Culver City Fleet Electrification Master Plan

Introduction

Prepared by Culver City and Center for Transportation and the Environment
March 31, 2021

CARB's Innovative Clean Transit Regulation

On December 14, 2018, the California Air Resources Board (CARB) enacted the Innovative Clean Transit (ICT) regulation, requiring all California public transit agencies to purchase only zero-emission buses (ZEB) from the years 2029–2040 with percentage requirements for ZEB purchasing beginning in the year 2023. The goal of the ICT regulation is to transition agencies to fully ZEB fleets.

Project Overview

Culver City Goals and Alignment with Electrification

Widespread adoption of zero-emission bus technology has the potential to significantly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. Culver City is wholeheartedly committed to implementing environmentally-friendly policies and reducing its carbon footprint; therefore, the City has committed to full fleet electrification by the year 2028. With this goal in mind, Culver City has worked diligently with the State of California to piggyback off of the statewide Department of General Services (DGS) contract and execute a purchase order with New Flyer of America for the purchase of 10 battery electric buses (BEBs) and associated charging infrastructure. The first four buses are scheduled to be delivered by August 2021.

The Culver City Department of Transportation will collaborate with New Flyer, Southern California Edison (SCE) and the Center for Transportation and the Environment (CTE) to plan the deployment of these ten buses and, in addition, will prepare a transition study to plan for a full fleet conversion to battery electric buses by 2028. The first phase of this project is the deployment of four buses, a temporary charger and the transition study. The second phase of this project is the deployment of the remaining six buses, charging for the ten buses and the phased design of the facilities required for full electrification.

Funding

The first phase of this project is funded through a mix of federal funding through 5307 funds and local funding provided through CA Transportation Development Act (TDA), SCE infrastructure programs, and other state electrification programs such as Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). The team is seeking funds to secure the second phase of the 10-pilot bus project and has multiple grant applications submitted for expanded 5307 funds, California Energy Commission and the Federal Low or No Emission Vehicle Program. This project will help Culver City enter the BEB market and begin to evaluate the technology and the operation of an electric bus within agency's service area. Furthermore, the final project report will determine the impact on operations and capital programs as the agency transitions to an all-electric fleet by 2028.

Project Partners

Culver City has executed a contract with CTE to prepare a ZEB Transition Plan and a Smart Deployment for the pilot deployment of ten buses in 2021 and 2023. CTE is the national leader in providing technical assistance for ZEB deployments, guiding transit agencies through battery electric and fuel cell electric bus deployment projects while minimizing project risks. CTE understands both the technical and administrative challenges associated with the procurement, deployment, and operation of zero-emission vehicles.

Joining CTE in its work will be two subcontractors: AECOM and Sage Energy Consulting, Inc (Sage). Working closely with CTE, AECOM has assembled a design team from offices in Northern and Southern California and will have primary responsibility for the facilities and infrastructure analysis and the design and construction management for the project. AECOM has teamed with CTE on several ZEB transition studies for transit agencies in California over the past few years. AECOM has helped CTE develop roadmaps for clients' transitions from existing CNG fleets to 100% BEBs, in compliance with the CARB ICT regulation. AECOM has also been the lead engineer on several transit and heavy-duty vehicle electrification projects.

Culver City has engaged New Flyer to provide the ten pilot buses and coordinate charging infrastructure. Culver City will also work with the local electrical utility, SCE, which will provide charger and power upgrade installation through its charge ready program. This program covers costs for "make ready" infrastructure enhancements, providing full-service design and construction of the electrical and site upgrades needed to add electric vehicle charging to a site. This includes installing a new panel, meter, conduit and wires leading up to the concrete pads to support EV charging stations owned and operated by Culver City. The costs associated with these enhancements are estimated to be approximately $500,000.

Project Management

CTE is providing project management services in conjunction with the Culver City Electrification Steering Committee, led by the Chief Transportation Officer, Rolando Cruz. See Methodology section and Figure 1 below for further details.

Pilot Deployment

Phase I: First Delivery of 4 buses & Temporary Charging

The first delivery will consist of four 40-foot, heavy-duty New Flyer Xcelsior CHARGE™ battery electric transit buses with a 439 kWh capacity battery. This delivery should be completed by the end of August 2021.

