In Depot Charging and Planning Study

Foothill Transit

Report
Project No. 110549

Final
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In Depot Charging and Planning Study

prepared for

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prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, MO

ebusplan
Aachen, Germany

Greenlots, A Member of the Shell Group
Los Angeles, CA

AMMA Transit Planning
Riverside, CA

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
BEB	Battery Electric Bus
BMcD	Burns & McDonnell Engineering Company, Inc.
Burns & McDonnell	Burns & McDonnell Engineering Company, Inc.
CCS	Combined Charging System
CNG	Compressed Natural Gas
CPUC	California Public Utilities Commission
DC	Direct Current
EOL	End of Life
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
LCC	Life Cycle Cost
HVAC	Heating ventilation, and air conditioning
kW	Kilowatt
kWh	Kilowatt hour
MW	Megawatt
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
PPA	Power Purchase Agreement
PVR	Peak Vehicle Requirement

Abbreviation	**Term/Phrase/Name**
RFI	Request for Information
RPS	Renewable Portfolio Standard
SAM	System Advisor Model
SCE	Southern California Edison
SOC	State of Charge
TOU	Time of Use
V	Volt

EXECUTIVE SUMMARY

In 2016 Foothill Transit's Executive Board set a goal of transitioning its fleet to 100% electric by 2030. To work toward this goal Foothill Transit hired Burns and McDonnell to better understand the challenges in growing the fleet and develop solutions. The scope of this study is to bolster this initial plan by providing route-based energy analysis and charging optimization, equipment market analysis, infrastructure and yard layout assessments at Foothill Transit depots, utility grid interconnection assessments, the development of a renewable energy integration and backup power plan, and a financial analysis of the fleet conversion. This report summarized the findings and recommendations and formulates an actionable work plan that Foothill Transit can use to work towards its goal of a reliable and sustainable 100% electric bus fleet.

The study assumes that Foothill will transition its fleet of approximately 373 buses to an all-electric fleet by 2030. The proposed study plan assumes that the fleet will be comprised of both 40 ft single deck 540 kWh BEBs and 864 kWh double deck BEBs. The Study made various assumptions regarding available battery operating capacity, battery performance impacts and efficiency impacts for cold weather conditions and heavy loading conditions respectively. Battery degradation was assumed as well to validate that the BEB operating plan would be feasible under all conditions and all years.

Based on the detailed route analysis conducted in this Study, Foothill Transit will be able to transition to a fully electrified fleet in the future, but it will require changes to its existing operations and bus procurement plan. Based on the analysis conducted, approximately 60% of the single deck bus blocks are feasible with the 540kWh BEBs and less than 50% of the double deck blocks are feasible with an 864 kWh battery BEB. The median energy use for single deck BEBs under worst case conditions is 2.94 kWh per mile while the double deck BEBs are 3.3 kWh per mile, with a high variation between the different blocks. To maintain operational feasibility, Foothill's total fleet peak vehicle requirement (PVR) will need to increase. Many of the existing blocks will need to be split and adjusted in the future. To maintain an existing minimum reserve ratio of 15 percent, Foothill will need to purchase additional BEBs.

In order to support the proposed plan, Foothill will require charging equipment to be installed at each of the depots over the next 10 to 12 years. Various charging equipment sizes and quantities were considered in the study to minimize the total PVR and total number of chargers and dispensers. The lowest cost charging plan is to utilize 325 kW overhead charging at each of the depots. Daily operational timetable models were developed for each depot to validate that the BEBs could be charged with 325 kW chargers.

The proposed operating plan assumes that Foothill will conduct the majority of BEB charging during low-cost off-peak hours.

Prior to developing site infrastructure plans, the Study team conducted a comprehensive market assessment and survey of charger vendors and bus manufacturers. Using the proposed charging power requirements and available charging equipment, the project team developed an infrastructure development plan for each depot based on the most recent fleet replacement plan. Dual port charging coupled with J3105-1 pantographs was assumed to maximize the utilization of each charger and minimize total infrastructure costs. The total infrastructure cost to Foothill over the next 12 years is estimated to be $120 million without rebates or subsidies.

The two existing depots' operations will need to change as the fleet transitions from CNG fueling to BEB charging. The project team prepared hourly models and layouts of how buses would operate within the depot in the future to validate that Foothill Transit's operators could charge the total PVR of 320 BEBs (130 at Pomona and 190 at Arcadia) with 95 chargers (40 at Pomona and 55 at Arcadia). The existing layouts and operating procedures will need to gradually change as the fleet is electrified.

The impacts of the additional load on the electric grid were quantified and provided to SCE, the local electric utility. Under SCE's current programs, SCE will fund all distribution system upgrades and line extension upgrades up to the new Foothill charging equipment. The layouts were developed and reviewed with SCE representatives in order to best utilize SCE capital investment. As part of the SCE Fleet Transit Ready program, the study plans for SCE to fund its own site infrastructure at a cost of $12 million. Foothill could also potentially receive up to $6 million in rebates for the 95 chargers proposed.

As Foothill Transit transitions to a 100 percent electric fleet, the proposed plan includes provisions for obtaining renewable power both onsite and offsite with a goal of reaching 100 percent renewable power supply. Based on the available footprint at Arcadia and Pomona depots, roughly 5 percent of Foothill's power supply can be generated from onsite canopy solar. The balance of Foothill Transit's renewable power will need to be obtained from SCE through their state RPS and other economical offsite contracts. While SCE transitions to 100 percent renewable by 2045, Foothill can secure other contracts. Procuring renewable power offsite could have other financial benefits such as additional LCFS credit revenue.

As detailed within this report, a future BEB fleet will include new onsite charging infrastructure costs and more costly BEBs. These incremental costs will be partially offset with lower bus maintenance costs and lower energy costs. Under a base case scenario which assumes no incentives or rebates are available in the future, Foothill Transit will pay over $15 million per year more on average over the next 25 years. If the existing California HVIP rebate of $110,000 per BEB, SCE 50% charger rebate, and California LCFS credits historically valued at $100 per Ton continue to be available, the incremental cost to convert from CNG buses to electric buses could be closer to $6.3 million per year.

1.0 INTRODUCTION

1.1 Scope of Work

Foothill Transit has set the goal to advance towards a 100% electrified bus fleet by 2030. To work toward this goal Foothill Transit has planned to purchase battery electric buses (BEB's) and install the necessary charging infrastructure on an annual basis until all existing compressed natural gas (CNG) buses are replaced. The scope of this study is to bolster this initial plan by providing route-based energy analysis and charging optimization, equipment market analysis, infrastructure and yard layout assessments at Foothill Transit depots, utility grid interconnection assessments, the development of a renewable energy integration and backup power plan, and a financial analysis of the fleet conversion. This report summarized the findings and recommendations and formulates an actionable work plan that Foothill Transit can use to work towards its goal of a reliable and sustainable 100% electric bus fleet.

1.2 Organization of Report

This report is divided into 13 sections. Each section is briefly explained below.

- Section 1.0 – Introduction
  This section describes the scope of this project.

- Section 2.0 - Foothill Transit Background and Electrification Plan
  This section provides background on Foothill Transit's bus operations and fleet transition plans.

- Section 3.0 – Study Assumptions and Technical Parameters
  This section outlines assumptions that were made to perform the route analysis and charging optimization scenarios.

- Section 4.0 - Route Analysis Scheduling and Charging Optimization
  This section reviews the block data provided by Foothill Transit and combines it with terrain data to create an energy-based analysis of each bus route. Once the energy needs are established, feasible and non-feasible blocks are assessed. Non-feasible blocks are adjusted to create feasible blocks. Lastly, peak vehicle requirements are established for each depot based on different charging scenarios.

- Section 5.0 - Route Prioritization and Electrification Planning
  This section describes the requirements on how Foothill Transits' CNG buses can be successfully transitioned to BEB's to create a 100% electrified bus fleet by 2030. A phased plan is provided

showing how Foothill will need to adjust its routes and number of buses over the next decade.

- Section 6.0 - Bus Equipment Market Analysis
  This section provides an overview of the different electric buses and charging equipment that is available in today's market.

- Section 7.0 - Charging Equipment Market Analysis and Selection
  This section presents the results from a request for information (RFI) conducted by the project team on existing charging equipment that is available from reputable charger original equipment manufacturers (OEMs). A scoring matrix was created and based on responses from the RFI and the charging requirements established in Section 4.0 of this report. Recommendations are presented on the best charging equipment options and OEM's for Foothill Transit.

- Section 8.0 - Depot Physical Layout Assessment
  This section presents an assessment on the current configuration of Foothill Transit's depots and how buses operate at each depot and considerations for a future electrified state. This section provides options for future charging equipment and the recommended future depot charging infrastructure layouts based on the charging and equipment requirements established in Section 4.0 and 7.0.

- Section 9.0 - Depot Infrastructure Phasing and Development
  This section provides options and recommendations for a phased transition to reach full electrification by 2030. The year by year civil, electrical, and charging equipment is described for each depot along with total installed costs by year. The phasing and development plan is based on Foothill Transit's fleet replacement schedule provided in March 2019.

- Section 10- Depot Operational Assessment
  This section presents a plan on how to charge BEBs at a full-scale electrification at each depot and how future depot equipment configurations and operations may need to be altered to fully support operating and charging a fully electrified bus fleet from each depot.

- Section 11- Utility Grid Infrastructure Assessment
  This section reviews the local electric utility, Southern California Edison, infrastructure servicing the Foothill Transit depots and discusses how future capacity will be added, who will be responsible, and what programs are available to support the installation of charging infrastructure.

- Section 12.0 - Renewable Energy Supply and Back Up Power Plan
  This section provides an analysis of the potential options Foothill Transit can use to deploy renewable energy power supply, both onsite and offsite, along with a plan to achieve a 100% electrified fleet powered by 100% renewable energy. This section also provides the back-up power assessment and plan so that Foothill Transit can continue to operate its electrified fleet during various scenarios.

- Section 13.0 - Fleet Electrification Life Cycle Cost Analysis
  This section assesses the financial impacts from transitioning to an electric fleet as compared to continuing to operate a CNG bus fleet. The incremental costs and benefits associated with a 100% fleet transition are estimated to determine the total net benefit or cost to Foothill Transit.

1.3 Sources of Data

The data for this project was collected from the sources listed below.

- Foothill Transit provided block data that represents each route that is currently serviced. The block data was provided for the time period between June 24th, 2018 and January 26th 2019. This block data was used to analyze each route, create energy-based scheduling and charging scenarios, and to determine whether routes would be feasible for BEB's.

- Publicly available data from electric bus and charging OEM's. This data was used to inform assumptions on battery sizes and peak charging power.

- Technical specifications were provided by charging equipment OEM's. This data was used to evaluate suitable charging technologies that meet the needs of BEB's that will operate on Foothill Transit routes.

- Onsite interviews of Foothill Transit staff and surveys of Foothill Transit depots.

- SCE provided data on its local distribution system and available programs for EV charging infrastructure.

- Renewable energy provided non-binding proposals for offsite wholesale renewable power supply.

1.4 Statement of Limitations

In the preparation of this report, the information provided to the project team by Foothill Transit, bus and charger OEM's, Southern California Edison, and renewable energy suppliers was used to make certain assumptions with respect to conditions which may exist in the future. While Burns & McDonnell believes the assumptions made are reasonable for the purposes of this report, Burns & McDonnell makes no representation that the conditions assumed will, in fact, occur. In addition, while Burns & McDonnell has no reason to believe that the information provided by the sources previously listed and on which this report is based, is inaccurate in any material respect, Burns & McDonnell has not independently verified such information and cannot guarantee its accuracy or completeness. To the extent that actual future conditions differ from those assumed herein or from the information provided to Burns & McDonnell, actual results may vary from those forecasted.

2.0 FOOTHILL TRANSIT BACKGROUND AND ELECTRIFICATION PLAN

Foothill Transit is leading the charge among transit agencies as it embarks on a journey to electrify its entire bus fleet by the year 2030. In this section, the background of Foothill's plan to deploy electric buses will be briefly described as well as an overview of bus routes, depots, key statistics, transition plans, and other goals that Foothill Transit is aiming to achieve in the next decade.

2.1 Foothill Transit Background

Located in eastern Los Angeles County, Foothill Transit serves 22 cities and unincorporated areas of Los Angeles County with a fleet of 373 buses that support 39 local and express routes. Foothill Transit has been leading the way in transit bus electrification since 2010. It was the first transit agency in the United States to deploy three 35 ft. in-route fast-charge BEBs and two overhead charging stations at the Pomona Transit Center operating on Line 291 between the cities of La Verne and Pomona. In 2014, Foothill Transit acquired 12 additional 35 ft. in-route fast-charge BEBs to fully electrify Line 291.

In 2016, Foothill Transit announced its initiative to completely electrify its bus fleet by the year 2030. By 2017, Foothill Transit had installed an in-depot charger at the Pomona yard and in-route charging stations at Pomona Transit Center and Azusa Intermodal Transit Center for opportunity charging. while adding 14 40 ft. extended range BEBs to operate on Line 280 between the cities of Azusa and Industry. Today, Foothill Transit has 33 BEB's in operation and has placed an order for two 42 ft. double-deck battery electric buses, which is slated to be delivered late spring 2020. The two pilot double-deck buses will be deployed on the commuter express route transporting customers to downtown Los Angeles.

2.2 Bus Depots

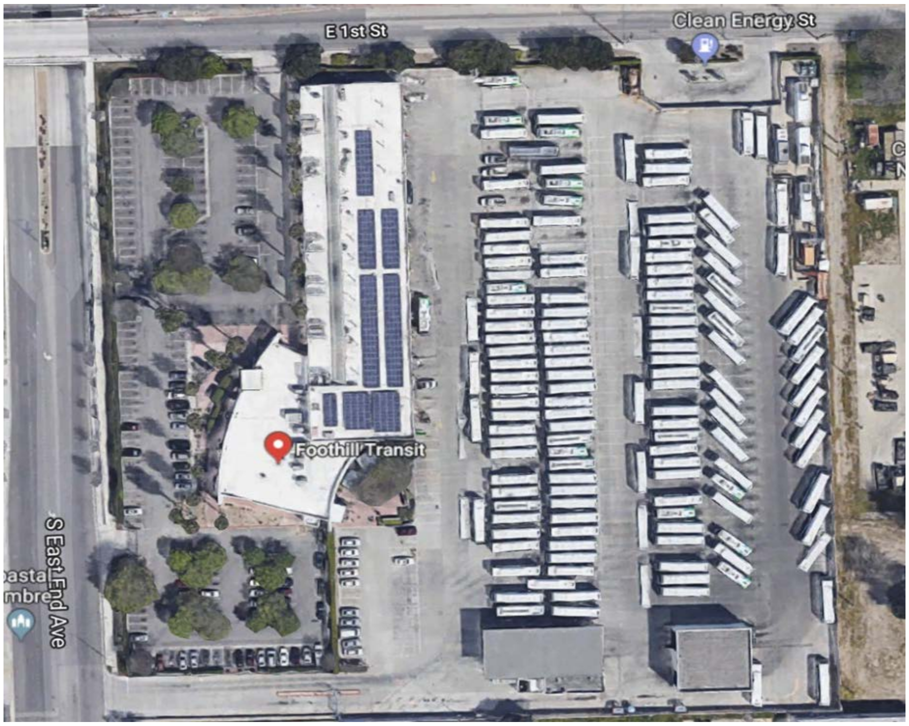
Foothill Transit operates its bus fleet out of two depots. The Arcadia depot, located in Arcadia, CA operates both single deck 40 ft and 35 ft buses and articulated 60ft. buses. The Pomona depot, located in Pomona, CA operates single deck 35 ft and 40 ft buses. Figure 2-1 presents the existing Arcadia depot while Figure 2-2 presents the Pomona depot. A summary of the existing bus fleet as of March 2019 is provided below:

- Arcadia Depot Existing Fleet
  - 176 40ft CNG buses
  - 14 40ft extended range battery-electric buses
  - 3 35ft extended range single deck
  - 30 60ft Articulated CNG buses
- Pomona Depot Existing Fleet

  - 134 40 ft CNG buses
  - 14 35 ft fast-charge battery-electric buses
  - 2 40 ft fast-charge battery-electric buses

Figure 2-1: Arcadia Bus Depot

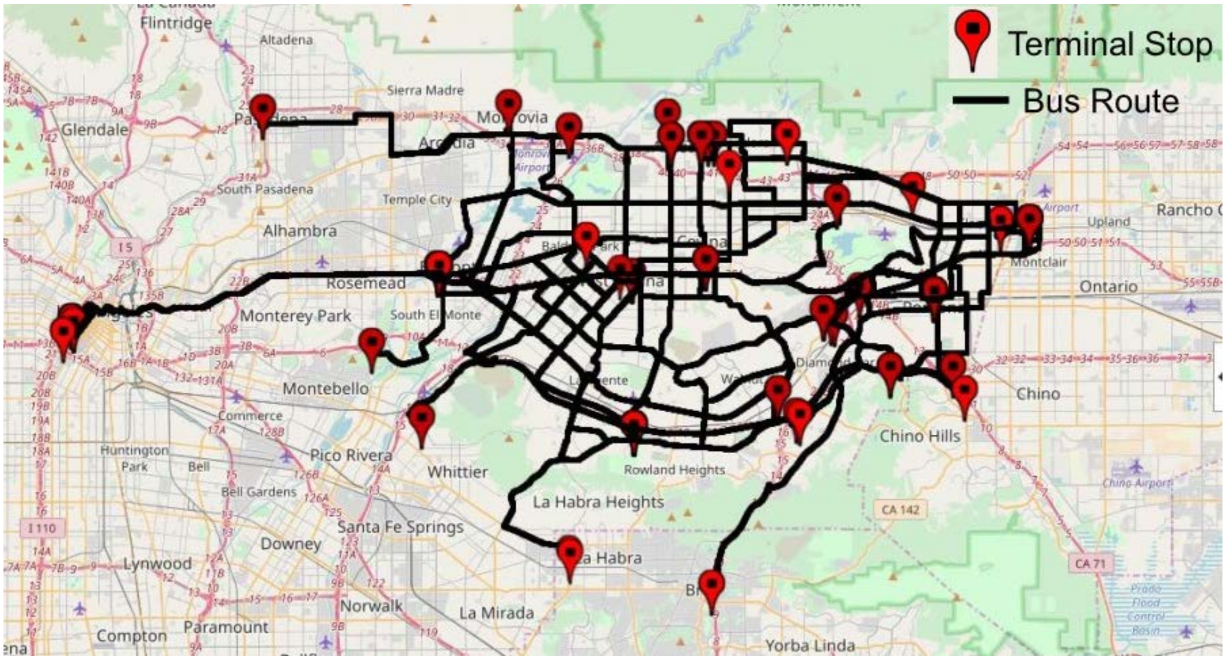
Figure 2-2: Pomona Bus Depot



2.3 Bus Routes

Figure 2-3 provides an overview of the bus routes Foothill Transit operates today along with terminal stops along the routes.

Figure 2-3: Overview of Foothill Transit Bus Routes



2.4 Key Statistics

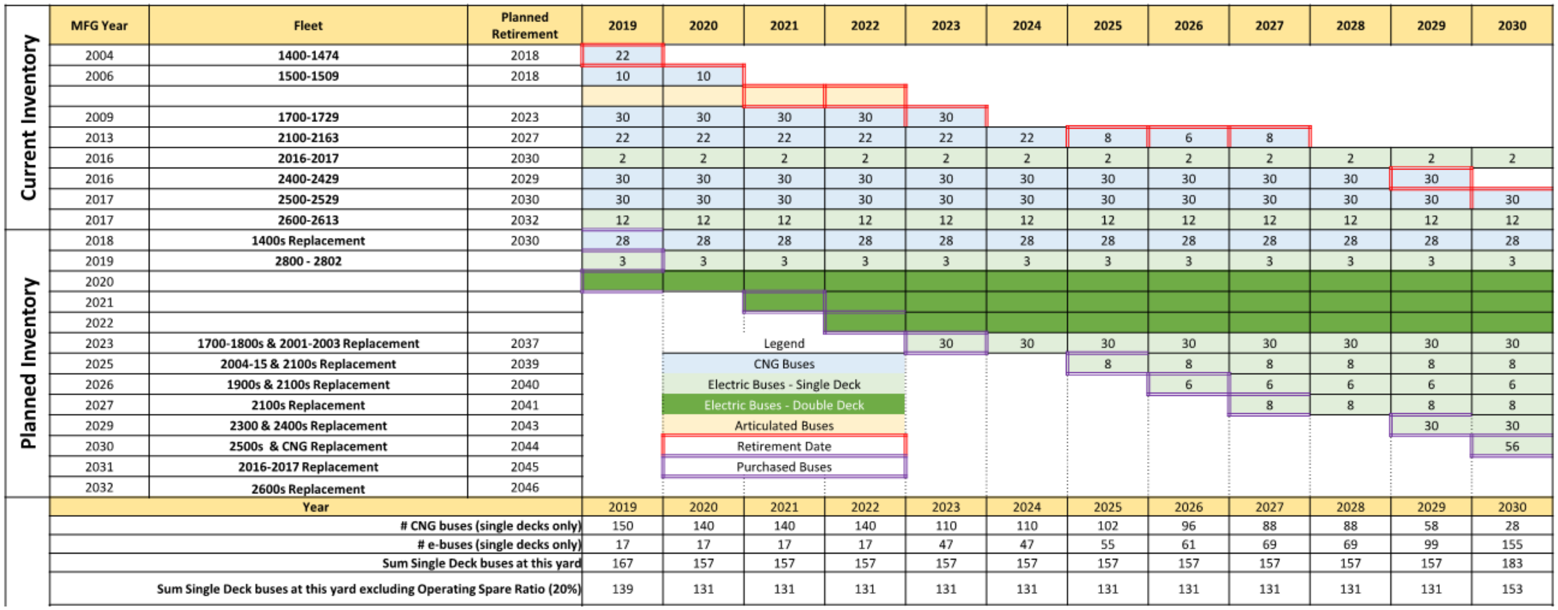
The following list summarizes some key metrics for Foothill Transit.

- **Buses in service:** 373 (340 Compressed Natural Gas or CNG and 33 electric)
- **Routes:** 32 local and 7 express routes
- **Area served:** 327 square miles of the San Gabriel and Pomona Valley
- **Ridership:** On average, more than 40,000 per weekday, and approximately 12.5 million a year
- **Comparative size:** Medium-sized municipal operator in Los Angeles County, second in fleet size only to regional provider Metro
- **Funding:** 16.6% from farebox revenue, 75% from Los Angeles County Proposition A and C funds and Measure R and M funds, California State Transportation Development Act (TDA) and State Transit Assistance (STA) funds

2.5 Fleet Transition Plans

The following tables outline the bus replacement schedules for single and double deck buses at Arcadia and single deck buses at Pomona as provided to the project team as of March 2019.

Table 2-1: Arcadia Single Deck Bus Transition



	MFG Year	Fleet	Planned Retirement	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Current Inventory	2004	**1400-1474**	2018	22											
	2006	**1500-1509**	2018	10	10										
				🟨	🟨	🟨	🟨								
	2009	**1700-1729**	2023	30	30	30	30	30							
	2013	**2100-2163**	2027	22	22	22	22	22	22	8	6	8			
	2016	**2016-2017**	2030	2	2	2	2	2	2	2	2	2	2	2	2
	2016	**2400-2429**	2029	30	30	30	30	30	30	30	30	30	30	30	
	2017	**2500-2529**	2030	30	30	30	30	30	30	30	30	30	30	30	30
	2017	**2600-2613**	2032	12	12	12	12	12	12	12	12	12	12	12	12
Planned Inventory	2018	**1400s Replacement**	2030	28	28	28	28	28	28	28	28	28	28	28	28
	2019	**2800 - 2802**		3	3	3	3	3	3	3	3	3	3	3	3
	2020			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	2021					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	2022						🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	2023	**1700-1800s & 2001-2003 Replacement**	2037		Legend			30	30	30	30	30	30	30	30
	2025	**2004-15 & 2100s Replacement**	2039		CNG Buses					8	8	8	8	8	8
	2026	**1900s & 2100s Replacement**	2040		Electric Buses - Single Deck						6	6	6	6	6
	2027	**2100s Replacement**	2041		Electric Buses - Double Deck							8	8	8	8
	2029	**2300 & 2400s Replacement**	2043		Articulated Buses									30	30
	2030	**2500s & CNG Replacement**	2044		Retirement Date										56
	2031	**2016-2017 Replacement**	2045		Purchased Buses										
	2032	**2600s Replacement**	2046												
	Year			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	# CNG buses (single decks only)			150	140	140	140	110	110	102	96	88	88	58	28
	# e-buses (single decks only)			17	17	17	17	47	47	55	61	69	69	99	155
	Sum Single Deck buses at this yard			167	157	157	157	157	157	157	157	157	157	157	183
	Sum Single Deck buses at this yard excluding Operating Spare Ratio (20%)			139	131	131	131	131	131	131	131	131	131	131	153

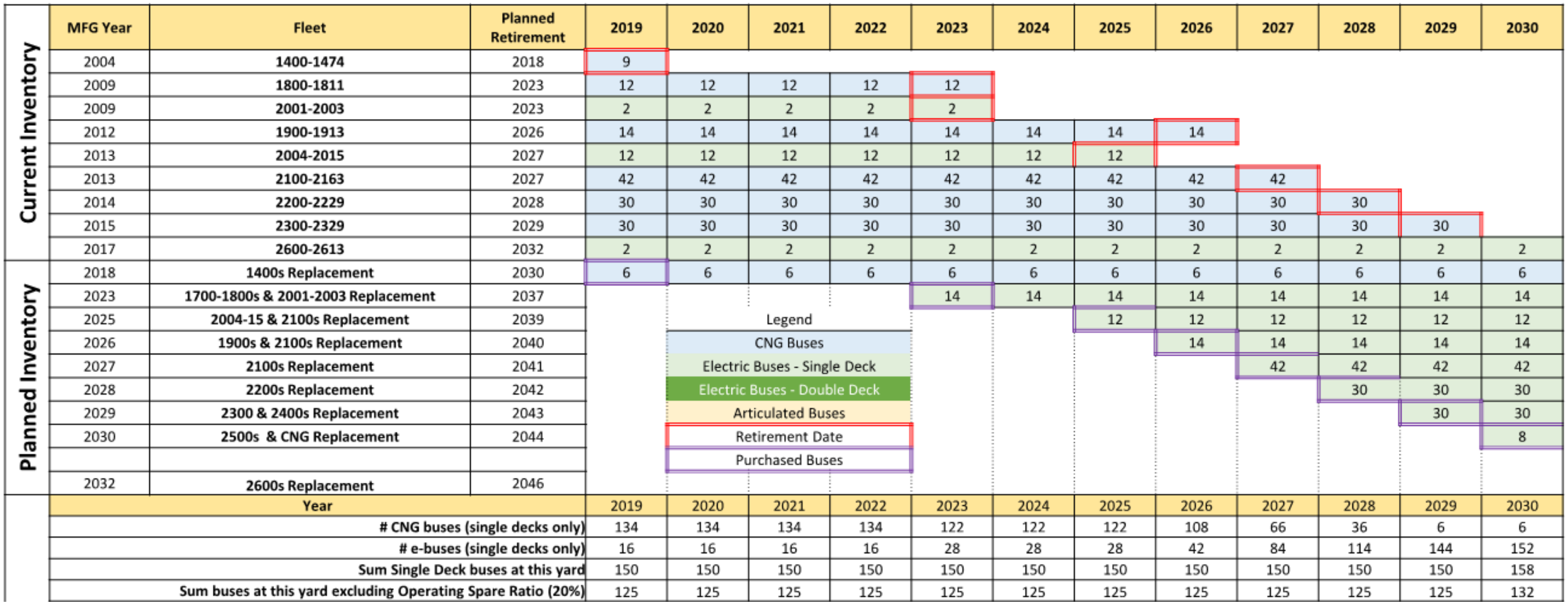
Table 2-2: Arcadia Double Deck Bus Transition

	MFG Year	Fleet	Planned Retirement	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Current Inventory	2006	**1600-1629**	2022	30	30	10	20								
Planned Inventory	2019	**Double Decks**	2033	2	2	2	2	2	2	2	2	2	2	2	2
	2021	**1600s Replacement**	2035			10	10	10	10	10	10	10	10	10	10
	2022	**1600s Replacement**	2036				20	20	20	20	20	20	20	20	20

Legend
- CNG Buses
- Electric Buses - Single Deck
- Electric Buses - Double Deck
- Articulated Buses
- Retirement Date
- Purchased Buses

Year	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
# CNG buses (double decks only)	30	30	20									
# e-buses (double decks only)	2	2	12	32	32	32	32	32	32	32	32	32
Sum Large Capacity buses at this yard	32	32	32	32	32	32	32	32	32	32	32	32
Sum Double Deck buses at this yard excluding Operating Spare Ratio (20%)	27	27	27	27	27	27	27	27	27	27	27	27

Table 2-3: Pomona Single Deck Bus Transition



	MFG Year	Fleet	Planned Retirement	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Current Inventory	2004	**1400-1474**	2018	9											
	2009	**1800-1811**	2023	12	12	12	12	12							
	2009	**2001-2003**	2023	2	2	2	2	2							
	2012	**1900-1913**	2026	14	14	14	14	14	14	14	14				
	2013	**2004-2015**	2027	12	12	12	12	12	12	12					
	2013	**2100-2163**	2027	42	42	42	42	42	42	42	42	42			
	2014	**2200-2229**	2028	30	30	30	30	30	30	30	30	30	30		
	2015	**2300-2329**	2029	30	30	30	30	30	30	30	30	30	30	30	
	2017	**2600-2613**	2032	2	2	2	2	2	2	2	2	2	2	2	2
Planned Inventory	2018	**1400s Replacement**	2030	6	6	6	6	6	6	6	6	6	6	6	6
	2023	**1700-1800s & 2001-2003 Replacement**	2037					14	14	14	14	14	14	14	14
	2025	**2004-15 & 2100s Replacement**	2039							12	12	12	12	12	12
	2026	**1900s & 2100s Replacement**	2040								14	14	14	14	14
	2027	**2100s Replacement**	2041									42	42	42	42
	2028	**2200s Replacement**	2042										30	30	30
	2029	**2300 & 2400s Replacement**	2043											30	30
	2030	**2500s & CNG Replacement**	2044												8
	2032	**2600s Replacement**	2046												
		Year		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		# CNG buses (single decks only)		134	134	134	134	122	122	122	108	66	36	6	6
		# e-buses (single decks only)		16	16	16	16	28	28	28	42	84	114	144	152
		Sum Single Deck buses at this yard		150	150	150	150	150	150	150	150	150	150	150	158
		Sum buses at this yard excluding Operating Spare Ratio (20%)		125	125	125	125	125	125	125	125	125	125	125	132

Legend

CNG Buses

Electric Buses - Single Deck

Electric Buses - Double Deck

Articulated Buses

Retirement Date

Purchased Buses

2.6 Renewable Energy Goals

Foothill Transit’s goal is to power its future electric bus fleet from 100% renewable energy resources. The renewable energy will come from a combination of onsite and offsite sources. Section 12 of this report will discuss options and strategies to achieve this goal.

2.7 Fleet Reliability and Resiliency Goals

In order to maintain fleet reliability and resiliency, Foothill Transit recognizes the need to maintain power reliability at each of its depots under various circumstances. Section 12 of this report discusses the proposed plan to maintain fleet reliability. Additionally, Foothill Transit recognizes the need to operate its electric bus fleet under all operating conditions, such as cold weather and heavy passenger loading. Section 3 and 4 of this report discuss the requirements Foothill Transit must consider to adequately charge and operate an electric bus fleet while considering these operating conditions.

3.0 STUDY ASSUMPTIONS OF TECHNICAL PARAMETERS

In this section all assumptions of the technical parameters used for developing route analysis and charging optimization based on the energy requirements of BEB transit buses is listed and discussed.

3.1 Reference Bus Selection

In order to create a route-based energy analysis and charging profile, several assumptions regarding technical parameters had to be determined. These assumptions and technical parameters include the bus type, battery capacity, passenger number, total weight, and energy consumption of an electric bus. For the analysis two single deck 40’ reference buses, named S1 and S2, and two double deck reference buses, named D3 and D4, were selected based on Foothill Transit’s operational needs and currently available or soon to be available models from North American electric bus manufacturers. Figure 3-1 shows the manufacturer, battery size, and the selection of S1 and S2 from available or soon to be available single deck electric buses. In this figure, the buses with overnight charging concept are marked by ONC, and those with opportunity charging concept by OPC. Figure 3-2 shows the manufacturer, battery size, and selection of D3 and D4 from available or soon to be available, double deck electric buses.

Figure 3-1: 40' Single Deck Bus Availability

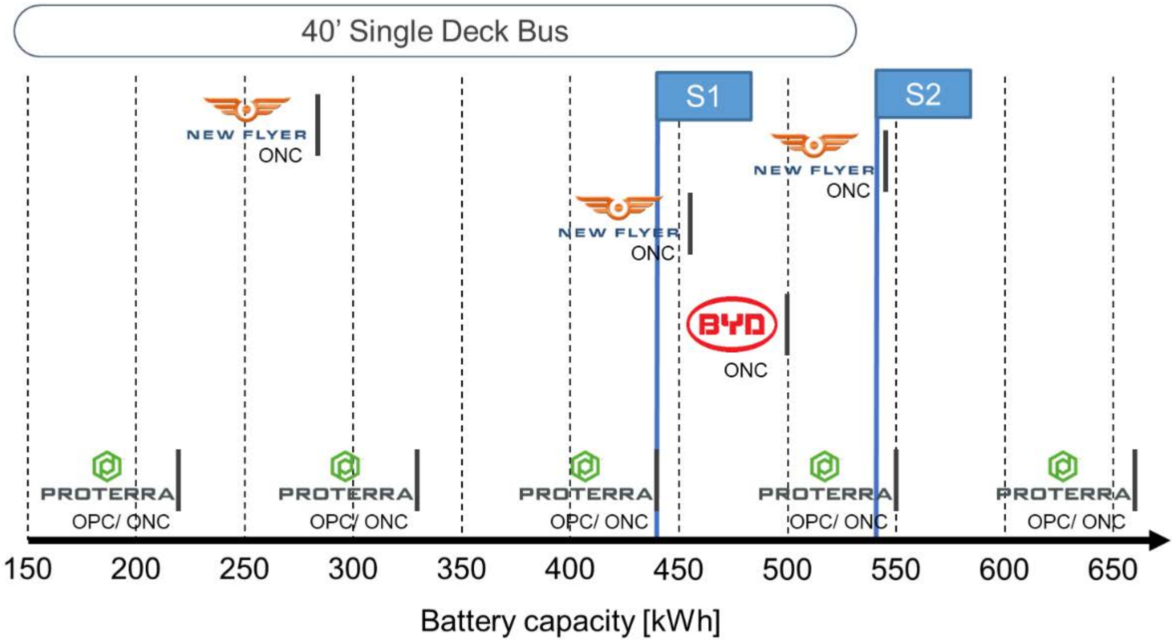


Figure 3-2: Double Deck Bus Availability

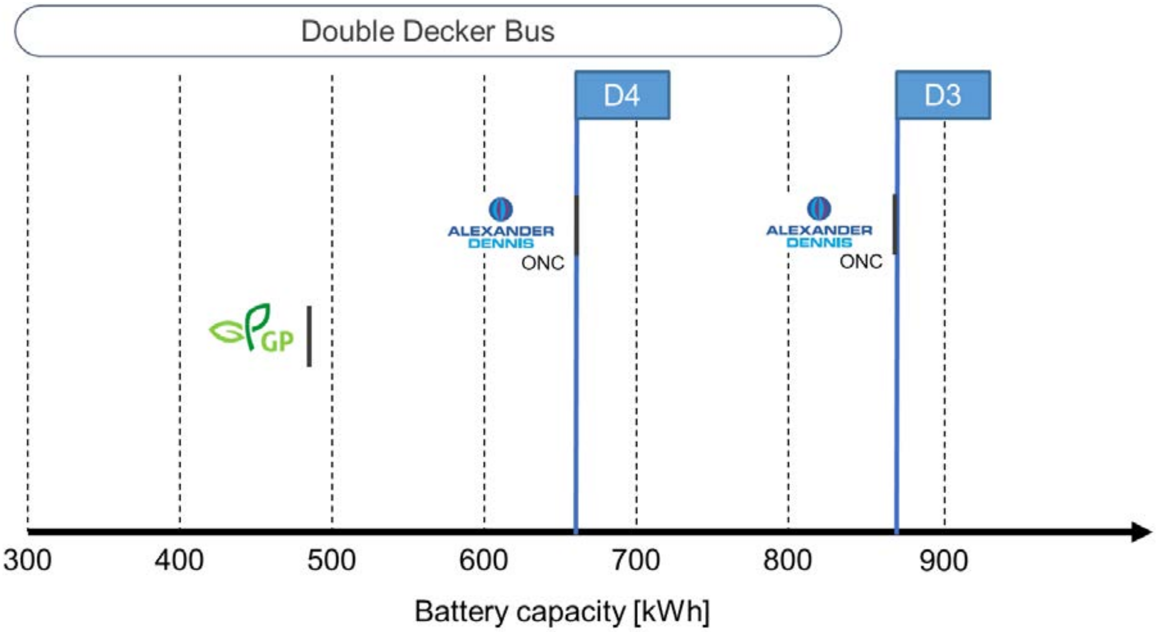


Table 3-1 summarizes the specifications of the reference electric buses that were selected for the analysis.

Table 3-1: Summary of Specifications for Electric Buses S1, S2, D3, and D4

Reference Bus Type	Size	Battery Capacity	Curb Weight	Passengers Number	Total Weight
S1	40‘ Single Deck	440 kWh	30,000 lbs.	40 passengers	37,200 lbs.
S2	40‘ Single Deck	540 kWh	31,500 lbs.	40 passengers	38,700 lbs.
D3	Double Deck	864 kWh	37,000 lbs.[1]	60 passengers	47,800 lbs.
D4	Double Deck	660 kWh	37,000 lbs.	60 passengers	47,800 lbs.

These electric buses were selected as they meet the operational needs specified by Foothill Transit with respect to passenger capacity without limiting Foothill Transit to a specific manufacturer. The passenger numbers represent a robust worst-case scenario and are assumed to be constant for each route service journey. These numbers are also expected to be higher than usual for Foothill Transit's workload requirements. The total weight of the reference bus types is calculated as the curb weight plus the passengers' weight. Passenger weight is assumed to be 180 pounds per passenger. Two different battery

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[1] The curb weight of reference buses D3 and D4 is assumed to be equal for the analysis that was completed for this project.

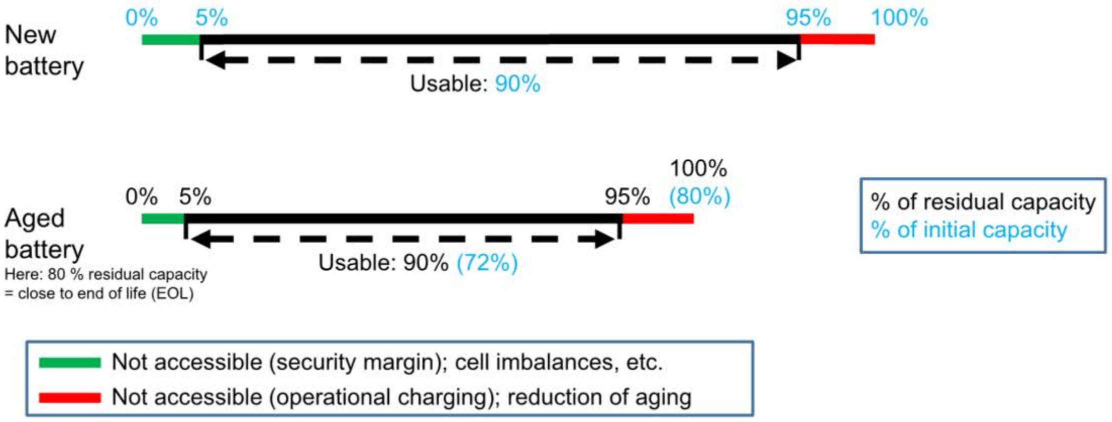
sizes were chosen to evaluate how energy capacity will impact Foothill Transit operations as electric buses are scaled to 100%.

To complete an energy-based route analysis based on Foothill Transits daily operations, energy consumption of the reference buses was estimated. This included an estimation of auxiliary power consumption.

3.2 Usable Battery Capacity

The battery capacities of the reference bus types in Table 3-1 refer to the installed battery capacity. However, the usable battery capacity is different and influenced by many factors. One of the main factors is the battery aging. The end of life (EOL) of a battery is usually specified as a decrease of the original capacity by 20%. The overall electric bus and charging systems need to be implemented and designed in a way that allows the electric bus to perform its required duties prior to the battery reaching its EOL. The boundary state-of-charge (SOC) ranges for the analysis for this project are assumed to be between 0 to 5% and 95 to 100%. Therefore, the usable battery capacity results in 72% of the installed battery capacity. Figure 3-3 represents the usable capacity of batteries for new and aged batteries.

Figure 3-3: Usable vs. Installed Battery Capacity



3.3 Auxiliary Power Consumption

The main auxiliary power consumer in a BEB is the heating, ventilation, and air conditioning (HVAC) system. According to Foothill Transit's requirements, in heating mode the HVAC system needs to be able to maintain an interior temperature of 75 °F when the outside temperature is t 40 °F. In cooling mode, the HVAC system needs to maintain an interior temperature of 62 °F when the outside temperature is 110 °F. These requirements represent worst-case conditions for the HVAC system. The resulting auxiliary energy consumption depends on the type of the HVAC system that is installed on the bus. A conservative approach was taken for the energy based scheduling and a HVAC system consisting of an electric heater and air conditioning unit was assumed. The resulting HVAC consumption is shown in Table 3-2. The heating power requirement will be considered as worst-case for the energy consumption analysis.

Table 3-2: Summary of HVAC Assumptions

	Ambient Temperature (continuous)	Set Temperature Inside Bus	Auxiliary Consumption (continuous) for a 40‘Single Deck Bus	Auxiliary Consumption (continuous) for a Double Deck Bus
Heating	40 °F	75 °F	HVAC: 12 kWh per hour Other: 2 kWh per hour	HVAC: 17 kWh per hour Other: 2 kWh per hour
A/C	110 °F	62 °F	HVAC: 7 kWh per hour Other: 2 kWh per hour	HVAC: 12 kWh per hour Other: 2 kWh per hour

3.4 Operations Planning Parameters

The operations planning parameters assumed for the analysis shown in this report include, the choice of bus routes variants, auxiliary power consumption during dwell times and a detour buffer. The energy consumption simulation for each bus line is discussed in section 4.2.1 and considers the main routes without shortenings. The main route is defined as the most operated route variant for each bus line. During operation, many blocks have dwell time at dedicated layover sites. During dwell time, the HVAC system is assumed to switch off after the first 20 min. Finally, an energy buffer for detours is included in the analysis. This buffer allows the BEBs to maintain a SOC reserve such that the BEBs do not arrive at the depot with a SOC of 0%. The specified detour buffer for each block is 0.5 hours.

4.0 ROUTE ANALYSIS SCHEDULING AND CHARGING OPTIMIZATION

The route analysis was conducted by reviewing Foothill Transit's current operations and assessing the suitability of each individual bus route to be operated with BEB's. An energy scheduling profile was established, using Foothill Transit block data, to determine the energy consumption for each bus route. Using the energy consumption for each route and assumptions on the technical parameters for each reference bus type, charging profiles and schedules were created and optimized to determine how many BEBs would be required to support Foothill Transits operations.

4.1 Current Operations

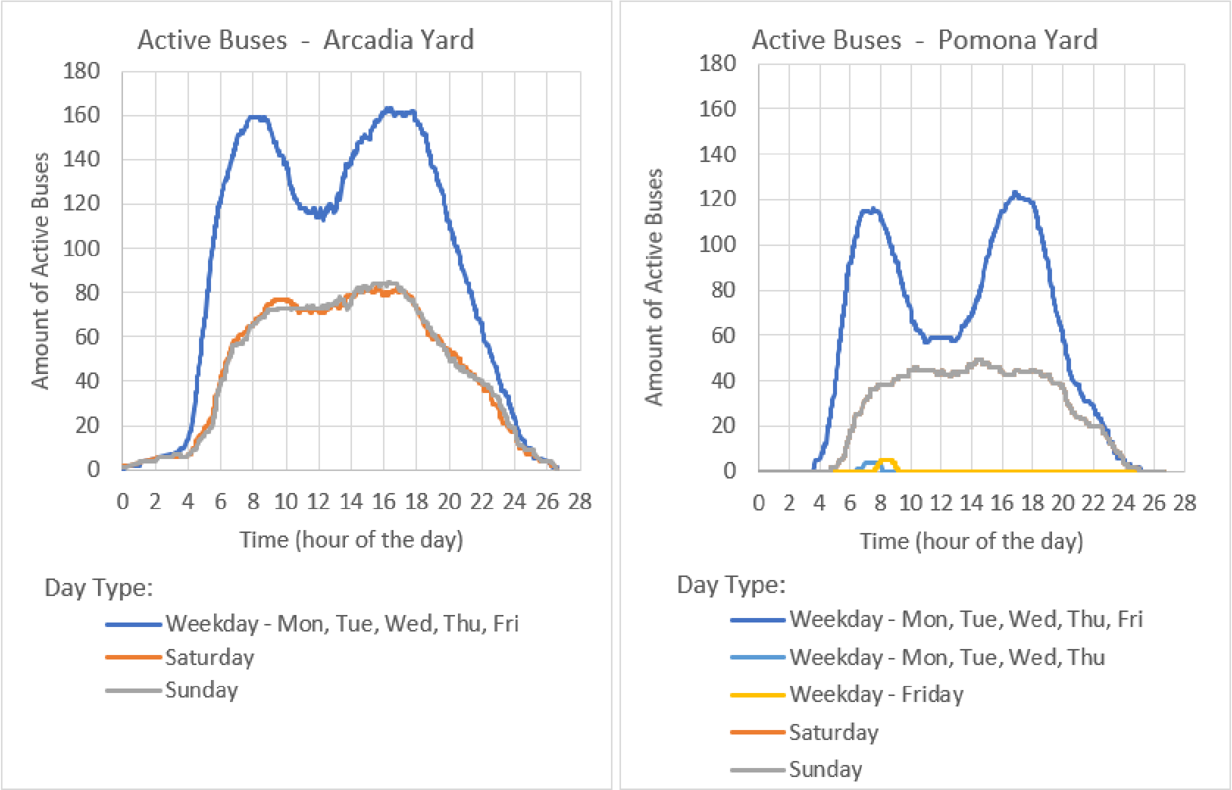
The current operation scheme (June 2018 – January 2019) provided by Foothill Transit contains blocks that consist of schemes such as a depot-out journey, one or more route services, empty journeys, and a depot-in journey. Foothill Transit currently operates CNG buses and BEBs out of both Arcadia Yard and Pomona Yard for different days of the week. From the operation scheme, the number of 'active buses', which are described as buses operating outside the depot, can be calculated for each depot and type of day as shown in Figure 4-1.

For Arcadia Yard, there are three different day types according to the operation scheme. Each curve in Figure 4-1 represents the number of active buses for Weekdays, Saturday, and Sunday. For Monday through Friday, the number of active buses is equal throughout the day because the operation scheme for each weekday day is the same. For Saturday and Sunday, the curves indicate that there are different operation schemes for each day. For Pomona Yard, there are two additional day types resulting from blocks that are operated only on these days. The weekday curve shows a typical shape with two maxima, one in the morning and one in the evening.

The maximum number of active buses operating out of the Arcadia and Pomona Yards are 163 and 123 respectively. The type of day with the most active buses in operation is Friday for both the Arcadia and Pomona Yards. Therefore, Friday is the crucial day for the magnitude of the forecasted load profiles. This day type is further analyzed in this section.

Foothill Transit's bus fleet presently consists of single deck buses that include 40 ft CNG buses, 35 ft BEBs and articulated 60 ft CNG buses for the express route known as the 'Silver Streak'. According to Foothill Transit's plans, the present 40 ft CNG buses and a majority of the 35 ft BEBs will be replaced by 40 ft BEBs in the future. The articulated 60 ft buses will be replaced by battery electric double deck buses according to Foothill Transit's procurement plan.

