Los Angeles County Metropolitan Transportation Authority

Final
Rollout Plan

Prepared for:

California Air Resources Board

Prepared by:

ZEBGO Partners

444 South Flower Street
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March 2021

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Acronyms and Abbreviations

BEB	Battery-Electric Bus
Board	Metro Board of Directors
BRT	Bus Rapid Transit
CARB	California Air Resource Board
CMF	Central Maintenance Facility
CNG	Compressed Natural Gas
DAC	Disadvantaged Communities
FCEB	Fuel Cell Electric Bus
ICT	Innovative Clean Transit
kW	Kilowatt
LADWP	Los Angeles Department of Water and Power
MW	Megawatts
OEM	Original Equipment Manufacturer
RFP	Request for Proposal
SBE	Standard Bus Equivalent
SCE	Southern California Edison
SP	Strategic Plan
ZE	Zero-Emission
ZEB	Zero-Emissions Bus(es)

E.1 ROLLOUT PLAN SUMMARY

Agency Background	
Transit Agency's Name	Los Angeles County Metropolitan Transportation Authority (Metro)
Mailing Address	One Gateway Plaza Los Angeles, California 90012-2952
Transit Agency's Air District	South Coast Air Quality Management District
Transit Agency's Air Basin	South Coast Air Basin
Total number of buses in Annual Maximum Service[1]	1,890[2]
Urbanized Area	Los Angeles – Long Beach – Anaheim, CA
Population of Urbanized Area[3]	12,150,996
Contact information of general manager, chief operating officer, or equivalent	James T. Gallagher Chief Operations Officer 213.418.3108 gallagherj@metro.net
Rollout Plan Content	
Is your transit agency part of a Joint Group[4]	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
Please explain how your transit agency plans to avoid potential early retirement of conventional buses in order to meet the 2040 goal	Staff is evaluating the pandemic's impact to service, ridership, and available funding. However, sufficient time appears to be available to preclude the need for early retirement of buses.

[1] The ICT regulation defines "Annual Maximum Service" (13 CCR § 2023(b)(3)) as the number of buses in revenue service that are operated during the peak season of the year, on the week and day that maximum service is provided but excludes demand response buses.
[2] This is based on December 2018 (directly operated and contracted) service levels.
[3] As last published by the Census Bureau before December 31, 2017
[4] The ICT regulation defines a Joint Zero-Emission Bus 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 zero-emission bus requirements of section 2023.1 of the ICT regulation.

Rollout Plan Development and Approval	
Rollout Plan's approval date	03/25/21
Resolution No.	2020-0636
Is copy of Board-approved resolution attached to the Rollout Plan?	Yes (Appendix A)
Contact for Rollout Plan follow-up questions	Marc Manning Senior Director, Vehicle Engineering & Acquisition 213.392.6896 Manningm@metro.net
Who created the Rollout Plan?	Consultant
Consultant	ZEBGO Partners

E.2 EXECUTIVE SUMMARY

In accordance with the California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation, the following report serves as Los Angeles County Metropolitan Transportation Authority's (Metro) Rollout Plan to transition its bus fleet to 100 percent zero-emission (ZE) by 2040.

E.2.1 CARB's Innovative Clean Transit Regulation

CARB's ICT regulation requires all public transit agencies in the State of California to transition from conventional buses (compressed natural gas, diesel, etc.) to ZE buses (battery-electric or fuel cell electric) by 2040. The regulation requires a progressive increase of an agency's new bus purchases to be zero-emission buses (ZEBs) based on fleet size. By 2040, CARB requires all transit agencies in the state to be operating only ZEBs.

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 a number of required components (as outlined in the Rollout Plan Guidelines) and must be approved by the transit agency's governing body through the adoption of a resolution, prior to submission to CARB.

Metro must comply with the following requirements under the ICT regulation:

- July 1, 2020 – Board-approved Rollout Plan must be submitted to CARB[5]
- January 1, 2023 – 25 percent of all new bus purchases must be ZE
- January 1, 2026 – 50 percent of all new bus purchases must be ZE
- January 1, 2029 – 100 percent of all new bus purchases must be ZE
- January 1, 2040 – 100 percent of fleet must be ZE
- March 2021 – March 2050 – Annual compliance report due to CARB

E.2.2 Zero-Emission Bus Technologies

According to the ICT regulation, a ZEB is a bus with zero tailpipe emissions and is either a battery-electric bus (BEB) or a fuel cell electric bus (FCEB).

BEBs depend on a system to store and retrieve energy much as cars and trucks need fuel. BEBs have multiple battery packs that power an electric motor, resulting in ZE. Similar to many other battery-powered products, BEBs must be charged for a period of time to be operational. Currently, BEBs can be charged at the facility or in-service (on-route charging) via a number of connectors and dispensers.

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. FCEBs can replace diesel or compressed natural gas (CNG) fuel buses without significant changes to operations and service and functions as a resilient backup alternative in case of natural disaster. The

[5] Due to the impacts of COVID-19, CARB provided an extension to all large transit agencies in California, upon request. Metro requested and was granted an extension to submit the Rollout Plan by December 31, 2020. In October 2020, Metro requested and was granted another extension to accurately capture the results of the recently released NextGen Plan and other service- and market-related updates. Metro now will submit its Board-approved Rollout Plan to CARB by March 2021.

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.

Metro's past and ongoing ZEB analysis has found that BEB adoption is the ZEB technology that best aligns with Metro's 2030 ZEB goals. This is in a large part due to the market of BEBs in terms of technological advancement, costs, and availability. While FCEBs are promising and have many potential benefits (as compared to both CNG and BEB), unpredictability in operation costs and a limited supply chain makes it an unviable option at this time, especially considering Metro's aggressive ZEB goals. However, Metro will continue to monitor FCEB advancements and consider the technology in future applications.

E.2.3 Metro's Zero-Emission Bus Efforts

Metro is already embracing the prospects of a ZE future and is taking multiple steps to not only meet the requirements of CARB's ICT regulation, but to also provide a cleaner and more sustainable future for the communities that it serves. These efforts include:

- **Metro's Strategic Plan to ZEB Transition.** In 2017, the Metro Board endorsed staff's Strategic Plan for the transition to ZEBs. The first phase is to convert the Orange Line to ZEBs by 2020 and the Silver Line as soon as feasible, thereafter. The second phase involves the creation of a ZE Master Plan that would evaluate the entire Metro bus system and map out the best strategy and anticipated cost to convert to ZE operation.
- **BEB and Infrastructure Investments.** Shortly after the Board's endorsement of the 2017 Strategic Plan, Metro awarded three ZEB contracts for the electrification of the Orange and Silver Lines; two with BYD for five 60-foot ZEBs intended for the Orange Line and 60 40-foot ZEBs for the Silver Line, and one with New Flyer for 40 60-foot ZEBs for the Orange Line. To support these BEBs, Metro is in the process of installing 10 plug-in chargers at Division 8 and eight on-route chargers to support the Orange Line's transition. In September 2019, Metro's Board approved exercising the options of 40 additional BYD 40-foot ZEBs. With this exercise, Metro has plans to deploy 145 BEBs.
- **ZEB Program Master Plan.** In July 2018, Metro awarded "ZEBGO", a joint venture of multiple industry experts to produce a Master Plan and action-ready RFPs to transition to all ZEBs by 2030 – an ambitious plan that will guide Metro in adopting all ZEBs - 10 years before the ICT regulation requires.
- **NextGen Study.** While not directly tied to ZEB efforts, Metro is currently restructuring existing service to better meet the needs of current and future riders. The NextGen Bus Study will evaluate a number of alternatives and strategies to improve service, which may include more frequent service and shorter headways. This study is ongoing and is being coordinated with Metro's ZEB Master Plan efforts.

E.2.4 Metro's Path to an All-Zero-Emission Fleet

The Rollout Plan identifies a strategy for Metro to procure and operate an all-ZEB fleet by 2030 – ten years before the ICT regulation requires. In accordance with the Rollout Plan Guidance, this document provides an overview of a number of key components to Metro's ZEB transition, including fleet acquisitions, schedule, training, and funding considerations. As previously mentioned, Metro is currently studying and has a goal of transitioning to all ZEBs by 2030. Therefore, there are no anticipated issues with meeting the ICT regulation's 2040 requirement.

Due to the rapidly evolving nature of ZEB technologies, it is possible that the findings and recommended approaches in this report will be outdated when it is time for implementation. The information in this Rollout Plan is informed and based on December 2018 service levels. This information is used because it represents the fleet under typical operating conditions. Since then, there have been a number of special projects, including bus bridges, that may skew the fleet size and division requirements.

It should also be noted that COVID-19 has caused unprecedented losses in Metro's revenue through both the loss of fares from diminished ridership and loss of sales tax revenue from a reduction in Los Angeles consumer spending. For these reasons, Metro has reduced service and operations and is still evaluating the long-term ramifications on the system and the agency's capital projects and goals. Metro will proceed with planning and will adjust as the results from COVID-19 impacts stabilize and trends are more predictable.

The following subsections provide a brief summary of the Rollout Plan.

E.2.4.1 Baseline Conditions

As of December 2018, Metro currently operates a fleet approximately 2,230 buses out of 11 divisions. Another 165 buses are leased to contractors to operate Metro routes. Table E.2-1 summarizes each division and its respective fleet.

Table E.2-1. Summary of Existing Divisions and Baseline Fleet

Div.	Address	Operator	Fuel Type	Main Functions	32' Buses	40' Buses	45' Buses	60' Buses	Total Buses	Total Buses (SBE #)
1	1130 E. 6th St, Los Angeles	Metro	CNG	O&M	-	132	35	22	189	207
2	720 E. 15th St, Los Angeles	Metro	CNG	O&M	-	172	-	-	172	172
3	630 W. Ave 28, Los Angeles	Metro	CNG	O&M	-	86	91	-	177	196
5	5425 Van Ness Ave, Los Angeles	Metro	CNG	O&M	-	134	7	52	193	221
7	8800 Santa Monica Bl. W.Hollywood	Metro	CNG	O&M	-	148	80	5	233	252
8	9201 Canoga Ave, Los Angeles	Metro	CNG	O&M	-	61	107	34	202	241
9	3449 Santa Anita Ave, El Monte	Metro	CNG	O&M	-	161	62	-	223	236
10	742 N. Mission Rd, Los Angeles	Metro	CNG	O&M	-	69	13	69	151	189
13	920 N. Vignes St, Los Angeles	Metro	CNG	O&M	-	56	14	93	163	213
15	11900 Branford St, Los Angeles	Metro	CNG	O&M	-	82	109	50	241	288
18	459 W. Griffith St, Gardena	Metro	CNG	O&M	-	74	116	62	252	307
278	Stored at D10 or CMF	Metro	CNG	Training	-	31	1	-	32	33
								Directly Operated Subtotal	2,228	2,555
95	14913 E. Ramona Bl Baldwin Park	Transdev	CNG	O&M	16	18	-	-	34	31
97	21222 S. Wilmington Ave, Carson	MV Transit	Diesel/CNG	O&M	5	70	-	-	75	74
98	1611 Naud St, Los Angeles	Southland	CNG	O&M	29	27	-	-	56	50
								Contracted Subtotal	165	155
								Fleet Total	**2,393**	**2,710**

Source: ZEBGO, 2018

Note: Division 10 has been repurposed. It will not being used for revenue service except for the temporary relocation of buses during ZEB retrofits. Also, the diesel buses at Division 97 have subsequently been replaced with CNG buses.

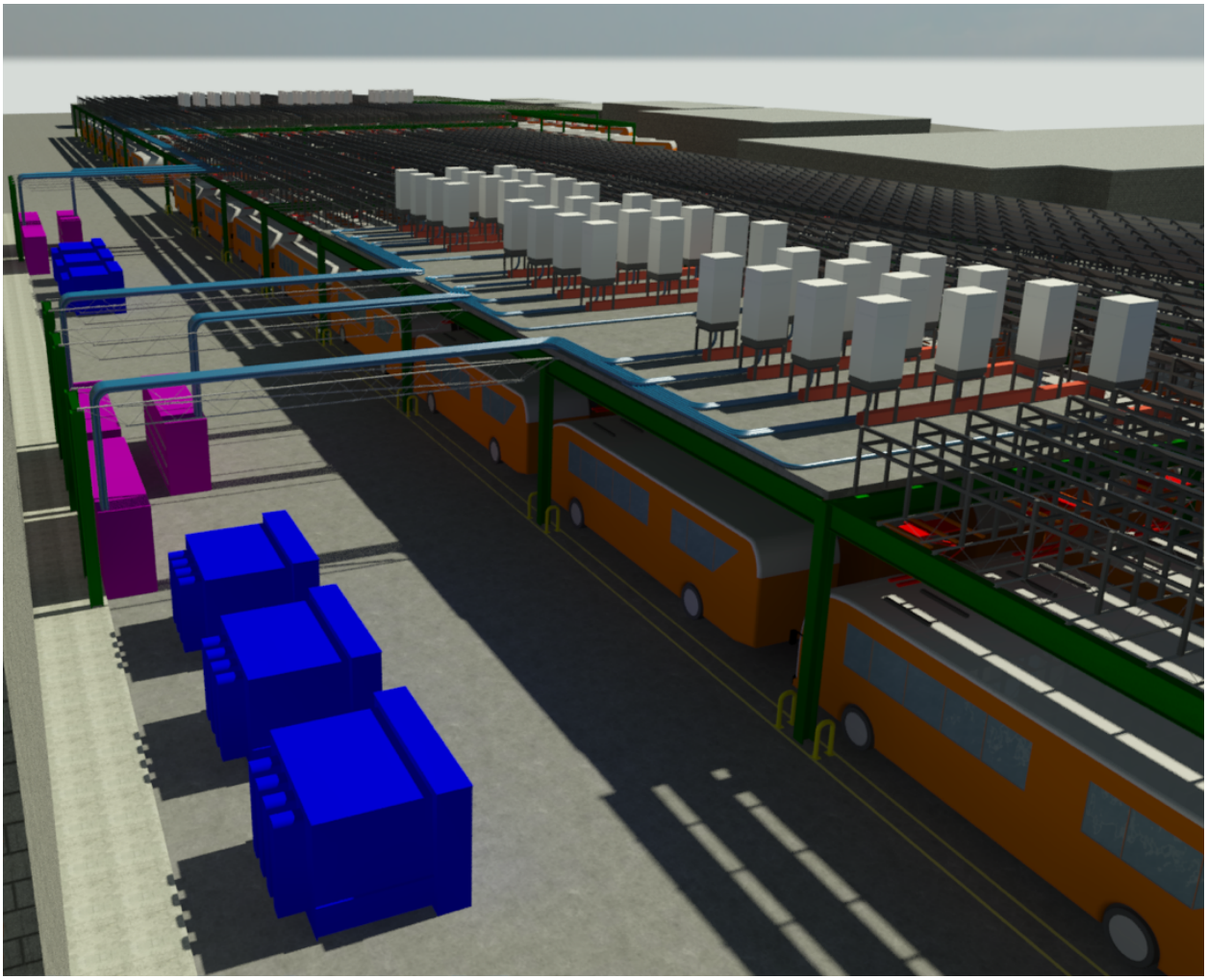
E.2.4.2 Proposed Zero-Emission Implementation Strategy

To achieve ZEB goals, Metro will adopt an inverted pantograph solution at both divisions and strategic layover locations (on-route charging). This technology (Figure E.2-1 and Figure E.2-2) will maximize space and safety of personnel due to the reduced interaction between staff and electrified equipment. These pantographs will be connected to chargers that vary in power. At this time, division-based chargers are expected to be provide 150 kilowatts (kW) of power in a "one to many" orientation (i.e., one charger energizes more than one dispenser), and on-route chargers will provide power in excess of 300 kW.

