One Bay Area Grant (OBAG) program discussed in Appendix B.

2.4.2 STATE FUNDING

A variety of funding programs within the state of California support transit fleet electrification efforts and achieve the California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation, which mandates that all transit agencies in California must transition to zero-emission buses (ZEBs) by 2040. The state funding options described and evaluated in this section include the following:

- California Air Resources Board (CARB) Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP);
- CARB State Volkswagen Settlement Mitigation;
- California State Transportation Agency (CalSTA) Transit and Intercity Rail Capital Program (TIRCP);
- California Transportation Commission (CTC) Solution for Congested Corridor Programs (SCCP);
- California Department of Transportation (Caltrans) Low Carbon Transit Operations Program (LCTOP);
- Caltrans Local Transportation Fund (LTF);
- Caltrans State Transit Assistance (STA);
- Caltrans State of Good Repair Program (SGR);
- CALSTART Clean Mobility Options (CMO); and,
- California Energy Commission (CEC) Clean Transportation Program

Additionally, STA and its member agencies can benefit from tax exemptions in California to aid in the fleet electrification transition. BEB purchases are exempt from California sales and use taxes when purchased by a transit agency and electricity that local agencies or public transit operators use as motor vehicle fuel to operate public transit services is exempt from applicable user taxes imposed by California counties.

Appendix B provides a high-level summary of the key characteristics and considerations of each funding sources evaluated in this section, followed by a comprehensive description of each option.

Other California State Programs & Incentives

In addition to the state funding options outlined in this section, STA and its member agencies can benefit from tax exemptions in California to aid in the fleet electrification transition. BEB purchases are exempt from

California sales and use taxes when purchased by a transit agency and electricity that local agencies or public transit operators use as motor vehicle fuel to operate public transit services is exempt from applicable user taxes imposed by California counties.

2.4.3 REGIONAL & LOCAL FUNDING

In addition to the regionally administered state funding discussed in the previous section, a few regional entities also disperse funding that could potentially be used for fleet electrification projects like those envisioned in the Solano *Countywide Electrification Transition Plan*. The regional/local funding options described and evaluated in this section include the following:

- Metropolitan Transportation Commission (MTC) One Bay Area Grant (OBAG);
- Bay Area Air Quality Management District (BAAQMD) Transportation Funds for Clean Air (TFCA);
- BAAQMD Carl Moyer Program;
- BAAQMD Community Emission Reduction Grant Program; and,
- Solano County Regional Traffic Impact Fee (RTIF)

Appendix B provides a high-level summary of the key characteristics and considerations of each funding sources evaluated in this section, followed by a comprehensive description of each option.

DIXON READI-RIDE

3 DIXON READI-RIDE

3.1 Introduction

This section outlines the cost assumptions for the lifecycle cost analysis of continued operations of internal combustion engine vehicles and transition to electric vehicles for Dixon Read-Ride. The four major categories for the cost assumptions are capital, operating, disposal, and environmental.

3.2 Capital Costs

Bus capital costs are based on standard vehicle purchase prices, after-market equipment, allowances for contingency, and charging infrastructure. Charging and fueling infrastructure requirements are a key consideration for battery-electric buses.

3.2.1 VEHICLE PURCHASE COSTS

Table 3.1 shows vehicle cost estimates for both the Build and No-Build scenarios. Each scenario includes four vehicles purchased in both 2024 and 2025. As noted in Section 2.3.2, capital costs of vehicles are sourced from the base vehicle prices provided through the California State Buy board for battery electric buses and the MTC bus pricing for ICE vehicles.

The analysis assumes additional costs to the standard base vehicle purchase price which includes service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price). For battery electric buses, an additional cost for battery extended warranty over the life of the vehicle is assumed. All values are rounded to the nearest thousands.

Table 3.1 Dixon Readi-Ride – Vehicle Purchase Costs (2021 $)

Scenario	Vehicle Type	Bus Cost Estimate	2024	2025
No-Build	Unleaded 22' (Glaval 450)	$132,514[1]	4 vehicles $530,056	4 vehicles $530,056
Build	BEB 25' (GreenPower EV Star)	$263,905[2]	4 vehicles $1,055,620	4 vehicles $1,055,620

Source: WSP and MTC Bus Pricing

3.2.2 CHARGING INFRASTRUCTURE COSTS

Table 3.2 show the overall utility improvement costs and Appendix A shows the detailed unit cost and materials that are purchased for the site retrofit.

1 MTC Cutaway gasoline vehicle price ($118,000)in FY22-23 and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

2 Includes an additional $35,000 for battery extended warranty on 118 kWh battery pack and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

There is no cost assumption for the no build scenario as Dixon Readi-Ride does not have any fueling infrastructure on-site. All values are rounded to the nearest thousands.

Table 3.2 Dixon Readi-Ride – Utility Improvement Costs for Build Scenario

Agency	Direct Cost	General Conditions (20%)	Contractor Fee (15%)	Bonds and Insurances (3%)	30 Percent Contingency	Total
Dixon Readi-Ride	$876,000	$175,000	$158,000	$36,000	$373,000	$1,618,000

Source: WSP Cost Estimator

3.3 Operating Costs

Vehicle operations and maintenance (O&M) costs include general vehicle maintenance costs, tire service costs, fueling infrastructure annual maintenance costs, fuel or energy costs, and bus disposal and retirement costs. Vehicle O&M costs are specific to the vehicle types and the length of the vehicles. Overall O&M costs are influenced by the operating costs per mile of each vehicle and annual mileage, both direct inputs into the lifecycle cost model.

3.3.1 AVERAGE MILEAGE PER VEHICLE

Average miles per vehicle per year are estimated using the Dixon Readi-Ride Short-Range Transportation Plan. Vehicle life was assumed based on the FTA's useful life benchmark. Average milage and useful life for each fleet type is shown below. Average annual mileage for Unleaded 22' was applied to BEB 25' for a direct comparison. Average miles are used as the basis to calculate fuel and energy consumption, operating and maintenance costs and tire replacement costs. Average annual mileage for existing vehicles were applied to BEBs for a direct comparison. The current analysis assumes the mileage for BEB replacement vehicles is consistent with the current fleet, operating similar routes and blocks.

Table 3.3 Dixon Readi-Ride – Average Vehicle Mileage and Vehicle Useful Life

Scenarios	Average Vehicle Mileage[3]	Useful Life[4]
Unleaded 22'	22,956	10
BEB 25'	22,956	10

Source: 2020 SRTP and FTA Useful Life Benchmark

3.3.2 OPERATIONS AND MAINTENANCE COST

General vehicle maintenance costs, tire replacement costs, and fueling unit maintenance costs for the build and no- build scenario is outlined in Table 3.4.

3 Estimated based on the fleet age and mileage outlined in the Dixon Readi-Ride Short-Range Transportation Plan
4 FTA useful life benchmark

Table 3.4 Dixon Readi-Ride – O&M Costs for Build and No-Build Scenarios (2021 $)

	Unleaded 22'[5]	BEB 25'
Year 1 ($/mi)	0.81	0.80
Year 2 ($/mi)	0.88	0.87
Year 3 ($/mi)	0.96	0.95
Year 4 ($/mi)	1.03	1.02
Year 5 ($/mi)	1.11	1.10
Year 6 ($/mi)	1.14	1.13
Year 7 ($/mi)	1.19	1.18
Year 8 ($/mi)	1.22	1.21
Year 9 ($/mi)	1.25	1.24
Year 10 ($/mi)	1.29	1.28
Tires ($/mi)	0.068[6]	0.07[7]
Fueling Unit/Charger ($/year)	0	218

Source: Peer Agency O&M Cost Curves

Energy Cost

Fuel and energy costs for vehicles are based on MCE Clean Energy and US EIA's fuel price. Additionally, annual demand charge per electric vehicle was applied for BEB replacement scenarios using the MCE Clean Energy rates. Table 3.5 summarizes the energy cost assumptions.

Table 3.5 Dixon Readi-Ride – Fuel/Energy Cost

	Electricity	Gasoline
Fuel/Energy Cost	$0.19/kWh[8]	$2.72/gal[9]
Demand Charges ($/vehicle-year)	$3,766[10]	N/A
Vehicle Type	25'	22'
Vehicle Fuel Efficiency (mpdge or kWh/mi)	0.79	8.1
Average Annual Miles	25,926	25,926
Total Fuel/Energy Costs per Year per Bus	$7,657	$8,706

Source: MCE Energy, PG&E and USEIA

5 Based on a peer agency's experience in San Bernadino County, California

6 Based on a peer agency's experience in Washington

7 Based on a peer agency's experience in Washington. Assumed 10 percent higher than baseline existing vehicles to account for the heavier weight of BEBs.

8 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming a mix of 33% of summer rates and 67% of winter rates. Within the summer and winter rates, the analysis assumes peak, part-peak, and off-peak splits to be 20%, 40%, and 40%, respectively. This rate also includes PG&E's delivery rate, power charge indifference adjustment (PCIA) and franchise fee (FF).

9 2021 California average sales for resale No 2 Distillate without tax from USEIA

10 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming 11% of summer peak, 22% of summer part-peak and 67% of winter peak rates. Based on 2:1 bus to charger ratio for 150 kW chargers.

3.4 Disposal Costs and Resale Value

It is assumed that at the end of the vehicle life, Dixon Readi-Ride will auction the vehicle. Vehicle sales pricing is assumed to be $5,000 per vehicle as any sales above that value may be reserved for next vehicle purchases with approval from FTA.

3.5 Environmental Costs

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.

3.5.1 GREENHOUSE GAS EMISSIONS AND PARTICULATE MATTER

The analysis applies the average annual mileage and the tailpipe and greenhouse gas emissions of g CO_2 equivalent/MJ per mile to estimate the lifecycle emissions in the build and no build scenarios.

Table 3.6 outlines the vehicle tailpipe emissions in g/mi provided by AFLEET Analysis, EPA MOVES 2014b model, and Pacific Gas & Energy (PG&E) carbon footprint calculator. Table 3.7 provides the lifecycle GHG emissions in All Pathways List by California Air Resources Board (CARB).

Table 3.6 Dixon Readi-Ride – Vehicle Tailpipe/Pollutants Emissions (g/VMT)

Emission	Unleaded 22'[11]	BEB 25'
NOX	0.12	-
SOX	-	-
PM10	0.19	0.11
VOC	1.50	-
PM2.5	0.03	0.01

Source: AFLEET Analysis and EPA Moves 2014 Model

Table 3.7 Dixon Readi-Ride – Lifecycle GHG Emissions (g/VMT)

Emission	Unleaded 22'	BEB 25'
CO2	1,705[12]	358[13]

Source: CARB and PG&E

3.6 Lifecycle Cost Analysis Results

The lifecycle cost analysis compares the lifecycle costs and benefits for each scenario in three primary cash cost categories: capital costs, operating costs, and disposal/salvage costs. Additionally, a non-cash cost of

11 Used school bus option in the AFLEET tool.

12 CARB All Pathways. 90 percent of CBO000L00072019, carbon intensity of 100.82 and 10 percent of ETHC244L, carbon intensity of 76.27

13 0.524 lbs. CO2/kWh by PG&E Carbon Footprint Calculator

environmental benefits and costs, which the lifecycle model monetizes to account for a holistic comparative cost and benefit, is assessed.

Table 3.8 shows the lifecycle costs for the Build and No-Build scenarios for Dixon Readi-Ride. The total cash costs for the Build scenario were found to be 56% greater than the No-Build scenario and including the non-cash costs for the Build scenario were found to decrease by 43%. On a per mile basis, the total costs (capital, O&M, disposal, and environmental) would increase from $2.70/mi. to $3.86/mi.

Table 3.8 Dixon Readi-Ride – Lifecycle Cost Analysis Results (YOE $ Thousands)

2021-2037 Fleet Replacement Cost Comparison (YOE $thousands)		Standard Scenario ("No-Build")	BEB Replacement Scenario ("Build")
Capital	Vehicle Purchase Price	$1,115	$2,221
	Modifications & Contingency	$137	$273
	Charging/Fueling Infrastructure	$0	$1,758
	Capital Costs Subtotal	**$1,253**	**$4,253**
Operating	Vehicle Maintenance	$2,743	$2,717
	Vehicle Tires	$169	$179
	Vehicle Fuel Costs	$863	$665
	Charging/Fueling Infrastructure	$0	$10
	Battery Replacement	$0	$0
	Operating Costs Subtotal	**$3,775**	**$3,572**
Disposal	Battery Disposal	$0	$0
	Bus Disposal	($62)	($62)
	Disposal Costs Subtotal	**($62)**	**($62)**
	Cash Costs Subtotal	**$4,966**	**$7,762**
Environmental	Emissions – Tailpipe/Pollutants	$87	$44
	Emissions – Lifecycle GHG	$368	$77
	Noise	$187	$139
	Environmental Costs Subtotal	**$642**	**$261**
	Total (Cash and Non-Cash)	**$5,608**	**$8,023**

Source: WSP

3.7 Total Project Cost

Table 3.9 shows the overall estimated capital costs (in year of expenditure dollars (YOE$)) of the Solano *Countywide Electrification Transition Plan* for Dixon Readi-Ride. These costs are inclusive of BEB purchases, charging infrastructure, additional options and charges or vehicles and battery extended warranties.

Table 3.9 Dixon Readi-Ride – Estimated Overall Electrification Plan Capital Costs by Year (all amounts in thousands of YOE$)

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
$0	$0	$2,383	$1,869	$0	$0	$0	$0	$0	$0	$4,253

Source: WSP

There is a capital funding gap (in year of expenditure dollars (YOE$)) between existing capital revenues and the costs associated with the program of projects discussed in this report and included within the Solano *Countywide Electrification Transition Plan*. Table 3.10 illustrates this estimated capital funding gap for Dixon Readi-Ride. Overall, the estimated budget shortfall is $1.65 million.

Table 3.10 Dixon Readi-Ride – Estimated Costs and Funding Shortfall by Year (all amounts in thousands of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Electrification Plan Capital Costs	$0	$0	$2,383	$1,869	$0	$0	$0	$0	$0	$0	**$4,253**
Potential Existing Electrification Funding Identified in SRTP	$0	$0	$188	$0	$0	$103	$0	$109	$0	$116	**$515**
Other Potential Existing Capital Revenues (e.g., LTF)	$289	$287	$258	$225	$225	$209	$198	$167	$106	$121	**$2,087**
Funding Surplus / (Gap)	**$289**	**$287**	**($1,937)**	**($1,644)**	**$225**	**$311**	**$198**	**$276**	**$106**	**$237**	**($1,650)**

Source: WSP, Agencies' SRTPs

RIO VISTA DELTA BREEZE

4 RIO VISTA DELTA BREEZE

4.1 Introduction

This section outlines the cost assumptions for the lifecycle cost analysis of continued operations of internal combustion engine vehicles and transition to electric vehicles for Rio Vista Delta Breeze. The four major categories for the cost assumptions are capital, operating, disposal, and environmental costs.

4.2 Capital Costs

Bus capital costs are based on standard vehicle purchase prices, after-market equipment, allowances for contingency, and charging infrastructure. Charging and fueling infrastructure requirements are a key consideration for battery-electric buses.

4.2.1 VEHICLE PURCHASE COSTS

Table 4.1 shows vehicle cost estimates for both the Build and No-Build scenarios. Each scenario includes two vehicles purchased in both 2024 and 2025. As noted in Section 2.3.2, capital costs of vehicles are sourced from the base vehicle prices provided through the California State Buy board for battery electric buses and the MTC bus pricing for ICE vehicles.

The analysis assumes additional costs to the standard base vehicle purchase price which includes service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price). For battery electric buses, an additional cost for battery extended warranty over the life of the vehicle is assumed. All values are rounded to the nearest thousands.

Table 4.1 Rio Vista Delta Breeze – Vehicle Purchase Costs (2021 $)

Scenario	Vehicle Type	Bus Cost Estimate	2024	2025
No-Build	Unleaded 25' (Ford Glaval)	$132,514[14]	2 vehicles $265,028	2 vehicles $265,028
Build	BEB 25' (GreenPower EV Star)	$263,905[15]	2 vehicles $527,810	2 vehicles $527,810

Source: WSP and MTC Bus Pricing

4.2.2 CHARGING INFRASTRUCTURE COSTS

Table 4.2 is the overall utility improvement costs and Appendix A shows the detailed unit cost and materials that are purchased for the site retrofit. All values are rounded to the nearest thousands.

14 MTC Cutaway gasoline vehicle price ($118,000)in FY22-23 and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

15 Includes an additional $35,000 for battery extended warranty on 118 kWh battery pack and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

Table 4.2 Rio Vista Delta Breeze – Utility Improvement Costs for Build Scenario

Agency	Direct Cost	General Conditions (20%)	Contractor Fee (15%)	Bonds and Insurances (3%)	30 Percent Contingency	Total
Rio Vista	$606,000	$121,000	$109,000	$25,000	$861,000	$258,000

Source: WSP Cost Estimator

4.3 Operating Costs

Vehicle operations and maintenance (O&M) costs include general vehicle maintenance costs, tire service costs, fueling infrastructure annual maintenance costs, fuel or energy costs, and bus disposal and retirement costs. Vehicle O&M costs are specific to the vehicle types and the length of the vehicles. Overall O&M costs are influenced by the operating costs per mile of each vehicle and annual mileage, both direct inputs into the lifecycle cost model.

4.3.1 AVERAGE MILEAGE PER VEHICLE

Average miles per vehicle per year are estimated using the Rio Vista Delta Breeze Short-Range Transportation Plan. Vehicle life was assumed based on the FTA's useful life benchmark. Average milage and useful life for each fleet type is shown below. Average annual mileage for Unleaded 25' was applied to BEB 25' for a direct comparison. Average miles are used as the basis to calculate fuel and energy consumption, operating and maintenance costs and tire replacement costs. Average annual mileage for existing vehicles were applied to BEBs for a direct comparison. The current analysis assumes the mileage for BEB replacement vehicles is consistent with the current fleet, operating similar routes and blocks.

Table 4.3 Rio Vista Delta Breeze – Average Vehicle Mileage and Vehicle Useful Life

	Average Vehicle Mileage[16]	Useful life[17]
Unleaded 25' Demand Response	35,595	10
Unleaded 25'	28,378	10
BEB 25' Demand Response	35,595	10
BEB 25'	28,378	10

Source: 2020 SRTP and FTA useful life benchmark

4.3.2 OPERATIONS AND MAINTENANCE COST

General vehicle maintenance costs, tire replacement costs, and fueling unit maintenance costs for the build and no build scenario are outlined in Table 4.4.

16 Estimated based on the fleet age and mileage outlined in the Rio Vista Delta Breeze Short-Range Transportation Plan
17 FTA useful life benchmark

Table 4.4 Rio Vista Delta Breeze – O&M Costs for Build and No-Build Scenarios (2021 $)

	Unleaded 25'[18]	BEB 25'[17]
Year 1 ($/mi)	0.81	0.80
Year 2 ($/mi)	0.88	0.87
Year 3 ($/mi)	0.96	0.95
Year 4 ($/mi)	1.03	1.02
Year 5 ($/mi)	1.11	1.10
Year 6 ($/mi)	1.14	1.13
Year 7 ($/mi)	1.19	1.18
Year 8 ($/mi)	1.22	1.21
Year 9 ($/mi)	1.25	1.24
Year 10 ($/mi)	1.29	1.28
Tires ($/mi)	0.068[19]	0.07[20]
Fueling Unit/Charger ($/year)	0	218[19]

Source: Peer Agency O&M Cost Curve

Energy Cost

Fuel and energy costs for vehicles are based on MCE Clean Energy and USEIA's fuel price. Additionally, annual demand charge per electric vehicle was applied for BEB replacement scenarios using the MCE Clean Energy rates. Table 4.5 summarizes the energy cost assumptions.

Table 4.5 Rio Vista Delta Breeze – Fuel/Energy Cost

	Electricity	Gasoline
Fuel/Energy Cost	$0.19/kWh[21]	$2.72/gal[22]
Demand Charges ($/vehicle-year)	$3,766[23]	N/A
Vehicle Type	**25'**	**22'**
Vehicle Fuel Efficiency (mpdge or kWh/mi)	0.79	8.1
Average Annual Miles	28,378	28,378
Total Fuel/Energy Costs per Year per Bus	**$8,026**	**$9,529**

Source: MCE Energy and USEIA

18 Based on Peer Agency's experience in San Bernadino County, California

19 Based on a peer agency's experience in Washington

20 Based on a peer agency's experience in Washington. Assumed 10 percent higher than baseline existing vehicles to account for the heavier weight of BEBs.

21 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming a mix of 33% of summer rates and 67% of winter rates. Within the summer and winter rates, the analysis assumes peak, part-peak, and off-peak splits to be 20%, 40%, and 40%, respectively. Also includes PG&E delivery rate, PG&E power charge indifference adjustment (PCIA) and franchise fee (FF).

22 2021 California average sales for resale No 2 Distillate without tax from USEIA

23 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming 11% of summer peak, 22% of summer part-peak and 67% of winter peak rates. Based on 2:1 bus to charger ratio for 150 kW chargers.

4.4 Disposal Costs and Resale Value

It is assumed that at the end of the vehicle life, Rio Vista Delta Breeze will sell the vehicle. Vehicle sales pricing is assumed to be $5,000 per vehicle as any sales above that value must be returned to FTA.

4.5 Environmental Costs

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.

4.5.1 GREENHOUSE GAS EMISSIONS AND PARTICULATE MATTER

The analysis applies the average annual mileage and the tailpipe and greenhouse gas emissions of g CO_2 equivalent/MJ per mile to estimate the lifecycle emissions in the build and no build scenarios. Table 4.6 outlines the vehicle tailpipe emissions in g/mi provided by AFLEET Analysis, EPA MOVES 2014b model, and Pacific Gas & Energy (PG&E) carbon footprint calculator. Table 4.7 provides the lifecycle GHG emissions in All Pathways List by California Air Resources Board (CARB).

PM10 and PM2.5 emissions include emissions generated from tire and brake wear and are applied to all vehicles.

Table 4.6 Rio Vista Delta Breeze – Vehicle Tailpipe/Pollutant Emissions (g/VMT)

Emission	Unleaded 25'[24]	BEB 25'
NOX	0.12	-
SOX	-	-
PM10	0.19	0.11
VOC	1.50	-
PM2.5	0.03	0.1

Source: AFLEET Analysis and EPA Moves 2014 Model

Table 4.7 Rio Vista Delta Breeze – Lifecycle GHG Emissions (g/VMT)

Emission	Unleaded 25'	BEB 25'
CO_2	1,704[25]	358[26]

Source: CARB and PG&E

4.6 Lifecycle Cost Analysis Results

The lifecycle cost analysis compares the lifecycle costs and benefits for each scenario in three primary cash cost categories: capital costs, operating costs, and disposal/salvage costs. Additionally, a non-cash cost of

24 Used the school bus option in AFLEET tool.

25 CARB All Pathways. 90 percent of CBO000L00072019, carbon intensity of 100.82 and 10 percent of ETHC244L, carbon intensity of 76.27

26 0.524 lbs. CO2/kWh by PG&E Carbon Footprint Calculator

environmental benefits and costs, which the lifecycle model monetizes to account for a holistic comparative cost and benefit, is assessed. Table 4.8 shows the lifecycle costs for the Build and No-Build scenarios for Rio Vista Delta Breeze.

The total cash costs for the Build scenario were found to be 58% greater than the No-Build scenario. The non-cash costs for the Build scenario were found decrease by 45%. On a per mile basis, the total costs (capital, O&M, disposal, and environmental) would increase from $2.73/mi. to $3.96/mi.

Table 4.8 Rio Vista Delta Breeze – Lifecycle Cost Analysis Results (YOE $ Thousands)

2021-2037 Fleet Replacement Cost Comparison (YOE $ thousands)		Standard Scenario ("No-Build")	BEB Replacement Scenario ("Build")
Capital	Vehicle Purchase Price	$558	$1,111
	Modifications & Contingency	$69	$137
	Charging/Fueling Infrastructure	$0	$1,216
Capital Costs Subtotal		**$626**	**$2,464**
Operating	Vehicle Maintenance	$1,498	$1,484
	Vehicle Tires	$92	$98
	Vehicle Fuel Costs	$587	$349
	Charging/Fueling Infrastructure	$0	$5
	Battery Replacement	$0	$0
Operating Costs Subtotal		**$2,177**	**$1,936**
Disposal	Battery Disposal	$0	$0
	Bus Disposal	($32)	($31)
Disposal Costs Subtotal		**($32)**	**($31)**
Cash Costs Subtotal		**$2,177**	**$1,936**
Environmental	Emissions – Tailpipe/Pollutants	$27	$24
	Emissions – Lifecycle GHG	$201	$29
	Noise	$102	$76
Total Environmental Costs		**$330**	**$129**
Total (Cash and Non-Cash)		**$3,101**	**$4,498**

Source: WSP

4.7 Total Project Cost

Table 4.9 shows the overall estimated capital costs (in year of expenditure dollars (YOE$)) of the Solano *Countywide Electrification Transition Plan* for Rio Vista Delta Breeze. These costs are inclusive of BEB purchases, charging infrastructure, additional options and charges or vehicles and battery extended warranties.

Table 4.9 Rio Vista Delta Breeze – Estimated Overall Electrification Plan Capital Costs by Year (all amounts in thousands of YOE$)

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
$0	$0	$1,414	$1,050	$0	$0	$0	$0	$0	$0	$2,464

Source: WSP

There is a capital funding gap (in year of expenditure dollars (YOE$)) between existing capital revenues and the costs associated with the program of projects discussed in this report and included within the Solano *Countywide Electrification Transition Plan*. Table 4.10 illustrates this estimated capital funding gap for Rio Vista Delta Breeze. Overall, the estimated budget shortfall is nearly $1.8 million.

Table 4.10 Rio Vista Delta Breeze – Estimated Costs and Funding Shortfall by Year (all amounts in thousands of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Electrification Plan Capital Costs	$0	$0	$1,414	$1,050	$0	$0	$0	$0	$0	$0	**$2,464**
Potential Existing Electrification Funding Identified in SRTP	$0	$98	$0	$0	$0	$451	$0	$116	$0	$0	**$665**
Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Funding Surplus / (Gap)	**$0**	**$98**	**($1,414)**	**($1,050)**	**$0**	**$451**	**$0**	**$116**	**$0**	**$0**	**($1,799)**

Source: WSP

SolTrans

5 SOLTRANS

5.1 Introduction

This section outlines the cost assumptions for the lifecycle cost analysis of continued operations of internal combustion engine vehicles and transition to electric vehicles for SolTrans. The four major categories for the cost assumptions are capital, operating, disposal, and environmental.

