Zero-Emission Bus Rollout Plan

Prepared for:

CALIFORNIA AIR RESOURCES BOARD

Prepared By:

wsp

SFMTA

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Acronyms & Abbreviations

BEB	Battery Electric Bus
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CNG	Compressed Natural Gas
DAC	Disadvantaged Community
dHEB	Diesel-Hybrid Electric Bus
FCEB	Fuel Cell Electric Bus
ICEB	Internal Combustion Engine Bus
ICT	Innovative Clean Transit
kW(h)	Kilowatt (hour)
MME	Muni Metro East
O&M	Operations & Maintenance
OCS	Overhead Catenary System
PG&E	Pacific Gas & Electric
RNG	Renewable Natural Gas
SMR	Steam-Methane Reform
SFPUC	San Francisco Public Utilities Commission
SFMTA	San Francisco Municipal Transportation Agency
FTA	Federal Transit Administration
WDT	Wholesale Distribution Tariff
ZE	Zero-Emission
ZEB	Zero-Emission Bus

1 Rollout Plan Summary

Agency Background	
Transit Agency's Name	San Francisco Municipal Transportation Agency
Mailing Address	1 S. Van Ness Avenue San Francisco, CA 94105
Transit Agency's Air District	Bay Area Air Quality Management District
Transit Agency's Air Basin	San Francisco
Total number of Buses in Annual Maximum Service	680[1]
Urbanized Area	San Francisco - Oakland
Population of Urbanized Area	3,557,982[2]
Contact information of general manager, chief operating officer, or equivalent	Jeffrey Tumlin Director of Transportation 415.646.2522 jeffrey.tumlin@sfmta.com
Rollout Plan Content	
Is your transit agency part of a Joint Group[3]	No
Is your transit agency submitting a separate Rollout Plan specific to your agency, or will one Rollout Plan be submitted for all participating members of the Joint Group?	N/A
Please provide a complete list of the transit agencies that are members of the Joint Group (optional)	N/A
Contact information of general manager, chief operating officer, or equivalent staff member for each participating transit agency member	N/A
Does Rollout Plan have a goal of full transition to ZE technology by 2040 that avoids early retirement of conventional transit buses?	Yes
Rollout Plan Development and Approval	
Rollout Plan's approval date	03.18.21
Resolution No.	XXXX
Is copy of Board-approved resolution attached to the Rollout Plan?	Yes (Appendix A)
Contact for Rollout Plan follow-up questions	Bhavin Khatri, PE, PMP Zero Emission Program Manager 415.646.2586 bhavin.khatri@sfmta.com
Who created the Rollout Plan?	Consultant
Consultant	WSP

[1] This is based on January 2020 (pre-COVID) service.
[2] ACS 2019 (https://censusreporter.org/profiles/40000US78904-san-francisco-oakland-ca-urbanized-area/)
[3] The ICT regulation defines a Joint ZEB Group or Joint Group (13 CCR § 2023.2) as two or more transit agencies that choose to form a group to comply collectively with the ZEB requirements of section 2023.1 of the ICT regulation.

2 Introduction

In accordance with the California Air Resource Board's (CARB) Innovative Clean Transit regulation (ICT regulation), the following report serves as the San Francisco Municipal Transportation Agency's (SFMTA) Rollout Plan to transition its bus fleet to 100% zero-emission (ZE) by 2040.

2.1 Background

2.1.1 California Air Resource Board's Innovative Clean Transit Regulation

Effective October 1, 2019, the ICT regulation requires all public transit agencies in the state to transition from internal combustion engine buses (ICEBs) to zero-emission buses (ZEBs), such as battery-electric (BEB) or fuel cell electric (FCEB), by 2040. The regulation requires a progressive increase of an agency's new bus purchases to be ZEBs based on its fleet size.

To ensure that each agency has a strategy to comply with the 2040 requirement, the ICT regulation requires each agency, or a coalition of agencies, to submit a ZEB Rollout Plan before purchase requirements take effect. The Rollout Plan is considered a living document and is meant to guide the implementation of ZEB fleets and help transit agencies work through many of the potential challenges and explore solutions. Each Rollout Plan must include several required components and must be approved by the transit agency's governing body through the adoption of a resolution, prior to submission to CARB.

According to the ICT regulation, each agency's requirements are based on its classification as either a "Large" or "Small" transit agency. The ICT defines a Large Transit Agency as an agency that operates in the South Coast or the San Joaquin Valley Air Basin and operates more than 65 buses in annual maximum service or it operates outside of these regions, but in an urbanized area with a population of at least 200,000 and has at least 100 buses in annual maximum service. A Small Transit Agency is an agency that doesn't meet the above criteria.

The SFMTA, as a Large Transit Agency must comply with the following requirements:

July 1, 2020 – Board of Directors (Board) approved Rollout Plan must be submitted to CARB

January 1, 2023 – 25% of all new bus purchases must be ZE

January 1, 2026 – 50% of all new bus purchases must be ZE

January 1, 2029 – 100% of all new bus purchases must be ZE

January 1, 2040 – 100% of fleet must be ZE

March 2021 – **March 2050** – Annual compliance report due to CARB

Due to the impacts of COVID-19, the SFMTA requested and was granted an extension for the submission of the Rollout Plan to March 31, 2021. The purpose of this request was to ensure that critical items such as the SFMTA's direction and decisions on trolley buses, yard rebuilds, and future funding were included in the analysis to define the framework of its ZEB transition more accurately.

2.1.2 Zero-Emission Bus Technologies

According to the ICT regulation, a ZEB is a bus with zero tailpipe emissions and is either a BEB or a FCEB. The following subsections provide a brief overview of each technology and how they compare to ICEBs. While both BEB and FCEB technologies provide ZE benefits, the feasibility and viability of their application is largely based on an agency's service and operational parameters. The following provides a brief overview of BEB and FCEB technologies.

Battery-Electric Buses (BEBs)

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.

BEB charging technology exists to charge vehicles 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). The most common dispensers in the U.S. market are plug-in and pantographs, as presented in Figure 2-1.

Figure 2-1. Plug-In and Pantograph Charging

Sources: YorkMix (Left) and ABB (formerly ASEA Brown Boveri) (Right)

Under existing conditions, BEBs cannot meet the ranges that ICEBs can. BEBs typically have a range of 125-150 miles, which is highly dependent on a myriad of factors, including climate, driving behavior, and topography. For this reason, if an agency's service blocks cannot be completed with BEBs, other capital-intensive strategies may be needed 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 FCEBs.

Fuel Cell Electric Buses (FCEBs)

FCEBs can typically replace ICEBs at a 1:1 replacement ratio without significant changes to operations and service. A FCEB uses hydrogen and oxygen to produce electricity through an electrochemical reaction to power the propulsion system and auxiliary equipment. This ZE process has only water vapor as a byproduct. The fuel cell is generally used in conjunction with a battery, which supplements the fuel cell's power during peak loads and stores electricity that is recaptured through regenerative braking, allowing for better fuel economy.

The process, operations, and equipment used to refuel hydrogen buses is similar to "lighter-than-air" fuels such as compressed natural gas (CNG). Typically, hydrogen is produced via steam-methane reform (SMR) or electrolysis. SMR, the most common method of producing hydrogen, uses high-pressure steam to produce hydrogen from a methane source, such as natural gas. Electrolysis, on the other hand, uses an electric current to decompose water into hydrogen and oxygen. After the hydrogen is produced, it can be delivered to the site via pipeline or delivered by a truck (as either a gas or liquid). Hydrogen is then stored, compressed, and dispensed to the buses on-site. Depending on space availability and resources, some agencies can produce hydrogen on-site.

Some of the most pressing challenges for FCEB operations is the limited supply network and the amount of energy, space, and high capital costs required to isolate, compress, and store hydrogen. Also, if renewable natural gas (RNG) - such as methane capture from organic matter – is not used as an alternative to natural gas via SMR operations, there are some concerns that FCEBs may not be the most sustainable vehicle to achieve GHG targets.

2.1.3 ZEB Suitability for the SFMTA's Service and Operations

The choice between adopting BEBs or FCEBs is contingent on the unique needs and conditions of an agency. Several variables need to be factored into this decision, including costs associated with bus acquisitions and associated infrastructure, spatial requirements, energy/fuel costs, and community acceptance. Based on existing conditions and the stated variables, BEBs appear to be the most suitable technology for the SFMTA to meet the requirements of the ICT regulation. The following provides a brief summary of the main findings of this analysis:

BEBs are more affordable than FCEBs at this time. There are barriers to entry for both BEBs and FCEBs, with both technologies exceeding the cost ICEBs. However, BEBs have achieved better economies of scale and are currently significantly less expensive than FCEBs.

The SFMTA's bus facilities are too space-constrained to accommodate FCEB-supporting infrastructure. Infrastructure to support BEBs (charging cabinets, dispensers, and associated utility equipment) can all be contained within the SFMTA's yard (either elevated or ground-mounted). In contrast, the infrastructure required for FCEBs (storage tanks, dispensers, etc.) requires a large footprint due to sizing and the National Fire Protection Association's (NFPA) required buffers. For example, a 15,000-gallon vertical hydrogen storage tank has a footprint of approximately 40 by 50 feet (not including the fueling island). This same tank would need to be located at least 75 feet from all air intakes, 50 feet from liquid or gas lines, and at least 25 feet from public ways, railroads, and property lines due to NFPA requirements. With the SFMTA's yards already being space-constrained in an urban environment, the SFMTA would risk losing a lot of potential bus parking – assuming that the infrastructure complies with NFPA requirements.

The SFMTA's existing rates for electricity are very competitive. With exceptionally low energy costs, powering BEBs is expected to be significantly less expensive than supplying hydrogen via liquid delivery. Hydrogen costs currently average around $8/kg and can have wide variability depending on local production supply and distance from the chosen supplier.

Hydrogen operations in the SF's dense neighborhoods may be a barrier to public acceptance. BEBs are widely accepted by communities and supported in terms of sustainability initiatives by both cities and transit agencies alike. This is in large part due to near or zero local emissions and quiet operations. Communities are generally more cautious with the installation of hydrogen storage near their community due to the risk of hydrogen seepage and combustion. When located near urban or residential areas, significant stakeholder outreach is often required to garner support for on-site hydrogen storage. With the majority of the SFMTA's yards located in urban regions, adoption of hydrogen may result in community pushback and potential delays in rollout.

2.1.4 San Francisco Municipal Transportation Agency

The SFMTA is a department of the City and County of San Francisco. The SFMTA plans and operates bus, rail, historic streetcar, cable car, and paratransit transit service within the City and County of San Francisco. In addition, the SFMTA also manages parking, traffic, bicycling, walking, and taxis in the city. Prior to the COVID-19 pandemic, the SFMTA provided approximately 726,000 weekday and 220 million annual passenger boardings.[4] 71% of these boardings — 520,000 per weekday and over 156 million annually — occurred on 76 weekday bus routes. Ridership from 654,300 weekday boardings in FY06 to 726,100 in FY16.[5]

Service Area

The SFMTA serves approximately 49 square miles within the City and County of San Francisco (Figure 2-2). San Francisco has added over 78,000 residents and over 175,000 jobs since 2009, and now has a population of 883,000 and 720,000 total jobs.[6]

Utility Provider

The San Francisco Public Utilities Commission (SFPUC) provides electrical service for the SFMTA service area by way of Pacific Gas & Electric (PG&E) electrical infrastructure. The SFPUC operates Hetch Hetchy Power, a Publicly Owned Utility. Although the SFPUC has served all municipal agencies within the City and County of San Francisco for many decades, it relies upon PG&E's transmission and distribution grid to serve its customers, for which PG&E receives a fee.

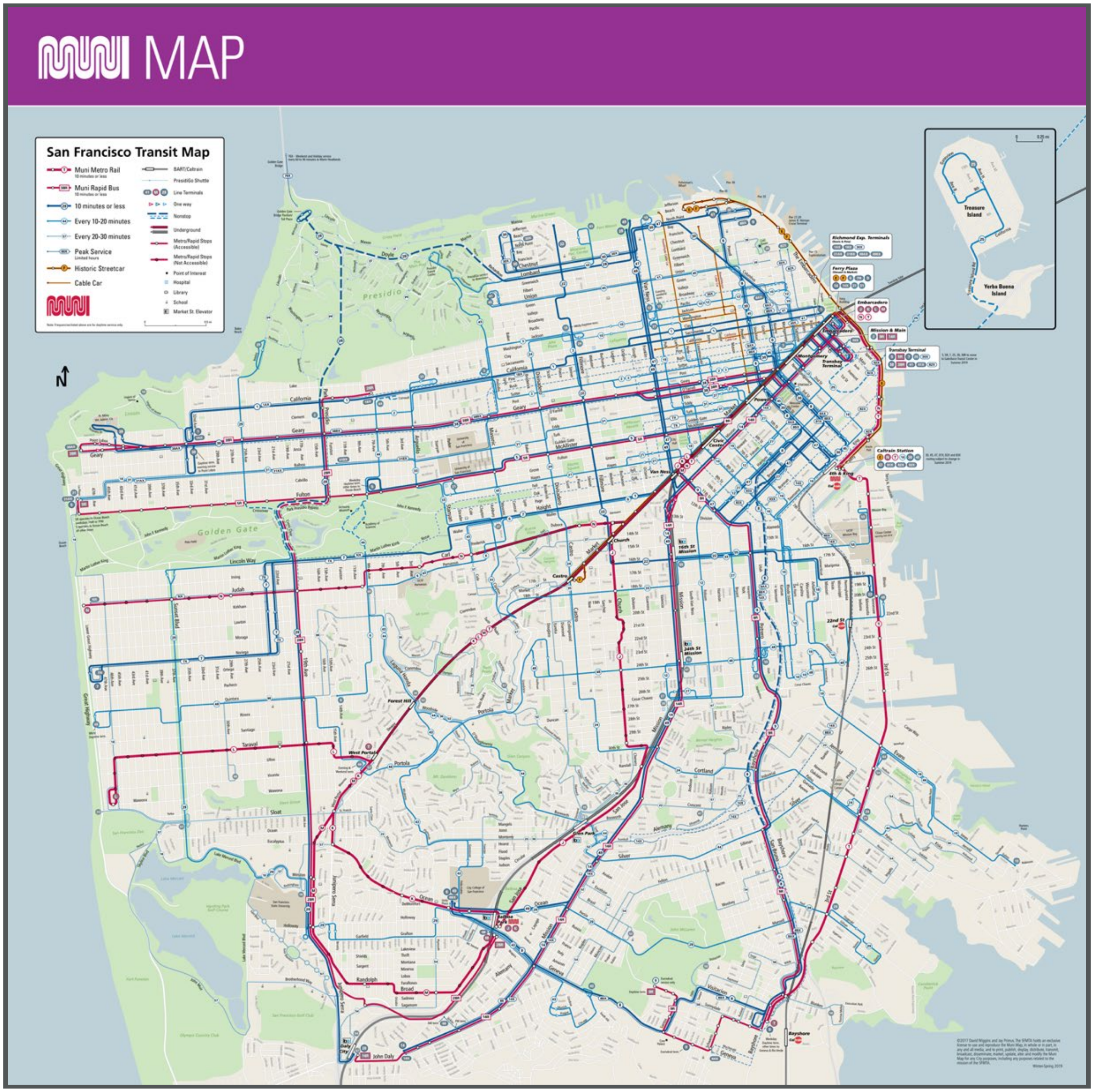
This situation, with the lack of designated service territory boundaries between the two utilities, is unlike any other in the country, and greatly limits the SFPUC's visibility into the detailed grid infrastructure and capacities. Despite multiple requests to gather details, PG&E will not provide information on feeder capacities unless the SFPUC submits an application for service through the Wholesale Distribution Tariff (WDT), a process that may require upwards of $150,000 and two years+ per service location to perform a System Impact Study to determine the capacity available for new loads.