Culver City Bus has selected to install a single ABB Terra HVC 150C 150 kW charger to power the initial four New Flyer 40' pilot buses to be delivered August 2021. Additional charging will be added for the second delivery of six buses in 2022.

Phase II: Second Delivery of 6 buses and Charging for up to 10 buses

The second delivery will consist of six 40-foot, heavy-duty New Flyer Xcelsior CHARGE™ battery electric transit buses with approximately 527 kWh battery capacity. This delivery is currently planned to be completed in December 2022.

Transition Planning

Methodology

This study uses CTE's ZEB Transition Planning Methodology, which is a complete set of analyses used to inform agencies converting their fleets to zero-emission technology. The methodology consists of data collection and analysis and assessment stages; these stages are sequential and build upon findings in previous steps. The work steps specific to this study are outlined below:

1. Planning and Initiation
2. Requirements & Data Collection
3. Service Assessment
4. Fleet Assessment
5. Fuel Assessment
6. Facilities Assessment
7. Maintenance Assessment
8. Total Cost of Ownership Assessment

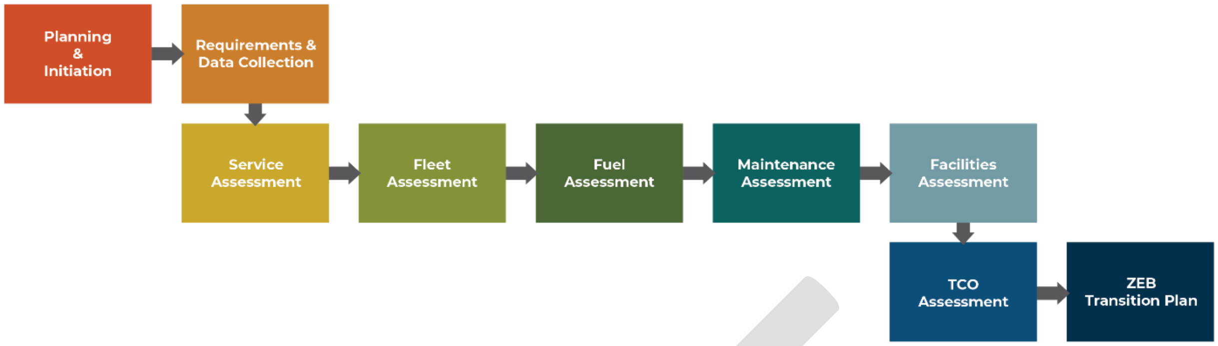


Figure 1 – CTE's ZEB Transition Study Methodology

The **Planning and Initiation** phase builds the administrative framework for the transition study. During this phase, the project team drafted the scope, approach, tasks, assignments, and timeline for the project. CTE worked with Culver City staff to plan the overall project scope and all deliverables throughout study timeline.

For the **Requirements Analysis & Data Collection,** CTE collects data on the agency's fleet, routes and blocks, operational data, like mileage and fuel consumption, and maintenance costs. Using this data, CTE establishes requirements for the planned zero-emission fleet to drive analyses in the later assessments.

The **Service Assessment** phase initiates the technical analysis of the study. Using information collected in the Data Collection phase, CTE evaluates the feasibility of a zero-emission fleet over the study timeframe. Results from the Service Assessment are used to guide ZEB procurements in the Fleet Assessment and to determine energy requirements in the Fuel Assessment.

The **Fleet Assessment** develops a projected timeline for replacement of current buses with ZEBs that is consistent with the agency's fleet replacement plan. This assessment also includes a projection of fleet capital cost over the transition timeframe and is optimized with regard to state mandates, like CARB's ICT regulation, or agency goals, such as minimizing cost or maximizing service levels.

The **Fuel Assessment** merges the results of the Service Assessment and Fleet Assessment to determine annual fuel requirements and associated costs. The Fuel Assessment calculates energy costs through the transition timeframe, including the agency's current fossil fuel buses, and considers applicable low-carbon fuel standard (LCFS) credits. To more accurately estimate BEB charging costs, a focused Charging Analysis is performed to simulate daily system-wide charging use. As current technologies are phased out in later years of the transition, the Fuel Assessment calculates the increasing energy requirements for ZEBs. The Fuel Assessment also provides a total energy cost over the transition lifetime.