Figure 4-1: Active Buses by Day and Over Time for Arcadia and Pomona Yard



4.2 Detailed Route Analysis

Foothill Transit's operations planning data was used to complete a detailed route analysis. The dataset was enriched with elevation profiles and allowable speeds for each bus route. The enriched dataset allowed for the operations planning data to be analyzed in detail for the particular bus routes. The data of each bus route and the data blocks which represent them are described in the sections 4.2.1 and 4.2.2.

4.2.1 Bus Lines

Foothill Transit's operations planning data provided contains 37 [illegible] lines that are both city routes and intercity routes. This is reflected by different journey distances and average travel speeds for each bus line. Figure 4-2 represents the journey distances of the bus lines according to the operations planning data. Some bus lines have different route variants and thus different journey distances. This is reflected in Figure 4-2 by the varying curves for the minimum, average, and maximum distance of the routes. The journey distances in Figure 4-2 incorporate only service trips. In general, the journey distances of the intercity lines 493 to 707 are higher than that of the city lines 178 to 492 and 851 to 854.

Figure 4-3 shows the average speed of the Foothill Transit bus lines. It is worth noting that the average speed of the intercity lines is higher than that of the city lines due to the intercity routes having longer freeway sections compared to the city lines which have short or no highway sections.

Figure 4-2: Journey Distance for Foothill Transit Bus Lines

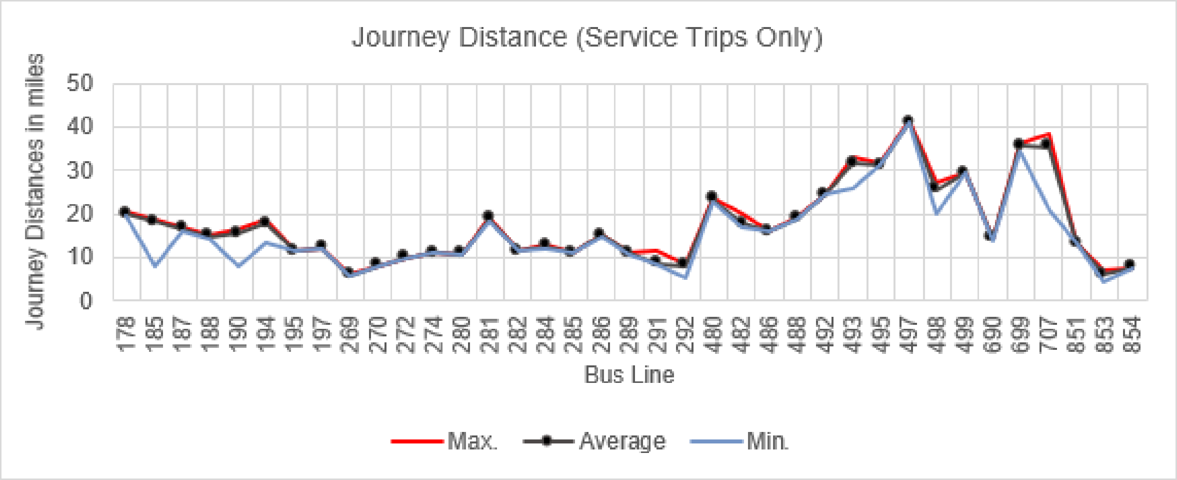
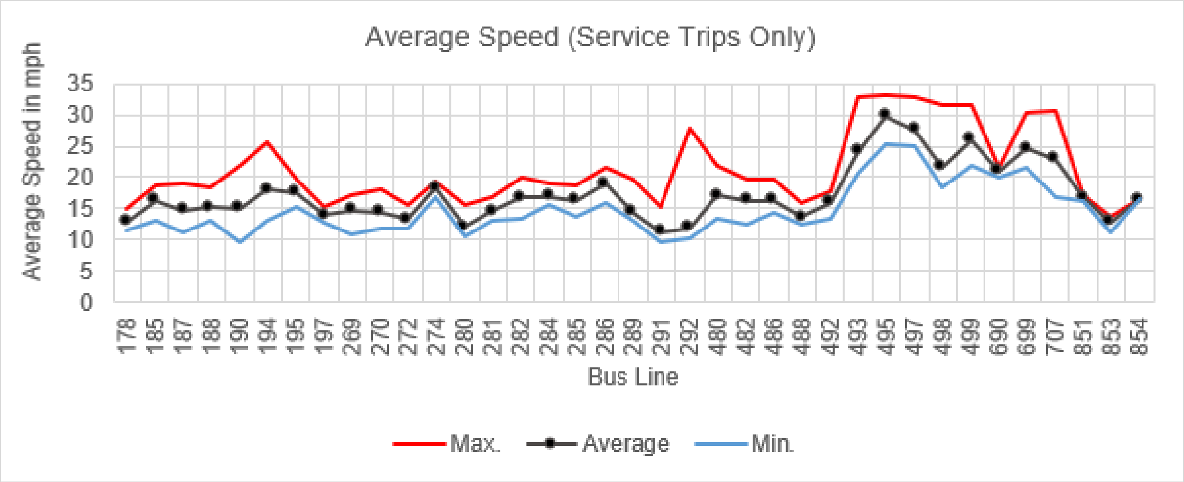


Figure 4-3: Average Speed for Foothill Transit Bus Lines

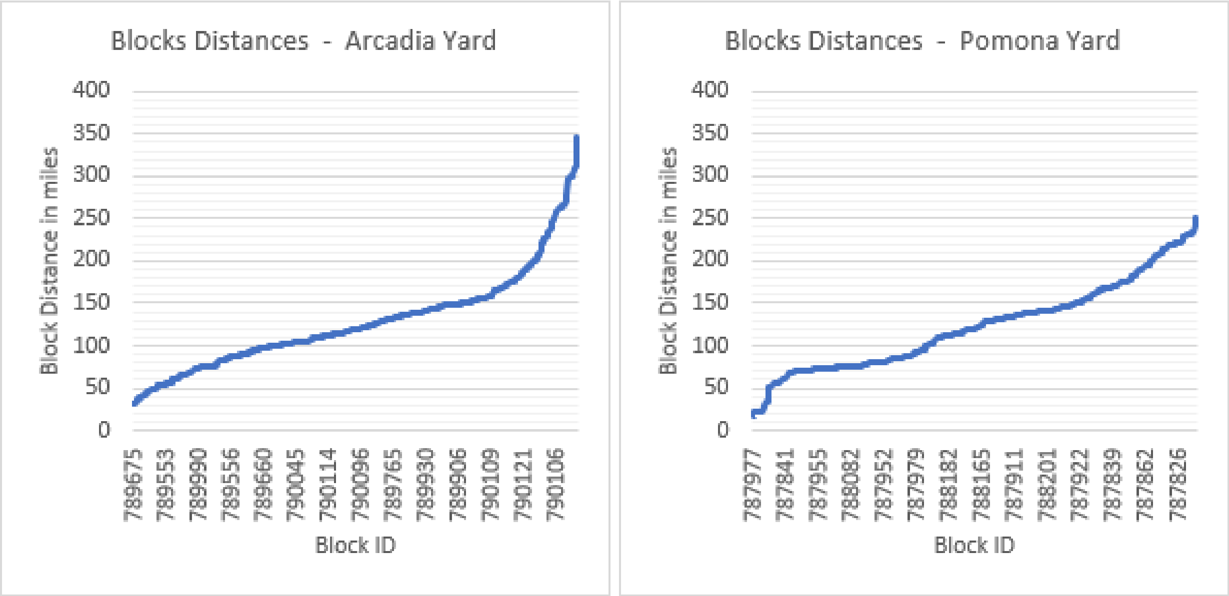


4.2.2 Route Data Blocks

The operations planning data contains 846 blocks. This breaks down to 520 blocks that are operated from Arcadia Yard and 326 blocks that are operated from Pomona Yard. Figure 4-4 shows the distances of the blocks operated from each yard. Note that the x axis does not show each block ID operated from each yard and that the blocks are sorted by ascending distance. The mileage of the blocks varies from 17 to

345 miles including both service and deadhead trips. On average, the share of service mileage versus total mileage equates to about 73% at the Arcadia Yard and roughly 70% at the Pomona Yard.

Figure 4-4: Block Distances for Arcadia and Pomona Yard



Another aspect of Foothill Transit's operation planning data is that several blocks contain multiple lines in a single block. These are known as "interlining" blocks. Buses that are used for "interlining" services change line numbers during operation of these blocks. On average, there are two different bus lines per a single block. However, this can vary from one to 6 bus lines per a single block.

4.3 Energy Consumption Analysis

The energy consumption of the reference bus type listed in Table 3-1 was determined based on the route data described in Section 4.2 and on the assumed technical parameters detailed in Section 3.0 for worst case conditions. Many of the assumed parameters such as HVAC energy consumption and passenger numbers correspond to the worst-case conditions that are required for the technical feasibility assessment of the current operating blocks.

The energy consumption was evaluated for every single block of the current operation scheme. Complete blocks were analyzed including both service trips and deadhead trips from and to the depots. The aggregated results depicted by the reference bus type are shown in Figure 4-5 and Figure 4-6.

Figure 4-5: Estimated Energy Consumption for Reference Bus S1 and S2

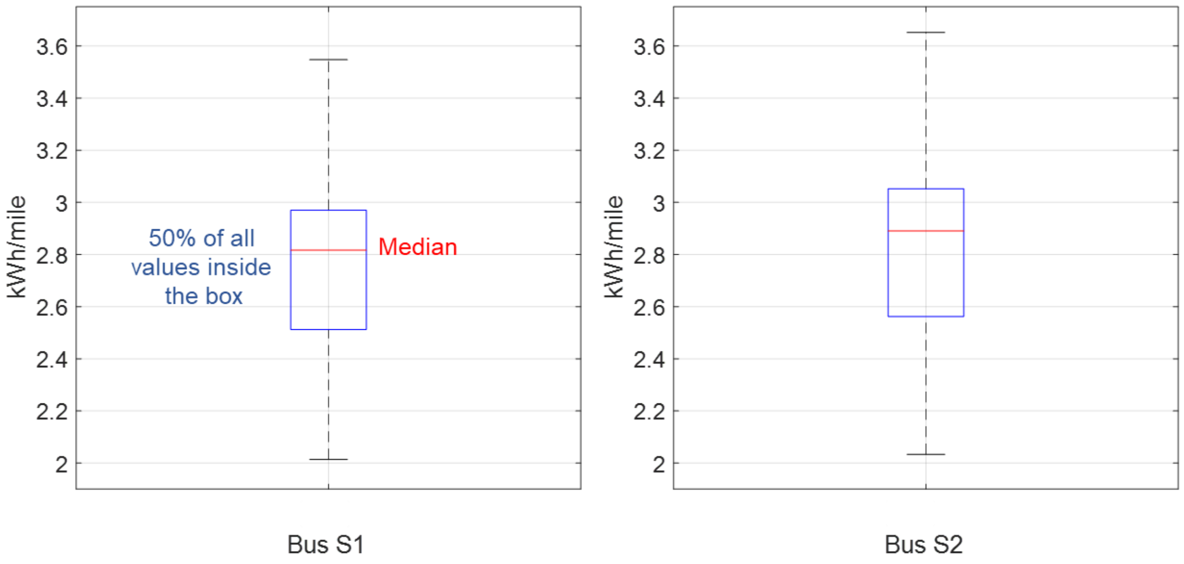
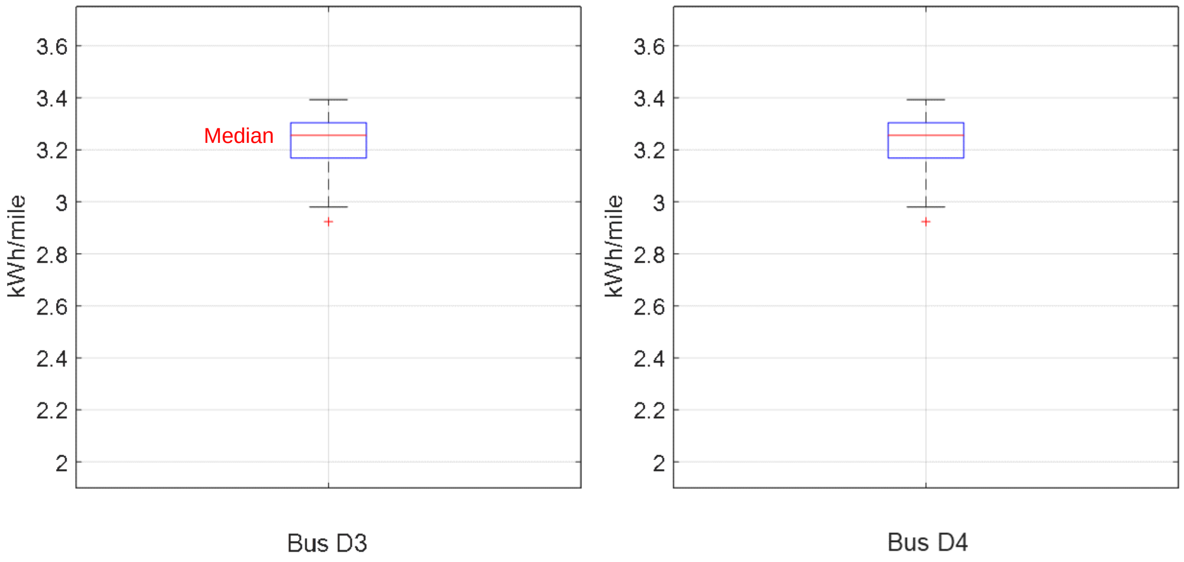


Figure 4-6: Estimated Energy Consumption for Reference Bus D3 and D43



The energy consumption of the single deck reference buses S1 and S2 varies significantly due to varying bus route characteristics such as urban and highway routes and height profiles of each bus. The lower margin of energy consumption is approximately 2 kWh/mile while the upper margin is around 3.6 kWh/mile. The median energy consumption for bus S1 is at about 2.8 kWh/mile and for bus S2 it is about 2.9 kWh/mile. Due to the larger energy capacity and heavier weight of bus S2, the energy consumption of bus S2 is higher than that of the bus S1.

The energy consumption of the double deck reference buses D3 and D4 varies less than the single deck buses because double deck buses mainly operate on the Silver Streak line which mostly consists of highway driving. The lower margin of efficiency is approximately 3 kWh/mile while the upper margin is 3.4 kWh/mile. The median energy consumption for both buses D3 and D4 is at about 3.3 kWh/mile. Assuming the same weight for buses D3 and D4, as shown in Table 3-1, leads to the energy consumption of these buses being the same. However, the battery capacities of D3 and D4 are different resulting in different route block feasibility.

4.4 Technical Feasibility of Current Operating Blocks

The technical feasibility of current operating blocks was analyzed by evaluating the energy consumption for each bus type and operating block. A block is considered feasible if the battery capacity of the particular reference bus type is sufficient to operate a block. The usable battery capacity incorporates battery aging and a 0.5 hours detour buffer as discussed in section 3.0.

Figure 4-7 demonstrates the number of feasible blocks at Arcadia Yard for single deck buses and double deck buses. For single deck buses, over 60% of the blocks are feasible for bus S1 and S2 between Monday and Friday. Operating blocks with buses S1and S2 is more challenging on Saturday and Sunday. Less than half of the blocks on these day types are feasible.

For the double deck buses, 50% of blocks are feasible for bus D3 and 40% of the blocks are feasible for bus D4 between Monday and Friday. The number of feasible blocks is reduced on Saturday and Sunday. The limited number of feasible blocks with double deck buses is attributed to the long blocks on the Silver Streak line.

Figure 4-7: Feasible Blocks at Arcadia Yard

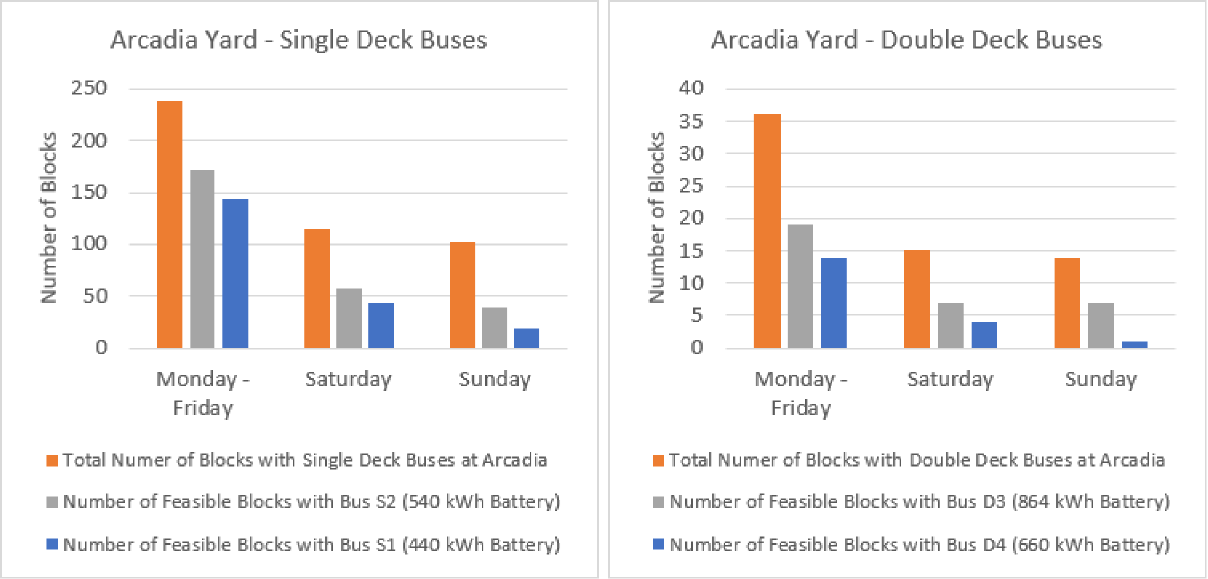
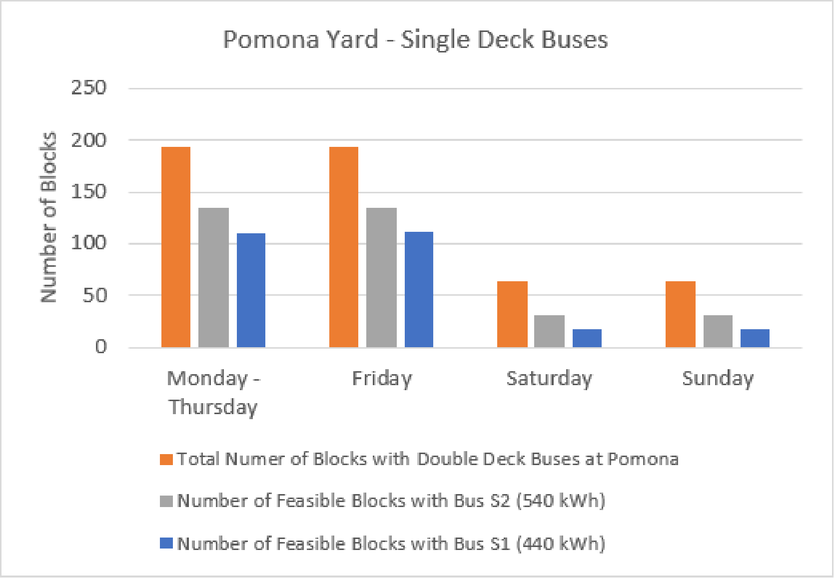


Figure 4-8 demonstrates the number of feasible blocks at Pomona Yard for single deck buses. The results are similar to Arcadia Yard. About 55% of the current blocks are feasible with the bus S1 and about 70% are feasible with the bus S2 from Monday to Friday. Less than half of the current blocks are feasible with buses S1 and S2 on Saturday and Sunday.

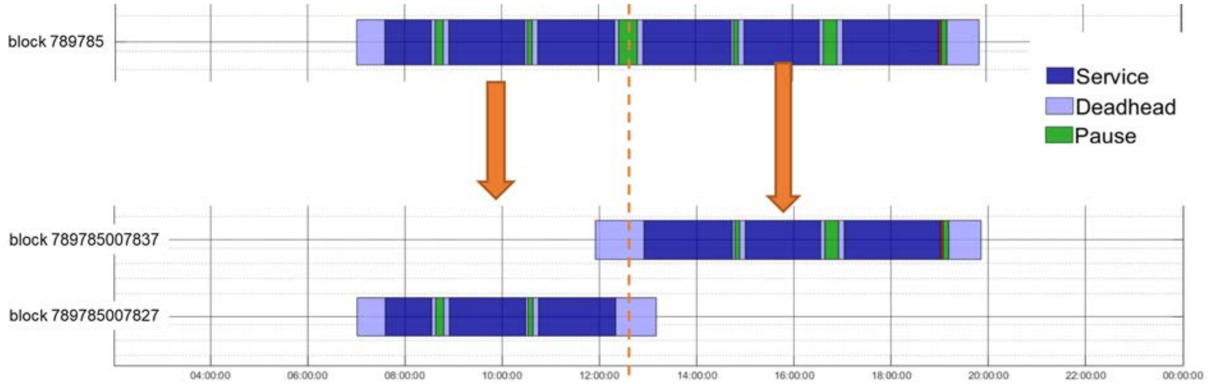
Figure 4-8: Feasible Blocks at Pomona Yard



4.5 Adjusting Non-Feasible Blocks

The feasible blocks from the current operation scheme can be operated by the considered reference bus types. The non-feasible blocks have to be adjusted in order to enable a BEB to operate the block. The approach for adjusting the non-feasible blocks is to split these blocks according to energy constraint while maintaining the general block structure. An example of splitting the blocks for the Silver Streak line is shown in Figure 4-9. The long non-feasible block with ID 789785 is split into two separate shorter blocks that are feasible for a reference bus type.

Figure 4-9: Splitting Non-Feasible Blocks into Two Feasible Blocks



This approach adjusts the current operation scheme to allow a BEB to operate the blocks while maintaining the general structure of the current blocks. BEBs need to recharge the energy that is consumed after operating the blocks at the depot. During charging, the bus is unavailable for route service. This means that another bus must provide or continue the service. Therefore, charging time is unproductive time that impacts the efficiency of operations, the PVR for BEBs, and the number of chargers that are needed to support the BEBs. It is assumed that the BEBs will start recharging immediately after returning to the depot and that the battery is recharged to the maximum usable SOC. The charging time is included in the analysis in order to determine the peak vehicle requirement and the required number of chargers. The charging time depends on the energy consumed by the BEB and the power output of the installed depot chargers.

Based on the current technical and commercial limitations for plug-in charging standards, both 150kW and 325 kW depot chargers were considered. These higher charging powers were considered due to the need to quickly recharge the buses during the middle of the day and high energy use requirements. The 150-kW charger level was considered because it represents the current technical limit for cable and plug solutions that can be plugged in manually. The 325-kW charger level was also considered because it is technically feasible through utilization of the SAE J3105 overhead charging standard and it can be provided by more than one supplier as outline in Section 7.0 of this report. These charging powers are examined in the subsequent analysis in section 4.6 and discussed in Section 6.0 and 7.0 of this report. The results in terms of PVR and charging quantities from both feasible blocks and adjusting non-feasible blocks are shown in the following subsections in 4.6 for different charging strategies.

4.6 Charging Scheme Optimization

This section discusses the process to optimize the charging behaviors of BEBs operating on Foothill Transit routes based on the feasible and adjusted non-feasible blocks. The charging behaviors were assessed with no smart charging and from this baseline, the charging was optimized with smart charging to demonstrate the difference in infrastructure requirements by utilizing smart charging schemes.

4.6.1 Non Optimized Charging

It is possible for BEBs to run on an adjusted operation scheme that includes splitting non feasible blocks to create feasible blocks. Due to splitting blocks and accounting for required recharge time of the reference bus types, the number of active buses during the daytime will change. Therefore, the peak vehicle requirement (PVR) may be higher when compared to the original operation scheme that is shown in Figure 4-1. The number of active buses during the daytime, PVR, and the required number of chargers are examined for the adjusted operation scheme.

Figure 4-10 shows the number of active buses when running on the adjusted operation scheme on Fridays from Arcadia Yard. Friday was selected since it has the most operating blocks. Active buses are considered to be either driving or charging. Figure 4-10 assumes that reference bus S2 will be used with charging supported by 150kW or 325kW charging infrastructure.

There is a noticeable offset between the ‘driving’ curve and the ‘charging’ curve because the buses charge after returning to the depot. The ‘driving’ and ‘charging’ curves represent the sum of the required buses for each hour of the day. The maximum value of this curve provides the PVR for each yard.

From Arcadia Yard, more than 200 S2 electric buses must be deployed to operate all feasible blocks when using 150 kW chargers. When using 325 kW chargers, the PVR of S2 electric buses reduces to 160 due to shorter charging durations. This PVR reduction of 40 buses represents a savings to Foothill Transit of nearly $36 million.

The number of chargers that is required can be determined from the maximum number shown on the ‘charging’ curve. Around 75 chargers are needed if 150kW chargers are used and around 40 chargers are needed when using 325kW chargers. It is critical to use chargers with higher power outputs to reduce the charging time. Foothill Transit will require less BEB to support its operations if charging durations are reduced by using higher output chargers. The increased unit cost of the 325 kW chargers when compared to the 150 kW chargers is offset by the significant reduction in the total quantity of chargers and supporting electrical and structural infrastructure.

Figure 4-10: Number of Active S2 Buses from Arcadia Yard

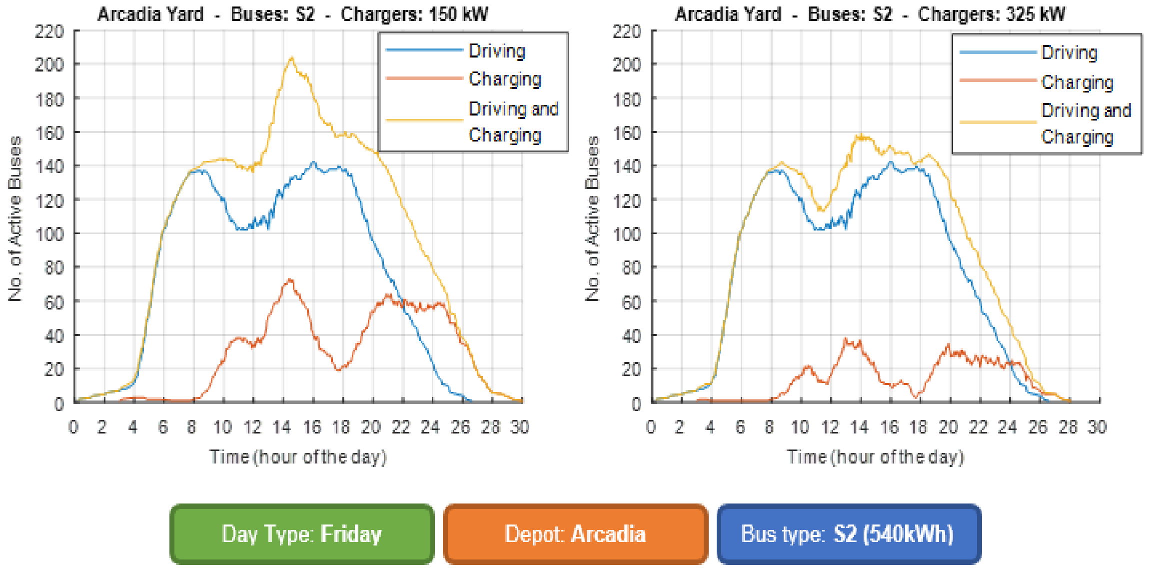


Figure 4-11 shows the number of active buses during different times of the day when using the adjusted operation scheme with double deck reference bus D3. When using 150 kW chargers, 38 D3 buses and 25 chargers are required to enable operation. When using 325 kW chargers the number of required D3 buses reduces to 30 and the number of chargers reduces to 15. As with the single deck buses, the reduction of 8 double decker buses provides roughly $10 million in bus procurement savings and reduced charging infrastructure costs.

Figure 4-11: Number of Active D3 Buses from Arcadia Yard

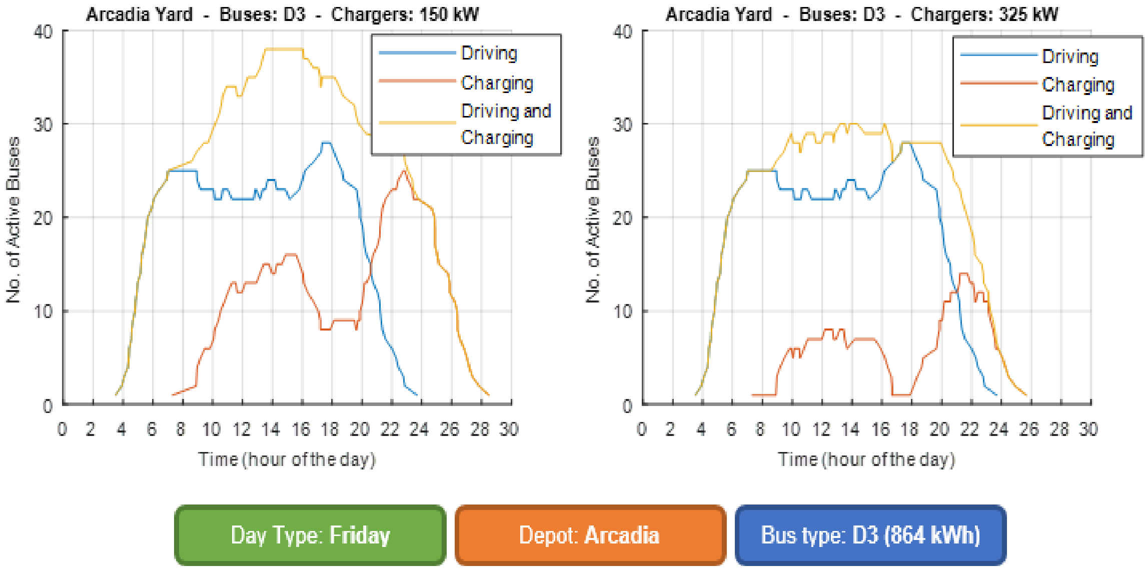
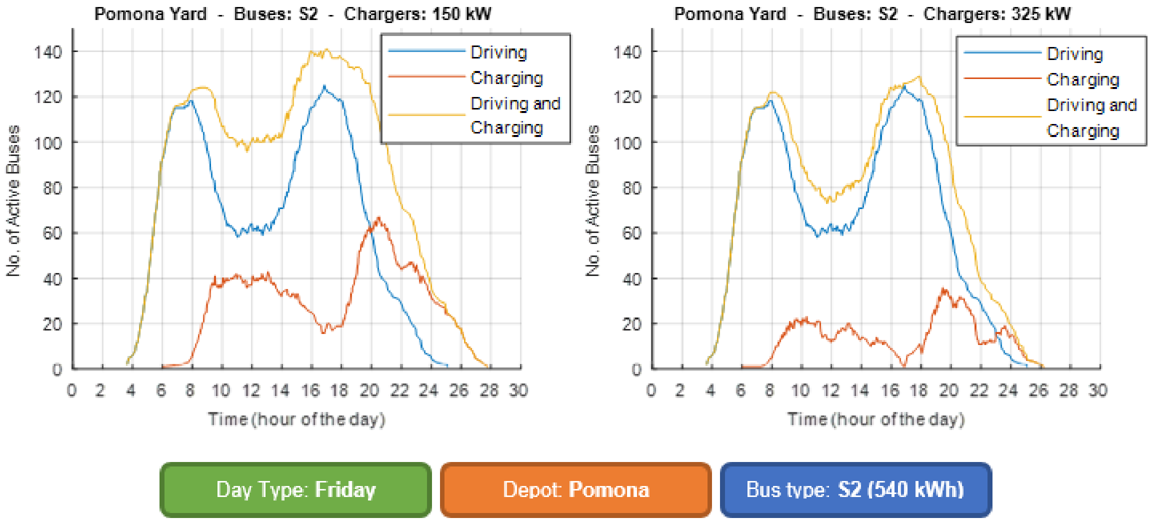


Figure 4-12 shows the number of active buses deployed on the adjusted operation scheme for Pomona Yard. Using 150 kW chargers requires about 140 S2 buses and 70 chargers. Using 325 kW chargers requires about 130 S2 buses and 40 chargers. Similar to Arcadia Yard, this 10-bus reduction provides roughly $9 million in bus procurement savings and reduced charging infrastructure costs

Figure 4-12: Number of Active S2 Buses from Pomona Yard



It is worth noting that reference buses S2 and D3 utilizing 325 kW chargers were chosen to determine the PVR that will be required to meet Foothill Transit operational needs. If buses with a smaller batter capacity are used, such as reference bus S1 and D4, or 150kW chargers are used, over 200 buses and an increased number of chargers will be required.

Table 4-1 summarizes the BEB requirements based on adjusted bus schedules using non-optimized charging. The preferred options for transitioning from CNG to BEB are highlighted in green.

Table 4-1: Summary of BEB Requirements for Conversion with Non-Optimized Charging

Yard	Bus Size	Electric Bus Type and Charging Power		PVR Original Schedules		PVR Adjusted Schedules	No. of Chargers
Arcadia	40‘ single deck	S1 (440 kWh)	150 kW	139	→	>200	~80
Arcadia	40‘ single deck	S1 (440 kWh)	325 kW	139	→	~160	~40
Arcadia	40‘ single deck	S2 (540 kWh)	150 kW	139	→	>200	~80
Arcadia	40‘ single deck	S2 (540 kWh)	325 kW	139	→	~160	~40
Arcadia	Double deck	D3 (864 kWh)	150 kW	26	→	~38	~25
Arcadia	Double deck	D3 (864 kWh)	325 kW	26	→	~30	~15
Pomona	40‘ single deck	S1 (440 kWh)	150 kW	123	→	~160	~70
Pomona	40‘ single deck	S1 (440 kWh)	325 kW	123	→	~143	~40
Pomona	40‘ single deck	S2 (540 kWh)	150 kW	123	→	~140	~70
Pomona	40‘ single deck	S2 (540 kWh)	325 kW	123	→	~130	~40

The analysis completed in this section of the report demonstrates that using 325 kW chargers instead of 150 kW chargers allows Foothill Transit to purchase 50 fewer S2 buses at Arcadia and Pomona Yards. This equates to a cost savings of approximately $45 million at current net bus pricing. Similarly, using 325 kW chargers reduces the number of D3 buses by 8 for a cost savings of approximately $11 million for a total savings to Foothill Transit of $56 million. Additionally, the depots cannot physically accommodate an additional 58 buses which further necessitates the need to use higher powered charging equipment. The next section will discuss how the PVR quantities can be reduced by using optimized charging scenarios.

4.6.2 Optimized Charging

In section 4.6.1 the required number of chargers was determined for non-optimized charging. Non-optimized charging for this report is defined as charging buses immediately after returning to the depot. The number of simultaneous charging sessions determines the number of required chargers. The goal of the optimizing process is to move the charging phases, the time when a bus recharges, in order to minimize the required number of chargers.

Figure 4-13 shows the number of chargers required for bus S2 to operate from Arcadia Yard. Non-optimized charging is shown on the left and optimized charging is shown on the right. Non-optimized charging results in about 40 chargers due to the midday peak between 12 p.m. and 2 p.m. when many buses are returning into the depot. The charging phases during this midday peak cannot be moved due to limited standstill times. This restricts the reduction of chargers to 33 units.

Figure 4-13: Non Optimized Charging Vs Optimized Charging for Bus S2 at Arcadia Yard

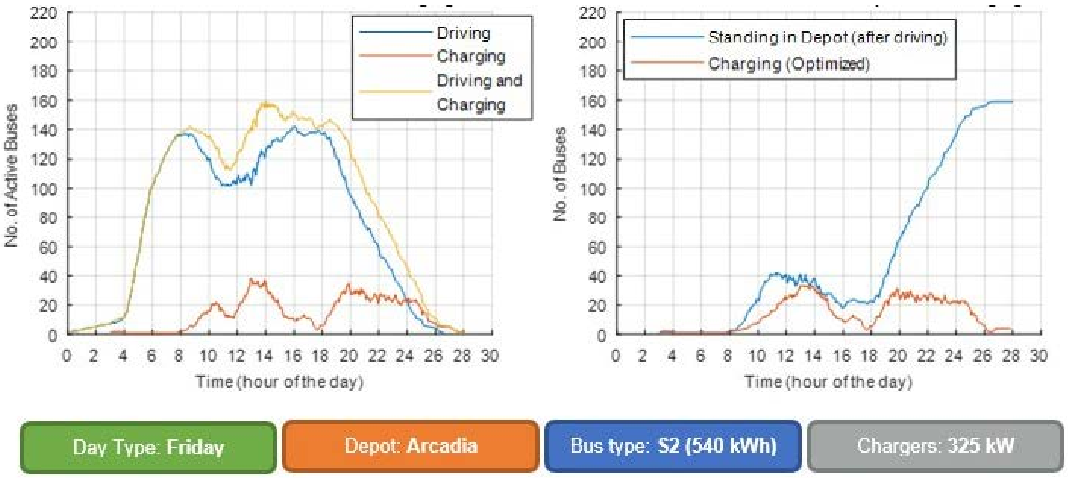


Figure 4-14 shows the number of chargers that are required for bus D3 to operate from Arcadia Yard when using non-optimized charging on the left and optimized charging on the right. Through optimization, the evening peak of the charging curve is flattened. By optimizing the charging, 7 chargers are sufficient instead of 15 chargers that would be required when using non-optimized charging.

Figure 4-14: Non Optimized Charging Vs Optimized Charging at for Bus D3 Arcadia Yard

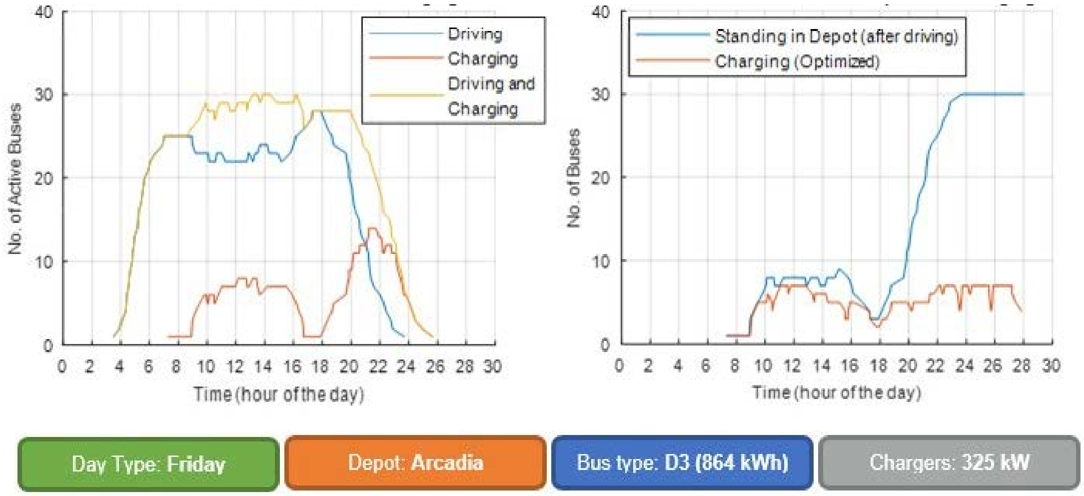


Figure 4-15 provides the required number of chargers required for bus S2 from Pomona Yard when using non-optimized charging on the left and optimized charging on the right. Around 40 chargers are needed when using non-optimized charging due to the evening peak when many buses return to the depot. Through optimization of the charging scheme, the required number of chargers can be reduced to around 20 units. This is achieved by flattening the evening peak charging curve by adjusting the charging phases to latter hours in the day.

Figure 4-15: Non Optimized Charging Vs Optimized Charging for Bus S2 at Pomona Yard

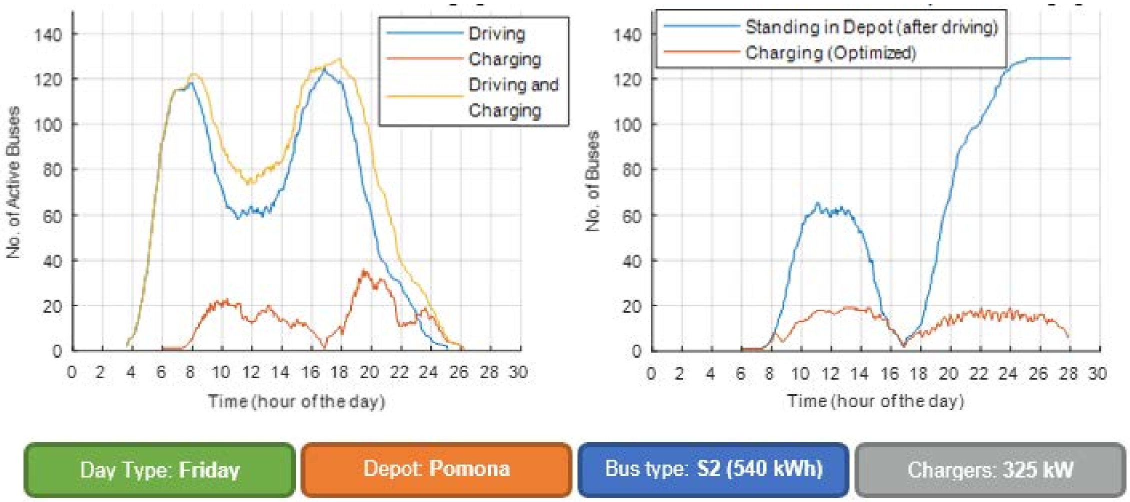


Table 4-2 summarizes the results of the charging scheme optimization without consideration for bus logistical movement in the depot or avoidance of charging during expensive on-peak periods.

Table 4-2: Summary of BEB with Optimized Charging

Yard	Bus Size	Electric Bus Type and Charging Power		PVR Modified Schedules	No. of Chargers (Non-optmized Charging)		No. of Chargers (Optimized Charging)
Arcadia	40‘ single deck	S1 (440 kWh)	325 kW	~160	~40	→	32
Arcadia	40‘ single deck	S2 (540 kWh)	325 kW	~160	~40	→	33
Arcadia	Double deck	D3 (864 kWh)	325 kW	~30	~15	→	7
Pomona	40‘ single deck	S1 (440 kWh)	325 kW	~143	~40	→	17
Pomona	40‘ single deck	S2 (540 kWh)	325 kW	~130	~40	→	19

4.6.3 Optimized Charging with an On-Peak Time Window

In this optimization case, the methodology presented in subsection 4.6.2 was adjusted by adding the constraint of an on-peak electric rate time window between 4 p.m. and 9 p.m. The charging phases were shifted from this time window to the evening hours after 9 p.m. or to the midday hours before 4 p.m. By applying the on-peak time window, the charging phases can be shifted to hours when the price of electricity is lower. Based on the current SCE electric vehicle (EV) time-of-use (TOU) rates, on-peak (4-9pm) energy rates are 4 times higher than off-peak rates in the summer and 2 times higher in the non-summer months. Shifting charging behaviors reduces Foothill Transit’s annual electricity costs at full fleet electrification by nearly $2.5 million per year or approximately $62 million over 25 years without accounting for inflation.

Figure 4-16 shows the number of S2 buses charging at Arcadia Yard when applying optimized charging (on the left) and optimized charging with on-peak window between 4 p.m. and 9 p.m. (on the right). During this time window, few charging phases occur that cannot be shifted to later or earlier hours. Although the on-peak window is applied, the required number of chargers remains at 33.

Figure 4-16: Optimized Charging with On-Peak Window for Bus S2 at Arcadia Yard

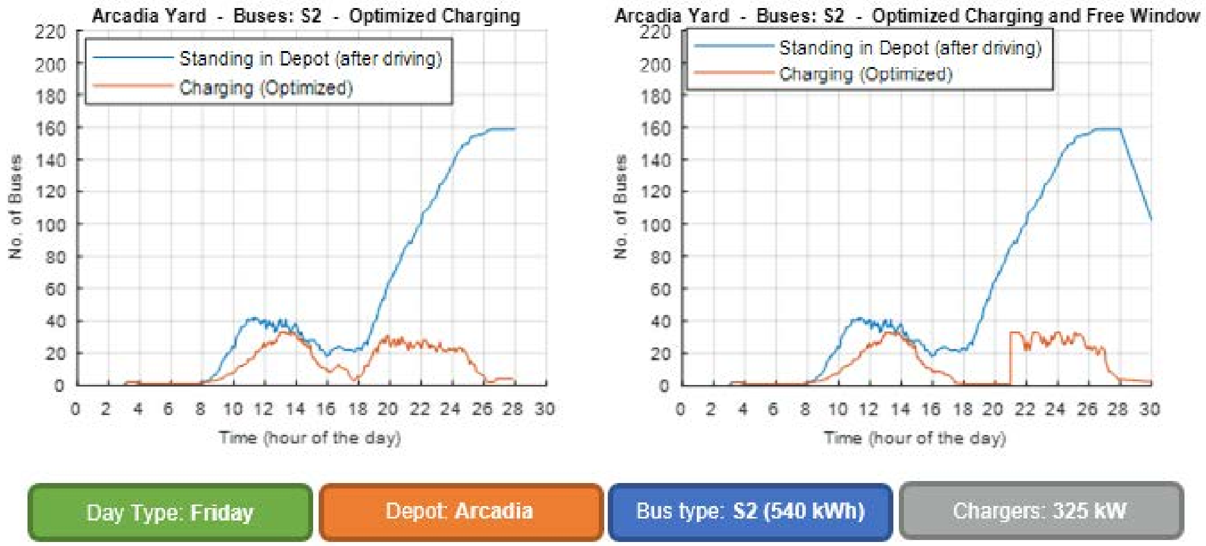
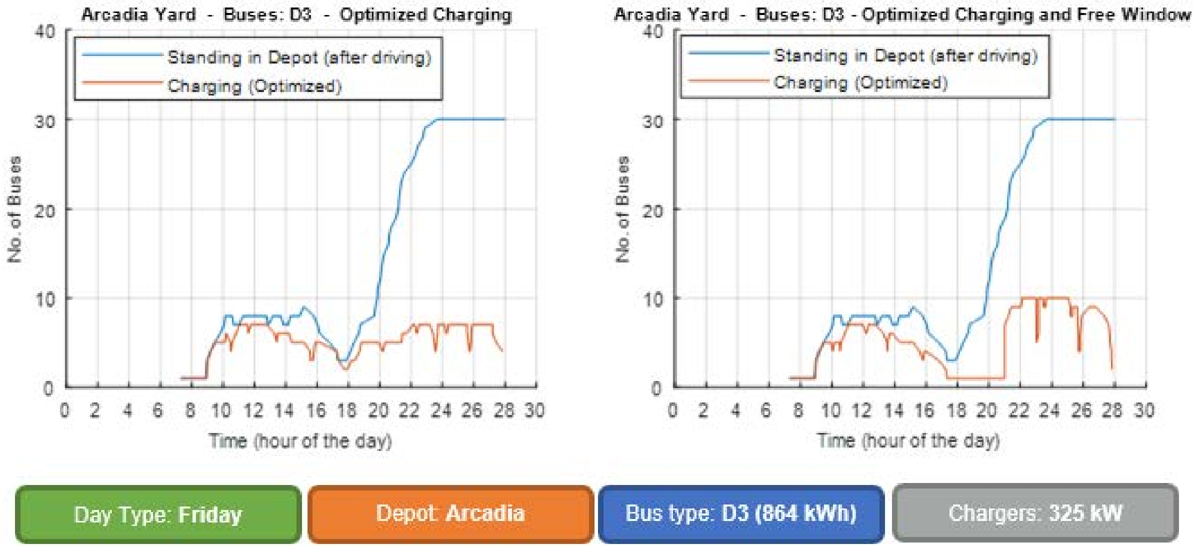


Figure 4-17 shows the number of D3 buses charging at Arcadia Yard applying optimized charging (on the left) and optimized charging with on-peak window between 4 p.m. and 9 p.m. (on the right). Shifting charging phases from the on-peak window requires a greater number of chargers in the evening hours. The required number of chargers increases from 7 to 10 chargers.

Figure 4-17: Optimized Charging with On-Peak Window for Bus D3 at Arcadia Yard



Applying the on-peak window at Pomona Yard causes a similar effect of increasing the number of required chargers. Figure 4-18 shows that 24 chargers are required when using an enforced on-peak window compared to 19 chargers without applying the on-peak time window.