Figure E.2-1. North Hollywood Station On-Route Charger

Source: Los Angeles County Metropolitan Transportation Authority, July 2020

Figure E.2-2. General Layout of Division Charging Infrastructure



Source: ZEBGO, December 2019

E.2.4.3 Phasing and Construction

To maintain Metro's transition schedule, the availability of buses, construction schedule adherence, and utility enhancements will all have to be aligned.

Metro's transition will be accomplished in multiple on-site construction stages across three phases (periods). These "stages" are segments of the division 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 or to a neighboring division or facility. This approach will ensure that construction and normal operations can proceed concurrently. This construction method avoids the complete shutdown of the division 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 division's layout, existing fleet, and additional capacity.

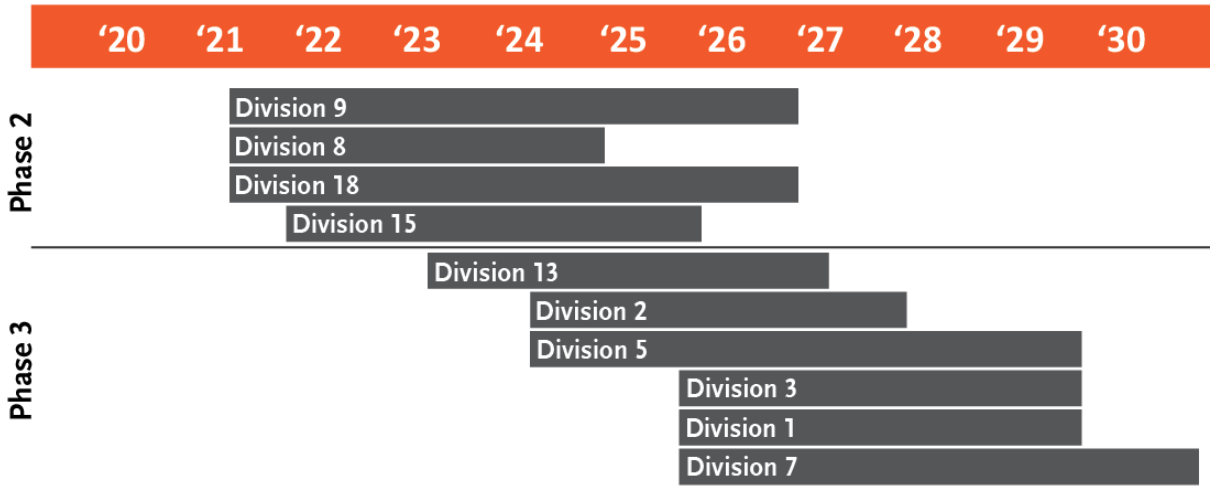
"Phases" are essentially classifications of when and how these divisions are grouped. Phase 1 of the transition is currently underway with the electrification of the Orange and Silver Lines. The remaining two phases are grouped based on a division's space availability and dependency on other divisions for temporary bus relocation. Phase 2 generally consists of "independent" divisions, divisions that have

available space to relocate its buses on-site during staged construction or are in close proximity to a division that does, and Phase 3, consists of "dependent" divisions, divisions that are dependent on other divisions for temporary bus storage or service.

As technology advances, Metro will make adjustments to maximize utility and cost feasibility. This will have direct impacts on the implementation schedule.

Figure E.2-3 presents the preliminary transition schedule. These activities include supplying additional power to the division, which includes utility applications, design, and construction, and the procurement, design, and construction of on-site charging equipment.

Figure E.2-3. LA Metro's Preliminary Transition Schedule



Source: ZEBGO, January 2021
Note: Division 10 will not be retrofitted to accommodate ZEBs. Division 10 will primarily be used for temporary storage and bus relocations during the transition.

E.2.4.4 Start-Up and Scale-Up Issues

To meet ICT deadlines, there are several challenges and opportunities that Metro has identified. The following briefly described some of the challenges that Metro faces for its transition:

- **Technological adaptation**. Currently, Metro is modeling and planning for a transition based on the baseline service and existing ZEB technology. With 2030 and 2040 deadlines looming, it is difficult to anticipate future technological enhancements and changes, such as improved batteries and chargers. Slight changes in these technologies could improve bus ranges, in turn, reducing costs. Metro will monitor these changes as it would be counterproductive to invest in technologies that will soon be outdated.
- **Costs.** Adoption of ZEBs has many benefits, including potential lifecycle cost savings. However, the investment required for capital and change management will be very expensive. Metro will have to be creative with funding mechanisms and sources to ensure that the transition to ZEB will not be detrimental to its operations and service.
- **Market Production Factors.** 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.

Legislative changes, such as the ICT regulation, will make it challenging to meet ZEB goals for agencies if the supply of buses cannot meet the demand.

- **Phasing and Transition.** 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 Metro's program. If one element of this transition doesn't go as planned, there will be implications for other components of the program.
- **Utility Upgrades.** Metro's divisions are currently under the jurisdiction of two utilities and its potential on-route charging locations are under nine. These utilities have different rate structures and protocols to apply for and receive additional power. How each utility is regulated, whether municipal or private, also dictates procedural requirements. These nuances will make it challenging to plan for due to the variances in schedule and procedure.
- **Managing Power Demand.** The transition to BEBs will require strategies to ensure that Metro can utilize power in the most cost-efficient way. Metro is currently doing this via utility negotiations and demand modeling to determine methods to reduce peak demand.
- **Uncertainty due to COVID-19.** COVID-19 has impacted all facets of the global economy, transit is not an exclusion. During the pandemic, ridership and revenues have plummeted and caused major shortfalls in Metro's budget which has impacted capital programs and operations. At this time, it is unclear what short- and long-term impacts will be for service. There is a possibility that service ridership levels may not return to previous levels resulting in changes to procurement and funding. Metro will continue to analyze trends to determine changes and plans.

E.2.4.5 Next Steps

The process to transition to ZEBs should and will be iterative to minimize risk, but also to accommodate new developments in a rapidly evolving market. Metro will use the information outlined in the Master Plan to identify and further refine the following:

- **Solutions to complete service if technology does not advance as forecasted.** Approximately 31 percent of Metro's baseline bus blocks travel further than 150 miles per day – a range that exceeds current batteries' capabilities. In order to meet 100% service completion, Metro will have to consider other solutions, including investing in additional on-route charging, filing for exemptions under the ICT regulation, purchasing additional buses, or restructuring service to suit technological limitation.
- **Costs refinement.** Construction, capital, operating, and maintenance costs vary based on a number of factors. It will be important to get an understanding of the up-front and lifecycle costs and savings of investing in ZEBs. Staff continues to develop cost estimates and Metro will need to revisit these estimates to determine if pricing has changed and make adjustments to procurements, as needed.
- **Explore collaboration opportunities.** Metro can continue to maximize outcomes by engaging with other regional and local agencies. Best practices, lessons learned, and cost-sharing among agencies will provide net benefits for Metro and partner agencies.
- **Continue to engage utilities**. Whether adopting BEBs or FCEBs, there is a good chance that the amount of power at the division is either insufficient or needs to be adapted to these new technologies. While procuring buses and installing chargers may be relatively straightforward, the process and protocols associated with electrical enhancements on the utility side can be complex. Therefore, it is essential that Metro continues to coordinate with electric utility providers to ensure critical deadlines are met.

1 INTRODUCTION

In accordance with the California Air Resource Board's Innovative Clean Transit regulation, the following report serves as Los Angeles County Metropolitan Transportation Authority's (Metro) Rollout Plan to transition its bus fleet to 100 percent zero-emission (ZE) by 2040.

1.1 Innovative Clean Transit Regulation

The California Air Resource Board's (CARB) Innovative Clean Transit (ICT) regulation became effective October 1, 2019 and requires all public transit agencies in the state to transition from conventional buses (compressed natural gas (CNG), diesel, etc.) to ZE buses (battery-electric or fuel cell electric) by 2040. The regulation requires a progressive increase of an agency's new bus purchases to be zero-emission buses (ZEBs) based on its fleet size. By 2040, CARB expects all transit agencies in the state to be operating only ZEBs.

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 ("Joint Group"), to submit a ZEB Rollout Plan ("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 a number of required components (as outlined in the Rollout Plan Guidelines) 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 Transit Agency" or a "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 areas, 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.

As a "Large Transit Agency" Metro must comply with the following requirements under the ICT regulation:

- July 1, 2020 – Board-approved Rollout Plan must be submitted to CARB[6]
- January 1, 2023 – 25 percent of all new bus purchases must be ZE
- January 1, 2026 – 50 percent of all new bus purchases must be ZE
- January 1, 2029 – 100 percent of all new bus purchases must be ZE
- January 1, 2040 – 100 percent of fleet must be ZE
- March 2021 – March 2050 – Annual compliance report due to CARB

[6] Due to the impacts of COVID-19, CARB provided an extension to all large transit agencies in California, upon request. Metro requested and was granted an extension to submit the Rollout Plan by December 31, 2020. In October 2020, Metro requested and was granted another extension to accurately capture the results of the recently released NextGen Plan and other service- and market-related updates. Metro now will submit its Board-approved Rollout Plan to CARB by March 2021.

1.2 Metro's Background

Metro serves as transportation planner, coordinator, designer, builder, and operator for one of the country's largest, most populous counties. More than 9.6 million people – nearly one-third of California's residents – live, work, and play within Metro's 1,433-square-mile service area.

As of December 2018, Metro directly and indirectly operates approximately 2,400 buses on 165 routes. In that same time period, directly operated Metro lines served approximately 17.3 million riders, per day.

1.3 Metro's Existing ZEB Plans, Procurements, and Projects

As early as 1993, Metro has adopted policies that commit the agency to using alternative energy buses. Pursuant to this vision, Metro successfully transitioned the second largest bus fleet in North America from all-diesel to CNG in 2011 and has continued to commit to innovative technologies and strategies to further reduce its carbon footprint. The conversion to ZEBs is the next step in Metro's future and it has the opportunity to further improve the air quality for Los Angeles residents and visitors in the future.

The transition to a ZEB fleet has been a goal of Metro even before the ICT regulation was adopted. In July 2017, the Metro Board endorsed staff's Strategic Plan for the transition to ZEBs. The first phase in the Strategic Plan is to convert the Metro Orange Line to ZEBs by 2020 and the Metro Silver Line as soon as feasible, thereafter. The second phase involves the creation of a ZE Master Plan that would evaluate the entire Metro bus system and map out the best strategy and anticipated cost to convert to an all-ZE operation.

Shortly after the Board's endorsement of the 2017 Strategic Plan, Metro awarded three ZEB contracts for the electrification of the Orange and Silver bus rapid transit (BRT) lines; two with *BYD* for five 60-foot ZEBs intended for the Orange Line, 60 40-foot ZEBs intended for the Silver Line; and one with *New Flyer* for 40 60-foot ZEBs intended for the Orange Line.

In September 2019, Metro's Board approved exercising the options of 40 additional BYD 40-foot ZEBs. With this exercise, Metro has plans to deploy 145 BEBs.

1.3.1 ZEB Program Master Plan

In July 2018, Metro awarded "ZEBGO" a joint venture of multiple industry experts to produce a Master Plan and action-ready RFPs to transition to all ZEBs by 2030. As part of this plan, ZEBGO is responsible for providing the following services:

- Industry Outreach
- Inventory of Metro Operations
- Assessment of Best Industry Practices
- Evaluation of Compliance with Existing Standards and Codes
- Support Negotiation of Rate Structures with Utilities
- Analyses/System Modeling and Phasing Options
- Development of Technical Specifications for ZEBs and Facilities
- Development of Action-Ready Request for Proposals (RFPs)

ZEBGO's efforts are still ongoing and many of its findings inform the Rollout Plan. The Master Plan's work is iterative and will continue beyond the Rollout Plan submission deadlines. Therefore, some of the information outlined in this report may be superseded based on technological advancements and new information and data.

1.3.2 NextGen Bus Study

In 2018, Metro also began the process of restructuring existing service to better meet the needs of current and future riders. The NextGen Bus Study will evaluate a number of alternatives and strategies to improve service, which may include more frequent service and shorter headways. This project is in now in the implementation phases, and its bus assignments and service blocks will be coordinated with Metro's ZEB Master Plan efforts.

1.4 Rollout Plan Approach

The Rollout Plan identifies a strategy for Metro to procure and operate an all-ZEB fleet by 2030 – 10 years before the ICT regulation requires. In accordance with the Rollout Plan Guidance, this document provides an overview of a number of key components to Metro's ZEB transition, including fleet acquisitions, schedule, training, and funding considerations. As previously mentioned, Metro is currently studying and has a goal of transitioning to all ZEBs by 2030. Therefore, there are no significant concerns with meeting the ICT regulation's 2040 requirement. Due to the rapidly evolving nature of ZEB technologies, it is possible that the findings and recommended approaches in this report will be outdated when it is time for implementation. For that reason, Metro continues to evaluate technologies and strategies beyond 2030, when a fully operational ZEB fleet is anticipated. Those areas of current study will be indicated, where applicable.

The information in this Rollout Plan is informed and based on December 2018 operations. This information is used because it represents the fleet under typical operations. Since then, there have been a number of special projects, including bus bridges, that may skew the fleet size and division requirements. The Master Plan, however, will make use of the most recent information available in anticipation of the release of the NextGen Bus Study, which will provide the foundation for the final version of Metro's Master Plan.

It should also be noted that COVID-19 has caused unprecedented losses in Metro's revenue through both the loss of ridership and a reduction in sales tax revenue. For these reasons, Metro has reduced service and operations and is still evaluating and forecasting the long-term ramifications on the system and the agency's capital projects and goals. That said, how COVID-19 impacts Metro's electrification goals is still unclear, however, Metro will continue to proceed with planning and adjust as needed once COVID-19 is stabilized and trends are more predictable.

1.5 Rollout Plan Structure

In accordance with CARB's Rollout Plan Guidance, Metro'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 4.2: Technology Portfolio)
- Current Bus Fleet Composition and Future Bus Purchases (Section 4: Fleet Acquisitions)
- Facilities and Infrastructure Modifications (Section 5: Facilities and Infrastructure Modifications)

- Providing Service in Disadvantaged Communities (Section 6: Disadvantaged Communities)
- Workforce Training (Section 7: Workforce Training)
- Potential Funding Sources (Section 8: Costs and Funding Opportunities)
- Start-up and Scale-up Challenges (Section 9: Start-up and Scale-up Challenges)

2 FLEET AND ACQUISITIONS

The following section provides an overview of Metro's baseline conditions, planned purchases, and description of how Metro will meet the requirements of the ICT regulation.