The **Facilities Assessment** determines the necessary infrastructure to support the projected zero-emission fleet based on results from the Fleet Assessment and Fuel Assessment. This assessment provides quantities of charging infrastructure and calculates associated costs sequenced over the transition timeframe.

The **Maintenance Assessment** calculates all projected fleet maintenance costs over the transition timeframe. This includes costs related to existing fossil fuel buses remaining in the fleet, as well as new BEBs.

The **Total Cost of Ownership Assessment** compiles results from the previous assessments and provides a comprehensive view of all associated costs over the transition timeframe.

Planning and Initiation

Project Charter

The project charter outlines the scope, timeline, budget, and risks of the project. This document ensures quality by defining the success of the project in advance. The project charter provides clarity on roles and responsibilities and serves to bring everyone into alignment and as the foundation of the project.

Scope

Table 1 below provides a summary of the scope agreed upon between stakeholders in the Project Charter.

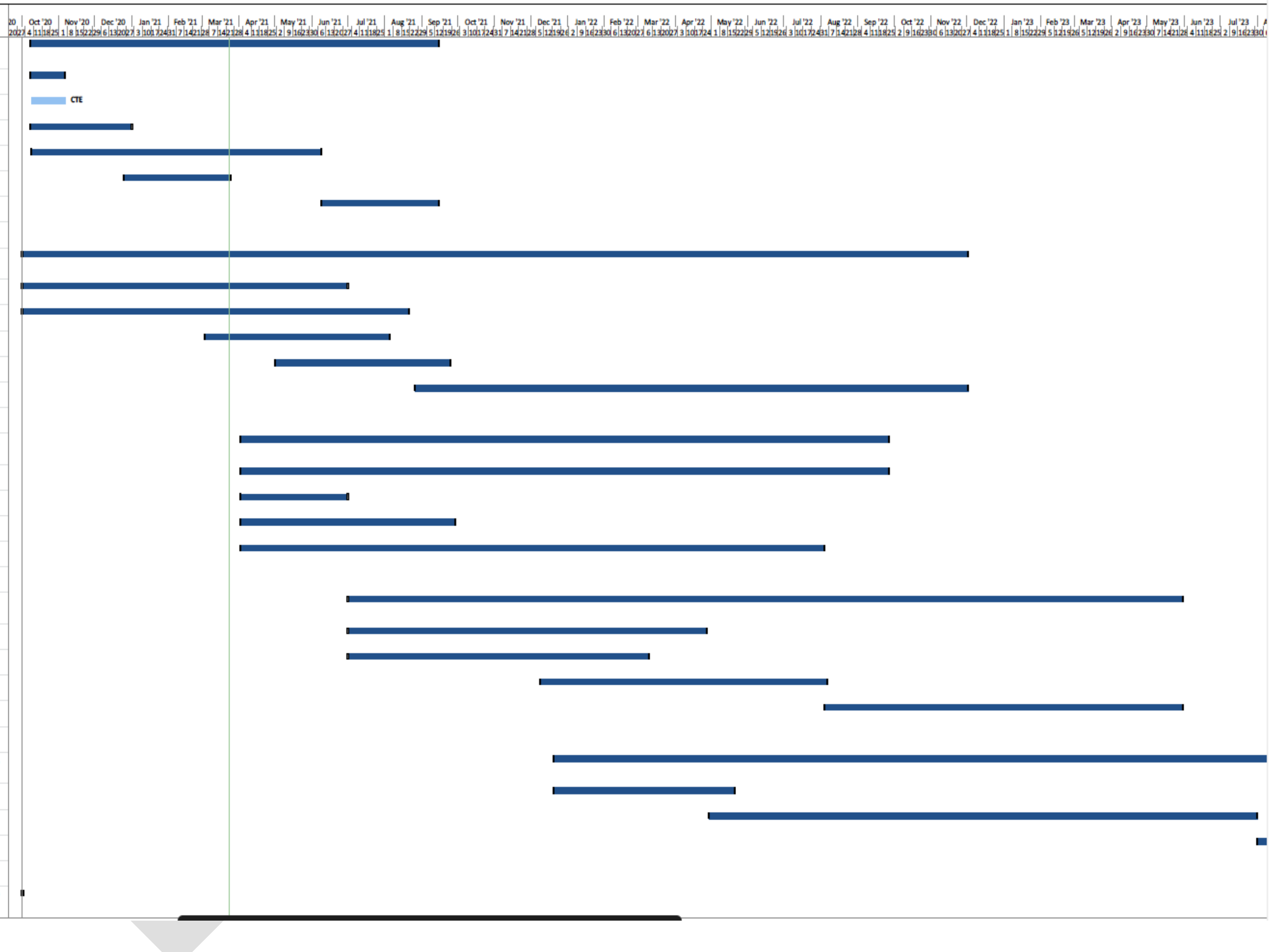
Table 1 - Project Scope

Project Deliverable	Responsibility	Summary
BEB Procurement and Commissioning	Culver City / New Flyer	Deliver and accept four 40' battery electric buses in August 2021 and six 40' battery electric buses in 2022
Route Modeling	CTE	Use real-world efficiency data to estimate the performance of the New Flyer BEB on Culver City routes.
Charging Equipment	CTE / New Flyer	Develop charging model to assess options for charging equipment, evaluating charger power and quantities to meet service requirements.
Rate Modeling	CTE	Use route model results combined with charge modeling to assess the operational cost of the pilot service.
Training	New Flyer	Provide training to all operators and maintenance technicians prior to deployment of buses into revenue service.

Diagnostic Equipment, Software & Data Access Tools	New Flyer / ViriCiti	Provide diagnostic equipment, software, and data access tools to be used by maintenance technicians to identify vehicle issues. ViriCiti will be used for data access and performance reporting.