Figure 4-18: Optimized Charging with Enforced On-Peak Window for Bus D3 at Pomona Yard

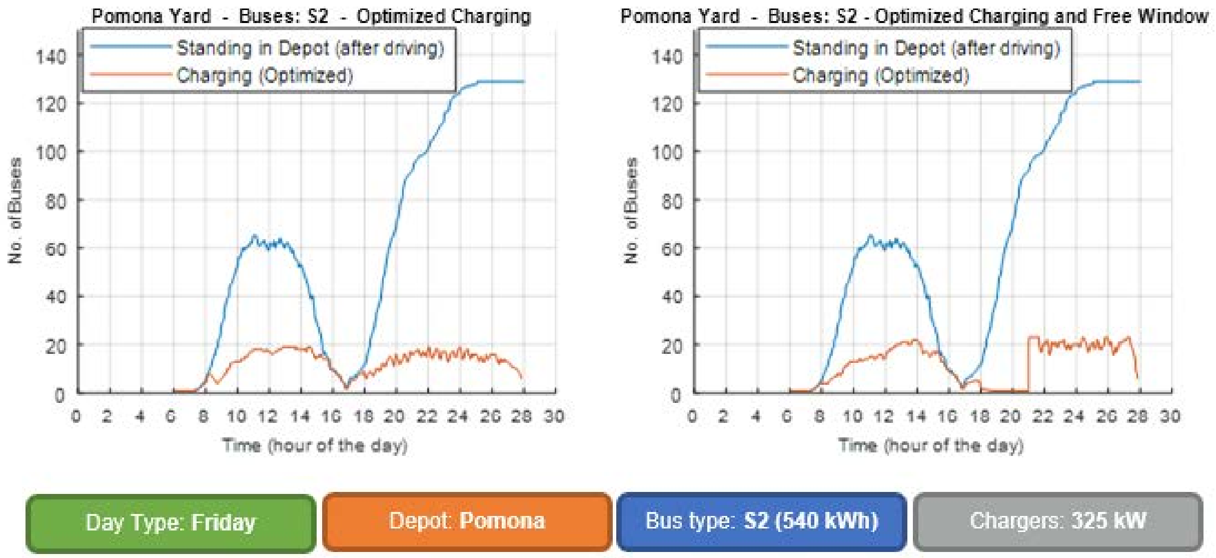


Table 4-3 provides an overview of the number of chargers required when applying the free time window between 4 p.m. and 9 p.m. when deploying different bus types at Arcadia Yard and Pomona Yard. In general, no charging between 4 p.m. and 9 p.m. requires a higher number of chargers compared to the optimized number of chargers without applying this time window. However, optimized numbers of chargers of both cases are still lower compared to the number of chargers using non-optimized charging.

Table 4-3: Overview of Optimized Chargers with an Enforced On-Peak Time Window

Yard	Bus Size	Electric Bus Type and Charging Power		No. of Chargers (Non Optimized)		No. of Chargers (Optimized Charging)	No. of Chargers (Optimized Charging incl. Free Time Window)
Arcadia	40‘ single deck	S1 (440 kWh)	325 kW	~40	→	32	36
Arcadia	40‘ single deck	S2 (540 kWh)	325 kW	~40	→	33	33
Arcadia	Double deck	D3 (864 kWh)	325 kW	~15	→	7	10
Pomona	40‘ single deck	S1 (440 kWh)	325 kW	~40	→	17	23
Pomona	40‘ single deck	S2 (540 kWh)	325 kW	~40	→	19	24

4.7 Summary of Charging Scheme Optimization

The results of the charging optimization scenarios can be used as a benchmark for the minimum number of chargers that Foothill Transit will need to support a fully electrified bus fleet. Installing the optimized number of chargers can only occur if a significant effort is made to move vehicles from charging to parking spots or by connecting multiple pantographs to a single charging unit. Furthermore, vehicle scheduling must ensure every bus is connected to a charger for sufficient time to allow a complete charge. In some charging scenarios, buses may require extra time to complete a cell balancing cycle.

The recommended scenario to use is the enforced on-peak window charging as this scenario shifts charging to times when there is less demand on the electrical grid and lower electricity costs. In this scenario, 43 chargers would need to be installed at Arcadia Yard and 24 chargers at Pomona Yard. However, due to space constraints for moving buses from parking to charging spaces and to account for operation constraints when scheduling bus charging, it is recommended that 55 325 kW chargers be installed at Arcadia Yard and 40 325 kW chargers at Pomona Yard. The charger selection and quantities are discussed further in sections 7, 8, and 9 of this report.

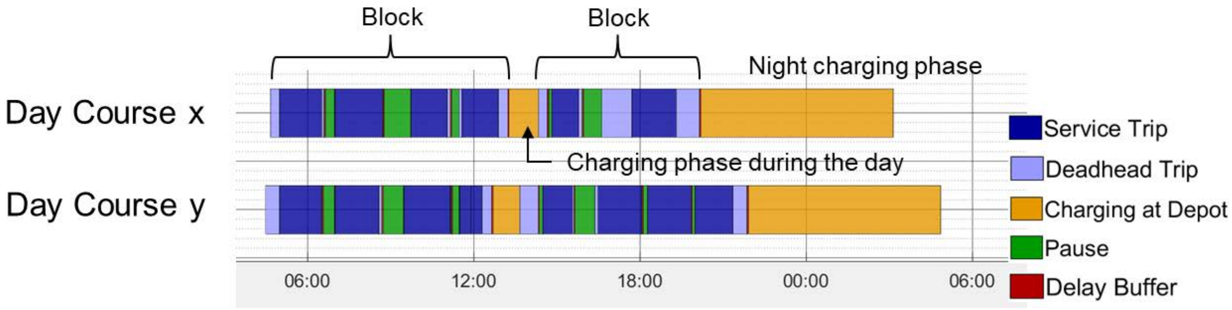
5.0 FLEET ELECTRIFICATION PLANNING

According to the Foothill Transit BEB procurement plan, electric buses will be added to the Foothill Transit fleet as CNG buses retire. A majority of the CNG buses will be replaced by BEBs by the year 2030 and the Foothill Transit operation will be close to 100% electrification by this year. The goal of this section is to describe electrification concepts that can assist with the transition from CNG buses to BEBs until the year 2030.

5.1 Electrification Phasing Method

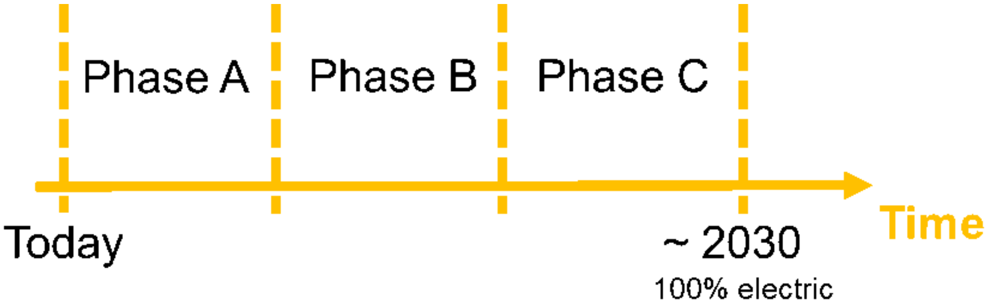
A bus can operate on several blocks in one day. For example, one block could be operated in the morning and a different block may be operated in the afternoon. Figure 5-1 shows an example of a block that contains service trips, deadhead trips, and pauses. This particular combination of blocks is referred to as a day course. A day course can consist of one or several blocks. A single bus can only operate one day course per day. In this example, the bus operating day course X is operating the first block in the morning and returning to the depot for a charging session. Once charging is completed, the bus operates the second block and returns to the depot for a night charging session. The total number of day courses is equal to the peak vehicle requirement (PVR) since one bus can only operate one day course.

Figure 5-1: Example Day Course



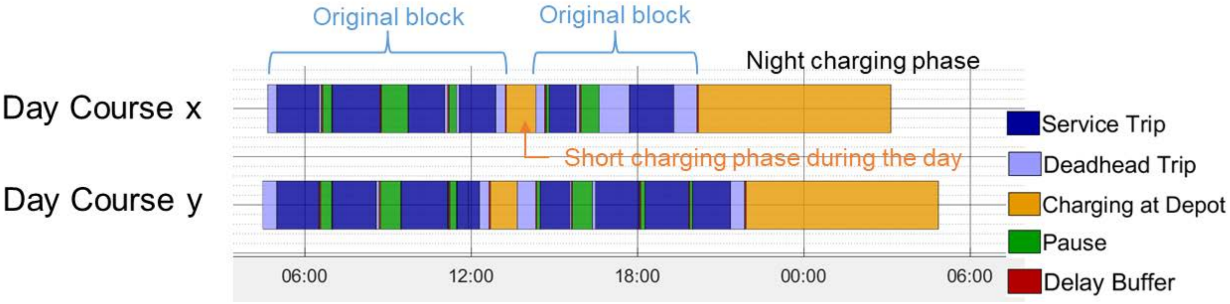
In the original (current) operation scheme by Foothill Transit, the day courses consisting of original blocks are mostly operated by CNG buses. As BEBs gradually replace CNG buses, the conversion is completed by aiming to keep the original day courses and PVR as long as possible. This can be achieved by utilizing BEBs on the original day courses that are feasible without adjustments and to continue to use CNG buses to operate day courses that require adjustments to work with BEB's. Following this approach allows Foothill Transit to delay adjusting the operation scheme, leading to a postponement of a higher PVR. Following this approach results in three electrification phases which will be named A, B and C as shown in Figure 5-2.

Figure 5-2: Electrification Phases



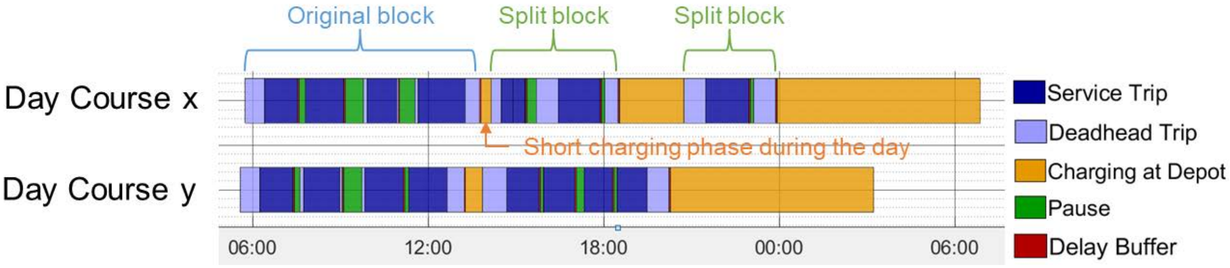
During Phase A, the original day courses from Foothill Transit's current operation scheme are left intact since they can be operated by CNG buses. The PVR also remains the same and no additional vehicles are required. During the day, there is no dedicated charging phase between blocks of a day course. BEBs are only deployed on feasible day courses and the CNG buses service the remaining day courses. An example day course for Phase A is represented in Figure 5-3.

Figure 5-3: Example Day Course in Phase A



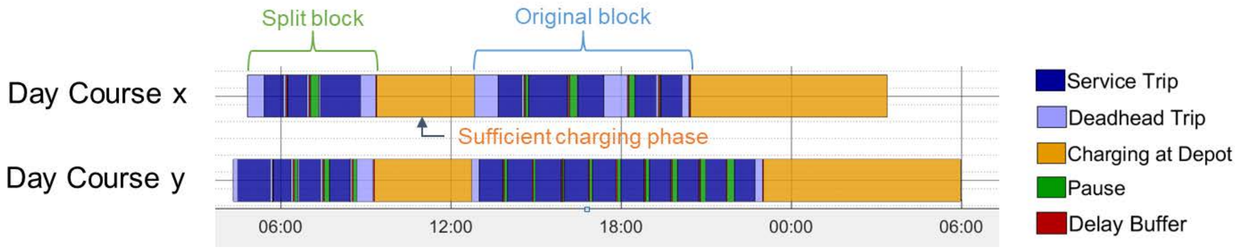
At the beginning of Phase B, the operation scheme changes to 'new' day courses. This change allows for more of Foothill Transit's fleet to be electrified by adjusting operating blocks and replacing CNG buses with BEBs. Like Phase A, there is no dedicated charging time between blocks of a day course. In Phase B, a day course can consist of both original and split blocks containing short charging phases during the day as represented in Figure 5-4.

Figure 5-4: Example Day Course in Phase B



Finally, at the beginning of Phase C, the operation scheme changes to ‘final’ day courses. As in Phase B, the day courses consist of original and adjusted blocks. However, in Phase C, the time at the depot between blocks of a day course are sufficient to completely recharge a BEB. The feasible and split blocks are again rearranged into day courses in order to minimize the PVR. Due to longer charging phases between the blocks, the PVR increases in Phase C as shown in Table 4-1. During Phase C, all day courses can be operated by BEB’s, thus successfully transitioning Foothill Transit’s bus fleet to 100% electric.

Figure 5-5: Example Day Course in Phase C



5.2 Electrification Concepts for Transitioning to BEB’s

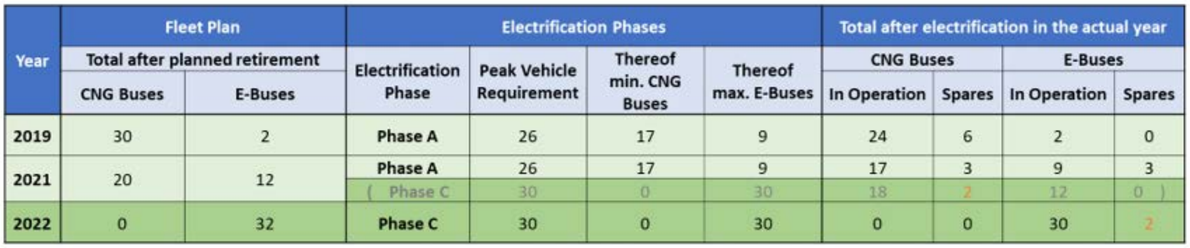
In this section conceptual plans describing how Foothill Transit can transition its current CNG bus fleet to BEB’s are discussed for each bus type in operation and for each yard. This transition plan is based on applying the methodology for prioritizing routes as discussed in Section 5.1 and by selecting buses and chargers that can support Foothill Transit routes as discussed in Section 4. By applying this phased strategy to the suitable BEB and charging infrastructure, Foothill Transit can move towards 100% electrification over the next decade.

The PVR of BEBs are calculated based on worst-case scenario assumptions. The common operation conditions for Foothill Transit may be less demanding. If operations are less demanding than the worst-case scenario, the PVR may be lower. Furthermore, new BEB models may come into the market in the coming years that have higher battery capacities or peak charging powers. Applying new BEB model battery capacities may decrease the PVR. In the future, a reassessment incorporating technology developments will be helpful to update the content of the electrification concepts presented in this section.

5.2.1 Electrification Concept for Double Deck Buses at Arcadia Yard

Figure 5-6 shows how double deck BEB type D3 can be placed into service over time. Figure 5-7 shows the transition of double deck buses during the different phases. Since the double deck bus will only operate on the Silver Streak line 707, it is the only route shown in Figure 5-7.

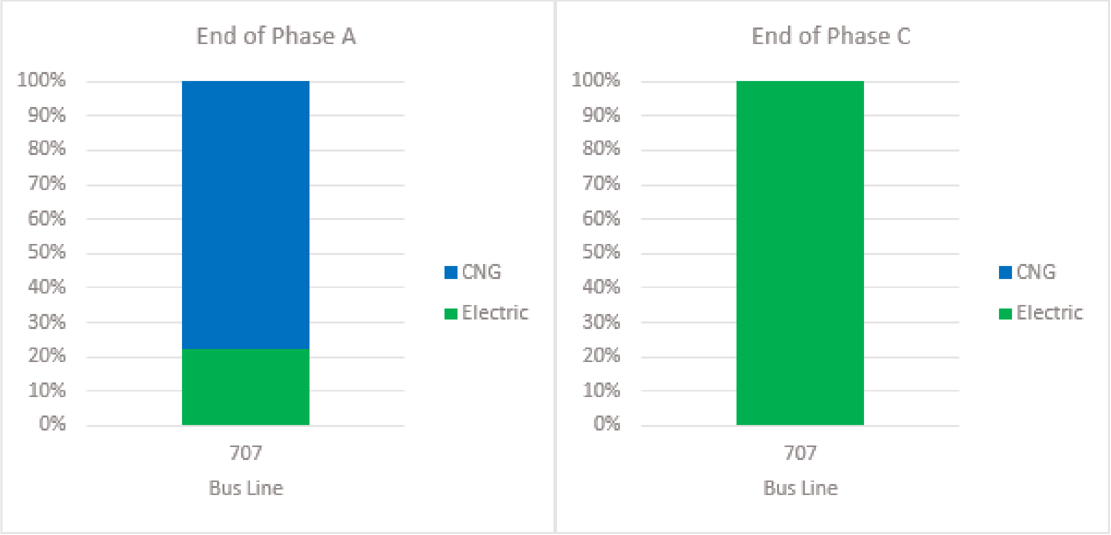
Figure 5-6: Transition of Double Deck Buses at Arcadia Yard



Year	Fleet Plan		Electrification Phases				Total after electrification in the actual year			
	Total after planned retirement						CNG Buses		E-Buses	
	CNG Buses	E-Buses	Electrification Phase	Peak Vehicle Requirement	Thereof min. CNG Buses	Thereof max. E-Buses	In Operation	Spares	In Operation	Spares
2019	30	2	Phase A	26	17	9	24	6	2	0
2021	20	12	Phase A (Phase C	26 30	17 0	9 30	17 18	3 2	9 12	3 0)
2022	0	32	Phase C	30	0	30	0	0	30	2

Depot: **Arcadia** Bus type: **D3 (864 kWh)** Chargers: **325 kW**

Figure 5-7: Transition of Double Deck Buses Per Route from Arcadia Yard

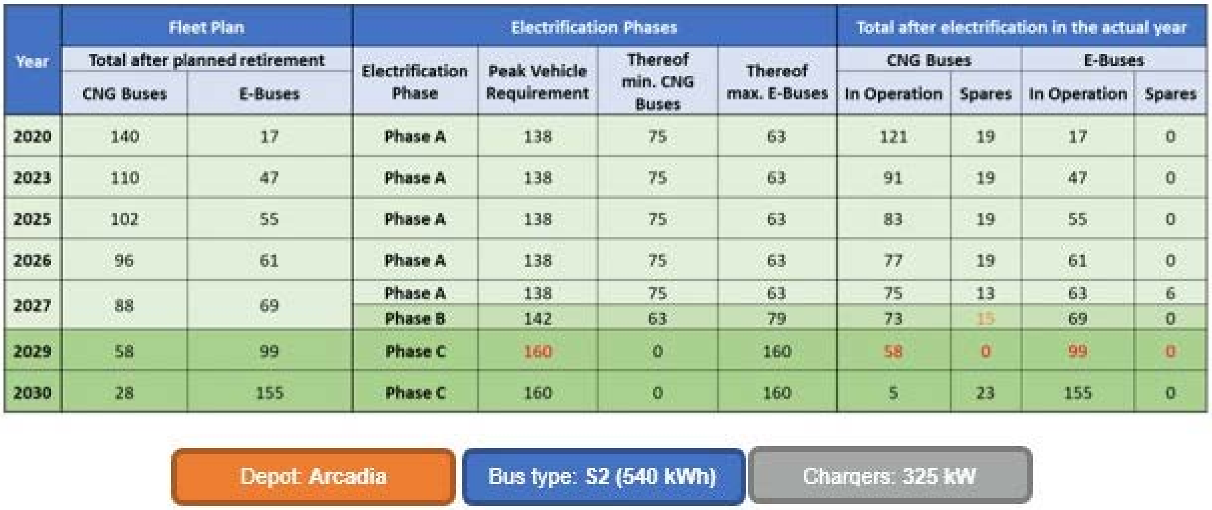


Day Type: **Friday** Depot: **Arcadia** Bus type: **D3 (864 kWh)** Chargers: **325 kW**

5.2.2 Electrification Concept for Single Deck Buses at Arcadia and Pomona

Figure 5-8 shows how single deck BEB type S2 can be placed into service over time. Figure 5-9 shows the transition of single deck buses during the different phases for the different bus routes. Figure 5-10 shows how single deck BEB type S2 can be placed into service over time. Figure 5-11 shows the transition of single deck buses during the different phases for the different bus routes.

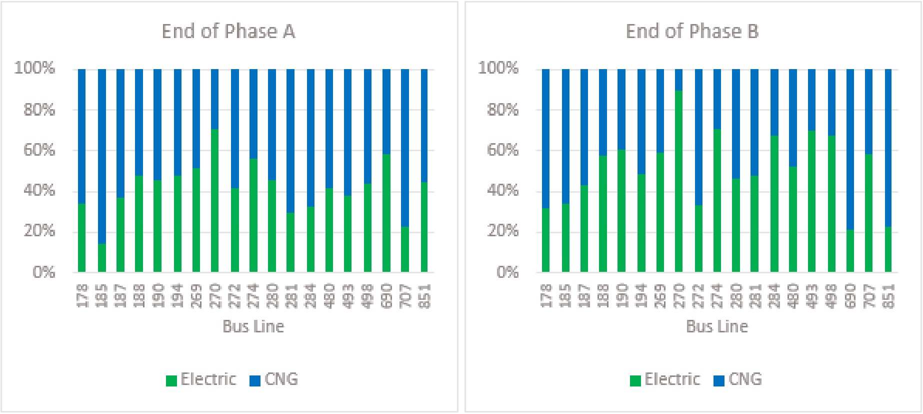
Figure 5-8: Transition of Single Deck Buses at Arcadia Yard



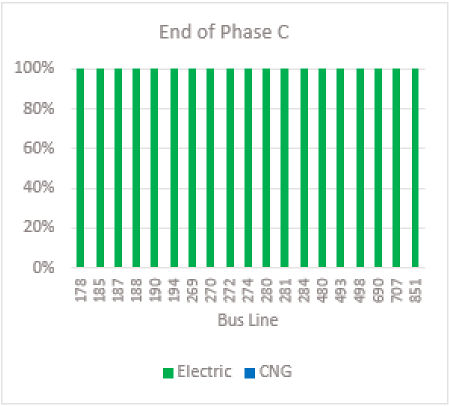
Year	Fleet Plan		Electrification Phases				Total after electrification in the actual year			
	Total after planned retirement		Electrification Phase	Peak Vehicle Requirement	Thereof min. CNG Buses	Thereof max. E-Buses	CNG Buses		E-Buses	
	CNG Buses	E-Buses					In Operation	Spares	In Operation	Spares
2020	140	17	Phase A	138	75	63	121	19	17	0
2023	110	47	Phase A	138	75	63	91	19	47	0
2025	102	55	Phase A	138	75	63	83	19	55	0
2026	96	61	Phase A	138	75	63	77	19	61	0
2027	88	69	Phase A	138	75	63	75	13	63	6
			Phase B	142	63	79	73	15	69	0
2029	58	99	Phase C	160	0	160	58	0	99	0
2030	28	155	Phase C	160	0	160	5	23	155	0

Depot: Arcadia | Bus type: S2 (540 kWh) | Chargers: 325 kW

Figure 5-9: Transition of Single Deck Buses Per Route from Arcadia Yard

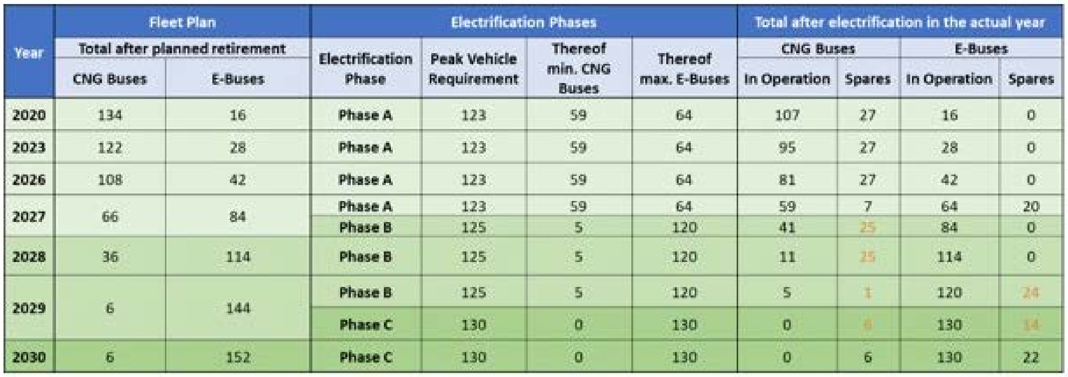


Day Type: Friday | Depot: Arcadia | Bus type: S2 (540 kWh) | Chargers: 325 kW



Day Type: Friday | Depot: Arcadia | Bus type: S2 (540 kWh) | Chargers: 325 kW

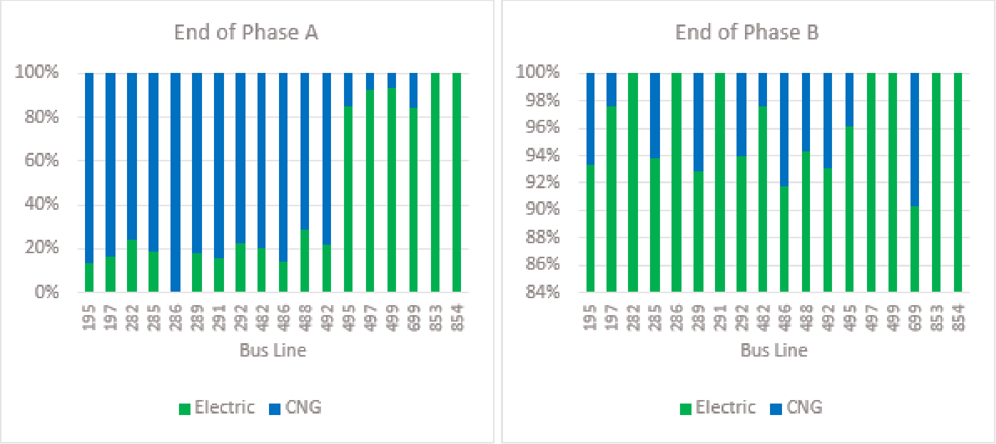
Figure 5-10: Transition of Single Deck Buses at Pomona Yard



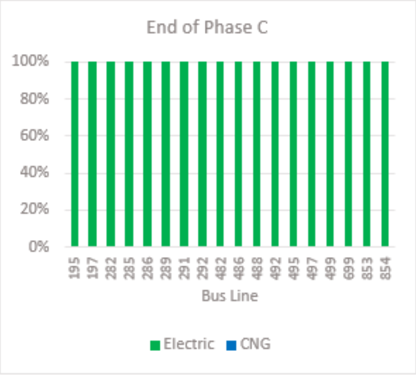
Year	Fleet Plan		Electrification Phases				Total after electrification in the actual year			
	Total after planned retirement						CNG Buses		E-Buses	
	CNG Buses	E-Buses	Electrification Phase	Peak Vehicle Requirement	Thereof min. CNG Buses	Thereof max. E-Buses	In Operation	Spares	In Operation	Spares
2020	134	16	Phase A	123	59	64	107	27	16	0
2023	122	28	Phase A	123	59	64	95	27	28	0
2026	108	42	Phase A	123	59	64	81	27	42	0
2027	66	84	Phase A	123	59	64	59	7	64	20
			Phase B	125	5	120	41	25	84	0
2028	36	114	Phase B	125	5	120	11	25	114	0
2029	6	144	Phase B	125	5	120	5	1	120	24
			Phase C	130	0	130	0	6	130	14
2030	6	152	Phase C	130	0	130	0	6	130	22

Depot: Pomona | Bus type: S2 (540 kWh) | Chargers: 325 kW

Figure 5-11: Transition of Single Deck Buses Per Route from Pomona Yard



Day Type: Friday | Depot: Pomona | Bus type: S2 (540 kWh) | Chargers: 325 kW



Day Type: Friday | Depot: Pomona | Bus type: S2 (540 kWh) | Chargers: 325 kW

6.0 BUS EQUIPMENT MARKET ANALYSIS

For this section, equipment that is commercially available for both EVSE and BEB's was assessed. A list of suitable EVSE for electric buses was compiled by reaching out to known EVSE manufacturers from the light-duty segment, researching manufacturers from other publicly announced BEB projects, and utilizing industry contacts. Information on currently available BEB's was captured from the various OEM's based on the needs of the Foothill Transit fleet.

6.1 Survey of Charger Demographics

The charging equipment research focused on EVSE that is capable of charging at 50kW or more, with one exception being a 25kW mobile charger. This unit was included as it could be used as a backup or convenience charger in a depot environment. The reason for focusing on high power EVSE was to ensure minimum recharging speeds that are practical for the range and schedule requirements that are necessary to convert Foothill Transit's routes to BEB's as demonstrated within this report. A 50kW charger will provide an equivalent of approximately 16 miles of range for every hour of charging, assuming an average BEB efficiency of 3 kWh per mile.

A survey was conducted to collect information from the various OEM's. The initial survey found a wide variety of at least 12 manufacturers offering chargers at various power levels while supporting both CCS and J3105 connector standards. While most of the manufacturers were focused on conductive charging, there were two manufacturers included in the survey that provide inductive wireless (J2954/2) charging solutions.

Table 6-1 outlines information collected from the survey, such as connector type and power output, for a variety of chargers.

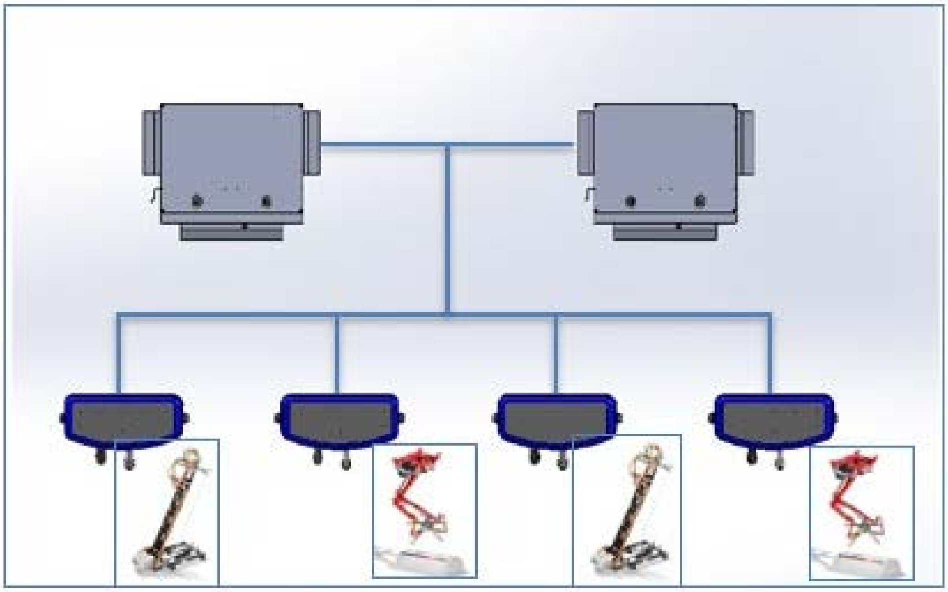
Table 6-1: List of Surveyed Charging Equipment

Manufacturer	Model	Connectors	Maximum Power Level (kW)	Mount Style (Ground / Wall / Overhead)	System Architecture
ABB	Terra 53/54	CCS / CHAdeMO	50	Ground	Integrated
ABB	HP Overnight / Opp	CCS / J3105-2	175	Ground	Modular Upgradable
ABB	Flash Charging (TOSA)	Proprietary overhead	600	Overhead	Unknown
BTC Power	50 kW DCFC	CCS / CHAdeMO	50	Ground	Integrated
BTC Power	100-200 kW Modular DCFC	CCS / CHAdeMO	200	Ground	Modular Upgradable
Chargepoint	Express 250	CCS / CHAdeMO	62.5	Ground	Modular Upgradable
Chargepoint	Express Plus	CCS / CHAdeMO	500	Ground	Modular Upgradable
Delta	DC City Charger	CCS / CHAdeMO Concurrent charging	100	Ground	Integrated
Efacec	QC Bus 90 / 150	CCS	150	Ground	Integrated
Efacec	QC 45	CCS / CHAdeMO	50	Ground	Integrated
Efacec	HV 175-350	CCS / CHAdeMO / J3105	350	Ground	Modular Upgradable
Heliox	25 kW Mobile DC charger	CCS	25	Mobile	Integrated
Heliox	30 / 50 kW DC	CCS / J3105	50	Ground	Integrated
Heliox	150 / 300 kW DC	CCS / J3105	300	Ground	Integrated
Heliox	450 / 600 kW DC	CCS / J3105	600	Ground	Integrated
Momentum Dynamics	50 - 200 kW	J2954/2	200	Ground	Unknown
Proterra	60 kW Depot	CCS / J3105	60	Ground	Integrated
Proterra	125 kW Depot	CCS / J3105	125	Ground	Integrated
Proterra	500 kW Depot / On-Route	J3105	500	Overhead	Integrated
Siemens	Top-Down Panto (150/300/450/600 kW)	J3105-2	600	Overhead	Integrated
Siemens	Bottom-up Panto (60/120 kW)	J3105-1	120	Overhead	Integrated
Siemens	Plug-In DC Charger (30-150kW)	CCS	150	Ground	Integrated
Signet	FC 50-100K	CCS / CHAdeMO	100	Ground	Integrated Upgradable
Signet	PB 175 - 350kW	CCS / CHAdeMO	350	Ground	Modular Upgradable
Tritium	Veefil - RT	CCS / CHAdeMO	50	Ground	Integrated
Tritium	Veefil - PK	CCS / CHAdeMO	175	Ground	Modular Upgradable
Wave	50 - 250 kW	J2954/2	250	Ground	Unknown

6.2 Different Types of Charging System Architecture

Designing for full depot electrification requires a charging system that is flexible and that can be upgraded. To cover these needs, the EVSE survey focused on the ability for charging equipment to work with different connector types and if the system architecture could be upgraded in the future. In general, chargers with a peak power output of 100kW or less have a system design that is typically integrated into a single unit that cannot be upgraded. Most charging systems that have a peak power output of 150kW or greater are based on a modular design that includes a power cabinet that is separate from the dispensing kiosk and connector. This allows multiple power cabinets to be combined to increase capacity at the site. Commercially available systems can be expanded to a peak power output of 600kW at this time. Figure 6-1 provides an example configuration of a modular charging system that provides charge power to multiple connectors.

Figure 6-1: Architecture of a Modular Charging System



6.3 Survey of BEB Market

Several requirements are considered when analyzing current BEB Manufacturers. These requirements include, but are not limited to: the number of BEB models, nominal range (miles), operating range (miles), battery size (kWh), supported charging standards, future supported charging standards, overhead charging (fastest time empty to full), plug-in-charging (fastest time empty to full), DC charging voltage, maximum charging power level (kW), and miles per hour of charging. Table 6-2 summarizes some key findings from the BEB survey assessment.

This study survey indicates there are only a handful of OEMs that can supply this information publicly and are able to support mass production of BEB’s. The information collected is constantly changing as more OEMs enter the market or existing products are improved and offered. The mix of OEMs that were included in this study include traditional bus manufacturers who are adding electric bus models to their portfolio, as well as start-up companies entering the market with an initial offering. The evolving market landscape offers an ever-growing set of choices.

It is important to mention that the OEMs contacted were unable to share data beyond what is publicly available. As such this study is unable to include parameters such as maximum passenger load, available auxiliary equipment, or real-world examples of range, impacts of climate, and efficiency for each OEM.

Assumptions on the type of BEB that Foothill Transit would require to convert to a fully electrified fleet were made in Section 3. Figure 3-1 and Figure 3-2 also represent standard battery sizes from different manufacturers of 40ft buses and double deck buses in addition to Table 6-2.

Table 6-2: Summary of Available BEB's

Manufacturer	Model	Battery Size (kWh)	Charging Compatibility	Overhead Charging Characteristics	Plug-in Charging Time
Proterra	Catalyst 35ft	220-440	J1772 CCS & SAE J3105	2.4hrs empty to full	1-3hr
Proterra	Catalyst 40ft	220-660	J1772 CCS & SAE J3105	2.4hrs empty to full	1-3hr
Nova Bus	LSFe	Not Advertised	Overhead Pantograph	5-minute fast charge per operating hour	Not Advertised
BYD	35ft Transit	352	Not Advertised	Not Advertised	2hrs
BYD	60ft Transit	652	Not Advertised	Not Advertised	3.5hrs
New Flyer	Xcelsior Charge 35ft	160-213	Siemens/ ChargePoint/ABB	32 minutes for 200kWh ESS (from 10%-90% SOC)	3.9hrs for 466 kWh ESS
New Flyer	Xcelsior Charge 40ft	213-466	Siemens/ ChargePoint/ABB	32 minutes for 200kWh ESS (from 10%-90% SOC)	3.9hrs for 466 kWh ESS
New Flyer	Xcelsior Charge 60ft	213-466	Siemens/ ChargePoint/ABB	32 minutes for 200kWh ESS (from 10%-90% SOC)	3.9hrs for 466 kWh ESS

7.0 CHARGING EQUIPMENT MARKET ANALYSIS AND SELECTION

After the survey of charging equipment was completed as described in Section 6, a Request for Information (RFI) was issued to 15 manufacturers of EVSE. The goal of the RFI was to determine which EVSE manufacturers and equipment would be best suited to meet the needs of Foothill Transit's goals to convert to a fully electrified bus fleet. In this section the summary of findings from the EVSE RFI is provided as well as the criteria that was used for evaluating the EVSE options. A key component of determining the best charging solutions also includes evaluating the constructability of different solutions based on constraints of Foothill Transits' depots. Lastly, recommendations for selecting equipment were provided considering the scoring matrix compiled from the RFI, constructability of equipment within the constraints of Foothill Transit's depots, and the requirements to support Foothill Transits goals to a fully electrified bus fleet.

7.1 Summary of Findings from EVSE RFI

The RFI was sent to 15 companies and only 11 replied by the deadline set for the RFI and in the requested format. Responses from the 11 companies, with relevant products and solutions, were compiled into a single document and a scoring matrix was created. The scoring matrix weighed information from the EVSE manufacturers based on equipment specifications, warranties, reliability and standards, customer services, network support, and pricing. A summary outlining all equipment information from the vendors and the scoring matrix was provided to Foothill Transit.

7.2 Initial RFI Results and Scoring Criteria

Based on the energy and charging requirements necessary for Foothill Transit to completely electrify its bus fleet, as determined from the energy-based scheduling, detailed route analysis, and optimized charging scenarios, the equipment evaluated was narrowed to equipment that could provide a charging power level of 325kW.

The top four EVSE manufactures according to the initial results of the scoring matrix were Heliox, ABB, BTC, and Tritium. Proterra and ChargePoint also received strong ratings; however, they have not manufactured and installed chargers with a peak capacity of 325 kW at the time of this evaluation.

ABB and Heliox both offer EVSE with a peak power output greater than 300 kW and that can operate as a pantograph connection following the J3105 standard. BTCPower and Tritium offer EVSE that have a cable connection following the CCS1 standard. All of these manufacturers offer charging hardware with 300 kW to 450 kW power output, which is in line with the recommended 325kW charger size as determined from the charging optimization study. Table 7-1 summarizes the top ranked chargers with greater than a 300-kW peak charging capacity.

Table 7-1: Summary of EVSE by Vendor

	Tritium	**BTCPower**	**ABB [1]**	**Heliox [2]**
Connection Standard	CCS1 / CCS2	CCS1 / CCS2	J3105-1	J3105-1
Power Output	350 kW	350 kW	300kW	450kW
Model	VeeFil PK 350kW Stand Alone	L4-350M	HVC 300P	Opportunity Charger 450kW UL
Charger Cost	$110,000	$123,000	$200,000	$178,500
Pantograph Cost	N/A	N/A	Included	Included

[1] ABB 300 kW charger can provide peak charging up to 325 kW.
[2] Heliox pantograph cost is estimated based on ABB pantograph pricing.
[3] Charger and pantograph costs from the RFI are unit prices and do not reflect bulk discounts and are representative prices only. Installation, commissioning, and other features vary by vendor.

7.3 Charger Constructability Constraints

Cable connected chargers operating in the 300-kW power class require the cables and CCS couplers to have a liquid cooling system due to physical limitations of cable. This requirement adds auxiliary load to each charger and causes the dispensers to become more complex. Since there is no readily available overhead system for supporting liquid cooled cables in a safe and reliable manner, the dispensers will need to be ground mounted and close to the bus charge port in an installation similar to a fueling station. Based on these constructability challenges and the footprint challenges at the Foothill Transit bus depots, the BTC Power and Tritium solutions are not viable for this type of installation at this time.

A pantograph-based system as provided by ABB or Heliox is the recommended path forward for Foothill Transit based upon the need for 325 kW charging power and dense parking configurations in the depots. The Heliox J3105 charger can currently be connected to two separate pantograph dispensers and power them in sequence using intelligent switching. The ABB J3105 charger has a similar feature under development for sequence charging of up to three pantograph dispensers. ABB has not provided a timeline for when this feature will be ready. Example of these systems can be viewed in Figure 6-1 in Section 6 of this report.

7.4 Preliminary Recommendations for EVSE Selection

Based on the 325 kW charging requirements and charger constructability constraints assessment, it is recommended that Foothill Transit use an overhead pantograph charging system employing either ABB or Heliox 325 kW (or higher) chargers. Conceptual plans and designs should incorporate a 2 pantographs per 1x325 kW dual port charger.

Based on the energy-based scheduling, detailed route analysis, optimized charging scenarios, and the depot layout assessment, the minimum number of chargers required for Arcadia at full fleet electrification at any one time is 55 x 325 kW chargers. These 55 chargers could be coupled with 110 pantographs above 110 parking spots. A similar configuration for Pomona would require 40 x 325 kW chargers and 80 pantograph power dispensers. This concept would require Foothill depot operators to move all 190 buses at Arcadia and 130 buses at Pomona throughout the depot at night to use the limited number of chargers and pantographs. It is assumed that existing depot fueling staff would gradually transition to moving electric buses around the depot as the fleet electrifies resulting in limited staffing increases.

Based on the layout and depot assessments, which is described in Sections 8, 9, and 10 of this report, one of the potential solutions would be to provide a pantograph power dispenser for each of the 180 bus parking positions at Arcadia with approximately 90 x 325 kW dual port chargers. The Pomona depot would have 65 x 325 kW dual port chargers and 130 pantographs for each of its 130 parking spots. This solution would eliminate nearly all depot fueling staff but would require nearly twice as much infrastructure. These configurations are explored and discussed further in Sections 8, 9, and 10.

8.0 DEPOT PHYSICAL LAYOUT ASSESSMENT

This section of the report summarizes the depot physical layout assessment, provides a review of existing policies and procedures, and identifies the footprints available for future charging infrastructure. These assessments served as an input into the development of the physical infrastructure layout options prepared for both Arcadia and Pomona yards which are also included within this section of the report.

8.1 Existing Depot Layout Assessment

The Arcadia Depot is the larger of the two depots and is home to 223 buses. The buses enter and exit via Peck Road at the north end of the yard as shown in Figure 8-4. Entering buses turn right past the administrative building and then left. The vault is located north of the maintenance building. The buses then continue to the parking location. All of Foothill Transit's articulated buses operate out of this depot, and they park on the north side of the yard facing northward. Other buses park on the east side of the yard, two deep and front to back facing eastward. When the yard is full, additional buses are parked in travel lanes against the east wall, shown by the red box in Figure 8-4, facing north in two lines and against the north wall facing west in two lines. Depot personnel fuel and clean the buses. Fueling occurs at the northeast corner of the yard. There is an additional area for bus storage south of the maintenance building. Electric buses that are not yet in service are parked here and are used for training operators. While it is unclear in Figure 8-4, diagonal parking south of the maintenance building is two deep, front to back. Employee parking, not shown in Figure 8-4, is along Peck Road west of the administrative building.

The Pomona Depot has 150 buses. The buses enter and exit via East End Avenue at the south end of the yard as shown in Figure 8-5. Entering buses stop at the vault, and then turn left at either the middle or far lane, and then turn left into the next available parking space. The buses park two deep and front to back facing westward. Fueling occurs at the southeast corner of the yard. Employee parking is along East End Avenue, west of the administrative/maintenance building.

At both locations, employee parking is separated from bus parking.. Both sites are also constrained by surrounding businesses and topography. During the site visits, the team asked if there are any bottlenecks or constraints within the depot. There are no constraints to current bus operations within either yard. As expected, existing protocols have been designed to ensure that buses pull out and pull in in an orderly fashion.

Figure 8-1: Bus Path within Arcadia Depot

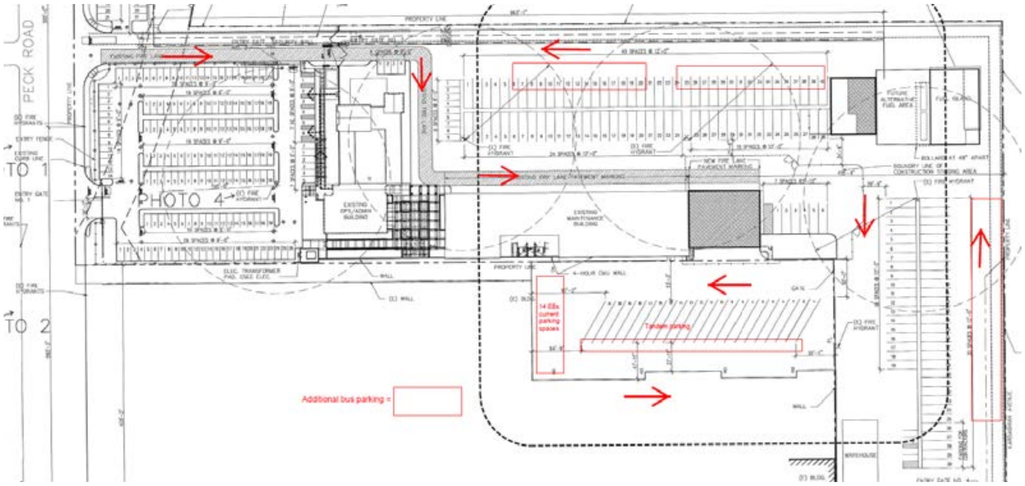
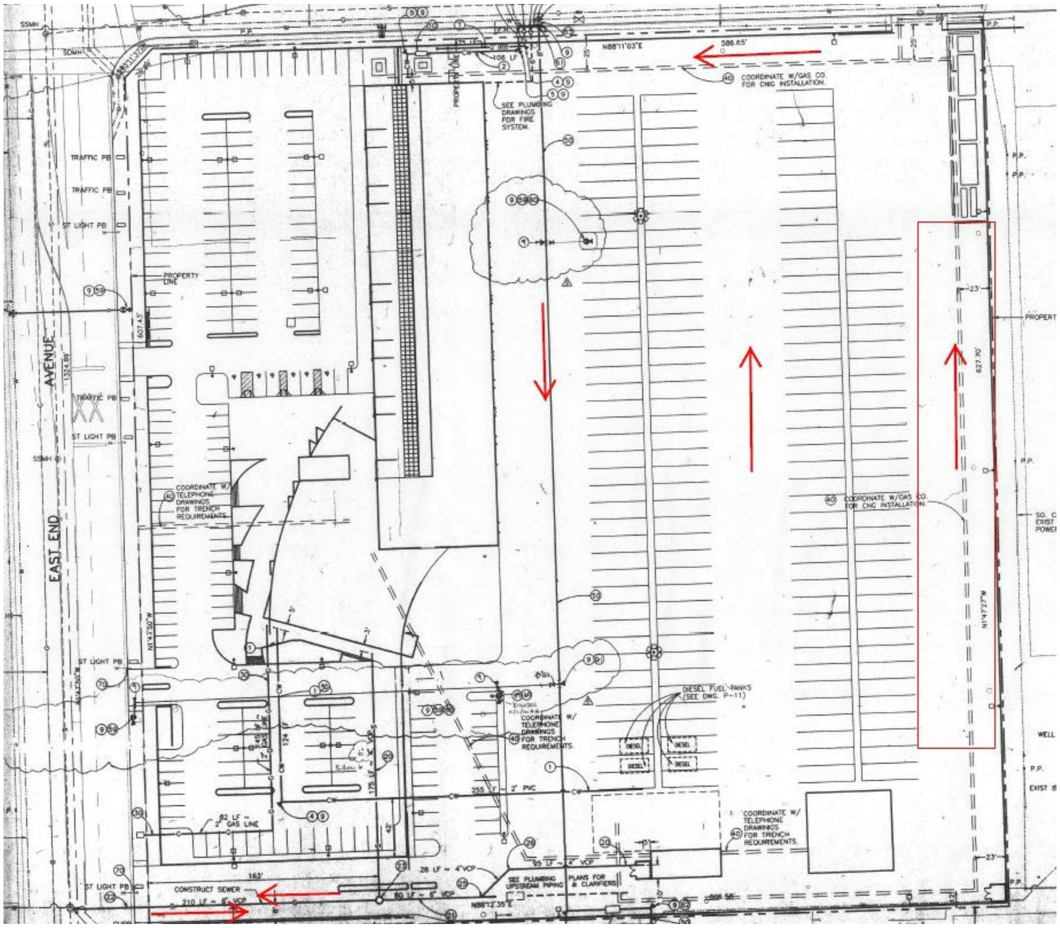


Figure 8-2: Bus Path within Pomona Depot



8.2 Depot Policies and Procedures Assessment

A bus operator’s workday includes “report time” for checking in with dispatch, obtaining any materials or information needed for the day, and inspecting the bus. Report time takes about 20 minutes if the operator is driving the bus from the yard. Operators are assigned to different buses on different days. Articulated and electric buses are parked in designated sections of the yard. Depot personnel prepare a map of where buses are parked to assist supervisors in directing operators to the correct bus; this procedure will be automated with the new Automatic Vehicle Location (AVL) system. Once the operator locates the correct bus, a brief pre-trip inspection is completed by the operator and the bus pulls out of the depot.