5.2 Capital Costs

Bus capital costs are based on standard vehicle purchase prices, after-market equipment, allowances for contingency, and charging infrastructure. Charging and fueling infrastructure requirements are a key consideration for battery-electric buses. Costs are based on the number of operating vehicles per facility and their expected lifespan, to estimate the total infrastructure costs per bus.

5.2.1 VEHICLE PURCHASE COSTS

Table 5.1 shows vehicle cost estimates per year for both the Build and No-Build scenarios. As noted in Section 2.3.2, capital costs of vehicles are sourced from the base vehicle prices provided through the California State Buy board for battery electric buses and the MTC bus pricing for ICE vehicles.

The analysis assumes additional costs to the standard base vehicle purchase price which includes costs additional options and charges for $120,000 on 40' transit buses, service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price). For battery electric buses, an additional cost for battery extended warranty over the life of the vehicle is assumed. All values are rounded to the nearest thousands.

Table 5.1 SolTrans –Vehicle Purchase Costs (2021 $)

Scenario	Vehicle Type	Bus Cost Estimate	2023	2024	2025	2026	2027
No-Build	Unleaded 24' (Arboc)	$132,514[27]	—	—	3 vehicles $397,542	3 vehicles $397,542	—
	CNG 24' (Arboc)	$249,306[28]	—	—	—	—	2 vehicles $498,612
	Hybrid 40' (Gillig)	$1,107,117[27]	7 vehicles $7,749,819	7 vehicles $7,749,819	7 vehicles $7,749,819		—
	CNG 40' (Nova)	$833,105[29]	—	—	—	1 vehicle $833,105	—
No-Build Total Vehicle Cost Per Year			**$7,749,819**	**$7,749,819**	**$8,147,361**	**$1,230,647**	**$498,612**
Build	BEB 25' (GreenPower EV Star)	$263,905[30]	—	—	3 vehicles $791,715	3 vehicles $791,715	2 vehicles $527,810
	BEB 40' (New Flyer 388 kWh)	$1,065,530[31]	7 vehicles $7,458,710	7 vehicles $7,458,710	7 vehicles $7,458,710	1 vehicle $1,065,530	—
Build Total Vehicle Cost Per Year			**$7,458,710**	**$7,458,710**	**$8,250,425**	**$1,857,245**	**$527,810**

Source: WSP and MTC Bus Pricing, California State Contract

27 MTC Cutaway gasoline vehicle price ($118,000)in FY22-23 and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

28 Based on MTC bus price for a cutaway CNG bus ($222,000) in FY22-23 and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

29 Based on MTC bus price for a 40' transit CNG bus in FY22-23 and additional options and charges for $120,000 on 40' transit buses, service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

30 WSP Internal Staff estimate and service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

31 Based on the California State Contract Buy Board with battery capacity increase and additional options and charges for $120,000 on 40' transit buses, service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

5.2.2 CHARGING AND FUELING INFRASTRUCTURE COSTS

Charging and fueling infrastructure includes the equipment and construction to support the operations and maintenance of buses. Charging infrastructure cost estimate is based on the recent bid tabulations of SolTrans Phase 1 and Phase 2 transitions for battery electric buses by M LEE Corporation in March 2021. Phase 1 is for the first 21 buses that SolTrans intends to transition to battery electric buses. Phase 2 is dedicated for the utility improvements needed to transition the rest of the fleet to battery electric buses.

The work to be done includes the installation of a new steel structure canopy located over the existing bus parking spaces intended to provide support for Battery Electric Bus charging equipment. The project also includes new electrical distribution underground and above ground with modifications to the existing building. The steel structure canopy will require deep underground piers and tie beams resulting in demolition and replacement of some existing concrete under the Caltrans 2018 Standard Specifications and Standard Plans. M LEE Corporation estimate did not include figures for charger costs. As such, additional costs for 80 kW and 150 kW chargers were added to the analysis.

SolTrans has three types of fuel tanks and integrated fueling stations. The current facility includes a CNG structure, three underground diesel fueling stations (unknown age) and one unleaded fueling station (unknown age). Supporting storage includes CNG, three diesel underground storage tanks, and one gasoline above ground storage tank. Assuming each storage tank has 30 years of asset life, the analysis assumes that the CNG tank installed in 2016 will be replaced in 2036, the three diesel storage tanks of unknown age are assumed to be replaced in 2025, and the above ground storage tank installed in 2010 will be replaced in 2040, . All values are rounded to the nearest thousands.

Table 5.2 SolTrans – Build Scenario Charging Infrastructure Costs

	Phase 1	Phase 2	Charger Costs
Cost	$9,925,000	$4,476,000	$3,331,000[32]

Source: M LEE Corporation and WSP

Table 5.3 SolTrans – No-Build Scenario Fueling Infrastructure Costs

	CNG Tank	Diesel Tank	Unleaded Tank
Cost	$1,100,000[33]	$3,000,000[34]	$1,000,000[34]

Source: Peer Agencies' Capital Improvement Programs

5.3 Operating Costs

Vehicle operations and maintenance (O&M) costs include general vehicle maintenance costs, tire service costs, fueling infrastructure annual maintenance costs, fuel or energy costs, and bus disposal and retirement costs. Vehicle O&M costs are specific to the vehicle types and the length of the vehicles. Overall O&M costs

32 Based on 21 chargers for 80 kW BYD chargers ($11,000 per charger) for first 21 vehicles being electrified. Additional 25 chargers for 150 kW DC charges ($124,000 per charger) for vehicles being electrified in phase 2.

33 Based on a peer agency's capital investment to upgrade their CNG underground storage

34 Based on a peer agency's capital investment to upgrade their diesel underground storage ($1 million per tank)

are influenced by the operating costs per mile of each vehicle and annual mileage, both direct inputs into the lifecycle cost model.

5.3.1 AVERAGE MILEAGE PER VEHICLE

Average miles per vehicle per year are estimated based on analysis of operations from FY 2018 to 2019 to approximate the pre-pandemic operating experience of SolTrans. Vehicle life was assumed based on the FTA's useful life benchmark. Average milage and useful life for each fleet type is shown below and used as the basis to calculate fuel and energy consumption, operating and maintenance costs and tire replacement costs. Average annual mileage for existing vehicles were applied to BEBs for a direct comparison. The current analysis assumes the mileage for BEB replacement vehicles is consistent with the current fleet, operating similar routes and blocks.

Table 5.4 SolTrans – Average Vehicle Mileage and Vehicle Useful Life

	Average Vehicle Mileage[35]	Useful life[36]
Unleaded 24' / CNG 24'	14,031	7
Hybrid 40' / CNG 40'	36,068	12
BEB 25'	14,031	7
BEB 40'	36,068	12

Source: SolTrans FY18-19 vehicle annual mileage and FTA Useful Life Benchmark

5.3.2 OPERATIONS AND MAINTENANCE COSTS

General vehicle maintenance costs, tire replacement costs, and fueling unit maintenance costs for the build and no build scenarios are outlined in Table 5.5.

35 Estimated based on the fleet age and mileage provided by staff at SolTrans. Assumed FY18-19 mileage to emulate operating experience prior to the COVID-19 pandemic.

36 FTA useful life benchmark and based on SolTrans' operating experience with existing vehicles.

Table 5.5 SolTrans – O&M Costs for Build and No-Build Scenarios (2021 $)

	No-Build			Build	
	Unleaded /CNG 24'[37]	Hybrid 40'[38]	CNG 40'[37]	BEB 25'[37]	BEB 40'[38]
Year 1 ($/mi)	0.81	0.40	0.20	0.77	1.17
Year 2 ($/mi)	0.88	0.57	0.20	0.87	1.26
Year 3 ($/mi)	0.96	0.66	0.25	0.95	1.45
Year 4 ($/mi)	1.03	0.90	0.30	1.02	1.42
Year 5 ($/mi)	1.11	1.05	0.51	1.10	1.81
Year 6 ($/mi)	1.14	1.11	0.45	1.13	2.31
Year 7 ($/mi)	1.19	1.27	0.50	1.18	2.31
Year 8 ($/mi)	1.22	1.26	0.56	1.21	2.52
Year 9 ($/mi)	1.25	1.58	0.52	1.24	2.79
Year 10 ($/mi)	1.29	1.35	0.57	1.28	2.53
Year 11 ($/mi)	N/A	1.04	0.62	0.77	2.35
Year 12($/mi)	N/A	1.03	0.65	0.87	2.25
Tires ($/mi)	0.068[38]	0.068[38]	0.068[38]	0.07[39]	0.07[36]
Fueling Unit/ Charger ($/year per Vehicle)	$8,251[40] / $1,933[41]	$1,703[42]	$1,933[43]	218[38]	218[38]

Source: Peer Agency O&M Cost Curve

Energy Cost

Fuel and energy costs for vehicles are based on MCE Clean Energy and USEIA's fuel price. Additionally, annual demand charge per electric vehicle was applied for BEB replacement scenarios using the MCE Clean Energy rates.

37 Based on a peer agency's experience in California

38 Based on a peer agency's experience in Washington

39 Based on a peer agency's experience in Washington. Assumed 10 percent higher than baseline existing vehicles to account for the heavier weight of BEBs.

40 Based on aboveground tanks' maintenance cost as outlined in the Life Cycle Cost (LCC) Study of Gasoline Storage and Dispensing Systems at AAFES Express Stores

41 Based on the current monthly CNG tank maintenance of SolTrans (inclusive of semi-annual calibration for 8 natural flammable detection sensors and general maintenance costs)

42 Based on direct bury underground tanks' maintenance cost as outlined in the Life Cycle Cost (LCC) Study of Gasoline Storage and Dispensing Systems at AAFES Express Stores

43 Based on the current CNG tank maintenance of SolTrans (inclusive of calibration for 8 natural flammable detection sensors and general maintenance costs)

Table 5.6 summarizes the energy cost assumptions.

Table 5.6 SolTrans – Fuel/Energy Cost Comparison

	Electricity		Diesel	Gasoline	CNG	
Fuel/Energy Cost	$0.19/kWh[44]		$2.33/gal[45]	$2.72/gal[46]	$2.41/gal[47]	
Demand Charges ($/vehicle-year)	$3,766[48]		N/A	N/A	N/A	
Vehicle Type	**40'**	**25'**	**40'**	**25'**	**40'**	**25'**
Vehicle Fuel Efficiency Diesel Equivalent (mpdge or kWh/mi)	2.08	0.79	6.1	8.1	3.0	5.59
Average Annual Miles	36,068	14,031	36,068	14,031	36,068	14,031
Total Fuel/Energy Costs per Year per Bus	**$18,020**	**$5,872**	**$13,777**	**$4,712**	**$28,975**	**$6,049**

Source: MCE Energy and USEIA

5.4 Disposal Costs and Resale Value

It is assumed that at the end of the vehicle life, SolTrans will auction the vehicle. Vehicle sales pricing is assumed to be $5,000 per vehicle as any sales above that value may be reserved for next vehicle purchases with approval from FTA.

5.5 Environmental Costs

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.

44 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming a mix of 33% of summer rates and 67% of winter rates. Within the summer and winter rates, the analysis assumes peak, part-peak, and off-peak splits to be 20%, 40%, and 40%, respectively. Also includes PG&E delivery rate, PG&E power charge indifference adjustment (PCIA) and franchise fee (FF).

45 2021 California average regular gasoline sales for resale average without tax from USEIA

46 2021 California average sales for resale No 2 Distillate without tax from USEIA

47 Five-year average fuel price with tax from CNGNOW

48 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming 11% of summer peak, 22% of summer part-peak and 67% of winter peak rates. Based on 2:1 bus to charger ratio for 150 kW chargers.

5.5.1 GREENHOUSE GAS EMISSIONS AND PARTICULATE MATTER

The analysis applies the average annual mileage and the tailpipe and greenhouse gas emissions of g CO2 equivalent/MJ per mile to estimate the lifecycle emissions in the build and no build scenarios. Table 5.7 outlines the vehicle tailpipe emissions in g/mi provided by AFLEET Analysis, EPA MOVES 2014b model, and Pacific Gas & Energy (PG&E) carbon footprint calculator.

PM10 and PM2.5 emissions include emissions generated from tire and brake wear and are applied to all vehicles.

Table 5.8 provides the lifecycle GHG emissions in All Pathways List by California Air Resources Board (CARB).

Table 5.7 SolTrans – Vehicle Tailpipe/Pollutant Emissions (g/VMT)

Emission	CNG 24'	Unleaded 24'[49]	Hybrid 40'	CNG 40'	BEB 25'	BEB 40'
NOX	0.13	0.12	2.63	0.13	-	-
SOX		-	0.01	-	-	-
PM10	0.22	0.19	0.21	0.22	0.11	0.11
VOC	0.44	1.50	0.50	0.44	-	-
PM2.5	0.03	0.03	0.03	0.03	0.01	0.01

Source: AFLEET Analysis and EPA Moves 2014 Model

Table 5.8 SolTrans – Lifecycle GHG Emissions (g/VMT)

Emission	CNG 24'	Unleaded 24'	Hybrid 40'	CNG 40'	BEB 25'	BEB 40'
CO2	1,397[50]	1,704[51]	1,997[52]	3,259[53]	358[54]	943[54]

Source: CARB and PG&E

5.6 Lifecycle Cost Analysis Results

The analysis compares the lifecycle costs and benefits for each scenario in three primary cash cost categories: capital costs, operating costs, and disposal/salvage costs. Additionally, a non-cash cost of environmental benefits and costs, which the lifecycle model monetizes to account for a holistic comparative cost and benefit, is assessed. Table 5.9 shows the lifecycle costs for the Build and No-Build scenarios for SolTrans.

49 Used the school bus option in the AFLEET tool.
50 CARB All Pathways. CNGF204 Carbon Intensity of 80.59.
51 CARB All Pathways. 90 percent of CBO000L00072019, carbon intensity of 100.82 and 10 percent of ETHC244L, carbon intensity of 76.27
52 CARB All Pathways. ULS000L00072019, carbon intensity of 100.45
53 CARB All Pathways. CNGF204, carbon intensity of 80.59.
54 0.524 lbs. CO2/kWh by PG&E Carbon Footprint Calculator

The total cash costs for the Build scenario were found to be 39% greater than the No-Build scenario and 33% greater than the No-Build scenario with non-cash costs. On a per mile basis, the total costs (capital, O&M, disposal, and environmental) would increase from $6.00/mi to $7.96/mi.

Table 5.9 SolTrans – Lifecycle Cost Analysis Results (YOE $ Millions)

2021-2037 Fleet Replacement Cost Comparison (YOE $million)		Standard Scenario (“No-Build”)	BEB Replacement Scenario (“Build”)
Capital	Vehicle Purchase Price	$27	$27
	Modifications & Contingency	$3	$3
	Charging/Fueling Infrastructure	$7	$19
	Capital Costs Subtotal	**$37**	**$49**
Operating	Vehicle Maintenance	$13	$25
	Vehicle Tires	$1	$1
	Vehicle Fuel Costs	$6	$6
	Charging/Fueling Infrastructure	$1	$0.04
	Battery Replacement	$0	$0
	Operating Costs Subtotal	**$21**	**$31**
Disposal	Battery Disposal	$0	$0
	Bus Disposal	- $0.2	- $0.2
	Disposal Costs Subtotal	**$0**	**$0**
	Cash Costs Subtotal	**$58**	**$80**
Environmental	Emissions – Tailpipe/Pollutants	$1	$0.2
	Emissions – Lifecycle GHG	$2	$1
	Noise	$1	$1
	Environmental Costs Subtotal	**$4**	**$2**
	Total (Cash and Non-Cash)	**$62**	**$82**

Source: WSP

5.7 Total Project Cost

Table 5.10 shows the overall estimated capital costs (in year of expenditure dollars (YOE$)) of the Solano *Countywide Electrification Transition Plan* for SolTrans. These costs are inclusive of BEB purchases, charging infrastructure, additional options and charges or vehicles and battery extended warranties.

Table 5.10 SolTrans – Estimated Overall Electrification Plan Capital Costs by Year (all amounts in thousands of YOE$)

2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
$18,661	$17,259	$10,045	$2,332	$681	$0	$0	$0	$0	$48,978

Source: WSP

There is a capital funding gap (in year of expenditure dollars (YOE$)) between existing capital revenues and the costs associated with the program of projects discussed in this report and included within the Solano *Countywide Electrification Transition Plan*. Table 5.11 illustrates this estimated capital funding gap for SolTrans. Overall, the estimated budget shortfall is over $29 million.

Table 5.11 SolTrans – Estimated Costs and Funding Shortfall by Year (all amounts in thousands of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Electrification Plan Capital Costs	$0	$18,661	$17,259	$10,045	$2,332	$681	$0	$0	$0	$0	**$48,978**
Potential Existing Electrification Funding Identified in SRTP	$3,782	$1,456	$1,459	$3,962	$2,912	$2,915	$588	$610	$2,130	$469	**$20,283**
Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Funding Surplus / (Gap)	**$3,782**	**($17,205)**	**($15,800)**	**($6,083)**	**$580**	**$2,234**	**$588**	**$610**	**$2,130**	**$469**	**($28,695)**

Source: WSP, Agencies' SRTPs

CITY COACH

6 VACAVILLE CITY COACH

6.1 Introduction

This section outlines the cost assumptions for the lifecycle cost analysis of continued operations of internal combustion engine vehicles and transition to electric vehicles for Vacaville City Coach. The four major categories for the cost assumptions are capital, operating, disposal, and environmental.

6.2 Capital Costs

Bus capital costs are based on standard vehicle purchase prices, after-market equipment, allowances for contingency, and charging infrastructure. Charging and fueling infrastructure requirements are a key consideration for battery-electric buses. Costs are based on the number of operating vehicles per facility and their expected lifespan, to estimate the total infrastructure costs per bus.

6.2.1 VEHICLE PURCHASE COSTS

Table 6.1 shows vehicle cost estimates per year for both the Build and No-Build scenarios. As noted in Section 2.3.2, capital costs of vehicles are sourced from the base vehicle prices provided through the California State Buy board and agency's bus pricing list used for planning purposes for battery electric buses, the MTC bus pricing and peer agencies for ICE vehicles.

The analysis assumes additional costs to the standard base vehicle purchase price which includes costs additional options and charges for $120,000 on 40' transit buses, service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price). For battery electric buses, an additional cost for battery extended warranty over the life of the vehicle is assumed. All values are rounded to the nearest thousands.

Table 6.1 Vacaville City Coach – Vehicle Purchase Costs (2021 $)

Scenario	Vehicle Type	Bus Cost Estimate	2023	2024	2025	2026
No-Build	CNG 35' (New Flyer)	$919,576[55]	10 vehicles $9,195,760	-	-	-
	Unleaded 24' (Chevrolet)	$132,514[55]	-	5 vehicles $662,570	5 vehicles $662,570	5 vehicles $662,570
Build	BEB 35' (New Flyer)	$1,048,081[56]	10 vehicles $10,480,809	-	-	-
	BEB 25' (GreenPower EV Star)	$263,905[57]	-	5 vehicles $1,319,525	5 vehicles $1,319,525	5 vehicles $1,319,525

Source: WSP, MTC Bus Pricing and California State Contract

55 MTC Bus Pricing. ($118,000)in FY22-23 and includes service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

56 Based on the California State Buy board with battery capacity increase and additional options and charges for $120,000 on 35' transit buses. Includes service preparation and inspection (2 percent of base vehicle price), special tools and diagnostic equipment (0.3 percent of base vehicle price) and allowances for contingency (10 percent of base vehicle price).

57 WSP Internal Staff estimate

6.2.2 CHARGING AND FUELING INFRASTRUCTURE COSTS

Table 6.2 show the overall utility improvement costs and Appendix A shows the detailed unit cost and materials that are purchased for the site retrofit.

Vacaville is currently expediting its fleet electrification process by coordinating with New Flyer and PG&E to procure 10 buses and power enhancements, respectively. The agency is also in contract negotiations to have Burns and McDonnell to develop 30 percent concept designs for the facility. This cost estimate is inclusive of all construction and materials needed to retrofit Vacaville's O&M facility and does not consider coordination efforts with other consultants and utility providers for the first 10 electric bus procurement and deployment.

According to Vacaville's SRTP, Vacaville has two CNG fueling stations that were completed work in 2001 and 2009 and one diesel tank. For the no build scenario, it was assumed that Vacaville's CNG fueling station and diesel fueling station will be replaced at the end of their useful life. Assuming each tank station has 30 years of asset life, the analysis assumes that one CNG tank will be replaced in 2031 and another will be upgrade in 2039. All values are rounded to the nearest thousands.

Table 6.2 Vacaville City Coach – Build Scenario Charging Infrastructure Costs

Agency	Direct Cost	General Conditions (20%)	Contractor Fee (15%)	Bonds and Insurances (3%)	30 Percent Contingency	Total
Vacaville	$4,342,300	$868,000	$782,000	$178,000	$1,852,000	$8,024,000

Source: WSP Cost Estimator

Table 6.3 Vacaville City Coach – No-Build Scenario Fueling Infrastructure Costs

	CNG Tank
Cost	$1,100,000[58]

Source: Peer Agencies' Capital Improvement Program

6.3 Operating Costs

Vehicle operations and maintenance (O&M) costs include general vehicle maintenance costs, tire service costs, fueling infrastructure annual maintenance costs, fuel or energy costs, and bus disposal and retirement costs. Vehicle O&M costs are specific to the vehicle types and the length of the vehicles. Overall O&M costs are influenced by the operating costs per mile of each vehicle and annual mileage, both direct inputs into the lifecycle cost model.

6.3.1 AVERAGE MILEAGE PER VEHICLE

Average miles per vehicle per year are estimated using the Vacaville City Coach Short-Range Transportation Plan and GTFS data. Vehicle life was assumed based on the FTA's useful life benchmark. Average milage and useful life for each fleet type is shown below. Average annual mileage for existing vehicles were applied to BEBs for a direct comparison. Average miles are used as the basis to calculate fuel and energy consumption, operating and maintenance costs and tire replacement costs. Average annual mileage for existing vehicles

58 Based on a peer agency's capital investment to upgrade their CNG underground storage

were applied to BEBs for a direct comparison. The current analysis assumes the mileage for BEB replacement vehicles is consistent with the current fleet, operating similar routes and blocks.

Table 6.4 Vacaville City Coach – Average Mileage per Vehicle and Vehicle Useful Life

	Average Mileage per Vehicle	Vehicle Useful Life (Years)
CNG 35' (New Flyer)	27,777	12
Unleaded 24' (Chevrolet)	39,273	10
BEB 25' (GreenPower EV Star)	39,273	12
BEB 35' (New Flyer)	27,777	10

Source: 2020 SRTP and FTA useful life benchmark

6.3.2 OPERATIONS AND MAINTENANCE COSTS

General vehicle maintenance costs, tire replacement costs, and fueling unit maintenance costs for the build and no build scenarios are outlined in Table 6.5.

Table 6.5 Vacaville City Coach – O&M Costs for Build and No-Build Scenarios (2021 $)

	No-Build		Build	
	Unleaded 24'[59]	CNG 35'[59]	BEB 25'[59]	BEB 35'[60]
Year 1 (2021$/mi)	0.81	0.20	0.80	1.17
Year 2 (2021$/mi)	0.88	0.20	0.87	1.26
Year 3 (2021$/mi)	0.96	0.25	0.95	1.45
Year 4 (2021$/mi)	1.03	0.30	1.02	1.42
Year 5 (2021$/mi)	1.11	0.51	1.10	1.81
Year 6 (2021$/mi)	1.14	0.45	1.13	1.92
Year 7 (2021$/mi)	1.19	0.50	1.18	2.19
Year 8 (2021$/mi)	1.22	0.56	1.21	2.15
Year 9 (2021$/mi)	1.25	0.52	1.24	2.71
Year 10 (2021$/mi)	1.29	0.57	1.28	2.31
Year 11 (2021$/mi)	N/A	0.62	N/A	1.79
Year 12 (2021$/mi)	N/A	0.65	N/A	1.76
Tires (2021$/mi)	0.068[60]	0.065[59]	0.072[61]	0.072[61]
Fueling Unit/Charger ($/year)	0	$805[62]	218[60]	218[60]

Source: Peer Agency O&M Cost Curve

59 Based on a peer agency's experience in California

60 Based on a peer agency's experience in Washington

61 Based on a peer agency's experience in Washington. Assumed 10 percent higher than baseline existing vehicles to account for the heavier weight of BEBs.

62 Based on SolTrans experience for CNG tank maintenance of their vehicles, ratioed to the number of CNG vehicles that Vacaville owns.

Energy Costs

Fuel and energy costs for vehicles are based on MCE Clean Energy and USEIA's fuel price. Additionally, annual demand charge per electric vehicle was applied for BEB replacement scenarios using the MCE Clean Energy rates.

Table 6.6 summarizes the energy cost assumptions.

Table 6.6 Vacaville City Coach – Fuel/Energy Cost

	Electricity		Gasoline	CNG
Fuel/Energy Cost	$0.19/kWh[63]		$2.72/gal[64]	$2.41/gal[65]
Demand Charges ($/vehicle-year)	$3,766[66]		N/A	N/A
Vehicle Type	25'	35'	25'	35'
Vehicle Fuel Efficiency (mpdge or kWh/mi)	0.79	1.88	8.1	3.9
Average Annual Miles	39,273	27,777	39,273	27,777
Total Fuel/Energy Costs per Year per Bus	$9,661	$13,688	$13,188	$17,165

Source: MCE Energy and USEIA

6.4 Disposal Cost and Resale Value

It is assumed that at the end of the vehicle life, Vacaville City Coach will sell the vehicle. Vehicle sales pricing is assumed to be $5,000 per vehicle as any sales above that value must be returned to FTA.

6.5 Environmental Costs

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.

6.5.1 GREENHOUSE GAS EMISSIONS AND PARTICULATE MATTER

The analysis applies the average annual mileage and the tailpipe and greenhouse gas emissions of g CO_2 equivalent/MJ per mile to estimate the lifecycle emissions in the build and no build scenarios. Table 6.7 outlines the vehicle tailpipe emissions in g/mi provided by AFLEET Analysis, EPA MOVES 2014b model, and Pacific Gas & Energy (PG&E) carbon footprint calculator. PM_{10} and $PM_{2.5}$ emissions include emissions generated from tire and brake wear and are applied to all vehicles.