Charging Infrastructure	SCE	Draft plans for constructing the infrastructure necessary to charge 10 buses at the Culver City Transportation facility, and the supporting vaults & transformer for the entire fleet.
Facility Electrification Plan	CTE / AECOM	Develop a battery electric bus deployment plan that complies with all California Air Resources Board (CARB) Innovative Clean Transit (ICT) regulations.
Analysis of Infrastructure Needs	CTE / AECOM	Evaluate capacity of current grid infrastructure to determine if it will be sufficient for the City's needs as its electric fleet grows. Determine the capacity constraints, possible problems, and identify when capacity is reached. Assess scale of required charging and electricity upgrades.
Analysis of Yard Layout and Charger Location	CTE / AECOM	Identify different charger layouts that can be implemented for an all-electric fleet, and how each layout will impact parking and operations.
EVSE Market Survey	CTE	Analyze the types of charging equipment that is available or under development, including plug-in, overhead, and in-ground technology. This analysis includes operational limitations, construction challenges, and cost.
Assess and Incorporate New Flyer Charging Options for Pilot Project	CTE / New Flyer	Assess charging options that are readily available for use by Culver City for the 10-bus pilot deployment using findings from the EVSE Market Survey.
Yard Layout Analysis	AECOM	Analyze and present multiple options for a 100% BEB yard layout, including impacts on traffic flow and turn radius, along with the reduction in parking and mitigation strategies.
Renewable Energy Analysis	Sage	Evaluate current electricity consumption and incorporate projections of future load from the BEB rollout plan. Identify strategies for using renewable power and provide costs and benefits of each. Outline key steps and strategies for implementing renewables in an optimal way.
BEB Transition Plan	CTE	Perform Total Cost of Ownership assessment for transitioning Culver City's fleet to 100% BEB by 2028. The TCO will calculate Culver City's total capital and operational costs from 2021-2040.