2.1 Baseline Bus Fleet

As of December 2018, Metro directly operates 2,228 buses (2,555 standard bus equivalents [SBEs]).[7] An additional 165 SBEs are indirectly operated through contracted services. Metro, as the owner of these buses, will work with contractors to ensure that these buses are replaced and that the owners of the facilities establish plans and support infrastructure pursuant to the ICT regulation. Metro's fleet consists of a mixture of 40-foot, 45-foot, and 60-foot CNG buses.[8] Table 2-1 and Table 2-2 presents a summary of Metro's directly operated bus fleet and contracted bus fleet, respectfully.

Table 2-1. Summary of Directly Operated Bus Fleet (Baseline Conditions)

Manufacturer	Series	Fuel Type	Length	In Service Year	Bus Type	No. of Buses	No. of Buses (SBE)
New Flyer	3850-4199	CNG	40'	2015	Standard	143	143
				2016		188	188
	5300-5522	CNG	40'	2001	Standard	183	183
	5600-6149	CNG	40'	2014	Standard	306	306
				2015		202	202
NABI	7000-7214	CNG	40'	2000	Standard	5	5
	7300-7514	CNG	40'	2001	Standard	24	24
	7525-7599	CNG	40'	2005	Standard	70	70
	7600-7949	CNG	40'	2002	Standard	85	85
	8000-8099	CNG	45'	2004	Standard	39	47
				2005		48	58
				2006		11	14
	8100-8359	CNG	45'	2009	Standard	130	156
				2010		129	155
	8360-8400	CNG	45'	2009	Standard	41	50
	8401-8491	CNG	45'	2010	Standard	29	35
				2011		53	64
				2012		6	8
	8500-8649	CNG	45'	2012	Standard	33	40

[7] SBEs were determined by applying a 1:1 ratio for 40-foot buses, 1:1.2 ratio for 45-foot buses, and 1:1.5 ratio for 60-foot buses, all values were rounded up to the next whole number.
[8] One 65-foot bus operates from Division 8

Manufacturer	Series	Fuel Type	Length	In Service Year	Bus Type	No. of Buses	No. of Buses (SBE)
				2013		116	140
	9200-9399	CNG	60’	2005	Articulated	84	126
				2006		112	168
	9400-9494	CNG	60’	2006	Articulated	40	60
				2007		55	83
	9495-9495	CNG	65’	2007	Articulated	1	2
	9500-9594	CNG	60	2007	Articulated	78	117
				2008		17	26
					Total Buses	**2,228**	**2,555**

Source: Los Angeles County Metropolitan Transportation Authority, December 2018

Table 2-2. Summary of Contracted Bus Fleet (Baseline Conditions)

Manufacturer	Series	Fuel Type	Length	In Service Year	Bus Type	No. of Buses	No. of Buses (SBE)
New Flyer	3850-4199	CNG	40’	2015	Standard	3	3
				2016		16	16
	5300-5522	CNG	40’	2001	Standard	10	10
	5600-6149	CNG	40’	2014	Standard	38	38
Orion	11001-11067	Diesel*	40’	2001	Standard	35	35
NABI	7600-7949	CNG	40’	2002	Standard	13	13
	3100-3149	CNG	32’	2010	Standard	50	40
					Total Buses	**165**	**155**

Source: Los Angeles County Metropolitan Transportation Authority, December 2018
*The diesel buses at have subsequently been replaced with CNG buses.

2.2 Technology Portfolio

Metro’s past and ongoing analysis has found that BEBs are the most suitable technology to meet ZEB goals. This is in a large part due to the market of BEBs in terms of technological advancement, costs, and availability. While FCEBs are promising and have many potential benefits as compared to both CNG and BEB, unpredictability in operation costs and a limited supply chain makes it an unviable option at this time, especially considering Metro’s aggressive ZEB goals. However, Metro will remain open for potential future FCEB integration into its fleet.

2.3 Existing ZEB Procurements and Projects

Metro has taken and is taking several steps to ensure that it is in the best position to meet the Board's 2030 ZEB goal. As mentioned, Metro's Board envisions the fleet transition in two phases. Phase 1 will focus on the conversion of the Orange and Silver BRT Lines to ZEB by 2020 and 2021, respectively, and Phase 2 will convert the rest of the fleet.

To date, Metro has approved the procurement of 145 BEBs. Table 2-3 presents Metro's existing BEB procurements and Table 2-4 details Metro's existing chargers both installed and under construction.

To support these buses, multiple enhancements have been initiated or completed at divisions and stops that serve these lines. For instance, at Division 8, which serves the Orange Line, Metro has coordinated with the utility, the Los Angeles Department of Water and Power (LADWP), to add additional electrical capacity, and ABB, a charger manufacturer, to construct 10 150-kW plug-in chargers to support overnight and midday charging. There is also ongoing construction for on-route chargers at three locations along the Orange Line's route. These on-route chargers range from 450-kW to 600-kW are based on the Society of Automotive Engineers (SAE) pantograph charging standard, J3105-1. The Orange Line is anticipated to be fully electrified by the end of 2020.

The Silver Line and the divisions and stations that serve it - Division 9, Division 18, and El Monte and Harbor Gateway Transit Centers - are all currently being analyzed and designed to determine the most suitable chargers. The Silver Line is anticipated to be electrified by 2021.

Table 2-3. Existing BEB Procurements

OEM	Model	Battery (kWh)	Length (ft.)	Route	No. of Buses	No. of Buses (SBE)
New Flyer	XE60	320	60	Orange	40	60
BYD	K11	610	60	Orange	5	8
BYD	K9	348	40	Silver	60	60
BYD	K9	348	40	TBD	40	60
Total					**145**	**168**

Source: Los Angeles County Metropolitan Transportation Authority, December 2019

Table 2-4. Existing ZEB Chargers

Location	Quantity	OEM	Power (kW)	Type	Status
Division 1	5	BYD	100	Plug-In	Installed
Division 8	10	ABB	150	Plug-In	2 Installed 8 in Procurement
Canoga Station	2	Siemens	450-600	Pantograph	Commissioning
North Hollywood Station	4	Siemens	450	Pantograph	In Operation
Chatsworth Station	2	Siemens	450-600	Pantograph	Under Construction

Source: Los Angeles County Metropolitan Transportation Authority, December 2020

2.4 Procurement Schedule

Based on initial analysis, all new bus purchases will be ZEB starting in 2022 – seven years before the ICT regulation requires. Early retirement should not be an issue pursuant to the ICT regulation based on Metro's future purchases, however, Metro is still evaluating strategies to avoid early retirement pursuant to its 2030 goals.

As previously indicated, Metro also leases approximately 165 buses to contractors to provide service on Metro routes – Metro does not own or operate the facilities where these buses are stored. That said, Metro will continue to provide buses and coordinate with contractors as facility master plans are developed. At this time the schedule and approach for these facilities' upgrades are under development.

Table 2-5 summarizes Metro's anticipated procurements through 2040. In September 2019, the Metro Board granted approval to execute 369 bus options (40 BEB and 329 CNG) to cover Metro's fleet needs (pre-pandemic) until 2022. This table is built off of the assumption that BEBs/battery capacities will be available to meet Metro's service block ranges so that a 1:1 replacement ratio is achievable. Years 2023, 2026, and 2029, are highlighted because these indicate when Metro's new purchases should be 25 percent, 50 percent, and 100 percent ZEB, respectively, in accordance with the ICT regulation.

Table 2-5. Summary of Future Bus Purchases (through 2040)

Year	Total Buses (SBE)	Zero Emission Buses				Conventional (CNG) Buses			
		No.	Pct.	Bus Type	Fuel Type	No.	Pct.	Bus Type	Fuel Type
2022	-	-	-	-	-	-	-	-	-
2023	4	4	100%	40'/60'	BEB	-	-	-	-
2024	156	156	100%	40'/60'	BEB	-	-	-	-
2025	140	140	100%	40'/60'	BEB	-	-	-	-
2026	259	259	100%	40'/60'	BEB	-	-	-	-
2027	259	259	100%	40'/60'	BEB	-	-	-	-
2028	259	259	100%	40'/60'	BEB	-	-	-	-
2029	259	259	100%	40'/60'	BEB	-	-	-	-
2030	259	259	100%	40'/60'	BEB	-	-	-	-
2031	-	-	-	-	-	-	-	-	-
2032	393	393	100%	40'/60'	BEB	-	-	-	-
2033	364	364	100%	40'/60'	BEB	-	-	-	-
2034	-	-	-	-	-	-	-	-	-
2035	4	4	100%	40'/60'	BEB	-	-	-	-
2036	156	156	100%	40'/60'	BEB	-	-	-	-
2037	140	140	100%	40'/60'	BEB	-	-	-	-
2038	259	259	100%	40'/60'	BEB	-	-	-	-

Year	Total Buses (SBE)	Zero Emission Buses				Conventional (CNG) Buses			
		No.	Pct.	Bus Type	Fuel Type	No.	Pct.	Bus Type	Fuel Type
2039	259	259	100%	40'/60'	BEB	-	-	-	-
2040	259	259	100%	40'/60'	BEB	-	-	-	-

Source: ZEBGO, 2020

2.4.1 ZEB Range Requirements and Costs

Approximately 31 percent of Metro's bus blocks travel more than 150 miles per day – a range that exceeds current batteries' capabilities. To reduce impacts to service, Metro intends to apply a number of strategies to meet service (range) requirements, including the investment in on-route chargers, additional bus purchases, battery/charging management systems, and solar and battery storage. In future ZEB applications, Metro will also consider FCEBs, especially if battery technology doesn't advance as forecasted.

2.4.2 Conversion of CNG Buses to ZEBs

A full fleet conversion to ZEBs by 2030 will require Metro to increase procurements by 848 buses. To address the increased capital costs associated with advanced procurements, the conversion of approximately 757 buses will be included in the procurement schedule.[9] Currently, conversions are anticipated to take place during the mid-life overhaul during the years 2027 and 2028, though this may be refined further to evenly distribute purchases across the transition period (Table 2-6).

Table 2-6. Summary of Future Bus Retrofits

Year	Number of Buses (SBE)	Bus/Conversion Type
2027	393	CNG to BEB
2028	364	CNG to BEB

Source: ZEBGO, 2020

[9] Addressing the 91-bus shortfall is currently being analyzed by Metro and will likely be addressed by additional procurements or retrofits (conversions).

3 FACILITIES AND INFRASTRUCTURE MODIFICATIONS

The following sections detail the planned charging strategies, infrastructure, detailed division improvements, and program schedule.

3.1 Facility Modifications

Metro's transition to ZE technologies, namely, BEB, will require several modifications and replacements to existing infrastructure and operations. This would include the decommissioning of CNG equipment, enhancements and expansions of electrical equipment, additional electrical capacity, and the installation of BEB gantries, chargers, dispensers, and other components. These changes will not only occur at 10 of Metro's directly-operated bus divisions – Division 10 will only be used for relocations during the transition - but also at select bus layover locations and transit centers that will function as on-route charging stations.

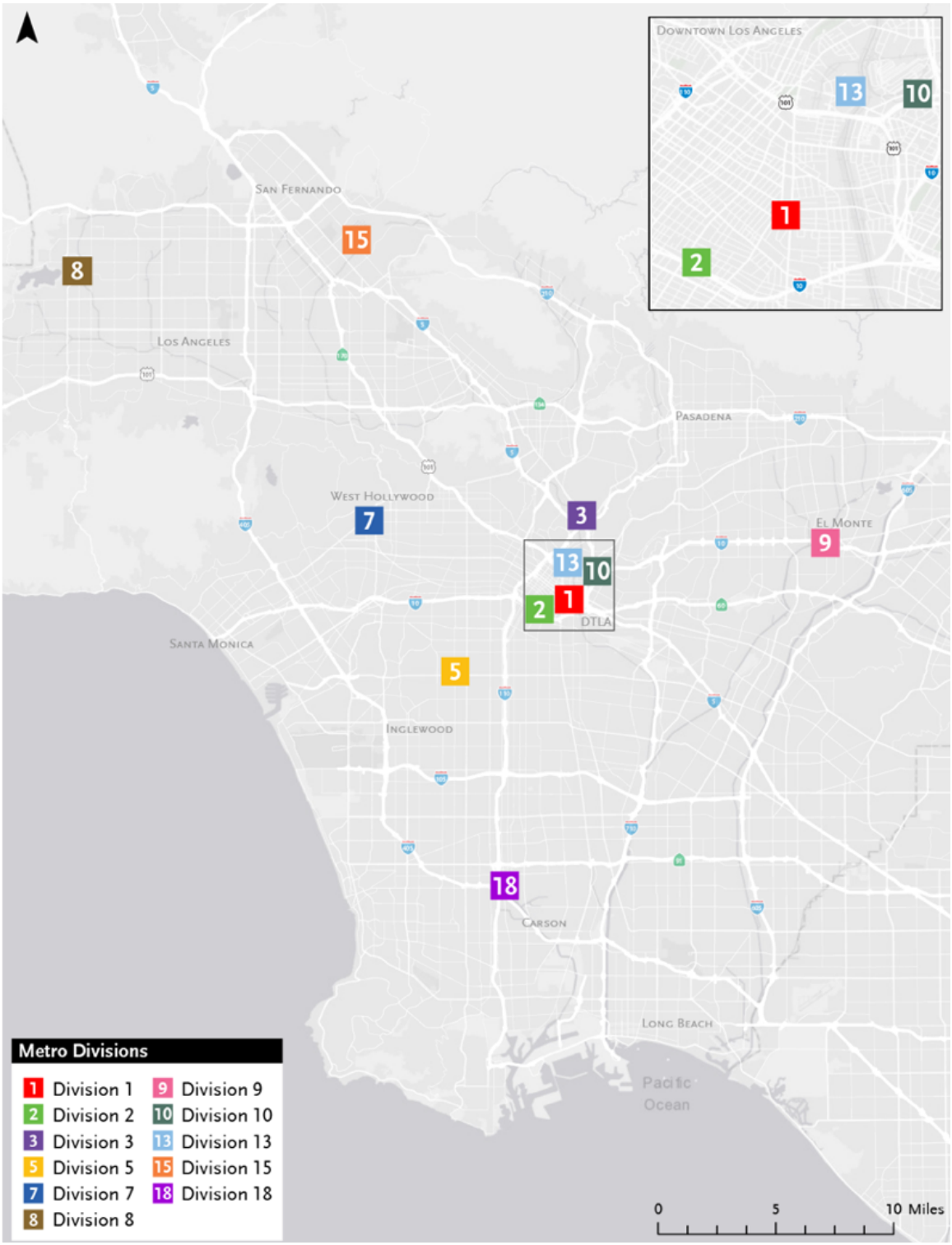
Figure 3-1 illustrates the location of Metro's divisions and Table 3-1 summarizes the modifications and schedules planned at 10 of Metro's bus divisions.