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63 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming a mix of 33% of summer rates and 67% of winter rates. Within the summer and winter rates, the analysis assumes peak, part-peak, and off-peak splits to be 20%, 40%, and 40%, respectively. Also includes PG&E delivery rate, PG&E power charge indifference adjustment (PCIA) and franchise fee (FF).

64 2021 California average sales for resale No 2 Distillate without tax from USEIA

65 Five-year average fuel price with tax from CNGNOW

66 Based on MCE Clean Energy rates for primary rates in the E20-Large General Service category. Assuming 11% of summer peak, 22% of summer part-peak and 67% of winter peak rates. Based on 2:1 bus to charger ratio for 150 kW chargers.

Table 6.8 provides the lifecycle GHG emissions in All Pathways List by California Air Resources Board (CARB).

Table 6.7 Vacaville City Coach – Vehicle Tailpipe/Pollutant Emissions (g/VMT)

Emission	Unleaded 24'[67]	CNG 35'	BEB 25'	BEB 35'
NOX	0.12	0.13	-	-
SOX	-	-	-	-
PM10	0.19	0.22	0.11	0.11
VOC	1.49	0.44	-	-
PM2.5	0.03	0.09	0.01	0.01

Source: AFLEET Analysis and EPA Moves 2014 Model

Table 6.8 Vacaville City Coach – Lifecycle GHG Emissions (g/VMT)

Emission	Unleaded 24'	CNG 35'	BEB 25'	BEB 35'
CO_2	1,704[68]	2,481[69]	358[70]	853[70]

Source: CARB and PG&E

6.6 Lifecycle Cost Analysis Results

The analysis compares the lifecycle costs and benefits for each scenario in three primary cash cost categories: capital costs, operating costs, and disposal/salvage costs. Additionally, a non-cash cost of environmental benefits and costs, which the lifecycle model monetizes to account for a holistic comparative cost and benefit, is assessed. Table 6.9 shows the lifecycle costs for the Build and No-Build scenarios for Vacaville City Coach.

The total cash costs for the Build scenario were found to be 36% greater than the No-Build scenario. The non-cash costs for the Build scenario were found decrease by 28%. On a per mile basis, the total costs (capital, O&M, disposal, and environmental) would increase from $3.92/mi. to $5.03/mi.

67 Used school bus option in the AFLEET tool.

68 CARB All Pathways. 90 percent of CBO000L00072019, carbon intensity of 100.82 and 10 percent of ETHC244L, carbon intensity of 76.27

69 CARB All Pathways. CNGF204, carbon intensity of 80.59.

70 0.524 lbs. CO_2/kWh by PG&E Carbon Footprint Calculator

Table 6.9 Vacaville City Coach – Lifecycle Cost Analysis Results (YOE $ Millions)

2021-2037 Fleet Replacement Cost Comparison (YOE $million)		Standard Scenario ("No-Build")	BEB Replacement Scenario ("Build")
Capital	Vehicle Purchase Price	$11	$15
	Modifications & Contingency	$1	$2
	Charging/Fueling Infrastructure	$5	$9
Capital Costs Subtotal		**$18**	**$26**
Operating	Vehicle Maintenance	$10	$15
	Vehicle Tires	$1	$1
	Vehicle Fuel Costs	$5	$3
	Charging/Fueling Infrastructure	$0.1	$0
	Battery Replacement	$0	$0
Operating Costs Subtotal		**$15**	**$19**
Disposal	Battery Disposal	$0	$0
	Bus Disposal	-$0.2	-$0.2
Disposal Costs Subtotal		**-$0.2**	**-$0.2**
Cash Costs Subtotal		**$33**	**$45**
Environmental	Emissions – Tailpipe/Pollutants	$0.4	$0.2
	Emissions – Lifecycle GHG	$2	$1
	Noise	$1	$1
Environmental Costs Subtotal		**$3**	**$1**
Total (Cash and Non-Cash)		**$36**	**$46**

Source: WSP

6.7 Total Project Cost

Table 6.10 shows the overall estimated capital costs (in year of expenditure dollars (YOE$)) of the Solano *Countywide Electrification Transition Plan* for Vacaville City Coach. These costs are inclusive of BEB purchases, charging infrastructure, additional options and charges or vehicles and battery extended warranties.

Table 6.10 Vacaville City Coach – Estimated Overall Electrification Plan Capital Costs by Year (all amounts in thousands of YOE$)

Agency	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Vacaville City Coach	$0	$11,909	$7,543	$4,772	$1,644	$0	$0	$0	$0	$0	$25,867

Source: WSP

There is a capital funding gap (in year of expenditure dollars (YOE$)) between existing capital revenues and the costs associated with the program of projects discussed in this report and included within the Solano *Countywide Electrification Transition Plan*. Table 6.11 illustrates this estimated capital funding gap for Vacaville City Coach. Overall, the estimated budget shortfall is nearly $6 million.

Table 6.11 Vacaville City Coach – Estimated Costs and Funding Shortfall by Year (all amounts in thousands of YOE$)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Electrification Plan Capital Costs	$0	$11,909	$7,543	$4,772	$1,644	$0	$0	$0	$0	$0	**$25,867**
Potential Existing Electrification Funding Identified in SRTP	$150	$150	$420	$330	$150	$10,000	$4,400	$150	$1,000	$3,150	**$19,900**
Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
Funding Surplus / (Gap)	**$150**	**($11,759)**	**($7,123)**	**($4,442)**	**($1,494)**	**$10,000**	**$4,400**	**$150**	**$1,000**	**$3,150**	**($5,967)**

Source: WSP

7 CONCLUSION

7.1 Total Project Cost

Overall, this report shows that the full lifecycle cash cost of a transition to battery electric buses is higher than the continued reliance on ICE vehicles. While the initial capital and operating costs are higher for BEBs, there are opportunities for some savings in fuel costs. Additionally, operating cost benefits are highly dependent on factors that are continually evolving as BEBs deploy in transit services.

The analysis also shows that the No-Build scenario would result in a large emission generation over the lifecycle of the ICE operations in comparison to the Build scenario. The large vehicle emission difference between the two replacement scenarios was expected, as the technology in the battery electric buses are aimed to reduce GHG emissions, particularly for carbon emissions. Table 7.1 shows the overall estimated capital costs (in year of expenditure dollars (YOE$)) of the Solano *Countywide Electrification Transition Plan* by agency. These costs are inclusive of BEB purchases, charging infrastructure, additional options and charges or vehicles and battery extended warranties. SolTrans and Vacaville operate larger transit buses (>35' buses) in addition to cutaway buses. As such, the total capital costs of SolTrans and Vacaville are larger in magnitude than Dixon Readi-Ride and Rio Vista Delta Breeze.

Table 7.1 Estimated Overall Electrification Plan Capital Costs by Agency by Year (all amounts in thousands of YOE$)

Agency	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Dixon Readi-Ride	$0	$0	$2,383	$1,869	$0	$0	$0	$0	$0	$0	**$4,253**
Rio Vista Delta Breeze	$0	$0	$1,414	$1,050	$0	$0	$0	$0	$0	$0	**$2,464**
Solano County Transit	$0	$18,661	$17,259	$10,045	$2,332	$681	$0	$0	$0	$0	**$48,978**
Vacaville City Coach	$0	$11,909	$7,543	$4,772	$1,644	$0	$0	$0	$0	$0	**$25,867**

Source: WSP

7.2 Funding Analysis

Overall, some of these fleet electrification investments can be funded through existing capital revenues outlined in each agency's FY 2021-2030 Short Range Transit Plans (SRTP) adopted in 2020; however, STA and member agencies will also need to pursue additional funding through federal, state, regional, and other formula, and discretionary grant opportunities to fill the estimated funding gap to carry out the full scope of the Solano *Countywide Electrification Transition Plan*. This section first outlines the estimated funding gap (in section 7.2.1) and then provides key takeaways of the funding analysis presented in this report that will help STA and member agencies to identify and secure additional funding to cover this transformative program of projects (in section 7.2.2).

7.2.1 ESTIMATED FUNDING GAP

There is a capital funding gap (in year of expenditure dollars (YOE$)) between existing capital revenues and the costs associated with the program of projects discussed in this report and included within the Solano *Countywide Electrification Transition Plan*. Table 7.2 illustrates this estimated capital funding gap by agency. Note that this table pulls the agency's existing overall capital program cost estimates from the SRTP Capital Plan Budget for each agency (Exhibit 5.3 within these plans) because it is the most recent document that shows capital expenditures of the four agencies in a consistent format. Since these SRTP plans were adopted in 2020, there may be some overlap between the capital costs outlined in the SRTP Capital Costs and the Electrification Plan Capital Cost line in this table. Funding resources outlined in the SRTPs to support revenue vehicle replacements, electrical charging infrastructure, and facilities-related expenses for maintenance/yards are shown in the row titled "Potential Electrification Funding Identified in SRTP" and are assumed to be available to support the Solano *Countywide Electrification Transition Plan*. Other existing agency revenues that could potentially be applied to this funding gap are also included. Across all STA member transit agencies, there is approximately a $38 million funding gap to fully fund the Solano *Countywide Electrification Transition Plan* over the next ten years. Strategies for addressing this gap are discussed in Section 7.2.2.

Table 7.2 Estimated Costs and Funding Shortfall by Agency by Year (all amounts in thousands of YOE$)

Agency		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
Dixon Readi-Ride	Electrification Plan Capital Costs	$0	$0	$2,383	$1,869	$0	$0	$0	$0	$0	$0	$4,253
	Potential Existing Electrification Funding Identified in SRTP	$0	$0	$188	$0	$0	$103	$0	$109	$0	$116	$515
	Other Potential Existing Capital Revenues (e.g., LTF)	$289	$287	$258	$225	$225	$209	$198	$167	$106	$121	$2,087
	Funding Surplus / (Gap)	**$289**	**$287**	**($1,937)**	**($1,644)**	**$225**	**$311**	**$198**	**$276**	**$106**	**$237**	**($1,650)**
Rio Vista	Electrification Plan Capital Costs	$0	$0	$1,414	$1,050	$0	$0	$0	$0	$0	$0	$2,464
	Potential Existing Electrification Funding Identified in SRTP	$0	$98	$0	$0	$0	$451	$0	$116	$0	$0	$665
	Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Funding Surplus / (Gap)	**$0**	**$98**	**($1,414)**	**($1,050)**	**$0**	**$451**	**$0**	**$116**	**$0**	**$0**	**($1,799)**
SolTrans[71]	Electrification Plan Capital Costs	$0	$18,661	$17,259	$10,045	$2,332	$681	$0	$0	$0	$0	$48,978
	Potential Existing Electrification Funding Identified in SRTP	$3,782	$1,456	$1,459	$3,962	$2,912	$2,915	$588	$610	$2,130	$469	$20,283
	Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Funding Surplus / (Gap)	**$3,782**	**($17,205)**	**($15,800)**	**($6,083)**	**$580**	**$2,234**	**$588**	**$610**	**$2,130**	**$469**	**($28,695)**
Vacaville City Coach	Electrification Plan Capital Costs	$0	$11,909	$7,543	$4,772	$1,644	$0	$0	$0	$0	$0	$25,867
	Potential Existing Electrification Funding Identified in SRTP	$150	$150	$420	$330	$150	$10,000	$4,400	$150	$1,000	$3,150	$19,900
	Other Potential Existing Capital Revenues	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Funding Surplus / (Gap)	**$150**	**($11,759)**	**($7,123)**	**($4,442)**	**($1,494)**	**$10,000**	**$4,400**	**$150**	**$1,000**	**$3,150**	**($5,967)**

Source: WSP, Agencies' SRTPs

71 SolTrans electrification plan capital costs and potential existing electrification funding identified in SRTP do not include intercity Solano Express vehicles.

7.2.2 KEY TAKEAWAYS

For federal funding programs, the BIL has significantly increased funding for formula programs like FTA Section 5307, 5311, and 5339. These sources of formula funding are fairly flexible and can be leveraged at an 80% federal / 20% local match to fund capital projects, including procurement of ZEBs, and construction of charging/ fueling infrastructure and/or associated maintenance facilities. Transit agencies in Solano County could consider allocating a portion of these additional formula funds above those amounts needed for operations to fund capital projects like ZEB purchases and charging infrastructure; however, agencies rely on these funds to cover operation costs, considering there are currently no local tax measures to fund transit. In addition to these formula funding programs, the FTA Section 5339(c) Low or No Emissions competitive grant program also received a big boost through the BIL – increasing in size from $182 M/year in FY 2021 to $1.1 B/year in awards starting in FY 2022 through FY 2026.

For state and regional funding programs, transit agencies in Solano County show a projected surplus of Caltrans TDA LTF funding in their SRTPs that could be used for electrification investments. This is because some agencies have specifically saved TDA LTF funds in order to plan for bus replacements and other capital investments. Additionally, STA controls the allocation of TDA STAF funding, a portion of BAAQMD TFCA funds and controls the prioritization of local projects that may receive MTC OBAG funding, all of which could be leveraged. In addition, STA and member agencies should pursue the following opportunities as fleet electrification projects are well aligned with program objectives (and have previous success in obtaining funds to support ZEB infrastructure investments in some cases):

- CalSTA Transit and Intercity Rail Capital Program (TIRCP)
- Caltrans Low Carbon Transit Operations Program (LCTOP)
- Caltrans/State Controller's Office SB1 State of Good Repair (SGR) Program
- Bay Area Air Quality Management District Carl Moyer and Community Emission Reduction Grant Programs

Other newer state transportation opportunities that STA and member agencies should monitor for funding and forthcoming procedural/eligibility requirements include the CALSTART CMO program as well as the CEC Clean Transportation Program.

Finally, with respect to other funding opportunities, SolTrans has applied for the PG&E EV fleet program, which can be used to support the purchase of ZEBs and charging infrastructure for PG&E customers. STA and other member agencies can also apply to this program.

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX G: FAIRFIELD TRANSIT FLEET ELECTRIFICATION FINAL BUSINESS PLAN REPORT

Solano Transportation Authority

City of Fairfield

HEART OF SOLANO COUNTY

FAIRFIELD

CALIFORNIA

Fairfield Transit Fleet Electrification Final Business Plan Report

August 18, 2021

WILLDAN

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Executive Summary

The Willdan team including subcontractors ANSER, CALSTART, KKCS, and InCharge have completed a comprehensive financial analysis of electrifying Fairfield's transit fleet through 2040. This report constitutes a deeper financial analysis based on the initial results of the Summary and Recommendations Report Prepared in December and modifications to the overall conversion strategy based on subsequent discussions with Fairfield. For this analysis Willdan modelled Fairfield's operations with a 35' Proterra Catalyst battery electric buses (BEBs) for the fixed local routes (FLRs), a 45' BYD CM10 coaches for the commuter routes, and Lion M Minibus for the paratransit operations. At the time the initial route modelling was completed, data was only available for Proterra's Catalyst E2 bus. Fairfield is expected to purchase Proterra's latest model, the ZX5, which is expected to perform similarly to the vehicle modeled. Fairfield is currently considering multiple paratransit OEMs; Lion M was selected for this analysis as it has the highest purchase price to maintain a conservative cost analysis. Willdan's analysis assumes Fairfield would use 30 ABB's HVC150 depot charger with two depot boxes each for the entire transit fleet, including paratransit buses. This provides one port for every bus, and since not all buses are expected to operate on a given day, provides redundancy to actual operations. Site upgrade costs for the corporation yard and on-route charging locations were also revised based on the final charging solution. The analysis contained in this report also reflects the latest transit electrification phase in plan, with the pilot BEBs being deployed directly on the east lot in 2023.

The previous Summary and Recommendations report from December 2020 focused primarily on the energy requirements necessary to run BEBs on Fairfield's existing routes and provided high level capital cost estimates for different electrification options. This report refines the previous analysis and estimates ongoing operating costs including energy costs to charge the BEBs and maintenance costs to service and repair a BEB fleet. In preparation for this report, the Willdan team also developed an optimized charging strategy that focuses on charging vehicles midday and overnight when energy rates are lowest to avoid the high energy costs associated with Pacific Gas and Electric's (PG&E's) 4-9PM peak rate period. The proposed charging strategy reserves time to perform maintenance on BEBs and charges buses sequentially, when possible, to reduce PG&E EV rate subscription charges.

To complement the planned conversion to an electric fleet, Fairfield has room for approximately 3.1 megawatts (MW) of solar photovoltaics (PV) at the corporation yard, but is it recommended to allocate up to 400kW for the public works fleet, leaving approximately 2.67MW available to offset future transit loads. This would offset an average of 80% of the transit EV loads through 2040. Since the BEB charging schedule is already designed to take advantage of low energy costs, solar PV provides marginal cost savings, but still pays for itself over the lifetime of the system. More importantly, however, is that Fairfield can finance the solar PV through a power purchase agreement (PPA) and fix their electricity rate for up to 25 years. This fixed rate provides greater long term cost savings as PG&E has historically increased utility rates by over 3% per year. Since the BEBs are not scheduled to charge during on-peak times, there is not an economic benefit to a battery energy storage system (BESS), but one could be considered as an option to provide resiliency to the site. For 24 hours of resiliency, Fairfield has the option of a 2.2MW diesel generator or a 2.2MW/7MWh BESS. A diesel generator would be a lower cost option; however, a battery system would be a more environmentally sustainable system. A battery could also be financed as part of a solar PPA.

Overall, between 2021 and 2040, Fairfield's transit electrification is expected to cost about $43.46M more over time versus "business as usual," continuing to purchase and operate diesel buses. This difference is driven primarily by the higher capital costs of the BEBs and the need to purchase EV chargers and install supporting infrastructure that would otherwise not be needed if Fairfield continued to operate diesel buses. BEBs are expected to cost significantly less to operate; however, as compared to diesel. Overall maintenance and repairs costs are expected to decrease by approximately 10% and fuel costs decrease by up to 50%. While "business as usual" is not a viable course of action for the City due to California Air Resources Board (CARB) Innovative Clean Transit (ICT) regulations which require the conversion of existing internal combustion engine transit fleets to zero-emission fleets by 2040, it is used as the baseline for this analysis because it illustrates the gaps in funding which will need to be closed as Fairfield's fleet is converted. After factoring in currently available and potential future incentives for BEBs and supporting infrastructure, the $43.4M funding gap may be reduced by $23.7M. Low Carbon Fuel Standard (LCFS) credits look to be the largest source of future incentives and provide a significant opportunity to reduce the total cost of ownership of BEBs. Installing up to 2.67 megawatts of solar photovoltaics (PV) at the corporation yard can provide an additional $2.5M in savings through 2040 and could further increase LCFS credit generation since the overall carbon intensity of electricity used to charge the buses would be lower than the carbon intensity of PG&E's electricity. Adding in a 7MWh BESS via a PPA would increase costs by about $4M through 2040 but would provide up to 24 hours of backup power when combined with the 2.67MW solar system.

Separate from this report, team member Anser has prepared a maintenance facility assessment that evaluated what facility retrofits would be needed to service and maintain an electric transit and public works fleet. Three different options were provided which envisioned adding two new bays to the existing facility, adding four new bays to the existing facility, and building a whole new maintenance facility. Our analysis assumes that Fairfield will ultimately add 4 new bays to the existing maintenance facility. Anser also prepared a separate training recommendations report outlining key trainings that Fairfield mechanics should take to be able to service electric buses. Team member KKCS is finalizing a funding analysis memo that will identify key sources of funding Fairfield may be able to leverage to help pay for the fleet transition, beyond what is described in this report.

In parallel with this report, Willdan is working alongside Fairfield to develop potential corporation yard layouts for their transit fleet, factoring in vehicle turning radii and space needs for an upgraded maintenance facility, bus wash, MV Transit's trailer and parking, electrical infrastructure, DCFC power cabinets, future solar carports, and future battery backup.

Route Analysis Results Review

As part of the initial Summary and Recommendations Report, Willdan and CALSTART completed a detailed route analysis of Fairfield's existing fixed local routes, commuter routes, and paratransit operations. After evaluating several different vehicle OEMs, Willdan and Fairfield selected the following vehicles for a detailed financial analysis for fixed route operations:

- 440kWH Proterra Catalyst XR for Fixed Local Routes, though the 660kWh model is used for energy consumption and charging requirements to conservatively size infrastructure for larger battery capacities in the future.
- BYD CM10 Coach for Commuter Routes

Table 1 summarizes the fixed local route analysis results for the Proterra 440kWh and 660kWh model BEBs. While Fairfield is expected to purchase the 35' BEB with a 440kWh battery for its pilot runs, Willdan will utilize the 660kWh model energy consumption for the financial analysis and charger buildout scenarios. This will help future proof the site against future increases in battery capacities that will then avoid the need for on-route chargers. For the purposes of the analysis a bus should complete the route with at least 20% state of charge (SOC) to be viable without an on-route charger.

Table 1 – Summary of Existing Fixed Local Route EBCM Results

ROUTE	OEM	Summer Final SOC	Winter Final SOC	On-Route Charger Required	Daily Maximum Available Charge Time (hr:min)	Daily Minimum Charge Time Required (hr:min)	Route Adjustment Needed
Route 1-1	Proterra - Catalyst XR	17.51%	25.33%	YES	1:24	0:02	NO
	Proterra - E2 Max	39.32%	44.69%	NO	1:24		NO
Route 1-2	Proterra - Catalyst XR	22.96%	30.48%	NO	1:18		NO
	Proterra - E2 Max	43.33%	48.51%	NO	1:18		NO
Route 2-1a	Proterra - Catalyst XR	73.92%	69.91%	NO	0:16		NO
	Proterra - E2 Max	82.07%	80.10%	NO	0:16		NO
Route 2-1b	Proterra - Catalyst XR	64.03%	68.56%	NO	0:20		NO
	Proterra - E2 Max	75.39%	79.14%	NO	0:20		NO
Route 2-2	Proterra - Catalyst XR	12.12%	15.16%	YES	0:52	0:08	NO
	Proterra - E2 Max	39.76%	43.78%	NO	0:52		NO
Route 3-1	Proterra - Catalyst XR	28.07%	34.06%	NO	1:24		NO
	Proterra - E2 Max	45.11%	50.16%	NO	1:24		NO
Route 3-2	Proterra - Catalyst XR	29.46%	36.25%	NO	1:24		NO
	Proterra - E2 Max	46.18%	51.81%	NO	1:24		NO
Route 4	Proterra - Catalyst XR	-9.52%	-8.72%	YES	0:14	0:30	YES
	Proterra - E2 Max	26.23%	30.28%	NO	0:14		NO
Route 5	Proterra - Catalyst XR	24.87%	26.77%	NO	1:30		NO
	Proterra - E2 Max	44.99%	48.66%	NO	1:30		NO
Route 6-1	Proterra - Catalyst XR	24.93%	28.42%	NO	1:57		NO
	Proterra - E2 Max	45.77%	48.12%	NO	1:57		NO
Route 6-2	Proterra - Catalyst XR	24.93%	28.42%	NO	1:57		NO
	Proterra - E2 Max	45.77%	48.12%	NO	1:57		NO
Route 6-3	Proterra - Catalyst XR	24.93%	28.42%	NO	1:57		NO
	Proterra - E2 Max	45.77%	48.12%	NO	1:57		NO
Route 7-1	Proterra - Catalyst XR	-15.00%	-10.35%	YES	1:44	0:36	NO

ROUTE	OEM	Summer Final SOC	Winter Final SOC	On-Route Charger Required	Daily Maximum Available Charge Time (hr:min)	Daily Minimum Charge Time Required (hr:min)	Route Adjustment Needed
	Proterra - E2 Max	20.26%	23.44%	NO	1:44		NO
Route 7-2	Proterra - Catalyst XR	-15.00%	-10.35%	YES	1:44	0:36	NO
	Proterra - E2 Max	20.26%	23.44%	NO	1:44		NO
Route 8-1	Proterra - Catalyst XR	7.01%	8.33%	YES	2:23	0:13	NO
	Proterra - E2 Max	33.75%	34.61%	NO	2:23		NO
Route 8-2	Proterra - Catalyst XR	89.09%	90.66%	NO			NO
	Proterra - E2 Max	92.20%	93.37%	NO			NO

Fairfield's existing Blue and Green Express (GX) lines are significantly more difficult to electrify given the mileage requirements of the individual blocks. The initial analysis suggested that the Blue line was not viable in its current form given current technology limitations and thus it was remodeled as two separate routes. In the new configuration, Blue Line South would run from Vacaville Transportation Center (VTC) Pleasant Hill BART (PH BART). Blue Line North would run from Fairfield Transportation Center (FTC) to Sacramento Valley Station (SVS). Fairfield has been in discussions with BYD for their initial electric coach since it must be configured with inductive on-route charging for regional interoperability and must meet Buy America requirements to qualify for federal funding. Other coach buses analyzed do not meet those requirements at the time of this analysis. As a result, Willdan is using the BYD route analysis results with the re-blocked Blue Line for the financial analysis. Table 2, Table 3, and Table 4 summarize the BYD route analysis results for the commuter routes.