Timeline

ID	Task Name	Start	Finish
1	**Objective 1: Facility Analysis and BEB Transition Plan**	**10/8/20**	**9/14/21**
2	Work Plan and Schedule	10/8/20	11/5/20
8	Analysis of Battery Electric Bus Market	10/9/20	11/5/20
9	Analysis of Battery Electric Bus Performance and Cost	10/8/20	12/31/20
22	Analysis of Infrastructure Needs	10/9/20	6/8/21
35	Renewable Energy Analysis	12/24/20	3/24/21
38	BEB Transition Plan	6/9/21	9/14/21
44			
45	**Objective 2: Pilot Project Phase 1: 4 BEBs**	**10/1/20**	**12/1/22**
46	Pilot Project Phase 1 Management & Reporting	10/1/20	7/1/21
52	Bus Design & Build	10/1/20	8/20/21
103	Infrastructure Design, Procurement & Build: Temporary Charging S	3/2/21	8/4/21
113	Bus Deployment	5/1/21	9/24/21
141	KPI Analysis & Reporting	8/26/21	12/1/22
150			
151	**Objective 3: Pilot Project Infrastructure Design**	**4/1/21**	**9/26/22**
152	Infrastructure Design Management & Reporting	4/2/21	9/26/22
158	Alternative 1: Ground-based plug-in pedestal charging	4/1/21	6/30/21
163	Alternative 2: Overhead pantograph charging system	4/1/21	9/28/21
171	Alternative 3: Parking Structure charging system	4/1/21	8/4/22
179			
180	**Objective 4: Pilot Project Infrastructure Build**	**6/30/21**	**5/31/23**
181	Infrastructure Build Management & Reporting	7/1/21	4/26/22
187	Alternative 1: Ground-based plug-in pedestal charging	6/30/21	3/9/22
192	Alternative 2: Overhead pantograph charging system	12/9/21	8/6/22
196	Alternative 3: Design-Build Documents for Parking Structure	8/4/22	5/31/23
199			
200	**Objective 5: Pilot Project Phase 2: 6 BEBs**	**12/20/21**	**8/29/24**
201	Bus Design & Build	12/20/21	5/20/22
213	Bus Deployment	4/29/22	7/31/23
241	KPI Analysis & Reporting	8/1/23	8/29/24
244			
245	**Objective 6: Secure Funding**	**10/1/20**	**10/1/20**



Requirements Analysis

It is essential to understand the key elements of Culver City's current service to evaluate the costs of a full zero-emission transition. Culver City staff provided key data elements of the current service as inputs to the analysis, which included the following:

- Fleet composition
- Routes and blocks
- Mileage and fuel consumption
- Maintenance costs

Fleet

Culver City's fleet is comprised of fifty-four (54) 40-foot New Flyer Renewable Compressed Natural Gas (RCNG) buses of varying ages. All buses are housed at a single depot, located at 4343 Duquesne Avenue, Culver City, CA. Buses range in age from model year 2001 to 2017; the average age is 9.7 years.

Routes and Blocks

Culver City's service is all fixed-route, operating on eight routes centered in downtown Culver City and serving Marina del Ray and the bordering Los Angeles neighborhoods. Routes 1 through 7 operate as local, frequent weekday and weekend service; in addition, route 6 runs as a separately-branded rapid service on weekdays. Culver City's service is organized into 105 unique blocks comprised of these eight routes. Blocks range in length from about 1 hour to 18 hours long, and in mileage from 7 miles to just over 200 miles. There are 68 weekday blocks, 20 Saturday blocks and 17 Sunday blocks. Buses pull out from the depot as early as 4:45 in the morning and can return after midnight.

Mileage and Fuel Consumption

Culver City operates an exclusively RCNG fleet. The annual fleet mileage of the 54 buses is 1.7 million miles and annual fuel consumption is approximately 1 million gasoline gallons equivalent (GGE) of CNG. Fleet average efficiency is 1.76 mpg. It cost Culver City $1.1 million in 2019 to fuel its fleet at an average cost of $1.10 per GGE of CNG and $0.62 per mile.

Maintenance Costs

In 2019, Culver City spent approximately $1.7 million on scheduled and unscheduled maintenance, including both parts and labor, for its entire fleet. This results in an average maintenance cost of $0.94 per mile. Buses also undergo a one-time engine and transmission overhaul during their lifetime at an average cost of $10,700 and $7,500, respectively.

Culver City Fleet Electrification Master Plan

Service Assessment

Prepared by Culver City and Center for Transportation and the Environment

March 31, 2021

Assessment Overview

The Service Assessment phase initiates the data collection and technical analysis of the study. CTE met with Culver CityBus (CCB) to define assumptions and requirements used throughout the study and to collect operational data. The results from the Service Assessment are used to guide ZEB procurement projections in the Fleet Assessment and to determine energy requirements in the Fuel Assessment.

This assessment analyzes the feasibility of maintaining CCB's current level of service with BEBs and does not plan for any expansions. The main focus of the Service Assessment is the block analysis, which determines if BEBs could meet the service requirements of the blocks throughout the transition period based on bus endurance, range limitations, weather conditions, levels of battery degradation and route specific requirements. The energy needed to complete a block is compared to the available energy for the respective bus type that is planned for the block to determine if a BEB can successfully operate on that block. This assessment also determines a timeline for when blocks become eligible for zero-emission buses as technology improves. This information is then used to inform BEB procurements in the Fleet Assessment.

