County Connection

INTER OFFICE MEMO

To: Board of Directors **Date:** 03/09/2022

From: Ruby Horta, Assistant General Manager, Administration **Reviewed by:** W.C.

SUBJECT: Draft Zero Emission Bus Fleet Transition Study

Background:

The California Air Resources Board (CARB) adopted the Innovative Clean Transit (ICT) regulation in December 2018 requiring all public transit agencies to gradually transition to a 100 percent zero-emission bus (ZEB) fleet. Beginning in 2029, 100% of new purchases by transit agencies must be ZEBs, with a goal for full transition by 2040. The rule applies to all transit agencies that own, operate, or lease buses with a gross vehicle weight rating (GVWR) greater than 14,000 lbs. It includes standard, articulated, over-the-road, double-decker, and cutaway buses.

The ZEB purchase schedule below shows the purchase requirements starting in 2023 for large transit agencies and 2026 for small transit agencies. County Connection is considered a small transit agency. The ZEB purchase requirements for articulated, over-the-road, double-decker, or cutaway buses do not start until 2026 or later. These bus types remain exempt from the ZEB purchase requirements until they pass the Altoona testing.

Year	Large Transit	Small Transit (County Connection)
2023	25%	-
2024	25%	-
2025	25%	-
2026	50%	25%
2027	50%	25%
2028	50%	25%
2029	100%	100%

The regulation allows for some flexibility, including bonus credits for early ZEB purchases. County Connection's battery-electric bus (BEB) purchases since 2016 qualifies for 12 bonus credits that can be used to offset the minimum purchases requirements outlined in the ZEB purchase schedule.

Finally, to ensure transit service is not adversely impacted, the regulation has exemptions for circumstances that are beyond a transit agency's control. Providing that all required information is correct and complete, exemptions will be granted upon request under the following circumstances:

- When the needed ZEB type is not available;
- When daily mileage needs cannot be met;
- When gradeability needs cannot be met;
- When incremental capital or electricity costs for depot-charging battery electric buses cannot be offset after applying for all available incentive and funding programs;
- When there is a delay in infrastructure construction; or
- When a transit agency declares a financial emergency.

Current Conditions:

County Connection operates a total of 125 transit buses (including 30-ft., 35-ft., and 40-ft. buses) that operate daily on the fixed route service and 63 cutaway vehicles that provide paratransit services. Eight of the 30-ft. buses are battery-electric; the remaining fleet fuel is diesel. The 900-series has been programmed for replacement and staff was awaiting the development of the transition study to finalize the fuel type request. Based on the scenarios developed by the Center for Transportation and the Environment (CTE), the upcoming vehicle replacement fuel type is recommended to be diesel. The agency's early battery-electric bus (BEB) adoption, efforts to deploy hydrogen fuel cell electric buses (FCEBs) along the I-680, ZEB technology advancements, infrastructure development and cost are all factors incorporated into the CTE recommendation.

County Connection has partnered with CTE since 2016 with CTE providing project management and technical assistance services for the Low-No battery electric bus project. With their support, County Connection deployed BEBs on Routes 4 and 5. Given their experience with our fleet and service area needs, as well as their work with neighboring agencies such as LAVTA, they were well positioned develop this study and assist with the rollout plan due June 30, 2023. CTE will summarize the report's key findings at the April Board meeting. A copy of the presentation is available in Attachment 1.

Proposed Scenarios:

CTE worked closely with County Connection staff throughout the project to develop an approach, define assumptions, and confirm the results for the Zero Emission Bus Fleet Transition Study found in Attachment 2. The approach for the study is based on analysis of five ZEB technology scenarios compared to a baseline scenario:

0. Baseline (current technology)
1. BEB with Depot-Only Charging (with diesels)
2. BEB Depot-Only Charging + Fleet Expansion
3. BEB with Depot and On-Route Charging
4. Mixed Fleet: BEB Depot-Only Charging and FCEB
5. FCEB Only

Each of the scenarios presented a different set of challenges and opportunities. The Baseline scenario (all diesel buses) does not meet the ICT requirements but was included to compare the cost of a ZEB transition. Scenario 1 assumes a fleet consisting of BEBs that only charge at a depot and may not be able to meet the range requirements of many routes. These constraints would necessitate maintaining a portion of diesel buses in the fleet. This would not be in compliance with the ICT regulation and would require an exemption, or as described in Scenario 2, the purchase of additional buses to cover the charging times. Alternatively, scenario 3 includes on-route charging to mitigate the need to purchase additional buses and reducing the time necessary to charge at the depot. On-route charging also allows a transit agency to focus on a single technology throughout the fleet and for the installation of a single fueling technology at the depot. The challenges of on-route charging are: finding space along the routes for chargers; additional costs of land acquisition, equipment, and infrastructure installation; operational costs; and the need to increase layover times for charging or accounting for the impact trip interruptions and/or delays on charging. A mixed fleet scenario was developed as a 4th alternative, with the assumption that FCEBs would cover the blocks that exceed the range of the BEBs. Scenario 5 assumes 100% FCEB fleet which could replace diesel buses on a 1:1 ratio but also present challenges when it comes to vehicle and fuel costs.