Under the WDT, each SFPUC customer inter-tie point is viewed by PG&E as a utility-to-utility connection. As such, PG&E applies the rules of the WDT to each SFPUC customer connection. This is significant to the SFMTA in several ways, but particularly in terms of project timelines and budget. Each service upgrade that utilizes the PG&E grid must go through PG&E's review process. The SFPUC therefore has no control over processing delays or resource constraints. Upon completion of the review, any grid or infrastructure upgrades required by PG&E are born solely by the SFPUC customer. Being an SFPUC customer, the SFMTA would not be eligible for any betterment cost sharing, like PG&E retail customers

[4] SFMTA Short-Range Transit Plan Fiscal Year 2019 – Fiscal Year 2030, p. 9.
[5] SFMTA Bus Fleet Management Plan 2017-2030, p. 25.
[6] SFMTA San Francisco Mobility Trends Report 2018, Jan 28, 2019, p2.

would, regardless of the quantity of PG&E customers that would benefit from the investment. Similarly, the SFMTA is ineligible for PG&E's EV Fleet programs, which provide funding for grid infrastructure builds and upgrades that support EV charging.

Figure 2-2. SFMTA System Map



Source: SFMTA, Winter/Spring 2019, prior to COVID- 19 induced service suspension

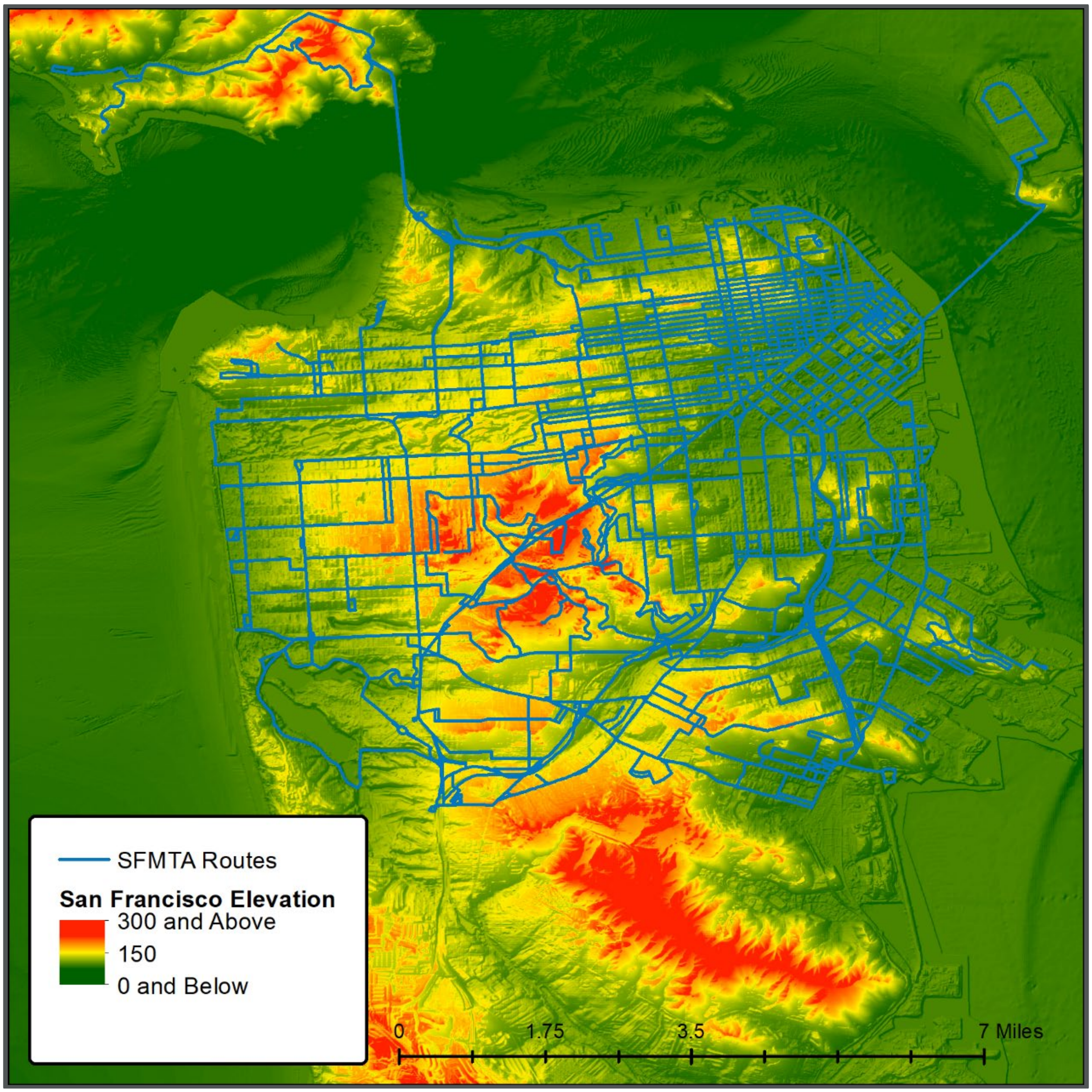
Environmental Factors

San Francisco's Mediterranean climate is characterized by dry summers and wet winters with relatively mild temperatures. Temperature does not vary much throughout the year, with average high temperatures of approximately 70°F during the summer, and average low temperatures of 45°F during the coldest winter days.

Topography is varied, with scores of hills ranging from seal level to over 900 feet in elevation. This varied topography, combined with the effects of cold ocean currents, gives rise to microclimates.

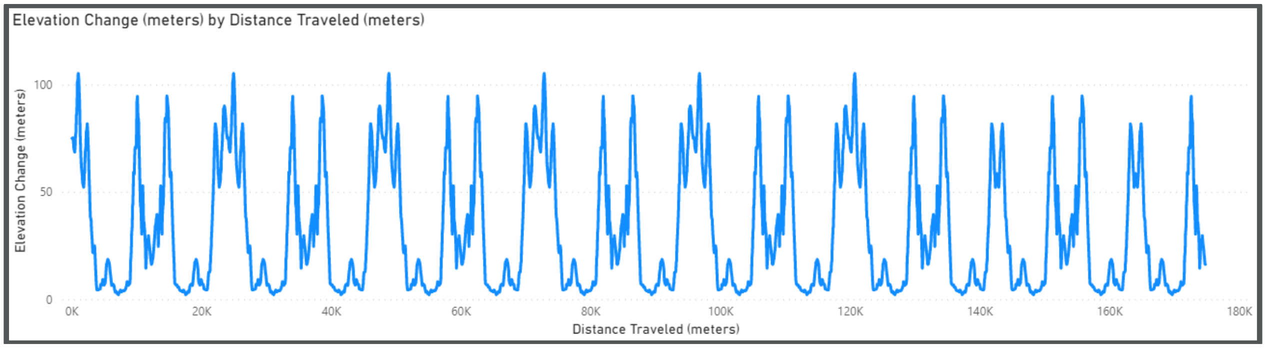
The SFMTA's buses must travel over multiple hills in a day – the steepest grade is 23%. Figure 2-3 shows San Francisco's service and the elevation profile, with much of the service feeding into downtown (which is near sea-level) over numerous hills. An example of the elevation change a transit vehicle may do while in-service is shown in Figure 2-4 with weekday vehicle block 1005 continuously traveling up and down hills for the entirety of its service. The block gains a total of 3,542 meters or 2.2 miles in a day (the equivalent of over 38 football fields or 11.6 times the height of San Francisco's tallest building, the Salesforce Tower, at 1,070 feet).

Figure 2-3. San Francisco Service and Elevation Profile



Source: WSP, USGS DEM

Figure 2-4. Vehicle Block 1005 Elevation Change



Source: WSP, USGS DEM

Schedule and Operations

As of January 2020, the SFMTA directly operates 844 diesel-hybrid and trolley buses on 76 regular weekday routes, which include supplemental Muni Metro Rail Owl service and routes with Rapid and Express service (e.g. Route 14, Route 14R, and Route 14X are three different routes) but excludes weekend-only route 76X and intermittent service to the Chase Center (78X and 79X).[7] These buses are served by six maintenance and storage yards: Flynn, Islais Creek, Kirkland, Potrero, Presidio, and Woods. Bus support functions also occur at 1399 Marin, and the SFMTA is planning bus storage improvements on 4 undeveloped acres east of the Muni Metro East light rail division. The SFMTA's trolley buses operate exclusively out of Potrero and Presidio yards, both of which are over 100 years old.

The SFMTA's fixed-route bus service is organized into six categories or types of service:

1. **Rapid Bus:** Routes that operate every 10 minutes, or more frequently, all day on weekdays and are the focus of transit-priority measures.
2. **Frequent:** Routes that also operate every 10 minutes, or more frequently, all day on weekdays in major corridors, but make more frequent stops than Rapid Bus routes.
3. **Grid:** Routes that form the framework of "trunk" routes across the city (along with Rapid and Frequent bus routes, and Muni SFMTA), with 12-30 minute headways all day on weekdays.
4. **Connector:** Shorter routes that provide coverage (including neighborhood "circulator" service to hillside neighborhoods) that generally operate every 30 minutes all day on weekdays.
5. **Specialized:** Routes with a focused purpose, including: express routes (primarily peak period-only services for commuters); supplemental service (to middle and high schools); and special event service (i.e., sporting events, concerts, etc.). Frequencies on these routes vary.
6. **Owl:** Some routes operate 24 hours a day, while other overnight routes (operating between 1 and 5 a.m.) are comprised of segments of multiple routes.

COVID-19-Related Impacts

As a response to the economic and health impacts of COVID-19, the SFMTA has made major interim service changes, including the closure of Muni Metro and prioritization of core bus routes (per the Muni Core Service Plan).

[7] This is based on January 2020 (pre-COVID) service.

The Muni Core Service Plan (April 2020) prioritizes the most-used routes to provide access to San Francisco's medical facilities while also increasing the volume of buses (to promote social distancing) for riders that are most reliant on transit. As of September 2020, the COVID-19 situation has resulted in a 71% reduction in bus boardings and a 95% reduction in transit revenue compared to the same time in 2019.

The federal government, through the CARES Act, provided some relief to the SFMTA to address the funding shortfall. However, long-term service levels will be contingent on revenues, ridership, and finding creative solutions to deliver that service efficiently and effectively.

COVID-19 directly impacts the SFMTA's transition to an all-ZEB fleet due to increased uncertainty of various important factors: future ridership, changes and adaptations to service planning, continued emergency declarations and operations, general economic health or recession, and capital funding.

2.1.5 The SFMTA's Existing ZEB Efforts

The SFMTA is a national leader in confronting climate change and embracing the prospects of a ZE future. The SFMTA has taken multiple steps to not only meet the requirements of CARB's ICT regulation, but also its own ambitious ZE goals, as detailed below.

— The SFMTA currently operates the largest fleet of ZE trolley buses in North America. Trolley buses run on 100% greenhouse gas-free hydropower via an overhead catenary system (OCS). The SFMTA also operates over 600 diesel-hybrid vehicles that run on batteries and renewable diesel.

— In April 2018, in celebration of Earth Day, the then current mayor, Mark Farrell, committed the City of San Francisco to net-zero greenhouse gas emissions by 2050, which would eliminate the city's carbon footprint. The SFMTA is already doing its part and accounts for less than 2% of citywide transportation emissions (45%).

— In partnership with the San Francisco Department of the Environment, the SFPUC, and other city agencies and stakeholders, the SFMTA supported the development of the Electric Mobility Roadmap that lays out a vision for reducing public health and environmental impacts of private transportation. The Roadmap also identifies strategies to help realize an emission-free transportation sector.

— In May 2018, the Board adopted its Zero-Emission Vehicle Policy resolution (ZEV Policy). Under the ZEV Policy, demonstrating the SFMTA's to achieving a 100% BEB fleet by 2035.[8]

— In November 2019, the SFMTA procured nine 40-foot BEBs (three each from New Flyer, Proterra, and BYD). These buses will be piloted in regular revenue service to analyze performance and to assist in developing a long-term charging strategy (expected delivery in early 2021).[9] This pilot program includes an electrical and facility upgrade at Woods Yard to accommodate BEB charging equipment and infrastructure.

— In 2018, as part of its Green Zone program, the SFMTA replaced 68 buses with diesel-hybrid buses outfitted with higher capacity batteries and a GPS-enabled switch, which automatically switches the bus to EV mode as it enters geo-fenced areas (Green Zones) throughout the city. In Green Zones,

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[8] Due to the impacts of COVID-19 (reduction in ridership, funding, etc.), the SFMTA is revisiting this policy to align it with the ICT regulation (2040).

[9] Nine buses are currently procured with an additional three in negotiations.

the vehicles operate entirely on battery power, reducing and eliminating SFMTA-generated emissions in some of the city's most environmentally burdened communities.

— In February 2020, the SFMTA awarded a contract to WSP to provide a roadmap for the SFMTA's transition to BEB facilities and transit fleet vehicles. This partnership will produce several deliverables that will guide the SFMTA to meet their electrification goals, including a BEB Facility Implementation Master Plan (Master Plan).

2.2 Rollout Plan Approach

In accordance with the Rollout Plan Guidance, this document provides an overview of several key components to the SFMTA's ZEB transition, including fleet acquisitions, schedule, training, and funding considerations.

Due to the rapidly evolving nature of ZEB technologies, it is likely that the recommended approaches in this Rollout Plan will be adjusted and changed over time. For that reason, the SFMTA will continue to evaluate technologies and strategies throughout the transition process. Areas that are currently under study will be indicated, where applicable. The service-related information in this Rollout Plan is based on January 2020 service (pre-COVID) and the fleet numbers are based on September 2020.

It should also be noted that COVID-19 has caused unprecedented losses in the SFMTA's revenue through the loss of ridership (fares) and the reduction in sales tax revenue. For these reasons, the SFMTA has reduced service and operations and continues to adapt in the near term and forecast the long-term implications on the system and the agency's capital projects and goals. While the impact of COVID-19 on the SFMTA's electrification pursuant to the ICT regulation is still unclear, the SFMTA will continue planning and adjust as needed once COVID-19 is stabilized and trends are more predictable.

2.3 Rollout Plan Structure

In accordance with CARB's Rollout Plan Guidance, the SFMTA's Rollout Plan includes all required elements. The required elements and corresponding sections are detailed below:

— Transit Agency Information (Section 1: Rollout Plan Summary)

— Rollout Plan General Information (Section 1: Rollout Plan Summary)

— Technology Portfolio (Section 2.1.3: ZEB Suitability for the SFMTA's Service and Operations)

— Current Bus Fleet Composition and Future Bus Purchases (Section 3: Fleet and Acquisitions)

— Facilities and Infrastructure Modifications (Section 4: Facilities and Infrastructure Modifications)

— Providing Service in Disadvantaged Communities (Section 5: Equity Considerations)

— Workforce Training (Section 6: Workforce Training)

— Potential Funding Sources (Section 7: Costs and Funding Opportunities)

— Start-up and Scale-up Challenges (Section 8: Start-up and Scale-up Challenges)

3 Fleet and Acquisitions

The following section provides an overview of the SFMTA's existing fleet, planned ZEB technology, and proposed procurement schedule.

3.1 Existing Bus Fleet

The SFMTA bus fleet includes diesel-hybrid (dHEB) and electric trolley buses ranging from 30- to 60-feet. As of September 2020, the SFMTA operates a fleet of 844 buses.