Some buses stay out in service all day, while others return to the depot after the morning peak period and go out again before the afternoon peak period. Approximately 75 percent of the buses at Arcadia stay out all day, mostly in local service. Most buses at Pomona return in the midday.

When operators pull into the depot, they stop at the vault to have the farebox emptied, then park their bus in the next available location in the yard and notify dispatch that they have returned to the yard. Depot personnel clean, wash, and fuel the buses overnight. Buses are washed every other day unless there are extenuating circumstances. Fueling occurs as the buses return and as depot personnel are available. The existing depot personnel would presumably be available for coordination of overnight bus charging activities in the future as the fleet transitions from CNG buses to BEB’s.

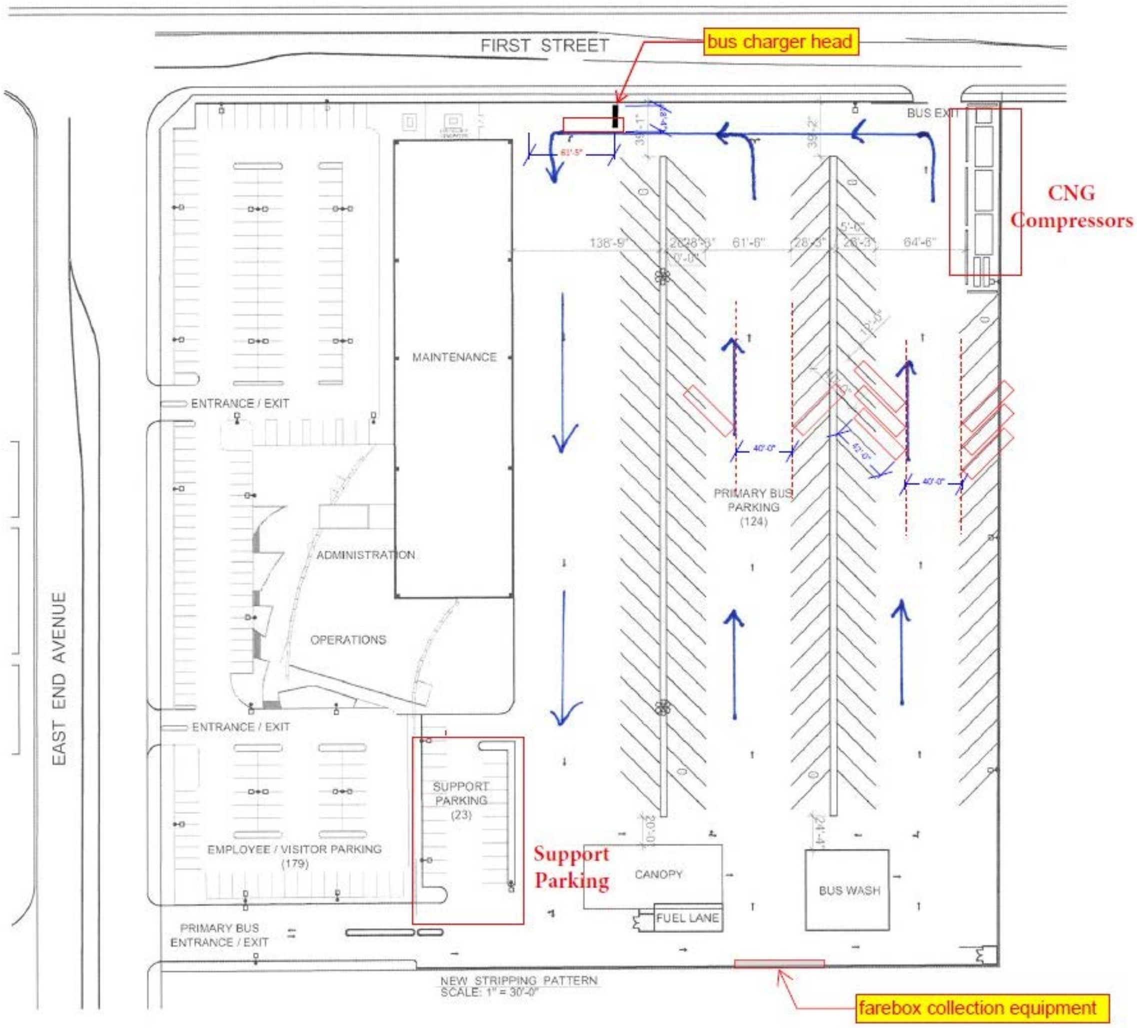
Foothill Transit has considered what policies and procedures would be most appropriate for an electric bus fleet. The preferred procedure is to spread out charging throughout the day as buses return to the depots. At the Arcadia Depot, the SCE pilot project concept will be to locate charging stations within the bus parking area to the east to allow 14 buses, parked front to back, to charge from the new stations which are proposed to be in the 2 northern most parking stalls. Going from 16 stalls to 14 stalls in this area of the depot results in a 12.5% net reduction in parking stalls. If this same charging equipment layout approach was used for the entire depot Foothill would likely lose nearly 15% of its parking when factoring in additional buffer areas between charging equipment islands. Nothing has been planned for Pomona yard at this time. A 15% reduction in parking will not be acceptable in the future for either Arcadia or Pomona, particularly if additional vehicles are required in the future. As part of the depot layout design process, the project team developed new layouts for charging and electrical equipment that consolidated and/or elevated charging and other electrical equipment such that a 0%-5% reduction in parking is achieved at each depot at most. These layouts are discussed and presented later within this section of the report.

8.3 Operational Limitations and Space Availability

The primary operational limitation to be considered in developing the conceptual incremental electrical infrastructure road map is that travel lanes throughout the yard must be kept clear. As the number of electric buses increases, the CNG fueling station can be downsized to fewer pumps. However, CNG fueling will be required during the transition period from 2021 to 2032 or longer depending on how long CNG buses are in operation. The available footprint at each depot is not large. The concept of charging in the bus parking areas can be expected to reduce the number of parking spaces in order to fit the charging equipment, although locating the charger's overhead can reduce the footprint required for this infrastructure. The proposed method of locating infrastructure overhead, to forgo additional losses of parking space, was reviewed with Foothill Transit engineering, operations, vehicle technology, and planning staff and determined the most feasible and cost-effective solution.

The new contractor operating the Pomona Depot has proposed a new parking scheme, shown in Figure 8-3 which has not yet been approved by Foothill Transit. Figure 8-6 highlights two areas within the Pomona Depot where additional space may be available. CNG compressors are located at the northeast corner of the yard. As the need for CNG is reduced during the transition period to all-electric operation, some of this space may be usable for other equipment since the existing public fueling will require much less gas compression. The project team asked about the availability of the support parking (space for 25 personal vehicles), at the south of the yard near the bus entrance/exit. The support parking is unlikely to be available either for additional bus parking or for other purposes because this space is used by managers and employees at the depot. Relief vehicles that are used to ferry operators to and from relief points on the routes, are already being parked in the employee parking lot. The project team and Foothill staff also considered eliminating the middle lane in the bus parking area and park buses four or five deep between the outermost lanes. Foothill Transit acknowledged that this is approach is indeed possible but that it would be a change to existing operating procedures used today. This approach was reviewed with Foothill Transit engineering, operations, vehicle technology, and planning staff and determined the most feasible and cost-effective solution to consolidate parking spots and add charging infrastructure to an already space constrained Pomona depot. Additionally, the proposed approach of placing charging infrastructure overhead would allow the co-utilization of an overhead structure to employ canopy solar within the Pomona depot.

Figure 8-3: Proposed Bus Parking Scheme Pomona Depot with CNG Fleet



At the Arcadia Depot, the transit agency owns the parcel of land north of the yard along Peck Road. The southern portion of this parcel is striped for employee overflow parking and a portion is leased by Clean Energy for public access CNG dispensers. The northern portion of this parcel is empty. The parcel could be used to support charging equipment, electric grid infrastructure, and on-site renewable power integration; however, the distance from the charging equipment to the buses would require significant underground infrastructure to reach the bus parking and would be much more costly. By moving the charging infrastructure overhead, the project team and Foothill Transit staff determined that it would be possible to maintain the existing depot layouts, incorporate additional charging infrastructure on the ground and overhead, and maintain the same number of parking spots that exist today. Additionally, the proposed approach of placing charging infrastructure (chargers and pantographs) overhead would allow the co-utilization of an overhead structure to employ canopy solar within the Arcadia depot.

8.4 Electric Bus Charging Equipment and Configurations

As mentioned previously in this report, there were several factors that led to the BEB charging equipment selected for the project. These factors included:

- Overhead Charging: An overhead solution will be required to maintain bus parking capacities at both depots due to the limited space availability as described previously within Section 8 of this report. The depots cannot sacrifice parking spots or drive lane space for more ground mount chargers.
- 325 kW Chargers: A 325 kW charger will be required to meet fleet operation requirements and minimize additional bus procurement as identified in the route analysis described in Section 4 of this report. A charger with less power capacity will not be able to charge buses fast enough to meet operational requirements.
- EVSE Availability: EVSE information compiled by vendor surveys as summarized in Section 7 of this report indicated that limited options for 325 kW overhead charging exists today. At 325 kW, cable reel charging is not feasible and is not recommended. Only ABB and Heliox OEMs provide overhead pantograph J3105-1 solutions at this power level capacity with each having the ability to support 2 ports and 2 pantographs per charger. Multiple bus manufactures are capable of providing BEBs that support J3105-1 solutions at 325 kW of charge power.

Table 8-1 presents the electric charging equipment requirements at each depot. The base scenario assumes a 2 pantograph per 1 charger solution at each site. The PVR and minimum number of chargers required is based on the route analysis summarized in Section 4 of this report. Under the base scenario the 190 buses in operation at Arcadia will need to be moved throughout the depot at night to use the 110 pantographs and 55 chargers. Similarly, the 130 buses in operation at Pomona will need to be moved throughout the night to use 80 pantographs and 40 chargers.

Table 8-1: Electric Bus Charging Equipment Requirements

Yard	Bus Size	Bus Type and Size	Charger Power	Peak Vehicle Requirement Modified Schedules	No of Chargers Required (Dumb Charging)	No. of Pantographs (Dumb Charging)	No of Chargers Required (Optimized Charging)	No. of Pantographs (Optimized Charging)
Arcadia	40'	S2 (540 kWh)	325 kW	160	40	80	36	72
Arcadia	DD	D3 (864 kWh)	325 kW	30	15	30	10	20
Arcadia Total				190	55	110	46	92
Pomona	40'	S2 (540 kWh)	325 kW	130	40	80	36	72

While it is theoretically possible that the number of chargers could be reduced further, moving 190 buses throughout the depot over an 8-hour period to use 55 dual port chargers via 110 pantographs will be challenging and will require depot operators to move nearly 26 buses per hour on average. The operational challenges and bus movement timetables are further assessed in Section 10 of this report.

8.5 Proposed Depot Infrastructure Layouts

The project team prepared 2 bus depot layout alternatives for both Arcadia and Pomona depots. For each site and layout alternative developed, the project team assumed that all charging equipment would be elevated and consolidated in order to maintain the same number of parking spots within the existing depots and minimize the number of service delivery points provided by Southern California Edison (SCE). The chargers were located such that the specific charger serving each spot is between 50 and 100 feet from the proposed charging pantograph. For each layout, constraints such as turning radius and drive lane space were also considered. For each site, 2 alternatives were developed in order to capture the range of the investment required. The first alternative considered a high capital investment with zero depot charging labor. The second alternative assumed a lower capital investment and a similar level of depot bus fueling labor as today. These alternatives are summarized and presented in the following pages.

i. Alternative 1 - High capital investment & no depot labor
   - One pantograph per bus; One charger per 2 buses
   - No bus depot operators for charging or moving buses
   - Pomona 130 PVR, 130 pantographs, 65x325 kW chargers, BOP and steel for 100%-yard coverage
   - Arcadia 190 PVR, 190 pantographs, 85x325 kW chargers, BOP and steel for 100%-yard coverage

ii. Alternative 2 - Low capital investment & existing depot labor - **Recommended**
   - Approximately one pantograph per 2 buses; Approximately one charger per 4 buses
   - Each depot requires 5 to 6 operators to move buses but with ~60% capital
   - Pomona 140 PVR, 80 pantographs, 40x325 kW chargers, BOP and steel for ~60% yard coverage
   - Arcadia 190 PVR, 110 pantographs, 55x325 kW chargers, BOP and steel for ~60% yard coverage

Figure 8-4 and Figure 8-5 presents Alternative 1 and 2 for Arcadia. Both layouts are organized similarly to the existing layout but have several charging islands where SCE can deliver underground service to their pad mounted transformers and switchboards with 480 V power serving the 325 kW chargers. Power would then be delivered from the chargers to the pantographs in cable trays above the bus parking spots. An overhead structure is planned to support the cable trays, the overhead pantographs, and future solar arrays described later Section 12 of this report. Alternative 2 uses approximately 60% less infrastructure but requires existing CNG fueling staff to move buses overnight. In both cases each charger would serve two parking spots; however, Alternative 1 requires significantly more infrastructure. Once the charger completes charging the first vehicle in position (A), the charger would switch over to the second vehicle in position (B) within 2 hours. With Alternative 2, once the buses in A position are charged a second set of vehicles would be moved into the A position while B continues to charge with B vehicles following. This would continue until all buses are charged. The operational assessment of the recommended alternative, Alternative 2, is described in Section 10 of this report.

Figure 8-4: Arcadia Depot Infrastructure Alternative 1 (High Capital + No Depot Labor)

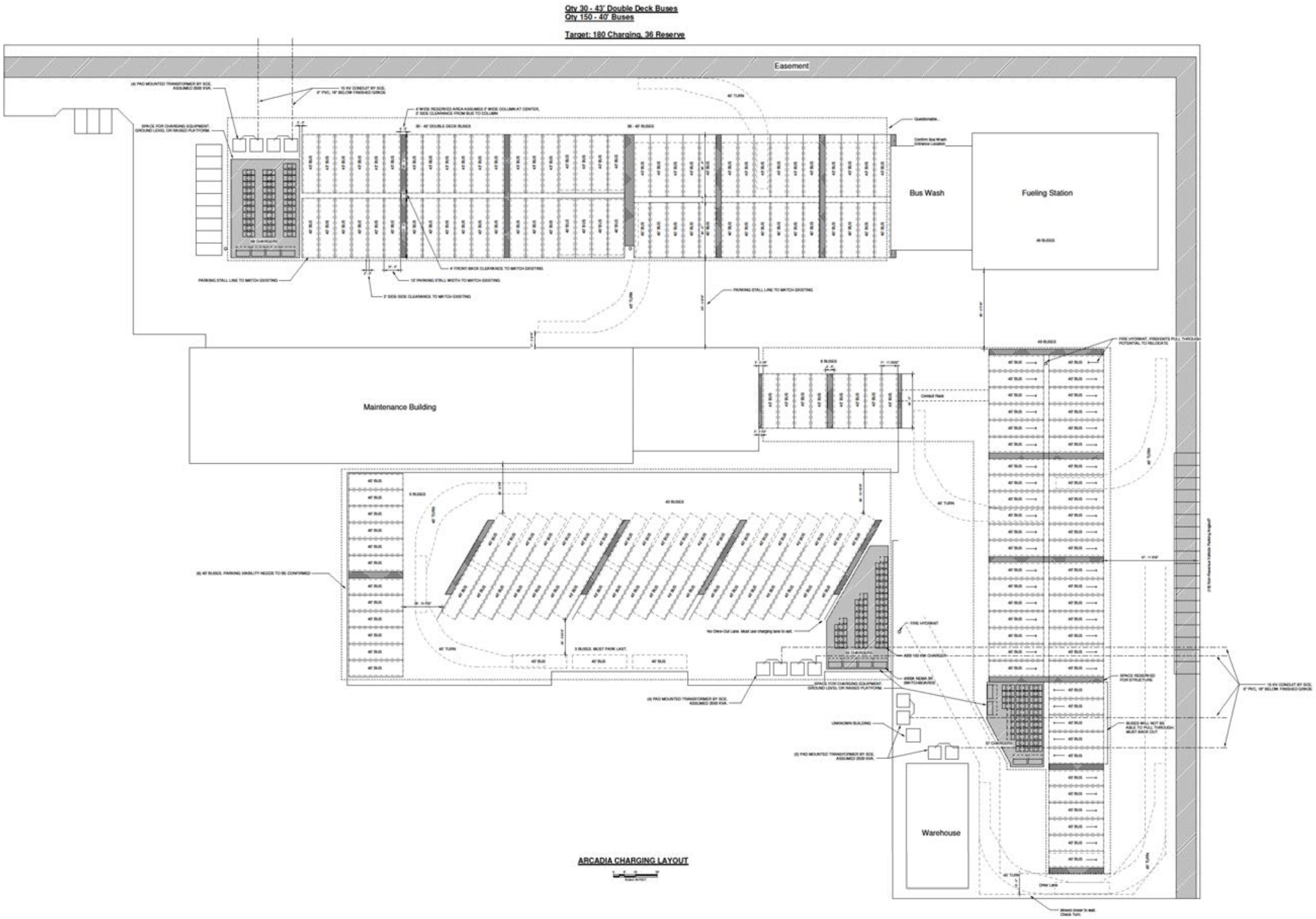
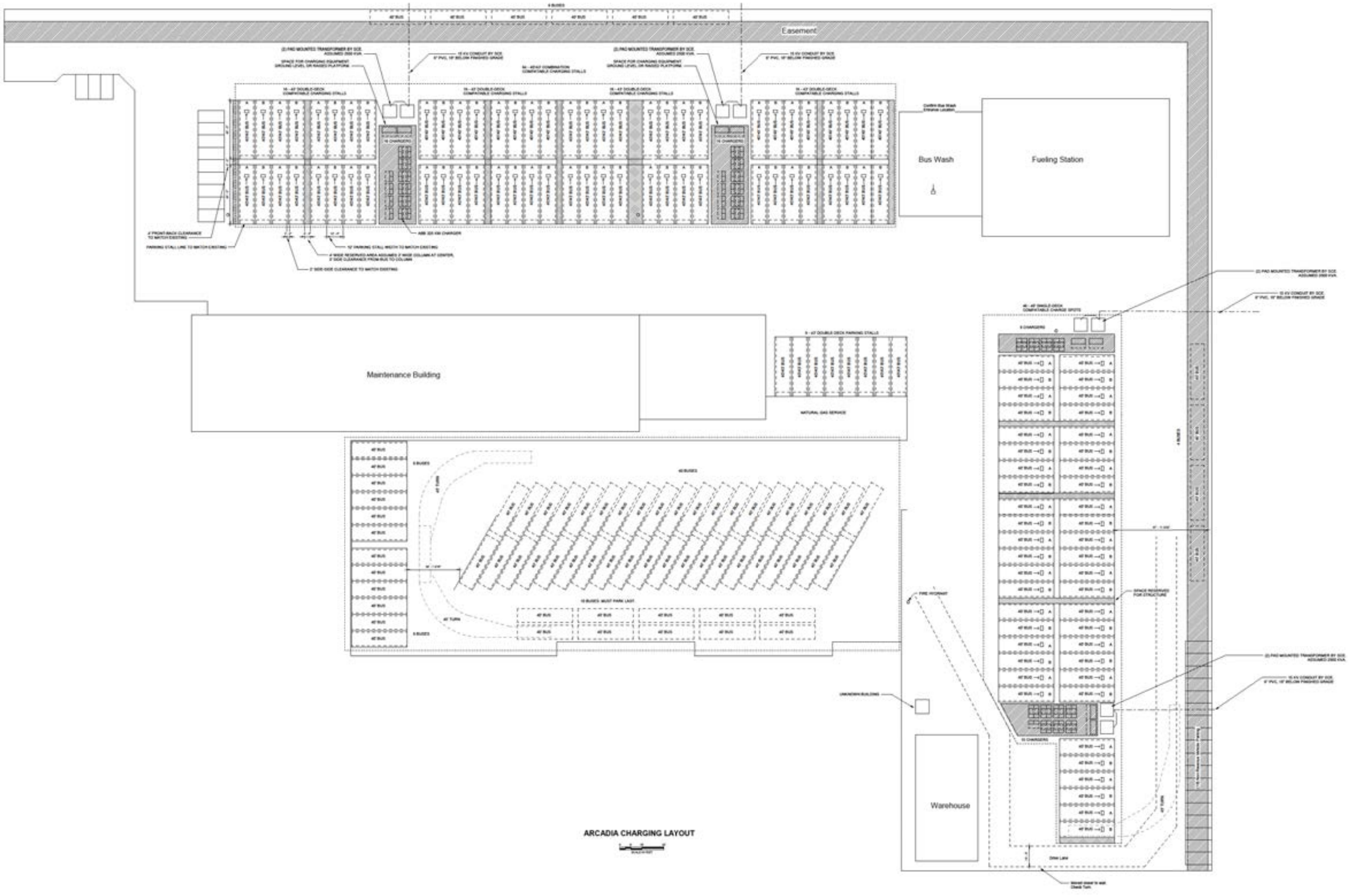


Figure 8-5: Arcadia Depot Infrastructure Alternative 2 (Low Capital + Existing Depot Labor)



Qty 30 - 43' Double Deck Buses
Qty 160 - 40' Buses

Target: 190 Bus Locations
112 Total Charging Spaces, 56 Chargers
  80 Spots for 40' Buses,
  32 Spots for 43' DD Buses
78 Parking Spaces

Reserve:
  32 - 40' Buses
  8 - DD Buses

ACHIEVED: 190 Bus Locations
110 Total Charging Spaces, 55 Chargers
  46 Spots for 40' Buses,
  64 Spots for BOTH 40' SD & 43' DD Buses
8 - DD Bus Parking Stalls
72 - 40' Bus Parking Spaces

No Reserve Scheduled.

Figure 8-6 and Figure 8-7 present Alternative 1 and Alternative 2 for the Pomona depot. Both layouts for Pomona are organized differently from the existing layout. The buses are arranged in rows of 4 or 5 to consolidate parking and make room for the additional charging equipment platforms and pad mounted transformers while allowing for no parking spots to be lost in the transition to an all-electric fleet. The buses would arrive into the depot in both alternatives and file into the parking spots in a first in first out operation pulling in from the west and then facing east while charging. Each alternative has either one or three charging islands where SCE can deliver underground service to their pad mounted transformers and switchboards, with 480 V power served to the 325 kW chargers. Power would be delivered in cable trays from the chargers to the pantographs above the bus parking spots. An overhead structure is planned to support the cable trays, the overhead pantographs, and future solar arrays. Alternative 2 uses approximately 60% less infrastructure but requires existing labor to move buses overnight. In both cases each charger would serve two parking spots; however, Alternative 1 requires significantly more infrastructure. Once the charger completes charging the first vehicle in position (A), the charger would switch over to the second vehicle in position (B) within 2 hours. However, under Alternative 2, once the buses in A position are charged a second set of vehicles would be moved into the A position while the buses in the B position continue to charge with B vehicles following the pattern of A vehicles once charged. This would continue until all buses are charged. The operational assessment of the recommended alternative, Alternative 2, is described in Section 10 of this report.

Figure 8-6: Pomona Depot Infrastructure Alternative 1 (High Capital + No Depot Labor)

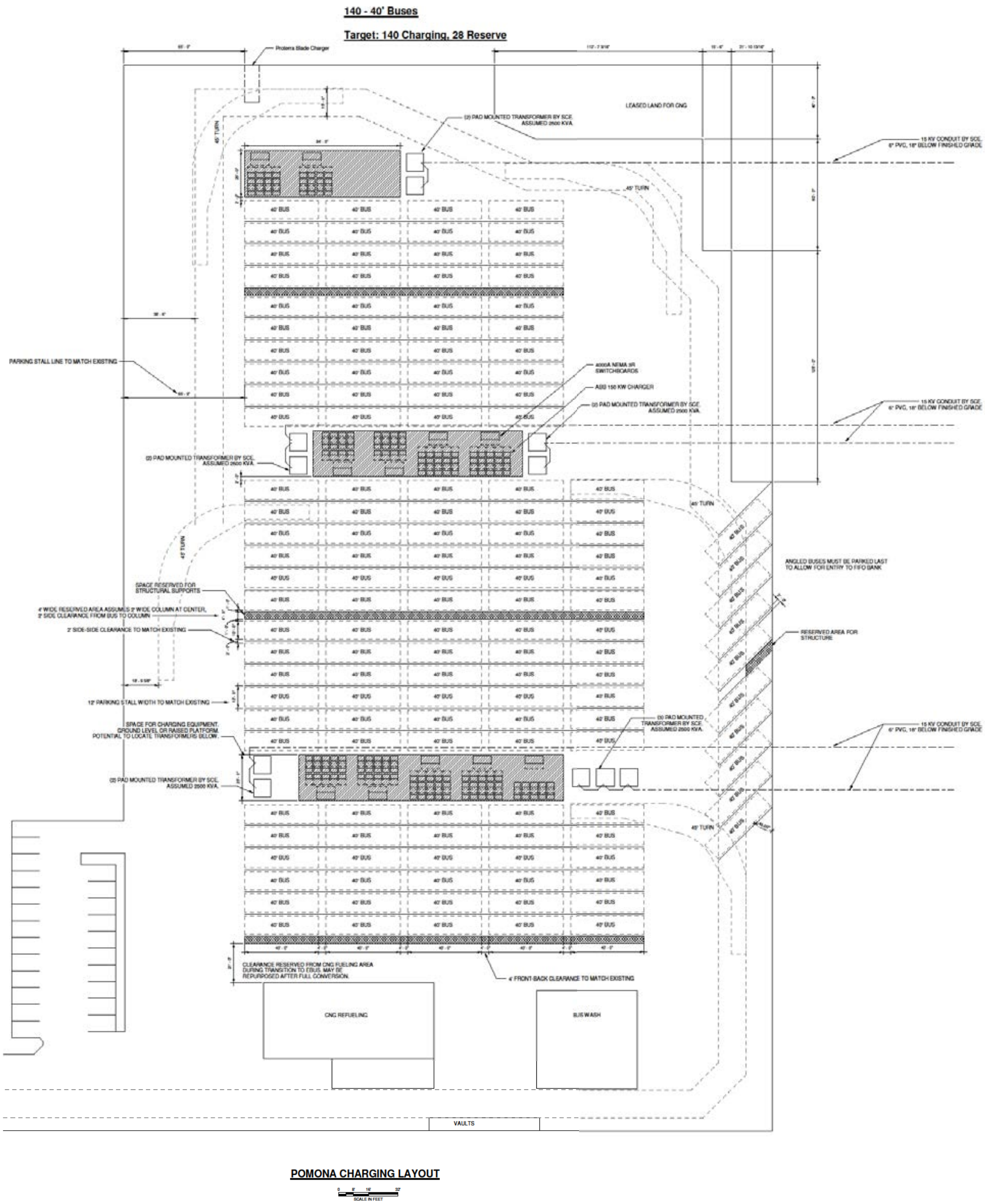
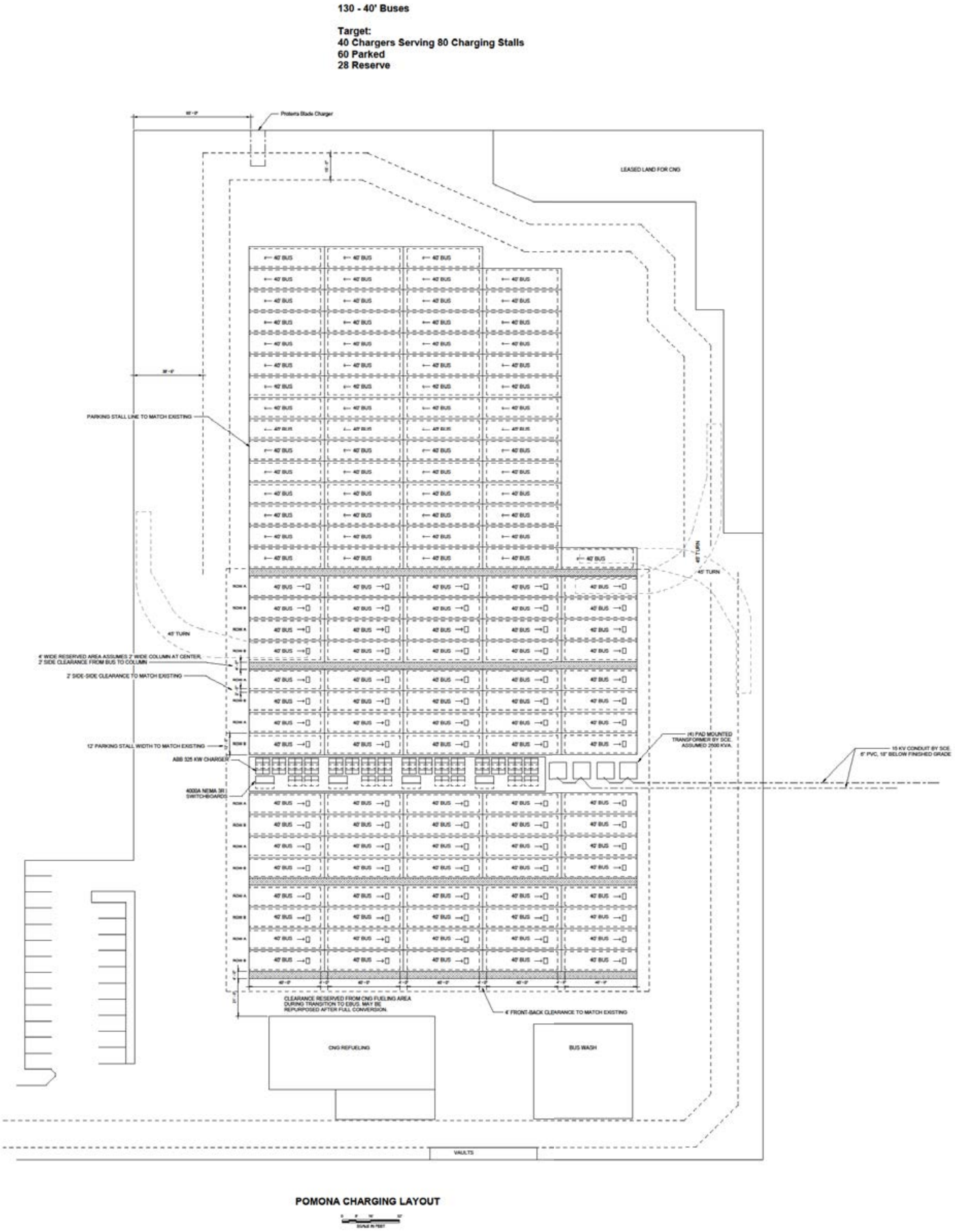


Figure 8-7: Pomona Depot Infrastructure Alternative 2 (Low Capital + Existing Depot Labor)



For both the Arcadia and Pomona depots, the cost to provide a pantograph connection point for every operating bus and a dual port charger for every 2 pantographs is almost 70% more costly than the alternative of providing nearly 1 charger and 2 pantographs for every 4 buses. The estimated cost in 2019 dollars (no inflation) to construct each alternative at Arcadia and Pomona is provided in Table 8-2. The existing depot fueling labor that refuels the buses overnight today is expected to be able to transition from fueling CNG buses to moving BEB's from parking to charging areas over the next 10 years. It is estimated that a total of 8 depot operators would be needed at Arcadia and 6 at Pomona, only over the night shifts, at a cost of $100,000 per person (2019$). These alternatives' costs are also considered and summarized in Table 8-2. This cost analysis further supports the decision to pursue the low capital + depot labor alternative.

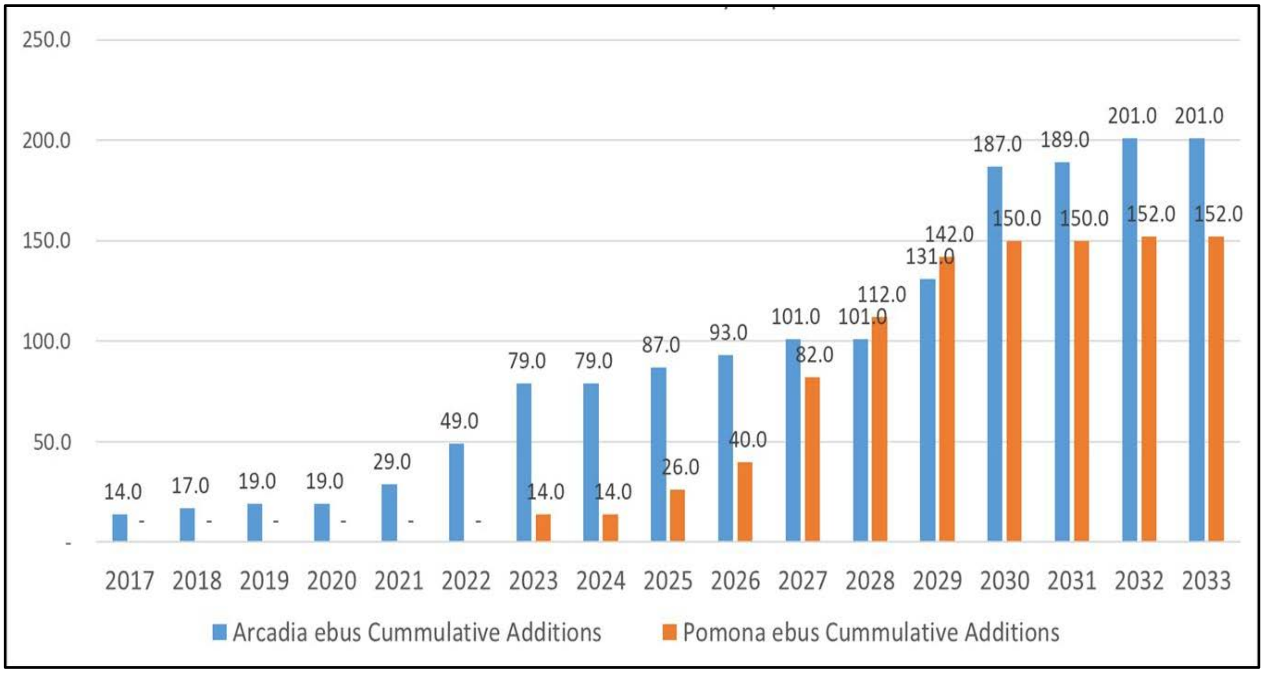
Table 8-2: Electric Bus Charging Infrastructure Alternatives Cost Analysis

	Alternate 1 High Capital + No Labor	Alternate 2 Low Capital + Depot Labor **Recommended**
Arcadia Depot	$102,880,000	$59,560,000
Peak Vehicle Requirement	190	190
Charging Stalls	190	110
Chargers	95	55
Pomona Depot	$71,390,000	$43,930,000
Peak Vehicle Requirement	130	130
Charging Stalls	130	80
Chargers	65	40
Total Depots	$174,270,000	$103,490,000
Peak Vehicle Requirement	320	320
Charging Stalls	320	190
Chargers	160	95
Arcadia Depot Operators		8
Pomona Depot Operators		6
Total Depot Operators		14
Depot Operator Cost Per Year		$100,000
Total Depot Operator Cost Per Year		$1,400,000
Total Depot Operator Cost 25 Year NPV		$26,700,000
Total Capital + Labor Cost	$174,270,000	$130,190,000

9.0 DEPOT INFRASTRUCTURE PHASING AND DEVELOPMENT

Foothill Transit plans to convert the existing CNG bus fleet of Arcadia and Pomona to an all-electric bus fleet over the next 12 years with a target of nearly 100 percent of its routes being fully electrified by 2030 and all CNG buses being removed from the site by 2032. The infrastructure phasing will need to coincide with the procurement of buses as planned in the fleet replacement schedule provided by Foothill Transit otherwise the buses will not be able to meet their routes. The cumulative number of electric buses by depot is presented in Figure 9-1.

Figure 9-1: Foothill Transit Fleet Replacement Plan and Cumulative Electric Buses by Depot



[1] Foothill fleet replacement plan as of March 2019

As presented in Section 8 of this report, the recommended infrastructure scenario is to use Alternative 2 which includes installing a total of 55 chargers and 110 pantographs at Arcadia and 40 chargers and 80 pantographs at Pomona. The timing of the when the infrastructure is needed is outlined in Table 9-1 with a description of each infrastructure deployment option following.

Table 9-1: Electric Bus Charging Infrastructure Requirements

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Arcadia ebus Cummulative Additions	14	17	19	19	29	49	79	79	87	93	101	101	131	187	189	201	201
Pomona ebus Cummulative Additions	-	-	-	-	-	-	14	14	26	40	82	112	142	150	150	152	152
Total ebus Cummulative Additions	14	17	19	19	29	49	93	93	113	133	183	213	273	337	339	353	353
Arcadia New CummulativePantographs	-	-	-	-	-	6	16	32	32	36	38	42	42	42	58	86	110
Pomona New CummulativePantographs	-	-	-	-	-	-	-	8	8	14	20	42	56	72	76	76	80
Total New CummulativePantographs	-	-	-	-	-	6	16	40	40	50	58	84	98	114	134	162	190
Arcadia New CummulativeChargers	-	-	-	-	-	3	8	16	16	18	19	21	21	21	29	43	55
Pomona New CummulativeChargers	-	-	-	-	-	-	-	4	4	7	10	21	28	36	38	38	40
Total New CummulativeChargers	-	-	-	-	-	3	8	20	20	25	29	42	49	57	67	81	95
Arcadia Depot	**BUILD PILOT (14 buses)**				**BUILD PH1**					**BUILD PH2**							
Pomona Depot							**BUILD PH1**					**BUILD PH2**					

[1] Based on Foothill fleet replacement plan as of March 2019

9.1 Depot Infrastructure Deployment Options and Plan

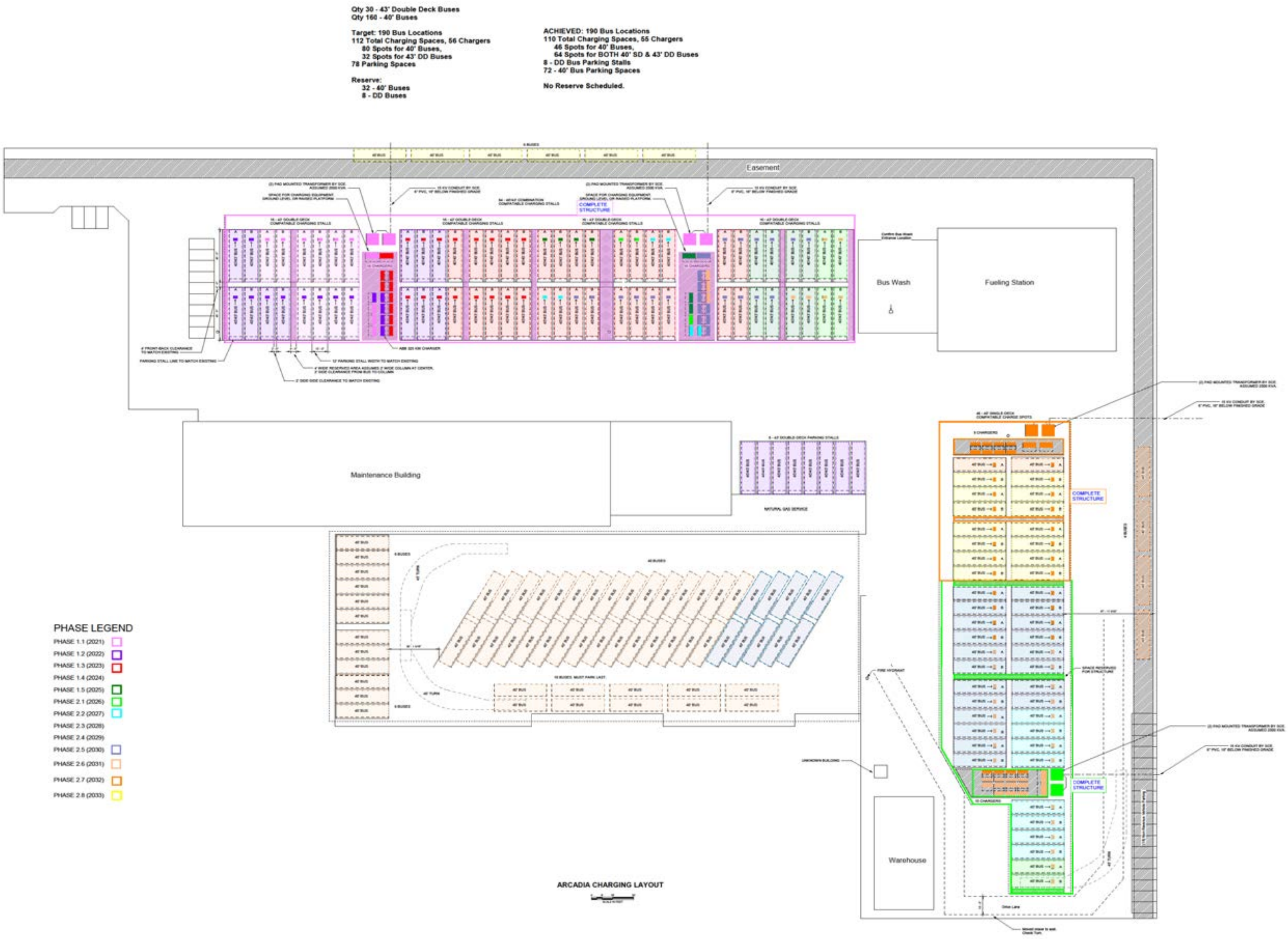
The deployment of this infrastructure can be executed by either a 2-Step Plan (Option 1) or a Year by Year Plan (Option 2).

Under the 2-step plan, Foothill Transit would build out major civil and electrical infrastructure in two phases. At Arcadia for example, all chargers and pantographs required between 2021 and 2026 would be built in 2021. Similarly, all remaining infrastructure for the latter years would be constructed under a separate contract in 2026. This approach would be the easiest to contract and manage and would enable all infrastructure to be in place when buses arrive. However, it would require a significant amount of infrastructure up front, at a large upfront cost, which would not be fully utilized until 2025.

Under the Year-by-Year plan, Foothill Transit would build out major civil and electrical infrastructure in two phases at each site. The chargers and pantographs would be installed year by year to align with the bus procurement plan. This approach would be slightly more complex but would result in right sizing the infrastructure to the bus procurement requirements and reduce the amount of upfront capital spending. It would further allow Foothill Transit to grow into electrification gradually and leave flexibility for new technologies and to adopt lessons learned throughout deployment.

Based on the capital spending constraints of Foothill Transit, the preferred and recommended method for infrastructure deployment is to install all infrastructure using a year by year approach. Figure 9-2 and Figure 9-3 present the Year-by-Year infrastructure deployment of Arcadia and Pomona respectively. Full size versions of these layouts can be found as an Appendix to the report.

Figure 9-2: Arcadia Depot Infrastructure Phasing Plan (Year by Year Deployment)



Qty 30 - 43' Double Deck Buses
Qty 160 - 40' Buses

Target: 190 Bus Locations
112 Total Charging Spaces, 56 Chargers
80 Spots for 40' Buses,
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78 Parking Spaces

Reserve:
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8 - DD Buses

ACHIEVED: 190 Bus Locations
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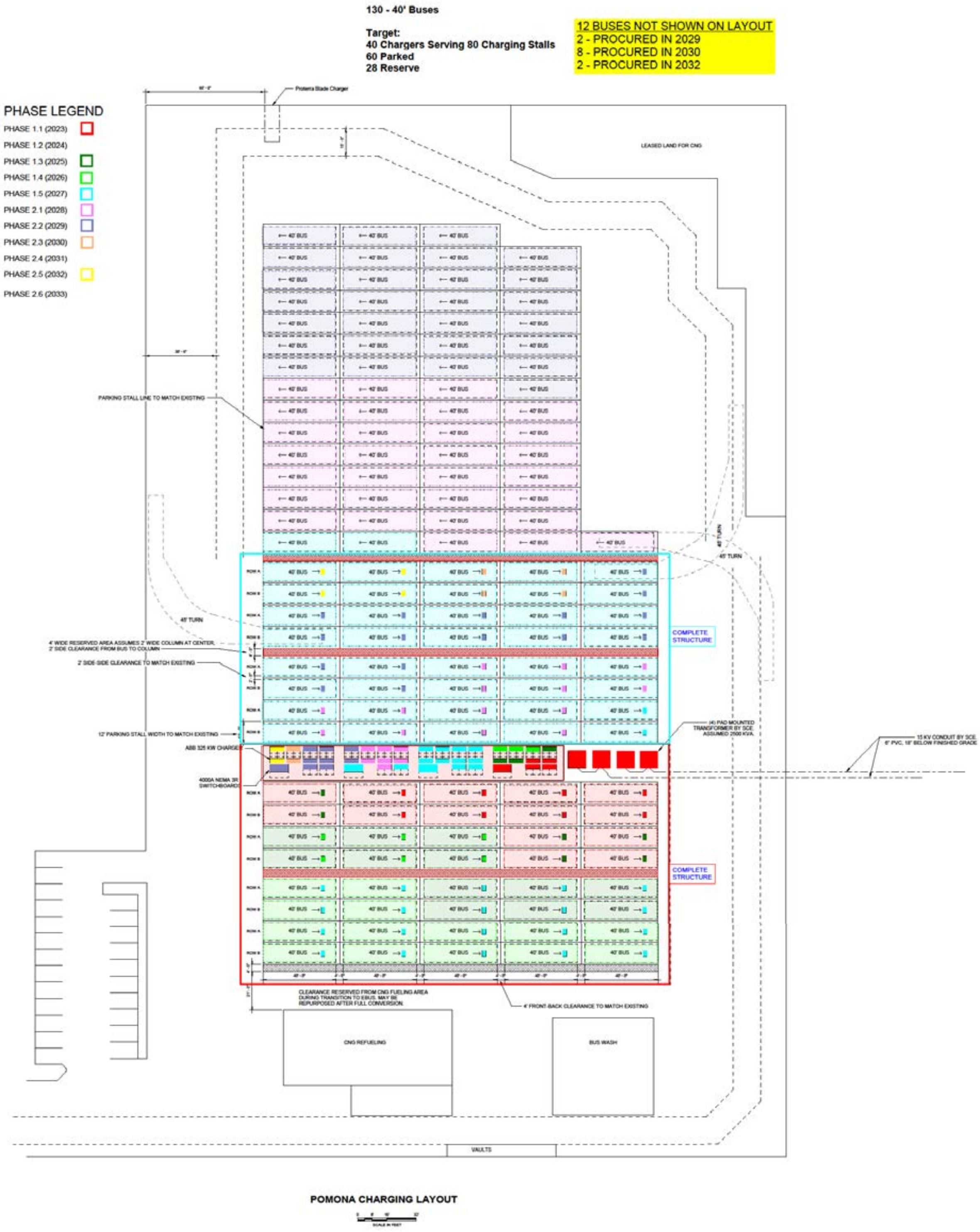
46 Spots for 40' Buses,
64 Spots for BOTH 40' SD & 43' DD Buses
8 - DD Bus Parking Stalls
72 - 40' Bus Parking Spaces

No Reserve Scheduled.