Table 2 – GX Line Route Modeling Results BYD CM10 Electric Coach

Route Name	Summer Final SOC (%)	Winter Final SOC (%)	On-Route Charger Required?	Maximum Available Charge Time on Route (hr:min)	Minimum Charge Time Required (hr:min)	Charging Time Constraint
Route 90-1	-3.53%	-12.01%	YES	0:37	0:33	NO
Route 90-2	28.45%	21.50%	NO	0:17		NO
Route 90-3	-6.59%	-14.15%	YES	0:28	0:35	YES
Route 90-4	28.17%	21.91%	NO	0:17		NO
Route 90-5	30.62%	24.64%	NO	0:26		NO
Route 90-6	-17.15%	-5.68%	YES	0:45	0:38	NO
Route 90-7	-10.90%	-0.99%	YES	0:45	0:32	NO
Route 90-8	-10.90%	-0.99%	YES	0:45	0:32	NO
Route 90-9	-19.16%	-9.94%	YES	0:44	0:41	NO
Route 90-10	19.15%	26.44%	YES	0:28	0:00	NO

Table 3 – Blue Line South VTC to PH BART Route Analysis BYD CM10 Electric Coach

Route Name	Summer Final SOC (%)	Winter Final SOC (%)	On-Route Charger Required?	Maximum Available Charge Time on Route (hr:min)	Minimum Charge Time Required (hr:min)	Charging Time Constraint
Route 30-1	4.99%	-4.03%	YES	0:29	0:25	NO
Route 30-2	16.36%	8.94%	YES	0:24	0:11	NO
Route 30-3	4.06%	-2.68%	YES	0:30	0:23	NO
Route 30-4	15.30%	10.26%	YES	0:36	0:10	NO
Route 30-5	21.88%	25.08%	NO	0:21	0:00	NO

Route Name	Summer Final SOC (%)	Winter Final SOC (%)	On-Route Charger Required?	Maximum Available Charge Time on Route (hr:min)	Minimum Charge Time Required (hr:min)	Charging Time Constraint
Route 30-6	21.24%	25.40%	NO	0:21	0:00	NO
Route 30-7	9.86%	16.95%	YES	0:14	0:10	NO
Route 30-8	-2.02%	5.03%	YES	0:30	0:23	NO
Route 30-9	22.04%	27.63%	NO	0:30	0:00	NO
Route 30-10	-9.97%	-3.04%	YES	0:56	0:31	NO

Table 4 – Blue Line North FTC to SVS Route Analysis BYD CM10 Electric Coach

Route Name	Summer Final SOC (%)	Winter Final SOC (%)	On-Route Charger Required?	Maximum Available Charge Time on Route (hr:min)	Minimum Charge Time Required (hr:min)	Charging Time Constraint
Route 30-1 (Sac)	-20.72%	-27.26%	YES	1:44	0:49	NO
Route 30-2 (Sac)	-20.78%	-22.81%	YES	1:14	0:44	NO
Route 30-3a (Sac)	51.01%	48.71%	NO	0:16	0:00	NO
Route 30-3b (Sac)	21.02%	26.31%	NO	0:19	0:00	NO
Route 30-4 (Sac)	47.87%	47.53%	NO	0:30	0:00	NO
Route 30-5 (Sac)	-5.72%	1.01%	YES	0:42	0:27	NO
Route 30-6 (Sac)	48.25%	51.66%	NO	0:26	0:00	NO
Route 30-7 (Sac)	46.71%	50.34%	NO	0:26	0:00	NO

Paratransit Analysis Results Review

Willdan also completed a review of Fairfield's paratransit operations and available battery electric vehicle conversion options to determine the viability of electrifying this portion of the fleet. At most, 11 paratransit buses can be in operation on a given day, with an average of eight buses deployed during peak periods in the morning and afternoon. Table 5 summarizes general operations of this fleet. Since most paratransit buses drive less than 75 miles per day, Willdan used this minimum range as a threshold for an electric paratransit vehicle to be viable.

Table 5 – Summary of Paratransit Operations

Paratransit Assumptions	Value
Average Daily Mileage	513
Maximum daily mileage	814
Typical Fleet Utilization (% of fleet in use)	72.73%
Times of highest demand	6:30am - 10am; 1pm - 5pm
Average Daily mileage per Bus	64
Max daily mileage per Bus	74

Paratransit routes vary daily based on customer demand and cannot be modeled like the fixed routes with CALSTART's EBCM tool. Therefore, Willdan made estimations about battery electric paratransit vehicle capabilities based on transit bus modeling and conservative engineering assumptions. More details on the assumptions used can be found in the Summary and Recommendations Report.

Results of battery electric Paratransit modeling are shown in Table 6 below for a variety of manufacturer products on the market today. Generally, most battery electric Paratransit vehicles will meet the daily average, worst case service requirements of Fairfield's operation with mid-day charging on a 60kW or higher power DC fast charger.

Table 6 – Electric Paratransit Capabilities Review

Product Parameters	Phoenix Motorcars	GreenPower	Lion	Average
Cost	$ 241,153	$ 282,674	$ 360,000	$ 275,412
Paratransit Listed Capacity (kWh)	125	118	160	133
Paratransit Useable Capacity (kWh)	100.00	94.40	128.00	105.44
Paratransit Stated Efficiency (kWh/mi)	0.96	0.79	1.07	0.97
Average Adjusted Summer Efficiency (kWh/mi)	1.31	1.07	1.46	1.39
Stated Range (mi)	130.00	150.00	150.00	137.50
Minimum Useable Range (mi)	76.19	87.91	87.91	75.74
Daily Final SOC (Average Mileage, Summer)	33%	42%	42%	32%
Daily Final SOC (Maximum Mileage, Summer)	22%	33%	33%	22%
Maximum Charge Time (to full) at 60 KW (hr:min)	2:17	1:10	2:06	1:50

Phase In Strategy

With Fairfield no longer considering initial Phase 1 Transit Charging buildout in the west lot, Willdan has revised the fleet replacement plan presented in the Summary and Recommendations report accordingly to ensure adequate charging infrastructure will be installed in the east lot for the first BEBs to arrive in 2023. In addition, the revised fleet replacement plan is less aggressive and more in line with Fairfield's available funding. Since CARB ICT requires transit fleets to plan their fleet replacements through 2040, Willdan extended Fairfield's revised plan accordingly using the following assumptions:

- Except for six gasoline paratransit vehicle purchases in FY 2021-22, all new transit vehicles purchased will be battery electric
- Internal combustions paratransit vehicles are assumed to operate approximately 9 years before they are replaced with electric versions (in alignment with Fairfield's current practices)
- Existing diesel fixed local and commuter buses are assumed to operate approximately 20 years before they are replaced with electric buses (in alignment with Fairfield's current practices).
- In the business-as-usual (BaU) scenario, new diesel fixed local and commuter buses are assumed to be replaced after 12 years which is FTA's EUL of transit buses
- Electric paratransit buses are expected to be replaced after 7 years which is FTA's EUL of paratransit vehicles
- Electric fixed local and commuter buses are expected to be replaced after 12 years which is FTA's EUL of transit buses
- All electric transit vehicles purchased are assumed to be charged in the east lot
- Of the six gas paratransit vehicles to be purchased in 2021, one of them are expected to replace Gillig fixed route buses and serve fixed local route operations. Therefore, the Gillig fixed route bus count will shrink by one after 2021.
- To account for the higher mileage of the paratransit vehicle used in fixed route operation, Gillig fixed local route fuel and maintenance costs were used as conservative estimates for this transit vehicle in the cost modeling.

The revised fleet replacement plan modeled in this report more closely aligns with Fairfield's actual fleet replacement history, which includes extending the life of diesel buses as needed until funding is available to replace them. Even though the useful life is extended on all vehicles, the plan still achieves a fully zero-emission transit fleet by 2033, ahead of CARB's ICT 2040 requirement, see Appendix A and Figure 1. Willdan did not change Fairfield's proposed replacement for the commuter buses purchased in 2018 as 15 years is already beyond FTA's EUL. This can be extended further if needed, but these buses must be replaced with zero-emission electric by 2040 for CARB's ICT regulations.

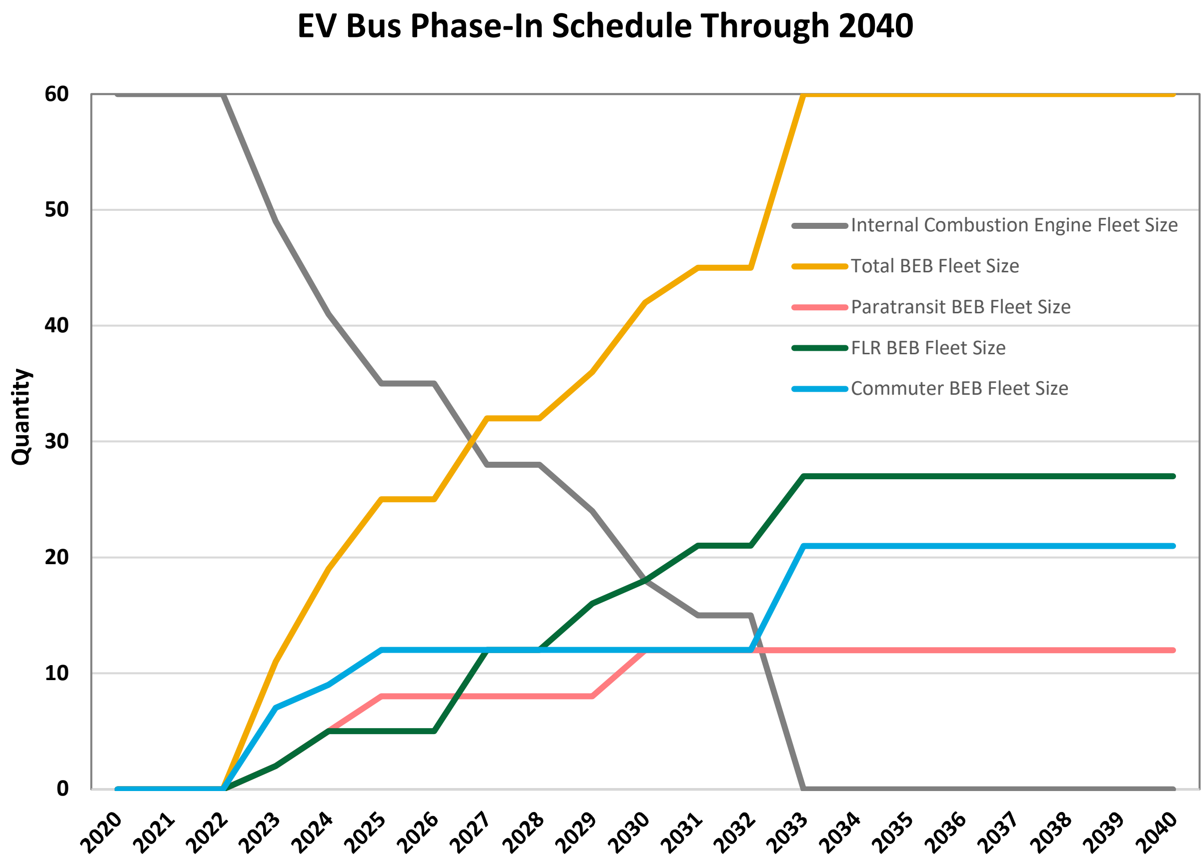


Figure 1. Fairfield EV Bus Phase-In Schedule

Battery Growth and Route Prioritization

Based on discussions with Fairfield, it is likely that the city will limit BEB purchases to primarily 35' BEBs for the fixed local routes in order to fit in the existing maintenance facility bays and to successfully maneuver certain turns on-route. However, current battery capacities on 35' Proterra BEBs are not enough to meet all fixed local route needs. A 40' BEB for fixed local routes may be viable and needed on certain routes but would only replace existing 40' Gillig vehicles. Larger battery capacities available on 40' BEBs can minimize the need for on-route charging on the FLRs.

Willdan thinks this strategy is workable with Fairfield's bus replacement plan as battery technology is expected to improve over time and Fairfield is not going to replace all its buses with BEBs at once. Battery capacity can be reasonably assumed to escalate by 5% per year. In addition, Fairfield can decide to run initial BEB purchases exclusively on less energy intensive routes to give BEB technology a chance to "catchup" to energy intensive route service requirements. Fairfield may also consider redesigning energy-intensive fixed local routes so that they operate within BEB range limits. Table 7 orders the current fixed local routes by energy consumption, the year that route would be electrified based on the phase in plan, and the estimated usable capacity of the Proterra 35' BEB assuming 5% capacity increase per year from 2020. The analysis suggests that battery capacity will meet current route needs over time, and it is unlikely on-route charging will be needed to meet FLR service requirements. Furthermore, Fairfield is currently working with a separate consultant to conduct a Comprehensive Operational Analysis (COA) of the local fixed routes. The COA's purpose is to identify innovative options, services, and programs to maximize post-COVID-19 ridership within the FAST service area. During this process routes and services will be designed with the current BEB range limitations in mind. So, it is possible present-day battery capacity will be able to handle all of FAST's FLR in the near future based on the outcome of the COA.

Table 7 – Fixed Local Route Prioritization and Battery Growth Projections

Route Name	Route Energy Consumption (kWh)	Year Electrified	Proterra 35' Estimated Usable Battery Capacity
Route 8-2	51.47	2023	407
Route 2-1a	131.34	2023	407
Route 2-1b	162.43	2024	428
Route 3-2	355.18	2024	428
Route 6-1	357.94	2024	428
Route 6-2	357.94	2027	495
Route 6-3	357.94	2027	495
Route 3-1	362.25	2027	495
Route 5	363.07	2027	495
Route 1-2	374.01	2027	495
Route 2-2	397.59	2027	495
Route 1-1	400.46	2027	495
Route 8-1	437.25	2029	546
Route 4	486.89	2029	546
Route 7-1	526.28	2029	546
Route 7-2	526.28	2029	546

Commuter routes generally operate a morning block and an afternoon block. Therefore, Willdan has paired morning and afternoon blocks such that a single BEB could run a morning block, return to the corporation yard to be fully recharged, and then run an afternoon block. There is flexibility in the GX Line blocks to pair different morning and afternoon runs, as shown in Table 8. The re-blocked sections of the Blue Line have less flexibility overall as some morning and afternoon run combinations do not allow sufficient midday recharging and shown in Table 9 and Table 10. The available time to charge does not account for any time unloading fares, conducting maintenance, or using the bus wash midday between runs.

In total, Willdan estimates that with a re-blocked Blue Line, Fairfield will have approximately 17 commuter buses in use for peak service: 5 for the GX Line, and 6 for each half of a new Blue Line. Given a commuter fleet size of 21 BEBs, this leaves 4 spares available to fill in for down buses. Fairfield may be able to bring the peak bus usage down by as many as three buses if blocking on the revised Blue Line is adjusted further.

Splitting the Blue Line increases the total number of buses needed to meet service requirements. The existing Blue Line blocking consists of 14 blocks: 4 all day blocks, 5 morning blocks, and 5 afternoon blocks. The existing Blue Line requires approximately 9 buses to operate in a given day, while the re-blocked Blue Line would require approximately 12.

Table 8 – GX Line Block Pairings

Morning Route			Afternoon Route			Available Time to Charge
Route	Yard Leaving	Yard Return	Route	Yard Leaving	Yard Return	
Route 90-1	3:48 AM	9:08 AM	Route 90-6	1:39 PM	7:12 PM	4:31
Route 90-3	4:08 AM	9:32 AM	Route 90-7	1:59 PM	7:32 PM	4:27
Route 90-2	4:12 AM	8:05 AM	Route 90-8	2:19 PM	7:52 PM	6:14
Route 90-4	4:32 AM	8:26 AM	Route 90-9	2:39 PM	8:32 PM	6:13
Route 90-5	4:52 AM	9:08 AM	Route 90-10	2:59 PM	6:52 PM	5:51

Table 9 – Blue Line South Pairings

Morning Route			Afternoon Route			Available Time to Charge
Route	Yard Leaving	Yard Return	Route	Yard Leaving	Yard Return	
Route 30-1	3:54 AM	9:10 AM	Route 30-7	1:43 PM	5:59 PM	4:33
Route 30-2	4:30 AM	8:54 AM	Route 30-10	2:03 PM	8:24 PM	5:09
Route 30-3	4:55 AM	10:13 AM	Route 30-8	2:10 PM	7:39 PM	3:57
Route 30-4	5:24 AM	10:25 AM	Route 30-9	3:03 PM	7:34 PM	4:38
Route 30-5	9:33 AM	1:27 PM	No afternoon pairing			
Route 30-6	10:33 AM	2:27 PM	No afternoon pairing			

Table 10 – Blue Line North Pairings

Morning Route			Afternoon Route			Available Time to Charge
Route	Yard Leaving	Yard Return	Route	Yard Leaving	Yard Return	
Route 30-1 (Sac)	4:29 AM	12:47 PM	No afternoon pairing			
Route 30-2 (Sac)	5:28 AM	1:48 PM	No afternoon pairing			
Route 30-3a (Sac)	6:17 AM	9:47 AM	Route 30-3b (Sac)	2:17 PM	6:49 PM	4:30
Route 30-4 (Sac)	7:47 AM	11:19 AM	Route 30-7 (Sac)	2:47 PM	6:31 PM	3:28
No morning pairing			Route 30-6 (Sac)	1:17 PM	4:40 PM	
No morning pairing			Route 30-5 (Sac)	12:17 PM	7:01 PM	

Table 11 orders the commuter route blocks by energy consumption, the year that route would be electrified, and the estimated usable capacity of the BYD's CM10 electric coach assuming 5% capacity increase per year from 2020. Instead of strictly evaluating a route's energy consumption order, Willdan evaluated commuter route prioritization within the context of implementing a re-blocked Blue Line. The electrification order assumes the GX Line would be fully electrified with the initial bus purchases in 2023, giving Fairfield another year to implement a re-blocked Blue Line starting in 2024. This would require on-route chargers be installed at FTC and El Cerrito del Norte BART stations by 2023. It is then recommended to electrify the southern half of the Blue Line separately since that route may only require a single on-route charger to support it, and the infrastructure costs could be captured under PG&E's EV Fleet Program. Electrifying the northern half of the Blue line last likely avoids the need for an on-route charger to be installed at SVS and having to coordinate with a separate utility, Sacramento Municipal Utility District (SMUD). Given the uncertainty of the Blue Line, and to maintain a conservative analysis overall, Willdan will assume that on-route charging will be needed for all the commuter routes. Solano Transportation Authority (STA) is currently developing inducting on-route charging projects at FTC, El Cerrito Del Norte BART, Suisun City Amtrak, and Walnut Creek BART which may support several of Fairfield's commuter routes.

Table 11 – Commuter Route Prioritization and Battery Growth Projections

Route	Route Pairing	Maximum Route Energy Consumption	Year Electrified	BYD CM10 Estimated Usable Battery Capacity	On Route Charging Required
GX Line	Route 90-5 + Route 90-10	360.60	2023	413	No
GX Line	Route 90-2 + Route 90-8	494.60	2023	413	Yes
GX Line	Route 90-3 + Route 90-7	509.12	2023	413	Yes
GX Line	Route 90-1 + Route 90-6	522.47	2023	413	Yes
GX Line	Route 90-4 + Route 90-9	531.48	2023	413	Yes
Blue South	Route 30-5	348.42	2024	434	No
Blue South	Route 30-6	351.26	2024	434	No
Blue South	Route 30-4 + Route 30-9	400.23	2025	455	No
Blue South	Route 30 -3 + Route 30-8	457.96	2025	455	Yes
Blue South	Route 30-1 + Route 30-7	463.96	2025	455	Yes

Route	Route Pairing	Maximum Route Energy Consumption	Year Electrified	BYD CM10 Estimated Usable Battery Capacity	On Route Charging Required
Blue South	Route 30-2 + Route 30-10	490.46	2033	673	No
Blue North	Route 30-4 (Sac) + Route 30-7 (Sac)	237.69	2033	673	No
Blue North	Route 30-6 (Sac)	230.81	2033	673	No
Blue North	Route 30-3a (Sac)+ Route 30-3a (Sac)	352.23	2033	673	No
Blue North	Route 30-5 (Sac)	471.53	2033	673	No
Blue North	Route 30-2 (Sac)	547.73	2033	673	No
Blue North	Route 30-1 (Sac)	567.58	2033	673	No

Capital Costs

Bus Costs

One of the largest capital costs in converting the bus fleet to battery electric is the cost of the buses themselves. As a basis for this calculation, Fairfield provided historical data for their bus purchases. To accurately reflect current diesel and gasoline vehicle prices, Willdan used the most recent bus purchase price for each vehicle type for baseline bus costs, shown in Table 12. Since Fairfield is considering BYD for their commuter coaches, Willdan recommends they procure the vehicle with both an inductive charging plate and DC charging capabilities BEB costs used in the financial analysis, including any add-on costs, are summarized in Table 13. Pricing for Lion is used for electric paratransit buses for the purposes of this analysis, though Fairfield has flexibility in using other OEM's for paratransit needs.

Table 12 – Existing Bus Costs

Line Item	Gillig Diesel Hybrid	MCI Commuter	Ford Paratransit
Base bus cost	$ 688,737	$ 587,712	$ 73,241
Extended Battery Warranty	N/A	N/A	N/A
Inductive Charging Add-on	N/A	N/A	N/A
Total Base Cost	$ 688,737	$ 587,712	$ 73,241

Willdan has included extended warranty costs into the bus capital costs. Standard warranties, included with the base purchase price, for Proterra and New Flyer buses are shown in Table 14. Standard bus battery warranties typically only cover 20% degradation through the first 6 years of the bus. Willdan recommends the City purchase an extended warranty on the batteries to cover 20% degradation for the full 12 year EUL. Where data on extended warranty costs for specific vehicle types or OEMs does not exist, warranty costs have been estimated based on the size of the vehicle's battery.

Table 13 – BEB Bus Costs

Line Item	Proterra Catalyst (440 kWh)	Proterra E2 Max (660 kWh)	BYD CM10	Lion M Minibus
Base bus cost	$ 789,000	$ 889,000	$ 950,000	$ 360,000
Extended Battery Warranty	$ 75,000	$ 112,000	$ 78,775	$ 28,260
Inductive Charging Add-on	Not Available	Not Available, but not needed for FLRs	$ 80,000	N/A
Total Base Cost	$ 864,000	$ 1,011,000	$ 1,108,775	$ 388,260
Difference from Existing Baseline Vehicle	$ 175,263	$ 322,263	$ 521,063	$ 315,019

Table 14 – Typical BEB Warranties

Warranty Description	Proterra's Warranty		New Flyer's Warranty	
	Years	Miles	Years	Miles
Complete Bus	2	100,000	2	100,000
Body Structure	3	150,000	3	150,000
Chassis Structure	12	500,000	12	500,000
Propulsion System	3	100,000	3	100,000
Battery Pack (As Applicable)	6	250,000	6	300,000
Drive Motor	3	100,000	3	100,000
Air Conditioner	2	unlimited	2	unlimited
Lift/Ramp	2	unlimited	2	unlimited
Flooring	3	150,000	12	unlimited
Brake System	2	100,000	2	100,000
Destination Signs	3	150,000	3	150,000
Door Systems	1	unlimited	3	150,000
Air Compressor and Dryer	2	100,000	2	100,000
Passenger Seating	2	100,000	2	100,000
AC to DC Converted	2	100,000	2	100,000
Multiplex System	2	unlimited	3	150,000
Power Steering	2	100,000	2	100,000

Charger Costs

Figure 2. Sample Power Cabinet and Depot Box Configuration

Willdan is using the "flexible" charging solution described in the previous Summary and Recommendations report for the financial analysis as it provides a balance of cost and flexibility in overall charging operations. In this scenario, each 150kW charger has two depot boxes and can sequentially charge the connected buses, see Figure 2. Given that paratransit vehicles will likely reside in their own parking spaces, separate from the FLR and commuter route buses, additional 150KW chargers have been added to the final financial analysis. Current electric paratransit bus offerings may only be able to charge at a maximum rate of 60-80kW; however, installing higher power chargers can help future proof equipment investments if future paratransit buses can charge at a higher rate. Paratransit buses are still assumed to charge primarily midday in between morning and afternoon runs. The final charging solution provides a dedicated charging port for each vehicle to ensure every bus can be recharged each day. Knowing that not all buses operate in a given day, this effectively provides a few spare chargers in case one needs to be serviced.

Estimated costs to purchase and install high power DCFCs in the East Lot of the Corporation Yard are summarized in Table 15. While Fairfield can ultimately select from a variety of charging vendors for their project buildout, Willdan used data available for ABB's HVC 150C chargers for the financial analysis. The chargers come standard with a 2 year warranty with the option to extend the warranty to 5 years. The warranty includes annual preventative maintenance visits in addition to parts and labor for warranty repairs Willdan is also including estimated installation costs for the chargers assuming the east lot is fully built out with the supporting electrical infrastructure, pads, conduit, etc. Depending on the final design and layout of the east lot, installation costs may vary from the conservative estimate shown below. ABB's chargers are also proven to work with Fairfield's existing Asset Works fuel management system, Fuel Focus EV. Fairfield should continue to work closely with Asset Works to make sure that their Fuel Focus EV program can meet Fairfield's tracking and billing requirements.

Table 15 – ABB HVC 150C Purchase and Installation Costs

COMPONENT	COST
Utility Upgrades Estimate (Front of Meter)	$ 0*
Electrical Infrastructure & Installation (Behind the meter)	$ 0*
Parking Lot Development	$ 0*
EVSE Installation	$ 43,643
EVSE Product	$ 146,552
Subtotal Contractor and Vendor	$ 190,194
Turnkey Design, Engineering, Management, and Admin	$ 9,510
Contingency	$ 13,314
Cost Per Installed Charger	$ 213,018
Total number of chargers	**30**
Total charger cost	**$ 6,390,540**

* Assumes the corporation yard is fully developed and all supporting infrastructure is in place

Infrastructure Costs

Willdan has refined our assessment of the infrastructure and associated costs for both the depot and on-route charging locations, updated from the initial assessment in the Summary and Recommendations report to better account for Paratransit bus charging. For the costs shown below in Table 20, Willdan is assuming the flexible charging scenario at the corporation yard which now includes thirty (30) 150KW power cabinets each with two depot boxes. All high-power chargers have a loss factor, so the total maximum potential load serving the transit fleet on a new dedicated meter at the corporation yard will be approximately 4.7MW. Similarly, we assume the on-route chargers draw approximately 10% more from the grid than what is delivered into the bus.

Willdan's other infrastructure cost assumptions follow the same methodology found in the Summary and Recommendations report. Categories and types of utility (in front of the meter) upgrades are shown in Table 16. Note that this is only an example of estimated possible scopes, as PG&E will determine actual upgrade needs for each site.

Table 16 – Utility Mitigations Scope Example Description

Utility Distribution Mitigations Category	Types of Upgrades Required
Extensive mitigations expected	Upstream SCADA, substation, distribution feeder, and large transformer upgrades, new service equipment for project
Moderate mitigations	Upstream feeder and transformer upgrades in addition to new service equipment for project

Minimal mitigations	Few upgrades to upstream infrastructure, mainly new service equipment for project

Behind the meter electrical upgrade assumptions follow the methodology stated in the initial Summary Recommendations report but have been updated to support the updated 4.7MW of BEB load at the Corporate Yard. Table 17 summarizes the costs to develop the corporation yard and each commuter route charging location including estimates for utility upgrades and electrical infrastructure upgrades. Other site upgrade costs include parking lot development and costs for a turnkey contractor to design, manage and complete the work. Commuter route site costs also include the cost to purchase and install a 300kW on-route charger. Costs for FTC assume two on-route chargers are installed. PG&E's EV Fleet program may be able to cover some of the In Front of the Meter and Behind the Meter Utility Upgrade Costs shown below if Fairfield's bus purchase schedule meets their requirements. PG&E will maintain infrastructure in front of the meter, bur Fairfield, or their designated contractor, would be responsible for maintaining infrastructure behind the meter, including the chargers. Fairfield has various options on how to handle charger maintenance including purchasing extended warranties from OEMs which include maintenance or working with other 3rd parties to maintain the infrastructure or training internal resources to take it on in house. Costs for extended 5-year warranties on the chargers are factored into the overall charger costs. STA has indicated they would be responsible for maintaining any inductive charging stations they install throughout the region.