The fleet is served by six bus maintenance and storage yards, two for trolley buses, two for 60-foot buses, and two for standard (30- and 40-foot) buses. Table 3-1 provides a detailed overview of the SFMTA's existing bus fleet.

Table 3-1. Summary of the SFMTA's Existing Bus Fleet

Manufacturer	Series	Fuel Type	Length	In Service Year	Bus Type	Quantity
New Flyer	8601-8662; 8701-8710; 8713-8750	dHEB	40'	2013	Standard	111
	8711			2014		1
	8800-8859; 8861; 8864-8866; 8869; 8871			2016		66
	8751-8780; 8860; 8862-8863; 8867-8868; 8870; 8872-8901			2017		66
	8902-8955			2018		54
	8956-8969			2019		14
	6500-6544; 6546-6553; 6700		60'	2015	Articulated	54
	6545; 6554; 6560-6605l; 6701-6730			2016		78
	6606-6644; 6646-6647; 6649-6650; 6653			2017		44
	6645; 6648; 6651-6652; 6654-6697			2018		48
	5701-5798	Trolley Bus	40'	2018	Standard	98
	5799-5885			2019		87
	7201-7225		60'	2015	Articulated	24
	7224; 7226-7260			2016		36
	7261-7280			2017		20
	7281-7293			2018		13
Orion	8501-8530	dHEB	30'	2007	Standard	30
					Total Buses	**844**

Source: SFMTA, September 2020

3.1.1 Battery-Electric Bus Technologies

As previously mentioned, the SFMTA intends to transition to an all-BEB fleet. The SFMTA's future BEBs are expected to have specifications that are compatible with the Society of Automotive Engineers' (SAE) J1772 (plug-in) and SAE J3105 (pantograph) charging standards. By supporting both standards, the SFMTA's buses will have the flexibility of charging in multiple layouts and orientations. The plug-in standard will allow buses to charge while being serviced, and the pantograph standard will allow buses to charge at the base and at potential on-route charging locations. The roof-mounted charging rails that are associated with the pantograph standard will allow the SFMTA's BEBs to access "fast" high-power charging (in excess of 150 kW) for a limited duration.

Based on the SFMTA's existing service needs and yard configurations, it is recommended that an inverted pantograph-charging strategy be implemented to support BEBs at all six yards. The pantographs will be supported by an overhead frame that covers the surface of the bus parking tracks. The overhead strategy was deemed to be the most suitable due to space constraints at the SFMTA's yards. The overhead frame will also be able to support photovoltaic panels (where applicable) and electrical equipment and components (conduit, etc.). Exceptions to the overhead frame solution could potentially occur in multi-level facilities as they are rebuilt, such as Potrero and Presidio Yards. Future design of those facilities would likely either include an overhead frame or an equipment mezzanine, but the SFMTA will leave those decisions to the facility design teams.

The proposed facility layouts for each yard are based on utilizing a 150-kW DC charging cabinet in a 1:2 charging orientation (one DC charging cabinet energizes two separate dispensers/buses). This charger-to-dispenser ratio maximizes space utility, reduces capital costs, and meets the requirements to charge the fleet during servicing and dwell time on the site while minimizing the peak electrical demand. That said, the SFMTA continues to monitor technological advancements and may explore other strategies that are advantageous to the SFMTA.

Figure 3-1 shows an example of a pantograph and charge rails.

Figure 3-1. Inverted Pantograph and Charge Rails

Source: WSP

3.2 Procurement Schedule

In accordance with the ICT regulation, the SFMTA will prioritize ZEB purchases and progressively increase the percentage of ZEB purchases over time. As planned, starting in 2027, all of the SFMTA's new bus purchases will be ZEB - two years before the ICT regulation requires.

Early retirement should not be an issue pursuant to the ICT regulation (2040) based on the SFMTA's future purchases. However, if early retirement becomes a risk, one potential strategy is to place newly acquired buses on the SFMTA's longest (distance) service blocks. This will ensure that buses meet the Federal Transit Administration's (FTA) 500,000-mile minimal useful life requirement sooner. Prior to implementing such a measure, the SFMTA will conduct an equity analysis to ensure that service distribution and vehicle choice is equitable across neighborhoods and districts.

Table 3-2 summarizes the SFMTA's anticipated procurements through 2040 and Figure 3-2 presents the percentage of the fleet that are powered by ZE technologies or fossil fuels through the same timeframe. These are built on the assumption that BEBs and associated battery capacities will be available to meet the SFMTA's service block ranges so that a 1:1 replacement ratio is achievable. It should be noted that this is contingent on the availability of funding, whether battery technology can meet the SFMTA's range requirements, and whether facilities and utility enhancements are completed. The COVID-19 pandemic has caused uncertainty in the long-term impacts to the SFMTA's funding and service. Staff is actively analyzing these changes and will update the schedule accordingly.

In 2025, the SFMTA plans to apply at least 28 "Bonus Credits" to their procurement to satisfy the 25% ZEB purchase requirement. In the year 2027 and beyond, all new bus purchases will be 100% BEB – two years prior to the ICT regulation's requirements.

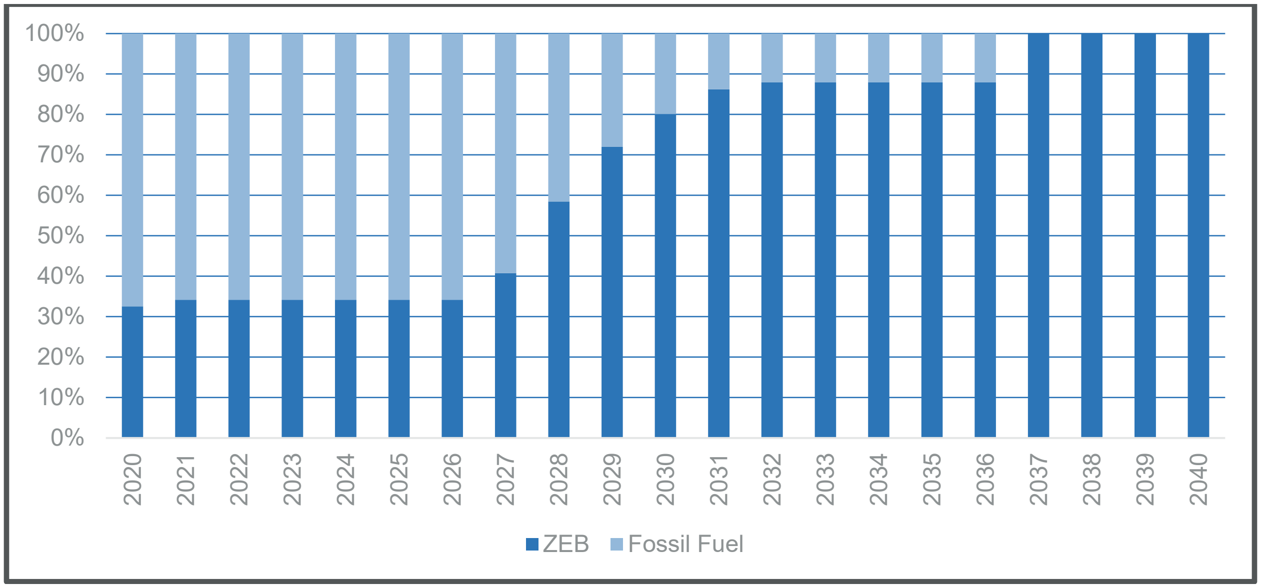
Table 3-2. Summary of the SFMTA's Future Bus Purchases (Through 2040)

Year	Total Buses	Zero-Emission Buses				Conventional Buses			
		Number	Pct.	Bus Type	Fuel Type	Number	Pct.	Bus Type	Fuel Type
2020	0	0	0%	-	-	0	0%	-	-
2021	30	0	0%	-	-	30	100%	Std.	dHEB
2022	0	0	0%	-	-	0	0%	-	-
2023	0	0	0%	-	-	0	0%	-	-
2024	0	0	0%	-	-	0	0%	-	-
2025	112	0	0%		-	112	100%	Std.	dHEB
2026	0	0	0%	-	BEB	0	0%	-	-
2027	54	54	100%	Artic.	BEB	0	0%	-	-
2028	144	144	100%	Std./Artic.	BEB	0	0%	-	-
2029	110	110	100%	Std./Artic.	BEB	0	0%	-	-
2030	126	126	100%	Std./Artic.	BEB	0	0%	-	-
2031	50	50	100%	Std./Artic.	BEB	0	0%	-	-
2032	20	20	100%	Artic.	BEB	0	0%	-	-
2033	141	141	100%	Std./Artic.	BEB	0	0%	-	-
2034	87	87	100%	Std.	BEB	0	0%	-	-
2035	**0**	0	0%	-	-	0	0%	-	-
2036	**0**	0	0%	-	-	0	0%	-	-
2037	112	112	100%	Std.	BEB	0	0%	-	-
2038	0	0	0%	-	-	0	0%	-	-
2039	54	54	100%	Artic.	BEB	0	0%	-	-
2040	144	144	100%	Std./Artic.	BEB	0	0%	-	-

Source: WSP

Note: The SFMTA's existing trolley buses and dHEBs are expected to be replaced with BEBs 15 and 12 years after their in-service date, respectfully. This procurement schedule assumes a 1:1 replacement ratio with BEBs being replaced every 12 years (mirroring 12-year warranties) and does not incorporate fleet growth projections/additions as these are still currently under study.

Figure 3-2. Percentage of ZEB and Fossil Fuel Fleet (2020-2040)



Source: WSP

3.2.1 ZEB Bonus Credits

Based on the ICT regulation, the SFMTA is entitled to 18 bonus credits for their existing trolley buses[10] and will have 12 bonus credits available for their planned BEB pilot buses[11], resulting in 30 available credits for the SFMTA. As indicated above, the SFMTA plans to exercise these credits in the 2025 procurement. In lieu of the 25% ICT ZEB purchase requirement, the SFMTA will use 28 of their credits (25% of 112 buses).

3.2.2 ZEB Range Requirements and Costs

Approximately 9% of the SFMTA's existing bus blocks travel farther than 150 miles per weekday – a range that exceeds current batteries' capabilities.[12] To reduce impacts to service, there are several strategies that the SFMTA can consider to meet service (range) requirements, including midday charging, battery/charging management systems, on-route chargers, additional bus purchases, and solar and battery storage. In addition, with battery technology rapidly evolving, future battery capacities and efficiencies may be sufficient to serve all blocks. However, this currently appears as a risk to full conversion to BEB and is discussed later in this Plan.

3.2.3 ZEB Conversions

Conventional bus conversions to ZEB technologies are not currently being considered. However, the SFMTA will remain open to conversions if they are deemed financially feasible and align with ZEB adoption goals.

[10] Per the ICT regulation: "Each electric trolley bus placed in service between January 1, 2018, and December 31, 2019, receives one-tenth of a Bonus Credit that will expire by December 31, 2024."
[11] Nine buses are currently procured with an additional three in negotiations.
[12] This is based on January 2020 (pre-COVID) service.

4 Facilities and Infrastructure Modifications

The following sections provide an overview of the existing fleet (by yard), proposed charging strategies, infrastructure, yard improvements, and program schedule.

4.1 Overview of Existing Facilities

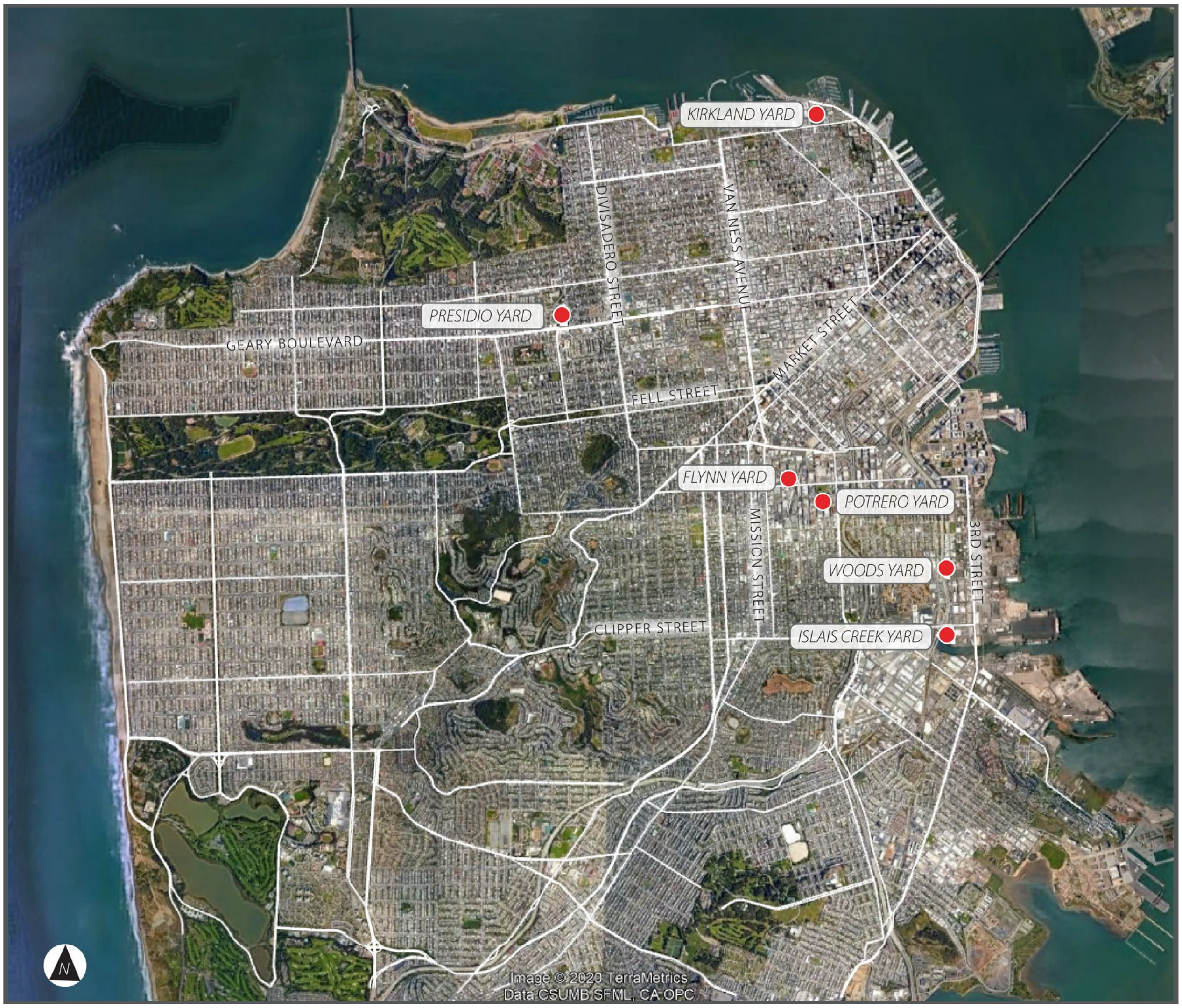
The SFMTA has six yards, all of which will require significant capital improvements to accommodate a 100% ZEB. Table 4-1 summarizes the number and type of buses that are currently stored at each facility and Figure 4-1 presents the locations of each yard.