Table 3-1. Summary of Bus Division ZEB Improvements

Div.	Address	Main Functions	Planned ZEB Infrastructure	Service Capacity	Upgrades Req'd?	Estimated Construction Timeline
1	1130 E. 6th St, Los Angeles, CA	O&M	Inverted pantograph charging	189 buses	Yes	2025-2029
2	720 E. 15th St, Los Angeles, CA	O&M	Inverted pantograph charging	172 buses	Yes	2024-2027
3	630 W. Ave 28, Los Angeles, CA	O&M	Inverted pantograph charging	177 buses	Yes	2025-2029
5	5425 Van Ness Ave, Los Angeles, CA	O&M	Inverted pantograph charging	193 buses	Yes	2024-2029
7	8800 Santa Monica Bl. West Hollywood, CA	O&M	Inverted pantograph charging	233 buses	Yes	2025-2030
8	9201 Canoga Ave, Los Angeles, CA	O&M	Inverted pantograph charging	202 buses	Yes	2021-2024
9	3449 Santa Anita Ave, El Monte, CA	O&M	Inverted pantograph charging	223 buses	Yes	2021-2026
13	920 N. Vignes St, Los Angeles, CA	O&M	Inverted pantograph charging	163 buses	Yes	2023-2026
15	11900 Branford St, Los Angeles, CA	O&M	Inverted pantograph charging	241 buses	Yes	2021-2025
18	459 W. Griffith St, Gardena, CA	O&M	Inverted pantograph charging	252 buses	Yes	2021-2026

Source: ZEBGO, February 2020
Note: On-route charging will also be utilized to supplement division charging

Figure 3-1. Metro's Divisions



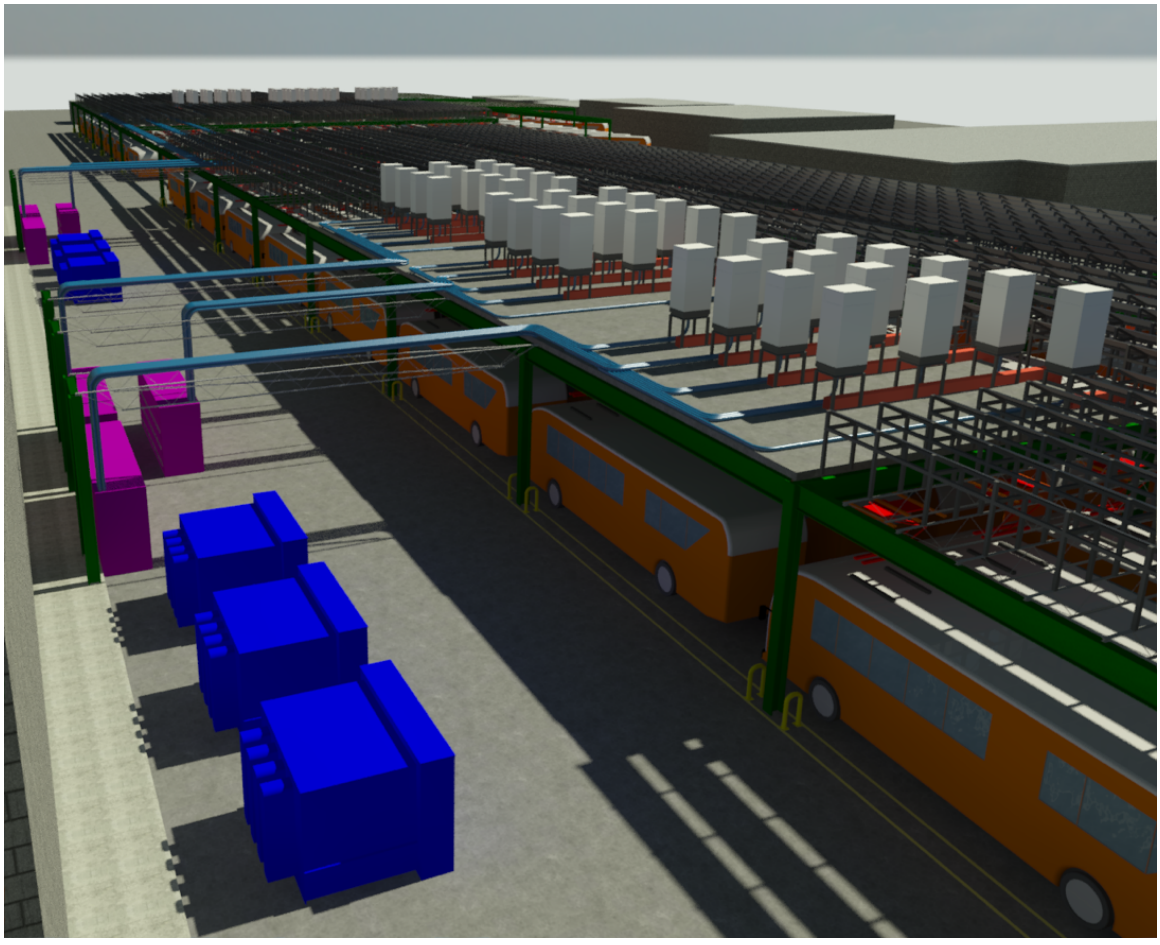
Source: ZEBGO, 2019

3.2 Division Charging Strategies and Infrastructure

All divisions will support DC inverted pantograph charging. In an effort to maximize space and cost savings via reduced demand charges, Metro is currently planning for a "one to many" 150-kW charger to dispenser ratio (one charger to more than one buses) for overnight charging. Metro will also integrate "fast charging lanes" at divisions to provide buses with the opportunity to "top off" during midday pull-ins and/or during servicing before connecting to the overnight "slow" chargers. These "fast charging lanes" will have chargers in excess of the 150-kW chargers. Individual division strategies are still being analyzed and may vary and change based on unique operating and service conditions. As technology develops, Metro will also consider other ratios and charging strategies which may impact the layout of each division.

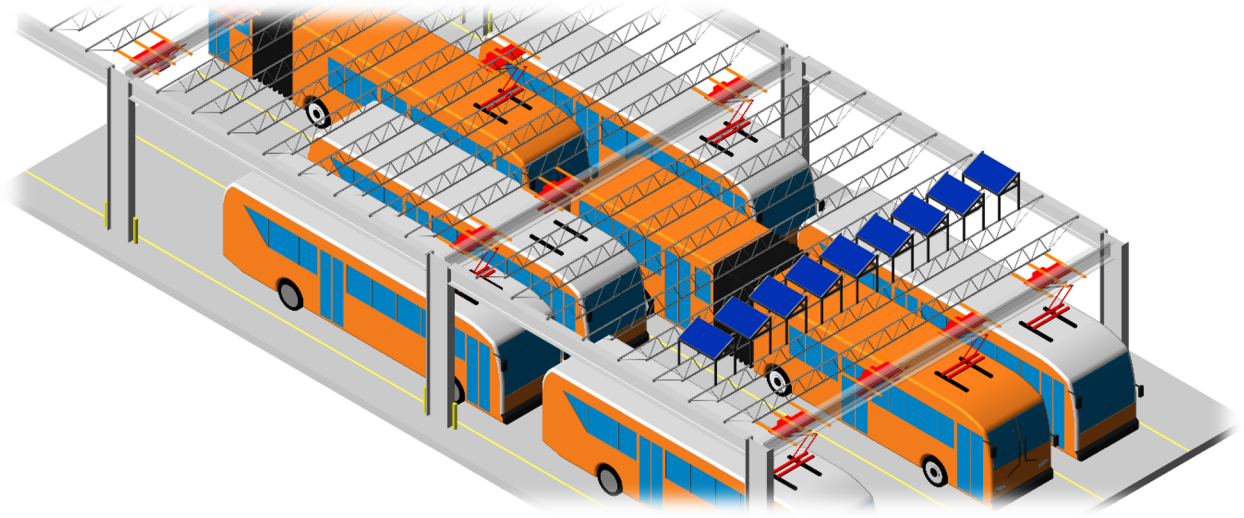
At the divisions, chargers, conduit, and associated pantographs will be supported by an overhead frame that will cover the surface of the bus parking tracks (Figure 3-2). This overhead strategy is due to the general constrained space at most of Metro's divisions. BEB charging infrastructure includes a number of charging cabinets, switches, switchgears, and transformers that require a considerable amount of space. This general design will be at divisions to maximize space and ensure compatibility with all procured BEBs.

Figure 3-2. General Layout of Division Charging Infrastructure



Source: ZEBGO, December 2019

Figure 3-3. Conceptual Division Pantograph-Charging



Source: ZEBGO, December 2019

3.3 On-Route Charging Strategies and Infrastructure

As mentioned, on-route charging is a consideration for Metro's ZEB transition. On-route charging will extend bus ranges, reduce peak demand (kW) at divisions, and serve as future-ready strategy as it is likely that charging during the day will eventually be more cost-competitive than charging at night due to an increasing availability of renewable power.

On-route charging facilities will also utilize DC inverted pantograph chargers. All on-route chargers are anticipated to be "high-powered" (in excess of 150-kW) to ensure that buses can receive more energy in a small period of time, typically during layovers. Metro is planning for up to 1.2 megawatts (MW) of power per SAE J-3105.

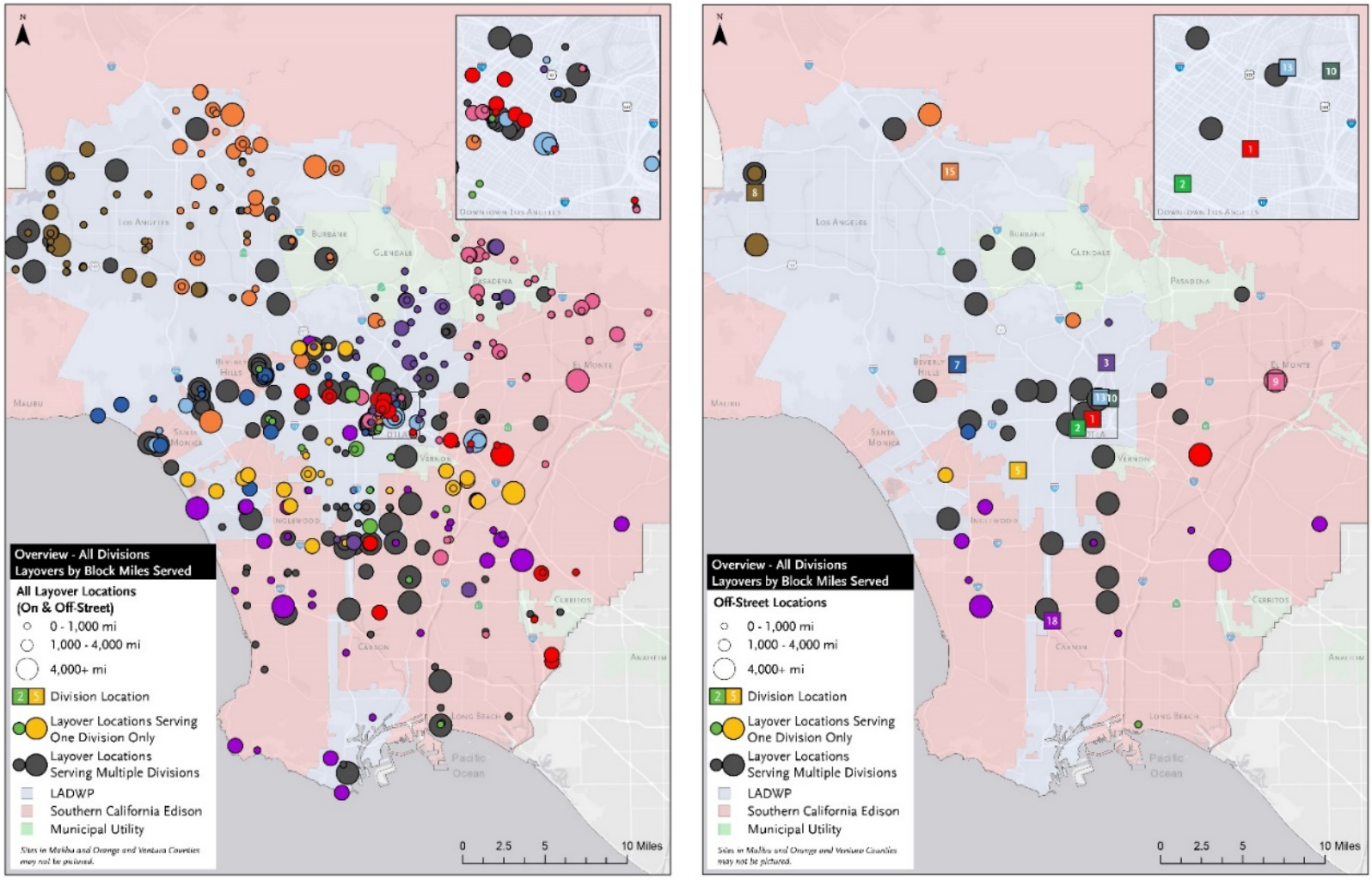
Figure 3-4. North Hollywood Station On-Route Charger

Source: Los Angeles County Metropolitan Transportation Authority, July 2020

On-route charging is most useful at endpoints or layover locations of trips. As of December 2018, Metro has 529 layover locations, of these, approximately 52 are considered ideal and deemed preliminarily feasible as on-route charging areas. These locations were based on the number of vehicles that layover, available space (for charging equipment), and its off-street orientation – for maintenance and safety issues, it was assumed that off-street locations would mitigate safety and vandalism issues with the public. Staff continues to refine modeling and related analysis at these locations to determine which ones will be candidates for implementation. It is assumed that all on-route locations will have 450 kW or greater chargers and will be pantograph-based to support Metro's fleet. It is likely that some of these will be at transit centers that are shared between other transit agencies. For that reason, Metro

is ensuring that an established charging standard is applied to promote future shared use. Figure 3-5 illustrates Metro's 529 layover and 52 potential on-route charging locations, respectively.

Figure 3-5. Metro's Layover Locations and Potential On-Route Charging Locations



Source: ZEBGO, December 2018

3.4 Phasing and Construction Staging

Adhering to the construction schedule and milestones will be critical because divisions' charging infrastructure construction and utility upgrades must be completed before buses are delivered, otherwise, the buses will not be able to operate. The following sections describes the order in which each division will be constructed (phased), and the work to be done on each division's site (staging).

3.4.1 Construction Phases

The prioritization of divisions' conversions will be based on a number of factors, however, space availability (i.e., divisions with more space can accept more buses on a temporary basis) is the most critical as it directly impacts the schedule and Metro's transition goal. It should be noted that the strategy that Metro plans to employ for facility construction will have minimal or no impact on service.

Staff has segmented the transition schedule into three distinct phases to accomplish both Metro and ICT requirements as presented in Table 3-2.