Table 17 – Summary of Estimated Utility, Infrastructure, and Site Upgrade Costs

Location	Maximum Charging Load	In Front of the Meter Utility Upgrade Cost ($)	Behind the Meter Electrical Upgrade Cost ($)	EVSE Product and Install Cost ($)	Additional Site Upgrade Costs ($)	Total Costs ($)
Corporation Yard (East)	4.7 MW	$ 987,216	$ 633,053	See Table 15	$ 2,317,111	$ 8,606,594
Fairfield Transportation Center	660kW	$ 247,779	$ 82,824	$ 428,746	$ 236,504	$ 999,853
Sacramento Valley Station	330 kW	$ 95,393	$ 61,155	$ 217,412	$ 145,900	$ 519,859
Walnut Creek BART	330 kW	$ 102,465	$ 61,155	$ 217,412	$ 148,587	$ 529,619
El Cerrito del Norte BART	330 kW	$ 102,465	$ 61,155	$ 217,412	$ 148,587	$ 529,619

Maintenance Facility Assessment

Anser completed a maintenance facility assessment that identified deficiencies of the existing facility and describes the upgrades needed to support an electric bus and public works fleet. The maintenance facility is undersized for current transit and public works fleet and does not have the capabilities to service electrical buses. Anser developed three options to retrofit the facility and rough order of magnitude (ROM) cost estimates of each option. More detail about the retrofit options and cost estimates can be found in the Maintenance Facility Assessment, dated May 14, 2021.

- **Expansion Option 1** proposes a new 15-bay maintenance facility where the transit buses currently park. ROM: $12,045,678. Note, since conceptualization, this option is no longer in consideration, as Fairfield’s Public Works fleet will be reconfiguring the West Lot to place a Spoils Yard where this facility would be located.

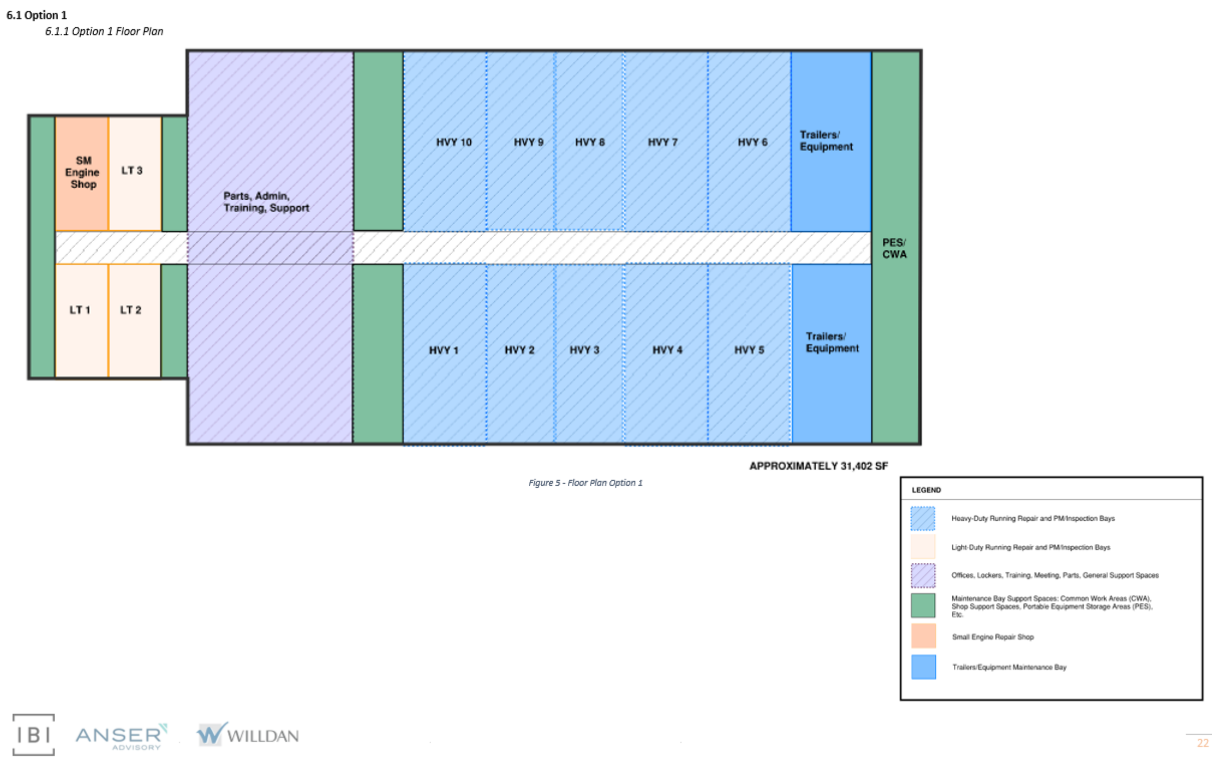


Figure 3. Mockup of New 15 Bay Maintenance Facility (Option 1)

- **Expansion Option 2** adds four 45’ bays to the southern end of the maintenance facility. ROM: $5,492,928

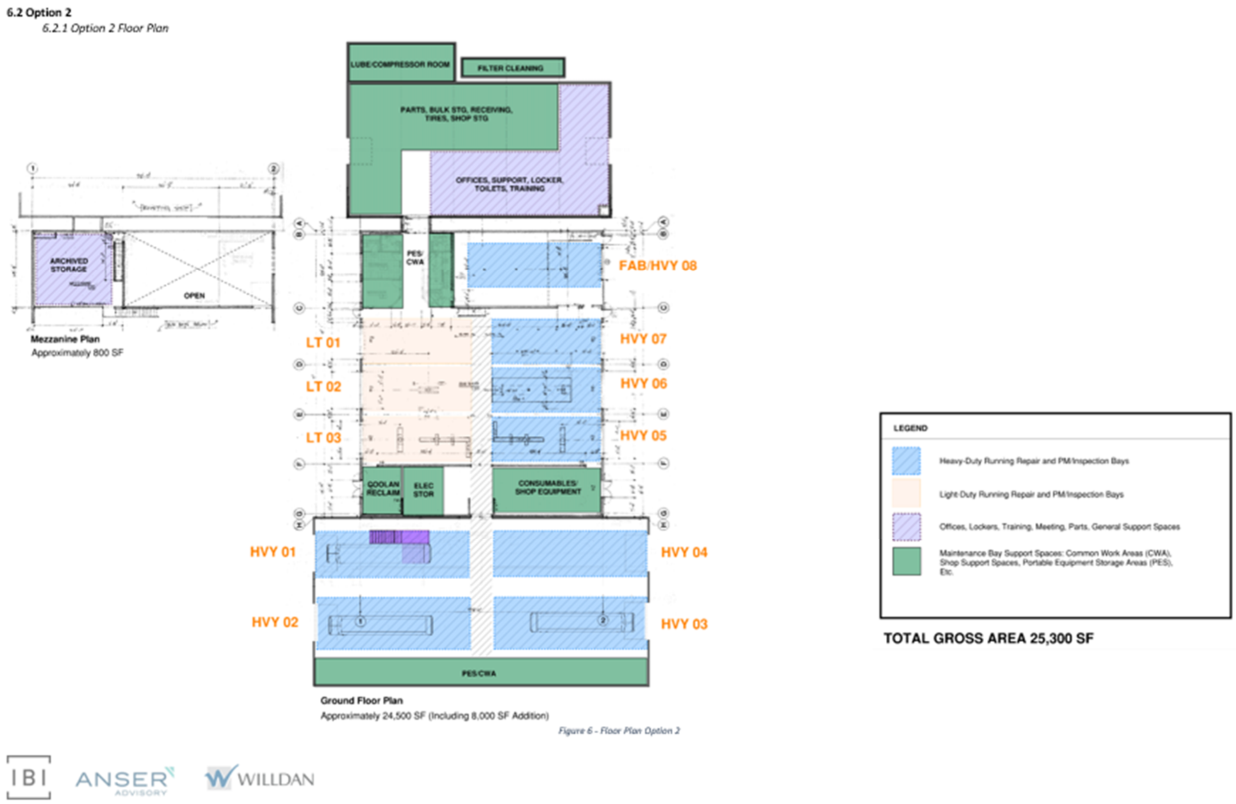


Figure 4. Mockup of 4 Bay Addition to Existing Maintenance Facility (Option 2)

- **Expansion Option 3** adds two 45' bays to the southern end of maintenance facility. ROM: $3,852,478

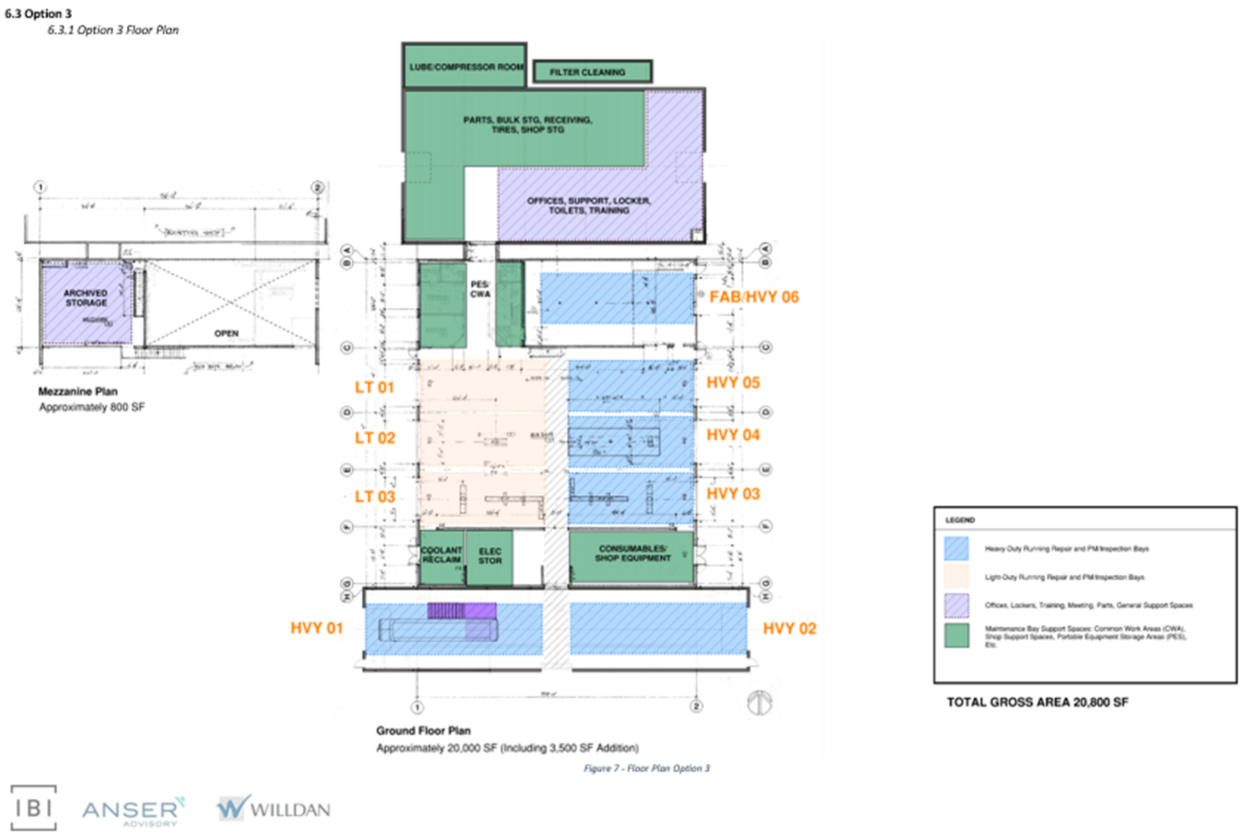


Figure 5. Mockup of Two Bay Addition to Existing Maintenance Facility (Option 3)

Operating and Other Ongoing Costs

Charging Schedule and Fuel Costs

Fairfield provided data for annual fuel costs of the existing transit fleet, summarized in Table 18. Average annual costs per bus are used in the baseline, business as usual financial analysis.

Table 18 – Existing Annual Fuel Costs

Route Type	Manufacturer	Gallons Issued	Total Cost ($)	Number of Buses	Average Annual Fuel Cost per Bus ($/bus/year)	Average Annual Mileage (miles)
Fixed Local Routes	GILLIG	168,650.75	$ 513,922	27	$ 19,034	848,540
Commuter Routes	MCI*	247,389.51	$ 752,917	21	$ 35,853	740,475
Paratransit	FORD	33,426.25	$ 101,869	12	$ 8,489	295,808

*Two 2002 Gillig suburban model buses are part of the commuter route fleet

For BEBs, when and how they are charged can significantly impact the cost to "refuel" the vehicles. Unlike gasoline or diesel prices which fluctuate over weeks or months, electricity prices vary throughout a given day as well as typically escalate over time. PG&E has developed a specific EV rate schedule, BEV-2, summarized in Figure 6 and Table 19, that offers low electricity prices during off-peak times when the grid is less constrained, super off-peak rates when solar production is its highest, and higher prices during on-peak times, currently 4PM-9PM. As a result, the recommended charging schedules avoid charging between 4PM-9PM and start overnight charging after 9PM. The charging schedules also take advantage of super off-peak rates to charge commuter buses and paratransit buses that are in the corporation yard between 9AM and 2PM. BEV-2 also includes a monthly demand block subscription charge in lieu of traditional demand charges. Fairfield would purchase a quantity of 50KW demand increments of load and pay a fixed fee per month based on the total expected load. If Fairfield exceeded the blocks in a given month the City would incur additional demand charges.

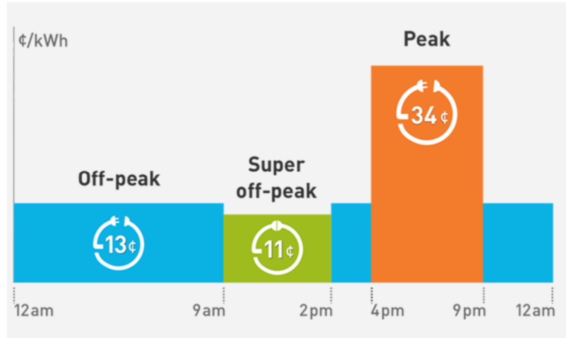


Figure 6. PG&E's BEV-2 Rate Schedule

Table 19 – PG&E BEV-2 Rate Schedule

Description	Time	Days	Cost ($/kWh, $/kW)
Peak	4PM-9PM	Every Day of the	$ 0.3397
Super Off Peak	9AM-2PM	year including	$ 0.1265
Off Peak	All other Times	weekend and holidays	$ 0.1032
Monthly Subscription Charge (per 50 kW block)	Per Month	Per Month	$ 95.56
Monthly Subscription Charge (per kW)	Per Month	Per Month	$ 1.91
Overage Fee ($/kW)	Per Month	Per Month	$ 3.82

For the charging schedules and resulting energy costs Willdan assumed the following:

- Fixed Local Route – Proterra 40' 660kWh. Fairfield has been working with Proterra for the pilot round of fixed local route BEBs. While it is expected Fairfield will purchase the 35' 440kWh version as a pilot, Willdan wanted to develop a charging solution that would still work as the battery capacities increase in the future.
- Commuter Bus – BYD CM10. Fairfield has been working with BYD for the pilot round of commuter buses and has confirmed compatibility with inductive on-route charging. Vanhool is not a viable procurement because it does not meet Buy America requirements. MCI is still working through on-route charging compatibility.
- Paratransit – Lion M Minibus. Fairfield has multiple viable OEM options for paratransit operations, Lion M is used for conservative pricing in the financial analysis.

Given the expected bus selections and phase in timeline, it is assumed that on-route charging will be required for the GX Line, and each half of the re-blocked Blue Line. Based on BYD's route modelling results, it is projected that the GX Line will have on-route charging at Suisun Amtrack and FTC; the southern half of the Blue Line will have on-route charging at Walnut Creek BART; and the northern half of the Blue Line will have on-route charging at Sacramento Valley Station, and FTC. Charging schedules assume the bus recharges for the full available layover time each time. Based on the assumed battery growth of the 35-foot Proterra BEB over time and a potential fixed local route design, it is assumed that on-route charging will not be required for fixed local routes.

Appendix B contains the charging schedule tables. Table 38 illustrates the weekday charging schedule on a route-by-route basis. It shows when the vehicle on each route would ideally charge based on operating schedule and demonstrates the available time to be serviced or inspected on a day the bus was in operation. In addition, the schedule shows when the commuter routes would charge on-route. Table 39 shows the weekday charging schedule on a charger-by-charger basis, including on-route chargers to illustrate the total number of chargers in use and the corresponding load for 30-minute intervals. The charging schedule utilizes sequential charging and charging midday to reduce the overall peak demand to approximately 2.5MW, nearly half of the potential peak demand of 4.7MW, as shown in Figure 7. This charging schedule can be implemented automatically and further optimized based on real time conditions with a smart charging software. With smart charging software, bus operators can plug in the vehicles after they have been washed and fare probing has occurred, and the chargers will not begin charging until after 9PM. Plugged in vehicles will then be charged optimally and ensure a full charge for when vehicles need to depart the next morning.

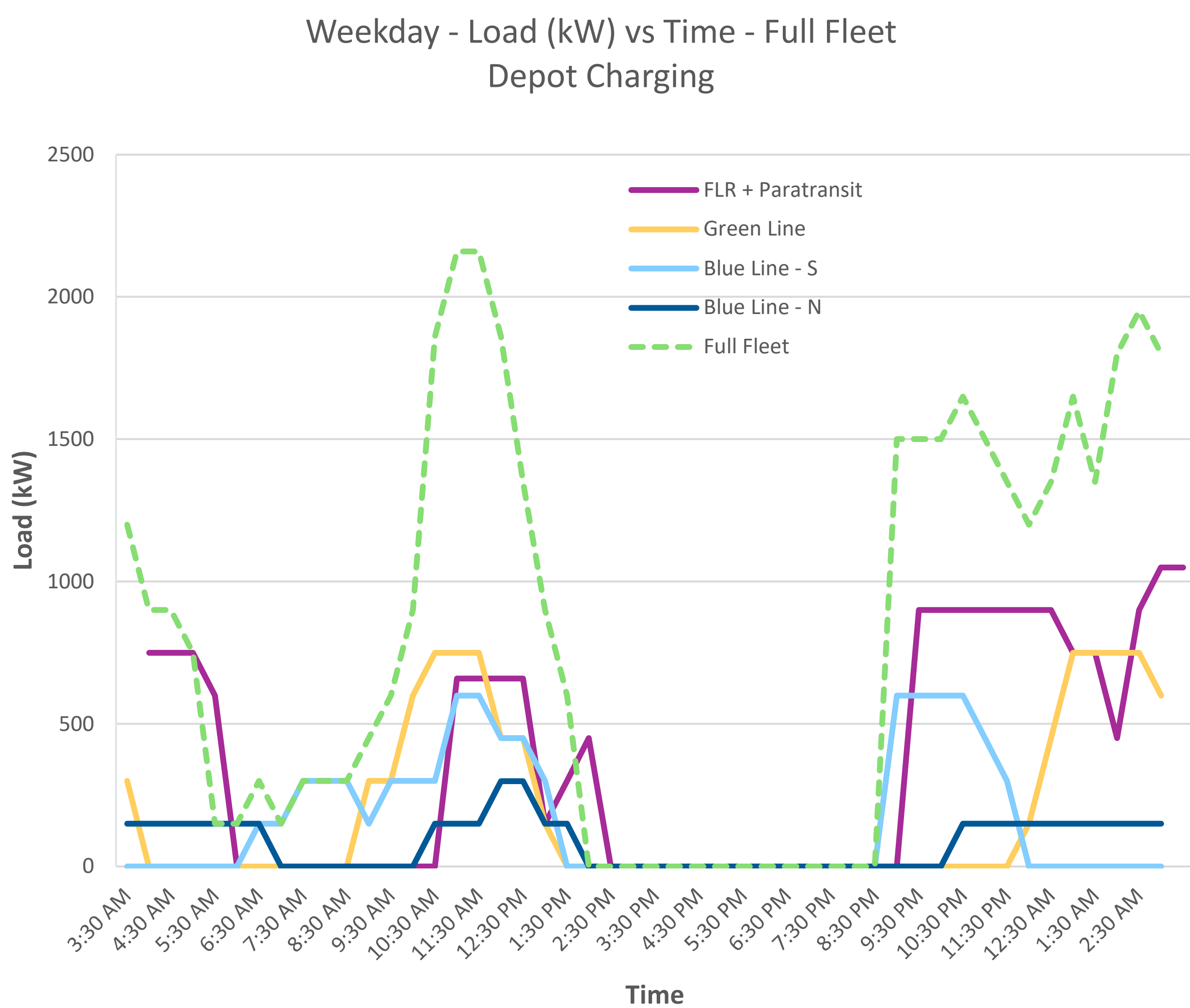


Figure 7. Corporation Yard Fully Electric Fleet Load Profile with Optimize Charge Schedule

Energy costs presented represent a “do no worse than” approach to allow Fairfield to begin to budget appropriately. Table 20 summarizes the total monthly electricity fuel expenditure during the summer and winter seasons for each vehicle type of a full electric transit fleet on PG&E’s current BEV-2 rate schedule. It is Willdan’s understanding that

BEBs will be rotated among various viable routes; therefore, Willdan assumed an average monthly energy cost for each bus based on the current route schedule. Average energy costs account for the total number of vehicles in the fleet, including spares that do not operate on a given day and aligns with how Willdan's model calculates fuel costs for diesel buses. Initial routes will likely be shorter and thus have a lower energy consumption due to battery capacity limitations. As a result, initial energy costs are likely an overestimate of what Fairfield will incur, assuming the same charging strategy principles are followed. Total kWh charges may not vary substantially if the charging schedule is altered, assuming on-peak times are avoided, but the monthly subscription charge would increase if a different charging schedule increased the total peak demand. Energy costs shown in Table 20 do not account for potential low carbon fuel standard credit incentives; therefore, actual energy costs may be lower than presented.

With the given charging schedule, it is expected that Fairfield will save significantly on fueling costs by switching to an electric fleet, particularly on FLRs and paratransit operations. Commuter routes; however, may experience smaller fuel savings for the following key reasons:

- The BYD CM10 coaches are not as efficient (in kWh/mi) as the FLR or paratransit vehicles.
- Commuter BEBs will need to charge on-route, incurring additional subscription charges at each location, and will need to charge during on-peak times during the afternoon runs.
- As previously mentioned, a re-blocked Blue Line would result in more buses in use on a given day than the existing blocking. Fairfield will likely not purchase additional buses in order to maintain its classification as a small transit agency; therefore, the energy costs are effectively spread among fewer buses, resulting in higher average energy costs per bus.

Table 20 – Summary of Electric Costs for BEBs on Optimized Charge Schedule

Route	Fixed Local Routes		Paratransit		GX Line		Blue South Line		Blue North Line	
Season	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Depot Chargers in Use at one time	7		11		5		5		2	
On-Route Chargers in Use	0		0		2 (FTC + El Cerrito)		1 (Walnut Creek)		2 (SVS + FTC)	
Total Monthly Energy Cost ($/mo)	$ 21,471	$ 22,200	$ 4,842	$ 4,842	$ 18,770	$ 16,047	$ 15,498	$ 18,975	$ 13,261	$ 13,630
Total Annual Energy Cost ($/yr)	$ 260,567		$ 58,105		$ 214,345		$ 199,888		$ 160,605	
Annual Average Energy Cost per Bus ($/Bus)	$ 9,651		$ 4,842		$ 30,621		$ 28,555		$ 22,944	
Total Annual Energy usage (kWh/yr)	2,019,857		407,314		1,386,429		1,378,286		1,000,286	
Average Annual Energy per Bus (kWh/Bus/yr)	74,810		33,943		198,061		196,898		142,898	
Baseline Fuel Costs ($/bus/yr)	$ 19,034		$ 8,489		$ 35,853		$ 35,853		$ 35,853	
Annual "Fuel" Savings Compared to Baseline ($/bus/yr)	$ 9,384		$ 3,647		$ 5,232		$ 7,298		$ 12,910	
Percent Savings by Converting to BEB (%)	49%		43%		15%		20%		36%	

Maintenance Costs

Willdan estimated potential maintenance cost savings of converting to an all-electric bus fleet. BEB OEMs claim maintenance savings upwards of 50% from diesel equivalents but there is little data to verify those savings. The majority of Fairfield's maintenance costs are categorized into the following groups: Preventative Maintenance, Repair Costs, and Accident Costs. Each of these cost categories has a parts component, and a labor component. Lastly, given the limitations of the existing maintenance facility, some maintenance items are subcontracted out. Other types of maintenance costs are generally negligible and are excluded from this analysis.

Preventative maintenance costs consist of any items noted in the vehicle's PM service sheet included in the Fairfield's Bus Fleet Operations, Maintenance, and Procedures document, and summarized in Table 21. Willdan then noted which PMs are not applicable in BEBs, primarily fluid changes related to the engine and transmission. To stay conservative, Willdan is assuming that the remaining PMs would either translate over to BEBs or cover the costs of any new PMs such as battery testing. Per FTA requirements, each bus must have a monthly operational safety inspection (OSI). Fairfield provided data on the average numbers of hours it takes to complete an OSI and a PM item. After removing most of the fluid related PMs, Willdan estimates that all PM could be completed in-house and overall PM costs would decrease by 30% for a BEB relative to a diesel or gasoline powered bus.