Figure 9-3: Pomona Depot Infrastructure Phasing Plan (Year by Year Deployment)



9.2 Depot Infrastructure Costs

For each depot, the project team prepared a bottom up cost estimate based on the scope and infrastructure required. The scope and costs were determined by year by depot. Additionally, the scope was also segregated between those infrastructure costs that will be directly paid by Foothill Transit, the installed costs of the chargers paid by Foothill Transit that could potentially be partially funded by rebates from SCE, and the cost of the electrical infrastructure that is eligible to be 100 percent paid for by SCE under the Charge Ready Transit Program. The detailed quantities and costs by year by depot ($2019) are provided as an Appendix to this report with the summary for each depot provided below. The total net cost to Foothill for the Arcadia depot with inflation is $69.9 million ($53 million in $2019). The total net cost to Foothill for the Pomona depot with inflation is $50.7 million ($39.9 million in $2019). The total Foothill cost requirements of $120.6 million developed within this section serve as an input into Section 13 Fleet Electrification Life Cycle Cost Analysis of this report.

Figure 9-4: Arcadia Depot Infrastructure Cost (Year by Year Deployment)

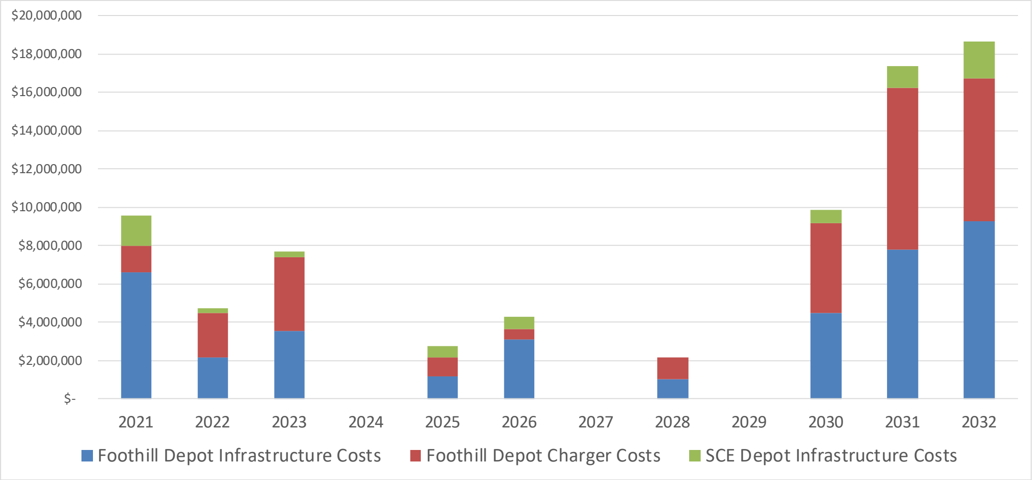
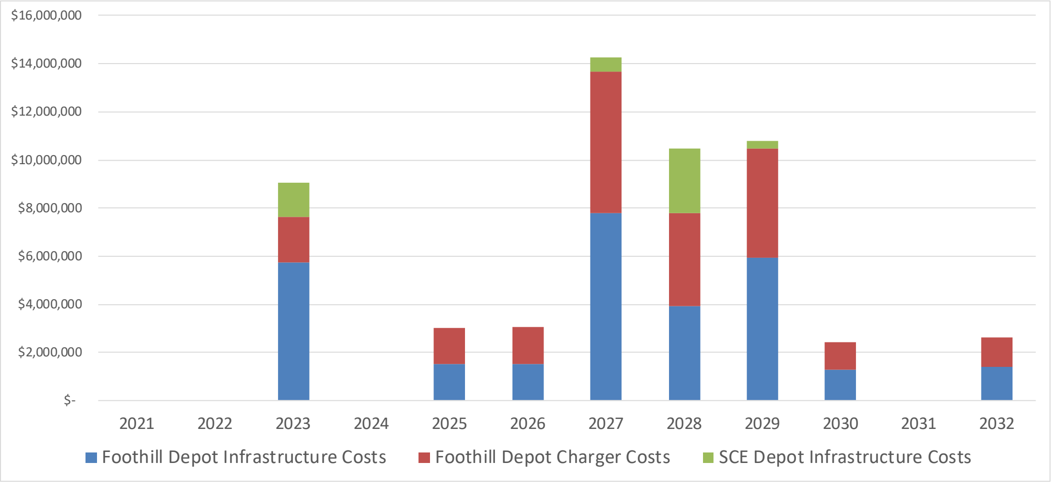


Figure 9-5: Pomona Depot Infrastructure Cost (Year by Year Deployment)



10.0 DEPOT OPERATIONAL ASSESSMENT

The recommended depot charging infrastructure provides the charging capacity to allow Foothill Transit to fully electrify its bus fleet by 2030. To validate that the proposed infrastructure plan is feasible from a depot operations standpoint, a series of investigations and analyses was conducted to validate feasibility. This section of the report summarizes the depot operational assessments conducted.

10.1 Review of Critical Operational and Non-Operational Concerns at Depots

Various critical various critical operational and non-operational concerns at the two depots were considered. These items are reviewed and are summarized in the following subsections.

10.1.1 Critical Travel Lanes, Entrances, and Exits

Figure 8-1 and Figure 8-2 show critical travel lanes within the depots and entry/exit points. Preliminary infrastructure plans for each depot retain or provide an acceptable alternative for each critical travel lane. Buses will continue to enter and exit the Arcadia Depot via Peck Road at the north end of the yard. Buses will continue to enter and exit the Pomona Depot via East End Avenue at the south end of the yard.

10.1.2 Remote Bus Storage Concerns

Overnight storage of all buses within bus depots is the preferred option in the transit industry. The proposed charging layouts for electric buses in the Arcadia and Pomona Depots, represented in Figure 8-6 and Figure 8-7, have space for overnight storage of all Foothill Transit operating buses (190 at Arcadia and 130 at Pomona). However, the movement of buses overnight may be of concern in specific areas of the depot where bus movement may be impeded by spare buses parked along the easements. If spare buses are parked in the maintenance shop overnight this may not be an issue similar to the existing depot logistics. If additional buses are procured to meet a specified peak reserve ratio, those additional spare buses may need to be parked elsewhere.

10.1.3 Bus Staging Concerns

The proposed layout of the Arcadia Depot is like its current layout. Foothill Transit does not consider the proposed infrastructure at the Arcadia Depot to be a critical concern. At the Pomona Depot, the proposed layout stores four or five buses in a single row, eliminating a center travel lane. This change reduces the flexibility of assigning buses for morning pullout. The new Automatic Vehicle Location (AVL) system will simplify the morning pullout process by providing dispatch with the location of each bus in the yard. Foothill Transit does not consider the proposed change at the Pomona Depot to be a critical concern.

10.1.4 Fueling, Charging, and Washing/Cleaning Concerns

Foothill Transit has no critical concerns regarding bus fueling, charging, or bus washing. The proposed layouts retain space for CNG fueling during the transition to an all-electric operation. Once the transition is complete, the CNG fueling space could be used for other purposes such as back-up power generation which is described in Section 12 of this report. The one non-critical concern in this area is the need for additional “spotters” who are used whenever a bus is backing up in the yard.

10.1.5 Space for Relief/Supervisor Vehicles and Employee Parking

The only major concern identified by the project team and Foothill Transit is related to adequate parking space for employee and relief vehicles, especially at Arcadia Depot. Employees currently park in the space reserved on the north side of Arcadia Depot where double-decker buses will be stored and charged. This space should still be available during the day, but it has been raised as a concern. Foothill Transit has approximately 30 relief vehicles that are used to bring operators to and from relief points on the routes. Parking for relief vehicles is a concern at Arcadia Depot because most of the buses at Arcadia stay out all day and thus require operator reliefs in the field. There are also vehicles that are used by supervisors.

10.1.6 Depot Operator Labor

The recommended infrastructure and operational plan will require the depots to continue to move buses overnight. There are currently depot utility workers located at both depots that are responsible for moving buses to the CNG refueling station overnight. As the bus fleet transitions to 100% electric buses, Arcadia will need to maintain approximately 5 depot utility workers, per 8-hour night shift, that are moving buses to and from staging areas to charging areas. This is based on a bus operator being able to move one bus every 5 minutes from one side of the depot to the other which yields 60 buses moved per hour. Pomona will require 4 depot utility workers per shift. This shift from CNG refueling activities to electric bus movement activities will occur over the next 10 years. The day shift will not require depot utility workers to move buses since there will be more than enough chargers available during the mid-day charging periods.

10.1.7 Summary

There are no critical operational concerns, either currently or for the proposed charging layouts at the Arcadia and Pomona Depots. Foothill Transit recognizes that storing four or five buses in a single lane is a change from current procedures but does not view this as a concern. The only concern raised relates to employee parking and parking for relief vehicles at Arcadia Depot.

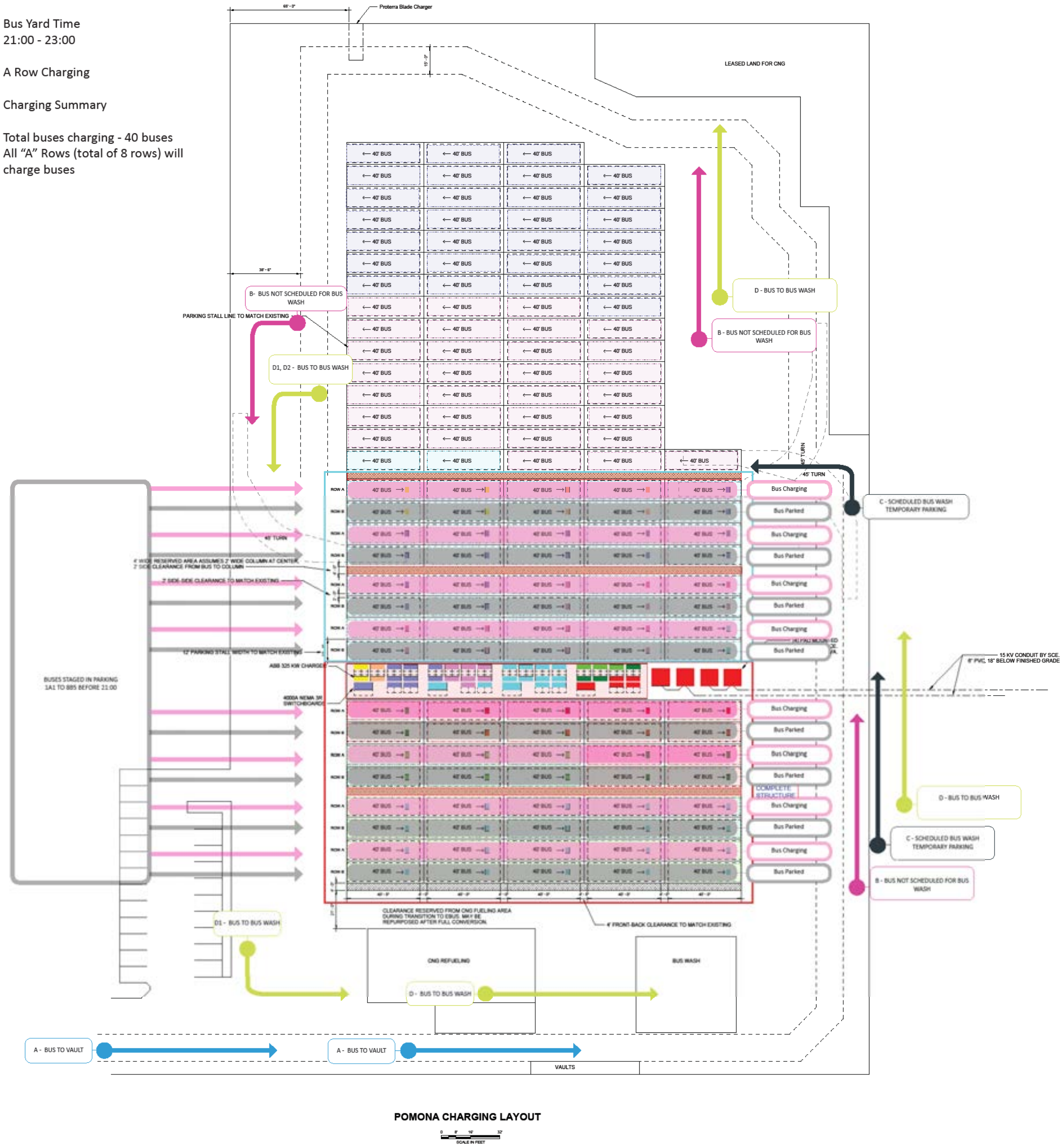
10.2 Pomona Depot Charging and Operational Plan

The proposed charging infrastructure for the Pomona depot has been sized and designed to meet the minimum fleet charging requirements based on the current and future fleet operational schedules. The Pomona depot hourly operating schedule was considered with regards to how the buses would enter through the depot, charge during the required charging cycle, and then move to a non-charging location within the depot. In 2033, the Pomona depot flow of operations will consist of the following:

1. A - Buses enter and stop at the vault to empty the farebox
2. B - If a bus is not scheduled to be washed that night, it will proceed to its overnight parking space. Buses will begin parking in Lane 1A, followed by 2A, 3A and so on through 8A and then the B lanes, lined up facing east.
3. C - If a bus is scheduled to be washed, it will park temporarily in lanes 11-14.
4. D - Depot personnel will wash the buses and park them in the overnight parking spaces, moving from south to north. In 2033, there will be 130 operating electric buses, 80 charging spaces in Lanes 1 through 16, and 40 chargers. The sequence of operations will be as follows.
    4.1. (9pm – 11 pm) The first 40 buses that arrive in the depot will be parked in the A lanes and will be charged first while the next 40 that arrive will be parked in the B lanes. The first 40 buses that arrive will charge first. The second group of 40 buses will not be charging but will be hooked up to the pantographs ready to charge as they arrive.
    4.2. (11pm – 1 am) At the end of the first 2 hours, the first 40 buses in the A lanes will be charged, and the second group of 40 buses parked in the B lanes will begin charging for 2 hours. While the 40 buses in the B lanes are charging, the first group of 40 buses in the A lanes that are fully charged will be moved to overnight parking in the north section of the depot while the third group of 40 electric buses initially parked in the north section of the depot are moved into the A lanes for charging.
    4.3. (1am – 3am) At the end of the second 2-hour time block, the second group of 40 buses in the B lanes will be charged, and the third group of 40 buses parked in the A lanes will begin charging for 2 hours. While the third group of 40 buses parked in the A lanes are charging, the second group of 40 buses in the B lanes that are fully charged will be moved to overnight parking in the north section of the depot while the remaining buses are moved into the B lanes to prepare for charging.
    4.4. (3 am – 5am) The last 14 buses in the B lanes will be charged for the last two-hour time block. The buses in the A lanes and B lanes will remain until dispatched in the morning.

The graphical representation of the bus flow throughout the Pomona depot for hours 9 pm – 11 pm and 11 pm – 1 am is provided in the following Figures. Hours 1 am - 3 am and 3 am - 5 am are similar.

Figure 10-1: Pomona Depot 2033 Charging and Operational Bus Flow (9 pm – 11 pm)



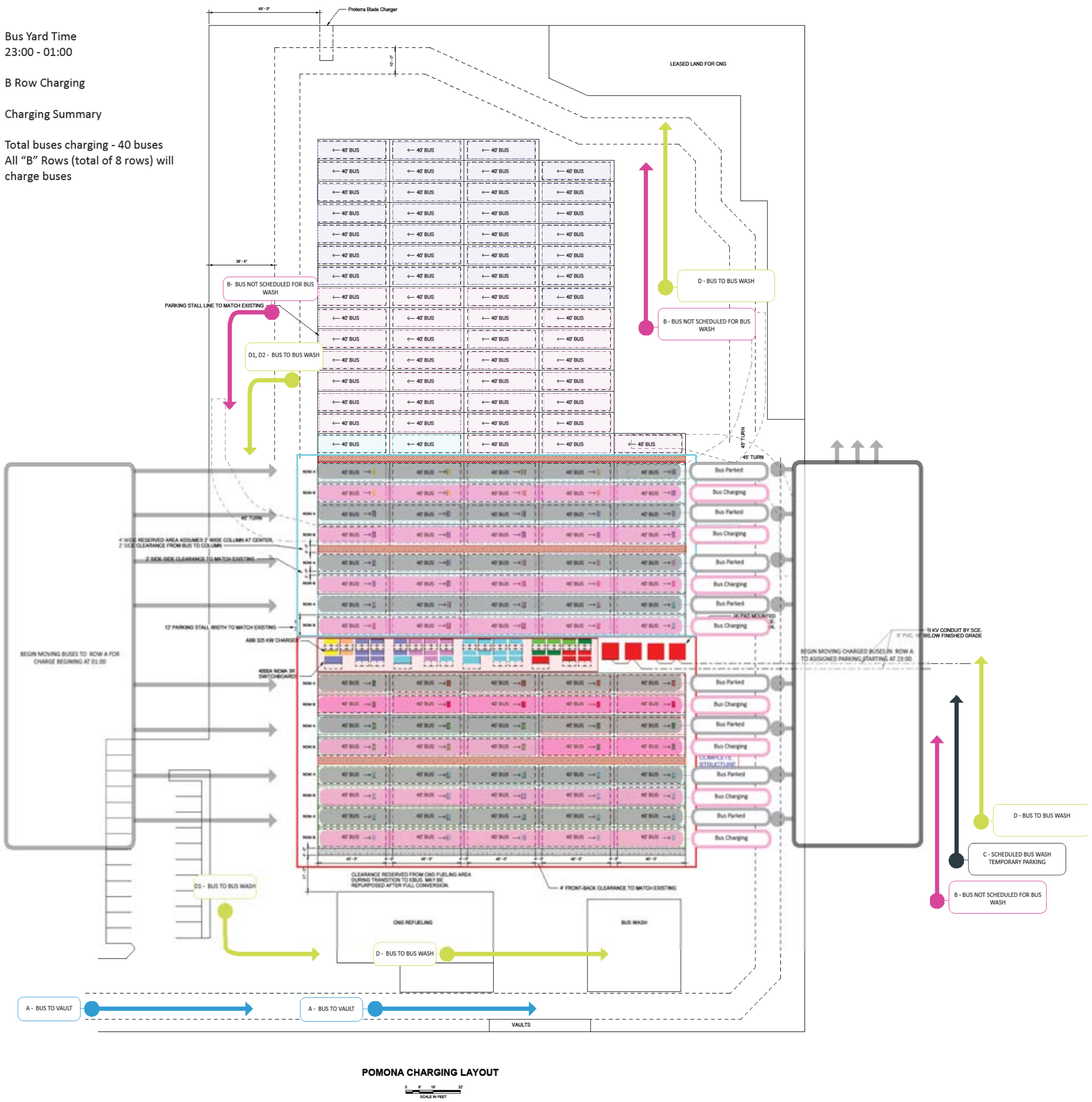
Bus Yard Time
21:00 - 23:00

A Row Charging

Charging Summary

Total buses charging - 40 buses
All “A” Rows (total of 8 rows) will charge buses

Figure 10-2: Pomona Depot 2033 Charging and Operational Bus Flow (11pm – 1 am)



10.3 Arcadia Depot Charging and Operational Plan

The proposed charging infrastructure for the Arcadia depot has been sized and designed to meet the minimum fleet charging requirements based on the current and future fleet operational schedules. The Arcadia depot hourly operating schedule was considered with regards to how the buses would enter through the depot, charge during the required charging cycle, and then move to a non-charging location within the depot. In 2033, the Arcadia depot flow of operations will consist of the following:

1. A. Buses enter and stop at the vault to empty the farebox
2. B. If a bus is not scheduled to be washed that night, it will proceed to its overnight parking space. Buses will begin parking in Lane 1A, followed by 2A, 3A and so on through 16A. Once the north depot A lanes are full, buses will proceed to lanes 17A to 29A and park facing east. Once the A lane is filled with buses, additional buses entering the depot would proceed to fill the B lanes in a similar order.
3. C. If a bus is scheduled to be washed, it will park temporarily in the overnight parking area south of the maintenance building.
4. D. Depot personnel will wash the buses and park them in the overnight parking spaces, moving from east to west. In 2033, there will be 190 electric buses in operation, 110 charging spaces and 55 chargers. The sequence of operations will be as follows.
    - 4.1. (9pm – 11 pm) The first 55 buses that arrive in the depot will be parked in the A lanes and will be charged first while the next 55 that arrive will be parked in the B lanes. The first 55 buses that arrive will charge first. The second group of 55 buses will not be charging but will be hooked up to the pantographs ready to charge.
    - 4.2. (11pm – 1 am) At the end of the first 2 hours, the first 55 buses in the A lanes will be charged, and the second group of 55 buses parked in the B lanes will begin charging for 2 hours. While the 55 buses in the B lanes are charging, the first group of 55 buses in the A lanes that are fully charged will be moved to overnight parking in the south section of the depot while the third group of 55 electric buses initially parked in the south section are moved into the A lanes to prepare for charging.
    - 4.3. (1am – 3am) At the end of the second 2-hour time block, the second group of 55 buses in the B lanes will be charged, and the third group of 55 buses parked in the A lanes will begin charging for 2 hours. While the third group of 55 buses parked in the A lanes are charging, 25 of the second group of 55 buses in the B lanes that are fully charged will be moved to the south section of the depot while the remaining 25 buses parked in the south are moved into the B lanes to prepare for charging.
    - 4.4. (3 am – 5am) The last 25 buses in the B lanes will be charged for the last two-hour time block. The buses in the A lanes and B lanes will remain until 5am. All buses will be charged before 5 am.

The graphical representation of the bus flow throughout the Arcadia depot is provided in the following Figures.

Figure 10-3: Arcadia Depot 2033 Charging and Operational Bus Flow (9 pm – 11 pm)

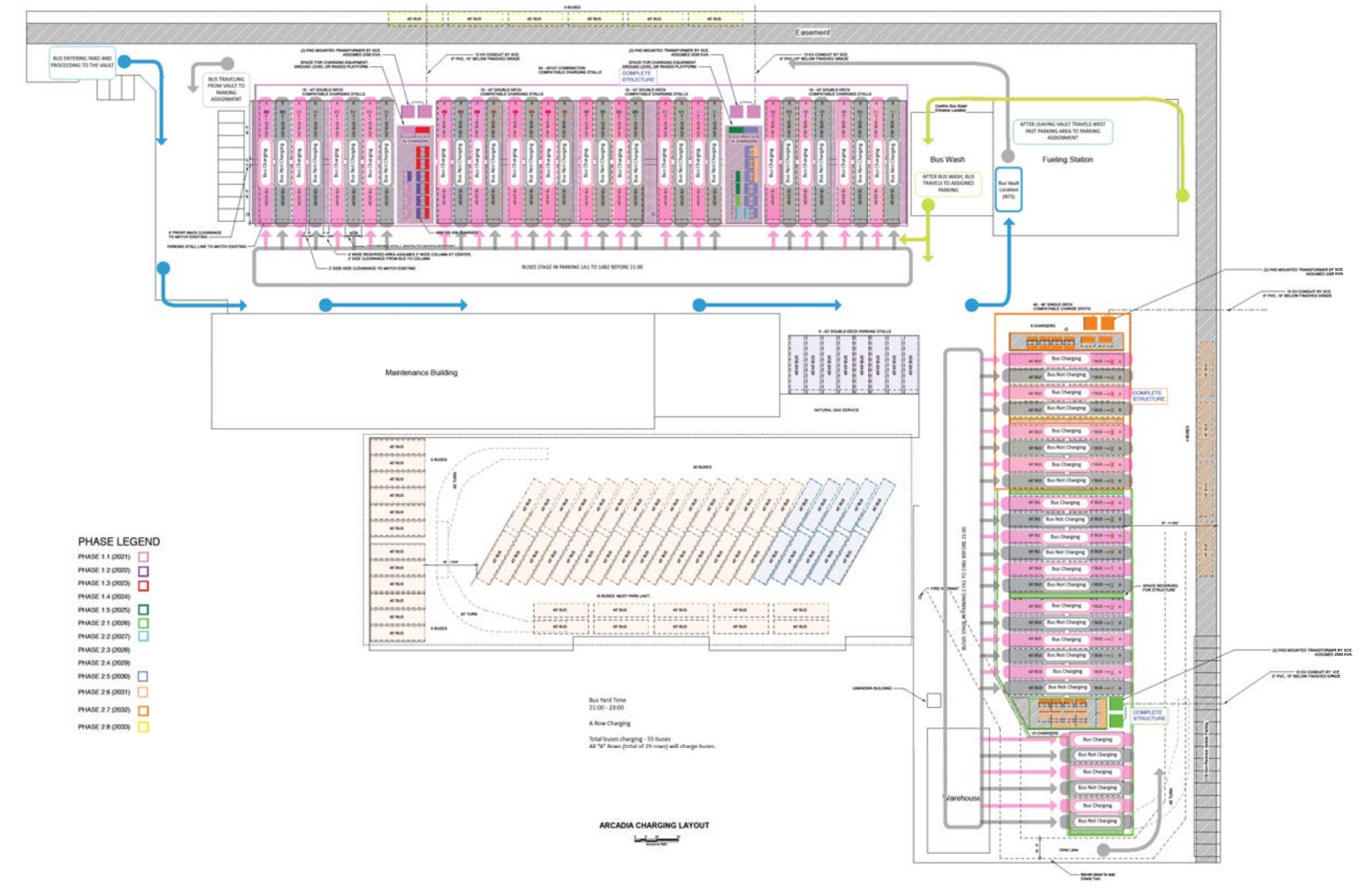
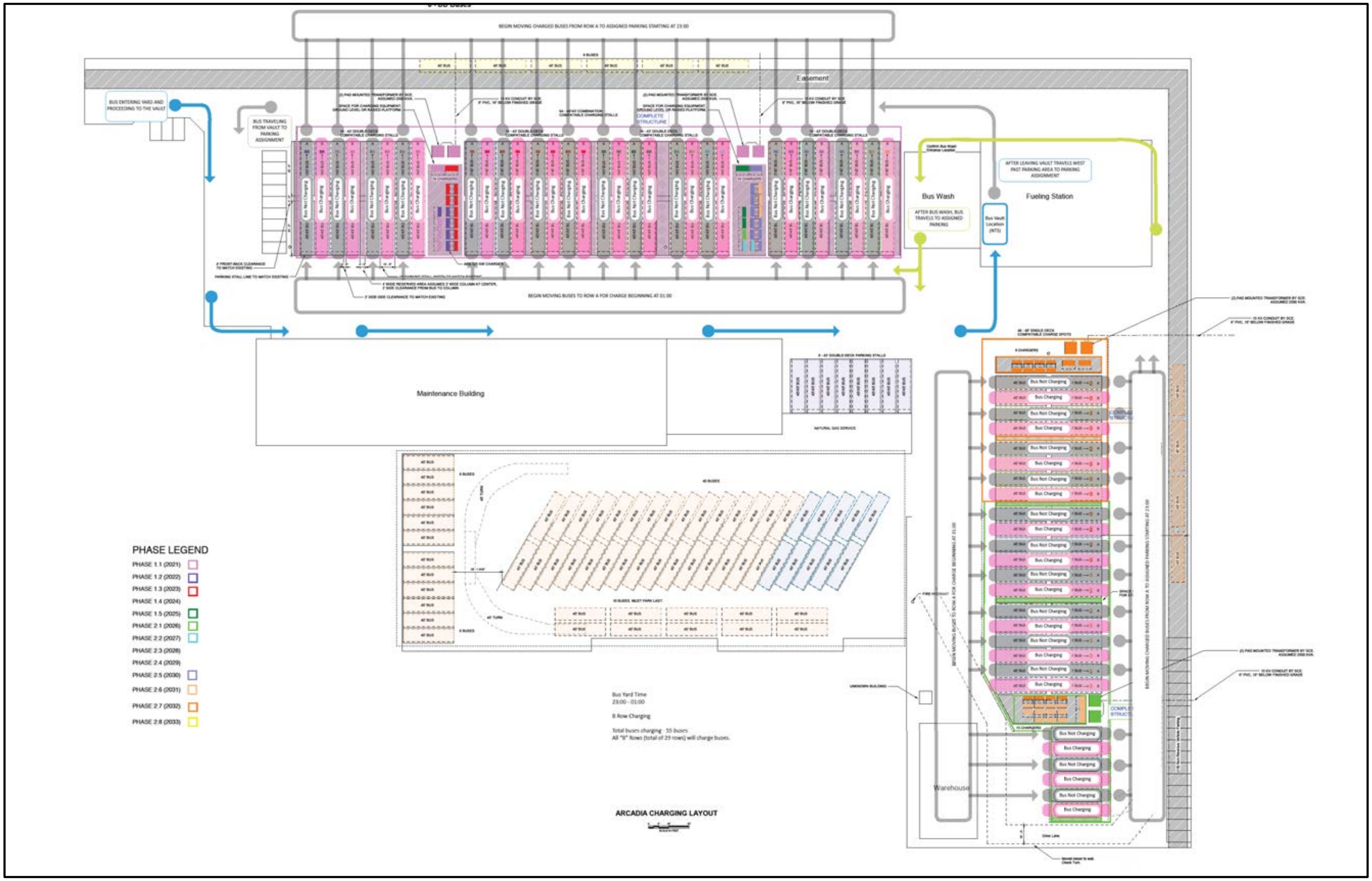


Figure 10-4: Arcadia Depot 2033 Charging and Operational Bus Flow (11 pm – 1 am)



As demonstrated in the figures above, the bus movements being conducted overnight to move buses from parking to charging areas will require operators to closely monitor charging levels of the buses during each two-hour period. The assumed size of the S2 bus is 540 kWh and it is planned to be charged with a 325-kW charger over a 2-hour time period. The bus operating schedule developed and presented in Section 4 of this report assumes that buses never return to the depot with less than 10 percent state of charge and charge up to 95 percent state of charge. The most energy that would be delivered into a bus over each 2-hour time period is 459 kWh which provides an ample buffer to account for various charging circumstances and bus movement delays overnight.

The peak charging requirements and bus charging logistics during the middle of the day at each depot are different from the overnight charging and logistics due to the far lower number of vehicles returning to the depot during the middle of the day. During the mid-day charging hours, buses will arrive in the depot and park at one of the charging stations throughout each of the depots so the bus can be recharged back to a 95 percent state of charge such that it is ready to for its scheduled bus runs in the afternoon.

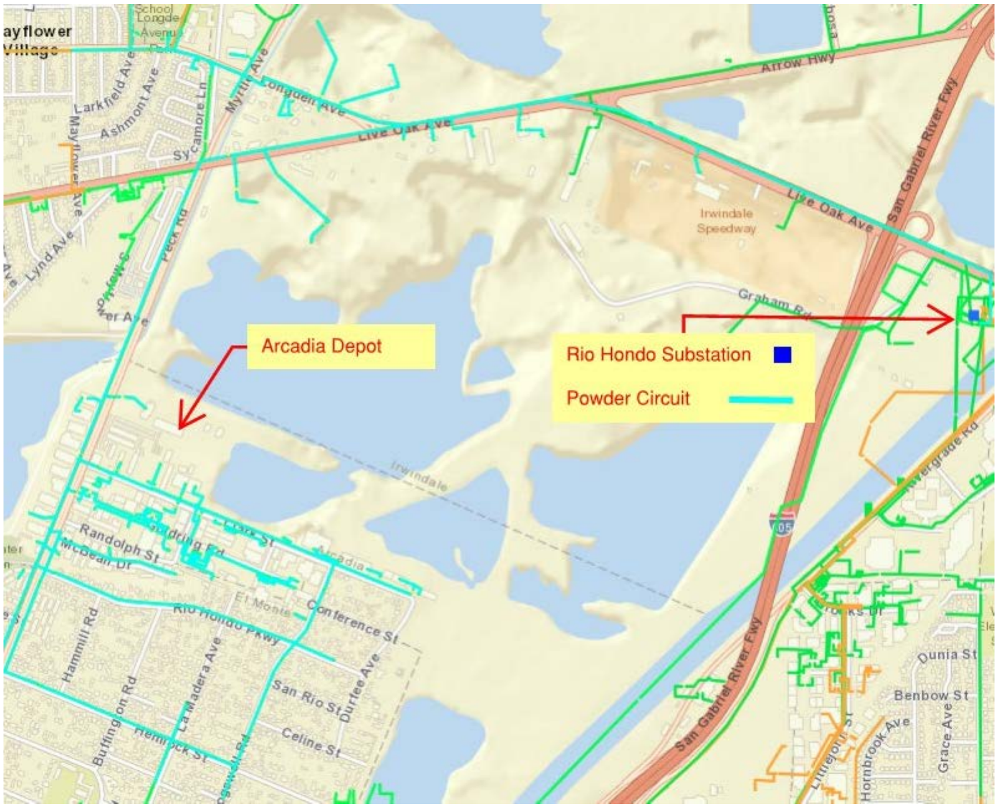
11.0 UTILITY GRID INFRASTRUCTURE ASSESSMENT

It is critical to understand the capacity of the local electric distribution network when considering a full-scale electrification of a bus fleet of over 350 buses. Foothill Transit bus depots are located in different cities that are both served by Southern California Edison (SCE). Engaging the local electric utility early in the planning stages for a full fleet electrification gives the utility an understanding of how load growth from bus electrification may impact the distribution grid and enables them to plan how future load growth may impact their planed upgrades and rate fillings. In this section the local distribution networks serving both Arcadia and Pomona depots were evaluated and a summary of SCE programs available to Foothill transit is discussed.

11.1 Identification of SCE's Distribution Grid Infrastructure

The Arcadia Yard is located at 5640 Peck Rd. in Arcadia CA. Electric service is provided by SCE from a 16 kV distribution circuit named Powder. The circuit is stepped down to 16 kV from 66 kV at Rio Hondo Substation. Rio Hondo Substation is in Irwindale, CA and located near the crossing of Live Oak Ave and Rivergrade Ave. Figure 11-1 provides an overview of the substation and circuit that serves the Arcadia depot.

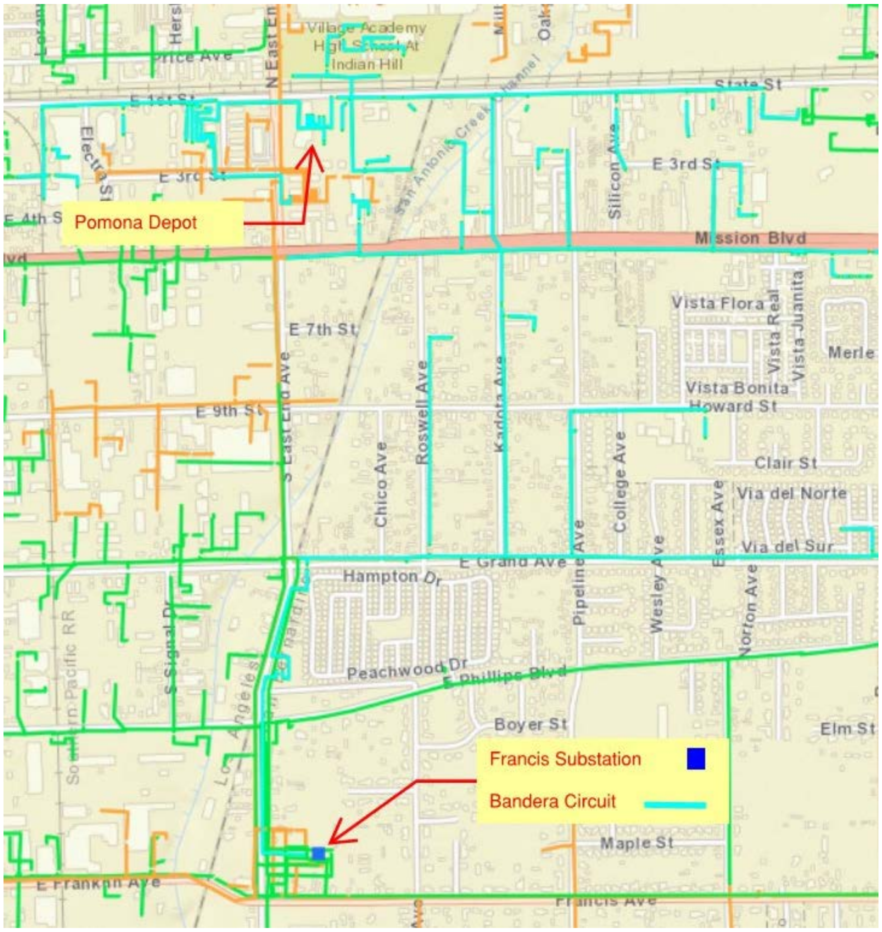
Figure 11-1: Arcadia Yard Local Distribution Network



SCE indicated to BMcD that as of November 2018, they should have sufficient capacity on the circuits serving Arcadia depot to serve the load growth over the next few years. SCE will integrate Arcadia's future load growth into their planning for the area so that they can support the planned growth. Foothill will not be responsible for any upgrades to the Powder Circuit resulting from Foothill Transit's load growth.

The Pomona Foothill Transit yard is located at 200 S East End Ave. in Pomona CA. Electric service is provided by SCE from a 12 kV distribution circuit named Bandera. The circuit is stepped down to 12 kV from 66 kV at Francis Substation. Francis Substation is in the northeast corner of S East End Ave and Francis Ave in Pomona. Figure 11-2 provides an overview of the substation and circuit that serves the Pomona depot.

Figure 11-2: Pomona Yard Local Distribution Network



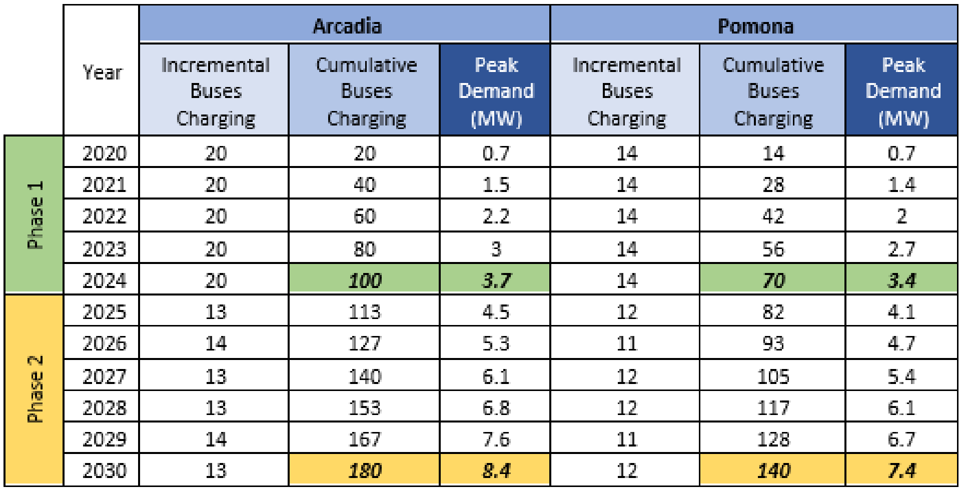
SCE indicated to BMcD that as of November 2018, they should have enough capacity on the circuits serving Pomona depot to serve the load growth over the short term. SCE will integrate Pomona's future load growth into their planning for the area so that they can support the planned growth. Foothill will not be responsible for any upgrades to the Bandera Circuit resulting from Foothill Transit's load growth.

It is worth noting that SCE prepares an "Annual System Reliability Report" that it files with the California Public Utilities Commission ("CPUC") on an annual basis. For 2017, Powder circuit serving Arcadia depot and Bandera circuit serving Pomona depot were not listed as the top 1% worst performing circuits.

11.2 Forecasted Bus Load at Arcadia and Pomona Yard

In November 2018, the project team that included members of Foothill Transit and Burns & McDonnell conducted a conference call with SCE representatives. The general discussion included a conversation regarding the expected load growth projections during the electrification of Foothill Transit's bus fleet. Coordination with SCE is continuous but based on the estimates provided from a load forecast analysis completed during this study, the combined peak use by 2030 is nearly 16 MW. With load management applications, the Arcadia depot will peak at 8.4 MW in 2030. Pomona will observe a peak of 7.4 MW for a complete electrification of buses. The projection, by year, shown in Figure 11-3 represents peak demand caused by bus charging with 100 kW chargers and load management after 9 pm. Figure 11-3 was provided to SCE.

Figure 11-3: Load Forecast as of November 2018

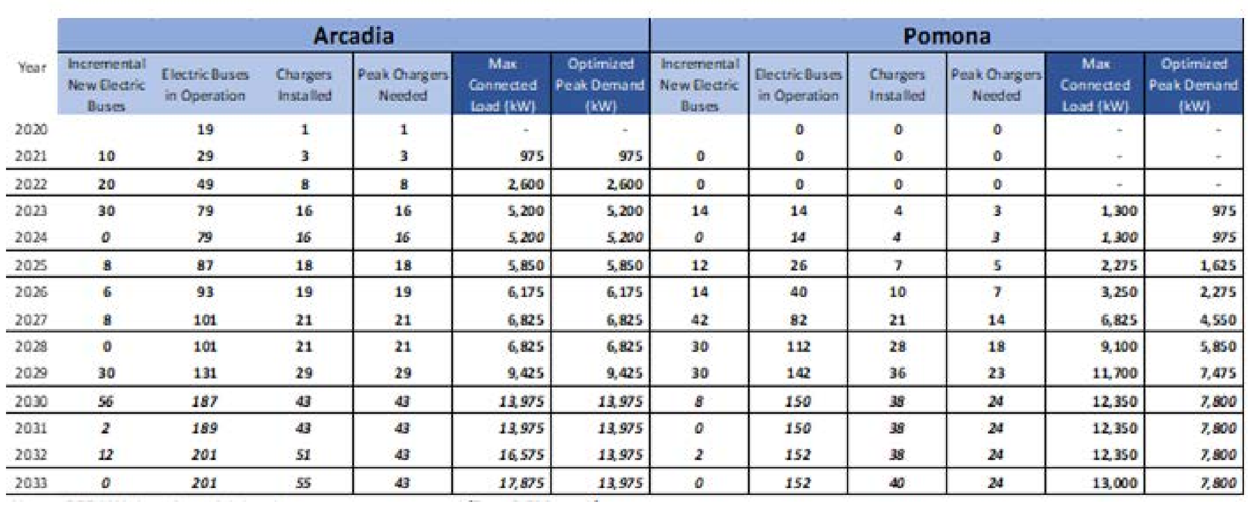


		Arcadia			Pomona		
	Year	Incremental Buses Charging	Cumulative Buses Charging	Peak Demand (MW)	Incremental Buses Charging	Cumulative Buses Charging	Peak Demand (MW)
Phase 1	2020	20	20	0.7	14	14	0.7
	2021	20	40	1.5	14	28	1.4
	2022	20	60	2.2	14	42	2
	2023	20	80	3	14	56	2.7
	2024	20	***100***	***3.7***	14	***70***	***3.4***
Phase 2	2025	13	113	4.5	12	82	4.1
	2026	14	127	5.3	11	93	4.7
	2027	13	140	6.1	12	105	5.4
	2028	13	153	6.8	12	117	6.1
	2029	14	167	7.6	11	128	6.7
	2030	13	***180***	***8.4***	12	***140***	***7.4***

The load forecast in Figure 11-3 was revised and updated based on the analysis completed in Section 4 of this report where 325 kW chargers were determined as the best option for charging electric buses operating on Foothill Transit routes. The revised load forecast providing number of electric buses, number of chargers installed, max connected load, and optimized peak demand is provided in Figure 11-4.

Charging is assumed to occur after 9pm. Arcadia's 2030 peak load forecast increased from 8,400 kW to 13,975 kW. Pomona's 2030 peak load forecast increased from 7,400 kW to 7,800 kW. These revised load forecasts should be provided to SCE when Foothill is prepared to move forward with the project.

Figure 11-4: Revised Load Forecast as of March 2019



Year	Arcadia						Pomona					
	Incremental New Electric Buses	Electric Buses in Operation	Chargers Installed	Peak Chargers Needed	Max Connected Load (kW)	Optimized Peak Demand (kW)	Incremental New Electric Buses	Electric Buses in Operation	Chargers Installed	Peak Chargers Needed	Max Connected Load (kW)	Optimized Peak Demand (kW)
2020		19	1	1	-	-		0	0	0	-	-
2021	10	29	3	3	975	975	0	0	0	0	-	-
2022	20	49	8	8	2,600	2,600	0	0	0	0	-	-
2023	30	79	16	16	5,200	5,200	14	14	4	3	1,300	975
2024	0	79	16	16	5,200	5,200	0	14	4	3	1,300	975
2025	8	87	18	18	5,850	5,850	12	26	7	5	2,275	1,625
2026	6	93	19	19	6,175	6,175	14	40	10	7	3,250	2,275
2027	8	101	21	21	6,825	6,825	42	82	21	14	6,825	4,550
2028	0	101	21	21	6,825	6,825	30	112	28	18	9,100	5,850
2029	30	131	29	29	9,425	9,425	30	142	36	23	11,700	7,475
2030	56	187	43	43	13,975	13,975	8	150	38	24	12,350	7,800
2031	2	189	43	43	13,975	13,975	0	150	38	24	12,350	7,800
2032	12	201	51	43	16,575	13,975	2	152	38	24	12,350	7,800
2033	0	201	55	43	17,875	13,975	0	152	40	24	13,000	7,800

11.3 Summary of SCE's Charge Ready Program

Foothill Transit is eligible to participate in the SCE Charge Ready Transit Bus Program. Preliminary discussions with SCE in November 2018, indicate that the deployment of make-ready electric vehicle charging infrastructure may result in some cost recovery. Participating transit agencies are eligible to receive rebates that help offset electric bus charging equipment. In part, program eligibility includes the following:

- Non-residential customer of SCE
- Purchase proof of new plug-in electric buses (w/in 5 years after installation of chargers)
- One bus route that impacts disadvantaged community
- Agreement to use EV Time-of-Use rates
- Easement rights granted to SCE

The electrification of bus fleets equates to electric load growth for SCE. The increased load resulting from Foothill Transit bus electrification will not result in line-extension charges. SCE aggregates this expected load growth with other customer growth to estimate future infrastructure requirements. SCE will pay 100% of the electrical costs for the distribution line modifications, distribution service transformers, and service drop leading up to the electric chargers located within the depot. Capital expenditures incurred by

SCE will be applied to the distribution system rate base through typical rate proceedings. SCE will review the proposed depot charging configurations developed within this study and provide electrical service to the chargers based on designs prepared by their engineering design team. All of the electrical equipment and circuits leading up to the 325-kW charger will be owned, operated, and maintained by SCE. Foothill Transit will receive and pay for service at the meter on the low side of the transformer under the appropriate SCE EV TOU rate.

12.0 RENEWABLE ENERGY SUPPLY AND BACK UP POWER PLAN

Multiple onsite and offsite renewable options were considered when determining the best path for Foothill Transit to implement renewable energy sources and back up generation for its fleet operations. The assessment started by evaluating the energy requirements of Foothill Transit as it transitions its fleet to 100% BEB's. Once the energy requirements through the different phases of implementation were established, an energy implementation plan was developed to demonstrate how Foothill Transit could successfully source energy from 100% renewable resources. Onsite generation was evaluated and developed by looking at how much solar and storage could be physically located at the Arcadia and Pomona depots. SCE's long-term renewable percentage mandate was evaluated along with the potential for sourcing renewable energy from purchase power agreements (PPA's). Lastly, since Foothill Transit's operations are critical to serving its community, back up generation options such as diesel and natural gas generators were explored and developed to allow Foothill Transit to continue to provide service even when grid power is unavailable.

12.1 Foothill Transit Energy Requirements

The forecasted electrical energy requirements presented in Table 12-1 and Table 12-2 indicate that the Arcadia and Pomona depots will gradually ramp up to a total electrical energy requirement of 29,222 MWh/year and 16,468 MWh/year with peak demands of 13.9 MW and 7.8 MW by 2030, respectively. The forecasted energy requirements by depot are based on the fleet electrification energy analysis including the number of 325 kW chargers required at each yard to support the electrification of buses for each year until 100% electrification in 2030. The highlighted cells in each table represent when new phases of EV overhead charging infrastructure are installed (i.e. 2021 and 2026 at Arcadia).