The analysis assumes a 5% improvement in battery capacity every other year and a starting battery capacity of 660 kWh, which is used to determine the timeline for when blocks become achievable for BEBs to replace fossil-fuel buses in a one-for-one ratio. The results from the analysis are used to determine when, or if, a full transition to BEBs may be feasible. Results from this analysis are also used to determine the specific energy requirements for the agency and develop the estimated costs to operate the BEBs in the Fuel Assessment. This modeling analysis also assumes blocks will maintain a similar distribution of distance, relative speeds, and elevation changes as exists at the time of the study since bus service will continue to serve similar locations within the city and use similar roads to reach these destinations even if specific routes and schedules change. This core assumption affects energy use estimates and block achievability in each year.

Bus efficiency and range are primarily driven by bus specifications; however, both metrics can be impacted by a number of variables including the route profile (i.e. distance, dwell time, acceleration, sustained top speed over distance, average speed, and traffic conditions), topography (i.e. grades), climate (i.e. temperature), driver behavior, and operational conditions such as passenger loads and auxiliary loads. As such, BEB efficiency and range can vary dramatically from one agency to another. Therefore, it is critical to determine efficiency and range estimates that are based on an accurate representation of CCB's operating conditions.

CTE's route modeling models the impact of varying passenger load, accessory load, and battery degradation on real-world bus performance, fuel efficiency, and range. CTE ran models with varying loads to represent "nominal" and "strenuous" loading conditions. Nominal loading conditions assume average passenger loads and moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditioning (HVAC) system. Strenuous loading conditions assume high or maximum passenger loading and near maximum output of the HVAC system. This nominal/strenuous approach offers a range of operating efficiencies to use for estimating average annual energy use (nominal) or planning minimum service demands (strenuous). Route modeling ultimately provides an average energy use per mile (kilowatt-hour/mile [kWh/mi]) associated with each route, bus size, and load case. System-wide energy use is estimated in subsequent assessments.

As noted previously, CTE models the impact of battery degradation. BEB range is negatively impacted by battery degradation over time. A BEB may be placed in service on a given block with beginning-of-life batteries; however, it may not be able to complete the entire block at some point in the future before the batteries reach end-of-life (typically considered 80% of available service energy). Conceptually, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding blocks. CCB can rotate the fleet to meet demand, assuming there is a steady procurement of BEBs each year to match service requirements.

Key Results

Figure 1 *– BEB Block Achievability Percentage by Year* shows that by 2028 nearly all CCB blocks can be completed by BEBs. It is likely that battery capacity will improve more quickly than by 5% every two years, which means that it is possible that all of CCB's blocks will be achievable by that time. If not, the range gap can be remedied through re-blocking. Re-blocking is the process by which blocks that are too long to be achieved by a single BEB are reworked to be completed by two BEBs. Re-blocking takes advantage of the buses that will return to the depot with significant charge remaining after morning operations and would therefore be available to go out and relieve BEBs on longer blocks. Based on this analysis, re-blocking is a viable option for CCB and would not require expanding their fleet even if 100% of their blocks are not achievable by 2028.