Table 21 – Existing Vehicle Preventative Maintenance Schedule

Paratransit PMs	Interval (miles)	Fixed Local Route PMs	Interval (miles)	Commuter Route PMs	Interval (miles)
Check and Replace Air Filters if needed	3,000	Check and Replace Air Filters if needed	6,000	Check and Replace Air Filters if needed	6,000
Change Oil and Filters*	3,000	Change Oil and Filters*	6,000	Change Oil and Filters*	6,000
Grease Zerk Fittings	3,000	Grease Zerk Fittings	6,000	Grease Zerk Fittings	6,000
Change Fuel Filters*	15,000	Change Fuel Filters*	6,000	Change Fuel Filters*	6,000
Test Coolant System	15,000	Test Coolant System	6,000	Test Coolant System	6,000
Change Transmission Fluid and Filter*	30,000	Change Transmission Fluid and Filter*	24,000	Change Transmission Fluid and Filter*	24,000
Service Front Axle Bearings	30,000	Change Power Steering fluid and filter	24,000	Change Power Steering fluid and filter	24,000
Change Coolant System Fluid	45,000	Service Front Axle Bearings	30,000	Change front axle and tag axle oil	24,000
Change Differential Fluid*	100,000	Change Coolant System Fluid	60,000	Change Coolant System Fluid	60,000
		Change Differential Fluid*	100,000	Change Differential Fluid*	96,000

*PMs not applicable for BEBs

Willdan's analysis assumes no changes to the repair costs for BEBs compared to Internal Combustion Engine (ICEs). Based on reports of other fleets transitioning to BEBs, repair costs are typically lower than ICE vehicles while the BEB is still under warranty. However, after the warranty period BEB repair costs may be greater than ICE costs[1,2]. Fairfield has had some preliminary discussions with BYD for the pilot commuter buses and how servicing for warranty repairs would work. BYD has indicated they would ship parts at no cost to Fairfield and reimburse Fairfield at a pre-determined rate, which is similar to how warranty repairs are handled for the existing MCI buses. Accident costs are

[1] https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/115086/zero-emission-bus-evaluation-results-king-county-metro-battery-electric-buses-fta-report-no-0118.pdf

[2] Eudy, Leslie, and Jeffers, Matthew. *Foothill Transit Battery Electric Bus Progress Report, Data Period Focus: July 2019 through December 2019*. United States: N. p., 2020. Web. doi:10.2172/1660046.

difficult to predict, and generally a smaller portion of overall maintenance costs. These costs are held constant for BEBs.

Fairfield provided two different datasets for maintenance costs. The first was the total spent in the FY18-19 and broken up by vehicle type, shown in Table 22. Fairfield was then able to provide a limited breakdown of specific maintenance and repairs costs for the FY18-19. Fairfield has been updating its internal maintenance tracking then provided a detailed breakdown of maintenance costs by service type for FY 19-20, Table 23. April through June of the FY 19-20 data period includes reduced services due to COVID restrictions; therefore, Willdan used a trendline to estimate costs for this period. If the trend resulted in negative numbers, reported values are used. The FY 19-20 dataset does not breakdown maintenance costs by vehicle type.

Table 22 – FY 18-19 Transit Maintenance Costs

Route Type	Number of Buses	Average Annual Mileage of the Fleet (miles)	Average Annual Mileage per Bus (miles)	Preventive Maintenance Cost ($)	Repair Costs ($)	Total Maintenance Cost ($)	Average Maintenance Cost per Bus ($)	Maintenance Cost per mile ($/mil)	Percentage Breakdown
Fixed Local Routes	27	848,540	31,427	$ 231,168	$ 950,234	$ 1,181,402	$ 43,756	$ 1.392	46%
Intercity Routes	21	740,475	35,261	$ 281,856	$ 864,036	$ 1,145,892	$ 54,566	$ 1.548	45%
Paratransit	12	295,808	24,651	$ 46,592	$ 181,025	$ 227,617	$ 18,968	$ 0.769	9%
Total	**60**			**$ 559,616**	**$ 1,995,295**	**$ 2,554,911**	**$ 117,290**		

Table 23 – FY 19-20 Maintenance Costs

Type of Charge	Total
In-House Repair Labor	$ 965,760.01
In-House Repair Parts	$ 667,887.15
Commercial Repair Labor	$ 205,811.12
Commercial Parts Cost	$ 317,514.38
In-House PM Labor	$ 587,019.30
In-House PM Parts	$ 108,889.85
Commercial PM Labor	$ 33,534.36
Commercial PM Parts	$ 1,789.01
In-House Accident Repair Labor	$ 15,208.71
In-House Accident Parts	$ 5,341.86
Commercial Accident Repair Labor	$ 9,014.43
Commercial Accident Repair Parts	$ 3,112.94
Upfit In-House Labor	$ -
Upfit In-House Parts	$ -
Upfit Commercial Labor	$ -
Upfit Commercial Parts	$ -
Prep for disposal In-House Labor	$ -

Fairfield repowers most of their fixed local route buses and commuter buses to extend their useful life. For the purposes of this analysis, Willdan assumed an average repower cost of $55,000 for the FLR buses, $65,000 for the commuter buses, and $80,000 every 6 years for diesel/electric hybrid FLR buses. In Willdan's cost model, repower costs are applied during year 12 of the diesel buses. No repower costs are assumed for the paratransit buses. There were no repower costs during the two fiscal years data was provided, so this will be an additional cost accounted for in the long-term forecasting. Willdan does not anticipate any repower or battery refresh costs for the BEBs since any battery replacements would be covered under the extended warranty through the 12-year EUL of the BEB.

Willdan also estimates that Fairfield would recognize cost savings by performing more maintenance work in-house. In-house labor can perform additional services due to the expected labor savings on BEB buses from reduced oil and fluid changes. Based on the maintenance facility report prepared as part of this project, the maintenance facility will need to be upgraded and expanded to properly service BEBs. The additional capacity will allow Fairfield's technicians to complete more work in-house. Fairfield has indicated that they would save approximately 40% on parts purchased in-house and 22% on maintenance labor performed in-house.

Based on FY19-20 data, based on total costs, Fairfield current performs about 80% of all maintenance and repairs in house. The remaining 20% is subcontracted out either due to capacity constraints or the need for specialized tools and labor. To estimate savings from doing more in-house maintenance and repair work with an improved maintenance facility, Willdan assumed that Fairfield would be able to perform 95% of all maintenance and repair work with the new right-sized maintenance facility. This accounts for a small percentage that would still need to be outsourced for specialized repairs. This assumption results in subcontracted maintenance costs being reduced by 74% (~20% subcontracted to 5% subcontracted). Willdan then scaled the approximate savings for expanding the maintenance facility based on the total bays added relative to this upper limit. Table 24 summarizes the different areas of maintenance cost savings in the financial analysis.

Table 24 – Summary of Maintenance Cost Reductions for BEB vs. Conventional Fuels

Areas of Maintenance Costs Savings	Percent Savings (%)
BEB Preventative Maintenance Savings	30%
BEB Repair Cost Savings	0%
BEB Accident Repair Savings	0%
Maintenance Facility Expansion 3 (Two New Bays) Subcontractor Savings	25%
Maintenance Facility Expansion 2 (Four New Bays) Subcontractor Savings	41%
Maintenance Facility Expansion 1 (New 15 Bay Facility) Subcontractor Savings	74%
Parts savings from purchasing in-house vs subcontracted	40%
Labor savings from purchasing parts in-house vs subcontracted	22%

Willdan used the FY19-20 data to establish the baseline and BEB cost data. Since this data does not account for costs by vehicle type, Willdan divided each cost type proportionally based on the split reported in FY18-19, see Table 22. Then Willdan applied the relative cost savings by converting to the BEB fleet and expanding the maintenance facility by the factors described in Table 24. Finally, Willdan estimated the cost per bus based on the quantity of each vehicle type in 2019. Average annual maintenance costs for each BEB vehicle type and the relative savings for each maintenance facility expansion option are summarized in Table 25, Table 26, and Table 27.

Table 25 – Fixed Local Route Maintenance Cost Estimates (full fleet)

Cost Category	FY 19/20 Total	Annual Forecasts with Full BEB Fleet, No Maintenance expansion	Annual Forecast with Maintenance Expansion 3 (Two New Bays)	Annual Forecast with Maintenance Expansion 2 (Four New Bays)	Annual Forecast with Maintenance Expansion 1 (New 15 Bay Facility)
In-House Repair Labor	$ 446,572	$ 446,572	$ 464,984	$ 477,259	$ 501,809
In-House Repair Parts	$ 308,834	$ 308,834	$ 337,240	$ 337,240	$ 337,240
Commercial Repair Labor	$ 95,1678	$ 95,168	$ 71,562	$ 55,825	$ 24,351
Commercial Parts Cost	$ 146,820	$ 146,820	$ 110,402	$ 86,124	$ 37,567
In-House PM Labor	$ 271,440	$ 198,934	$ 198,934	$ 198,934	$ 198,934
In-House PM Parts	$ 50,351	$ 35,676	$ 35,676	$ 35,676	$ 35,676
Commercial PM Labor	$ 15,506	$ 0	$ 0	$ 0	$ 0
Commercial PM Parts	$ 827	$ 0	$ 0	$ 0	$ 0
In-House Accident Repair Labor	$ 7,033	$ 7,033	$ 7,839	$ 8,377	$ 9,452
In-House Accident Parts	$ 2,470	$ 2,470	$ 2,749	$ 2,749	$ 2,749
Commercial Accident Repair Labor	$ 4,168	$ 4,168	$ 3,134	$ 2,445	$ 1,067
Commercial Accident Repair Parts	$ 1,439	$ 1,439	$ 1,082	$ 844	$ 368
Total	$ 1,350,629	$ 1,247,114	$ 1,233,603	$ 1,205,472	$ 1,149,211
Annual Average Total Maintenance Cost per Bus	$ 50,023	$ 46,189	$ 45,689	$ 44,647	$ 42,563
Percent Savings from FY 19/20	0%	7.66%	8.66%	10.75%	14.91%

Table 26 – Commuter Route Maintenance Cost Estimates (full fleet)

Labor Hours	FY 19/20 Total	Annual Forecasts with Full Fleet BEBs, No Maintenance expansion	Annual Forecast with Maintenance Expansion 3 (Two New Bays)	Annual Forecast with Maintenance Expansion 2 (Four New Bays)	Annual Forecast with Maintenance Expansion 1 (New 15 Bay Facility)
In-House Repair Labor	$ 433,149	$ 433,149	$ 451,008	$ 462,914	$ 486,726
In-House Repair Parts	$ 299,551	$ 299,551	$ 327,103	$ 327,103	$ 327,103
Commercial Repair Labor	$ 92,307	$ 92,307	$ 69,411	$ 54,147	$ 23,619
Commercial Parts Cost	$ 142,407	$ 142,407	$ 107,084	$ 83,535	$ 36,438
In-House PM Labor	$ 263,281	$ 192,955	$ 192,955	$ 192,955	$ 192,955
In-House PM Parts	$ 48,838	$ 34,603	$ 34,603	$ 34,603	$ 34,603
Commercial PM Labor	$ 15,040	$ 0	$ 0	$ 0	$ 0
Commercial PM Parts	$ 802	$ 0	$ 0	$ 0	$ 0
In-House Accident Repair Labor	$ 6,821	$ 6,821	$ 7,603	$ 8,125	$ 9,168
In-House Accident Parts	$ 2,396	$ 2,396	$ 2,666	$ 2,666	$ 2,666
Commercial Accident Repair Labor	$ 4,043	$ 4,043	$ 3,040	$ 2,372	$ 1,034
Commercial Accident Repair Parts	$ 1,396	$ 1,396	$ 1,050	$ 819	$ 357
Total	$ 1,310,033	$ 1,209,628	$ 1,196,523	$ 1,169,239	$ 1,114,669
Annual Average Total Maintenance Cost per Bus	$ 62,383	$ 57,601	$ 56,977	$ 55,678	$ 53,079
Percent Savings from FY 19/20		7.66%	8.66%	10.75%	14.91%

Table 27 – Paratransit Maintenance Cost Estimates (full fleet)

Labor Hours	FY 19/20 Total	Annual Forecasts with Full Fleet BEBs, No Maintenance expansion	Annual Forecast with Maintenance Expansion 3 (Two New Bays)	Annual Forecast with Maintenance Expansion 2 (Four New Bays)	Annual Forecast with Maintenance Expansion 1 (New 15 Bay Facility)
In-House Repair Labor	$ 86,040	$ 86,040	$ 89,587	$ 91,952	$ 96,682
In-House Repair Parts	$ 59,502	$ 59,502	$ 64,975	$ 64,975	$ 64,975
Commercial Repair Labor	$ 18,336	$ 18,336	$ 13,788	$ 10,756	$ 4,692
Commercial Parts Cost	$ 28,287	$ 28,287	$ 21,271	$ 16,593	$ 7,238
In-House PM Labor	$ 52,298	$ 38,328	$ 38,328	$ 38,328	$ 38,328
In-House PM Parts	$ 9,701	$ 6,874	$ 6,874	$ 6,874	$ 6,874
Commercial PM Labor	$ 2,988	$ 0	$ 0	$ 0	$ 0
Commercial PM Parts	$ 159	$ 0	$ 0	$ 0	$ 0
In-House Accident Repair Labor	$ 1,355	$ 1,355	$ 1,510	$ 1,614	$ 1,821
In-House Accident Parts	$ 476	$ 476	$ 530	$ 530	$ 530
Commercial Accident Repair Labor	$ 803	$ 803	$ 604	$ 471	$ 205
Commercial Accident Repair Parts	$ 277	$ 277	$ 209	$ 163	$ 71
Total	$260,221	$ 240,277	$ 237,674	$ 232,254	$ 221,415
Annual Average Total Maintenance Cost per Bus	$ 21,685	$ 20,023	$ 19,806	$ 19,355	$ 18,451
Percent Savings from FY 19/20	0%	7.66%	8.66%	10.75%	14.91%

Distributed Energy Resource (DER) Analysis

As the transit fleet becomes increasingly reliant on electricity for fuel, managing the source, cost, and reliability of the electricity becomes increasingly important. Onsite solar generation can be an effective way to reduce the overall cost of electricity, and battery storage can provide backup power in the event of a Public Safety Power Shutoff (PSPS) event. Utilizing carport structures can also shade the buses to improve driver comfort and reduce HVAC loads needed to keep buses cool. Willdan has modeled potential solar carport locations throughout the corporation yard to offset the load generated from the electric transit fleet, and future electrified public works fleet. As shown in Figure 8, a total of 2.67MW solar carports are potentially available at the Corporation Yard; however, most of the available carport space is on the west side of the corporation yard, while the transit buses will be moved to the east side of the corporation yard. Some of the west side carports may be used to offset electricity usage from future public works vehicles, but it does pose a potential engineering challenge to electrically connect the west side carports to the east side load. If the west and east sides are not interconnected, the east side of the corporation yard will benefit from a 910kW carport system generating approximately 1.5MWh or roughly 30% of the full BEB fleet's energy consumption needs at the Corporation Yard.

Figure 8. Potential Solar Carports at the Corporation yard

Array	Size (kW)
Array 1	167
Array 2	111
Array 3	401
Array 4	511
Array 5	110
Array 6	107
Array 7	910
Array 8	89
Array 9	100
Array 10	162
Total	**2,668**

The charging schedules are designed to minimize the cost of recharging the buses, taking advantage of off-peak periods. As a result, there are not substantial economic savings from purchasing a solar PV system outright, as shown in Table 28. Note that Table 28 is based on a 2.67MW system, which based on the first-year production of all the arrays, would offset approximately 88% of the EV transit load at the corporation yard. This is slightly larger than the 2.3 MW of solar PV envisioned in the preliminary analysis. This is the result of additional carport spaces where paratransit parking, MV employee parking, and electrical infrastructure are expected to reside. The uncovered parking in the northwest corner of the corporation yard represents another 400kW of potential solar carports; however, those potential PV arrays have been reserved to offset Fairfield's medium and heavy-duty municipal fleet once they have been electrified.

The financials of a solar PV system scale linearly with system size so a range of installation sizes above 1MW would still payback in about 15-16 years. Solar PV panels are designed to last at least 25 years, so the system is expected to pay for itself over time. Willdan's initial battery storage analysis indicates that it does not provide an economic benefit, since the charging loads are already expected to avoid peak demand periods; however, Fairfield is interested in understanding battery options for resiliency.

Table 28 – Summary of Solar and Battery Cost Savings

Parameter	Value
Annual Utility Bill (BEV2-S)	$ 687,047
Solar Size (kW DC)	2,690
Yr 1 Solar Savings	$ 547,993
BESS Savings	N/A
Yr 1 Utility Bill After PV	$ 139,054
PV System Cost	$ 10,087,500
Payback (yrs)	15.5

Beyond the direct economic benefits of a solar PV system, there are ancillary benefits to installing solar carport structures at the corporation yard. If designed appropriately, the carport structure can support charging depot boxes from the ceiling via a gantry as illustrated in Figure 9. This keeps expensive infrastructure off the ground and less likely to be damaged a bus as it is pulling in and out of the yard. Charging cables could be rolled up and kept out of the way until they are needed. This strategy can also reduce charger installation costs since the only trenching would be required up to the structure. Raceways and conduit can be run along the structure itself to avoid trenching beneath the carport and can easily accommodate the installation of additional chargers in the future.

Figure 9. Example of Depot boxes Suspended from a Gantry Structure

Another advantage of installing a comprehensive solar carport that also supports the fleet's charging infrastructure, is the upfront construction costs can be amortized in a long-term power purchase agreement (PPA). Antelope Valley Transit recently constructed a specialized bus solar canopy, with the supporting electrical infrastructure to support a full fleet of suspended chargers for no upfront cost and a blended cost of $0.19/kWh. While this is higher than the basic blended utility rates, this project strategy allows supporting infrastructure to be installed immediately without requiring upfront capital expenditures. Even with a higher PPA rate, it is likely Fairfield would still realize a net savings on fuel costs. As Fairfield works with Bennet Engineering on the final civil and electrical design for the corporation yard, it is suggested that the design account for future solar and battery storage opportunities. With Fairfield's approval, Willdan can advise Bennet on accounting for future distributed energy resources in the final site design.

Willdan sized potential resilient battery storage systems assuming a fully electrified transit fleet would need to maintain full operation. Battery storage systems are sized based on their peak discharge (kW) and total capacity (kWh). To mimic the peak load of the modelled charging profile, a battery system would need a peak discharge of 2.2MW. Battery manufactures then size the capacity based on the duration of that peak discharge needed, with a minimum capacity equal to two hours. Based on total daily loads Fairfield would need a minimum discharge duration of approximately 3 hours to back up 95% of one days' worth of load, as shown in Table 29. The table shows the estimated turnkey costs to install different resiliency systems.

Willdan simulated PSPS events over the course of a year to determine how resilient a given battery storage system would perform, factoring in daily recharge from 2.67MW of on-site solar PV throughout the year. The backup efficacy refers to what percentage of load over 24 or 48 hours the noted backup power system would be able to mitigate and maintain normal operations. A 48-hour diesel generator was also considered and is generally a lower cost option to provide multi-day backup power. A diesel generator would need to be permitted through the Bay Area Air Quality Management District and be subject to regular testing and emissions requirements.

Table 29 – Summary of Transit Fleet Resiliency Options

Resiliency Efficacy	BESS (2.2 MW)		Generator
	24 hr	48 hr	48 hr
95%	7 MWh	15 MWh	
	$ 5,950,000	$ 11,250,000	
99%	12 MWh	24 MWh	
	$ 8,625,000	$ 18,000,000	
100%	16 MWh	31 MWh	2.2 MW
	$ 2,000,000	$ 23,250,000	$ 2,355,100

The analysis in the previous table annualizes potential PSPS events. Table 30 summarizes the monthly efficacy of a 2.2MW/7MWh battery system throughout the year. The winter months tend to be less resilient because solar PV production is lower during this time of the year and may not be able to fully recharge the battery energy storage system. However, recent PSPS events tend to occur in the summer months when solar production is higher to recharge more of the battery. As a result, the solar and battery system would be expected to cover 100% of loads for 24 hours in the summer months. As a result, even slightly undersized systems may perform better in practice than an annual average may suggest. The analysis assumes the transit operations continue as normal, if Fairfield reduced operations during an extended power shutoff, the storage system would be able to provide greater resiliency.

Table 30 - Monthly 24-Hour Efficacy for a 2.2MW/7MWh Battery for a Fully Electrified Transit Fleet

Month	Resiliency Efficacy	Month	Resiliency Efficacy
January	86.8%	July	100.0%
February	91.2%	August	100.0%
March	95.6%	September	99.1%
April	97.9%	October	96.2%
May	99.6%	November	87.3%
June	100.0%	December	84.7%

Both solar PV and batteries have multiple financing options. Fairfield could purchase and own the systems outright or consider financing them through a loan or PPA. For the purposes of the cost analysis, it is assumed Fairfield would pursue a PPA to avoid upfront capital expenditures. Based on current pricing, Fairfield can expect an average solar PPA rate of approximately $0.1301/kWh that does not escalate over time for 25 years. A solar PPA would only likely offset the energy charges incurred by PG&E, but not the subscription charges since a single cloudy day in a given month would result in a demand spike, and the solar would not directly offset any overnight charging loads. The solar PPA rate would actually be greater than the average PG&E energy charge incurred at the corporation yard, but the long-term benefit is that the PPA rate would not increase over time. As a result, Fairfield would realize long term cost savings as California utilities have historically increased energy rates by over 3% per year. Based on annual solar production and subsequent degradation, Willdan assumes that solar PV would provide supply an average of 80% of the annual electricity needed by the transit buses charging at the corporation yard. The remaining 20% of energy costs would be subject to PG&E's utility rate escalation over time. No solar is assumed at any on-route charging locations.

For the battery storage system, the final cost analysis assumed that Fairfield would procure a 2.2MW/7MWh battery, which is enough to backup 95% of the transit energy needs, on average, for up to 24 hours. For this system size, Fairfield could then expect an additional PPA adder of $0.0786/kWh for a total rate of $0.2087/kWh. This rate is much more expensive than PG&E's native BEV-2 rates, but considering this would be a fixed over time, in the final years of the PPA agreement, energy costs would be at parity or slightly cheaper than PG&E's energy rates. **Even at**

this higher rate, the "fuel" costs for the electric buses would be comparable to or less than that of diesel fuel, as shown in Table 31.

Table 31 – Summary of Electric Costs for BEBs on Optimized Charge Schedule with DERs

Route	Fixed Local Routes	Paratransit	GX Line	Blue South Line	Blue North Line
Annual Average Energy Cost per Bus no DERs ($/Bus)	$ 9,651	$ 4,842	$ 30,621	$ 28,555	$ 22,944
Annual Average Energy Cost per Bus Solar PPA ($/Bus)	$ 9,951	$ 5,570	$ 32,652	$ 30,254	$ 23,564
Annual Average Energy Cost per Bus Solar and battery PPA ($/Bus)	$ 14,656	$ 7,705	$ 39,496	$ 39,496	$ 27,838
Baseline Fuel Costs ($/bus/yr)	$ 19,034	$ 8,489	$ 35,853	$ 35,853	$ 35,853
Annual "Fuel" Savings Compared to Baseline no DERs ($/bus/yr)	$ 9,384	$ 3,647	$ 5,232	$ 7,298	$ 12,910
Annual "Fuel" Savings Compared to Baseline with Solar PPA ($/bus/yr)	$ 9,083	$ 2,919	$3,201	$ 5,599	$ 12,289
Annual "Fuel" Savings Compared to Baseline with Solar and Battery PPA ($/bus/yr)	$ 4,378	$ 784	-$3,643	($ 3,643)	$ 8,015
Percent Savings by Converting to BEB (%)	49%	43%	15%	20%	36%
Percent Savings by Converting to BEB (%)	48%	34%	9%	16%	34%
Percent Savings by Converting to BEB (%)	23%	9%	-10%	-10%	22%

The solar and battery storage analysis shown above considers the load of a fully electrified transit fleet. A more optimal approach will be to phase in different carport systems as the electric transit fleet, and resulting load, grows over time. Willdan will further refine a solar PV and battery phase in schedule as part of the final master buildout plan. For the purposes of the cost analysis, it is assumed that solar and batteries would start to be installed in 2025.

Training Requirements

Willdan team member Anser has prepared a separate Training Recommendations report that describes suggested trainings for Fairfield's maintenance staff, drivers, and other support staff as the City transitions to an electric fleet.

In summary, most BEB operator and maintenance training are included in the price of the bus. Costs for supplementary training and tool lists are small relative to the cost of buses, infrastructure, electricity, and maintenance activities. In the financial analysis, Willdan assumed a nominal $5,000 per year for ongoing supplementary training in the BEB scenario.

Site Layouts and Configuration

In parallel with this report, Willdan is working with Fairfield to finalize the layout of the entire corporation yard. Willdan will help develop options for transit buses parking arrangements on the east lot, factoring in vehicle turning radii and space needs for an upgraded maintenance facility, bus wash, MV Transit trailer and staff parking, electrical infrastructure, DCFC power cabinets, a future solar carport, and future battery backup. The layout of the west lot will include reorganization of the public works fleet, employee parking, spoils yard, future solar carports and future battery backup. Final layouts will be included in the final master buildout plan.

Funding and Incentives Review

Willdan team member KKCS is preparing a standalone funding memo that identifies different sources of funding and incentives Fairfield may be able to leverage to fund the electrification process. A subset of major incentives included in Willdan's financial analysis are presented in this section.

HVIP

EV bus purchase costs account for existing rebates available through California's Hybrid and Zero-Emissions Truck and Bus Voucher Incentive Project (HVIP) program. Currently, 45' electric coach buses and 35' electric buses are eligible for a $120,000 rebate per vehicle. Paratransit vehicles are eligible for a $60,000 rebate per vehicle. As EV bus and charger technology improves and becomes more accepted in the market., we expect this program to decrease and incentives to phase out. We are assuming that the HVIP incentive for buses and chargers will decrease by 10% per year although an incentive decrease could vary substantially depending on future funding availability and the status of the technology.

Low Carbon Fuel Standard

Willdan also accounts for potential Low Carbon Fuel Standard (LCFS) credits that may be generated from operating BEBs. When the LCFS program was first implemented in 2011, it was designed to promote fleet operators to use a less carbon-intensive fuel in their vehicles, and since few vehicles were operating solely on electricity alone, electricity was not a regulated fuel source, nor subject to GHG intensity requirements. In the last number of years, as electric fleets have become more prevalent, transit operators can "opt-in" to the program and generate credits for electricity used to power zero emission vehicles. The program is currently extended up to 2030; however, given California's GHG reduction goals and the state's tendency to favor decarbonization regulations, we assume that this program will continue through 2040.