Table 12-1: Arcadia Depot Load and Energy Growth

Year	New Busses	Total Busses	Foothill Bus Power Demand (kW)	Foothill Bus Energy (kWh)
2020	0	0	0	0
2021	19	19	1,398	2,922,200
2022	30	49	3,604	7,536,200
2023	30	79	5,811	12,150,200
2024	0	79	5,811	12,150,200
2025	8	87	6,399	13,380,600
2026	6	93	6,840	14,303,400
2027	8	101	7,429	15,533,800
2028	0	101	7,429	15,533,800
2029	30	131	9,635	20,147,800
2030	56	187	13,754	28,760,600
2031	3	190	13,975	29,222,000

Table 12-2: Pomona Depot Load and Energy Growth

Year	New Busses	Total Busses	Foothill Bus Power Demand (kW)	Foothill Bus Energy (kWh)
2020	0	0	0	0
2021	0	0	0	0
2022	0	0	0	0
2023	13	13	780	1,752,200
2024	1	14	840	1,886,985
2025	12	26	1,560	3,504,400
2026	14	40	2,400	5,391,385
2027	42	82	4,920	11,052,338
2028	30	112	6,720	15,095,877
2029	5	117	7,020	15,769,800
2030	13	130	7,800	17,522,000
2031	0	130	7,800	17,522,000

12.2 Foothill Transit Renewable Power Supply Plan

Based on the estimated load growth and energy requirements from the phased bus electrification plan, Foothill Transit could work towards obtaining renewable power supply from three different sources as outlined below. For each source of renewable energy supply, an implementation plan is also provided. The balance of loads and resources from 2021 to 2045 are presented in Table 12-3 and Table 12-4 and Figure 12-1. The SCE Non-Renewable Energy values shown in the tables below represent the non-renewable portion of energy purchased at each of the facilities. The basic components of the renewable power supply plan are summarized as follows.

1. SCE Renewable Energy - Purchase SCE grid energy which will increase from 30% renewable (2020) to 100% renewable (2045).

2. On-Site Renewable Energy - Install on-site solar on overhead charging structures as charging infrastructure is completed. This can provide roughly 5% of Foothill's total energy requirement.

3. Off-Site Renewable Energy - Purchase off-site wind energy through a PPA between 2021 and 2041 if economical. This can be used to replace the balance of the SCE non-renewable power.

Table 12-3: Arcadia Depot Energy Uses and Sources

Arcadia

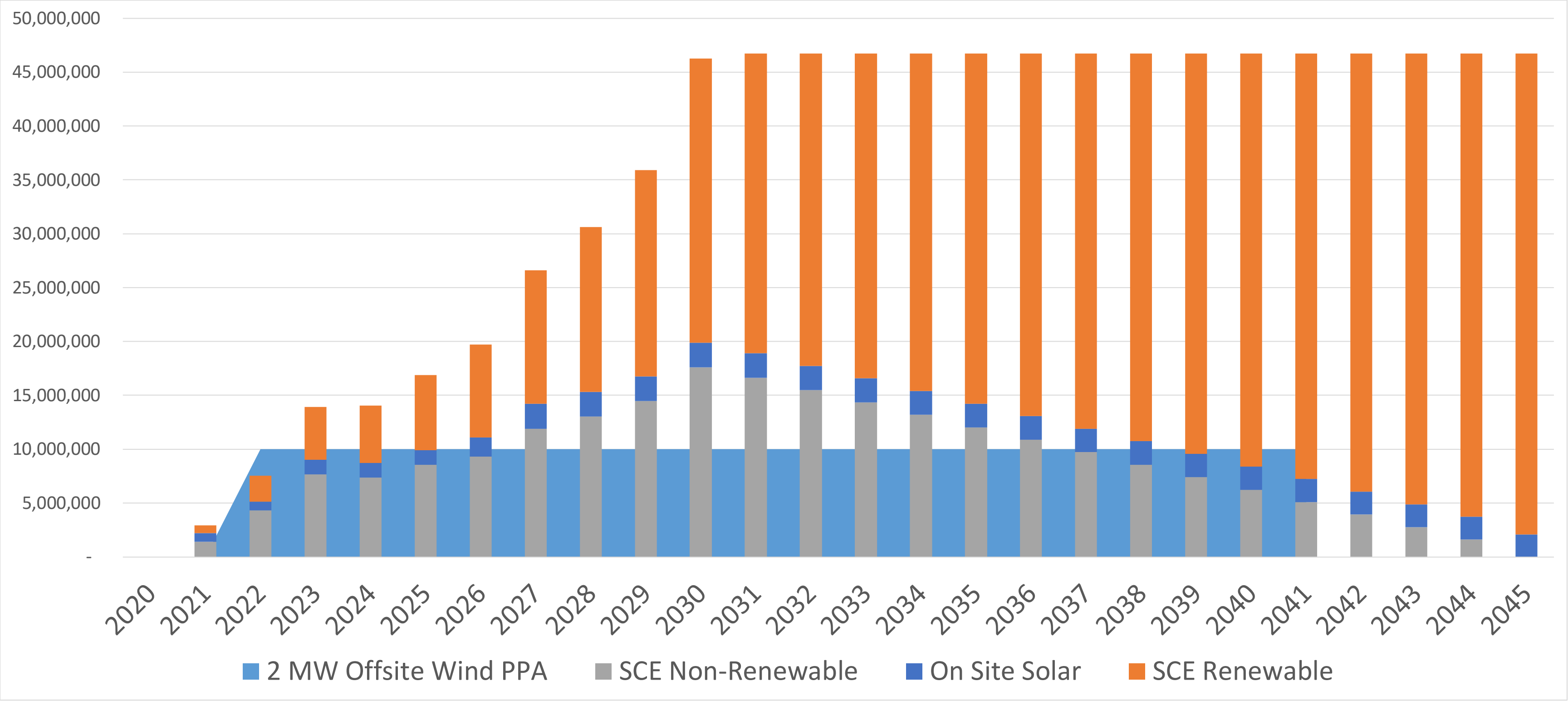
Year	New Busses	Total Busses	Foothill Bus Power Demand (kW)	Foothill Bus Energy (kWh)	Max On Site Solar Energy (kW)	Max On Site Solar Energy (kWh)	SCE Energy (kWh)	SCE Renewable %	SCE Renewable Energy (kWh)	SCE Non-Renewable Energy (kWh)
2020	0	0	0	0		0	0	30%	0	0
2021	**19**	**19**	**1,398**	**2,922,200**	**467**	**812,211**	**2,109,989**	**33%**	**696,296**	**1,413,692**
2022	30	49	3,604	7,536,200	467	808,176	6,728,024	36%	2,422,089	4,305,935
2023	30	79	5,811	12,150,200	467	804,156	11,346,044	39%	4,424,957	6,921,087
2024	0	79	5,811	12,150,200	467	800,153	11,350,047	42%	4,767,020	6,583,027
2025	8	87	6,399	13,380,600	467	796,150	12,584,450	45%	5,663,003	6,921,448
2026	**6**	**93**	**6,840**	**14,303,400**	**718**	**1,228,688**	**13,074,712**	**48%**	**6,275,862**	**6,798,850**
2027	8	101	7,429	15,533,800	718	1,222,516	14,311,284	51%	7,298,755	7,012,529
2028	0	101	7,429	15,533,800	718	1,216,353	14,317,447	54%	7,731,422	6,586,026
2029	30	131	9,635	20,147,800	718	1,210,198	18,937,602	57%	10,794,433	8,143,169
2030	56	187	13,754	28,760,600	718	1,204,043	27,556,557	60%	16,533,934	11,022,623
2031	**3**	**190**	**13,975**	**29,222,000**	**718**	**1,197,888**	**28,024,112**	**63%**	**17,543,094**	**10,481,018**
2032	0	190	13,975	29,222,000	718	1,191,733	28,030,267	65%	18,275,734	9,754,533
2033	0	190	13,975	29,222,000	718	1,185,578	28,036,422	68%	19,008,694	9,027,728
2034	0	190	13,975	29,222,000	718	1,179,424	28,042,576	70%	19,741,974	8,300,603
2035	0	190	13,975	29,222,000	718	1,173,269	28,048,731	73%	20,475,574	7,573,157
2036	0	190	13,975	29,222,000	718	1,167,114	28,054,886	76%	21,209,494	6,845,392
2037	0	190	13,975	29,222,000	718	1,160,959	28,061,041	78%	21,943,734	6,117,307
2038	0	190	13,975	29,222,000	718	1,154,804	28,067,196	81%	22,678,294	5,388,902
2039	0	190	13,975	29,222,000	718	1,148,649	28,073,351	83%	23,413,174	4,660,176
2040	0	190	13,975	29,222,000	718	1,142,495	28,079,505	86%	24,148,375	3,931,131
2041	0	190	13,975	29,222,000	718	1,136,340	28,085,660	89%	24,883,895	3,201,765
2042	0	190	13,975	29,222,000	718	1,130,185	28,091,815	91%	25,619,735	2,472,080
2043	0	190	13,975	29,222,000	718	1,124,030	28,097,970	94%	26,355,896	1,742,074
2044	0	190	13,975	29,222,000	718	1,117,875	28,104,125	96%	27,092,376	1,011,748
2045	0	190	13,975	29,222,000	718	1,111,720	28,110,280	100%	28,110,280	-

Table 12-4: Pomona Depot Energy Uses and Sources

Pomona

Year	New Busses	Total Busses	Foothill Bus Power Demand (kW)	Foothill Bus Energy (kWh)	Max On Site Solar Energy (kW)	Max On Site Solar Energy (kWh)	SCE Energy (kWh)	SCE Renewable %	SCE Renewable Energy (kWh)	SCE Non-Renewable Energy (kWh)
2020	0	0	0	0		0	0	30%	0	0
2021	0	0	0	0		0	0	33%	0	0
2022	0	0	0	0		0	0	36%	0	0
2023	**13**	**13**	**780**	**1,752,200**	**312**	**542,634**	**1,209,566**	**39%**	**471,731**	**737,835**
2024	1	14	840	1,886,985	312	539,938	1,347,047	42%	565,760	781,287
2025	12	26	1,560	3,504,400	312	537,252	2,967,148	45%	1,335,217	1,631,931
2026	14	40	2,400	5,391,385	312	534,578	4,856,807	48%	2,331,267	2,525,540
2027	**42**	**82**	**4,920**	**11,052,338**	**624**	**1,074,537**	**9,977,802**	**51%**	**5,088,679**	**4,889,123**
2028	30	112	6,720	15,095,877	624	1,069,166	14,026,710	54%	7,574,424	6,452,287
2029	5	117	7,020	15,769,800	624	1,063,806	14,705,994	57%	8,382,417	6,323,577
2030	13	130	7,800	17,522,000	624	1,058,457	16,463,543	60%	9,878,126	6,585,417
2031	**0**	**130**	**7,800**	**17,522,000**	**624**	**1,053,108**	**16,468,892**	**63%**	**10,309,526**	**6,159,366**
2032	0	130	7,800	17,522,000	624	1,047,759	16,474,241	65%	10,741,205	5,733,036
2033	0	130	7,800	17,522,000	624	1,042,410	16,479,590	68%	11,173,162	5,306,428
2034	0	130	7,800	17,522,000	624	1,037,061	16,484,939	70%	11,605,397	4,879,542
2035	0	130	7,800	17,522,000	624	1,031,712	16,490,288	73%	12,037,910	4,452,378
2036	0	130	7,800	17,522,000	624	1,026,363	16,495,637	76%	12,470,702	4,024,935
2037	0	130	7,800	17,522,000	624	1,021,014	16,500,986	78%	12,903,771	3,597,215
2038	0	130	7,800	17,522,000	624	1,015,665	16,506,335	81%	13,337,119	3,169,216
2039	0	130	7,800	17,522,000	624	1,010,316	16,511,684	83%	13,770,745	2,740,940
2040	0	130	7,800	17,522,000	624	1,004,967	16,517,033	86%	14,204,649	2,312,385
2041	0	130	7,800	17,522,000	624	999,618	16,522,382	89%	14,638,831	1,883,552
2042	0	130	7,800	17,522,000	624	994,269	16,527,731	91%	15,073,291	1,454,440
2043	0	130	7,800	17,522,000	624	988,919	16,533,081	94%	15,508,030	1,025,051
2044	0	130	7,800	17,522,000	624	983,570	16,538,430	96%	15,943,046	595,383
2045	0	130	7,800	17,522,000	624	978,221	16,543,779	100%	16,543,779	-

Figure 12-1: Foothill Transit Energy Uses and Sources (kWh)



12.3 SCE Renewable Energy Supply Plan

SCE is currently required to provide its retail customers power consisting of 30% renewable energy by 2020 and 100% renewable energy by 2045. This will provide a significant contribution towards meeting Foothill Transit's goal of obtaining renewable power supply. Several considerations that should be discussed as Foothill transitions to renewable energy are provided below:

a. SCE power purchased under EV TOU rate schedules already provides Foothill with power that is 30% renewable. This will increase over time without any incremental investment by Foothill Transit.
b. As SCE's power becomes more renewable (solar), the cost will increase and added TOU rate components will require Foothill Transit to avoid charging during on-peak periods when electricity prices are high.
c. Currently, it is not necessary for Foothill Transit to commit to procuring on-site solar or off-site renewable energy contracts or projects with terms extending past 2045 due to SCE's 100% renewable portfolio standard (RPS) requirement.
d. Foothill Transit can install on-site solar over the next several years to bridge the renewable gap until SCE reaches its 100% renewable goal by 2045. Foothill can procure offsite wind energy through a PPA to meet its goal of economical renewable energy until 2045.

12.4 Arcadia On-Site Renewable Energy Plan

On-site solar is economically viable today under the current EV TOU rate structure for the Arcadia depot based on analyses completed in this study. The phased site charging infrastructure plan was considered in the development of on-site solar and it was determined to be feasible to install a 467 kW array in the north portion of the depot (phase 1 - 2021) and a 251 kW array in the east portion of the depot (phase 2 - 2026). The size of the PV area is based on estimated area available within the Arcadia Depot to install a suitable PV array. Stationary battery energy storage, while not economical today, may become a viable option in the future; therefore space has been included in the future Arcadia infrastructure layout. The implementation plan to install this solar in coordination with the other overhead charging infrastructure is outlined below.

1. Phase 1 - Install 467 kW DC solar roof top canopy on top of phase 1 overhead charging structure in 2021.
    a. The phase 1 overhead charging structure should be designed to support solar racking, modules, and cables.
    b. Solar power should be fed directly into SCE's future EV switchgear to meet EV phase 1 loads. Switchgear should be designed to accommodate future solar and potential storage systems.

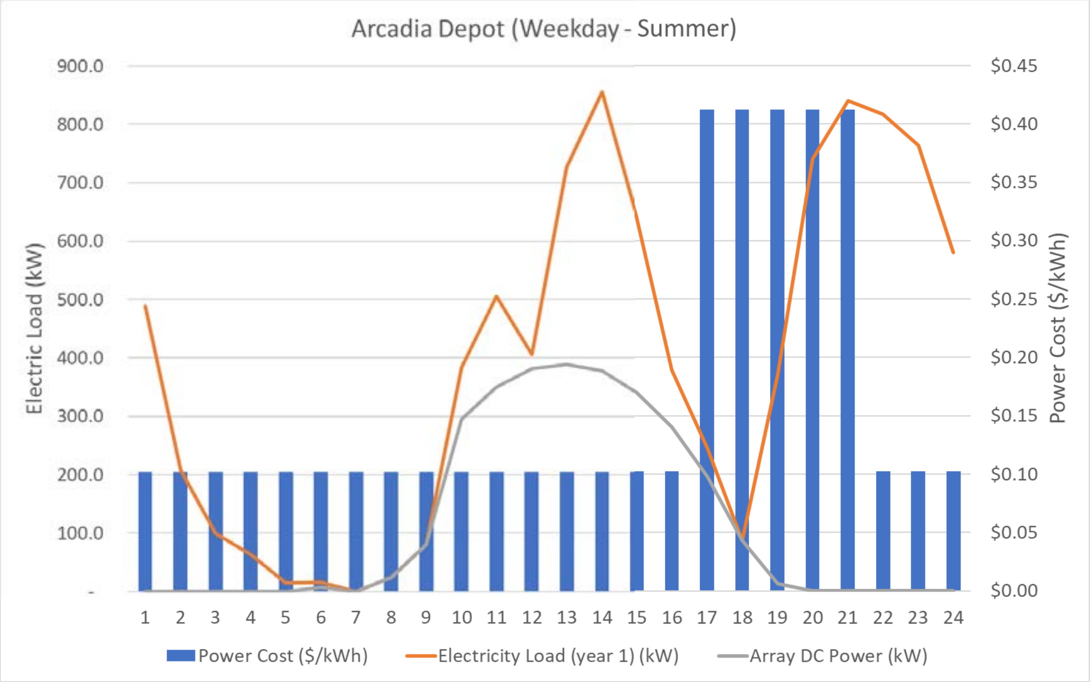
   c. Once Foothill Transit has completed its phase 1 charging structure design, Foothill should issue an RFP for the solar project. Foothill should request bids for PPA and EPC contracts by 11/2020.
   d. Preliminary design and performance information should be submitted with proposals to provide a fair evaluation of various module and inverter technologies costs and performance.
   e. Foothill Transit should evaluate the cost of owning the solar project versus purchasing a PPA contract based on bids provided. The evaluation and selection of the solar provider should be completed within 1 to 2 months with design and installation following over the next 12 months. If a PPA contract is selected, negotiations can take longer and delay the project.
   f. The Phase 1 solar project should be installed by a competent commercial solar company after the charging infrastructure is installed. The interconnection application to SCE is typically provided by the solar company.
   g. Target solar completion by 12/2021.

2. Phase 2 - Install 251 kW DC solar roof top canopy on top of phase 2 overhead charging structure in 2026
   a. The phase 2 overhead charging structure should be designed to support solar racking, modules, and cables.
   b. Solar power should be fed directly into SCE's future EV switchgear to meet EV phase 2 loads. Switchgear should be designed to accommodate future solar and potentially storage.
   c. Once Foothill has completed its phase 1 charging structure design, Foothill should issue an RFP for the solar project. Foothill should request bids for PPA and EPC contracts by 11/2025.
   d. Preliminary design and performance information should be submitted with proposals to provide a fair evaluation of various module and inverter technology, costs, and performance.
   e. Foothill should evaluate the cost of owning the solar project versus purchasing a PPA contract based on bids provided. The evaluation and selection of the solar provider should be completed within 1 to 2 months with design and installation following over the next 12 months. If a PPA contract is selected, negotiations can take longer and can delay the project.
   f. The Phase 2 solar project should be installed by a competent regional commercial solar company after the charging infrastructure is installed. Target solar completion by 12/2026.
   g. Total phase 1 and 2 on-site solar will provide 4% of Arcadia's energy requirement in 2030.

Figure 12-2 provides a conceptual overview of where the solar system could be installed for phase 1 and phase 2. Figure 12-3 provides a typical daily generation and load profile curve of the site in year 1 including only phase 1.

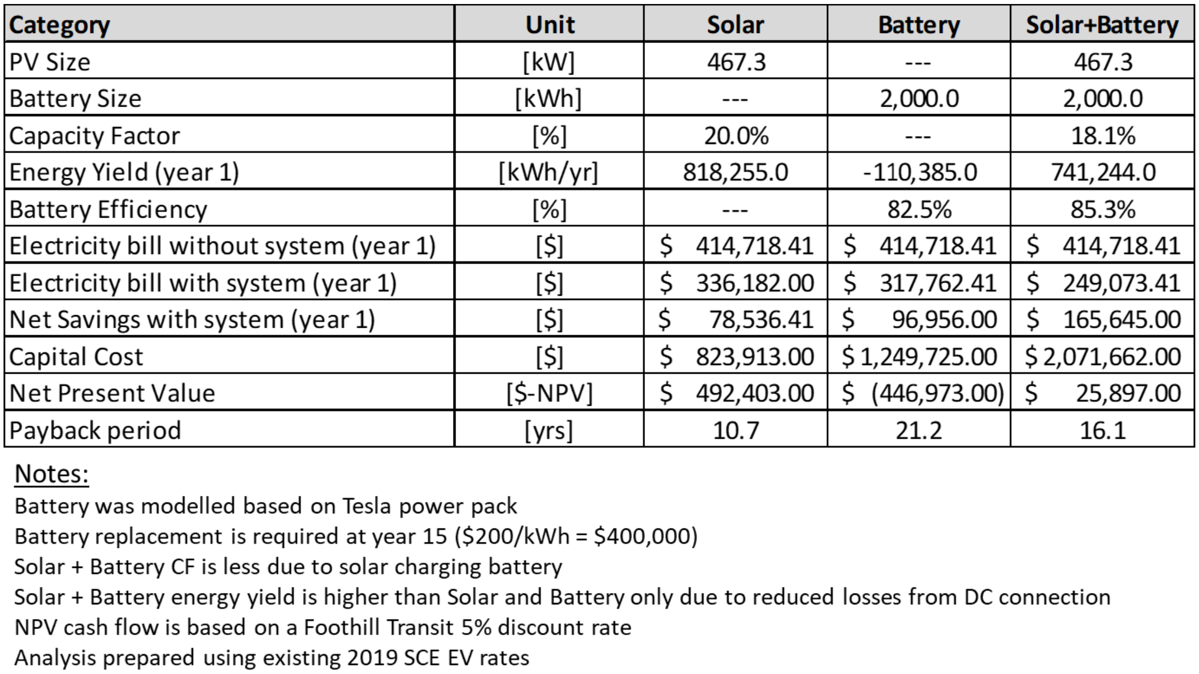
Figure 12-2: Arcadia Depot Solar Layout

Figure 12-3: Arcadia Load and Solar Generation versus Time of Use Rates (Phase 1 - Year 1)



The economics of installing solar and battery energy storage was analyzed in detail using the National Renewable Energy Laboratory software called System Advisor Model. Detailed hourly loads, electric rates, hourly generation yield, project costs, and economic parameters were developed and used to analyze the economic performance of the solar, storage, and solar/storage options at the Arcadia depot for phase 1. A summary of the financial results from that analysis are provided in Table 12-5 along with several of the key assumptions from that analysis. Based on the results of the analysis, Foothill should only install solar on the BEB charging canopy structures today as the addition of a battery does not generate enough incremental savings to offset the incremental cost. However, once Foothill Transit begins to be charged demand charges by SCE, the addition of a battery energy storage system should be reconsidered as it may generate additional savings to Foothill.

Table 12-5: Arcadia On-Site Solar and Energy Storage Economic Analysis Results



Category	Unit	Solar	Battery	Solar+Battery
PV Size	[kW]	467.3	---	467.3
Battery Size	[kWh]	---	2,000.0	2,000.0
Capacity Factor	[%]	20.0%	---	18.1%
Energy Yield (year 1)	[kWh/yr]	818,255.0	-110,385.0	741,244.0
Battery Efficiency	[%]	---	82.5%	85.3%
Electricity bill without system (year 1)	[$]	$ 414,718.41	$ 414,718.41	$ 414,718.41
Electricity bill with system (year 1)	[$]	$ 336,182.00	$ 317,762.41	$ 249,073.41
Net Savings with system (year 1)	[$]	$ 78,536.41	$ 96,956.00	$ 165,645.00
Capital Cost	[$]	$ 823,913.00	$ 1,249,725.00	$ 2,071,662.00
Net Present Value	[$-NPV]	$ 492,403.00	$ (446,973.00)	$ 25,897.00
Payback period	[yrs]	10.7	21.2	16.1

Notes:

Battery was modelled based on Tesla power pack

Battery replacement is required at year 15 ($200/kWh = $400,000)

Solar + Battery CF is less due to solar charging battery

Solar + Battery energy yield is higher than Solar and Battery only due to reduced losses from DC connection

NPV cash flow is based on a Foothill Transit 5% discount rate

Analysis prepared using existing 2019 SCE EV rates

12.5 Pomona On-Site Renewable Energy Plan

On-site solar is economically viable today under the current EV TOU rate structure for the Pomona depot based on analyses completed in this study. The phased site charging infrastructure plan was considered in the development of on-site solar and it was determined to be feasible to install a 312 kW array in the north portion of the depot (phase 1 - 2023) and a 312 kW array in the east portion of the depot (phase 2 - 2027). The size of the PV area is based on estimated area available within the Pomona depot to install a suitable PV array. Stationary battery energy storage, while not economical today, may be a viable option in the future and therefore space has been included in the future Pomona infrastructure layout. The implementation plan to installing this solar in coordination with the other overhead charging infrastructure is outlined below:

1. Phase 1 includes installing a 312 kW DC solar roof top canopy on top of the phase 1 overhead charging structure in 2023.
    a. The phase 1 overhead charging structure should be designed to support solar racking, modules, and cables.
    b. Solar power shall be fed directly into SCE’s future EV switchgear to meet EV phase 1 loads. Switchgear shall be designed to accommodate future solar and potential energy storage.
    c. Once Foothill Transit has completed its phase 1 charging structure design, Foothill should issue an RFP for the solar project. Foothill Transit should request bids for PPA and EPC contracts by 11/2022.
    d. Preliminary design and performance information should be submitted with proposals to provide a fair evaluation of various module and inverter technology, costs, and performance.
    e. Foothill Transit should evaluate the cost of owning the solar project versus purchasing a PPA contract based on bids provided. The evaluation and selection of the solar provider should be completed within 1 to 2 months with design and installation following over the next 12 months. If a PPA contract is selected, negotiations can take longer and can delay the project.
    f. The Phase 1 solar project should be installed by a competent regional commercial solar company after the charging infrastructure is installed. Target solar completion by 12/2023.

2. Phase 2 includes installing a 312 kW DC solar roof top canopy on top of phase 2 overhead charging structure in 2027.
    a. The phase 2 overhead structure should be designed to support solar racking, modules, and cables.
    b. Solar power shall be fed directly into SCE’s future EV switchgear to meet EV phase 2 loads. Switchgear shall be designed to accommodate future solar and potentially storage.
    c. Once Foothill has completed its phase 2 charging structure design, Foothill should issue an RFP for the solar project. Foothill Transit should request bids for PPA and EPC contracts by 11/2026.
    d. Preliminary design and performance information should be submitted with proposals to provide a fair evaluation of various module and inverter technologies costs and performance.
    e. Foothill should evaluate the cost of owning the solar project versus purchasing a PPA contract based on bids provided. The evaluation and selection of the solar provider should be completed within 1 to 2 months with design and installation following over the next 12 months. If a PPA contract is selected, negotiations can take longer and can delay the project.

f. The phase 1 solar project should be installed by a competent regional commercial solar company after the charging infrastructure is installed. Target solar completion by 12/2027.

g. Total phase 1 and 2 on-site solar will provide 6% of Pomona's energy requirement in 2030

Figure 12-4 provides a conceptual overview of where the solar system could be installed for phase 1 and phase 2. Figure 12-5 provides a typical daily generation and load profile curve of the site in year 2 including phase 1 solar only.

Figure 12-4: Pomona Depot Solar Layout

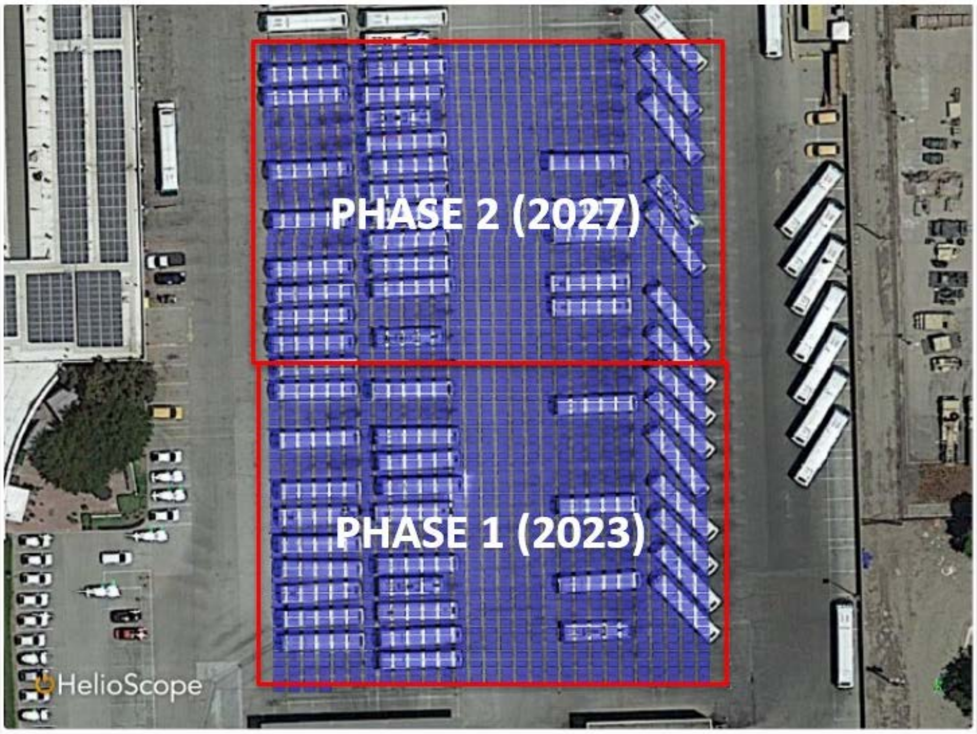
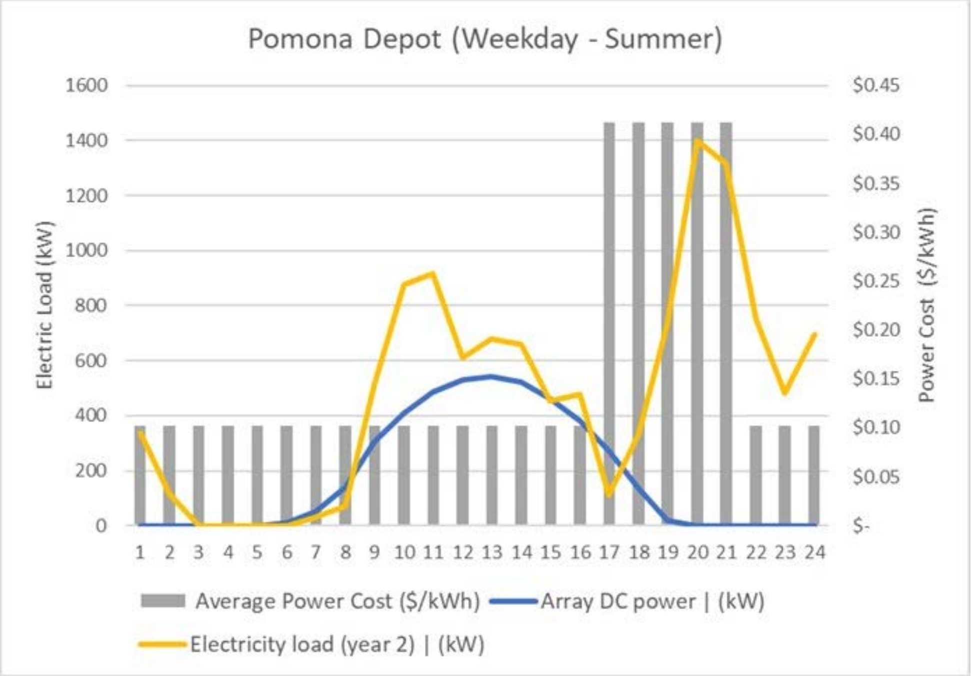
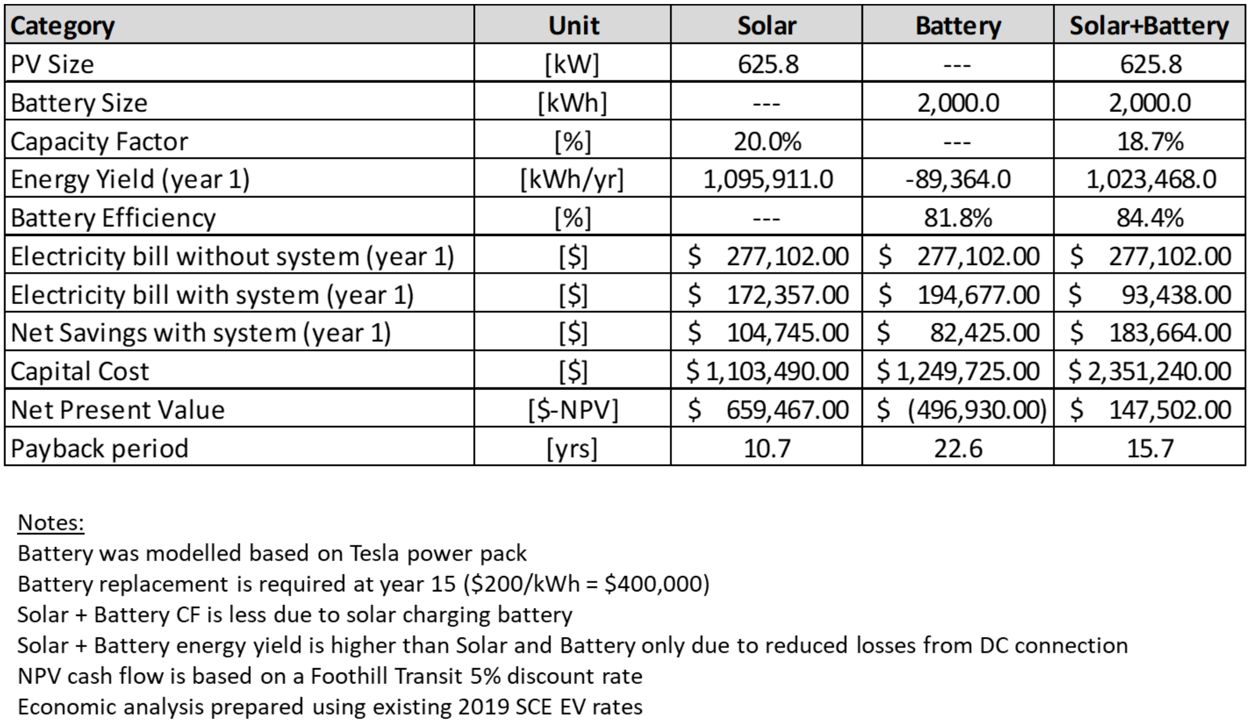


Figure 12-5: Pomona Load and Solar Generation versus Time of Use Rates (Phase 1 - Year 2)



Like Arcadia, the economics of installing solar and energy storage were analyzed in detail using the National Renewable Energy Laboratory software called System Advisor Model. Detailed hourly loads, electric rates, hourly generation yield, project costs, and economic parameters were developed and used to analyze the economic performance of the solar, storage, and solar/storage options at the Pomona site for a full future build out. A summary of the financial results from that analysis are provided in Table 12-6 along with several of the key assumptions from that analysis. Based on the results of the analysis, Foothill should install 312 kW of solar on the phase 1 canopy structures in 2023 and then another 312 kW of solar on the phase 2 canopy structures in 2027 for a full 625 kW. Like Arcadia, battery storage can be incorporated later as demand rates are implemented into the SCE bills charged to Foothill.

Table 12-6: Pomona On-Site Solar and Energy Storage Economic Analysis Results



Category	Unit	Solar	Battery	Solar+Battery
PV Size	[kW]	625.8	---	625.8
Battery Size	[kWh]	---	2,000.0	2,000.0
Capacity Factor	[%]	20.0%	---	18.7%
Energy Yield (year 1)	[kWh/yr]	1,095,911.0	-89,364.0	1,023,468.0
Battery Efficiency	[%]	---	81.8%	84.4%
Electricity bill without system (year 1)	[$]	$ 277,102.00	$ 277,102.00	$ 277,102.00
Electricity bill with system (year 1)	[$]	$ 172,357.00	$ 194,677.00	$ 93,438.00
Net Savings with system (year 1)	[$]	$ 104,745.00	$ 82,425.00	$ 183,664.00
Capital Cost	[$]	$ 1,103,490.00	$ 1,249,725.00	$ 2,351,240.00
Net Present Value	[$-NPV]	$ 659,467.00	$ (496,930.00)	$ 147,502.00
Payback period	[yrs]	10.7	22.6	15.7

Notes:
Battery was modelled based on Tesla power pack
Battery replacement is required at year 15 ($200/kWh = $400,000)
Solar + Battery CF is less due to solar charging battery
Solar + Battery energy yield is higher than Solar and Battery only due to reduced losses from DC connection
NPV cash flow is based on a Foothill Transit 5% discount rate
Economic analysis prepared using existing 2019 SCE EV rates

12.6 Off-Site Renewable Energy Plan

Foothill Transit cannot achieve a 100% economical renewable power supply through on-site resources and SCE's power supply mix until 2045. However, Foothill Transit may purchase off-site renewable energy through a PPA. The PPA contract enables Foothill Transit to purchase energy directly from a solar or wind project at a cost and sell that energy into the wholesale energy market for a margin. Based on the power supply RFI bids received in the study, there are financially attractive opportunities available to secure long term economical renewable energy. The implementation plan to securing off-site renewable power is provided below:

a. Once the fleet electrification procurement plan is finalized, Foothill Transit should establish the final balance of renewable energy desired. Assuming on-site solar and SCE power is purchased, the renewable energy deficit between 2021 and 2041 is 210,000 MWh or 10,000 MWh per year on average. If the procurement and operation of electric buses is delayed several years, the amount of off-site power should be reduced.
b. Conduct a renewable power RFP to secure off-site renewable PPA proposals beginning in 2021 or 2022. The RFP should be managed by Foothill Transit's procurement with bid evaluations done by others. Foothill Transit should release the renewable power supply RFP by 12/2020.

c. Foothill Transit should provide up to 2 months for bidders to respond to the renewable RFP with 1 month of evaluation and 2 months for contract negotiations. Existing projects energy will be available within a few months while new project PPAs may not be online for 1 to 2 years.

d. Off-site renewable power supply should be for a term between 10 and 20 years. In no event should Foothill Transit commit to purchasing off-site renewable energy beyond 2045.

e. Foothill Transit should only secure offsite renewable power PPAs that provide a positive cash flow. The location of the project does not need to be within California but should be located within a relatively stable and well-established U.S. wholesale energy market.

12.6.1 Off-Site Renewable Energy Solicitation and Analysis

As part of the renewable energy supply analysis, the project team solicited proposals from renewable energy projects across the United States through a non-binding request for information process. The solicitation requested non-binding proposals from renewable energy project companies and suppliers for 10,000 MWh per year over a term of 20 years. Confidential proposals for offsite renewable energy were received for 4 wind projects and one geothermal project. The project proposals were all priced for energy to be delivered at various wholesale market pricing nodes which included the Southwest Power Pool (SPP), Electric Reliability Council of Texas (ERCOT), and California Independent System Operator (CAISO). A summary of the project proposals received through the process is provided in Table 12-7.

For each of the confidential proposals received, the project team compared the cost of the renewable energy PPA with the value of the energy at the settlement location, also known as the locational marginal price (LMP). The annual production output of each project was weighted against the 2018 historically settlement point LMPs to determine the annual wholesale market revenue that would be generated by the project contract. The annual wholesale market revenues were compared to the annual contract costs to determine if the proposals provided positive value (profit) or negative value (loss) to Foothill under today’s market conditions. The results of this assessment are presented in Table 12-8.

Table 12-7: Off-Site Renewable Power Supply Proposals Received and Analyzed

Developer	Balancing Authority	Location / Technology	Project Size (MW)	Term
Developer 1	SPP	Oklahoma Wind	~300 MW 2021 COD	20
Developer 2	ERCOT	Texas Wind	~200 MW	10
One Wind Project	ERCOT	Texas Wind	Existing	10
3 LMPs Offerred	ERCOT	Texas Wind		10
Developer 3	CAISO	California Geothermal	Confidential MW Existing	20
Developer 4	SPP	Kansas Wind	~200 MW Existing	20
Two Wind Projects	SPP	Oklahoma Wind	<100 MW Existing	20

Table 12-8: Off-Site Renewable Power Supply Results

Developer	Location	LMP/Project	20 YEAR LCOE ($/MWh)	2018 P50 LMP ($/MWh)	NET PROFIT/LOSS ($/MWh)	ANNUAL NET PROFIT/LOSS
Developer 1	Oklahoma		**$18.00**	**$23.12**	**$5.12**	**$51,192**
Developer 2	Texas	LMP 1	**$16.75**	**$26.84**	**$10.09**	**$100,887**
	Texas	LMP 2	**$16.75**	**$24.72**	**$7.97**	**$79,719**
	Texas	LMP 3	**$16.75**	**$27.26**	**$10.51**	**$105,143**
Developer 3	California		**$84.48**	**$34.91**	**($49.57)**	**($495,671)**
Developer 4	Oklahoma	Project 1	**$18.00**	**$22.05**	**$4.05**	**$40,467**
	Kansas	Project 2	**$18.00**	**$23.13**	**$5.13**	**$51,344**

Based on the initial responses to the offsite renewable contract request for information, there are projects and contracts available that can provide renewable energy and the associated renewable attributes without requiring Foothill to pay more for that energy. As an example, the Oklahoma wind project PPA cost is $18 per MWh and the generation weighted market value for that energy is $23.12 per MWh for 10,000 MWh per year. Under today's market pricing conditions, this yields a potential profit of nearly $51,000 per year. However, if the LMP rises or falls, the profit (or loss) from this contract to Foothill may change in the future. These contracts are commonly employed by non-utility entities as a means of obtaining contracted renewable power supply without direct involvement with their utility company.

12.7 Emergency Response Planning and On-Site Backup Power

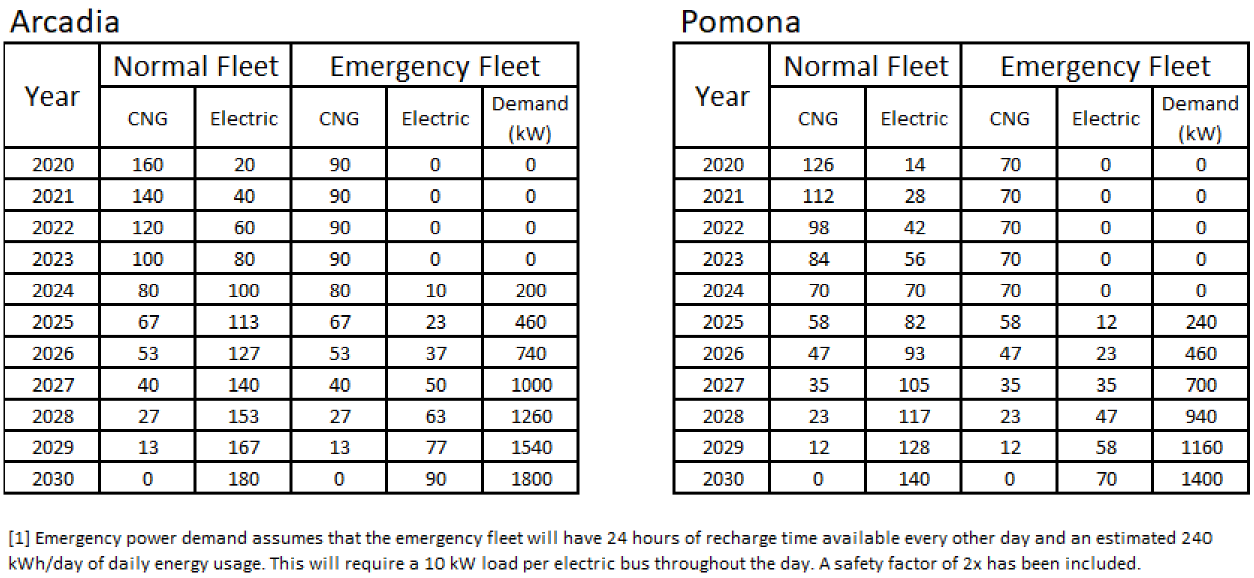
There are a multitude of potential power outage threats that could impair Foothill Transit's ability to operate its bus fleet. These threats change as Foothill Transit's fleet transitions to 100% BEB's. For example, an electrical power outage at either the depot or throughout the region would prevent recharging of the buses. Foothill Transit desires to have at least 50% of their fleet available during any extended power outage scenario. This section of the report provides a proposed solution to this requirement.

It is assumed that the 50% fleet requirement equates to 50% of the total energy demand daily. Unlike the CNG fleet, which can refuel quickly and return to service, the electric fleet needs multiple hours of charging to return to full readiness. Thus, if the electric fleet is pressed into longer than normal routes or higher than normal passenger counts, the total recharge time may dramatically increase over the normal charge period.

Since any on site generation asset does not carry a demand charge cost, charging twenty-four hours per day is a cost-effective solution. Therefore, each bus can be immediately recharged upon entering the depot, and any bus in the depot can be charged at any time. Since only half the fleet is deployed each day, it may be possible to divide the fleet into an odd/even dispatch model with odd numbered buses deployed on odd numbered days and vice versa for the even buses. On even numbered days, the odd fleet would have twenty-four hours to completely recharge while the even fleet would be serving the community's needs. In a theoretically perfect charging scenario, where each bus was given exactly the amount of charge it needed for the next day and there is no time lost switching between buses, it is theoretically possible to recharge the Arcadia or Pomona depot with a single 1 MW diesel or natural gas generator.

As Foothill Transit transitions from a fully CNG fleet to a fully electrified fleet, the required generation for the region-wide power outage scenario changes. The forecasted number of CNG and BEB in operation as well as the peak electrical demand requirements are presented in Table 12-9. The recommended back up source over the next 10 years is also presented and described in the following paragraphs.

Table 12-9: Emergency Fleet and Back Up Power Demand Requirement



Arcadia

Year	Normal Fleet		Emergency Fleet		
	CNG	Electric	CNG	Electric	Demand (kW)
2020	160	20	90	0	0
2021	140	40	90	0	0
2022	120	60	90	0	0
2023	100	80	90	0	0
2024	80	100	80	10	200
2025	67	113	67	23	460
2026	53	127	53	37	740
2027	40	140	40	50	1000
2028	27	153	27	63	1260
2029	13	167	13	77	1540
2030	0	180	0	90	1800

Pomona

Year	Normal Fleet		Emergency Fleet		
	CNG	Electric	CNG	Electric	Demand (kW)
2020	126	14	70	0	0
2021	112	28	70	0	0
2022	98	42	70	0	0
2023	84	56	70	0	0
2024	70	70	70	0	0
2025	58	82	58	12	240
2026	47	93	47	23	460
2027	35	105	35	35	700
2028	23	117	23	47	940
2029	12	128	12	58	1160
2030	0	140	0	70	1400

[1] Emergency power demand assumes that the emergency fleet will have 24 hours of recharge time available every other day and an estimated 240 kWh/day of daily energy usage. This will require a 10 kW load per electric bus throughout the day. A safety factor of 2x has been included.

Assuming that the existing CNG equipment at each depot is already capable of supplying 50% of the existing fleet with fuel during a prolonged power outage, between 2020 and 2023, both Arcadia and Pomona will be able to support emergency services with the remaining CNG busses.

At some point in 2024, fewer than half of the buses in operation on any given day are anticipated to be CNG. Thus, it will be necessary to implement an onsite back up power strategy by 2024 in order to allow the electric bus fleet to meet the community's needs during a widespread power outage. Since grid outages at either depot are rare and short lived, the most efficient solution is to utilize portable generators to supply power for recharging the fleet. These generators may be either directly owned by Foothill Transit or rented on an as needed basis with some sort of retainer fee paid to ensure their availability. The generators would be parked in bus stalls immediately adjacent to the power service points and connect to the distribution boards to supply power in place of the utility service. Each generator would be anticipated to nominally provide 2 MW in capacity, but smaller generators would be acceptable based on the actual number of electric buses needed. For example, in 2024 a 150 kW to 300 kW generator would be the minimum recommended size.

As noted earlier, due to the infrequent outages it is most cost efficient to rent portable generators on an as needed basis. However, there are two critical downsides to this approach. First, the rental generators, although contractually obligated to be available, may not be available during a large-scale power outage due to oversubscription of the actual generators (like overbookings by airlines). Secondly, there is an inherent time delay between the time the generator is called for and when it becomes available. As the fleet becomes more electrified, this delay may result in a shortage of buses. Thus, it is recommended to install a permanent source of power at each site.