Table 3-2. Metro Transition and Construction Phases

Phase #	Description	Divisions
1	**On-Going Work** includes Metro's ongoing construction and ZEB-related work to transition the Orange and Silver Lines.	8, 9, and 18
2	**Independent Divisions** require few or no bus relocations for ZEB-related construction.	8, 9, 15, and 18
3	**Dependent Divisions** require the temporary relocation of buses to nearby divisions in order to make room for staged construction.	1, 2, 3, 5, 7, and 13

Source: ZEBGO, December 2018

Phase 1 – On-Going Work

Phase 1 is the full electrification of Metro's BRT services, the Orange and Silver Lines as shown in Table 3-2. Electrical enhancements and chargers are currently being installed at Division 8, along with on-route chargers at multiple stations. Concepts for Divisions 9 and 18 are currently under development to serve future BEBs.

Phase 1 is illustrated in Figure 3-6.

Figure 3-6. Phase 1: On-Going Work

Source: ZEBGO, December 2018

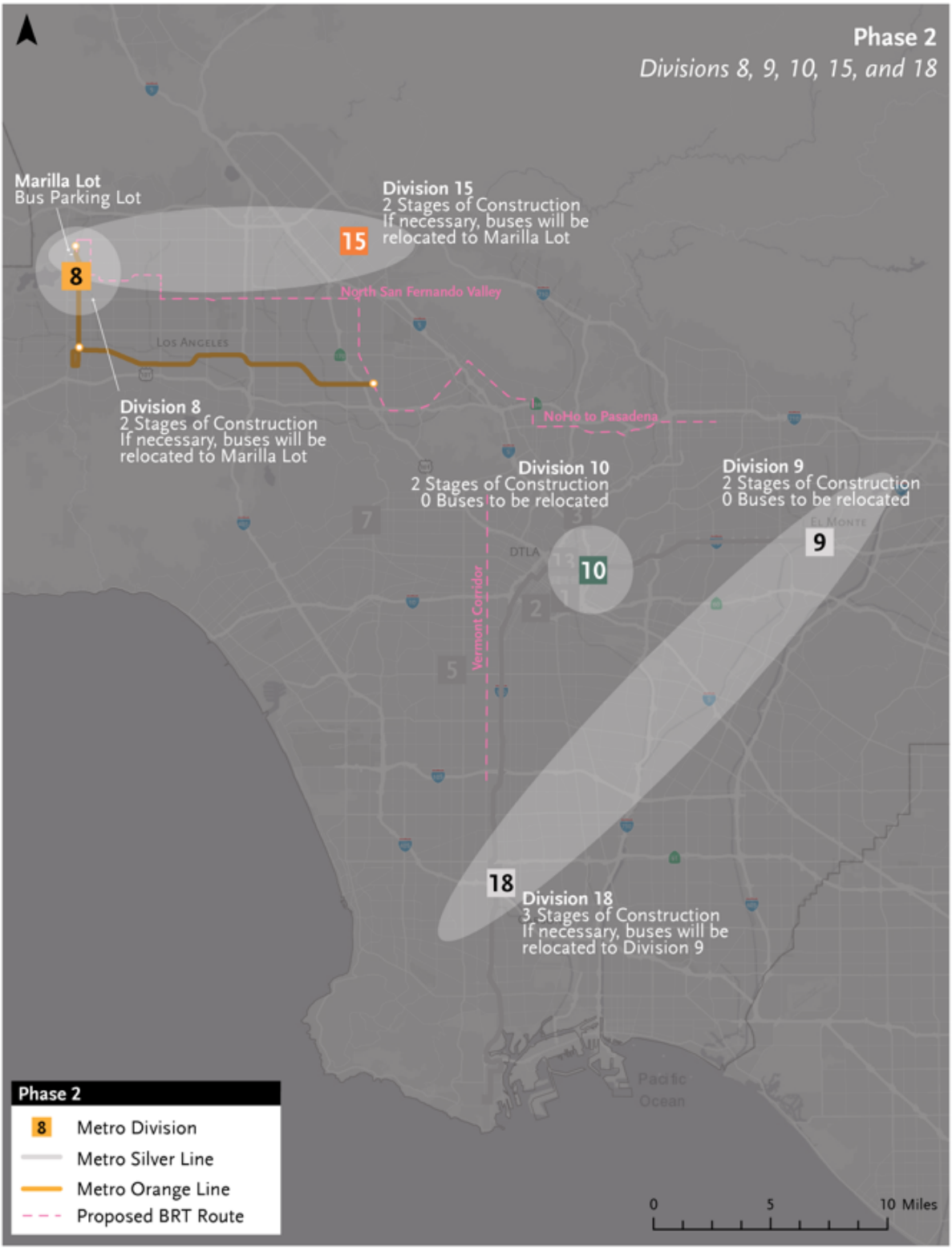
Phase 2 – Independent Divisions

Phase 2 consists of the conversion of Metro's remaining services, including all local, rapid, shuttle, and express routes. Due to adequate on-site space or adjacent Metro property, Divisions 8, 9, 15, and 18 are considered "independent divisions" because BEB infrastructure enhancements can largely be completed with no or minimal buses relocations. Initial work has begun on Division 9 and 18 due to Metro's Board approval of exercising the 40 additional BYD buses in September 2019.

Construction work will be done in stages, on-site, to allow on-going transit service and operations to continue without interruption. Buses can be shifted around on-site to vacate areas for electrification improvements while still operating all buses and serving all routes assigned to these divisions.

Phase 2 is illustrated in Figure 3-7.

Figure 3-7. Phase 2: Independent Divisions



Source: ZEBGO, December 2018
Note: Division 10 will not be retrofitted to accommodate ZEBs. Division 10 will primarily be used for temporary storage and bus relocations during the transition.

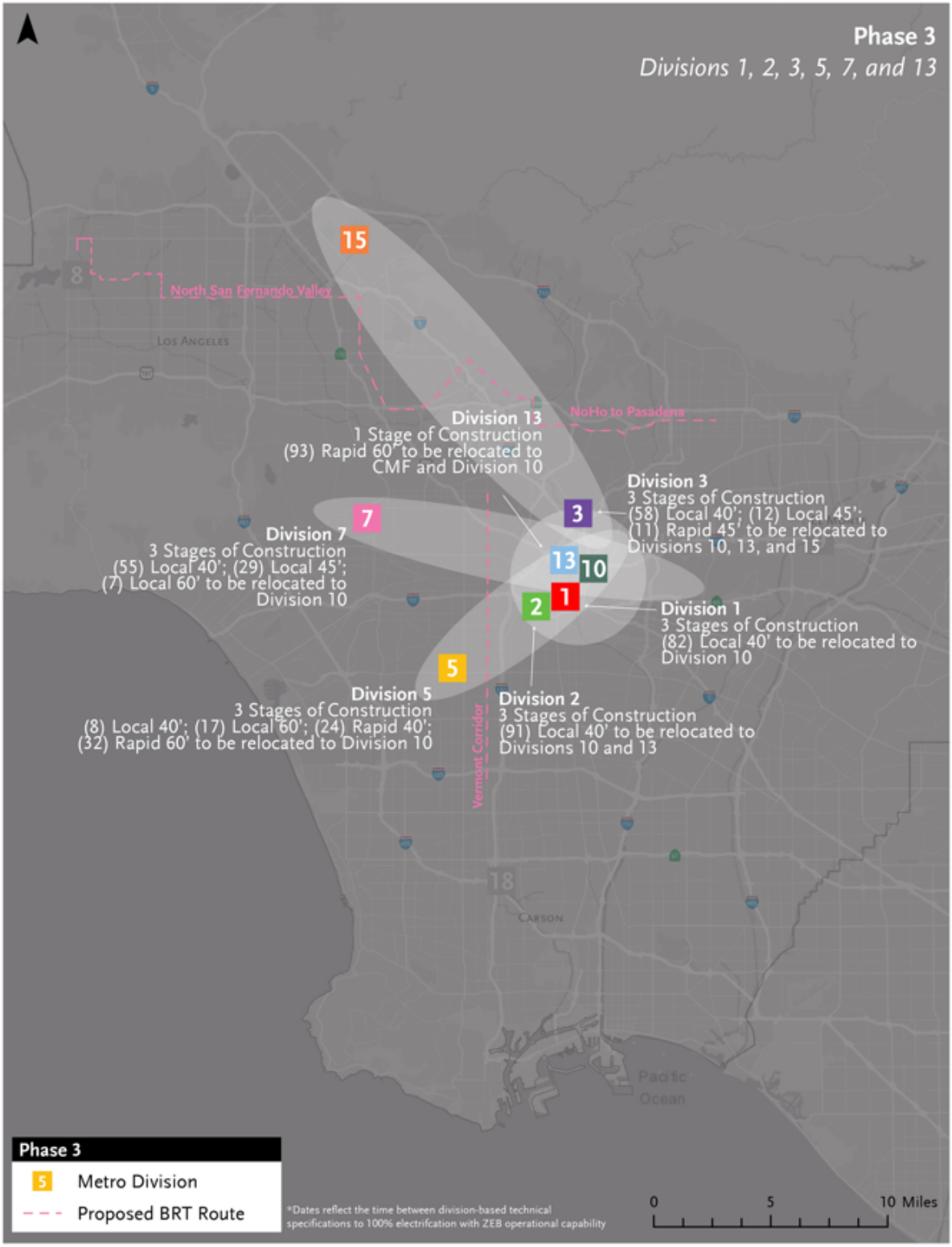
Phase 3 – Dependent Divisions

Phase 3 continues Phase 2 conversions by focusing on the remaining local, rapid, shuttle, and express routes. Due to space constraints, Divisions 1, 2, 3, 5, 7 and 13 are considered "dependent divisions" and will require portions of assigned fleets to be temporarily relocated to and operated from other divisions to allow portions of the site to be turned over for staged construction activities. Phase 3 will likely result in increased operational costs due to the increased deadhead miles incurred.

If one of the Phase 3 divisions is under construction while a portion of its fleet is temporarily relocated to Division 10, no other dependent division can be improved unless additional relocation storage space is identified and made available.

Phase 3 is illustrated in Figure 3-8.

Figure 3-8. Phase 3: Dependent Divisions



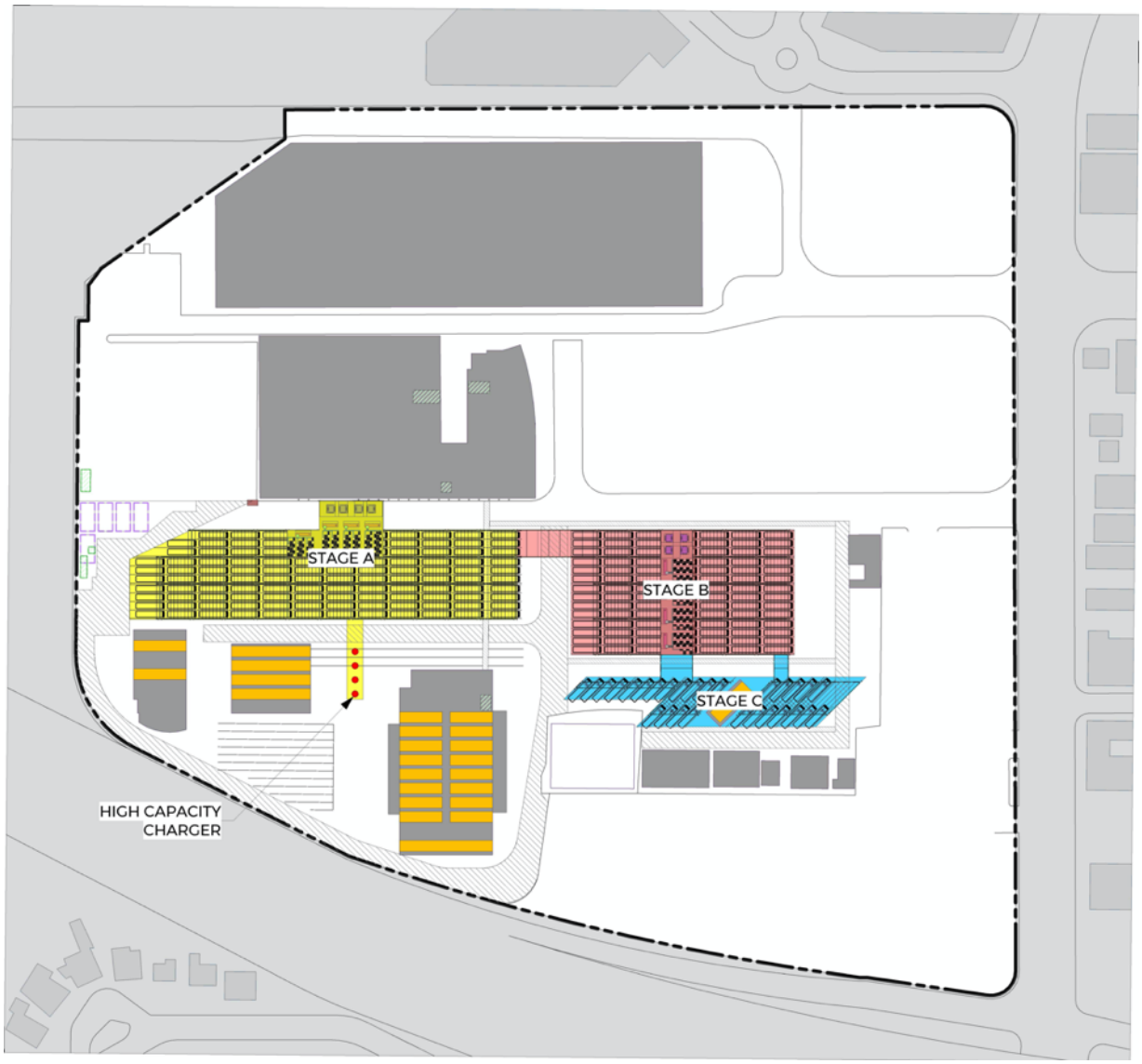
Source: ZEBGO, December 2018

3.4.2 On-Site Staging

Due to space constraints at each division, most divisions' ZEB infrastructure upgrades will be done in multiple on-site "stages" which will require the temporary relocation of buses to other divisions.

Each stage generally represents a natural break of bus parking at each division. For each stage, buses will be relocated for approximately six months so that BEB charging equipment can be installed. At the conclusion of the staged construction, buses can once again be parked there. Figure 3-9 provides an example of the stages of construction at Division 9.