Table 4-1. Summary of Existing Yards and Fleets

Yard	Address	Total	Diesel-Hybrid Buses			Trolley Buses	
			30'	40'	60'	40'	60'
Flynn	1940 Harrison St.	119	-	-	119	-	-
Islais Creek	1301 Cesar Chavez St.	115	10	-	105	-	-
Kirkland	2301 Stockton St. and 151 Beach St.	91	-	91	-	-	-
Potrero	2500 Mariposa St.	146	-	-	-	53	93
Presidio	949 Presidio Ave.	132	-	-	-	132	-
Woods	1095 Indiana St.	241	20*	221	-	-	-
	Total	844	30	312	224	185	93

Source: SFMTA Master Fleet Assign Ratio, September 2020

Figure 4-1. The SFMTA's Bus Yards



Source: WSP

4.2 ZEB Facility and Infrastructure Strategy

Since ZEB technology continues to evolve, it is difficult to commit to a costly strategy that may quickly become outdated or obsolete. However, it is also important to ensure that strategies are future-ready. For this reason, the recommended facility and infrastructure modifications are based on what each yard is planned to accommodate in 2040 per the *2017 SFMTA Facilities Framework* report and resulting *Building Progress* capital program. Since service changes and bus movements may occur multiple times a year, by establishing a full-build scenario, the SFMTA can optimize and tailor strategies based on existing (or anticipated) service.

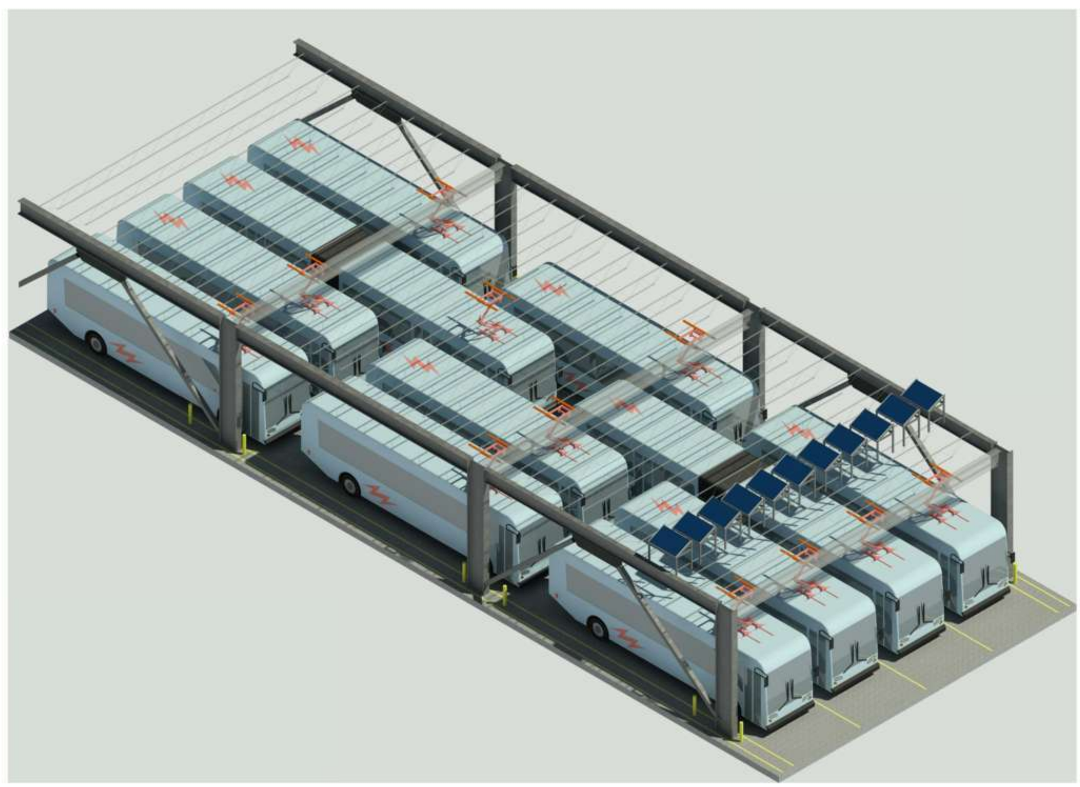
The SFMTA's transition to an all-BEB fleet will require an increase in the electrical supply to the site, enhancements and expansions of electrical equipment, and the installation of gantries, chargers, dispensers, and other components. These modifications must occur at all six yards. While the SFMTA is not currently actively seeking on-route charging locations, we remain open to the concept, particularly if it is required to meet the service plan.

During preliminary concept discussions, both conductive and inductive charging solutions were considered and analyzed by the SFMTA and the design team. Based on several factors, including the space constraints at each yard and the desire for uniform infrastructure for ongoing maintenance efficiency, the SFMTA committed to an inverted pantograph strategy for all yards. However, where applicable, such as in maintenance areas, plug-in dispensers may be utilized.

To support the inverted pantographs, a scalable and modular overhead support structure is proposed in open bus yards to retain maximum bus parking capacity while implementing BEB charging. This type of overhead structure can be rapidly modified to meet changes in the SFMTA's fleet mix. The system consists of an overhead structure spanning up to four tracks of bus parking with pantographs mounted at various five-foot intervals as required by the assigned bus fleet. Charger cabinets, switchboards, transformers, and all electrical distribution will be kept above the bus parking area, where possible, to avoid costly trenching and reduce service interruptions during the transition.

Figure 4-2 illustrates inverted pantographs mounted to the modular overhead support structure.

Figure 4-2. Inverted Pantographs and Modular Support Structure



Source: WSP
Note: The frame can also support plug-in dispensers.

The proposed layouts are based on utilizing a 150-kW DC charging cabinet in a 1:2 or 1:3 charging orientation (one DC charging cabinet energizes two separate dispensers/buses). This charger-to-dispenser ratio would meet the requirements to charge the SFMTA's fleet overnight and minimize peak electrical demand.

4.3 ZEB Transition

The process of integrating BEBs into the SFMTA's fleet is very complex. Each yard will need to have sufficient power (utility enhancements) and charging infrastructure in place before buses are delivered. While the utility enhancements can generally be done without impacting normal operations, the installation of the support structure and charging equipment (chargers, switchgear, transformer, etc.) could negatively impact operations. For that reason, the planning of distinct on-site construction stages and program-level phasing is essential.

Staging

To avoid service disruptions and operational impacts, the SFMTA's yards will undergo BEB upgrades in several on-site stages. These "stages" are segments of the yard that will be temporarily shut down to install the necessary BEB-supporting infrastructure. The buses that would normally occupy the staging space will be temporarily relocated on-site (if space allows) or to a neighboring yard or facility. This approach will ensure that construction and normal operations can proceed concurrently. This construction method avoids the complete shutdown of the yard undergoing improvements, which reduces the risks of service impacts.

The number of stages and number of buses that need to be temporarily relocated during each stage vary based on a yard's layout, existing fleet, and additional capacity.

Phasing

In order to electrify the fleet by 2040, it will be necessary to have multiple yards undergoing construction, concurrently. "Phases" are essentially classifications of when and how these yards are grouped. Typically, the phase in which a yard is transitioned is based on agency's priorities or technical feasibility. The SFMTA is also concurrently implementing a facility capital rebuild program. When conceived in 2017, the *Building Progress Program* proposed rebuilds of the SFMTA's three oldest and most obsolete facilities: Potrero Yard, Presidio Yard, and Kirkland Yard. The *Building Progress Program* must be adapted to accommodate BEB infrastructure projects.

The number of phases, stages, and details on bus relocations are currently being analyzed and will be finalized in the SFMTA's ongoing Feasibility and Fleet Transition Plan Study.

Figure 4-3 presents a concept of Islais Creek Yard and how its construction can be staged.

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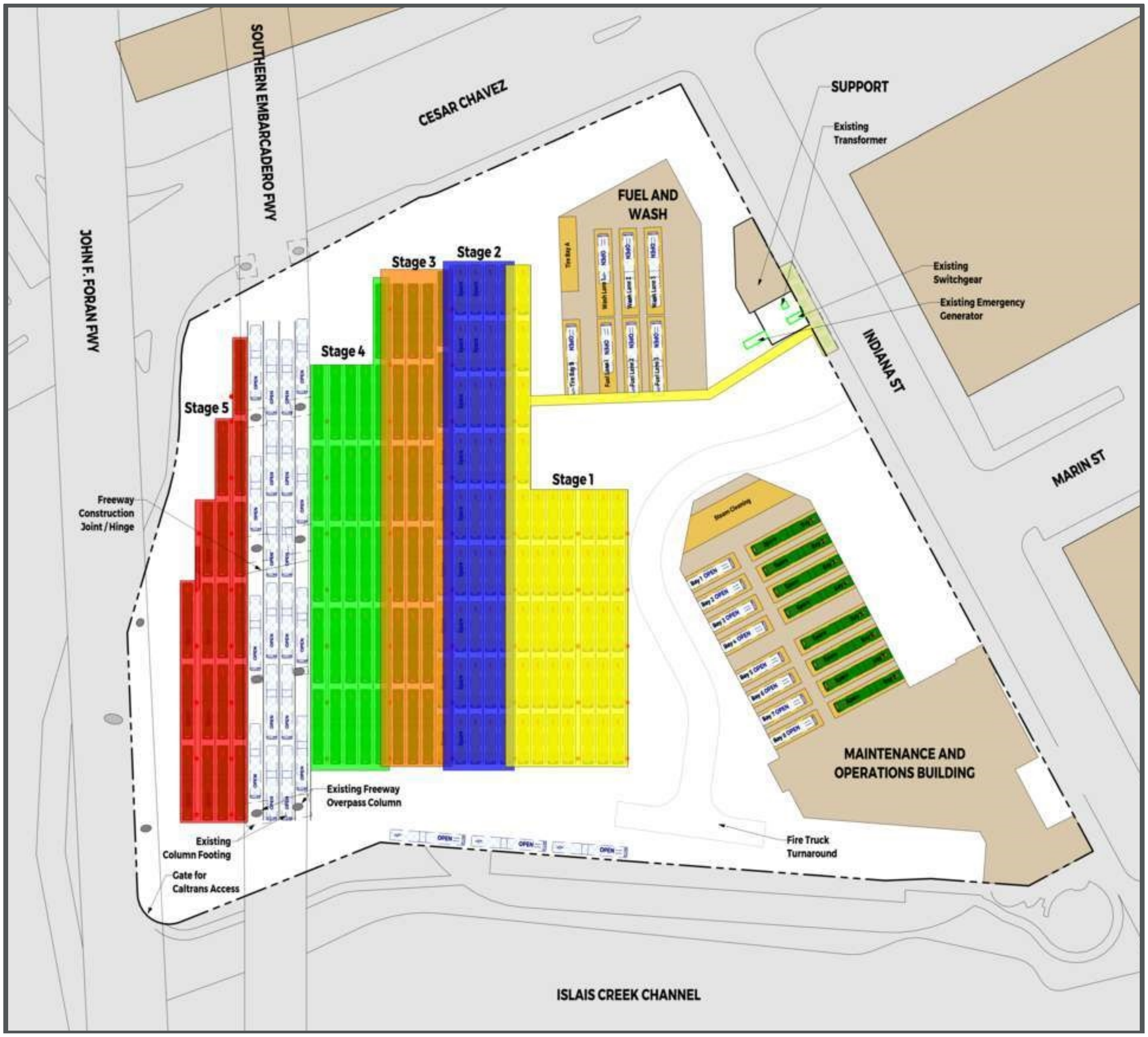
Figure 4-3. SFMTA Staging Example



Source: WSP

4.4 Transition Considerations

There are multiple factors and timetables that must be considered to meet the SFMTA's ZEB fleet goals in accordance with the ICT regulation. Since BEBs are not operational unless the facilities are in place to energize them, it is essential to meet deadlines because it can impact both service and ICT regulation compliance.

The following provides a brief overview of the various processes and timetable assumptions for each, Figure 4-4 presents the proposed schedule for the SFMTA's ZEB fleet conversion.

Bid Documents

The electrification process will require multiple subject matter experts, planners, designers, architects, engineers, OEMs, and contractors. For this reason, multiple requests for proposals (RFPs) will need to be developed and put out for bid for various phases of the project. For example, there may need to be an

RFP for a firm to take the project from 30% design to 100% design. There may also be a separate RFP for the construction component. This assumes a typical design-bid-build concept. For more complex rebuild projects, like Potrero and Presidio Yards, the projects will be delivered in a joint development progressive design-build or design-build model. The SFMTA will continue to evaluate the best strategy to meet goals. If a design-bid-build strategy were to be implemented, it is assumed that each stage of bidding would take six months.

BEB-Supporting Enhancements

With the amount of time it will take to construct the pantograph-supporting structures and other BEB enhancements, it is assumed that each “stage” of construction at a yard will take approximately six months to be completed. For example, a yard with three distinct stages would take approximately 18 months to be BEB-ready.

Utility Infrastructure Enhancements

Even with BEBs and BEB-supporting equipment in place, the fleet can only operate if the electrical utility and supporting circuits can meet the energy and power demands of the BEBs. In the SFMTA’s case, power is provided by PG&E by way of SFPUC. The SFMTA must undergo a lengthy and uncertain process to request and receive additional power. This process includes an application, a study, permitting, planning and design, and construction (on behalf of SFPUC). This process could take as long as five years. The utility enhancements dictate when a yard is deemed fully operational for BEBs.

Bus Procurements

It is assumed that buses can be procured 18 months before the conclusion of the BEB-supporting enhancements. Typically, ordering buses is not an arduous endeavor. However, the procurements will have to be aligned with the construction of charging equipment at the yard and utility enhancements.

Environmental Clearance

Yards that are scheduled to be demolished and rebuilt, such as Potrero and Presidio, are considered “projects” under the California Environmental Quality Act (CEQA) and an environmental impact report (EIR) will need to be prepared. The process of developing and certifying an EIR can take 2-3 years, pre-construction. The other four divisions may be exempt from developing an EIR pursuant to California’s Senate Bill 288, if all requirements, including workforce and labor provisions, of the exemption can be met. The exemption, in part, grants extensions to “transit agency projects to construct or maintain infrastructure to charge or refuel zero-emission transit buses,” However, the specific details and guidelines for the exemptions will be further evaluated in subsequent stages of planning.

Temporary Relocations

The SFMTA’s 1399 Marin and Muni Metro East (MME) facilities have been identified as sites that can temporarily store and dispatch buses during construction at other sites. For instance, when Potrero and Presidio are being reconstructed, the SFMTA is planning to temporarily relocate their trolley bus fleets there. Procurement tables and construction schedules will have to be in alignment with the timing of these temporarily relocations to avoid scheduling delays or impacts to operations or service.

Yard Management and Operations

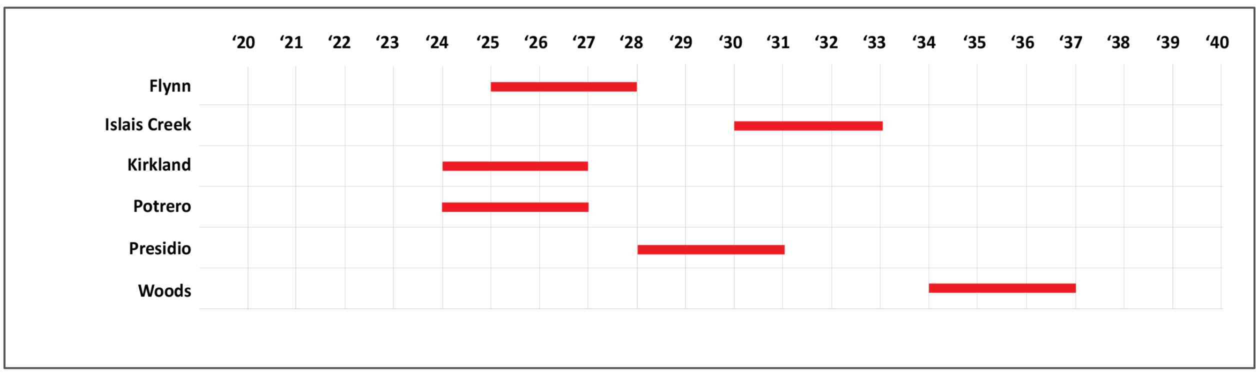
The layout and operations of the yard will be vastly different during and after construction. Currently, there are no range issues with the SFMTA’s buses and the time it takes to fuel buses is negligible. However, with the transition to BEBs, more considerations to how buses are parked, operated, and dispatched will be required due to the reduction in range and relatively long charge times. These issues will be even more important during the time(s) that yards are operating mixed fleets (BEB and dHEB). To mitigate any negative impacts to operations, significant planning and updates to standard operating procedures will be needed to achieve a successful transition.