Once the fleet is fully electrified in 2030, Foothill Transit will no longer require its CNG refueling stations. This real estate within the depot can be repurposed to serve as the location for a permanent diesel or natural gas-fired generator. For the purpose of redundancy, a typical solution would include two, 1,500 kW gas fired emergency generators at each depot to allow a sufficient number of buses would be available for the majority of scenarios. The existing high-pressure gas pipeline that delivers gas to the CNG refueling stations could be repurposed to provide backup gas supply to a natural gas generator. Each generator would tie to the 480V power panel from a single SCE electrical service thus repowering one or two of the charging islands at each depot. The fleet charging software would need to be adjusted to limit the power demand at these two locations to match the generator capacity, and bus handlers would need to cycle the buses through the energized charging stations around the clock. Preliminary concepts of this configuration are represented in Figure 12-6 and Figure 12-7.

Figure 12-6: Arcadia Depot Preliminary Natural Gas Backup Generator Power Concept

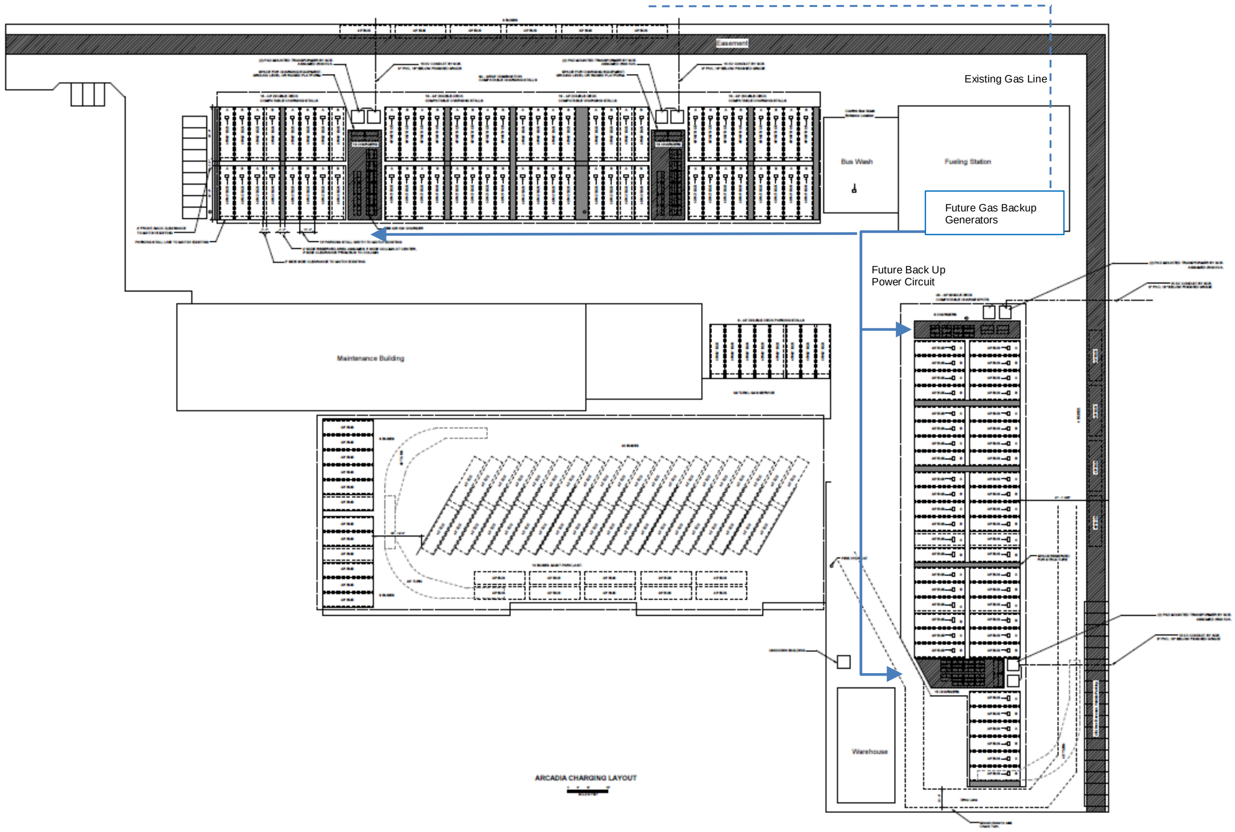
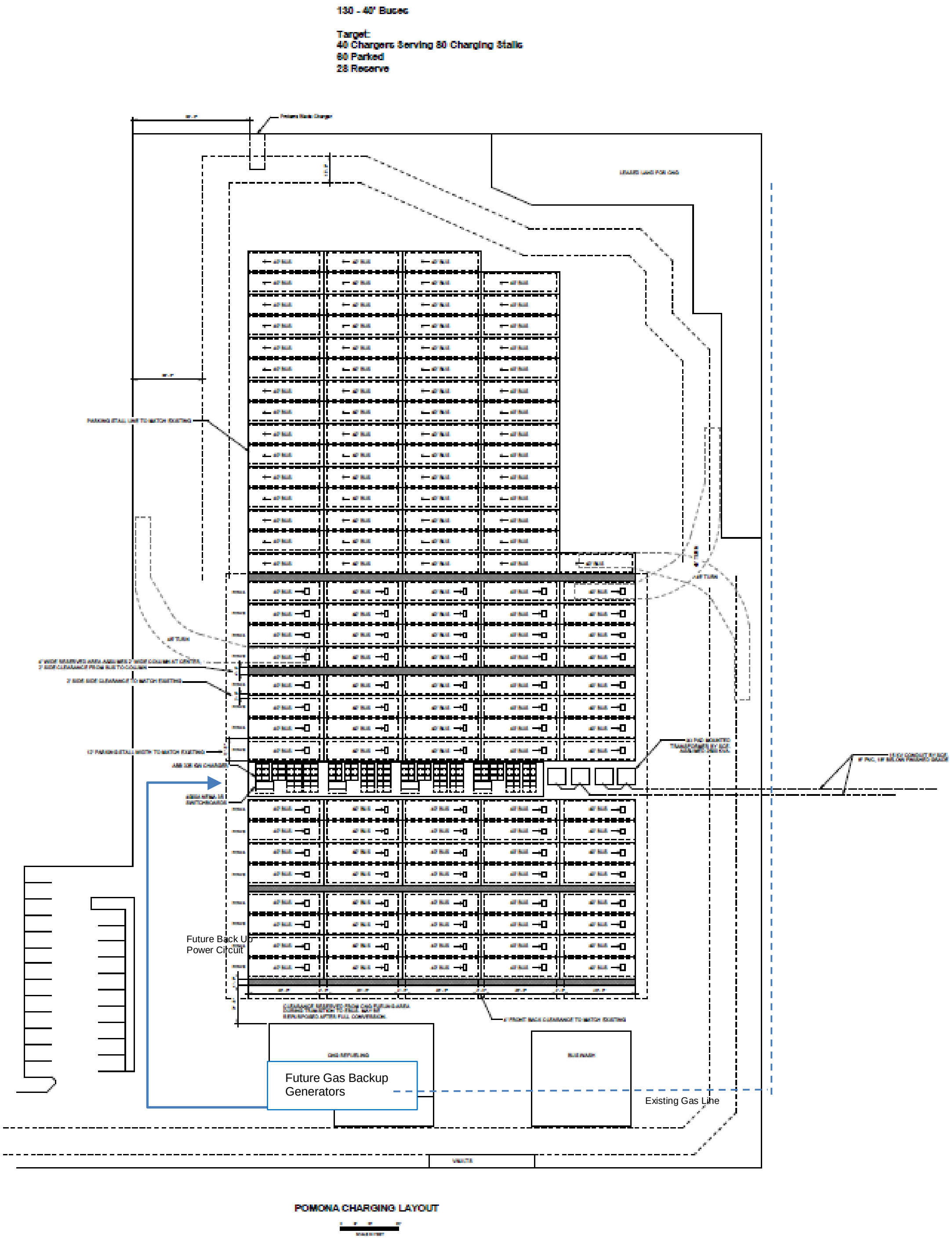


Figure 12-7: Pomona Depot Preliminary Natural Gas Backup Generator Power Concept



13.0 FLEET ELECTRIFICATION LIFE CYCLE COST ANALYSIS

As part of this Study, a life cycle cost (LCC) analysis was developed to evaluate the cost differences between owning and operating electric buses as compared to continued use of CNG buses. Previous study results from work prepared by the NREL, as well as results from this Study were used in the preparation of the analysis. The LCC analysis includes a fleet replacement transition plan under each of the two scenarios, as well as forecasts for operation and maintenance (O&M), electricity and CNG fuel, bus replacement costs, battery replacements, electric charging infrastructure, and charging infrastructure O&M. Understanding the total LCC differences between an transition to an electric bus fleet and the continued use of a CNG bus fleet provides Foothill Transit with the incremental cost to transition to an electric fleet over the next 25 years which is the expected useful life of the charging infrastructure while buses and chargers are assumed to have a 12 year life.

13.1 Approach

The approach for the LCC analysis included evaluating results derived from previous tasks completed within this Study, reviewing results prepared by NREL, and analyzing additional data to properly capture costs associated with each scenario. Core assumptions were developed pertaining to the costs to operate and maintain an electric bus fleet and the existing CNG bus fleet, with specific assumptions by location of bus depots in Pomona and Arcadia. These assumptions were used in a proforma model to forecast the estimated costs of bus equipment, energy and fuel, O&M, replacements of buses, engines, batteries and battery chargers, as well as capital and O&M for charging infrastructure. The forecast extended out 25 years with a net present value (NPV) calculation discounting costs back to today’s dollars. Cost summaries were developed to determine the estimated difference of replacing the existing fleet with electric buses and infrastructure as opposed to replacing the existing fleet with CNG buses.

13.2 Study Assumptions

Assumptions were developed for two scenarios; owning and operating an electric bus fleet versus the CNG bus fleet that Foothill Transit has in place today. These assumptions were specific to bus depot locations in both Pomona and Arcadia, as the average cost per bus and average miles driven per bus are different between locations. Cost assumptions were developed on a dollars per mile basis for O&M, while bus equipment, engine repairs, batteries, and charger replacements were on a dollar per bus basis. The annual electricity or fuel CNG fuel costs were developed using other methods described later in this section. Capital for infrastructure costs were forecasted based on Foothill Transit’s plan to transition their existing CNG bus fleets of Arcadia and Pomona to an all-electric bus fleet over the next 12 years with a target of nearly 100 percent of its routes being fully electrified by 2030 and all CNG buses being removed from the site by 2032. These assumptions are discussed in more detail in Sections 8 and 9 of this report. Annual inflation was applied to costs associated with O&M, electricity, fuel, and infrastructure while battery replacement costs were forecasted to remain constant.

13.3 Fleet Transition Plan

An annual fleet replacement plan was prepared for both the electric bus fleet and the existing CNG bus fleet, which is provided in Figure 9-1 of this report. The total number of future electric buses purchased is based on the March 2019 fleet procurement plan provided by Foothill Transit. The March 2019 plan assumed that the electric bus fleet would be sized similarly to a CNG fleet and that bus replacements would occur as the 12-year life of existing CNG buses come to an end. The March 2019 plan assumes that all CNG buses would be replaced by electric buses by 2032 with a total of 353 electric buses in service to serve a PVR of 287 buses. The existing fleet today operates with a reserve ratio of 15 to 20 percent with a minimum contract reserve ratio of 15 percent. Based on the analysis described in Section 4 of this report, Foothill will have a PVR of 320 and thus would need to purchase an additional 15 electric buses in order to maintain the 15 percent reserve ratio requirement in 2032 for a total adjusted fleet size of 368 buses. The cost of these 15 additional electric buses is factored into this LCC analysis.

13.4 Bus Equipment Costs

Bus equipment costs are based on the most recent costs Foothill Transit received when purchasing buses for their fleet. Cost assumptions were assumed for an electric 40-foot single deck ($900,000), electric double deck bus ($1,380,000), CNG 40-foot single deck ($654,000) and CNG 60-foot articulated bus ($1,000,000). Electric bus costs used in the forecast were assumed to not include existing California Hybrid and Zero-Emission Bus Incentive Project (HVIP) rebates that Foothill has historically received when purchasing electric buses. These are not assumed to be available in the base case as the state transitions to electric buses over the next 10 to 15 years.

13.5 Bus Operation & Maintenance Costs

O&M expense forecasts were based on information developed in the NREL Foothill Transit Agency Battery Electric Bus Progress Report (NREL Report). The NREL Report summarizes Foothill’s historical total scheduled repair cost per mile and unscheduled repair cost per mile. O&M expenses were recorded for electric buses versus CNG buses, but not by location. For electric buses, scheduled O&M costs averaged $0.08 per mile, and for CNG, scheduled O&M costs averaged $0.12 per mile. These average costs per mile were used to calculate an O&M cost per operating bus by multiplying the unit cost by the average miles driven by a bus per year, for both Arcadia and Pomona locations. Forecasted O&M expenses were inflated annually by 3.0 percent.

13.6 Electricity Costs

Electricity costs associated with charging the electric buses at the Arcadia and Pomona depots was determined based on the hourly energy usage models described in Section 4 of this report as well as the SCE EV TOU rates. It is assumed that buses are charged during the mid-peak (mid-day hours) and off-peak (late night) time periods as opposed to the on-peak (late afternoon) periods. This shift in load to low cost periods will result in a substantial cost reduction for Foothill Transit as SCE's EV TOU rate is far less expensive during the mid-peak and off-peak times. Estimated bills varied between Arcadia and Pomona as each depot has different charging profiles and usage amounts. On average, electric buses at Arcadia have a higher energy use per mile which contributes to the higher average electric cost per mile at Arcadia. The average electric cost at Pomona is $0.24 per mile while the average electric cost at Arcadia is $0.25 per mile with an average electric cost of approximately $0.097 per kWh between the two sites.

13.7 CNG Fuel Costs

Fuel costs are associated with Foothill Transit's existing CNG bus fleet. Forecasted fuel costs under the continued operation of the CNG bus fleet were estimated from actual monthly bills Foothill incurred from January of 2018 thru December of 2018. The most recent annual bills and the total number of miles driven by operating buses at each location were used to derive an average fuel cost per mile. Average fuel costs varied between locations, with Pomona at $0.25 per mile, and Arcadia at $0.45 per mile, both of which are higher than the average electric cost per mile for electric buses. The Pomona CNG fuel cost is considerably less expensive than at the Arcadia depot.

13.8 Bus Major Overhaul and Replacement Costs

Major overhaul and replacement costs are necessary for both electric buses and CNG buses. Electric bus batteries are expected to have an estimated useful life of approximately 6 years or half the life of the bus and are expected to require replacement at a cost of $90,000 per battery per bus due to expected battery degradation. Additionally, Foothill also completes major overhauls and engine replacements on each of its CNG buses at year 6 at a cost of $95,000 per engine per bus based on information provided by Foothill staff. These costs were applied to both the electric and CNG bus LCC forecasts appropriately.

13.9 Charger Equipment O&M and Replacement Costs

Charging equipment proposed within this study is expected to have an estimated useful life of approximately 10 to 12 years, with replacement of each charger after 12 years of its in-service date at a cost of $200,000 per 325 kW charger. The chargers will also have annual O&M costs for every charger that is outside of the three-year manufacturer's warranty at a cost of $6,500 per charger per year. Charger O&M and replacement costs were included in the LCC analysis forecasts.

13.10 Charging Infrastructure Costs

For each depot, bottom up cost estimates were prepare based on the scope and infrastructure required as presented in Section 9 of this report. The scope and costs were determined by year by depot. Additionally, the scope was also segregated between those costs that will be directly paid by Foothill Transit and the total installed cost of the electrical infrastructure that is eligible to be 100 percent paid for by SCE under the Charge Ready Transit Program. SCE project costs were not included in the LCC analysis. The detailed quantities and costs by year by depot are provided as an Appendix to this report with the summary for each depot provided in Figure 9-4. The total charging infrastructure costs paid by Foothill, with inflation, over the analysis period is estimated to be $120.6 million.

13.11 LCC Analysis Results

To evaluate the overall LCC of operating an electric bus fleet as compared to the existing CNG bus fleet, the various cost assumptions were forecasted on an annual basis and are summarized below in Table 13-1. Six cost categories were evaluated and are shown in the left column of each summary. The cost summaries for both the electric bus fleet and CNG bus fleet include a 25-year NPV cost, cumulative costs over 25-years, and an annual levelized cost. The two scenarios were compared against each other, with the dollar and percentage difference shown in the table below. Pursuing an electric bus fleet will cost Foothill Transit $15.4 million more per year over the next 25 years on a levelized basis.

Table 13-1: Electric Bus Fleet versus CNG Bus Fleet Cost Summaries

25 Year NPV Cost Summary	Electric Bus	CNG Bus	Difference ($)	Difference (%)
Bus Equipment Cost	$ 536,671,000	$ 375,283,000	$ 161,388,000	43%
Bus Maintenance Cost	$ 21,559,000	$ 29,500,000	$ (7,941,000)	-27%
Energy Cost	$ 66,906,000	$ 99,166,000	$ (32,260,000)	-33%
Battery/ Engine Replacement	$ 19,252,000	$ 20,125,000	$ (873,000)	-4%
Charger O&M and Replacement Cost	$ 16,916,000	$ -	$ 16,916,000	n/a
Charging Infrastructure Cost	$ 80,281,000	$ -	$ 80,281,000	n/a
Total	$ 741,585,000	$ 524,074,000	$ 217,511,000	42%

25 Year Cumulative Cost Summary	Electric Bus	CNG Bus	Difference ($)	Difference (%)
Bus Equipment Cost	$ 1,076,831,600	$ 745,175,600	$ 331,656,000	45%
Bus Maintenance Cost	$ 47,154,200	$ 63,972,000	$ (16,817,800)	-26%
Energy Cost	$ 146,259,500	$ 213,624,000	$ (67,364,500)	-32%
Battery/ Engine Replacement	$ 41,670,000	$ 44,717,800	$ (3,047,800)	-7%
Charger O&M and Replacement Cost	$ 44,694,000	$ -	$ 44,694,000	n/a
Charging Infrastructure Cost	$ 120,654,543	$ -	$ 120,654,543	n/a
Total	$1,477,263,843	$1,067,489,400	$ 409,774,443	38%

Annual Levelized Cost Summary ($/year)	Electric Bus	CNG Bus	Difference ($/year)	Difference (%)
Bus Equipment Cost	$ 38,078,000	$ 26,627,000	$ 11,451,000	43%
Bus Maintenance Cost	$ 1,530,000	$ 2,093,000	$ (563,000)	-27%
Energy Cost	$ 4,747,000	$ 7,036,000	$ (2,289,000)	-33%
Battery/ Engine Replacement	$ 1,366,000	$ 1,428,000	$ (62,000)	-4%
Charger O&M and Replacement Cost	$ 1,200,000	$ -	$ 1,200,000	n/a
Charging Infrastructure Cost	$ 5,696,000	$ -	$ 5,696,000	n/a
Total	$ 52,617,000	$ 37,184,000	$ 15,433,000	42%

Figure 13-1 and Figure 13-2 present the annual incremental costs of operating the electric bus fleet and the annual incremental cost of replacing the existing fleet with new CNG buses. The costs are inclusive of bus equipment, energy and fuel, O&M, replacement of buses, replacement of engines and batteries, charger O&M and replacement, as well as capital for charging infrastructure over 25 years. The annual levelized costs are presented in Figure 13-3 which shows the estimated annual levelized cost difference between the electric bus fleet versus the existing CNG bus fleet.

Figure 13-1: Electric Bus Fleet Incremental Annual and Cumulative Costs

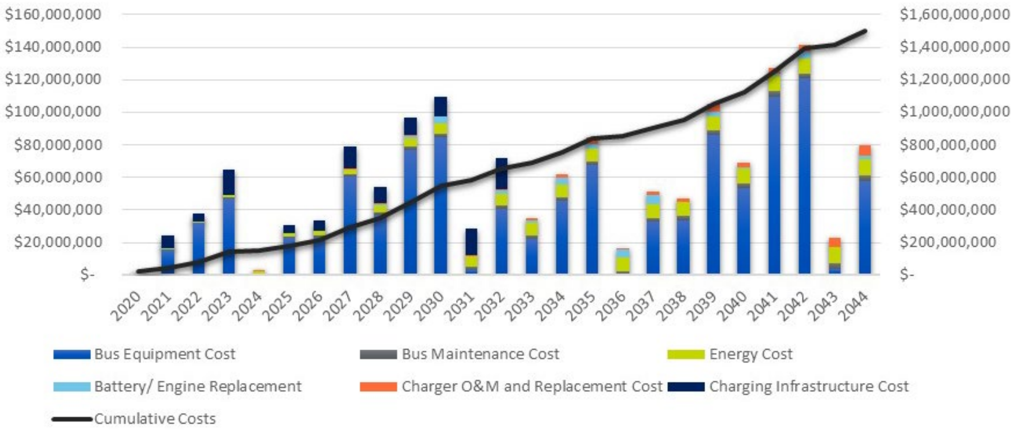


Figure 13-2: CNG Bus Fleet Incremental Annual and Cumulative Costs

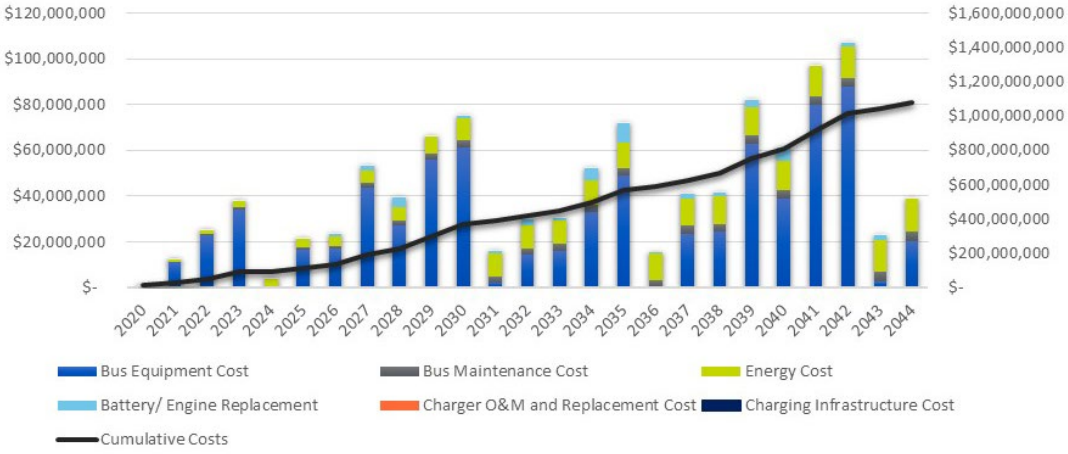
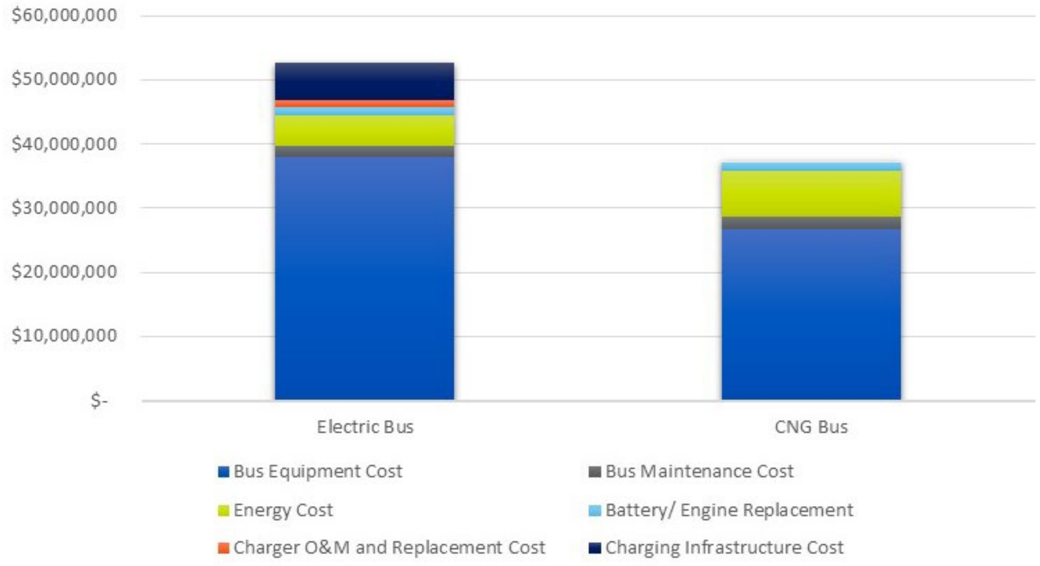


Figure 13-3: Annual Levelized cost of Electric Bus Fleet versus CNG Bus Fleet



13.12 Electric Bus Rebates and Incentives

There are currently several rebates and financial incentives available in the State of California that help to make the total cost of owning and operating a BEB more financially feasible. These rebates and incentives were not included in the base 25-year LCC analysis however they are available today and could continue to be over the study period considered. The additional incentives that were considered included (1) the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), (2) the SCE 50% charger rebate program, and (3) California Low Carbon Fuel Standard (LCFS) credits.

13.12.1 HVIP Rebates

BEB manufacturers currently can apply a $120,000 HVIP rebate to the purchase of BEBs sold in the state of California. This reduces the cost of the bus to Foothill Transit from $900,000 to $780,000 per bus. The HVIP credit may continue to be available over the next 25 years. If the HVIP credit remains available, this will provide a total BEB cost reduction of $138 million over 25 years.

13.12.2 SCE Charger Rebates

The local electric utility, SCE, is currently offering a 50% rebate off chargers that meet certain specifications under its Charge Ready Transit Program. At the time of this report SCE did not offer a rebate for 325 kW chargers however it is expected that SCE would be willing to provide a 50% rebate to cover the cost of the $100,000 equipment cost. This credit may continue over the next 10 to 12 years and was included in the analysis. Assuming the rebates are available to Foothill, this would reduce the capital cost of the project by $6.2 million.

13.12.3 Low Carbon Fuel Standard Credits

Foothill Transit currently earns LCFS credits for its utilization of both BEBs and renewable CNG. In 2019, California LCFS credits have been trading at nearly $200 per Ton which equates to nearly $0.20 per kWh. From 2015 to 2018 LCFS credits have been valued closer to $100 per Ton or $0.10 per kWh. There has been a steep increase in the value of LCFS credits over the last 12 months and this market price may not be sustainable over the next 25 years. This analysis assumed a price of $100 per Ton. Including LCFS credits would offset all of Foothill Transit's electricity costs in the future and provide a total 25-year net energy cost reduction of $152 million. LCFS credits were also included for the CNG case at $100 per Ton which also provide some cost savings.

13.12.4 Electric Bus Rebates and Incentives Scenario LCC Analysis Results

The three rebates and incentives described above were included into the LCC Analysis model to determine the overall impact cost impact of converting from CNG to electric buses. Assuming the rebates and incentives for BEBs are available, pursuing a BEB fleet will cost Foothill Transit $6.3 million more per year over the next 25 years on a levelized basis. The BEB incentives and rebates provide an overall BEB fleet scenario cost reduction of nearly $9 million per year versus the base case.

Table 13-2: Electric Bus Fleet versus CNG Bus Fleet Cost Summaries with Rebates and Incentives

25 Year NPV Cost Summary	Electric Bus	CNG Bus	Difference ($)	Difference (%)
Bus Equipment Cost	$ 468,592,000	$ 375,283,000	$ 93,309,000	25%
Bus Maintenance Cost	$ 21,559,000	$ 29,500,000	$ (7,941,000)	-27%
Energy Cost	$ (2,874,000)	$ 86,190,000	$ (89,064,000)	-103%
Battery/ Engine Replacement	$ 19,252,000	$ 20,125,000	$ (873,000)	-4%
Charger O&M and Replacement Cost	$ 16,916,000	$ -	$ 16,916,000	n/a
Charging Infrastructure Cost	$ 76,260,000	$ -	$ 76,260,000	n/a
Total	$ 599,705,000	$ 511,098,000	$ 88,607,000	17%

25 Year Cumulative Cost Summary	Electric Bus	CNG Bus	Difference ($)	Difference (%)
Bus Equipment Cost	$ 938,607,600	$ 745,175,600	$ 193,432,000	26%
Bus Maintenance Cost	$ 47,154,200	$ 63,972,000	$ (16,817,800)	-26%
Energy Cost	$ (6,210,300)	$ 185,484,800	$ (191,695,100)	-103%
Battery/ Engine Replacement	$ 41,670,000	$ 44,717,800	$ (3,047,800)	-7%
Charger O&M and Replacement Cost	$ 44,694,000	$ -	$ 44,694,000	n/a
Charging Infrastructure Cost	$ 114,466,673	$ -	$ 114,466,673	n/a
Total	$ 1,180,382,173	$ 1,039,350,200	$ 141,031,973	14%

Annual Levelized Cost Summary ($/year)	Electric Bus	CNG Bus	Difference ($/year)	Difference (%)
Bus Equipment Cost	$ 33,248,000	$ 26,627,000	$ 6,621,000	25%
Bus Maintenance Cost	$ 1,530,000	$ 2,093,000	$ (563,000)	-27%
Energy Cost	$ (204,000)	$ 6,115,000	$ (6,319,000)	-103%
Battery/ Engine Replacement	$ 1,366,000	$ 1,428,000	$ (62,000)	-4%
Charger O&M and Replacement Cost	$ 1,200,000	$ -	$ 1,200,000	n/a
Charging Infrastructure Cost	$ 5,411,000	$ -	$ 5,411,000	n/a
Total	$ 42,551,000	$ 36,264,000	$ 6,287,000	17%

[1] Energy costs include LCFS credits.

APPENDIX A - DEPOT INFRASTRUCTURE COST ESTIMATES

STUDY CAPITAL COST ESTIMATE
FOOTHILL TRANSIT
ARCADIA
EV INFRASTRUCTURE
WEST COVINA
BMcD #110549

Acct	Area / Discipline	Direct MHRS	Labor Cost	Material Cost	Engr Equip/ Subcontract Cost	Const. Equipment Cost	Total Cost
01	Engineered Equipment			$23,714,977		$47,084	$23,762,062
02	Civil						
03	Deep Foundations	1,524	$241,919	$234,818	$348,317	$62,875	$887,929
04	Concrete						
05	Structural Steel				$3,172,700		$3,172,700
06	Architectural						
07	Piping						
08	Electrical	24,594	$4,112,177	$1,768,750		$233,333	$6,114,261
09	T&D						
10	Insulation						
11	Coatings						
12	Specialty						
13	Demolition						
14	Misc Directs						
	Total Direct Cost	**26,118**	**$4,354,096**	**$25,718,546**	**$3,521,017**	**$343,293**	**$33,936,952**

Rev.	Revision Date

Construction Mgmt & Indirects	15%	$5,090,543
Engineering	12%	$4,072,434
Start-Up	6%	$2,036,217
Permitting	2%	$678,739
Total Indirect Cost		**$11,877,933**
Total Direct and Indirect Costs		**$45,814,885**
	Cost	
Design Contingency	25%	$11,453,721
Contractor Fee	5%	$2,290,744
Total Project Cost	**30%**	**$59,559,350**
Total Project Cost Incl. Owner Cost		**$59,559,350**

BURNS McDONNELL V 3.5

FOOTHILL TRANSIT
ARCADIA
EV INFRASTRUCTURE
WEST COVINA
110549

Sort 2	Description	Direct MHRS	Labor Cost	Material Cost	Engr Equip/ Subcontract Cost	Const. Equipment Cost	Total Cost	Indirect, Design Contingency and Contractor Fee	Phase Totals
1.0	PH.1.1 Foothill Scope (2021)	3,393	$559,645	$905,651	$2,028,483	$61,327	$3,555,106	176%	$6,239,211
2.0	PH.1.1 SCE Scope (2021)	2,002	$334,747	$504,900		$27,444	$867,091	176%	$1,521,744
3.0	PH.1.1 Chargers (2021)	33	$5,518	$717,911		$582	$724,011	176%	$1,270,638
4.0	PH.1.2 Foothill Scope (2022)	941	$157,291	$954,565		$9,822	$1,121,678	176%	$1,968,546
5.0	PH.1.2 SCE Scope (2022)	314	$52,529	$71,791		$5,544	$129,863	176%	$227,910
6.0	PH.1.2 Chargers (2022)	55	$9,196	$1,196,518		$971	$1,206,684	176%	$2,117,731
7.0	PH.1.3, 1.4 Foothill Scope (2023-2024)	1,625	$271,678	$1,521,166		$16,851	$1,809,695	176%	$3,176,015
8.0	PH.1.3, 1.4 SCE Scope (2023-2024)	656	$109,765	$31,924		$6,228	$147,918	176%	$259,595
9.0	PH.1.3, 1.4 Chargers (2023-2024)	88	$14,714	$1,914,428		$1,553	$1,930,695	176%	$3,388,369
10.0	PH.1.5 Foothill Scope (2025)	807	$134,928	$409,677		$8,015	$552,619	176%	$969,847
11.0	PH.1.5 SCE Scope (2025)	971	$162,294	$103,716		$11,772	$277,781	176%	$487,505
12.0	PH.1.5 Chargers (2025)	22	$3,678	$478,607		$388	$482,674	176%	$847,092
13.0	PH.2.1 Foothills Scope (2026)	1,347	$221,971	$294,654	$900,736	$24,963	$1,442,324	176%	$2,531,278
14.0	PH.2.1 SCE Scope (2026)	516	$86,227	$200,592		$7,836	$294,655	176%	$517,120
15.0	PH.2.1 Chargers (2026)	11	$1,839	$239,304		$194	$241,337	176%	$423,546
16.0	PH.2.2,2.3 & 2.4 Foothill Scope (2028-2029)	401	$66,971	$386,142		$4,159	$457,272	176%	$802,512
17.0	PH.2.2,2.3 & 2.4 SCE Scope (2028-2029)							176%	
18.0	PH.2.2,2.3 & 2.4 Chargers (2028-2029)	22	$3,678	$478,607		$388	$482,674	176%	$847,092
19.0	PH.2.5 Foothill Scope (2030)	1,816	$303,649	$1,519,460		$18,665	$1,841,774	176%	$3,232,314
20.0	PH.2.5 SCE Scope (2030)	971	$162,294	$103,716		$11,772	$277,781	176%	$487,505
21.0	PH.2.5 Chargers (2030)	88	$14,714	$1,914,428		$1,553	$1,930,695	176%	$3,388,369
22.0	PH.2.6 Foothill Scope (2031)	2,821	$471,695	$2,605,170		$29,278	$3,106,143	176%	$5,451,281
23.0	PH.2.6 SCE Scope (2031)	1,456	$243,442	$181,958		$18,939	$444,339	176%	$779,814
24.0	PH.2.6 Chargers (2031)	154	$25,749	$3,350,249		$2,717	$3,378,716	176%	$5,929,646
25.0	PH.2.7 Foothill Scope (2032)	3,514	$585,431	$2,374,703	$591,798	$43,299	$3,595,231	176%	$6,309,631
26.0	PH.2.7 SCE Scope (2032)	1,964	$328,383	$387,069		$26,702	$742,155	176%	$1,302,482
27.0	PH.2.7 Chargers (2032)	132	$22,071	$2,871,642		$2,329	$2,896,042	176%	$5,082,554
									$59,559,350
	PH.1.1								$9,031,594
	PH.1.2								$4,314,186
	PH. 1.3 & 1.4								$6,823,980
	PH.1.5								$2,304,444
	PH.2.1								$3,471,944
	PH.2.2, 2.3 & 2.4								$1,649,604
	PH.2.5								$7,108,189
	PH.2.6								$12,160,742
	PH.2.7								$12,694,667
	Total Foothill Scope								$30,680,634
	Total SCE Scope								$5,583,676
	Total Chargers								$23,295,039
	Total Direct Cost	**26,118**	**$4,354,096**	**$25,718,546**	**$3,521,017**	**$343,293**	**$33,936,952**		

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
ENGINEERED EQUIPMENT

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	LABOR		MATERIAL COST	EQUIPMENT COST	EQUIPMENT RENT / STS	**TOTAL COST**
	MH	COST				
P 2 ENGINEERED EQUIPMENT			23,714,977		47,084	**23,762,062**
ESTIMATE TOTALS			**$23,714,977**		**$47,084**	**$23,762,062**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ENGINEERED EQUIPMENT

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		PROCESS EQUIP		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
ENGINEERED EQUIPMENT														
Transformers (1.1)	4	ea			180.23		95721.40	382,886			1471.72	5,887	97193.12	**388,772**
480V Swgr (1.1)	1	ea			180.23		71791.05	71,791			2562.94	2,563	74353.99	**74,354**
Chargers (1.1)	3	ea			180.23		239303.51	717,911			89.74	269	239393.24	**718,180**
Pantographs (1.1)	6	ea			180.23		83756.23	502,537			89.74	538	83845.97	**503,076**
480V Swgr (1.2)	1	ea			180.23		71791.05	71,791			2562.94	2,563	74353.99	**74,354**
Chargers (1.2)	5	ea			180.23		239303.51	1,196,518			89.74	449	239393.24	**1,196,966**
Pantographs (1.2)	10	ea			180.23		83756.23	837,562			89.74	897	83845.97	**838,460**
Chargers (1.3 & 1.4)	8	ea			180.23		239303.51	1,914,428			89.74	718	239393.24	**1,915,146**
Pantographs (1.3 & 1.4)	16	ea			180.23		83756.23	1,340,100			89.74	1,436	83845.97	**1,341,535**
480V Swgr (1.5)	1	ea			180.23		71791.05	71,791			2562.94	2,563	74353.99	**74,354**
Chargers (1.5)	2	ea			180.23		239303.51	478,607			89.74	179	239393.24	**478,786**
Pantographs (1.5)	4	ea			180.23		83756.23	335,025			89.74	359	83845.97	**335,384**
Transformers (2.1)	2	ea			180.23		95721.40	191,443			1471.72	2,943	97193.12	**194,386**
Chargers (2.1)	1	ea			180.23		239303.51	239,304			89.74	90	239393.24	**239,393**
Pantographs (2.1)	2	ea			180.23		83756.23	167,512			89.74	179	83845.97	**167,692**
Chargers (2.2, 2.3, 2.4)	2	ea			180.23		239303.51	478,607			89.74	179	239393.24	**478,786**
Pantographs (2.2, 2.3, 2.4)	4	ea			180.23		83756.23	335,025			89.74	359	83845.97	**335,384**
480V Swgr (2.5)	1	ea			180.23		71791.05	71,791			2562.94	2,563	74353.99	**74,354**
Chargers (2.5)	8	ea			180.23		239303.51	1,914,428			89.74	718	239393.24	**1,915,146**
Pantograph (2.5)	16	ea			180.23		83756.23	1,340,100			89.74	1,436	83845.97	**1,341,535**
480V Swgr (2.6)	2	ea			180.23		71791.05	143,582			2562.94	5,126	74353.99	**148,708**
Chargers (2.6)	14	ea			180.23		239303.51	3,350,249			89.74	1,256	239393.24	**3,351,505**
Pantographs (2.6)	28	ea			180.23		83756.23	2,345,174			89.74	2,513	83845.97	**2,347,687**
Transformers (2.7)	2	ea			180.23		95721.40	191,443			1471.72	2,943	97193.12	**194,386**
480V Swgr (2.7)	2	ea			180.23		71791.05	143,582			2562.94	5,126	74353.99	**148,708**
Chargers (2.7)	12	ea			180.23		239303.51	2,871,642			89.74	1,077	239393.24	**2,872,719**
Pantographs (2.7)	24	ea			180.23		83756.23	2,010,149			89.74	2,154	83845.97	**2,012,303**
TOTALS								23,714,977				47,084		**23,762,062**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR: **JAS**

DESCRIPTION		LABOR MH	LABOR COST	MATERIAL COST	SUBCON COST	EQUIPMENT RENT / STS	**TOTAL COST**
P 2	DEEP FOUNDATIONS	1,278	202,900	196,944	239,749	52,734	**692,328**
P 3	DEEP FOUNDATIONS	246	39,019	37,874	108,567	10,141	**195,601**
	ESTIMATE TOTALS	**1,524**	**$241,919**	**$234,818**	**$348,317**	**$62,875**	**$887,929**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **JAS**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
DEEP FOUNDATIONS														
Phase 1.1														
Qty 55 Depth 25 LF/EA														
36" Drilled Piers	1375	VLF	0.4224	581	158.71	92,179	46.80	64,357			23.38	32,144	137.22	**188,680**
Mobilization	1	LS							40600	40,600			40600.00	**40,600**
Layout	55	EA	1.1	61	158.71	9,602							174.58	**9,602**
Reinforcing	48600	LB					1.51	73,160					1.51	**73,160**
Waste Spoils Off-Site	360	CY	0.0495	18	158.71	2,828					5.40	1,944	13.26	**4,772**
Pile Cut-Offs	55	EA	4.4	242	158.71	38,408					55.66	3,061	753.99	**41,469**
Testing														
Test Piles	2	EA							12898	25,796			12897.91	**25,796**
Load Tests	2	EA							30450	60,900			30450.00	**60,900**
Phase 2.1														
Qty 23 Depth 25 LF/EA														
36" Drilled Piers	575	VLF	0.4224	243	158.71	38,548	46.80	26,913			23.38	13,442	137.22	**78,902**
Mobilization	1	LS							40600	40,600			40600.00	**40,600**
Layout	23	EA	1.1	25	158.71	4,015							174.58	**4,015**
Reinforcing	21600	LB					1.51	32,515					1.51	**32,515**
Waste Spoils Off-Site	160	CY	0.0495	8	158.71	1,257					5.40	864	13.26	**2,121**
Pile Cut-Offs	23	EA	4.4	101	158.71	16,062					55.66	1,280	753.99	**17,342**
Testing														
Test Piles	2	EA							5477	10,954			5476.77	**10,954**
Load Tests	2	EA							30450	60,900			30450.00	**60,900**
TOTALS				1,278		202,900		196,944		239,749		52,734		**692,328**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **JAS**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
DEEP FOUNDATIONS														
Phase 2.7														
Qty 15 Depth 25 LF/EA														
36" Drilled Piers	375	VLF	0.4224	158	158.71	25,140	46.80	17,552			23.38	8,766	137.22	**51,458**
Mobilization	1	LS							40600	40,600			40600.00	**40,600**
Layout	15	EA	1.1	17	158.71	2,619							174.58	**2,619**
Reinforcing	13500	LB					1.51	20,322					1.51	**20,322**
Waste Spoils Off-Site	100	CY	0.0495	5	158.71	786					5.40	540	13.26	**1,326**
Pile Cut-Offs	15	EA	4.4	66	158.71	10,475					55.66	835	753.99	**11,310**
Testing														
Test Piles	2	EA							3534	7,067			3533.59	**7,067**
Load Tests	2	EA							30450	60,900			30450.00	**60,900**
TOTALS				246		39,019		37,874		108,567		10,141		**195,601**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
STRUCTURAL STEEL

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR: **JAS**

DESCRIPTION	LABOR		MATERIAL COST	SUBCON COST	EQUIPMENT RENT / STS	**TOTAL COST**
	MH	COST				
P 2 STEEL				3,172,700		**3,172,700**
ESTIMATE TOTALS				**$3,172,700**		**$3,172,700**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
STRUCTURAL STEEL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **JAS**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
STEEL														
Phase 1.1 PEMB Structure	50555	sf							25	1,282,833			25.38	**1,282,833**
Phase 1.1 Standing Seam Roof	50555	sf							12	615,760			12.18	**615,760**
Phase 2.1 PEMB Structure	20958	sf							25	531,809			25.38	**531,809**
Phase 2.1 Standing Seam Roof	20958	sf							12	255,268			12.18	**255,268**
Phase 2.7 PEMB Structure	12851	sf							25	326,094			25.38	**326,094**
Phase 2.7 Standing Seam Roof	12851	sf							12	156,525			12.18	**156,525**
Phase 1.1 Striping	2556	lf							1	2,594			1.02	**2,594**
Phase 2.1 Striping	1187	lf							1	1,205			1.02	**1,205**
Phase 2.7 Striping	602	lf							1	611			1.02	**611**
TOTALS										3,172,700				**3,172,700**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	LABOR		MATERIAL COST	SUBCON COST	EQUIPMENT RENT / STS	**TOTAL COST**
	MH	COST				
P 2 PH. 1.1	4,527	756,892	315,820		42,947	**1,115,659**
P 3 PH.1.2	1,310	219,016	117,003		12,427	**348,446**
P 4 PH.1.3 & 1.4	2,369	396,157	212,991		22,479	**631,626**
P 5 PH.1.5	1,800	300,900	106,576		17,074	**424,549**
P 6 PH.2.1	1,496	250,155	76,863		14,194	**341,212**
P 7 PH.2.2, 2.3 & 2.4	423	70,650	51,117		4,009	**125,775**
P 8 PH.2.5	2,875	480,656	211,285		27,273	**719,215**
P 9 PH.2.6	4,431	740,886	298,371		42,039	**1,081,297**
P 10 PH.2.7	5,364	896,866	378,724		50,890	**1,326,480**
ESTIMATE TOTALS	**24,594**	**$4,112,177**	**$1,768,750**		**$233,333**	**$6,114,261**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH. 1.1														
Equipment														
Transformers	4	ea	180.4	722	167.20	120,654					1711.54	6,846	31875.08	**127,500**
480V Swgr	1	ea	314.16	314	167.20	52,529					2980.58	2,981	55509.28	**55,509**
Chargers	3	ea	11	33	167.20	5,518					104.36	313	1943.60	**5,831**
Pantographs	6	ea	11	66	167.20	11,035					104.36	626	1943.60	**11,662**
Cable Tray														
(Dc) 36" Stacked Cable Tray	300	lf	0.8032	241	167.20	40,291	40.60	12,179			7.62	2,286	182.52	**54,757**
(Dc) Single 36" Cable Tray	110	lf	0.5419	60	167.20	9,966	38.64	4,251			5.14	566	134.38	**14,782**
36" Cable Tray Fittings	3	ea	6.3113	19	167.20	3,166	299.80	899			59.88	180	1414.95	**4,245**
(480V) 36" Stacked Cable Tray	130	lf	0.8032	104	167.20	17,460	40.60	5,278			7.62	991	182.52	**23,728**
480V Feeders														
Xfmr To Swgr 4000A	400	lf	1.6412	656	167.20	109,765	79.81	31,924			15.57	6,228	369.79	**147,918**
Swgr To Chargers 600A	385	lf	0.2369	91	167.20	15,252	36.91	14,210			2.25	865	78.77	**30,328**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	1580	lf	0.0994	157	167.20	26,255	24.65	38,950			0.94	1,490	42.21	**66,695**
Control Cables & Terms	2364	lf	0.0812	192	167.20	32,105	4.97	11,744			0.77	1,822	19.32	**45,671**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	144	ea	9.1779	1,322	167.20	220,979	422.92	60,900			87.07	12,539	2044.57	**294,419**
Lightning Protection	43000	sf					2.21	95,191					2.21	**95,191**
Grounding														
4/0 Bare Ground Ring	1200	lf	0.1088	131	167.20	21,837	13.01	15,613			1.03	1,239	32.24	**38,689**
3/4" Ground Rod	10	ea	1.6473	16	167.20	2,754	128.32	1,283			15.63	156	419.38	**4,194**
Test Well	2	ea	5.247	10	167.20	1,755	479.17	958			49.78	100	1406.27	**2,813**
Ground Connection	10	ea	8.2364	82	167.20	13,772	414.00	4,140			78.14	781	1869.30	**18,693**
15Kv Ductbank	100	lf	3.098	310	167.20	51,800	182.98	18,298			29.39	2,939	730.37	**73,037**
				4,527		756,892		315,820				42,947		**1,115,659**