Figure 3-9. Division 9 Staged Construction



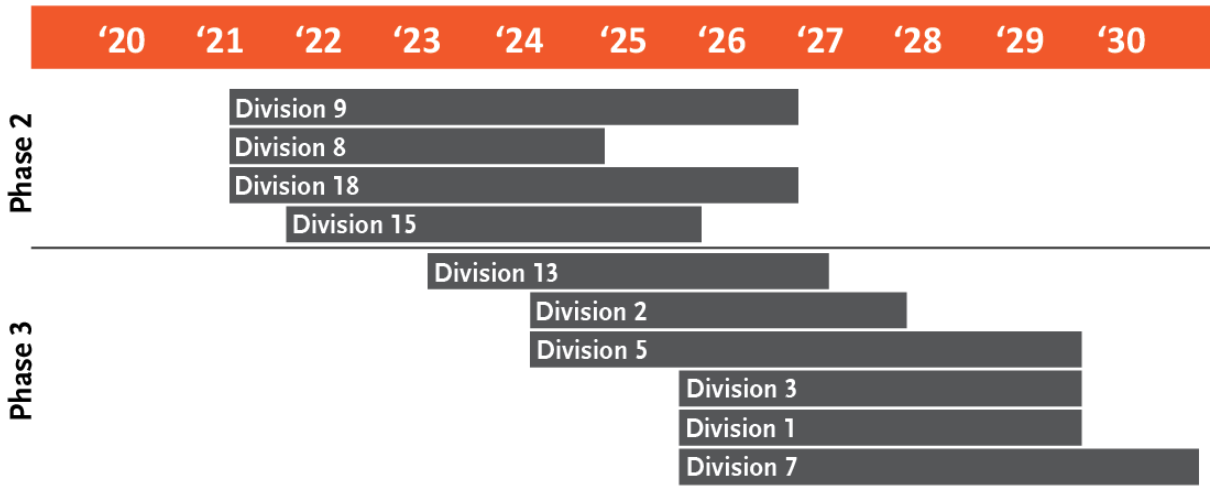
Source: ZEBGO, December 2018

3.5 Schedule and Adaptability

As previously discussed, Metro has a very aggressive ZE transition schedule. While the ICT regulation requires a full fleet conversion by 2040, Metro is planning on converting by 2030. To maintain this schedule, the availability of buses, construction schedule adherence, and utility enhancements will all have to be aligned. It should also be noted that as technology develops and new data is acquired, Metro will continue to make adjustments to maximize utility and cost feasibility. This will have direct impacts on the implementation schedule.

Figure 3-10 presents the preliminary transition schedule. These activities include electrification, design, and construction.

Figure 3-10. LA Metro's Preliminary Transition Schedule



Source: ZEBGO, January 2021
Note: Division 10 will not be retrofitted to accommodate ZEBs. Division 10 will primarily be used for temporary storage and bus relocations during the transition.

The following sections detail the existing conditions and planned modifications for 10 of Metro's 11 divisions. As noted previously, December 2018 service levels were used as a baseline. The number of existing buses on-site are based on the total (regardless of active or spare, or vehicle length). All divisions are able to accommodate at least the number of existing buses if converted to BEBs. Ongoing analysis and bus procurements will refine these numbers based on fleet mix and the advancement of battery technology.

3.5.1 Division 1

Existing Conditions

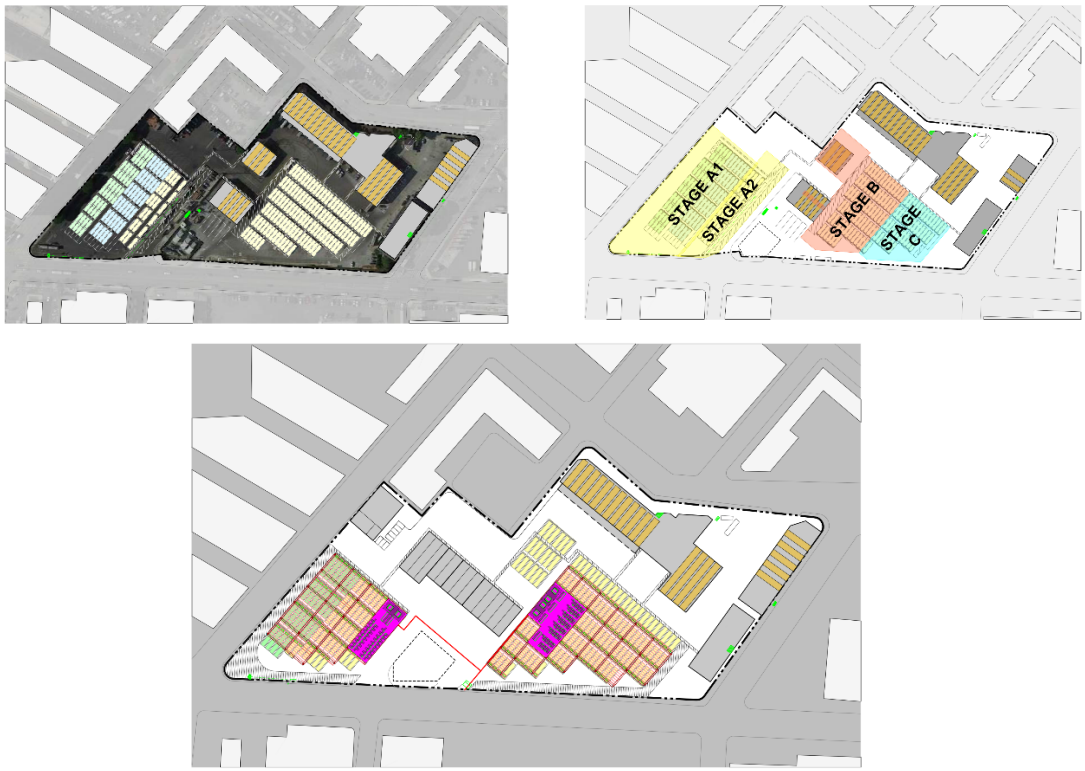
Division 1 is located at 1130 E. 6th Street in the City of Los Angeles. 189 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 1's fleet consists of 132 40-foot, 35 45-foot, and 22 60-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment. Five 100-kW BYD plug-in chargers are onsite (pre-ICT and Master Plan).

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 1. Based on preliminary demand modeling, approximately 12 MW of power will be needed from LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

Construction for Division 1 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Buses are anticipated to be temporarily stored at Division 10 during these stages. Ultimately, Division 1 is expected to have 66 150-kW and six 450-kW chargers and will be BEB-operational in 2029. Figure 3-11 illustrates the process that Division 1 will undergo towards full electrification.

Figure 3-11. Division 1 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.2 Division 2

Existing Conditions

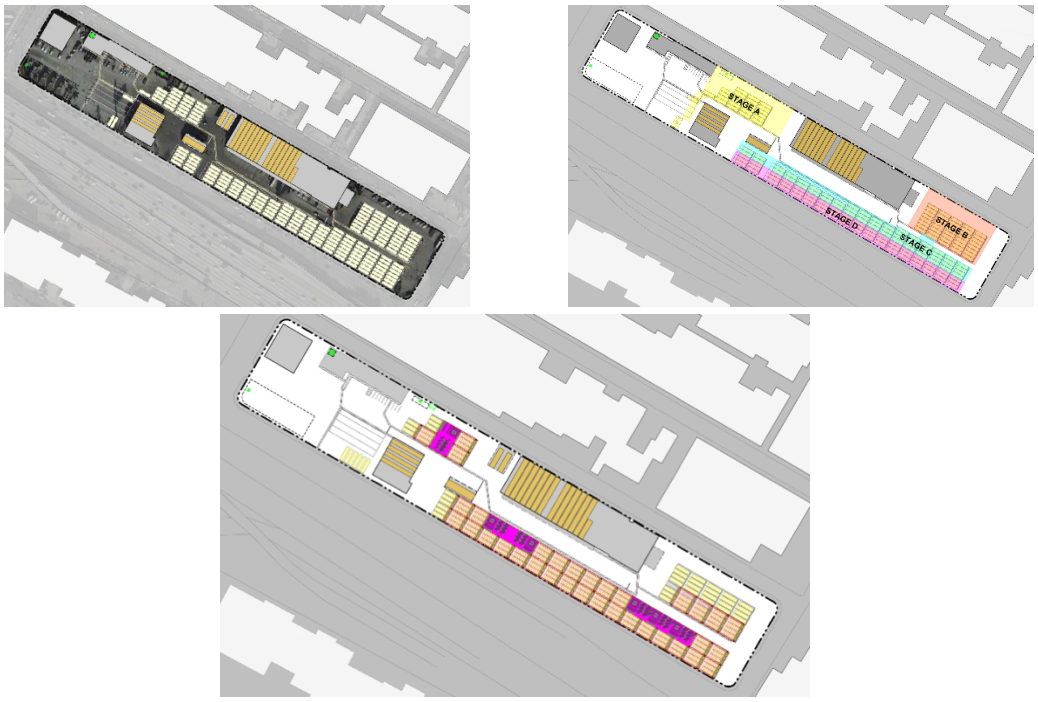
Division 2 is located at 720 E. 15th Street in the City of Los Angeles. 172 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 2's fleet consists of all 40-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses Division 2. Based on preliminary demand modeling, approximately 12 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

Construction for Division 2 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Buses are anticipated to be temporarily stored at Division 10 during these stages. Ultimately, Division 2 is expected to have 86 150-kW and four 450-kW chargers and will be BEB-operational in 2027. Figure 3-12 illustrates the process that Division 2 will undergo towards full electrification.

Figure 3-12. Division 2 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.3 Division 3

Existing Conditions

Division 3 is located at W. Avenue 28 in the City of Los Angeles. 177 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 3's fleet consists of 86 40-foot and 91 45-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 3. Based on preliminary demand modeling, approximately 13 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

Construction for Division 3 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Buses are anticipated to be temporarily stored at Division 10 during these stages. Ultimately, Division 3 is expected to have 89 150-kW and four 450-kW chargers and will be BEB-operational in 2029. Figure 3-13 illustrates the process that Division 3 will undergo towards full electrification.

Figure 3-13. Division 3 – Existing, Construction Staging, and Buildout

Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.4 Division 5

Existing Conditions

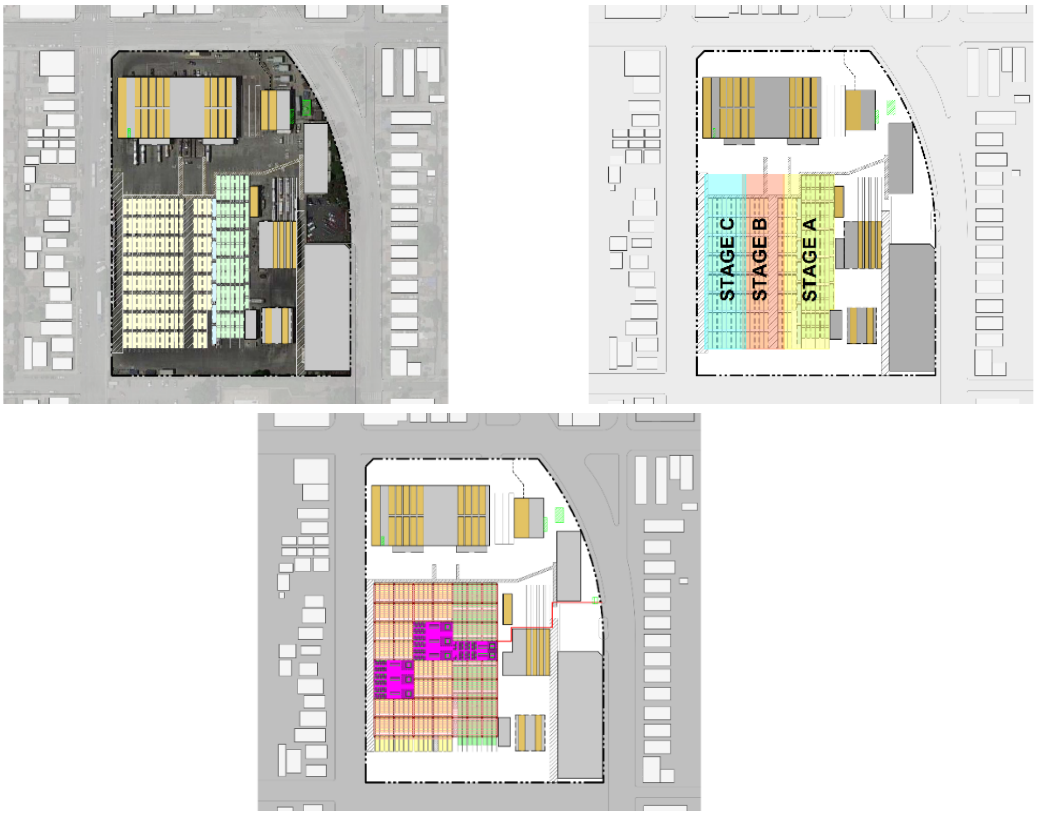
Division 5 is located at 5425 S. Van Ness Avenue in the City of Los Angeles. 193 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 5's fleet consists of 134 40-foot, seven 45-foot, and 52 60-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses Division 5. Based on preliminary demand modeling, approximately 14 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

Construction for Division 5 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Buses are anticipated to be temporarily stored at Division 10 during these stages. Ultimately, Division 5 is expected to have 97 150-kW and four 450-kW chargers and will be BEB-operational in 2029. Figure 3-14 illustrates the process that Division 5 will undergo towards full electrification.

Figure 3-14. Division 5 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.5 Division 7

Existing Conditions

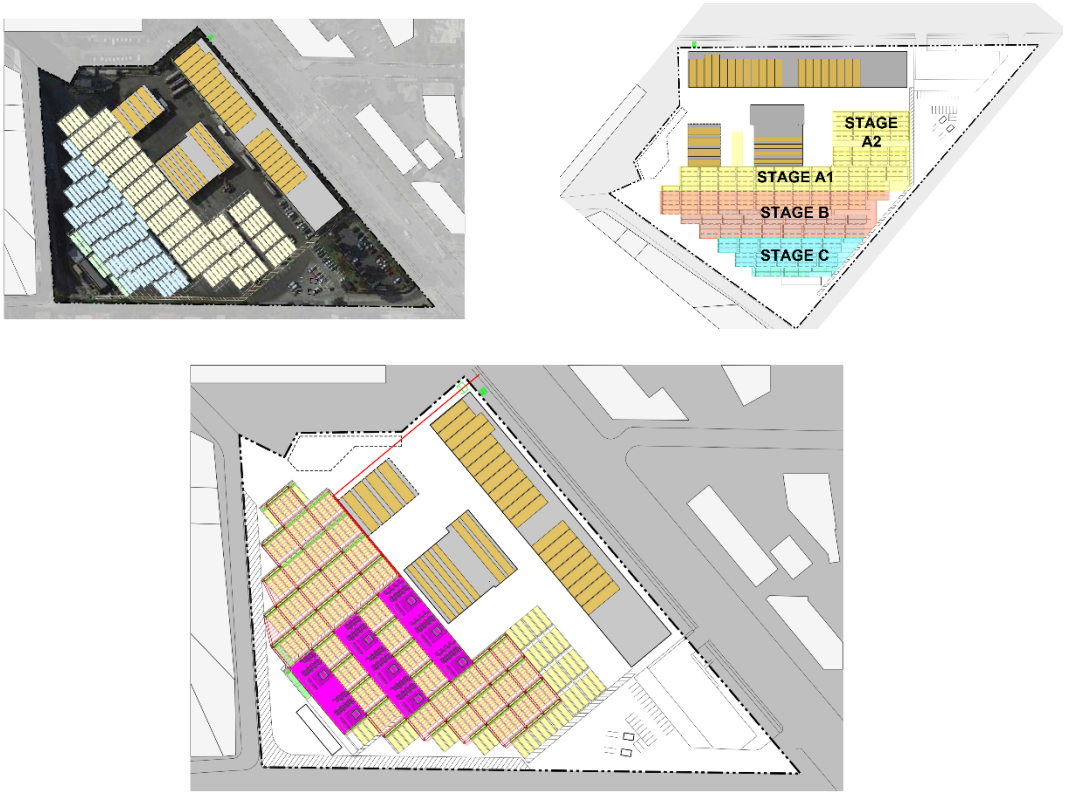
Division 7 is located at 8800 Santa Monica Boulevard in the City of West Hollywood. 233 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 7's fleet consists of 148 40-foot, 80 45-foot, and five 60-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses Division 7. Based on preliminary demand modeling, approximately 14 MW of power will be needed to be provided by Southern California Edison (SCE) to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take three to five years.