Schedule

As indicated above, there are multiple prevailing factors that will dictate the SFMTA's transition schedule. Figure 4-4 illustrates a conceptual schedule that can meet ICT regulation goals. This schedule largely follows the priorities of the *2017 Facilities Framework* report and uses the utility provider's conservative five-year estimate as the span of time it will take to enhance all facilities. This schedule does not consider the specifics of bus procurement quantities, service planning, or phasing and is highly contingent on the SFMTA's funding and PG&E and SFPUC's ability to meet construction deadlines.

It should also be noted that the SFMTA is currently evaluating the cost effectiveness of implementing the BEB transition at two facilities that are generally in poor condition (Kirkland and Woods). The capital investment of BEB conversion is significant, and the SFMTA is committed to fiscally responsible capital projects that meet the larger needs of the SFMTA's service and workforce. All of these factors will have impacts to the conceptual schedule.

Figure 4-4. Conceptual Schedule



Source: WSP

4.5 Summary of Yard Enhancements

By 2040, all of the SFMTA's yards will be capable of operating a 100% BEB fleet. Table 4-2 summarizes the modifications and schedule of each yard, and the following sections detail the process of each yard's transition from existing conditions to BEB-readiness. The facility narrative is listed in alphabetical order.

Table 4-2. SFMTA ZEB Yard Summary

Yard	Address	Main Functions	Planned Infrastructure	Existing Capacity (2020)	Service Capacity (2040)	Upgrades Req'd?	Timeline
Flynn	1940 Harrison St.	Storage/ O&M	Inverted Pantograph	119	109	Yes	2025-2028
Islais Creek	1301 Cesar Chavez St.	Storage/ O&M	Inverted Pantograph	115	153	Yes	2030-2033
Kirkland	2301 Stockton St. and 151 Beach St.	Storage/ O&M	Inverted Pantograph	91	81	Yes	2024-2027
Potrero	2500 Mariposa St.	Storage/ O&M	Inverted Pantograph	146	206	Yes	2024-2027
Presidio	949 Presidio Ave.	Storage/ O&M	Inverted Pantograph	132	217	Yes	2028-2031
Woods	1095 Indiana St.	Storage/ O&M	Inverted Pantograph	241	233	Yes	2034-2037

Source: WSP
Note: Potrero and Presidio will be fully rebuilt, the scope of the projects includes more than BEB enhancements. Woods will likely also be fully rebuilt.

4.5.1 Flynn Yard

Existing Conditions

Flynn Yard is located at 1940 Harrison Street in the City of San Francisco.

Currently, 119 60-foot diesel-hybrid buses are stored, maintained, fueled, and serviced at Flynn Yard. The yard includes a maintenance area with drive-through bays, transportation area, stand-alone wash canopy, and a stand-alone fuel canopy. All of these facilities are integrated into the lone, single-story building on the site. A tire shop is located separately from the main facility in a building across Harrison Street. The southeast corner of the main Flynn Yard has a cutout that houses separate businesses not related to or owned by the SFMTA. Electrical utility service is provided by the SFPUC.

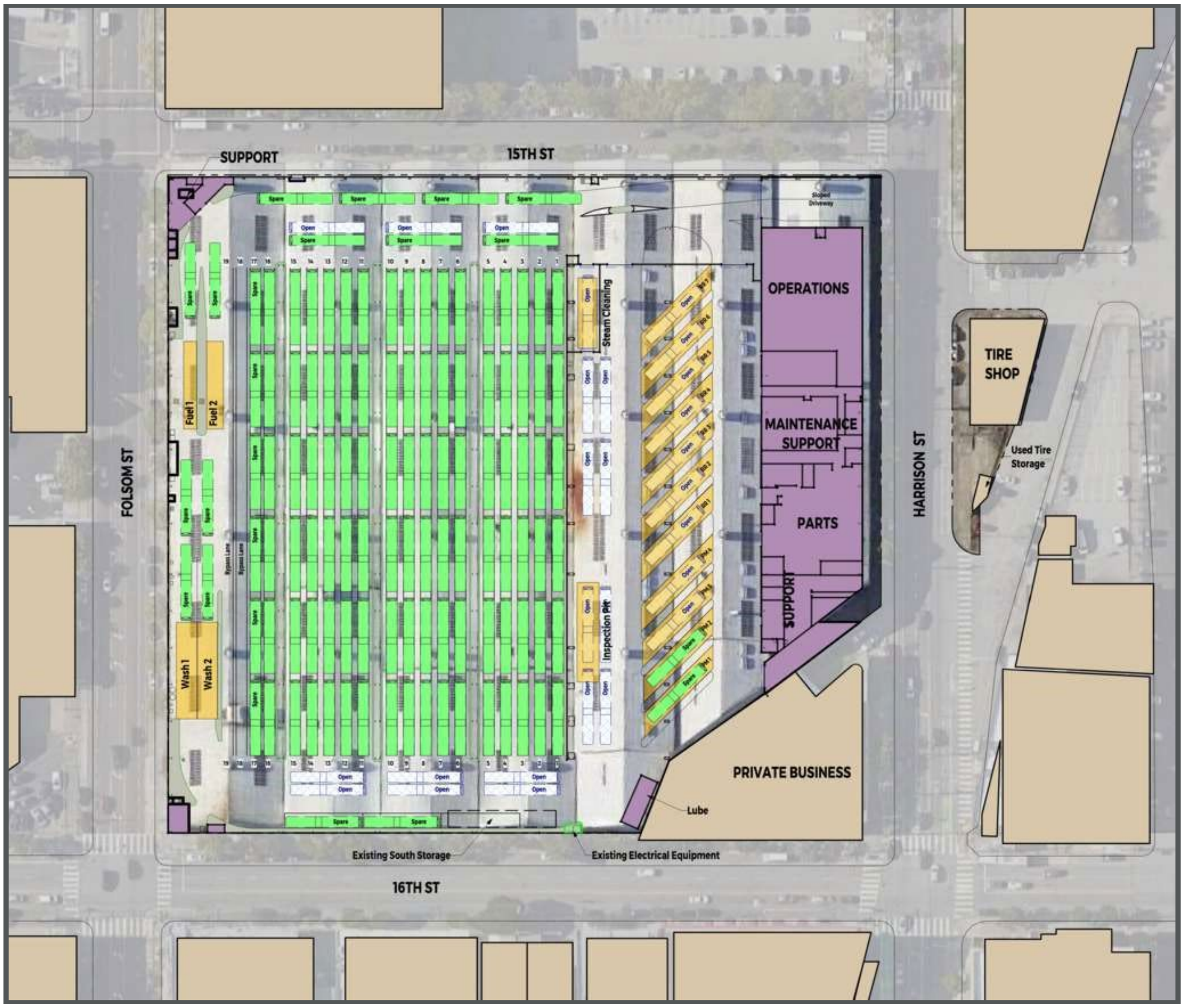
After revenue service, buses enter the yard from Harrison Street and are parked in unassigned, stacked (nose-to-tail) storage tracks in the northern circulation area. Individual buses are then pulled from the storage tracks and taken by nightly service staff to the fuel lanes for fare retrieval, interior cleaning, and fueling before pulling forward to the bus wash lanes. After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. Non-revenue vehicles (NRVs) are parked in a row of spaces near the transportation area adjacent to the bus circulation's northernmost lane.

An aerial and site plan of Flynn Yard are presented in Figure 4-5 and Figure 4-6, respectively.

Figure 4-5. Flynn Yard - Existing Conditions (Aerial)

Source: Google Earth

Figure 4-6. Flynn Yard - Existing Conditions (Site Plan)



Source: WSP

Planned ZEB Modifications

The Flynn Yard will be capable of storing and charging 109 total BEBs. 107 buses can be charged with pantographs via an overhead supporting structure that spans the area of the existing parking tracks. An additional two buses can be charged in the maintenance bays via plug-in dispensers.

Table 4-3 summarizes the ZEB infrastructure planned at Flynn Yard.

Table 4-3. Flynn Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	119
No. of BEBs Supported (2040)	109
No. of Charging Cabinets	56
No. of Dispensers/Charging Positions	109

Source: WSP
Note: It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio)

The following BEB equipment and locations are proposed:

— 56 DC charging cabinets located on a platform attached to the overhead support structure. 55 of these charging cabinets will distribute to 107 pantograph-charging positions over the existing storage tracks and satellite spaces. An additional charging cabinet will power two dispensers installed in the maintenance bays.

— The support structure columns are to be placed every two to three tracks. These columns will also provide the support for the overhead mounted pantographs.

The charging cabinets will be served by the following electrical infrastructure:

— Two interrupter switches and a meter to be installed on the southern exterior of the building along 16th Street. The first interrupter will be owned and operated by PG&E, and the second interrupter and meter will be owned by SFPUC. Power will be distributed from the meter up along and through the building exterior to the medium-voltage switchgear.

— One medium-voltage switchgear and three medium- to low-voltage transformers with corresponding low-voltage switchgear will be installed on the proposed platforms.

Figure 4-7 illustrates the Flynn Yard at full build-out.

Figure 4-7. Flynn Yard - Full ZEB Build-Out

Source: WSP

Phasing and Construction Strategy

As discussed, the specific phasing for each yard is still being analyzed. However, this section provides details on the proposed improvements in Phase 1 and work to be completed in subsequent phases.

Phase 1

The recommended first phase for the Flynn Yard would include the installation of two new interrupter switches on the exterior of the facility along 16^{th} Street, routing the utility-provided power into the facility to the site's new transformers. Conduit and routing from the utility should be sized to serve the yard's full fleet. Phase 1 will also include the construction of the overhead support structure with distribution conduit, transformers and switchgears, pantographs, and charging cabinets to serve the easternmost four tracks of bus parking.

Future Phases

Each subsequent phase of deployment will be accomplished by adding a similar modular overhead support structure and the required charging infrastructure to support the number of buses to be charged in the phase. The breakdown of this phasing will follow the SFMTA's growth plans and prioritization schedule.

4.5.2 Islais Creek Yard

Existing Conditions

Islais Creek Yard is located at 1301 Cesar Chavez Street in the City of San Francisco.

Currently, 115 diesel-hybrid buses (10 30-foot and 105 60-foot) are stored, maintained, fueled, and serviced at Islais Creek Yard. The yard includes the following separate structures and major site areas: a two-story maintenance building, two-story transportation building, and a combined fuel, wash, and tire repair building. Electrical utility service is provided by the SFPUC.

After revenue service, buses enter the yard from Indiana Street and are parked in numbered, stacked (nose-to-tail) storage tracks. Individual buses are then pulled from the storage tracks and taken by nightly service staff to the fuel lanes for fare retrieval, interior cleaning, and fueling before pulling forward to the bus wash lanes. After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. NRVs are parked throughout the site on facility exteriors and the yard perimeter.

Interstate 280 (I-280) traverses over the western side of the site with support columns located in the bus parking yard. Caltrans owns the property under I-280, which the SFMTA leases for bus parking. Due to Caltrans' I-280 maintenance requirements of the support columns and freeway, the SFMTA's ability to construct in this area of the yard may be significantly restricted. Any proposed BEB or other construction under I-280 need to be reviewed and approved by Caltrans.

An aerial and site plan of Islais Creek Yard are presented in Figure 4-8 and Figure 4-9, respectively.

Figure 4-8. Islais Creek Yard - Existing Conditions (Aerial)

Source: Google Earth

Figure 4-9. Islais Creek Yard - Existing Conditions (Site Plan)

Source: WSP

Planned ZEB Modifications

The Islais Creek Yard will be capable of storing 153 total BEBs, of which, 149 can be charged (simultaneously). 145 buses can be charged with pantographs via an overhead supporting structure that spans the area of the existing parking tracks. An additional four buses can be charged in the maintenance bays via plug-in dispensers. As previously mentioned, Caltrans has an existing easement that may preclude or limit BEB infrastructure. The final determination of what can be built within this easement will be evaluated in future analyses.

Table 4-4 summarizes the ZEB infrastructure planned at Islais Creek Yard.

Table 4-4. Islais Creek Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	115
No. of BEBs Supported (2040)	153
No. of Charging Cabinets	75
No. of Dispensers/Charging Positions	149

Source : WSP
Notes: It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio).
Any proposed BEB or other construction under I-280 needs to be reviewed and approved by Caltrans.

The following BEB equipment and locations are proposed:

— 73 DC charging cabinets located on a platform attached to the overhead support structure spanning a portion of the bus storage tracks and terminating at the edge of the overhead I-280 offset limits.[13] These charging cabinets will distribute to 145 pantograph-charging positions over the existing main storage tracks with a gap in charging positions under I-280 for storing spare buses. The charging positions begin again in the parking area west of I-280's offset limits.

— The overhead support structure columns are to be placed every three to four tracks. These columns will also provide the support for the overhead mounted pantographs.

— Two charging cabinets and four dispensers located in the maintenance building (with four dispensers) will charge the eight remaining spare buses that cannot be charged in the main parking area.