Based on data from other BEB deployments in PG&E territory, transit agencies may accrue one LCFS credit for every 1,200 kWh supplied to the buses, as determined from utility bills. Credit prices have fluctuated around $200 per credit over the past few years, though current policies cap the prices at $200 (2016 dollars) and then indexed to inflation. The maximum real credit price in 2021 is $221.67[3]. There are several factors, all changing differently over time, that will impact the actual revenue Fairfield may receive throughout the duration of the program:

1. Value of a credit over time. LCFS credit prices have generally trended upward over time, but macroeconomic changes in the market may influence the future trajectory of credit prices. At the time of this report, credit prices are below CARB's price ceiling limit; however, CARB may increase or reduce the price ceiling over time.
2. Energy needed to generate a single credit is driven by two main factors:
    a. California requirements on maximum carbon intensity allowed in fuels will be more stringent over time and require more kWh to generate a credit.
    b. The carbon intensity of the electricity in a given year is expected to decline over time and require fewer kWh to generate a credit. This factor may further incentivize on-site solar PV if it directly powers (is on the same meter as) the buses, resulting in an increase potential in LCFS credit generation.

Given the uncertainty of the potential revenue generation from LCFS, Willdan assumed the following throughout the 20-year analysis:

1. Fairfield will accrue one LCFS credit every 1,200 kWh. Willdan assumes the two carbon intensity factors determining the kWh/credit cancel themselves out.[4] This assumption is maintained even if Fairfield were to install solar PV to keep a conservative financial analysis.

[3] https://ww2.arb.ca.gov/resources/documents/lcfs-credit-clearance-market
[4] https://calevip.org/sites/default/files/docs/calevip/Low-Carbon-Fuel-Standard-Overview.pdf

2. The credit price will average $200 per unit through 2040.

PG&E's EV Fleet Program

PG&E currently offers an incentive program designed to subsidize the cost of medium and heavy-duty fleets through 2024 transitioning to electric vehicles. PG&E's EV Fleet program will cover any in front of the meter upgrade costs needed to support buses and chargers up to the meter that will be purchased, so long as at least two electric buses are purchased now and at least four total buses are purchased by 2024. The program will also provide incentives for behind the meter electrical upgrade costs based on the quantity and type of vehicles purchased through 2024. On-route charging locations can be included in the program, but each site requires an additional four buses to be purchased by 2024. The program also includes rebates on approved chargers that increase based on the maximum power output. The ABB chargers referenced previously qualify for this incentive, but on-route chargers currently do not qualify. Charger incentives are capped at up to 50% of the charger and its installation costs. Chargers and vehicles must be owned and maintained for at least 10 years to be eligible for the program. Incentive values are summarized in Table 32.

Table 32 – Summary of PG&E EV Fleet Program Incentives

Equipment Description	Incentive
Charger <50kW	$15,000 towards charger and installation
Charger 50<150kW	$25,000 towards charger and installation
Charger >150kW	$42,000 towards charger and installation
Transit Buses and Class 8 vehicles	$9,000 towards behind the meter infrastructure
Transportation refrigeration units, truck stop electrification, ground support equipment and forklifts	$3,000 towards behind the meter infrastructure
School buses, local delivery trucks, and other vehicles	$4,000 towards behind the meter infrastructure

Based on the phase in plan, a total of 19 BEBs will be purchased by 2024, which is enough to apply up for up to 4 sites: the Fairfield Corporation Yard, FTC, El Cerrito del Norte BART, and Walnut Creek BART. The actual value of the incentive may be subject to PG&E's final application approval, but maximum estimated incentives are summarized in Table 33. Incentives assume that site upgrades, and therefore, their costs and incentives, occur the year before buses are expected to need to charge at the location. Incentives assume that all on-route chargers, except the SVS station, can be captured under this program as long as the applications are carefully thought out and strategic.

Table 33 – Estimated Maximum PG&E EV Fleet Program Incentives

Year	Fixed Local Route Buses	Commuter Route Buses	Paratransit Buses	Front-of-the-Meter ($)	Behind-the-Meter ($)	Charger Incentives ($)	Total ($)
2021				$ -	$ -	$ -	
2022				$ 1,209,927	$ -	$ -	$1,209,927
2023	2	7	2	$ 75,296	$ 89,000	$ 252,000	$ 416,296
2024	3	2	3	$ 68,375	$ 57,000	$ 168,000	$ 293,375
Total	**5**	**9**	**5**	**$ 1,353,598**	**$ 146,000**	**$ 420,000**	**$1,919,598**

Solano Transportation Authority (STA)

STA has been coordinating with other operators in the region to target opportunities to share on-route charging infrastructure. STA has been coordinating with consultant WSP to design one on-route charging station at the following locations: FTC, Walnut Creek BART, El Cerrito del Norte BART, Vallejo Transit Center, and Suisun Amtrak. Fairfield should continue to work closely with STA to ensure that Fairfield's on-route charging needs can be incorporated at these locations, particularly at the FTC, El Cerrito del Norte BART, and Walnut Creek BART locations which are needed to support Fairfield's commuter routes. This may mean coordinating with STA to add in a second on-route charger dedicated for Fairfield's routes or synchronizing blocking with other local transit agencies so multiple operators can use one on-route charger.

To maintain a conservative analysis, potential STA contributions to on-route charging locations are not included in the final forecast. It is assumed that Fairfield will need to budget for these costs, less any potential PG&E Fleet EV Program incentives.

Financial Analysis and Forecast

The final cost forecast analysis estimates costs for new bus purchases starting in 2021 for a Business-as-Usual (BaU) scenario and EV scenarios. The BaU case assumes that ICT mandate does not exist, and Fairfield would continue to purchase and operate only fossil fuel powered buses through 2040. While Fairfield does not have the option to use only diesel and gasoline buses over the next 19 years, it is included as a reference so Fairfield can start budgeting for future expenditures accordingly. The EV scenarios are based on the phase in plan bus procurement and route electrification schedules previously described and are shown with and without the incentives previously mentioned. An additional scenario is shown with Fairfield procuring solar PV through a PPA. While this option would be expected to increase costs initially, it would result in long term costs savings as the bulk of the energy consumption will be at a fixed cost over time. The final scenario accounts for a solar and battery storage PPA, as a way to finance added resiliency to the corporation yard. Costs may change depending on actual procurement schedule, charging strategy implemented, future fleet size, or future route modifications. Total cumulative costs over time for the BaU and EV scenarios are calculated using the inputs and assumptions previously described and are summarized in Table 34. Table 35 summarizes how Willdan inflates or depreciates these key assumptions over time. The assumptions are generally conservative for transitioning to BEBs to present Fairfield with high end estimates on the cost of electrifying the transit fleet.

Table 34 – Summary of Key Financial Analysis Assumptions in 2020 Dollars

Description	Assumption	Cost/unit	Notes
FLR Diesel Bus	Gillig Hybrid	$ 688,737	Based on most recent purchases
Commuter Route Diesel Bus	MCI	$ 587,712	Based on most recent purchases
Paratransit Gasoline Bus	Ford F-450	$ 73,241	Based on most recent purchases
FLR Electric Bus	Proterra 35' 440kWh	$ 864,000	Includes extended battery warranty, without HVIP
Commuter Route Electric Bus	BYD CM10	$ 1,108,775	Includes extended battery warranty, and on-route charger add on, without HVIP
Paratransit Electric Bus	Lion Minibus	$ 388,260	Includes extended battery warranty, without HVIP
Transit Fleet Chargers	ABB 150KW with two depot boxes	$ 213,018	Cost includes five year warranty and installation
On-route Charger	300KW	$ 214,373	Typical cost, includes installation
Corporation Yard Infrastructure Upgrade Cost (East lot)	Full Buildout to support for 30 Dual port Chargers	$ 3,937,380	Assumes no support from PG&E, but may be subsidized by PG&E Fleet program, applied in year 2022
Fairfield Transit Center Infrastructure Upgrade Cost	To support two on-route chargers	$ 401,806	Assumes no support from PG&E, may be covered by STA improvements. 50% applied in year 2022 and 2024

Description	Assumption	Cost/unit	Notes
Del Norte BART Infrastructure Upgrade Cost	To support one on-route charger	$ 312,207	Assumes no support from PG&E, may be covered by STA improvements applied in year 2022
Walnut Creek BART Infrastructure Upgrade Cost	To support one on-route charger	$ 312,207	Assumes no support from PG&E, may be covered by STA improvements if stop is relocated to Walnut Creek, applied in year 2023
Sacramento Valley Station Infrastructure Upgrade Cost	To support one on-route charger	$ 302,448	Assumes no support from SMUD, applied in year 2032
FLR Annual Diesel Fuel Cost	N/A	$ 19,034	Based on FY18/19 data
Commuter Annual Diesel Fuel Cost	N/A	$ 35,853	Based on FY18/19 data
Paratransit Annual Gasoline Fuel Cost	N/A	$ 8,489	Based on FY18/19 data
FLR BEB Average Annual Electricity Cost	PG&E BEV-2	$ 9,651	Assumes charging schedule presented
Commuter BEB Average Annual Electricity Cost	PG&E BEV-2	$ 27,373	Assumes charging schedule presented
Paratransit Annual Electricity Cost	PG&E BEV-2	$ 4,842	Assumes charging schedule presented
FLR BEB Average Annual Electricity Cost	Solar PPA	$ 9,951	Only 20% of cost is subject to annual escalation
Commuter BEB Average Annual Electricity Cost	Solar PPA	$ 28,823	On-route and 20% of corporation yard cost is subject to annual escalation
Paratransit Annual Electricity Cost	Solar PPA	$ 5,570	Only 20% of cost is subject to annual escalation
FLR BEB Average Annual Electricity Cost	Solar + BESS PPA	$ 14,656	Only 20% of cost is subject to annual escalation
Commuter BEB Average Annual Electricity Cost	Solar + BESS PPA	$ 7,705	On-route and 20% of corporation yard cost is subject to annual escalation
Paratransit Annual Electricity Cost	Solar + BESS PPA	$ 36,717	Only 20% of cost is subject to annual escalation
Annual Maintenance Cost for Diesel FLR	N/A	$ 50,023	Based on FY 19/20 data
Annual Maintenance Cost for Diesel Commuter Bus	N/A	$ 62,383	Based on FY 19/20 data
Annual Maintenance Cost for Gasoline Paratransit	N/A	$ 21,685	Based on FY 19/20 data
Average Diesel Commuter Bus Repower Cost	N/A	$ 65,000	Applied in year 12 of diesel bus
Average Diesel FLR Bus Repower Cost	N/A	$ 82,000	Applied in year 12 of diesel bus
Annual Maintenance Cost for FLR BEB	N/A	$ 44,647	Assumes additional savings from maintenance expansion Option 2, four additional bays
Annual Maintenance Cost for Commuter BEB	N/A	$ 55,678	Assumes additional savings from maintenance expansion Option 2, four additional bays

Description	Assumption	Cost/unit	Notes
Annual Maintenance Cost for Paratransit BEB	N/A	$ 19,355	Assumes additional savings from maintenance expansion Option 2, four additional bays
Estimated LCFS Credit	N/A	$ 200	Assumes an average of 1 credit for every 1,200kWh dispensed to buses though 20240
FLR BEB HVIP Incentive	N/A	$ 120,000	Current incentive rates
Commuter BEB HVIP Incentive	N/A	$ 120,000	Current incentive rates
Paratransit BEB HVIP Incentive	N/A	$ 60,000	Current incentive rates

Table 35 – Summary of Line item Annual Escalations

Description	Value
Vehicle Cost Inflation	2.5%
Charger Cost Inflation	2.5%
Diesel and Gasoline Fuel Cost Inflation	2%
Maintenance Costs Inflation	2.5%
Depreciation in HVIP incentives	10%
PG&E Electricity Cost Inflation	3%
PPA Electricity Cost Inflation	0%

The financial analysis accounts for the annual costs associated with any newly purchased vehicles (after 2020), whether they are fossil fuel powered or EV. It excludes operating and maintenance costs of existing vehicles before they are purchased since it would be identical in both scenarios. This way, the analysis shows the differential in costs between phasing in electric vehicles versus maintaining a fossil fuel powered fleet. Chargers are purchased at the same time EVs are purchased as needed to support the fleet size at the time; however, infrastructure costs at the corporation yard and on-route charging locations are applied when the first electric buses charge at a given site. Infrastructure costs assume a full initial buildout to support BEBs and chargers procured over time. Operation and maintenance costs are cumulative year over year for all the buses purchased starting in 2020. In the Business as Usual (BaU) scenario, annual fuel and maintenance costs increase each time a new diesel bus is purchased until all existing (Pre 2020) diesel buses have been replaced, less escalation factors. This occurs in 2033, when Fairfield will have completely turned over its existing fleet. In the EV scenarios, annual fuel and maintenance costs are based on the number of BEBs and diesel buses in operation that are purchased after 2020. BEB purchases that replace previous BEB purchases do not affect the annual energy and operation costs in that year, less the escalation in electricity costs.

The financial forecast, Figure 10, illustrates five key scenarios to help Fairfield understand the financial implications of converting to an electric bus fleet: Business as Usual (BaU), Electrification without Incentives, Electrification with incentives, Electrification with incentives and a solar PPA, and Electrification with incentives with a solar and battery PPA. Table 36 summarizes the total costs through 2040 for each scenario and the key cost categories. In all cases, converting to electric buses is expected to cost more than diesel buses over time.

Under the Business-as-Usual scenario, Fairfield may spend approximately $146.5M on new capital and operating costs for diesel buses through 2040. Without any financial incentives, Fairfield may spend an additional $43M to electrify the transit fleet over 20 years, approximately 30% more than the baseline scenario. This is driven primarily from higher capital costs for BEBs, procuring chargers, and making site upgrades that would otherwise not need to be done in the baseline scenario. While Fairfield is expected to have lower fueling, maintenance, and repair costs with an electric bus fleet, these savings are not large enough to overcome the additional capital expenditures.

Factoring in the incentives previously discussed significantly bring down the total cost of electrification, but Fairfield would still be expected to spend an additional $20 million dollars more through 2040. LCFS credits are the largest source of incentives in the financial forecast, bringing the cost of electricity to nearly zero over time. LCFS is the main driver in bringing down the cost of the Electrification Scenario. If the LCFS program is not extended through 2040 or credit values fall over time incentives may only provide modest savings for the Electrification Scenario. Adding solar PV arrays in the corporation yard could save an additional $2.5M through 2040, though this is still not enough to overcome the cost differential from the Business-as-Usual scenario. While still conservative, the additional energy cost savings from solar PV and LCFS credits may result in net negative fuel costs, where the LCFC credits are worth more than the total energy spend. This does not account for potentially faster credit generation by sourcing a greater percentage of carbon free electricity. Adding battery storage to the electrification scenario increases total costs by about $1.5M through 2040, but the primary benefit is providing resiliency to the site.

Table 36 – Summary of Key Costs Through 2040 in Financial Forecast

Scenario	Bus Purchase Costs ($M)	Charger Costs ($M)	Infrastructure and Site Upgrade Costs ($M)	Fuel Costs ($M)	Maintenance and Repair Costs ($M)	Other Ongoing Costs ($M)	Total ($M)	Difference from BaU ($M)	Difference from BaU (%)
Business as Usual (BaU)	$ 64.43	$ -	$ -	$ 24.42	$ 57.66	$ -	$ 146.51	$ -	0%
Electrification without Incentives	$ 102.39	$ 9.01	$ 11.13	$ 8.11	$ 49.13	$ 0.10	$ 189.87	$ 43.36	30%
Electrification with Incentives	$ 98.61	$ 8.59	$ 9.60	$ 0.17	$ 49.13	$ 0.10	$ 166.21	$ 19.69	13%
Electrification with Incentives and Solar PPA	$ 98.61	$ 8.59	$ 9.60	$(2.36)	$ 49.13	$ 0.10	$ 163.68	$ 17.17	12%
Electrification with Incentives and Solar + Battery PPA	$ 98.61	$ 8.59	$ 9.60	$ 1.60	$ 49.13	$ 0.10	$ 167.64	$ 21.13	14%

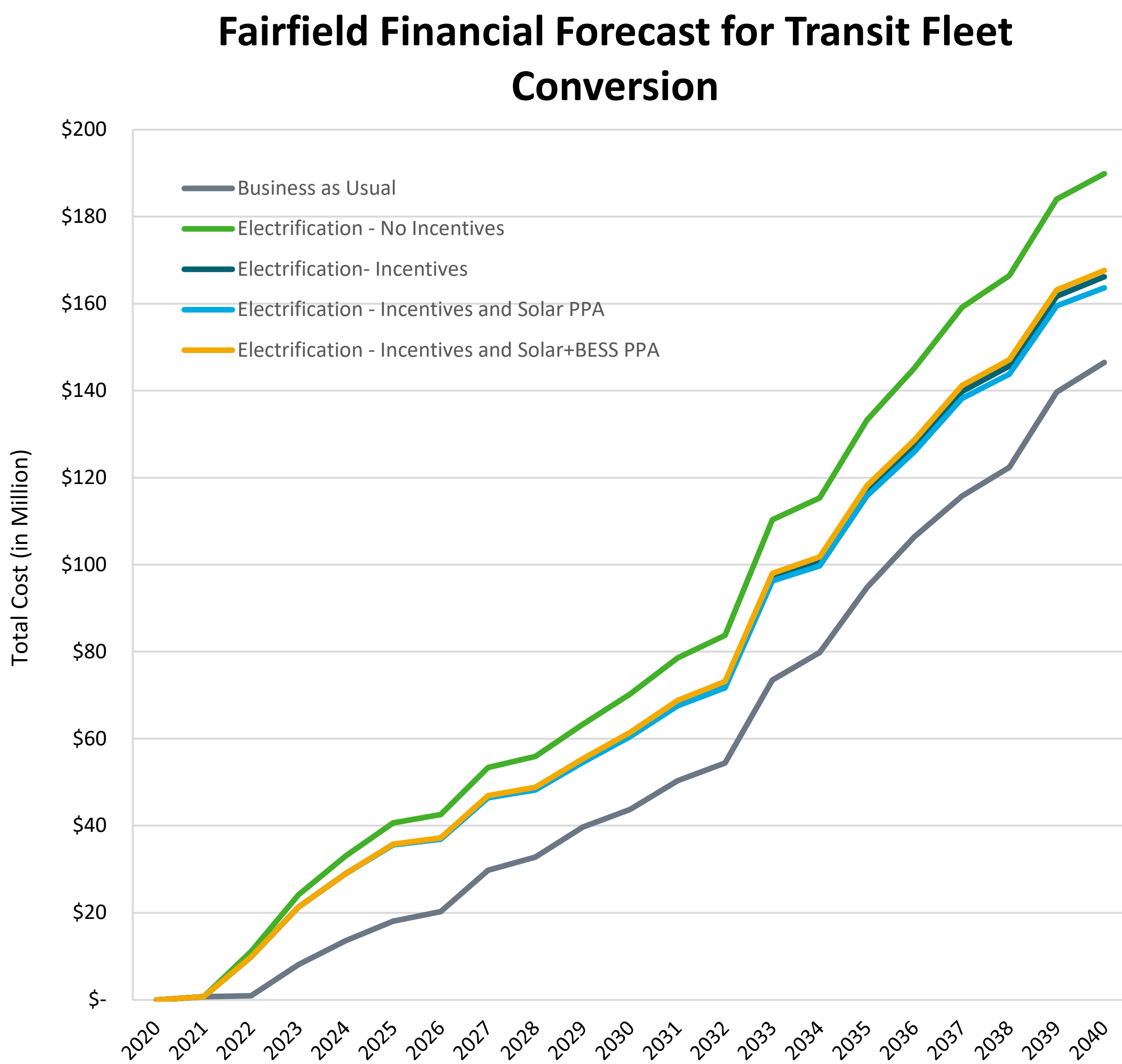


Figure 10. Financial Forecast through 2040

Conclusion

Willdan completed a detailed, conservative analysis of the key cost factors for Fairfield to transition to an electric fleet. Overall, it is expected that electrifying the transit fleet will be more expensive than continuing to operate a diesel fleet, but available incentive programs can help bring the total costs down over time. Operating costs are expected to decrease overall, so if Fairfield can secure outside funding for most of the capital costs, Fairfield stands to realize cost savings over time. The financial analysis was based on the FLR and commuter route buses Fairfield is likely to purchase for its pilot deployment and assumes those OEMs are used through 2040. The analysis assumes an optimized charging schedule that focuses on charging buses midday and overnight when energy rates are lowest. After Fairfield operates the pilot buses, route modelling, energy costs, maintenance costs, and repair costs can be compared against this analysis and refined to inform future financial forecasting.

Aside from costs, several changes must also be made to Fairfield's existing operations to successfully operate an electric transit fleet such as retrofitting the maintenance facility, splitting up the Blue Line into two routes, and incorporating maintenance and repair work within gaps in bus charging schedules. Fairfield may need to train or hire specialized mechanics that service electric buses, and drivers will need to be trained on how to drive the buses most efficiently and how to properly use the chargers.

Appendices

Appendix A – Fleet Replacement Plan

Table 37 – Fleet Replacement Plan through 2040

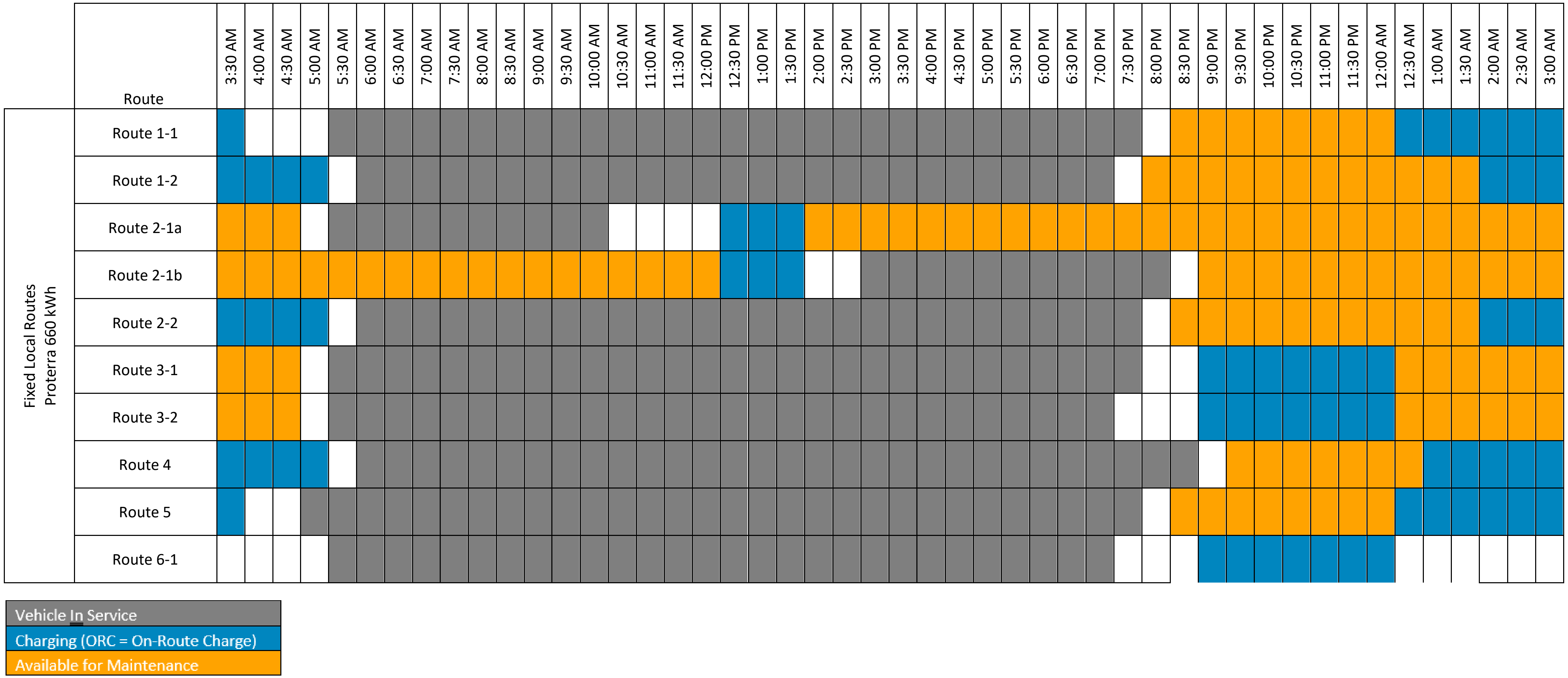
Bus Number	Make	Use Type	Model Year	Fairfield Planned Year of Retirement	Fairfield Planned Retirement Age (years)	Willdan Proposed Year of Retirement	Willdan Proposed Retirement Age (years)	Comments	Willdan Proposed 2nd Replacement	Willdan Proposed 3rd Replacement
7708	Ford	Paratransit	2007	FY 14/15	8	2021	14	Replace with gas paratransit, electric in 2030	2030	2037
7709	Ford	Paratransit	2007	FY 14/15	8	2021	14	Replace with gas paratransit, electric in 2030	2030	2037
11700	Ford	Paratransit	2011	FY 18/19	8	2021	10	Replace with gas paratransit, electric in 2030	2030	2037
11703	Ford	Paratransit	2011	FY 18/19	8	2021	10	Replace with gas paratransit, electric in 2030	2030	2037
11704	Ford	Paratransit	2011	FY 18/19	8	2021	10	Replace with gas paratransit, electric in 2030	2030	2037
14701	Ford	Paratransit	2014	FY 20/21	7	2023	9	Phase 1 in East Lot	2030	2037
14702	Ford	Paratransit	2014	FY 20/21	7	2024	10	Phase 2 in East Lot	2031	2038
16705	Ford	Paratransit	2016	FY 22/23	7	2024	8	Phase 2 in East Lot	2031	2038
16706	Ford	Paratransit	2016	FY 22/23	7	2024	8	Phase 2 in East Lot	2031	2038
16707	Ford	Paratransit	2016	FY 22/23	9	2025	9	Assume 9 yr useful life before first replacement	2032	2039
16708	Ford	Paratransit	2016	FY 22/23	9	2025	9	Assume 9 yr useful life before first replacement	2032	2039
16709	Ford	Paratransit	2016	FY 22/23	9	2025	9	Assume 9 yr useful life before first replacement	2032	2039
647	Gillig	Fixed Local Route	2002	FY 18/19	17	2021	19	Replace with gas paratransit, electric in 2030	2030	2037
648	Gillig	Fixed Local Route	2002	FY 18/19	17	2023	21	Phase 1 in East Lot	2035	N/A
649	Gillig	Fixed Local Route	2002	FY 18/19	17	2023	21	Phase 1 in East Lot	2035	N/A
650	Gillig	Fixed Local Route	2002	FY 18/19	17	2024	22	Phase 2 in East Lot	2036	N/A
651	Gillig	Fixed Local Route	2002	FY 18/19	17	2024	22	Phase 2 in East Lot	2036	N/A
652	Gillig	Fixed Local Route	2002	FY 18/19	17	2024	22	Phase 2 in East Lot	2036	N/A
653	Gillig	Fixed Local Route	2002	FY 18/19	17	2027	20	Assume 25 yr useful life before 1st replacement	2039	N/A