Construction for Division 7 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Buses are anticipated to be temporarily stored at Division 10 during these stages. Ultimately, Division 7 is expected to have 117 150-kW and three 450-kW chargers and will be BEB-operational in 2030. Figure 3-15 illustrates the process that Division 7 will undergo towards full electrification.

Figure 3-15. Division 7 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.6 Division 8

Existing Conditions

Division 8 is located at 9201 Canoga Avenue in the City of Los Angeles. 202 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 8's fleet consists of 61 40-foot, 107 45-foot, 33 60-foot, and one 65-foot bus. Bus parking predominates the site and buses are parked in diagonal stacked rows in the south and west portions of the division. As part of a recent reconfiguration of the parking, two diagonal rows have been combined to be nose-to-tail.

10 ABB 150-kW plug-in chargers will be installed on western wall of the Division. However, this work preceded the ZEB Master Plan which is recommending a different charging strategy and layout.

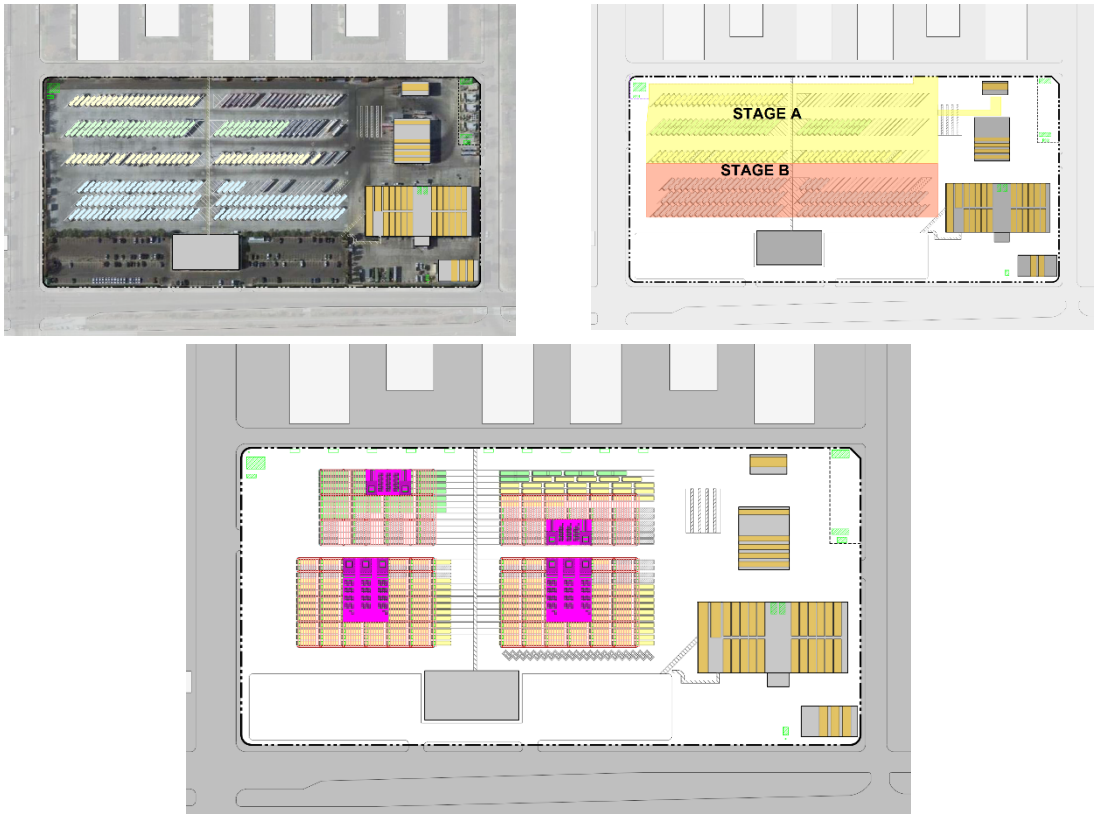
Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses Division 8. Based on preliminary demand modeling, approximately 14 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years. It should be noted that additional capacity was installed at the division to accommodate the 10 plug-in chargers.

To accommodate additional buses and future BEB equipment, the division is being designed for nose-to-tail track parking. Construction for Division 8 and its associated BEB charging equipment and support systems will be completed in two, six-month stages. Due to available storage capacity at Division 8 and the adjacent Marilla Lot (Metro-owned parking lot), buses can be rearranged on site and/or moved temporarily to Marilla Lot during construction.

Ultimately, Division 8 is expected to have 101 150-kW and three 450-kW chargers and will be BEB-operational in 2024. Figure 3-16 illustrates the process that Division 8 will undergo towards full electrification.

Figure 3-16. Division 8 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.7 Division 9

Existing Conditions

Division 9 is located at 3449 Santa Anita Avenue in the City of El Monte. 223 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 9's fleet consists of 161 40-foot and 62 45-foot buses. Division 9 has both nose-to-tail parking and diagonal parking. Buses assigned to the division are parked in one of 11 parallel rows at the western end of the site. Overflow parking is provided for buses in the diagonal-arranged lot to the east.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 9. Based on preliminary demand modeling, approximately 19 MW of power will be needed to be provided by SCE to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take three to five years. Existing diagonal parking will be transitioned to nose-to-tail to accommodate more buses and conform with BEB infrastructure plans.

Construction for Division 9 and its associated BEB charging equipment and support systems will be completed in two, six-month stages. Due to available storage capacity at Division 9, buses can be rearranged on site without temporary displacement. Ultimately, Division 9 is expected to have 112 150-kW and four 450-kW chargers and will be BEB-operational in 2026. Figure 3-17 illustrates the process that Division 9 will undergo towards full electrification.

Figure 3-17. Division 9 – Existing, Construction Staging, and Buildout

Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout
Source: ZEBGO, December 2018

3.5.8 Division 10

Division 10 is located at 742 N. Mission Road in the City of Los Angeles.

As of September 2020, due to future anticipated service needs, Metro has permanently closed Division 10 for revenue service. However, Division 10 is expected to be a key component in Metro's ZEB transition as it will be relied upon for temporary storage and bus relocations as other divisions are being improved.

3.5.9 Division 13

Existing Conditions

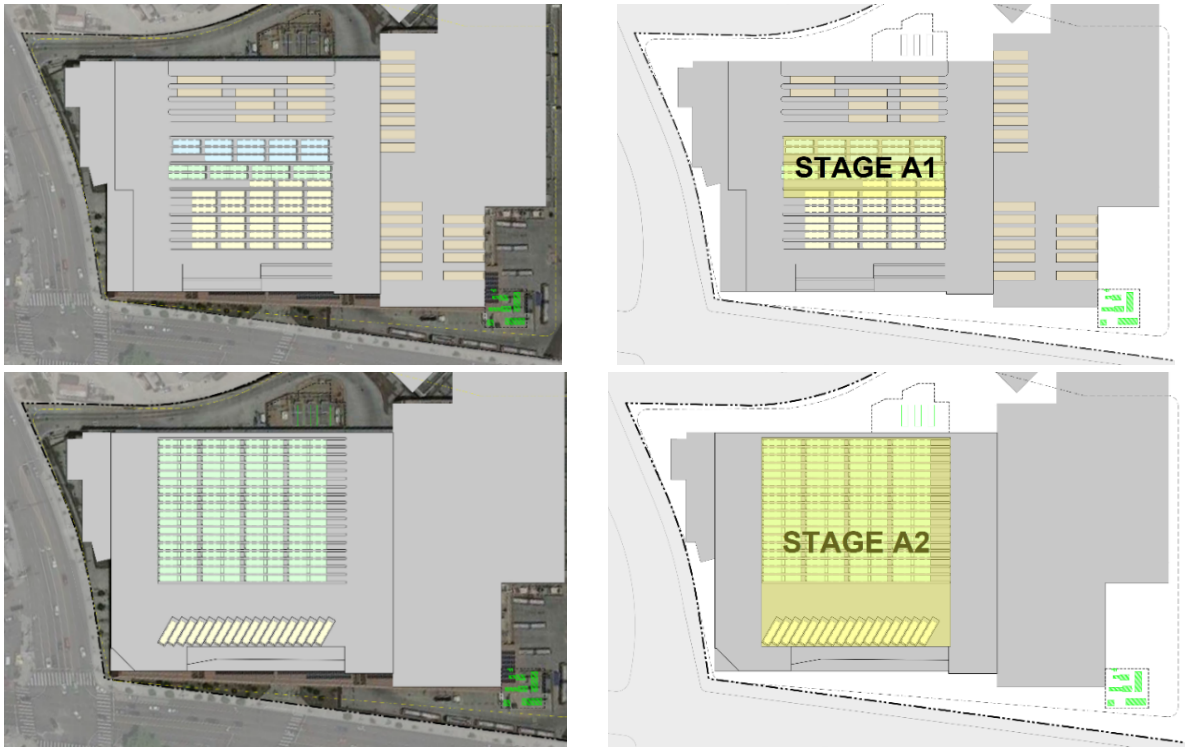
Division 13 is located at 920 N. Vignes Street in the City of Los Angeles. Division 13 is also connected to Metro's Central Maintenance Facility (CMF). 163 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 13's fleet consists of 56 40-foot, 14 45-foot, and 93 60-foot buses. Division 13 is a multi-level structure. The "Lower Level" (subterranean) is for employee parking, "Level 1" (street level) is for 40- and 45-foot bus parking, maintenance, fueling, and wash, and the "Upper Level" is for 60-foot bus parking. Buses are parked in unassigned, numbered tracks (nose-to-tail).

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 13. Based on preliminary demand modeling, approximately 10 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

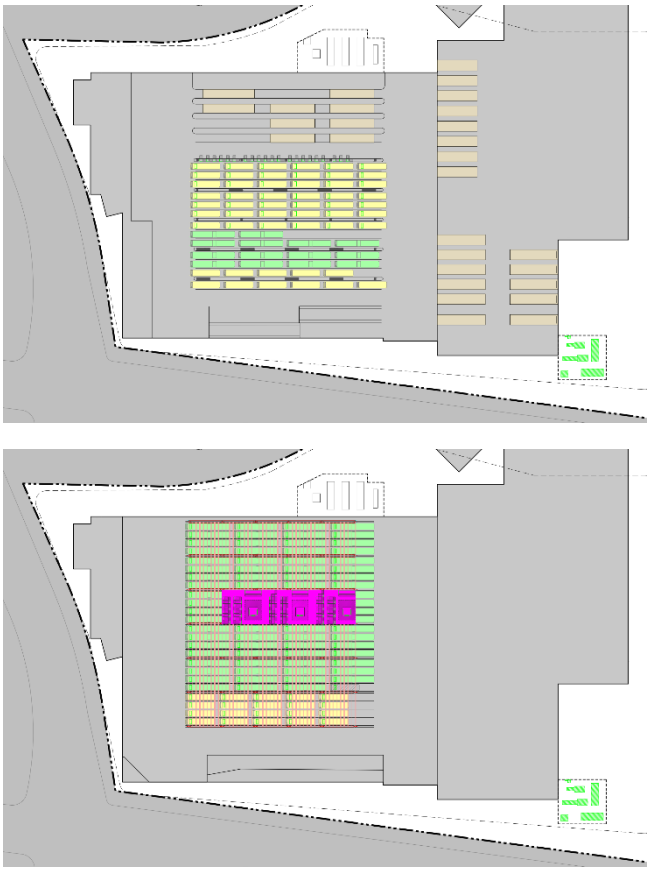
Construction for Division 13 and its associated BEB charging equipment and support systems will be completed in one six-month stage. Buses are anticipated to be temporarily stored at Division 10 and CMF during these stages. Ultimately, Division 13 is expected to have 95 150-kW and three 450-kW chargers and will be BEB-operational in 2026. Figure 3-18 illustrates the existing (December 2018) and construction staging for the 2nd and 3rd levels, and Figure 3-19 illustrates these levels at full buildout.

Figure 3-18. Division 13 – Existing and Construction Staging (2nd and 3rd Levels)



Source: ZEBGO, December 2018

Figure 3-19. Division 13 – Buildout (2nd and 3rd Levels)



Source: ZEBGO, December 2018

3.5.10 Division 15

Existing Conditions

Division 15 is located at 11900 Branford Street in the City of Los Angeles. 241 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 15's fleet consists of 82 40-foot, 109 45-foot, and 50 60-foot buses. Bus parking comprises the majority of the site in the south and west portions of the division. Parking is single row diagonal and has recently been expanded into an underutilized space.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 15. Based on preliminary demand modeling, approximately 17 MW of power will be needed to be provided by LADWP to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take two to three years.

Given the current layout, making room for charging equipment could be challenging but rearranging two or more rows, as was done at Division 8, would provide ample parking space.

Construction for Division 15 and its associated BEB charging equipment and support systems will be completed in two, six-month stages. Due to available storage capacity at Division 15 and the nearby Marilla Lot (Metro-owned parking lot), buses can be rearranged on site and/or moved temporarily to Marilla Lot during construction. Ultimately, Division 15 is expected to have 121 150-kW and three 450-kW chargers and will be BEB-operational in 2025. Figure 3-20 illustrates the process that Division 15 will undergo towards full electrification.