The pantographs and charging cabinets will be served by the following electrical infrastructure:

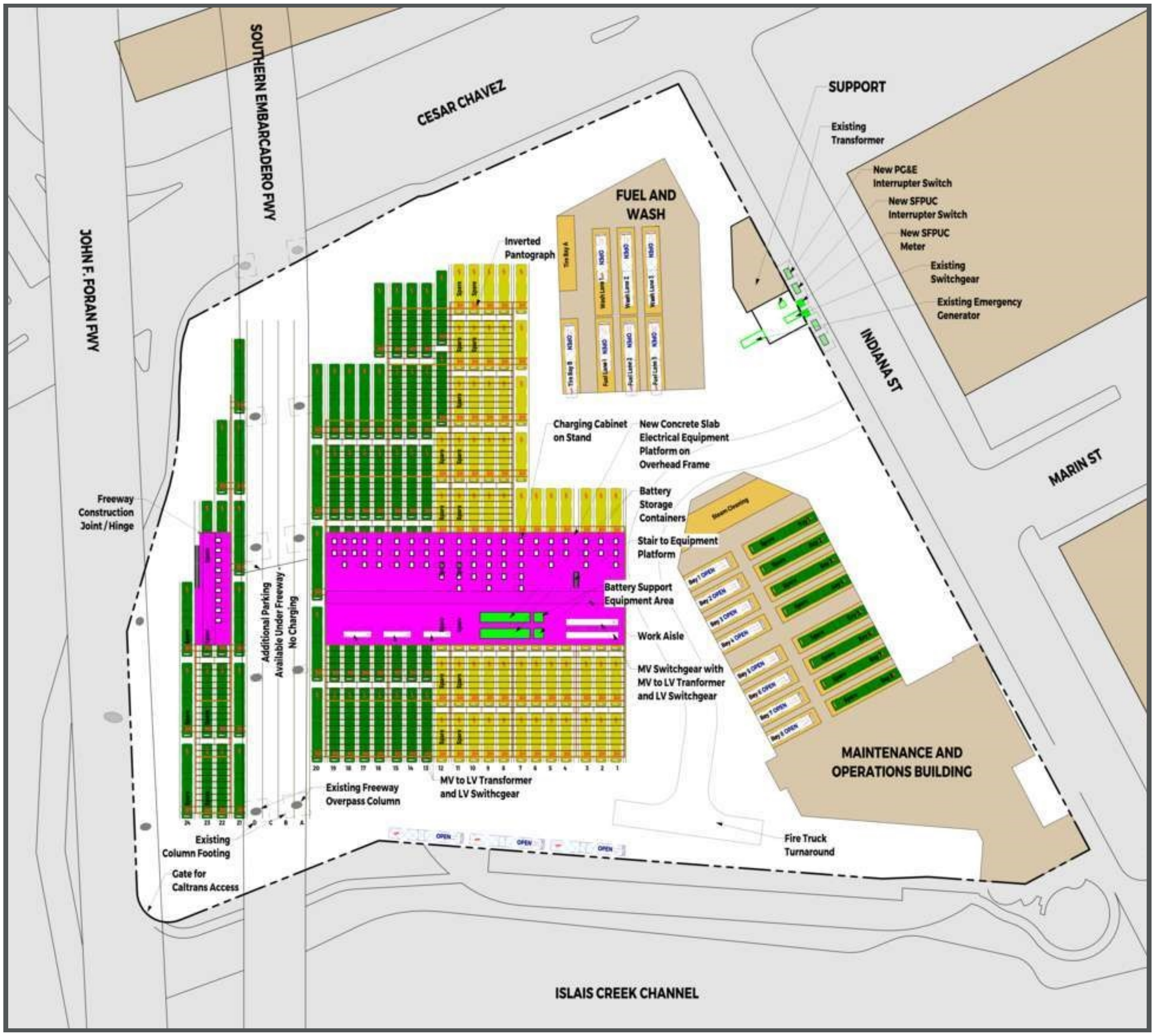
— Two interrupter switch pairs and two meters will be installed in the existing electrical yard. The first interrupter in each pair will be owned and operated by PG&E, and the second interrupter in each pair and both meters will be owned by SFPUC. Power will be distributed from the meter up along the fuel and wash building before crossing to the platform to the medium-voltage switchgear.

— Two medium-voltage switchgears and five medium- to low-voltage transformers with corresponding low-voltage switchgear will be installed on the platform, above the bus parking area. The switchgear and transformers will be rated for exterior use.

Figure 4-10 illustrates the Islais Creek Yard at full build-out.

[13] Any proposed BEB or other construction under I-280 needs to be reviewed and approved by Caltrans.

Figure 4-10. Islais Creek Yard - Full ZEB Build-Out



Source: WSP

Phasing and Construction Strategy

As discussed, the specific phasing for each yard is still being analyzed. However, this section provides details on the proposed improvements in Phase 1 and work to be completed in subsequent phases.

Phase 1

The recommended first phase for the Islais Creek Yard involves the installation of the four interrupter switches and two meters in the existing electrical yard and the routing of utility-provided power into the facility to the site's new transformers. Conduit and routing from the utility should be sized to serve the yard's full fleet. Phase 1 will also include the construction of the overhead support structure with distribution conduit, transformers and switchgears, pantographs, and charging cabinets to serve the easternmost seven tracks of bus parking.

Future Phases

Each subsequent phase of deployment will be accomplished by adding a similar modular overhead support structure and the required charging infrastructure to support the number of buses to be charged in the phase. The breakdown of this phasing will follow the SFMTA's growth plans and prioritization schedule

4.5.3 Kirkland Yard

Existing Conditions

Kirkland Yard is located at 2301 Stockton Street and 151 Beach Street in the City of San Francisco.

Currently, 91 standard diesel-hybrid buses are stored, maintained, fueled, and serviced at Kirkland Yard. The yard includes the following separate structures and major site areas: a maintenance canopy, one-story maintenance support building, one-story transportation building, wash lane (centered in the yard), stand-alone fuel building, and fuel storage yard with support equipment. Electrical utility service is provided by the SFPUC.

After revenue service, buses enter the yard from Stockton Street and are parked in unassigned, stacked (nose-to-tail) storage tracks. Individual buses are then pulled from the storage tracks and taken by nightly service staff to the fuel lanes for fare retrieval, interior cleaning, and fueling before pulling forward to the bus wash lane, Track 9, if being washed (not all buses are washed due to site restrictions). After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. NRVs are parked in a row of spaces along the northern site perimeter, where possible.

The *Building Progress Program* envisions a full rebuild of Kirkland Yard following completion of Presidio Yard (estimated 2029-2030). However, due to the operational necessity of Woods Yard and the high capital cost of converting to BEB at Woods, the SFMTA is now prioritizing the rebuild of Woods Yard in advance of Kirkland Yard. This means that Kirkland would be upgraded to BEB in its existing configuration as an interim improvement before a full buildout of the site closer to 2040.

An aerial and site plan of Kirkland Yard are presented in Figure 4-11 and Figure 4-12, respectively.

Figure 4-11. Kirkland Yard - Existing Conditions (Aerial)

Source: Google Earth

Figure 4-12. Kirkland Yard - Existing Conditions (Site Plan)

Source: WSP

Planned ZEB Modifications

The Kirkland Yard will be capable of storing 81 total BEBs, of which, 77 can be charged (simultaneously). 72 can be charged with pantographs via an overhead supporting structure that spans the area of the existing parking tracks. An additional five buses can be charged in the maintenance bays via plug-in dispensers. To meet the 2040 conversion timelines, this would be an interim improvement for approximately 10-15 years. Then, the Kirkland Yard would need to be fully rebuilt around 2040.

Table 4-5 summarizes the ZEB infrastructure planned at Kirkland Yard.

Table 4-5. Kirkland Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	91
No. of BEBs Supported (2040)	81
No. of Charging Cabinets	39
No. of Dispensers/Charging Positions	77

Source : WSP
Note: It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio).

The following BEB equipment and locations are proposed:

— 36 DC charging cabinets located on a platform attached to the overhead support structure spanning the northwest quadrant of the parking area. These charging cabinets will distribute to 72 pantograph-charging positions mounted from overhead support structures over the bus parking tracks.

— The overhead support structure columns are to be placed every three to four tracks. These columns will also provide the support for the overhead mounted pantographs.

— Three charging cabinets installed on a mezzanine located inside the new maintenance building adjacent to or near the electrical room. These charging cabinets will be connected to five dispensers installed between every two bays. This will provide charging for the nine buses that cannot be charged in the main parking area.

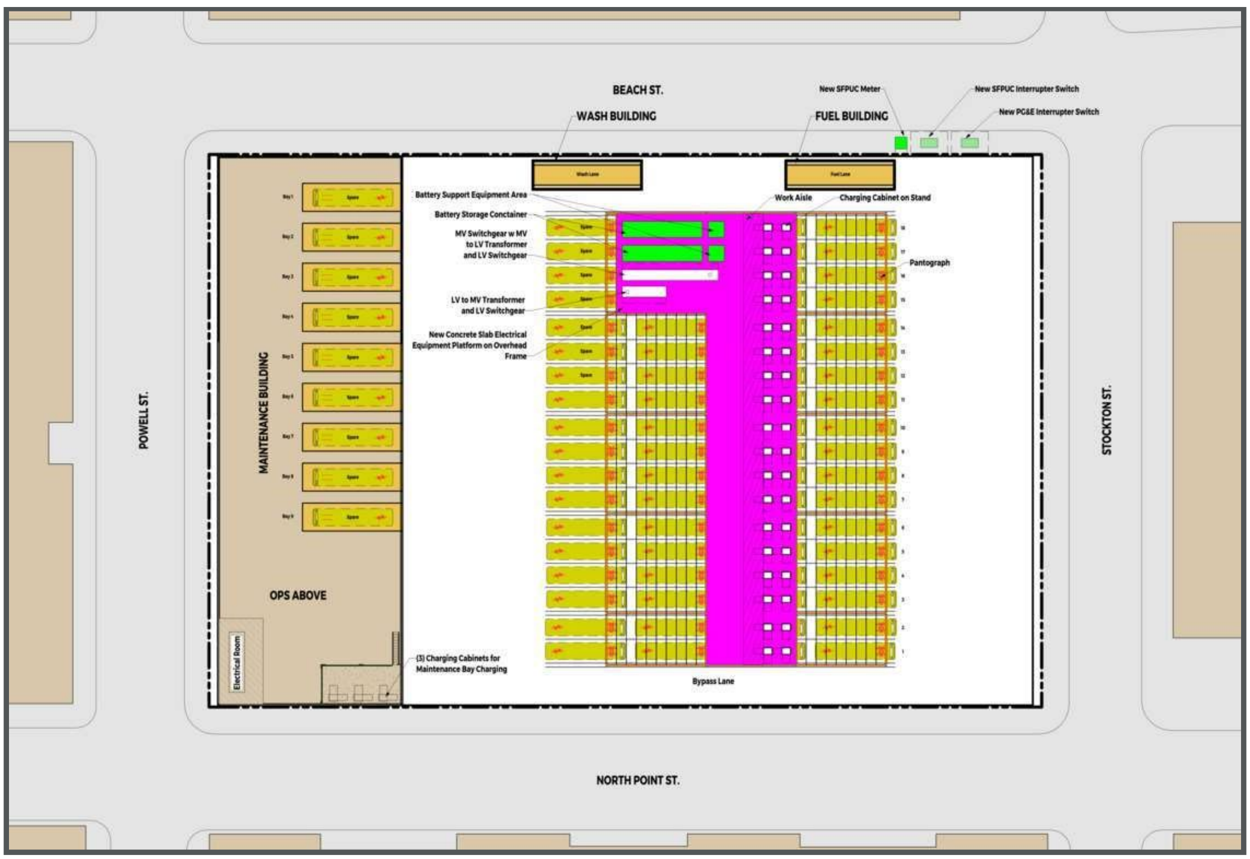
The pantographs and charging cabinets will be served by the following electrical infrastructure:

— One pair of interrupter switches and a meter will be installed on the northeast side of the site along Beach Street. The first interrupter will be owned and operated by PG&E, and the second interrupter and meter will be owned by SFPUC. Power will be routed up along the new fuel lane and across to the platform to feed the new medium-voltage switchgear.

— One medium-voltage switchgear and two medium- to low-voltage transformers with corresponding low-voltage switchgear will be installed on the platform, above the bus parking area. The switchgear and transformers will be rated for exterior use.

Figure 4-13 illustrates a conceptual rebuild of Kirkland Yard with associated ZEB improvements.

Figure 4-13. Kirkland Yard - Full ZEB Build-Out



Source: WSP

Phasing and Construction Strategy

Kirkland Yard was expected to be fully demolished and redeveloped prior to implementing BEBs on the site. However, due to financial and schedule issues, the SFMTA is developing an interim improvement at Kirkland that may include BEB infrastructure and several smaller facility improvement projects.

4.5.4 Potrero Yard

Existing Conditions

Potrero Yard is located at 2500 Mariposa Street in the City of San Francisco.

Currently, 146 trolley buses (53 40-foot and 93 60-foot) are stored, maintained, fueled, and serviced at Potrero Yard. The yard includes the following separate structures and major site areas: a two-story combined maintenance and transportation building, separate tire shop and body building, wash area, carbon-check area, and two separate bus parking yards. The upper yard and body/tire building are located on the deck above the maintenance building which is accessible from the north via 17th Street. Electrical utility service is provided by the SFPUC.

After revenue service, buses enter the yard from Mariposa Street and are parked in unassigned, stacked (nose-to-tail) storage tracks in front of the carbon check area. Individual buses are then pulled from the storage tracks and taken by nightly service staff to have their carbon checked, fare retrieved, interior cleaned, and fueled before pulling forward to the bus wash area. After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. NRVs are parked along the western site perimeter.

Potrero Yard is over 100 years old and anticipated to be demolished and rebuilt with modern bus facilities and potential residential element per the Potrero Yard Modernization Project. The expected in-service date for the new building is end of 2026.

Figure 4-14 presents Potrero Yard under existing conditions.

Figure 4-14. Potrero Yard - Existing Conditions (Aerial)

Source: Google Earth

Planned ZEB Modifications

As previously mentioned, the Potrero Yard Modernization Project aims to rebuild and expand the 4.4-acre site. The goal of the project is to replace the obsolete two-story maintenance building and bus yard with a modern, three-story, efficient bus maintenance and storage garage, equipped to serve the SFMTA's grown fleet as it transitions to BEBs.

As of February 2021, the Project is about to enter the Request for Proposals phase, during which ZEB modifications will be defined. As the future yard will to be multi-level, the Potrero Yard design guidelines include an overhead structure-mounted inverted pantograph-charging solution. Depending on the design choices made by the future Potrero Yard design team, the required electrical infrastructure could be installed in multiple configurations to suit the final design of the facility. Table 4-6 summarizes the ZEB infrastructure proposed at Potrero Yard.

Table 4-6. Potrero Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	146
No. of BEBs Supported (2040)	206
No. of Charging Cabinets	103
No. of Dispensers/Charging Positions	206

Source: WSP
Note: It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio)

Phasing and Construction Strategy

Since Potrero Yard will be fully redeveloped prior to implementing BEBs on the site, it is recommended that the entire infrastructure and charging position deployment be included in the redevelopment project. This will allow the ZEB transition to occur concurrently to the planned redevelopment construction process and avoid any further operational interruptions.

4.5.5 Presidio Yard

Existing Conditions

Presidio Yard is located at 949 Presidio Avenue in the City of San Francisco.

Currently, 132 40-foot trolley buses are stored, maintained, fueled, and serviced at Presidio Yard. The yard includes the following separate structures and major site areas: a two-story combined maintenance and transportation building, wash area, carbon check area, and bus parking yard. Electrical utility service is provided by the SFPUC.

After revenue service, buses enter the yard from Presidio Avenue and are parked in unassigned, stacked (nose-to-tail) storage tracks in front of the carbon check area. Individual buses are then pulled from the storage tracks and taken by nightly service staff to have their carbon checked, fare retrieved, interior cleaned, and fueled before pulling forward to the bus wash area. After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. NRVs are parked along the northern site perimeter.

Presidio Yard is over 100 years old and anticipated to be demolished and rebuilt with modern bus facilities. The Presidio Yard Modernization Project began pre-development and planning in early 2020. The expected in-service date for the new building is end of 2029.

Figure 4-15 presents Presidio Yard under existing conditions.

Figure 4-15. Presidio Yard - Existing Conditions (Aerial)

Source: Google Earth

Planned ZEB Modifications

Similar to Potrero Yard, Presidio Yard is planned to be fully redeveloped.

Although the design for the redevelopment project and specific ZEB modifications are still being evaluated, it is recommended that the Presidio Yard adopt an overhead structure-mounted inverted pantograph-charging solution. Depending on the design choices and criteria developed by the SFMTA and the future Presidio Yard design team, the required electrical infrastructure could be installed in multiple configurations to suit the final design of the facility.

Table 4-7 summarizes the ZEB infrastructure planned at Presidio Yard.

Table 4-7. Presidio Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	132
No. of BEBs Supported (2040)	217
No. of Charging Cabinets	109
No. of Dispensers/Charging Positions	217

Source : WSP
Note : It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio).

Phasing and Construction Strategy

Since Presidio Yard is expected to be redeveloped prior to implementing BEBs on the site, it is recommended that the entire infrastructure and charging position deployment be included in the redevelopment project. This will allow the ZEB transition to occur concurrently to the planned redevelopment construction process and avoid any further operational interruptions.