PROJECT CLIENT: **FOOTHILL TRANSIT**

PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**

PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**

ESTIMATE DATE: **4/22/2019**

ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.2														
Equipment														
480V Swgr	1	ea	314.16	314	167.20	52,529					2980.58	2,981	55509.28	**55,509**
Chargers	5	ea	11	55	167.20	9,196					104.36	522	1943.60	**9,718**
Pantographs	10	ea	11	110	167.20	18,392					104.36	1,044	1943.60	**19,436**
Cable Tray														
(Dc) Single 36" Cable Tray	100	lf	0.5419	54	167.20	9,060	38.64	3,864			5.14	514	134.38	**13,438**
36" Cable Tray Fittings	4	ea	6.3113	25	167.20	4,221	299.80	1,199			59.88	240	1414.95	**5,660**
480V Feeders														
Swgr To Chargers 600A	561	lf	0.2493	140	167.20	23,380	36.98	20,744			2.36	1,327	81.02	**45,450**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	2846	lf	0.098	279	167.20	46,651	24.64	70,115			0.93	2,647	41.96	**119,413**
Control Cables & Terms	4269	lf	0.0779	332	167.20	55,587	4.94	21,081			0.74	3,154	18.70	**79,822**
				1,310		219,016		117,003				12,427		**348,446**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.3 & 1.4														
Equipment														
Chargers	8	ea	11	88	167.20	14,714					104.36	835	1943.60	**15,549**
Pantographs	16	ea	11	176	167.20	29,428					104.36	1,670	1943.60	**31,098**
Cable Tray														
(Dc) 36" Stacked Cable Tray	300	lf	0.8032	241	167.20	40,291	40.60	12,179			7.62	2,286	182.52	**54,757**
(Dc) Single 36" Cable Tray	200	lf	0.5419	108	167.20	18,121	38.64	7,728			5.14	1,028	134.38	**26,877**
36" Cable Tray Fittings	5	ea	6.3113	32	167.20	5,276	299.80	1,499			59.88	299	1414.95	**7,075**
(480V) 36" Stacked Cable Tray	130	lf	0.8032	104	167.20	17,460	40.60	5,278			7.62	991	182.52	**23,728**
480V Feeders														
Xfmr To Swgr 4000A	400	lf	1.6412	656	167.20	109,765	79.81	31,924			15.57	6,228	369.79	**147,918**
Swgr To Chargers 600A	690	lf	0.2787	192	167.20	32,158	37.14	25,624			2.64	1,825	86.39	**59,607**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	4045	lf	0.1001	405	167.20	67,724	24.66	99,753			0.95	3,843	42.35	**171,320**
Control Cable & Terms	6066	lf	0.0604	366	167.20	61,221	4.78	29,005			0.57	3,474	15.45	**93,699**
				2,369		396,157		212,991				22,479		**631,626**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.5														
Equipment														
480V Swgr	1	ea	314.16	314	167.20	52,529					2980.58	2,981	55509.28	**55,509**
Chargers	2	ea	11	22	167.20	3,678					104.36	209	1943.60	**3,887**
Pantographs	4	ea	11	44	167.20	7,357					104.36	417	1943.60	**7,774**
Cable Tray														
(Dc) 36" Stacked Cable Tray	300	lf	0.8032	241	167.20	40,291	40.60	12,179			7.62	2,286	182.52	**54,757**
(Dc) Single 36" Cable Tray	110	lf	0.5419	60	167.20	9,966	38.64	4,251			5.14	566	134.38	**14,782**
36" Cable Tray Fittings	3	ea	6.3113	19	167.20	3,166	299.80	899			59.88	180	1414.95	**4,245**
(480V) 36" Stacked Cable Tray	140	lf	0.8032	112	167.20	18,803	40.60	5,684			7.62	1,067	182.52	**25,553**
480V Feeders														
Xfmr To Swgr 4000A	400	lf	1.6412	656	167.20	109,765	79.81	31,924			15.57	6,228	369.79	**147,918**
Swgr To Chargers 600A	200	lf	0.2612	52	167.20	8,735	37.04	7,408			2.48	496	83.19	**16,639**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	1386	lf	0.0951	132	167.20	22,028	24.60	34,097			0.90	1,250	41.40	**57,375**
Control Cable & Terms	2079	lf	0.0707	147	167.20	24,582	4.87	10,133			0.67	1,395	17.37	**36,110**
				1,800		300,900		106,576				17,074		**424,549**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.1														
Equipment														
Transformers	2	ea	180.4	361	167.20	60,327					1711.54	3,423	31875.08	**63,750**
Chargers	1	ea	11	11	167.20	1,839					104.36	104	1943.60	**1,944**
Pantographs	2	ea	11	22	167.20	3,678					104.36	209	1943.60	**3,887**
Cable Tray														
(Dc) Single 36" Cable Tray	40	lf	0.5419	22	167.20	3,624	38.64	1,546			5.14	206	134.38	**5,375**
36" Cable Tray Fittings	1	ea	6.3113	6	167.20	1,055	299.80	300			59.88	60	1414.95	**1,415**
480V Feeders														
Swgr To Chargers 600A	135	lf	0.2327	31	167.20	5,253	36.89	4,980			2.21	298	78.00	**10,530**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	540	lf	0.0989	53	167.20	8,933	24.65	13,309			0.94	507	42.13	**22,749**
Control Cable & Terms	810	lf	0.0645	52	167.20	8,730	4.89	3,961			0.61	495	16.28	**13,187**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	66	ea	9.1779	606	167.20	101,282	422.92	27,913			87.07	5,747	2044.57	**134,942**
Grounding														
4/0 Bare Ground Ring	800	lf	0.1088	87	167.20	14,558	13.01	10,409			1.03	826	32.24	**25,793**
3/4" Ground Rod	8	ea	1.6473	13	167.20	2,203	128.32	1,027			15.63	125	419.38	**3,355**
Test Well	2	ea	5.247	10	167.20	1,755	479.17	958			49.78	100	1406.27	**2,813**
Ground Connection	8	ea	8.2364	66	167.20	11,017	414.00	3,312			78.14	625	1869.30	**14,954**
15Kv Ductbank	100	lf	1.549	155	167.20	25,900	91.49	9,149			14.70	1,470	365.19	**36,519**
				1,496		250,155		76,863				14,194		**341,212**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.2, 2.3 & 2.4														
Equipment														
Chargers	2	ea	11	22	167.20	3,678					104.36	209	1943.60	**3,887**
Pantographs	4	ea	11	44	167.20	7,357					104.36	417	1943.60	**7,774**
Cable Tray														
(Dc) Single 36" Cable Tray	50	lf	0.5419	27	167.20	4,530	38.64	1,932			5.14	257	134.38	**6,719**
36" Cable Tray Fittings	2	ea	6.3113	13	167.20	2,111	299.80	600			59.88	120	1414.95	**2,830**
480V Feeders														
Swgr To Chargers 600A	276	lf	0.2309	64	167.20	10,657	36.88	10,178			2.19	605	77.68	**21,440**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	1200	lf	0.0972	117	167.20	19,498	24.63	29,551			0.92	1,106	41.80	**50,156**
Control Cable & Terms	1800	lf	0.0758	136	167.20	22,819	4.92	8,856			0.72	1,295	18.32	**32,969**
				423		70,650		51,117				4,009		**125,775**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.5														
Equipment														
480V Swgr	1	ea	314.16	314	167.20	52,529					2980.58	2,981	55509.28	**55,509**
Chargers	8	ea	11	88	167.20	14,714					104.36	835	1943.60	**15,549**
Pantograph	16	ea	11	176	167.20	29,428					104.36	1,670	1943.60	**31,098**
Cable Tray														
(Dc) 36" Stacked Cable Tray	300	lf	0.8032	241	167.20	40,291	40.60	12,179			7.62	2,286	182.52	**54,757**
(Dc) 36" Single Cable Tray	180	lf	0.5419	98	167.20	16,308	38.64	6,955			5.14	925	134.38	**24,189**
36" Cable Tray Fitting	6	ea	6.3113	38	167.20	6,332	299.80	1,799			59.88	359	1414.95	**8,490**
(480V) 36" Stacked Cable Tray	140	lf	0.8032	112	167.20	18,803	40.60	5,684			7.62	1,067	182.52	**25,553**
480V Feeders														
Xfmr To Swgr 4000A	400	lf	1.6412	656	167.20	109,765	79.81	31,924			15.57	6,228	369.79	**147,918**
Swgr Tp Chargers 600A	842	lf	0.2557	215	167.20	36,002	37.01	31,164			2.43	2,043	82.20	**69,208**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	3726	lf	0.1017	379	167.20	63,385	24.68	91,957			0.97	3,597	42.66	**158,938**
Control Cable & Terms	5589	lf	0.0996	557	167.20	93,100	5.30	29,623			0.95	5,283	22.90	**128,006**
				2,875		480,656		211,285				27,273		**719,215**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.6														
Equipment														
480V Swgr	2	ea	314.16	628	167.20	105,057					2980.58	5,961	55509.28	**111,019**
Chargers	14	ea	11	154	167.20	25,749					104.36	1,461	1943.60	**27,210**
Pantographs	28	ea	11	308	167.20	51,499					104.36	2,922	1943.60	**54,421**
Cable Tray														
(Dc) 36" Stacked Cable Tray	510	lf	0.8032	410	167.20	68,495	40.60	20,705			7.62	3,887	182.52	**93,087**
(Dc) Single 36" Cable Tray	250	lf	0.5419	135	167.20	22,651	38.64	9,660			5.14	1,285	134.38	**33,596**
36" Cable Tray Fittings	7	ea	6.3113	44	167.20	7,387	299.80	2,099			59.88	419	1414.95	**9,905**
(480V) 36" Stacked Cable Tray	100	lf	0.8032	80	167.20	13,430	40.60	4,060			7.62	762	182.52	**18,252**
480V Feeders														
Xfmr To Swgr 4000A	700	lf	1.1823	828	167.20	138,384	54.82	38,376			11.22	7,852	263.73	**184,612**
Swgr To Chargers 600A	763	lf	0.353	269	167.20	45,035	37.54	28,643			3.35	2,555	99.91	**76,233**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	5820	lf	0.1042	606	167.20	101,396	24.71	143,804			0.99	5,753	43.12	**250,954**
Control Cable & Terms	9603	lf	0.1008	968	167.20	161,802	5.31	51,026			0.96	9,181	23.12	**222,009**
				4,431		740,886		298,371				42,039		**1,081,297**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **ARCADIA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.7														
Equipment														
Transformers	2	ea	180.4	361	167.20	60,327					1711.54	3,423	31875.08	**63,750**
480V Swgr	2	ea	314.16	628	167.20	105,057					2980.58	5,961	55509.28	**111,019**
Chargers	12	ea	11	132	167.20	22,071					104.36	1,252	1943.60	**23,323**
Pantographs	24	ea	11	264	167.20	44,142					104.36	2,505	1943.60	**46,646**
Cable Tray														
(Dc) 36" Stacked Cable Tray	372	lf	0.8075	300	167.20	50,224	40.63	15,114			7.66	2,850	183.30	**68,187**
(Dc) Single 36" Cable Tray	275	lf	0.5371	148	167.20	24,697	38.61	10,617			5.10	1,401	133.51	**36,715**
36" Cable Tray Fittings	6	ea	6.3113	38	167.20	6,332	299.80	1,799			59.88	359	1414.95	**8,490**
(480V) 36" Stacked Cable Tray	240	lf	0.8032	193	167.20	32,233	40.60	9,743			7.62	1,829	182.52	**43,805**
480V Feeders														
Xfmr To Swgr 4000A	600	lf	1.3666	820	167.20	137,099	71.49	42,895			12.97	7,779	312.96	**187,773**
Swgr To Chargers 600A	926	lf	0.2937	272	167.20	45,480	37.22	34,464			2.79	2,581	89.12	**82,524**
Dc Cabling & Terms														
(2) #750Mcm 1000V Cables & Terms	7115	lf	0.0974	693	167.20	115,833	24.63	175,231			0.92	6,573	41.83	**297,636**
Control Cable & Terms	10671	lf	0.0864	922	167.20	154,106	5.15	54,910			0.82	8,744	20.41	**217,761**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	37	ea	9.1779	340	167.20	56,779	422.92	15,648			87.07	3,222	2044.57	**75,649**
Grounding														
4/0 Bare Ground Ring	500	lf	0.1088	54	167.20	9,099	13.01	6,505			1.03	516	32.24	**16,120**
3/4" Ground Rod	4	ea	1.6473	7	167.20	1,102	128.32	513			15.63	63	419.38	**1,678**
Test Well	1	ea	5.247	5	167.20	877	479.17	479			49.78	50	1406.27	**1,406**
Ground Connection	4	ea	8.2364	33	167.20	5,509	414.00	1,656			78.14	313	1869.30	**7,477**
15Kv Ductbank	100	lf	1.549	155	167.20	25,900	91.49	9,149			14.70	1,470	365.19	**36,519**
				5,364		896,866		378,724				50,890		**1,326,480**

STUDY CAPITAL COST ESTIMATE
FOOTHILL TRANSIT
POMONA
EV INFRASTRUCTURE
POMONA
BMcD #110549

Acct	Area / Discipline	Direct MHRS	Labor Cost	Material Cost	Engr Equip/ Subcontract Cost	Const. Equipment Cost	Total Cost
01	Engineered Equipment			$16,942,688		$24,344	$16,967,033
02	Civil						
03	Deep Foundations	984	$156,155	$153,528	$231,445	$40,619	$581,747
04	Concrete						
05	Structural Steel				$2,092,570		$2,092,570
06	Architectural						
07	Piping						
08	Electrical	20,475	$3,403,299	$1,797,953		$191,273	$5,392,525
09	T&D						
10	Insulation						
11	Coatings						
12	Specialty						
13	Demolition						
14	Misc Directs						
	Total Direct Cost	**21,459**	**$3,559,454**	**$18,894,169**	**$2,324,014**	**$256,236**	**$25,033,874**

Rev.	Revision Date
1	03/06/19
2	03/21/19

Construction Mgmt & Indirects	15%	$3,755,081
Engineering	12%	$3,004,065
Start-Up	6%	$1,502,032
Permitting	2%	$500,677
Total Indirect Cost		**$8,761,856**
Total Direct and Indirect Costs		**$33,795,729**
	Cost	
Design Contingency	25%	$8,448,932
Contractor Fee	5%	$1,689,786
Total Project Cost	**30%**	**$43,934,448**
Total Project Cost Incl. Owner Cost		**$43,934,448**

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FOOTHILL TRANSIT
POMONA
EV INFRASTRUCTURE
POMONA
110549

Sort 2	Description	Direct MHRS	Labor Cost	Material Cost	Engr Equip/ Subcontract Cost	Const. Equipment Cost	Total Cost	Indirect, Design Contingency and Contractor Fee	Phase Totals
1.0	PH.1.1 & 1.2 Foothill Scope (2023)	3,300.6	$543,699	$1,021,878	$1,285,419	$52,872	$2,903,868	176%	$5,096,288
2.0	PH.1.1 & 1.2 SCE Scope (2023)	1,346	$223,657	$472,975		$21,216	$717,848	176%	$1,259,824
3.0	PH.1.1 & 1.2 Chargers (2023)	44	$7,314	$957,214		$776	$965,304	176%	$1,694,109
4.0	PH.1.3 Foothill Scope (2025)	822	$136,560	$579,020		$8,333	$723,913	176%	$1,270,467
5.0	PH.1.3 SCE Scope (2025)							176%	
6.0	PH.1.3 Chargers (2025)	33	$5,485	$717,911		$582	$723,978	176%	$1,270,581
7.0	PH.1.4 Foothill Scope (2026)	695	$115,442	$576,592		$7,128	$699,161	176%	$1,227,028
8.0	PH.1.4 SCE Scope (2026)							176%	
9.0	PH.1.4 Chargers (2026)	33	$5,485	$717,911		$582	$723,978	176%	$1,270,581
10.0	PH.1.5 Foothill Scope (2027)	6,074	$1,009,653	$2,428,755		$59,603	$3,498,011	176%	$6,139,010
11.0	PH.1.5 SCE Scope (2027)	628	$104,439	$143,582		$11,087	$259,108	176%	$454,734
12.0	PH.1.5 Chargers (2027)	121	$20,112	$2,632,339		$2,135	$2,654,586	176%	$4,658,799
13.0	PH.2.1 Foothills Scope (2028)	2,325	$384,070	$257,484	$1,038,595	$32,507	$1,712,656	176%	$3,005,711
14.0	PH.2.1 SCE Scope (2028)			$1,172,587		$1,256	$1,173,844	176%	$2,060,095
15.0	PH.2.1 Chargers (2028)	77	$12,799	$1,675,125		$1,359	$1,689,282	176%	$2,964,690
16.0	PH.2.2 Foothill Scope (2029)	4,264	$708,789	$1,763,239		$41,892	$2,513,921	176%	$4,411,931
17.0	PH.2.2 SCE Scope (2029)	314	$52,219	$71,791			$124,010	176%	$217,638
18.0	PH.2.2 Chargers (2029)	88	$14,627	$1,914,428		$1,553	$1,930,608	176%	$3,388,217
19.0	PH.2.3 & 2.4 Foothill Scope (2030-2031)	604	$100,363	$412,172		$6,088	$518,623	176%	$910,183
20.0	PH.2.3 & 2.4 SCE Scope (2030-2031)							176%	
21.0	PH.2.3 & 2.4 Chargers (2030-2031)	22	$3,657	$478,607		$388	$482,652	176%	$847,054
22.0	PH.2.5 & 2.6 Foothill Scope (2032-2033)	646	$107,427	$421,953		$6,491	$535,870	176%	$940,451
23.0	PH.2.5 & 2.6 SCE Scope (2032-2033)							176%	
24.0	PH.2.5 & 2.6 Chargers (2032-2033)	22	$3,657	$478,607		$388	$482,652	176%	$847,054
									$43,934,448
	PH.1.1 & 1.2								$8,050,221
	PH.1.3								$2,541,048
	PH 1.4								$2,497,609
	PH.1.5								$11,252,543
	PH.2.1								$8,030,497
	PH.2.2								$8,017,786
	PH.2.3 & 2.4								$1,757,238
	PH.2.5 & 2.6								$1,787,506
	Total Foothill Scope								$23,001,070
	Total SCE Scope								$3,992,292
	Total Chargers								$16,941,086
	Total Direct Cost	**21,459**	**$3,559,454**	**$18,894,169**	**$2,324,014**	**$256,236**	**$25,033,874**		

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
ENGINEERED EQUIPMENT

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR:

DESCRIPTION	LABOR		MATERIAL COST	EQUIPMENT COST	EQUIPMENT RENT / STS	**TOTAL COST**
	MH	COST				
P 2 ENGINEERED EQUIPMENT			16,942,688		24,344	**16,967,032**
ESTIMATE TOTALS			**$16,942,688**		**$24,344**	**$16,967,032**

PROJECT CLIENT: **FOOTHILL TRANSIT**

PROJECT DESC: **POMONA - EV INFRASTRUCTURE**

PROJECT # **110549**

ESTIMATE DETAIL
ENGINEERED EQUIPMENT

DO NOT COPY WHITE CELLS

EST LEVEL: **STUDY**

ESTIMATE DATE: **4/22/2019**

ESTIMATOR:

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		PROCESS EQUIP		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
ENGINEERED EQUIPMENT														
Transformers (1.1 & 1.2)	4	ea					95721.40	382,886			1471.72	5,887	97193.12	**388,772**
480V Swgr (1.1 & 1.2)	1	ea					71791.05	71,791			2562.94	2,563	74353.99	**74,354**
Chargers (1.1 & 1.2)	4	ea					239303.51	957,214			89.74	359	239393.24	**957,573**
Pantographs (1.1 & 1.2)	8	ea					83756.23	670,050			89.74	718	83845.97	**670,768**
Chargers (1.3)	3	ea					239303.51	717,911			89.74	269	239393.24	**718,180**
Pantographs (1.3)	6	ea					83756.23	502,537			89.74	538	83845.97	**503,076**
Chargers (1.4)	3	ea					239303.51	717,911			89.74	269	239393.24	**718,180**
Pantographs (1.4)	6	ea					83756.23	502,537			89.74	538	83845.97	**503,076**
480V Swgr (1.5)	2	ea					71791.05	143,582			2562.94	5,126	74353.99	**148,708**
Chargers (1.5)	11	ea					239303.51	2,632,339			89.74	987	239393.24	**2,633,326**
Pantographs (1.5)	22	ea					83756.23	1,842,637			89.74	1,974	83845.97	**1,844,611**
Chargers (2.1)	7	ea					239303.51	1,675,125			89.74	628	239393.24	**1,675,753**
Pantographs (2.1)	14	ea					83756.23	1,172,587			89.74	1,256	83845.97	**1,173,844**
480V Swgr (2.2)	1	ea					71791.05	71,791					71791.05	**71,791**
Chargers (2.2)	8	ea					239303.51	1,914,428			89.74	718	239393.24	**1,915,146**
Pantographs (2.2)	16	ea					83756.23	1,340,100			89.74	1,436	83845.97	**1,341,535**
Chargers (2.3 & 2.4)	2	ea					239303.51	478,607			89.74	179	239393.24	**478,786**
Pantographs (2.3 & 2.4)	4	ea					83756.23	335,025			89.74	359	83845.97	**335,384**
Chargers (2.5 & 2.6)	2	ea					239303.51	478,607			89.74	179	239393.24	**478,786**
Pantographs (2.5 & 2.6)	4	ea					83756.23	335,025			89.74	359	83845.97	**335,384**
TOTALS								16,942,688				24,344		**16,967,032**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR:

DESCRIPTION	LABOR		MATERIAL COST	SUBCON COST	EQUIPMENT RENT / STS	**TOTAL COST**
	MH	COST				
P 2 DEEP FOUNDATIONS	984	156,155	153,528	231,445	40,619	**581,747**
ESTIMATE TOTALS	**984**	**$156,155**	**$153,528**	**$231,445**	**$40,619**	**$581,747**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR:

DO NOT COPY WHITE CELLS

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
DEEP FOUNDATIONS														
Phase 1.1														
Qty 40 Depth 25 LF/EA														
36" Drilled Piers	1000	VLF	0.4224	422	158.71	67,040	46.80	46,805			23.38	23,377	137.22	**137,222**
Mobilization	1	LS							40600	40,600			40600.00	**40,600**
Layout	40	EA	1.1	44	158.71	6,983							174.58	**6,983**
Reinforcing	36450	LB					1.51	54,870					1.51	**54,870**
Waste Spoils Off-Site	270	CY	0.0495	13	158.71	2,121					5.40	1,458	13.26	**3,579**
Pile Cut-Offs	40	EA	4.4	176	158.71	27,933					55.66	2,226	753.99	**30,160**
Testing														
Test Piles	2	EA							9452	18,904			9452.21	**18,904**
Load Tests	2	EA							30450	60,900			30450.00	**60,900**
Phase 2.1														
Qty 20 Depth 25 LF/EA														
36" Drilled Piers	500	VLF	0.4224	211	158.71	33,520	46.80	23,402			23.38	11,689	137.22	**68,611**
Mobilization	1	LS							40600	40,600			40600.00	**40,600**
Layout	20	EA	1.1	22	158.71	3,492							174.58	**3,492**
Reinforcing	18900	LB					1.51	28,451					1.51	**28,451**
Waste Spoils Off-Site	140	CY	0.0495	7	158.71	1,100					5.40	756	13.26	**1,856**
Pile Cut-Offs	20	EA	4.4	88	158.71	13,967					55.66	1,113	753.99	**15,080**
Testing														
Test Piles	2	EA							4770	9,540			4770.05	**9,540**
Load Tests	2	EA							30450	60,900			30450.00	**60,900**
TOTALS				984		156,155		153,528		231,445		40,619		**581,747**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
DEEP FOUNDATIONS

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR:

DO NOT COPY WHITE CELLS

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
TOTALS														

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
STRUCTURAL STEEL

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR:

DESCRIPTION	LABOR		MATERIAL	SUBCON	EQUIPMENT	**TOTAL**
	MH	COST	COST	COST	RENT / STS	**COST**
P 2 STEEL				2,092,570		**2,092,570**
ESTIMATE TOTALS				**$2,092,570**		**$2,092,570**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
STRUCTURAL STEEL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR:

DO NOT COPY WHITE CELLS

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
STEEL														
Phase 1.1 PEMB Structure	30976	sf							25	786,016			25.38	**786,016**
Phase 1.1 Standing Seam Roof	30976	sf							12	377,288			12.18	**377,288**
Phase 2.1 PEMB Structure	24653	sf							25	625,570			25.38	**625,570**
Phase 2.1 Standing Seam Roof	24653	sf							12	300,274			12.18	**300,274**
Phase 1.1 Striping	1686	lf							1	1,711			1.02	**1,711**
Phase 2.1 Striping	1686	lf							1	1,711			1.02	**1,711**
TOTALS										2,092,570				**2,092,570**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # : **110549**

SUMMARY
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DUE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	LABOR MH	LABOR COST	MATERIAL COST	SUBCON COST	EQUIPMENT RENT / STS	**TOTAL COST**
P 2 PH.1.1	4,034	670,593	268,452		38,276	**977,321**
P 3 PH.1.3	855	142,045	76,483		8,108	**226,635**
P 4 PH.1.4	728	120,927	74,055		6,902	**201,884**
P 5 PH.1.5	6,824	1,134,204	586,118		64,738	**1,785,060**
P 6 PH.2.1	2,074	344,791	205,631		19,680	**570,102**
P 7 PH.2.2	4,666	775,636	423,140		41,291	**1,240,067**
P 8 PH.2.3 & 2.4	626	104,020	77,147		5,937	**187,105**
P 9 PH.2.5 & 2.6	668	111,083	86,928		6,340	**204,351**
ESTIMATE TOTALS	**20,475**	**$3,403,299**	**$1,797,953**		**$191,273**	**$5,392,525**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.1														
Equipment														
Transformers	4	ea	180.4	722	166.22	119,944					1711.54	6,846	31697.43	**126,790**
480V Swgr	1	ea	314.16	314	166.22	52,219					2980.58	2,981	55199.92	**55,200**
Chargers	4	ea	11	44	166.22	7,314					104.36	417	1932.77	**7,731**
Pantographs	8	ea	11	88	166.22	14,627					104.36	835	1932.77	**15,462**
Cable Tray														
(Dc) 36" Stacked Cable Tray	470	lf	0.8032	378	166.22	62,751	40.60	19,081			7.62	3,582	181.73	**85,414**
(Dc) Single 36" Cable Tray														
36" Cable Tray Fittings	1	ea	6.3113	6	166.22	1,049	299.80	300			59.88	60	1408.73	**1,409**
(480V) 36" Stacked Cable Tray	80	lf	0.8032	64	166.22	10,681	40.60	3,248			7.62	610	181.73	**14,539**
480V Feeders														
Xfmr To Swgr 4000A	1000	lf	1.1469	1,147	166.22	190,638	64.84	64,837			10.88	10,881	266.36	**266,356**
Swgr To Chargers 600A	275	lf	0.3112	86	166.22	14,224	37.31	10,261			2.95	812	91.99	**25,297**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	1785	lf	0.1026	183	166.22	30,451	24.69	44,072			0.97	1,738	42.72	**76,261**
Control Cables & Terms	2700	lf	0.1018	275	166.22	45,682	5.33	14,379			0.97	2,607	23.21	**62,668**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	28	ea	9.1779	257	166.22	42,715	422.92	11,842			87.07	2,438	2035.54	**56,995**
Lightning Protection	30323	sf					2.21	67,127					2.21	**67,127**
Grounding														
4/0 Ground Ring	810	lf	0.1088	88	166.22	14,653	13.01	10,539			1.03	836	32.13	**26,028**
3/4" Ground Rod	8	ea	1.6473	13	166.22	2,190	128.32	1,027			15.63	125	417.75	**3,342**
Test Well	2	ea	5.247	10	166.22	1,744	479.17	958			49.78	100	1401.10	**2,802**
Ground Connection	6	ea	8.2364	49	166.22	8,214	414.00	2,484			78.14	469	1861.19	**11,167**
15Kv Ductbank	200	lf	1.549	310	166.22	51,495	91.49	18,298			14.70	2,939	363.66	**72,732**
				4,034		670,593		268,452				38,276		**977,321**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.3														
Equipment														
Chargers	3	ea	11	33	166.22	5,485					104.36	313	1932.77	**5,798**
Pantographs	6	ea	11	66	166.22	10,970					104.36	626	1932.77	**11,597**
Cable Tray														
(Dc) 36" Stacked Cable Tray	60	lf	0.8032	48	166.22	8,011	40.60	2,436			7.62	457	181.73	**10,904**
(Dc) Single 36" Cable Tray	135	lf	0.5516	74	166.22	12,377	38.71	5,226			5.23	706	135.62	**18,309**
36" Cable Tray Fittings	2	ea	6.3113	13	166.22	2,098	299.80	600			59.88	120	1408.73	**2,817**
(480V) 36" Stacked Cable Tray	80	lf	0.8032	64	166.22	10,681	40.60	3,248			7.62	610	181.73	**14,539**
480V Feeders														
Swgr To Chargers 600A	100	lf	0.4811	48	166.22	7,997	38.23	3,823			4.56	456	122.77	**12,277**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	1727	lf	0.0978	169	166.22	28,088	24.63	42,543			0.93	1,603	41.83	**72,234**
Control Cables & Terms	2625	lf	0.0872	229	166.22	38,031	5.15	13,532			0.83	2,171	20.47	**53,734**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	12	ea	9.1779	110	166.22	18,306	422.92	5,075			87.07	1,045	2035.54	**24,426**
				855		142,045		76,483				8,108		**226,635**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.4														
Equipment														
Chargers	3	ea	11	33	166.22	5,485					104.36	313	1932.77	**5,798**
Pantographs	6	ea	11	66	166.22	10,970					104.36	626	1932.77	**11,597**
Cable Tray														
(Dc) Single 36" Cable Tray	110	lf	0.5419	60	166.22	9,908	38.64	4,251			5.14	566	133.85	**14,724**
36" Cable Tray Fittings	1	ea	6.3113	6	166.22	1,049	299.80	300			59.88	60	1408.73	**1,409**
(480V) 36" Stacked Cable Tray	80	lf	0.8032	64	166.22	10,681	40.60	3,248			7.62	610	181.73	**14,539**
480V Feeders														
Swgr To Chargers 600A	235	lf	0.2916	69	166.22	11,391	37.21	8,743			2.77	650	88.45	**20,785**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	1640	lf	0.0987	162	166.22	26,912	24.64	40,417			0.94	1,536	41.99	**68,864**
Control Cables & Terms	2460	lf	0.0641	158	166.22	26,224	4.89	12,021			0.61	1,497	16.16	**39,742**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	12	ea	9.1779	110	166.22	18,306	422.92	5,075			87.07	1,045	2035.54	**24,426**
				728		120,927		74,055				6,902		**201,884**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.1.5														
Equipment														
480V Swgr	2	ea	314.16	628	166.22	104,439					2980.58	5,961	55199.92	**110,400**
Chargers	11	ea	11	121	166.22	20,112					104.36	1,148	1932.77	**21,260**
Pantographs	22	ea	11	242	166.22	40,225					104.36	2,296	1932.77	**42,521**
Cable Tray														
(Dc) 36" Stacked Cable Tray	285	lf	0.8032	229	166.22	38,051	40.60	11,570			7.62	2,172	181.73	**51,794**
(Dc) Single 36" Cable Tray	400	lf	0.5419	217	166.22	36,028	38.64	15,456			5.14	2,056	133.85	**53,540**
36" Cable Tray Fittings	2	ea	6.3113	13	166.22	2,098	299.80	600			59.88	120	1408.73	**2,817**
(480V) 36" Stacked Cable Tray	140	lf	0.8032	112	166.22	18,692	40.60	5,684			7.62	1,067	181.73	**25,442**
480V Feeders														
Xfmr To Swgr 4000A	2950	lf	0.9271	2,735	166.22	454,616	57.96	170,972			8.80	25,949	220.86	**651,536**
Swgr To Chargers 600A	415	lf	0.4427	184	166.22	30,538	38.03	15,781			4.20	1,743	115.81	**48,062**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	8750	lf	0.0933	816	166.22	135,679	24.58	215,079			0.89	7,744	40.97	**358,502**
Control Cables & Terms	13125		0.074	971	166.22	161,434	5.00	65,646			0.70	9,214	18.00	**236,295**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	44	ea	9.1779	404	166.22	67,124	422.92	18,608			87.07	3,831	2035.54	**89,564**
Lightning Protection	23829	sf					2.21	52,751					2.21	**52,751**
Grounding														
4/0 Ground Ring	750	lf	0.1088	82	166.22	13,568	13.01	9,758			1.03	774	32.13	**24,100**
3/4" Ground Rod	6	ea	1.6473	10	166.22	1,643	128.32	770			15.63	94	417.75	**2,507**
Test Well	2	ea	5.247	10	166.22	1,744	479.17	958			49.78	100	1401.10	**2,802**
Ground Connection	6	ea	8.2364	49	166.22	8,214	414.00	2,484			78.14	469	1861.19	**11,167**
					6,824		1,134,204		586,118				64,738		**1,785,060**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.1														
Equipment														
Chargers	7	ea	11	77	166.22	12,799					104.36	731	1932.77	**13,529**
Pantographs	14	ea	11	154	166.22	25,598					104.36	1,461	1932.77	**27,059**
Cable Tray														
(Dc) 36" Stacked Cable Tray	260	lf	0.8032	209	166.22	34,714	40.60	10,555			7.62	1,981	181.73	**47,250**
(Dc) Single 36" Cable Tray	220	lf	0.5419	119	166.22	19,815	38.64	8,501			5.14	1,131	133.85	**29,447**
36" Cable Tray Fittings	3	ea	6.3113	19	166.22	3,147	299.80	899			59.88	180	1408.73	**4,226**
(480V) 36" Stacked Cable Tray	85	lf	0.8032	68	166.22	11,349	40.60	3,451			7.62	648	181.73	**15,447**
480V Feeders														
Swgr To Chargers 600A	510	lf	0.3022	154	166.22	25,615	37.26	19,004			2.87	1,462	90.36	**46,082**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	4700	lf	0.0955	449	166.22	74,602	24.61	115,650			0.91	4,258	41.39	**194,510**
Control Cables & Terms	7032	lf	0.0808	568	166.22	94,437	5.08	35,728			0.77	5,390	19.28	**135,555**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	28	ea	9.1779	257	166.22	42,715	422.92	11,842			87.07	2,438	2035.54	**56,995**
				2,074		344,791		205,631				19,680		**570,102**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	TOTAL COST
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.2														
Equipment														
480V Swgr	1	ea	314.16	314	166.22	52,219							52219.34	**52,219**
Chargers	8	ea	11	88	166.22	14,627					104.36	835	1932.77	**15,462**
Pantographs	16	ea	11	176	166.22	29,255					104.36	1,670	1932.77	**30,924**
Cable Tray														
(Dc) 36" Stacked Cable Tray	100	lf	0.8032	80	166.22	13,351	40.60	4,060			7.62	762	181.73	**18,173**
(Dc) Single 36" Cable Tray	340	lf	0.5419	184	166.22	30,623	38.64	13,138			5.14	1,748	133.85	**45,509**
36" Cable Tray Fittings	4	ea	6.3113	25	166.22	4,196	299.80	1,199			59.88	240	1408.73	**5,635**
(480V) 36" Stacked Cable Tray	60	lf	0.8032	48	166.22	8,011	40.60	2,436			7.62	457	181.73	**10,904**
480V Feeders														
Xfmr To Swgr 4000A	1700	lf	1.0112	1,719	166.22	285,744	60.73	103,234			9.59	16,310	238.40	**405,288**
Swgr To Chargers 600A	760	lf	0.267	203	166.22	33,728	37.07	28,175			2.53	1,925	83.99	**63,829**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	8065	lf	0.0907	732	166.22	121,653	24.54	197,954			0.86	6,944	40.49	**326,550**
Control Cables & Terms	12093	lf	0.0664	803	166.22	133,411	4.91	59,410			0.63	7,615	16.57	**200,436**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	32	ea	9.1779	294	166.22	48,817	422.92	13,533			87.07	2,786	2035.54	**65,137**
				4,666		775,636		423,140				41,291		**1,240,067**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.3 & 2.4														
Equipment														
Chargers	2	ea	11	22	166.22	3,657					104.36	209	1932.77	**3,866**
Pantographs	4	ea	11	44	166.22	7,314					104.36	417	1932.77	**7,731**
Cable Tray														
(Dc) Single 36" Cable Tray	20	lf	0.5419	11	166.22	1,801	38.64	773			5.14	103	133.85	**2,677**
36" Cable Tray Fittings	1	ea	6.3113	6	166.22	1,049	299.80	300			59.88	60	1408.73	**1,409**
(480V) 36" Stacked Cable Tray	45	lf	0.8032	36	166.22	6,008	40.60	1,827			7.62	343	181.73	**8,178**
480V Feeders														
Swgr To Chargers 600A	110	lf	0.3512	39	166.22	6,421	37.53	4,128			3.33	366	99.23	**10,916**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	2090	lf	0.0904	189	166.22	31,417	24.55	51,303			0.86	1,793	40.44	**84,513**
Control Cables & Terms	3150	lf	0.0652	205	166.22	34,149	4.90	15,433			0.62	1,949	16.36	**51,531**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	8	ea	9.1779	73	166.22	12,204	422.92	3,383			87.07	697	2035.54	**16,284**
				626		104,020		77,147				5,937		**187,105**

PROJECT CLIENT: **FOOTHILL TRANSIT**
PROJECT DESC: **POMONA - EV INFRASTRUCTURE**
PROJECT # **110549**

ESTIMATE DETAIL
ELECTRICAL

EST LEVEL: **STUDY**
ESTIMATE DATE: **4/22/2019**
ESTIMATOR: **RHR**

DESCRIPTION	QTY.	UNIT	LABOR				MATERIAL		SUBCONTRACT		EQUIPMENT RENT		UNIT COST	**TOTAL COST**
			U MH	MH	RATE $/MH	L TTL COST	UNIT COST	M TTL COST	UNIT COST	S TTL COST	UNIT COST	ER TTL COST		
PH.2.5 & 2.6														
Equipment														
Chargers	2	ea	11	22	166.22	3,657					104.36	209	1932.77	**3,866**
Pantographs	4	ea	11	44	166.22	7,314					104.36	417	1932.77	**7,731**
Cable Tray														
(Dc) Single 36" Cable Tray	90	lf	0.5419	49	166.22	8,106	38.64	3,478			5.14	463	133.85	**12,047**
480V Feeders														
Swgr To Chargers 600A	70	lf	0.4654	33	166.22	5,415	38.15	2,670			4.42	309	119.92	**8,395**
Dc Cabling & Terms														
(2) #750Mcm 1000 Cables & Terms	2380	lf	0.0893	213	166.22	35,338	24.53	58,391			0.85	2,017	40.23	**95,746**
Control Cables & Terms	3930	lf	0.0598	235	166.22	39,049	4.84	19,005			0.57	2,229	15.34	**60,283**
General Lighting														
Led Surface Fixture & Branch Conduit/Cable	8	ea	9.1779	73	166.22	12,204	422.92	3,383			87.07	697	2035.54	**16,284**
				668		111,083		86,928				6,340		**204,351**

APPENDIX B - DEPOT YARD LAYOUTS

Qty 30 - 43' Double Deck Buses
Qty 160 - 40' Buses

Target: 190 Bus Locations
112 Total Charging Spaces, 56 Chargers
- **80 Spots for 40' Buses,**
- **32 Spots for 43' DD Buses**

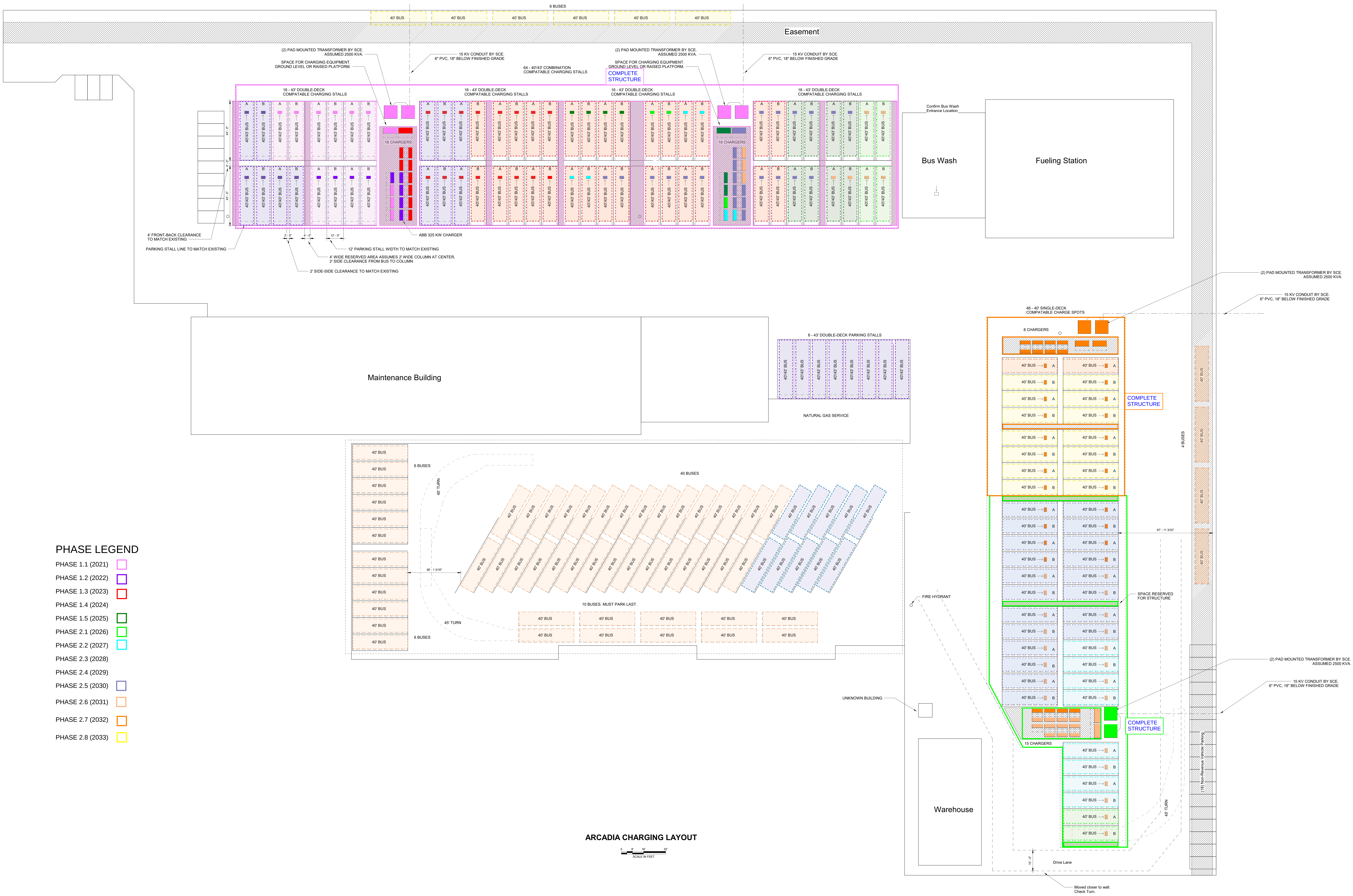
78 Parking Spaces

Reserve:
- **32 - 40' Buses**
- **8 - DD Buses**

ACHIEVED: 190 Bus Locations
110 Total Charging Spaces, 55 Chargers
- **46 Spots for 40' Buses,**
- **64 Spots for BOTH 40' SD & 43' DD Buses**

8 - DD Bus Parking Stalls
72 - 40' Bus Parking Spaces

No Reserve Scheduled.



PHASE LEGEND

- PHASE 1.1 (2021) ☐
- PHASE 1.2 (2022) ☐
- PHASE 1.3 (2023) ☐
- PHASE 1.4 (2024)
- PHASE 1.5 (2025) ☐
- PHASE 2.1 (2026) ☐
- PHASE 2.2 (2027) ☐
- PHASE 2.3 (2028)
- PHASE 2.4 (2029)
- PHASE 2.5 (2030) ☐
- PHASE 2.6 (2031) ☐
- PHASE 2.7 (2032) ☐
- PHASE 2.8 (2033) ☐

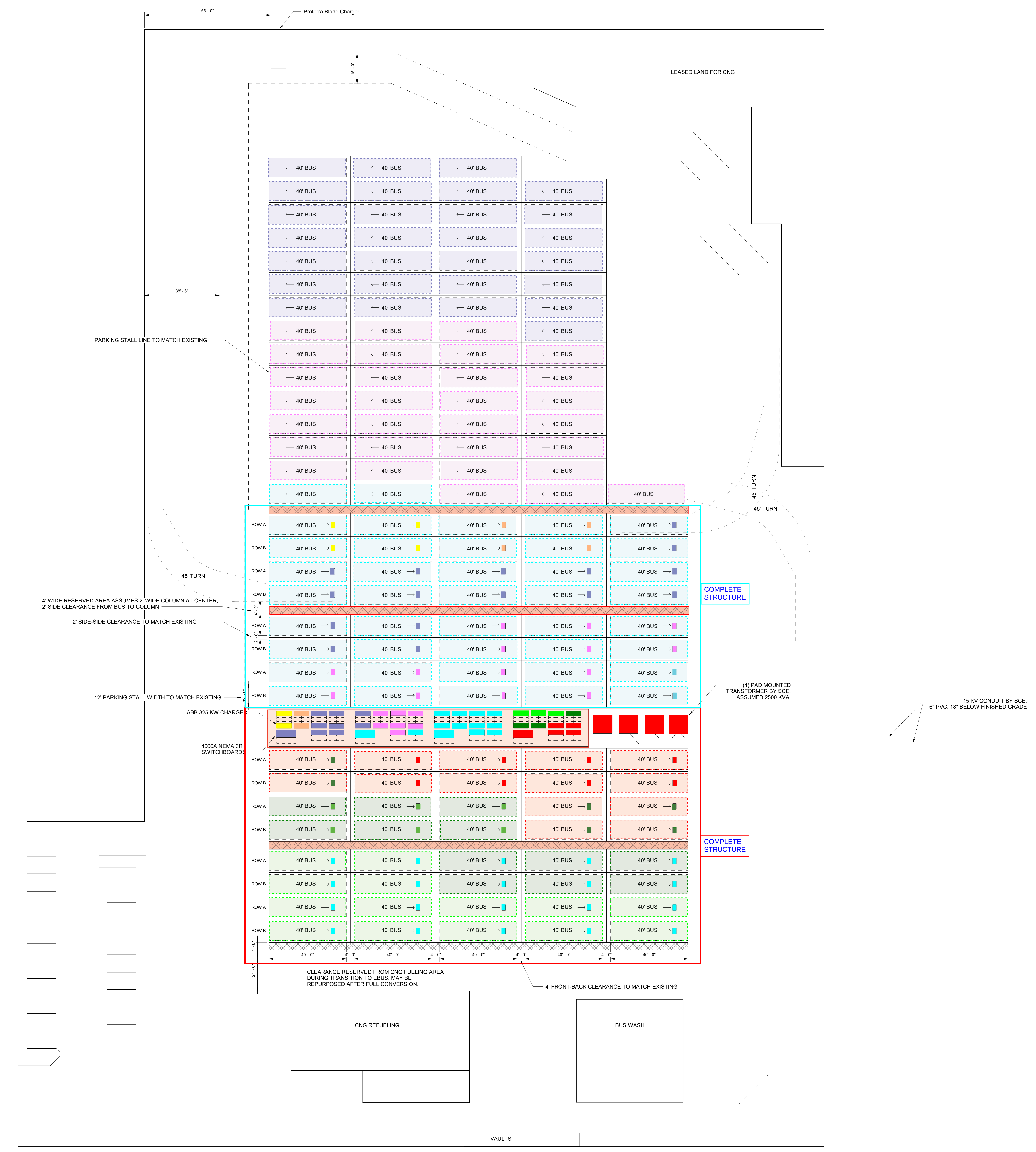
ARCADIA CHARGING LAYOUT

0 8' 16' 32'
SCALE IN FEET

130 - 40' Buses

Target:
40 Chargers Serving 80 Charging Stalls
60 Parked
28 Reserve

12 BUSES NOT SHOWN ON LAYOUT
2 - PROCURED IN 2029
8 - PROCURED IN 2030
2 - PROCURED IN 2032



PHASE LEGEND

PHASE 1.1 (2023)	🟥
PHASE 1.2 (2024)	
PHASE 1.3 (2025)	🟩
PHASE 1.4 (2026)	🟩
PHASE 1.5 (2027)	🟦
PHASE 2.1 (2028)	🟪
PHASE 2.2 (2029)	🟪
PHASE 2.3 (2030)	🟧
PHASE 2.4 (2031)	
PHASE 2.5 (2032)	🟨
PHASE 2.6 (2033)	

POMONA CHARGING LAYOUT

0 8' 16' 32'
SCALE IN FEET

BURNS & McDONNELL

CREATE AMAZING.

Burns & McDonnell World Headquarters
9400 Ward Parkway
Kansas City, MO 64114
O 816-333-9400
F 816-333-3690
www.burnsmcd.com