Figure 3-20. Division 15 – Existing, Construction Staging, and Buildout

Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout.
Source: ZEBGO, December 2018

3.5.11 Division 18

Existing Conditions

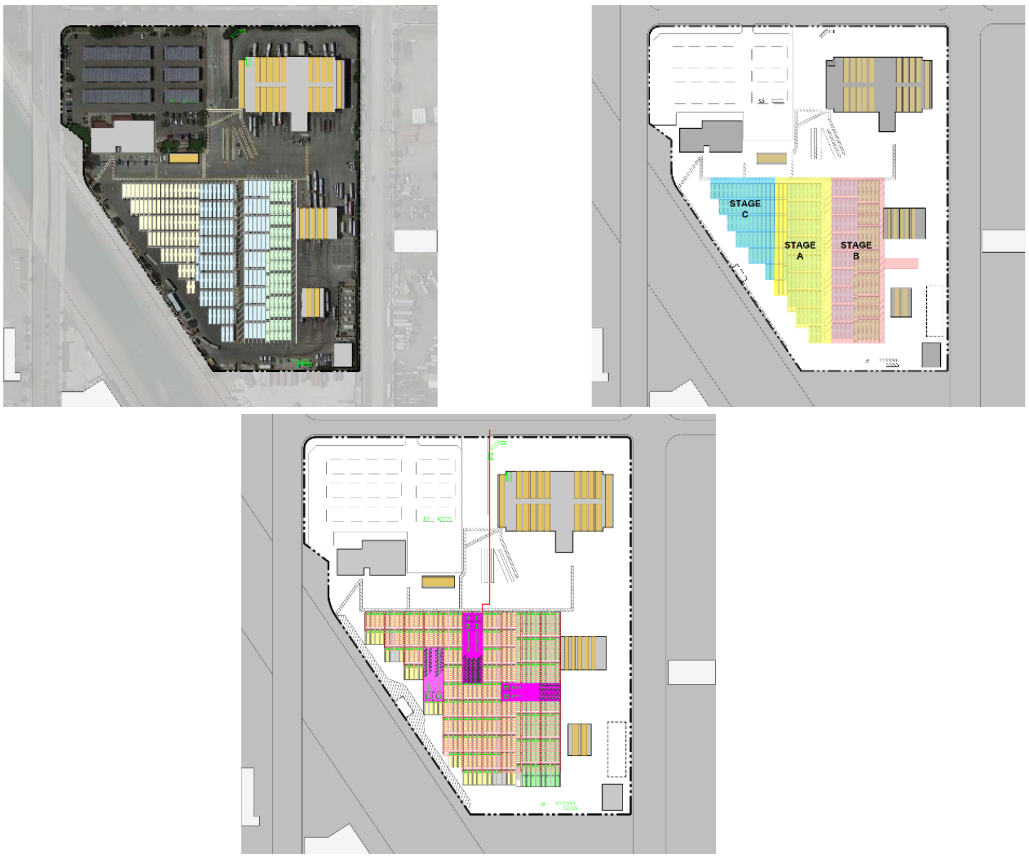
Division 18 is located at 450 W. Griffith Street in the City of Gardena. 252 CNG-powered buses are stored, maintained, fueled, and serviced at the division. Division 18's fleet consists of 74 40-foot, 116 45-foot, and 62 60-foot buses. Buses are parked in unassigned, numbered tracks (nose-to-tail). The division is constrained with no significant space for future ground-level BEB charging equipment.

Planned ZEB Modifications and Timeline

Additional electrical capacity will be required to meet the service needs of buses at Division 18. Based on preliminary demand modeling, approximately 17 MW of power will be needed to be provided by SCE to support the current fleet. Construction and enhancements to bring this additional capacity is anticipated to take three to five years.

Construction for Division 18 and its associated BEB charging equipment and support systems will be completed in three, six-month stages. Due to available storage capacity at Division 18, buses can be rearranged on site without temporary displacement. Ultimately, Division 18 is expected to have 126 150-kW and five 450-kW chargers and will be BEB-operational in 2026. Figure 3-21 illustrates the process that Division 18 will undergo towards full electrification.

Figure 3-21. Division 18 – Existing, Construction Staging, and Buildout



Clockwise (from the upper left), from existing conditions (December 2018), to construction staging, to full buildout.
Source: ZEBGO, December 2018

4 DISADVANTAGED COMMUNITIES

The following section provides an overview of disadvantaged communities (DACs) in Metro's service area and the strategy to prioritize them for ZEB adoption.

4.1 Disadvantaged Communities Served

73 percent of Metro's divisions are located in communities that are classified as "disadvantaged" according to CalEnviroScreen. The conversion of existing CNG operations to BEB operations will directly benefit the communities in the vicinity of these divisions by way of a reduction in noise and local emissions. These divisions also serve multiple routes that traverse multiple DACs across Los Angeles County.

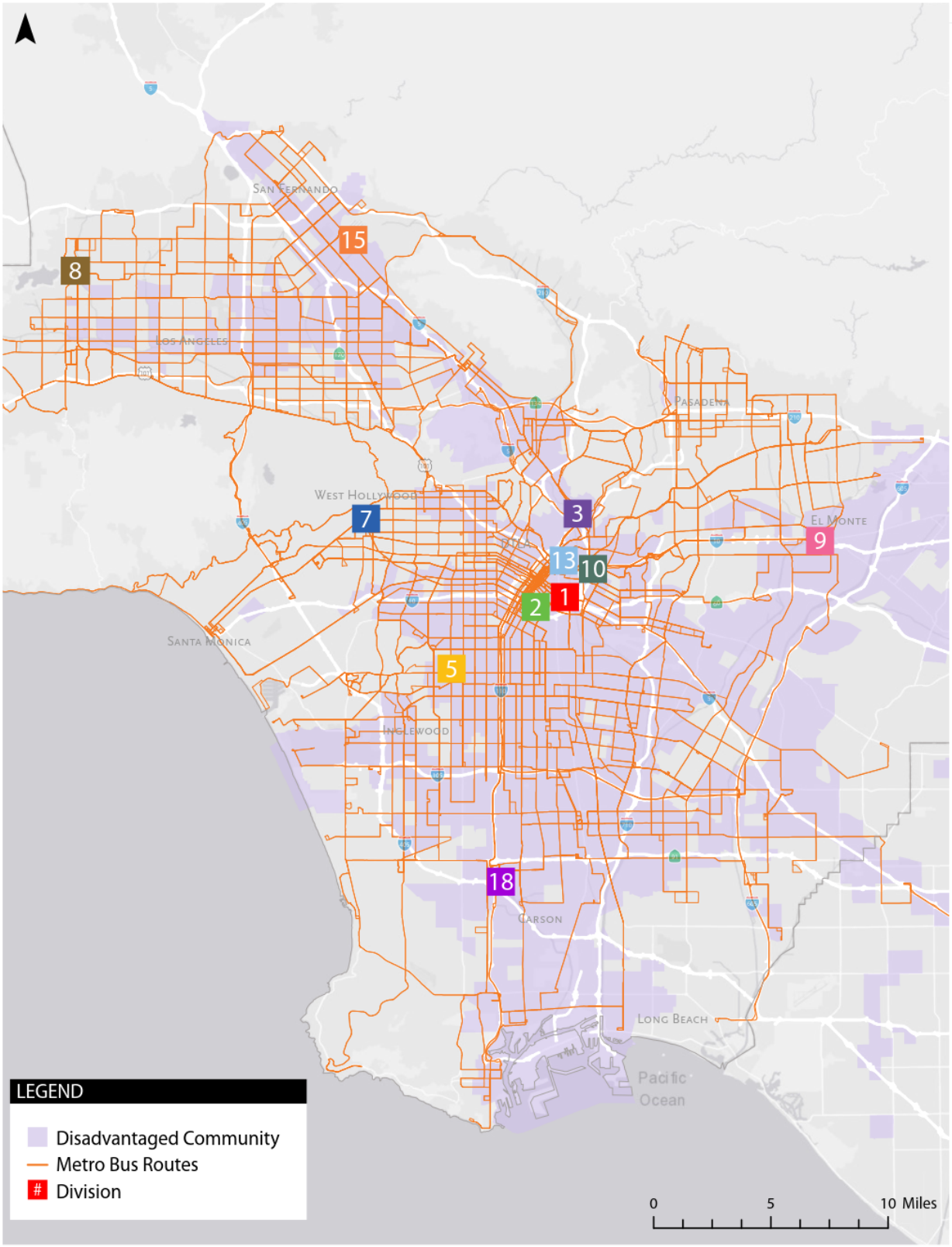
Table 4-1 summarizes whether or not divisions are located in DACs and the number and percentage of DACs that its respective routes serve. Figure 4-1 illustrates Metro divisions and routes in DACs.

Table 4-1. Disadvantaged Communities

Division	In DAC?	NOx Exempt Area?	Communities (Tracts) Served	DACs Served (#)	DACs Served (%)
1	Yes	No	299	206	69%
2	Yes	No	299	234	78%
3	Yes	No	343	213	62%
5	Yes	No	285	211	74%
7	No	No	362	194	54%
8	No	No	283	114	40%
9	Yes	No	343	188	55%
13	No	No	251	148	59%
15	Yes	No	404	181	45%
18	Yes	No	480	339	71%

Source: CalEnviroScreen 3.0, June 2018

Figure 4-1. DACs in Service Area



Source: ZEBGO, CalEnviroScreen 3.0, June 2018

4.2 DAC Prioritization Strategy

As previously mentioned, Phase 1's ZEB transition is focused on the Silver and Orange BRT lines. The second and third phases will focus on Metro's other routes and services.

Since ZEBs cannot operate unless infrastructure is in place to charge buses, Metro's transition (primarily Phases 2 and 3) largely focuses on division electrification and not individual routes. Once divisions are electrified, buses will be strategically deployed to routes and service blocks with a priority of DAC service. It should be noted that in Phase 2, three of the four divisions to be electrified divisions are in DACs, the remaining four DAC divisions will be electrified in Phase 3.

The population that resides in DACs tend to be society's most vulnerable. They typically rely on the public transit system, are more likely to be impoverished, and are more frequently exposed to harmful emissions and pollutants that result in negative health outcomes. Thus, DAC communities will benefit the most once ZEBs are adopted and this is why Metro is making a concerted effort to ensure that divisions and routes within and that service DACs are among the first to be transitioned to ZEBs, as shown in Table 4-1.

5 WORKFORCE TRAINING

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

5.1 Training Requirements

The transition to ZEBs will significantly alter Metro's service and operations. Converting to ZEBs from CNG is an arduous endeavor and will impact all ranks of the organization. This will require extensive change management and training which will be provided by the OEMs and Metro. Training will need to be conducted after buses are procured and in advance of the delivery of said buses. Therefore, it is expected that all personnel will be sufficiently trained before the buses arrive. Training conditions and schedules will be included in procurement documents, as they are with all existing procurements. If other OEM-provided buses are procured in the future and/or if new components, software, or protocols are implemented, it is expected that Metro's staff will be trained well in advance of the commissioning of these additions. Since battery technology is rapidly evolving, it is likely that buses and supporting battery chemistries and software will change between 2020 and 2040, therefore, Metro's future procurements/deliveries will require refresher or updated trainings for relevant staff.

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

- **Bus Operators**
  Bus operators will need to be familiarized with the buses, safety, bus operations, and pantograph operations.
- **Facilities Maintenance Staff and Maintenance**
  Facilities 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.
- **Mechanics**
  Mechanics will need to be familiarized with the safety-related features and other components of ZEBs.
- **Instructors**
  For both Operator Central Instruction and Maintenance, instructors will need to understand all aspects of the transition of ZEBs to train others.
- **Service Attendants**
  Service attendants will become familiarized with proper charging protocol and procedures that are ZEB-specific.
- **Management Staff**
  All management staff (supervisors, directors, etc.) will be familiarized with ZEB operations and safety procedures.

6 COSTS AND FUNDING

The following section identifies potential funding sources that Metro may pursue in its adoption of ZEBs.

6.1 Preliminary Costs

Based on preliminary estimates, Metro's transition is expected to cost between $1.3 billion and $1.6 billion. Infrastructure will cost between $900 million and $1.4 billion. and BEBs are expected to cost $222 million more than the conventional CNG buses. These costs only reflect capital infrastructure. Various operations and maintenance costs, including utility, operating, and maintenance costs are still be analyzed.

6.2 Funding Sources

There are a number of potential federal, state, local, and project-specific funding, and financing sources at Metro's disposal. To date, Metro has applied for and been awarded various Federal, State, and Local funds for ZEB projects, as indicated in Table 6-1.

Table 6-1. Metro's ZEB Funding

Type	Agency	Funding Mechanism	Year	Status	Award
Federal	FTA	Low- or No-Emission Vehicle Grant	2015	Awarded	$4.3M
Federal	FTA	Low- or No-Emission Vehicle Grant	2016	Not Awarded	N/A
State	Caltrans	Transit and Intercity Rail Capital Program	2016	Not Awarded	N/A
Local	SQAMD	AB2766 Discretionary Fund	2017	Awarded	$2M
State	CARB	Carl Moyer Memorial Air Quality Standards Attainment Program	2018	Not Awarded	N/A
State	Caltrans	Transit and Intercity Rail Capital Program	2020	Not Awarded	N/A

Source: Los Angeles Metropolitan Transportation Authority, February 2020

Metro is also leveraging utility-based programs such as LADWP's Commercial EV Charging Station Rebate Program and SCE's Charge Ready Program. For funding, Metro will also continue to use local tax measure(s) and other strategies to meet its 2030 goals, such as public-private partnerships, and other grant opportunities.

7 START-UP AND SCALE-UP CHALLENGES

As mentioned, Metro has a very aggressive ZEB transition schedule – 10 years before the ICT regulation requires. To meet both deadlines, there are several challenges and opportunities that Metro has identified. The following briefly described some of the challenges that Metro faces for its transition:

- **Technological adaptation.** Currently, Metro is modeling and planning for a transition based on December 2018 service levels and existing ZEB technology. With challenging 2030 and 2040 deadlines looming, it is difficult to anticipate future technological enhancements and changes, such as improved batteries and chargers. Slight changes in these technologies could improve bus ranges, in turn, reducing costs. Metro (and the market) must be aware of these changes as it would be counterproductive to invest in technologies that will soon be outdated.
- **Costs.** Adoption of ZEBs has many benefits, including potential lifecycle cost savings. However, the investment required for capital and change management will be very expensive. Metro will have to be creative with funding mechanisms and sources to ensure that the transition to ZEB will not be detrimental to its operations and service.
- **Market Production Factors.** 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 multi-state policy changes will have a great impact on these transitions; however, it will also make it challenging to meet ZEB goals for agencies if supply of buses can meet with demand.
- **Phasing and Transition.** Metro has the second largest transit fleet in the United States. Transitioning to ZEBs without any service interruptions will be very challenging due to the limited space for construction, staging buses, and maintaining service.
- **Utility Upgrades.** Metro's divisions are currently under the jurisdiction of two utilities, whereas potential on-route charging locations are under nine. These utilities have different rate structures and protocols to apply for and receive additional power. How each utility is sanctioned (whether municipal or private) also dictates procedural requirements. These nuances will make it challenging to plan for due to the variances in schedule and process.
- **Managing Power Demand.** The transition to BEBs will require strategies to ensure that Metro can utilize power in the most cost-efficient way. Metro is currently doing this via utility negotiations and demand modeling to determine methods to reduce peak demands. However, shaving demand may also come at a hefty capital cost, something that staff is currently analyzing.
- **Uncertainty of COVID-19.** COVID-19 has impacted all facets of our global economy, transit is not an exclusion. During the pandemic, ridership has plummeted and caused major shortfalls in Metro's budget which has impacted capital programs and operations. At this time, it is unclear what short- and long-term impacts will be for service. There is a possibility that service ridership levels may not return to previous levels resulting in changes to procurement and funding. Metro will continue to analyze trends to determine service changes and plans.

In conclusion, Metro is still determining the path forward towards its transition goals. At this time, Metro is slated to convert its entire fleet to ZEBs by 2030, 10 years in advance of what is required by the ICT. Metro's next steps in this process is to continue refining analysis and Master Planning efforts.

Appendix A: Metro Board-Approved Resolution