4.5.6 Woods Yard

Existing Conditions

Woods Yard is located at 1095 Indiana Street in the City of San Francisco.

Currently, 221 (221 40-foot and 20 30-foot) diesel-hybrid buses are stored, maintained, fueled, and serviced at Kirkland Yard. The 20 30-foot buses are exclusively used for training purposes. Woods has the largest bus capacity in Muni's system and is of strategic importance in the overall Muni service plan. The yard includes the following separate structures and major site areas: a two-story maintenance building, two-story tire shop, stand-alone fuel building, and stand-alone wash building. The site is bisected from north to south by Indiana Street. Electrical utility service is provided by the SFPUC.

After revenue service, buses enter the yard from Indiana Street and are parked in unassigned, stacked (nose-to-tail) storage tracks. Individual buses are then pulled from the storage tracks and taken by nightly service staff to the fuel lanes for fare retrieval, interior cleaning, and fueling before pulling forward to the bus wash lane. After fuel and wash, buses are re-parked in the storage tracks. Buses remain parked until morning pull out unless a maintenance issue has been identified. NRVs are parked in a row of spaces along the northern site perimeter, between the fuel and wash areas.

As a result of BEB facility conversion scope and high cost of improvements and electrical upgrade, the SFMTA is analyzing a potential full rebuild and expansion of the Woods Yard following completion of Presidio Yard. Woods Yard is inefficient in its site design and the maintenance function limits it to only 40-foot buses, which constrains the SFMTA's overall maintenance flexibility. If a rebuild scenario moves forward for Woods Yard, the anticipated in-service date range would be between 2032-2035.

An aerial and site plan of Woods Yard are presented in Figure 4-16 and Figure 4-17, respectively.

Figure 4-16. Woods Yard - Existing Conditions (Aerial)

Source: Google Earth

Figure 4-17. Woods Yard - Existing Conditions (Site Plan)

Source: WSP

Planned ZEB Modifications

If BEB infrastructure is integrated into the Woods Yard's existing layout, it will be capable of storing 233 total BEBs, of which, 177 can be charged (simultaneously). 158 can be charged with pantographs via an overhead supporting structure that spans the area of the existing parking tracks. An additional 19 buses can be charged in the maintenance bays via plug-in dispensers. It is assumed that not all assigned buses will be able to be charged concurrently. As buses finish charging, they should be moved to non-charging positions to allow the next bus to begin charging.

Woods Yard is also candidate for a full rebuild – an option that is still under study. It is assumed that if it is rebuilt, the proposed layout will be designed to charge the entire fleet, simultaneously.

Table 4-8 summarizes the ZEB infrastructure planned at Woods Yard.

Table 4-8. Woods Yard ZEB Infrastructure Summary

Primary Charging Strategy	Overhead Inverted Pantograph
No. of Existing Buses (September 2020)	241
No. of BEBs Supported (2040)	233
No. of Charging Cabinets	90
No. of Dispensers/Charging Positions	177

Source : WSP
Note: It is assumed that one charger will provide power for two charging positions/buses/dispensers (1:2 ratio).

The following BEB equipment and locations are proposed:

— 44 DC charging cabinets located primarily on a platform attached to the overhead support structure spanning the southern block of bus parking. These charging cabinets will distribute to 87 pantograph-charging positions mounted from overhead support structures over the existing main bus parking tracks and satellite spaces.

— 36 DC charging cabinets located primarily on a platform attached to the overhead support structure spanning the northern block of bus parking. These charging cabinets will distribute to 71 pantograph-charging positions mounted from overhead support structures over the existing main bus parking tracks and satellite spaces.

— The overhead support structure columns are to be placed every three to four tracks. These columns will also provide the support for the overhead mounted pantographs.

— In the maintenance building, 10 charging cabinets will be installed and connect to 19 dispensers. The dispensers will be mounted between every two bays. This will provide charging to 37 buses that cannot be charged in the main parking area.

The pantographs and charging cabinets will be served by the following electrical infrastructure:

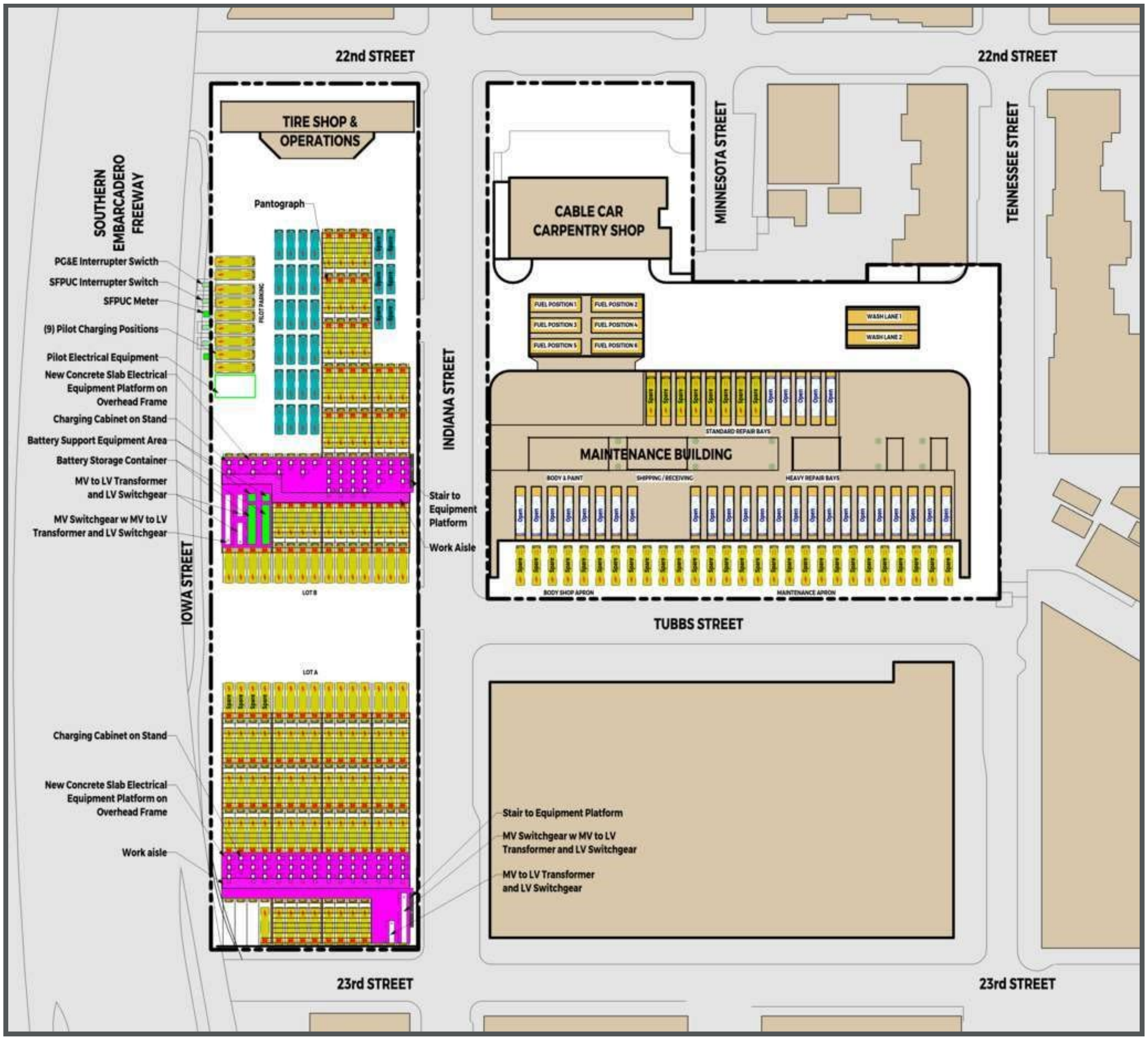
— Two interrupter switch pairs and two meters will be installed on the west side of the site along Iowa Street. The first interrupter in each pair will be owned and operated by PG&E, and the second interrupter in each pair as well as both meters will be owned and operated by SFPUC. Power will transition from the meters to the medium-voltage switchgear located on the two platforms located at the north end of the site and the south end of the site, above the bus parking.

— On the northern platform, one medium-voltage switchgear and three medium- to low-voltage transformers with corresponding low-voltage switchgear will be installed. The switchgear and transformers will be exterior rated.

— On the southern platform, one medium-voltage switchgear and two medium- to low-voltage transformers with corresponding low-voltage switchgear will be installed. The switchgear and transformers will be exterior rated.

Figure 4-18 illustrates the Woods Yard at full build-out.

Figure 4-18. Woods Yard - Full ZEB Build-Out



Source: WSP

Phasing and Construction Strategy

As discussed, the specific phasing for each yard is still being analyzed. However, this section provides details on the proposed improvements in Phase 1 and work to be completed in subsequent phases.

Phase 1

The recommended first phase for the Woods Yard includes the installation of four new interrupter switches and two meters on the exterior of the facility along Iowa Street, routing the utility-provided power into the site along the eastern wall to the site's new transformers. Conduit and routing from the utility should be sized to serve the yard's full fleet. Phase 1 will also include the construction of the overhead support structure with distribution conduit, transformers and switchgears, pantographs, and charging cabinets to serve the northern block of bus parking.

Future Phases

Each subsequent phase of deployment will be accomplished by adding a similar modular overhead support structure and the required charging infrastructure to support the number of buses to be charged in the phase. The breakdown of this phasing will follow the SFMTA's growth plans and prioritization schedule.

5 Equity Considerations

The following section provides an overview of disadvantaged communities within the SFMTA's service area and information on how the SFMTA plans to ensure that BEBs are prioritized in these communities .

5.1 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) and California's Senate Bill 535, define a "disadvantaged" community as a community (census tract) that is located in the top 25th percentile of U.S. Census tracts identified by the results of 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. The SFMTA will ensure that equity and DACs are prioritized as yards are equipped with charging infrastructure and as buses are deployed on the yard's BEB-compatible blocks

In addition to upcoming BEB deployments, the SFMTA specifically addresses equity through two focused initiatives: The Muni Service Equity Policy and the Green Zone project.

The SFMTA Service Equity Policy is a process to identify and correct transit performance disparities. The SFMTA has prepared three equity strategy reports since the policy was adopted in 2014. The 2016 Equity Strategy identified seven neighborhoods: Bayview, Chinatown, Excelsior/Outer Mission, Inner Mission, Tenderloin, Visitacion Valley, and Western Addition. The Oceanview/Ingleside neighborhood was added in the 2018 Equity Strategy, and Treasure Island was added in the 2020 Equity Strategy. The intent is that these neighborhoods see improvement equal to or better than the overall system.

The "Green Zone" project, initiated in 2019, utilizes existing technology that permits diesel-hybrid vehicles to run on full electric battery power in select neighborhoods with poor air quality. 68 of these vehicles have larger batteries and a GPS-enabled switch, which will cause the bus to automatically switch to EV mode as it enters geo-fenced areas (Green Zones) throughout the city. The geo-fenced zones were chosen to focus primarily on Muni Equity Strategy neighborhoods, those with high percentages of low-income households and people of color, and where respiratory illnesses occur at a disproportionate rate.

5.2 Summary of The SFMTA's DACs

To understand the potential benefits that ZEBs will provide to DACs in the SFMTA's service area, it is necessary to establish if (1) a yard is in a DAC, and (2) if its routes travel within or alongside a DAC boundary.

As shown in Table 5-1 and Figure 5-1, none of the SFMTA's bus yards are located within a DAC. However, routes that are served from each yard *do* serve DACs – Woods Yard serves the most DACs (12), which account for approximately 6% of all of its communities served. As noted above, several routes are operated with buses from more than one garage, so a single route in a DAC could be served by multiple yards.

Table 5-1. The SFMTA's Disadvantaged Communities - Yard Summary

Yard	In DAC?	NOx Exempt Area?	Communities Served	DACs Served	Pct. Of DACs Served
Flynn	No	No	102	2	2%
Islais Creek	No	No	112	4	4%
Kirkland	No	No	120	5	4%
Potrero	No	No	74	2	3%
Presidio	No	No	92	4	6%
Woods	No	No	192	12	6%

Source: CalEnviroScreen 3.0

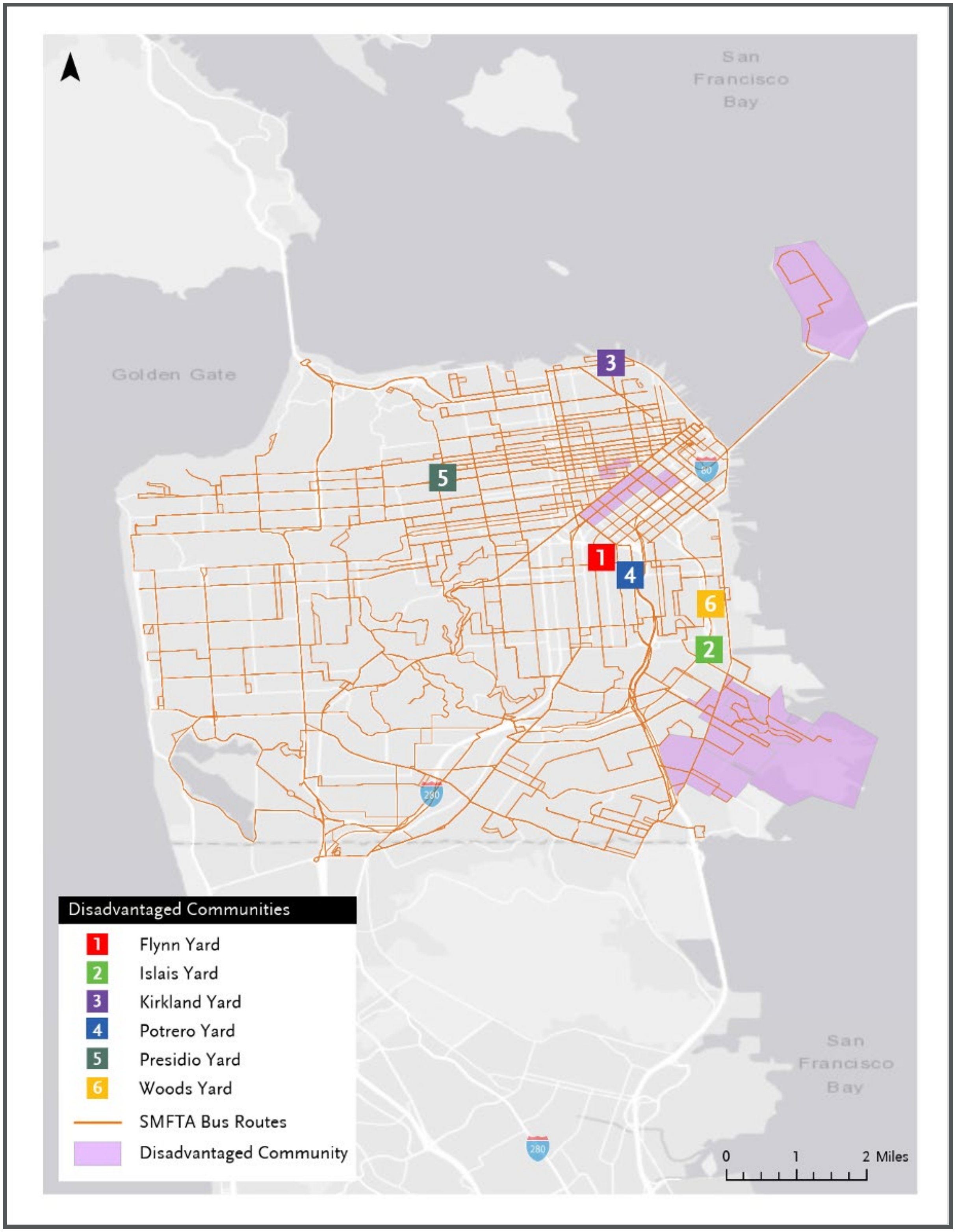
Table 5-2 details the number of DAC-serving routes by yard.