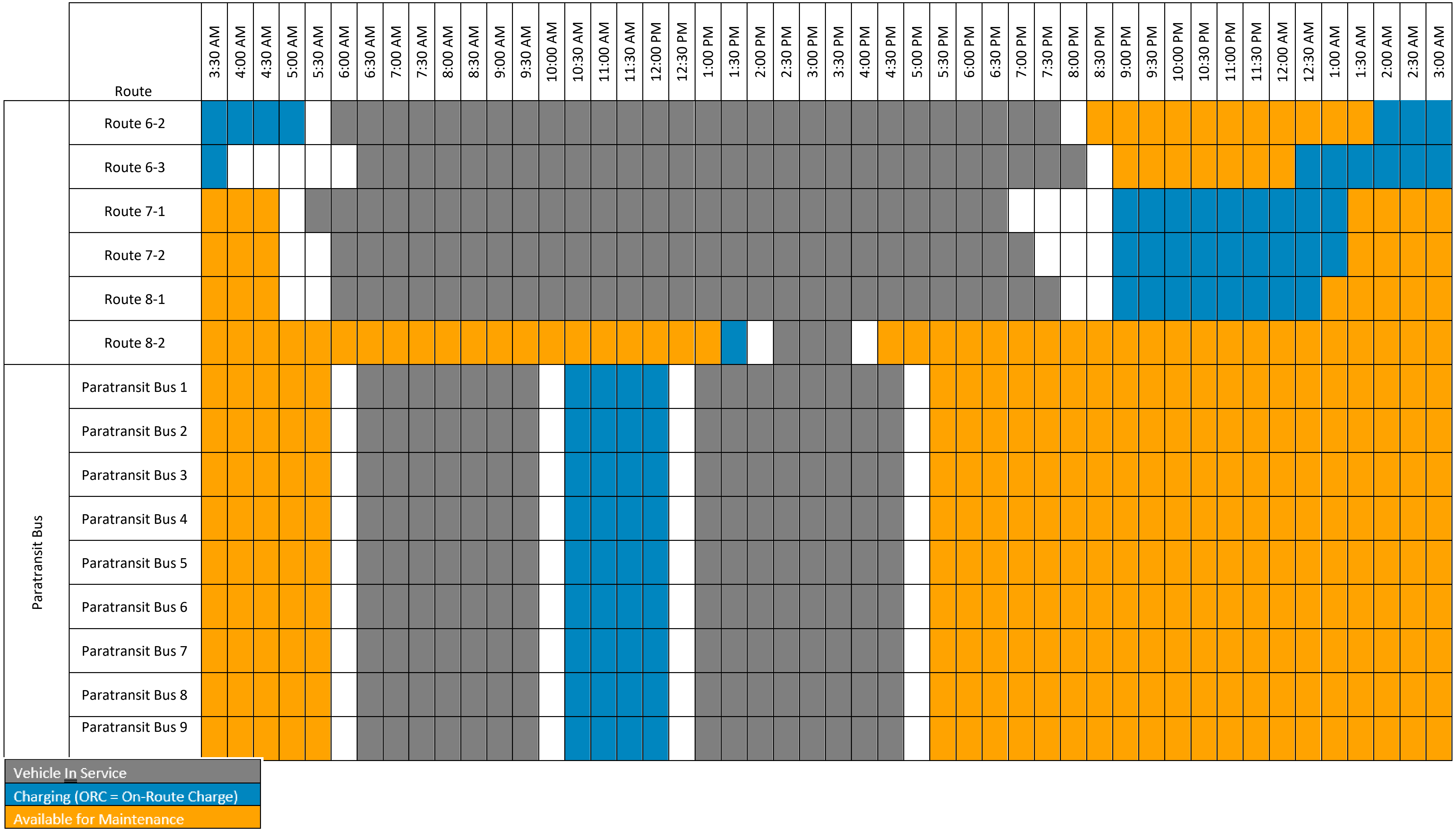
Bus Number	Make	Use Type	Model Year	Fairfield Planned Year of Retirement	Fairfield Planned Retirement Age (years)	Willdan Proposed Year of Retirement	Willdan Proposed Retirement Age (years)	Comments	Willdan Proposed 2nd Replacement	Willdan Proposed 3rd Replacement
7620	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7621	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7622	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7623	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7629	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7630	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
7633	Gillig	Fixed Local Route	2007	FY 19/20	13	2027	20	Assume 20 yr useful life before 1st replacement	2039	N/A
9636	Gillig	Fixed Local Route	2009	FY 22/23	14	2029	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
9625	Gillig	Fixed Local Route	2009	FY 22/23	14	2029	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
9626	Gillig	Fixed Local Route	2009	FY 22/23	14	2029	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
9635	Gillig	Fixed Local Route	2009	FY 22/23	14	2029	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
11631	Gillig	Fixed Local Route	2011	FY 23/24	13	2031	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
11632	Gillig	Fixed Local Route	2011	FY 23/24	13	2031	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
11645	Gillig	Fixed Local Route	2011	FY 23/24	13	2031	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
13640	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
13641	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
13642	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A

Bus Number	Make	Use Type	Model Year	Fairfield Planned Year of Retirement	Fairfield Planned Retirement Age (years)	Willdan Proposed Year of Retirement	Willdan Proposed Retirement Age (years)	Comments	Willdan Proposed 2nd Replacement	Willdan Proposed 3rd Replacement
13643	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
13644	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
13654	Gillig	Fixed Local Route	2013	FY 24/25	12	2033	20	Assume 20 yr useful life before 1st replacement	N/A	N/A
3668	Gillig	Commuter Route	2003	Indefinite	N/A	2023	20	Phase 1 in East Lot	2035	N/A
3669	Gillig	Commuter Route	2003	Indefinite	N/A	2023	20	Phase 1 in East Lot	2035	N/A
684	MCI	Commuter Route	2003	FY 19/20	17	2023	20	Phase 1 in East Lot	2035	N/A
670	MCI	Commuter Route	2003	FY 21/22	19	2023	20	Phase 1 in East Lot	2035	N/A
671	MCI	Commuter Route	2003	FY 21/22	19	2023	20	Phase 1 in East Lot	2035	N/A
672	MCI	Commuter Route	2003	FY 21/22	19	2023	20	Phase 1 in East Lot	2035	N/A
673	MCI	Commuter Route	2003	FY 21/22	19	2023	20	Phase 1 in East Lot	2035	N/A
674	MCI	Commuter Route	2003	FY 21/22	19	2024	21	Phase 2 in East Lot	2036	N/A
675	MCI	Commuter Route	2003	FY 22/23	20	2024	21	Phase 2 in East Lot	2036	N/A
676	MCI	Commuter Route	2003	FY 22/23	20	2025	22	Extend useful life until funding is available to replace	2037	N/A
677	MCI	Commuter Route	2003	FY 22/23	20	2025	22	Extend useful life until funding is available to replace	2037	N/A
678	MCI	Commuter Route	2003	FY 22/23	20	2025	22	Extend useful life until funding is available to replace	2037	N/A
18679	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18680	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18681	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18682	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18683	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18685	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18686	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18687	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A
18688	MCI	Commuter Route	2018	FY 32/33	15	2033	15	No change	N/A	N/A

Appendix B Charging Schedules

Table 38 – Charging Schedule by Route

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4:00 AM
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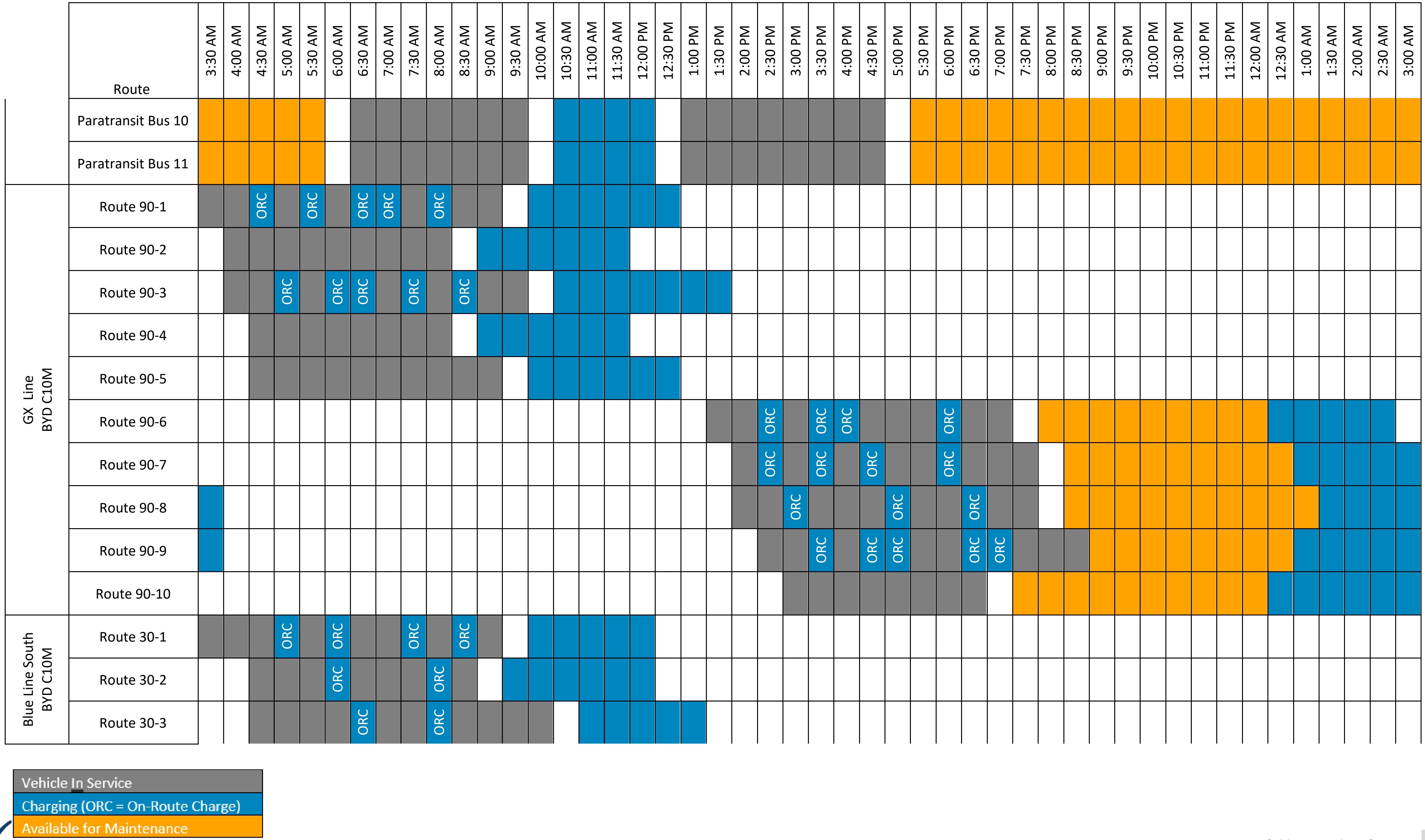
Route 6-2
Route 6-3
Route 7-1
Route 7-2
Route 8-1
Route 8-2
Paratransit Bus
Paratransit Bus 1
Paratransit Bus 2
Paratransit Bus 3
Paratransit Bus 4
Paratransit Bus 5
Paratransit Bus 6
Paratransit Bus 7
Paratransit Bus 8
Paratransit Bus 9
Vehicle In Service
Charging (ORC = On-Route Charge)
Available for Maintenance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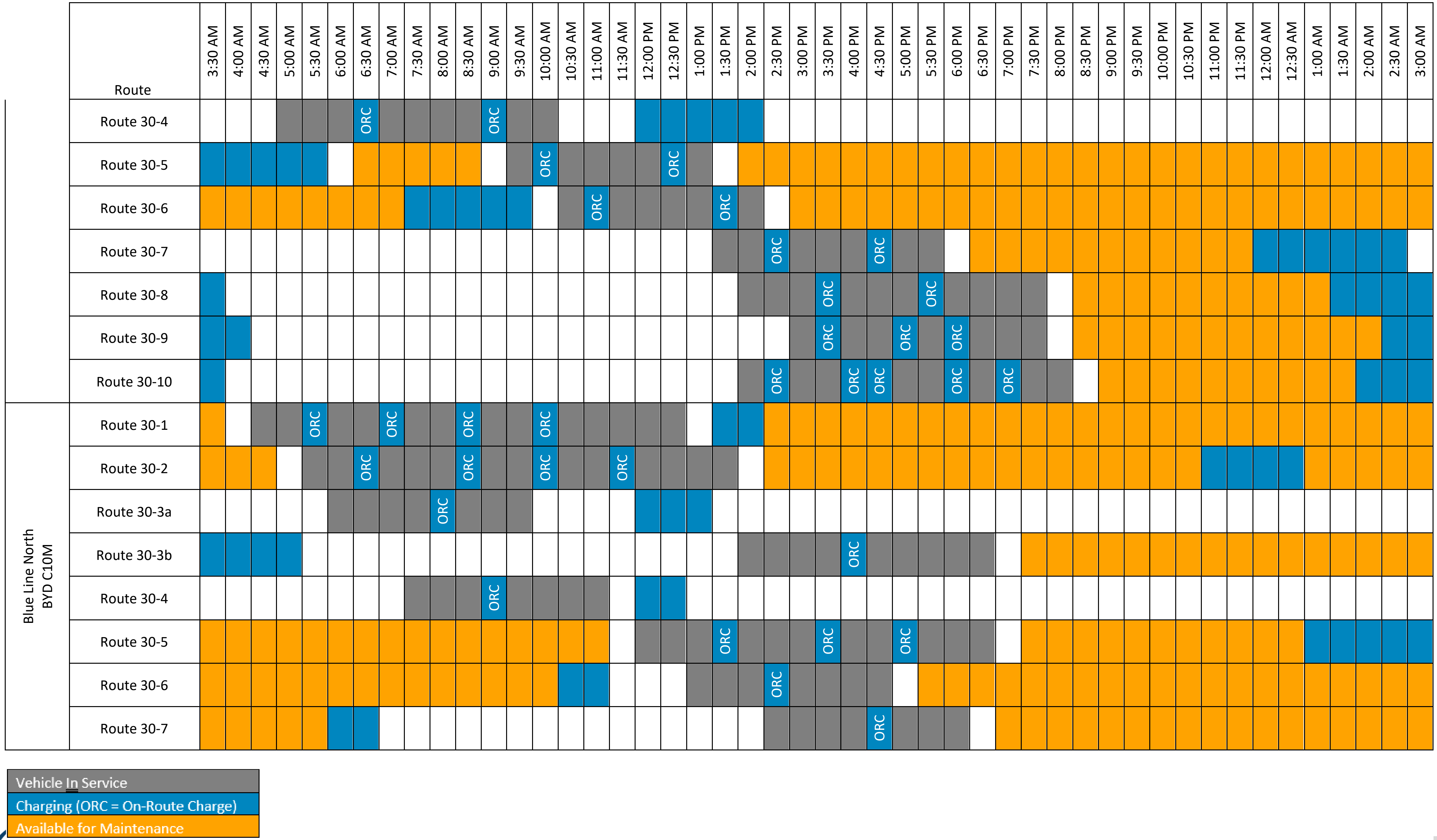
Paratransit Bus 10
Paratransit Bus 11
GX Line
BYD C10M
Route 90-1
Route 90-2
Route 90-3
Route 90-4
Route 90-5
Route 90-6
Route 90-7
Route 90-8
Route 90-9
Route 90-10
Blue Line South
BYD C10M
Route 30-1
Route 30-2
Route 30-3
ORC
Vehicle In Service
Charging (ORC = On-Route Charge)
Available for Maintenance


Route
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4:00 AM
4:30 AM
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Route 30-4
Route 30-5
Route 30-6
Route 30-7
Route 30-8
Route 30-9
Route 30-10
Blue Line North
BYD C10M
Route 30-1
Route 30-2
Route 30-3a
Route 30-3b
Route 30-4
Route 30-5
Route 30-6
Route 30-7
ORC
Vehicle In Service
Charging (ORC = On-Route Charge)
Available for Maintenance

Table 39 – Charging Schedule by Charger

												Super OFF Peak														Peak Hours																						
Charger	3:30 AM	4:00 AM	4:30 AM	5:00 AM	5:30 AM	6:00 AM	6:30 AM	7:00 AM	7:30 AM	8:00 AM	8:30 AM	9:00 AM	9:30 AM	10:00 AM	10:30 AM	11:00 AM	11:30 AM	12:00 PM	12:30 PM	1:00 PM	1:30 PM	2:00 PM	2:30 PM	3:00 PM	3:30 PM	4:00 PM	4:30 PM	5:00 PM	5:30 PM	6:00 PM	6:30 PM	7:00 PM	7:30 PM	8:00 PM	8:30 PM	9:00 PM	9:30 PM	10:00 PM	10:30 PM	11:00 PM	11:30 PM	12:00 AM	12:30 AM	1:00 AM	1:30 AM	2:00 AM	2:30 AM	3:00 AM
Charger 1																																																
Charger 2																																																
Charger 3																																																
Charger 4																																																
Charger 5																																																
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Charger 11																																																
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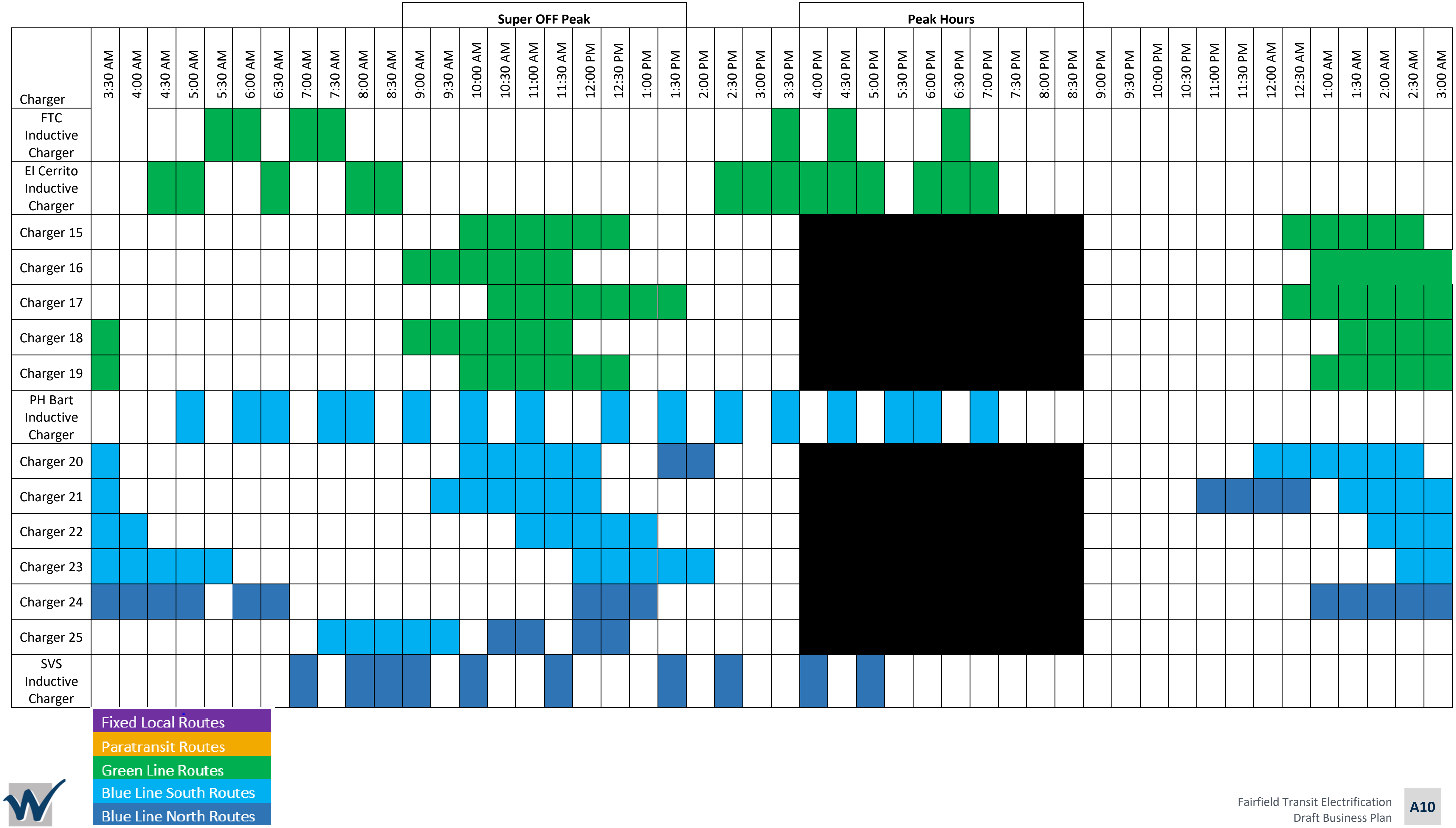
Fixed Local Routes
Paratransit Routes
Green Line Routes
Blue Line South Routes
Blue Line North Routes


Super OFF Peak
Peak Hours
Charger
3:30 AM
4:00 AM
4:30 AM
5:00 AM
5:30 AM
6:00 AM
6:30 AM
7:00 AM
7:30 AM
8:00 AM
8:30 AM
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3:00 AM
FTC Inductive Charger
El Cerrito Inductive Charger
Charger 15
Charger 16
Charger 17
Charger 18
Charger 19
PH Bart Inductive Charger
Charger 20
Charger 21
Charger 22
Charger 23
Charger 24
Charger 25
SVS Inductive Charger
Fixed Local Routes
Paratransit Routes
Green Line Routes
Blue Line South Routes
Blue Line North Routes

												Super OFF Peak												
Charger	3:30 AM	4:00 AM	4:30 AM	5:00 AM	5:30 AM	6:00 AM	6:30 AM	7:00 AM	7:30 AM	8:00 AM	8:30 AM	9:00 AM	9:30 AM	10:00 AM	10:30 AM	11:00 AM	11:30 AM	12:00 PM	12:30 PM	1:00 PM	1:30 PM	2:00 PM	2:30 PM	3:00 PM
FTC Inductive Charger																								
# of Chargers Connected	12	8	8	8	3	4	4	2	3	5	5	5	4	9	19	21	20	20	10	6	8	2	3	1
Load (kW)	1800	1200	1305	1410	660	915	915	510	660	1170	1170	960	600	1665	1860	2265	2115	2010	1605	900	1410	300	765	255

		Peak Hours																						
Charger	3:30 PM	4:00 PM	4:30 PM	5:00 PM	5:30 PM	6:00 PM	6:30 PM	7:00 PM	7:30 PM	8:00 PM	8:30 PM	9:00 PM	9:30 PM	10:00 PM	10:30 PM	11:00 PM	11:30 PM	12:00 AM	12:30 AM	1:00 AM	1:30 AM	2:00 AM	2:30 AM	3:00 AM
FTC Inductive Charger																								
# of Chargers Connected	4	3	4	3	1	3	2	2	0	0	0	6	6	6	6	7	7	7	9	10	11	14	17	14
Load (kW)	1020	765	1020	765	255	765	510	510	0	0	0	900	900	900	900	1050	1050	1050	1350	1500	1650	2100	2550	2100

- Fixed Local Routes
- Paratransit Routes
- Green Line Routes
- Blue Line South Routes
- Blue Line North Routes

SOLANO TRANSPORTATION AUTHORITY

COUNTYWIDE ELECTRIFICATION TRANSITION PLAN

APPENDIX H: SOLANOEXPRESS SERVICE MODELING

Solano Transportation Authority

When the FAST's *Fleet Electrification Final Business Plan Report* (Report) and the STA *Countywide Electrification Transition Plan* (Plan) were developed, FAST exclusively operated the SolanoExpress' Blue (B) and Green Express (GX) lines and SolTrans operated the SolanoExpress' Red (R), Yellow (Y), and 82 lines. The FAST Report analyzed the energy requirements and feasibility of the Blue and Green lines; whereas, the modeling of SolTrans' SolanoExpress lines were not included in the analysis of the STA Plan. To gather a better understanding of the viability of electrifying SolTrans-operated SolanoExpress lines, the WSP team reviewed the FAST Report and applied the modeling methodology to the Red, Yellow, and 82 lines.

Table 1 summarizes the assumptions that were made to perform this modeling based on those listed in the FAST Report.

Table 1. Assumptions

Vehicle	Battery Capacity (kWh)	Summer Efficiency (kWh/mi)	Winter Efficiency (kWh/mi)	Charger rating (kW)	Minimum SOC (%)
BYD CM10	466	2.4	2.6	300	20%

Block-level data was based on August 2021 service. The analysis applied a 20% minimum SOC to determine a block's viability without on route charging. If on route charging was deemed necessary, the analysis determined the amount of charging time required to maintain a 20% SOC. Table 2 summarizes the block-by-block analysis.

Table 2. August 2021 Weekday

Route	Block ID	Summer Final SOC (%)	Winter Final SOC (%)	On-Route Charger Required?	Maximum Charge time on Route (hr:mm)	Minimum Charge Time Required	Charging Time Constraint
82	3016	29%	23%	No	0:21	0:00	NO
82	3017	62%	59%	No	0:17	0:00	NO
82	3018	62%	59%	No	0:17	0:00	NO
R	3001	-13%	-22%	Yes	0:10	0:29	YES
R	3002	-22%	-33%	Yes	0:30	0:37	YES
R	3003	-1%	-9%	Yes	0:30	0:18	NO
R	3004	17%	10%	Yes	0:30	0:02	NO
R	3005	78%	76%	No	0:21	0:00	NO
R	3006	-40%	-51%	Yes	0:30	0:53	NO
R	3007	-40%	-51%	Yes	0:34	0:53	YES
R	3008	-58%	-71%	Yes	0:30	1:09	YES
R	3009	-30%	-40%	No	0:30	0:44	YES
R	3010	78%	76%	No	0:21	0:00	NO
R	3011	78%	76%	No	0:21	0:00	NO
Y	3012	-18%	-28%	Yes	0:21	0:33	YES

Based on the analysis, several blocks require some level of opportunity charging. The 82-serving blocks appear to be sufficient with only depot-level charging; however, the Red and Yellow lines require some level of opportunity charging.