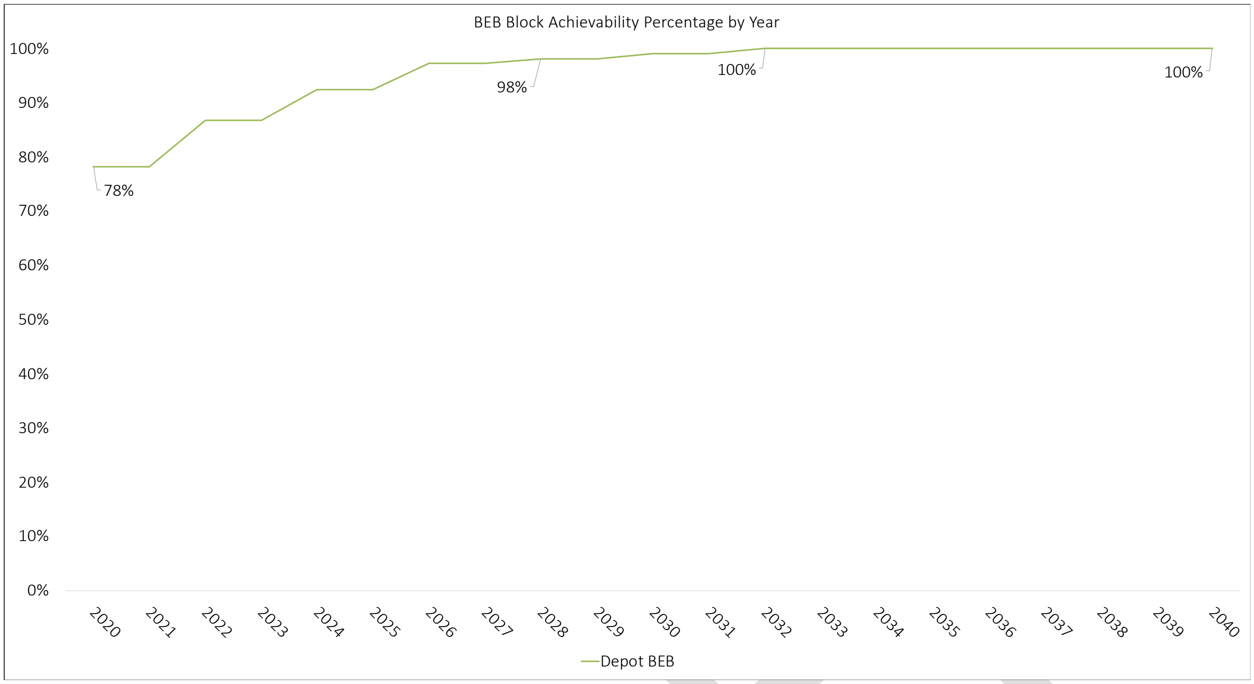


Figure 1 – BEB Block Achievability Percentage by Year

Culver CityBus's Current Plan for Pilot Deployment

CCB's transition will begin with a pilot deployment of ten buses that will take part in two phases. In Phase I, CCB will receive four BEBs with a 439kWh battery capacity and in Phase II, the agency will receive six buses with 527 kWh batteries. CTE has assessed CCB's blocks and determined that these battery capacities will be sufficient for many of the agency's blocks and that putting a higher capacity bus on these blocks would not be necessary and would only incur increased cost and weight. By beginning with lower capacity battery BEBs, CCB is also familiarizing themselves with the technology while allowing the industry time to develop before committing to higher capacity battery buses. CTE anticipates that batteries will continue to increase in energy density, while maintaining, or even decreasing, in battery weight, which means that when CCB is ready to transition the remainder of the fleet beyond the pilot, the buses will not be heavier than the buses in the pilot deployment, but will be able to travel further on a single overnight depot charge.

Conclusion

Assuming a 5% improvement in battery capacity every other year and a starting battery capacity of 660kWh, CTE concludes that Culver City will be able to achieve a full battery electric fleet by 2028, which is in line with the agency's zero-emission goals. These results will be used to inform the following Fleet, Fuel, Maintenance and Facilities Assessments, which will produce an estimate of the total cost of this full fleet transition to depot charged BEBs. Because all blocks will be achievable with battery electric technology, no other ZEB transition scenarios will be explored further.

Culver City Fleet Electrification Master Plan

Fleet Assessment

Prepared by Culver City and Center for Transportation and the Environment
March 31, 2021

Assessment Overview

The Fleet Assessment develops a projected timeline for the replacement of existing buses with BEBs that is consistent with CCB's fleet replacement plan. This assessment also includes a projection of fleet capital costs over the transition timeline. The assessment can be optimized with regard to any state mandates such as CARB's ICT regulation or agency goals such as minimizing cost or maximizing service levels.

Cost Assumptions

CTE and CCB developed cost assumptions for future bus purchases. Key assumptions for bus costs for the CCB Transition Study are as follows:

- Bus costs are based on CCB's most recent procurement price and the State of California statewide procurement contract base bus price for 40' BEBs executed in 2019 with Producer Price Index (PPI) inflationary rates used to adjust to current pricing
- Bus costs are inclusive of estimates for configurable options and taxes
- Future bus costs are estimated using PPI inflationary rates from 2019 state contract pricing
- The battery capacity will continue to increase, but the cost will not increase or decrease. The technology will improve, but the cost will remain stable due to economies of scale.