Table 5-2. The SFMTA's Disadvantaged Communities - Route Summary

Yard	No. of DAC-Serving Routes	DAC-Serving Routes
Flynn	5	9R, 14R, 14X, 38R, 714
Islais Creek	7	7, 7X, 8, 8AX, 8BX, 38, 714
Kirkland	6	12, 19, 30, 47, 81X, 83X
Potrero	5	5, 5R, 6, 14, 30,
Presidio	4	21, 24, 31, 45
Woods	22	5, 7, 7X, 9, 23, 25, 27, 29, 38, 44, 54, 81X, 83X, 91, K-OWL, L-OWL, N-OWL, JBUS, KTBUS, LBUS, MBUS, NBUS

Source: CalEnviroScreen 3.0

Figure 5-1. The SFMTA's Disadvantaged Communities and Bus Yards



Source: CalEnviroScreen 3.0

6 Workforce Training

The following section provides an overview of the SFMTA's plan to train personnel on the impending transition.

6.1 Training Requirements

The transition to an all-ZEB fleet will significantly alter SFMTA's service and operations. Converting to BEBs from their existing diesel-hybrid and trolley bus fleet(s) 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. For example, SFMTA has already procured nine buses for their pilot project (expected delivery in 2021).[14] Table 6-1 provides an example of training modules that are included with one of their 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 SFMTA's staff will be trained well in advance of the commissioning of these additions.

Table 6-1. Zero-Emission Bus 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

The following provides a list of personnel and positions that will need to be retrained upon adoption of ZEBs (this list is not exhaustive):

[14] Nine buses are currently procured with an additional three in negotiations.

- **Bus Operators and Supervisors**
  Bus operators and field supervision will need to be familiarized with the buses, safety, bus operations, and pantograph operations.

- **Facilities Maintenance Staff**
  Maintenance staff will need to be familiarized with scheduled and unscheduled repairs, high-voltage systems, and the specific maintenance and repair of equipment.

- **First Responders**
  Local fire station staff will need to be familiarized with the new buses and supporting facilities.

- **Tow Truck Service Providers**
  Tow truck providers will need to be familiarized with the new buses and proper procedures for towing ZEBs.

- **Mechanics**
  Mechanics will need to be familiarized with the safety-related features and other components of ZEBs.

- **Instructors**
  Maintenance and bus operator instructors will need to understand all aspects of the transition of ZEBs to train others.

- **Utility Service Workers**
  Staff will become familiarized with proper charging protocol and procedures that are ZEB-specific.

- **Management Staff**
  Maintenance and Operations managerial staff will be familiarized with ZEB operations and safety procedures.

7 Costs and Funding Opportunities

The following section identifies preliminary capital costs and potential funding sources that the SFMTA may pursue in its adoption of ZEBs.

7.1 Preliminary Capital Expenditure Costs

While costs for a full fleet transition are still being analyzed, it is estimated that the costs of chargers, pantographs, buses, and on-site construction, alone, will be in excess of $1.8B (2020 dollars). This estimate is based on a 1:1 bus replacement ratio. The following costs are excluded from the estimate:

- purchase of additional buses (due to range limitations)
- on-site battery storage or photovoltaics
- charge management software
- on-route charging infrastructure
- costs associated with the transition (i.e., temporary relocating and rerouting of service)

The estimate is only based on infrastructure *within* the SFMTA's property lines – it does not consider utility infrastructure enhancements that are required to energize the fleet (design, permitting, and construction of substations, circuits, etc.). The SFMTA has been advised by the SFPUC that it is most likely that PG&E will pass along the cost of any downstream improvements to the SFMTA, at a likely cost of several million dollars per site. Costs are variable and the SFPUC could not provide a per cost mile estimate due to site-specific factors such as age of existing infrastructure, location of existing electrical improvements, density of equipment within the utility vault, etc.

Furthermore, Potrero and Presidio yards (and likely Woods) are planned to be fully rebuilt. An August 2020 cost estimate for the Potrero Yard Modernization Project (bus facility component only) exceeds $406M, not including BEB supporting infrastructure. Prior to the ICT regulation, the current state of the facility has caused the SFMTA to reconsider the priority to rebuild Woods in advance of Kirkland. The SFMTA is still analyzing the facility sequencing and scope of work, with the cost of BEB improvements as a major factor in decision making. The costs associated with the demolition, staging, and construction at these existing sites is also not included with the capital cost estimate.

The cost for BEB improvements at each yard ranges from a low estimate of $130M (Kirkland) to a high of $406M (Potrero). The average capital cost per yard is approximately $303M.

The associated costs of a full fleet transition for each yard is provided in Table 7-1.

Table 7-1. Preliminary Bus and Charger Infrastructure (Only) Expenditure Estimates by Yard

Yard	Buses	Charging Infrastructure (Only)	Total
Flynn	$174.4M	$65.5M	$239.9M
Islais Creek	$236.8M	$83.0M	$319.8M
Kirkland	$101.3M	$28.7M	$130.0M
Potrero	$303.4M	$102.6M	$406.0M
Presidio	$272.3M	$81.8M	$353.1M
Woods	$286.4M	$86.4M	$372.8M
Total	$1.4B	$448M	$1.8B

Source: WSP
Notes: These estimates do not reflect the full facility upgrades required which are highly variable based on state of repair, location, etc. Pending further analysis, there will likely be additional capital improvements and costs to ensure a successful BEB operation, including battery storage, photovoltaics, additional vehicles, contingency components, utility enhancements, etc.
-Rounded to the nearest tenth.

7.2 Potential Funding Sources

There are a number of potential federal, state, local, and project-specific funding and financing sources that may be available to the SFMTA. The SFMTA will monitor funding cycles and pursue opportunities that yield the most benefits for the agency pursuant to the ICT regulation. Table 7-2 identifies the many funding opportunities that the SFMTA may take advantage of in the next 20 years.

Table 7-2. ZEB Funding Opportunities

Type	Agency	Funding Mechanism
Federal	United States Department of Transportation (USDOT)	Better Utilizing Investments to Leverage Development (BUILD) Grants
	FTA	Capital Investment Grants – New Starts
		Capital Investment Grants – Small Starts
		Bus and Bus Facilities Discretionary Grant
		Low- or No-Emission Vehicle Grant
		Metropolitan & Statewide Planning and Non-Metropolitan Transportation Planning
		Urbanized Area Formula Grants
		State of Good Repair Grants
		Flexible Funding Program – Surface Transportation Block Grant Program
	Federal Highway Administration (FHWA)	Congestion Mitigation and Air Quality Improvement Program

Type	Agency	Funding Mechanism
	Environmental Protection Agency (EPA)	Environmental Justice Collaborative Program-Solving Cooperative Agreement Program
	Department of Energy (DOE)	Design Intelligence Fostering Formidable Energy Reduction and Enabling Novel Totally Impactful Advanced Technology Enhancements
State	CARB	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)
		State Volkswagen Settlement Mitigation
		Carl Moyer Memorial Air Quality Standards Attainment Program
		Cap-and-Trade Funding
	California Transportation Commission (CTC)	Solution for Congested Corridor Programs (SCCP)
	Caltrans	Low Carbon Transit Operations Program (LCTOP)
		Transportation Development Act
		Transit and Intercity Rail Capital Program
		Transportation Development Credits
		New Employment Credit
Local and Project-Specific		Joint Development
		Parking Fees
		Tax Rebates and Reimbursements
		Enhanced Infrastructure Financing Districts
		Opportunity Zones

Source: WSP

8 Start-Up and Scale-Up Challenges

The SFMTA is an industry leader in implementing clean fleets and we share the California Air Resource Board's (CARB) vision to mitigate the impacts of climate change. The transportation sector is San Francisco's largest contributor to the city's overall carbon footprint. As the biggest source of greenhouse gas emissions, it makes up nearly half of all citywide emissions. The pollutants from cars, trucks and other private vehicles account for more than 70% of transportation emissions, while public transportation accounts for only 5% of transportation emissions. SFMTA's transit fleet accounts for less than 2% of public transportation emissions (which is less than .01% of the city's overall greenhouse gas emissions). Our initial analysis identifies significant challenges to further reducing our 2% share of emissions via a full ZE transition by 2040. These include time constraints, unpredictable advancements in ZE technology that could risk transit performance and service reliability, and significant capital, operational, and ongoing maintenance costs while our budget remains impacted by the COVID-19 pandemic. The following list of challenges is not exhaustive, and the SFMTA would like to explore with CARB the additional risks and complications to the ICT regulation.

- **Uncertainty of COVID-19.** COVID-19 has impacted all facets of our global economy, and transit is not an exclusion. During the pandemic, the SFMTA's ridership has plummeted and caused major shortfalls in revenue, resulting in impacts to both capital programs and operations. In addition, a global economic recession that came about with almost no warning is worsening as the COVID-19 crisis persists. At this time, it is unclear what the long-term impacts will be on service. There is a possibility that service ridership levels may not return to previous levels, resulting in changes to procurement and funding. As we look towards our recovery, we believe our limited resources are best used in retaining and growing our ridership. By prioritizing our commitment to providing reliable, high-frequency buses, we will improve environmental conditions at a lower cost than total fleet conversion While current CARB fleet conversion goals will help us further reduce, we believe high quality service is the key to even greater emissions reductions. The SFMTA will continue to analyze trends to determine service changes and plans.

- **Rapid Technological Advancement.** The SFMTA is currently planning for a transition based on the fleet as of September 2020 (with January 2020 service, pre-COVID). The SFMTA will soon need to make decisions on fleet requirements and it is difficult to anticipate future technological changes, such as improved batteries and chargers. The SFMTA (and the market) will have to make decisions to purchase fleets based on what is known at the time of the contract. This exposes the SFMTA to a risk of missing out on improvements that come soon after contract execution, rendering purchased technologies outdated on arrival.

- **Insufficient BEB Performance and Range.** The BEB industry is constantly innovating and developing vehicles with longer ranges and more efficient batteries. However, the SFMTA's analysis currently shows some service blocks that cannot be completed under existing technologies, particularly the hilliest routes. Unless battery technologies evolve, the SFMTA will have to spend additional monies to meet range requirements due to OEM's inability to develop better performing batteries.

- **Resiliency and Emergency Response.** The SFMTA is also seeking solutions to address resiliency and emergency response within the context of an all-BEB fleet. Service that is dependent on electricity is vulnerable during outages and emergencies. In addition, the SFMTA provides regional emergency responses and high-capacity evacuation for wildfires, which would be challenging to do with reduced bus ranges, such as BEBs. Thus, the SFMTA is considering retaining a dHEB sub fleet for these rare occasions, although we acknowledge this fleet would not be CARB-compliant.

- **High Capital and O&M Costs.** To maintain pre-COVID-19 service with BEBs (with existing technologies), the SFMTA would need more vehicles (more than a 1:1 replacement ratio). The SFMTA's facilities are at crush capacity and cannot accommodate even 10% more vehicles. Therefore, to convert with current technologies, the SFMTA would have to acquire additional real estate and build new facilities, which is a daunting and extremely expensive endeavor. Additionally, the SFMTA's buses operate on some of the steepest grades in the US. The gradeability will require the SFMTA to purchase extended warranties (likely 12-year) which increases the purchase price of each bus, and it can also lead to more expensive midlife overhaul costs – further ballooning the lifecycle costs of the transition.

- **Uncertain Capital Funding Streams in a Major Economic Recession.** Adoption of BEBs has many benefits, including potential lifecycle cost savings. However, the investment required for capital and change management is significant. In an increasingly constrained funding environment, and with little to no operating reserves due to the recession induced by COVID-19, the SFMTA does not have funds for these capital projects if specific funding streams are not identified through other resources. The conversion of the SFMTA's bus facilities to accommodate BEBs is especially complex, particularly given the 2040 time horizon. Like much of United States' public infrastructure, the SFMTA is faced with aged, obsolete facilities and significant deferred maintenance due to decades without flexible facility funding. The SFMTA's Building Progress Program, a facility capital renewal program, aims to strategically address this state of disrepair by rebuilding the SFMTA's oldest and most obsolete facilities. This ambitious and billion-dollar program includes BEB adaptability of two yards but leaves four with no funding framework for the significant modifications that BEB requires.

  To electrify the full fleet by 2040, SFMTA would need to have multiple yards undergoing construction concurrently. In addition, the high cost of the improvement requires a cost-benefit analysis of making BEB improvements without addressing existing condition of the facilities. For at least two facilities (Kirkland and Woods), BEB conversion without complete rebuild of the sites is not fiscally responsible. This clearly adds additional budget, schedule, and risk complexity to the BEB conversion decision matrix.

- **Strains on Market Supply.** The ICT regulation will put a lot of pressure on OEMs to produce ZEBs at unprecedented rates. However, it is not only California that is interested in converting to ZEBs. These monumental policy changes make it challenging to meet ZEB goals for agencies if the supply of buses cannot meet demand. This may cause strains on supply, resulting in risk to meeting purchase requirement deadlines. If the supply industry cannot keep up and we end up with a less reliable vehicle, this could suppress transit use and not meet program goals. We cannot go electric if vehicles are not reliable.

- **Transition Complexity**. Maintaining service and adhering to ICT regulation purchase requirements, all while managing on-site construction, facility rebuilds, temporary bus relocations, bus procurements, and utility enhancements introduces a lot of risk to the SFMTA's program. If one element of this transition doesn't go as planned, there will be implications for other components of the program.

- **Dependence on SFPUC and PG&E Enhancements**. All of the SFMTA's yards will require additional electrical service and infrastructure. Installation of the support structure and charging equipment (chargers, switchgear, transformer, etc.) will impact transit operations. To date, PG&E has not provided a path for the SFMTA to collaborate on planning for electrical service enhancement at the SFMTA bus yards, despite the San Francisco Public Utilities Commission's (SFPUC) persistence. Additionally, it is anticipated that utility infrastructure enhancements will also need to occur outside of the SFMTA's property lines, which may require for upstream improvements to the power grid. Current cost estimates do not consider these improvements, and the SFMTA has been advised by the SFPUC that PG&E will most likely pass these costs to the SFMTA at the likely cost of several million dollars per site.

– **Additional Strain on PG&E Resources.** Further complicating the SFMTA's dependency on PG&E coordination is the State's competing policies, programs, and regulation of other electric fleets, including commercial fleets and private vehicles. As State transportation electrification efforts take hold, PG&E will be incentivized to address the needs of rate-paying customers first. The SFMTA anticipates that commercial rate-paying customers will be prioritized over the SFMTA (as a wholesale customer).

– **The Results of the SFPUC Power Rate Study.** The SFPUC is currently undertaking an analysis of their rate structure. The SFMTA currently pays a wholesale distribution rate and receives power to its traction power system and facilities at very favorable rates. The outcome of this study and any resulting rate change impacts the SFMTA's cost to convert to BEB.

– **Managing Power Demand**. The transition to BEBs will require strategies to ensure that the SFMTA can utilize power in the most efficient way. The SFMTA is coordinating with utility providers to determine methods to reduce peak demands. However, managing demand may also come at a hefty capital cost, something that staff is currently analyzing.