Table 2 *provides estimated bus costs used in the analysis. Table 2 – Fleet Assessment Cost Assumptions*

	Pilot Deployment	Deployments from 2023 On
Bus Cost (CA State Contract Average)	$742,000	$764,000
Taxable Options Pricing (New Flyer Contract)	$169,000	$169,000
Non-Taxable Options Pricing (ADA, Delivery) (New Flyer Contract)	$42,000	$42,000
Extended Battery Warranty (State Contract)	$51,000	$51,000
Tax	*6.31%*	*10.25%*
Inflation (PPI Commodity Data - WPU141301)	*1.5%*	*1.5%*
Total	**$1,045,000**	**$1,131,000**

Note: Based on California State Contract, Inclusive of Options and Extended Battery Warranty

Key Results

As previously discussed in Chapter 2: Service Assessment, depot-charged BEBs will be sufficient to meet CCB's range demands. The fleet transition strategy is to replace each CNG series with BEBs as they reach the end of their useful life at the end of 12-years of service. **Figure 2** provides the number of each bus type that is purchased each year through 2040 with this replacement strategy.

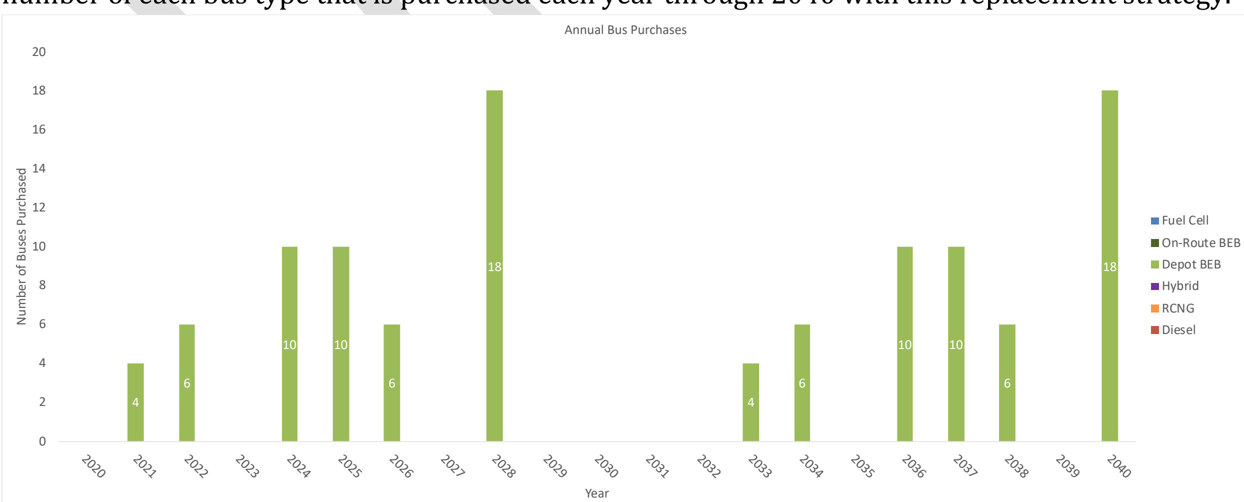


Figure 2 – Projected Bus Purchases, BEB with Depot Only Charging Scenario

Figure 3 depicts the annual fleet composition through 2040. CCB phases out their RCNG buses for BEBs. By 2028, CCB's fleet consists entirely of BEBs. The fleet is able to transition to 100% ZEB using depot-charged BEBs without the addition of any buses.

Figure 3 – Annual Fleet Composition, BEB with Depot Only Charging Scenario

Figure 4 shows the annual total bus capital costs for BEBs purchased in a given year through 2040. The expected total cost over the entire transition period is around $145 million. As noted in **Table 1**, these cost estimates include a PPI inflationary rate of 1.5% per year and an extended battery warranty that will cover the cost of a mid-life battery replacement.

Figure 4 – Annual Capital Costs, BEB with Depot Only Charging Scenario

Conclusion

The Service Assessment concludes that it will be possible for CCB to transition to an entirely BEB fleet without the need for on-route charging. The expected total bus capital cost of the transition to a BEB fleet is estimated at $145 million. The years with highest costs will be 2028 and 2040, which are years when the agency is expecting to replace 18 buses in a single year. It may be possible to split those purchases into two years to avoid incurring such a high expense in a single year.