Financial Implications:

A summary of the total cost of ownership is presented on the table below, which ranges from $253 million as the baseline to $456 million under Scenario 2.

Assessment Type	0. Baseline (All diesel)	1. BEB Depot Only (Some Diesels)	2. BEB Depot Only (With Expansion)	3. BEB Depot + On-Route	4. BEB Depot + FCEB	5. FCEB Only
Fleet	$165M	$ 208M	$ 315M	$ 243M	$253M	$ 270M
Additional Labor	$0	$0	$0	$ 1M	$0	$0
Fuel*	$ 33M	$ 31M	$ 31M	$ 32M	$ 33M	$ 42M
Maintenance	$ 56M	$ 56M	$ 64M	$ 62M	$ 57M	$ 58M
Infrastructure	$ 0	$ 21M	$ 46M**	$ 49M***	$ 33M	$ 14M
Total	**$253 M**	**$317 M**	**$456 M**	**$386 M**	**$373 M**	**$384 M**
% ZEB in 2040	0%	61%	100%	100%	100%	100%

*Near-term cost estimates.
** Excludes costs for necessary yard expansion to accommodate expanded fleet.
***Excludes the cost of land acquisition for on-route charging stations.

Recommendation:

The O&S Committee and staff recommend Board discussion and feedback to staff on the proposed scenarios. Based on the feedback received, the O&S Committee will finalize the recommendation to be presented to the Board for adoption at the April Board meeting. The selected scenario will be used to develop the ICT Rollout Plan, due June 30, 2023. Additionally, staff will provide bi-annual updates on ZEB technology to provide the Board an opportunity to revise the ICT Rollout Plan, as needed.

Action Requested:

The O&S Committee and staff requests Board direction on the proposed scenarios.

Attachments:

Attachment 1: ZEB Fleet Transition Study (Presentation)

Attachment 2: Draft Zero Emission Bus Fleet Transition Study (Report)

ZEB Fleet Transition Study

March 17, 2022

Steve Clermont, Director of Planning & Deployment
Savannah Gupton, Lead Managing Consultant

CTE Overview

Center for Transportation & the Environment

WHO WE ARE

501(c)(3) nonprofit engineering and planning firm

OUR MISSION

Improve the health of our climate and communities by bringing people together to develop and commercialize clean, efficient, and sustainable transportation technologies

Education & Outreach

We help organizations of all shapes and sizes stay ahead of the technology curve.

Prototype Development & Demonstration

We support technology providers through technology research, development, and demonstration.

Smart Deployment

We support early adopters by providing the best technical solutions for initial deployments.

Fleet Transition

We help fleet operators implement strategic plans for full electrification.

CARB ICT Regulation

Bonus Credits

County Connection has credits available to offset ICT purchase mandate for 12 vehicles. The credits are earned from the following:

- 8 BEBs in fleet (2016 Deployment)
- 4 Bonus credits for BEBs purchased prior to January 1, 2018

ZEB Bonus Credits Applied to CARB ICT Transition Schedule

Starting January 1	ZEB Percentage of Total New Bus Purchases	County Connection Scheduled Bus Purchases	Number of ZEBs to Purchase Per Requirement	Offsets Available	Offsets Used to Reduce ZEB Purchases	ZEBs Scheduled and Required to Purchase
2026	25%	7	2	12	2	0
2027	25%	0	0	10	0	0
2028	25%	37	10	10	10	0
2029	100%	26	26	0	0	26

Transition Master Plan vs ICT Rollout Plan

	Transition Master Plan	ICT Rollout Plan
Purpose	• Detailed comprehensive plan • Typically for internal use & as a living document (i.e. expected to change over time) • May advance purchases based on agency ZEB goals	• High-level plan • Developed based on ***one*** scenario selected from Transition Plan • Public plan
Methodology	CTE's ZEB Transition Methodology of six key assessments	• Summary of Master Plan analyses • Added sections describing disadvantaged communities, workforce training, and potential funding sources
Update Frequency	Recommended every 2-5 years	Submitted once to comply with CARB regulation

ZEB Technology Overview

Battery Electric Buses & Fuel Cell Electric Buses

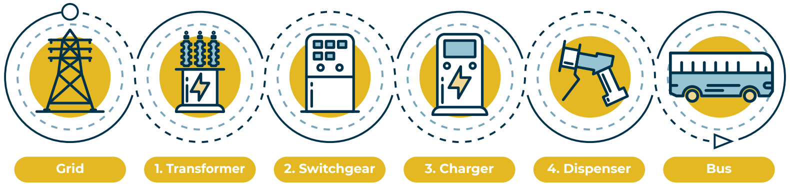
Battery Electric Buses (BEB)

- May need to increase fleet size
- Fueling time longer than diesel bus
- Fuel cost highly variable; could be higher or lower than fossil fuels
- Bus cost approximately moderately higher than diesel bus
- Infrastructure costs increases per bus when scaled up

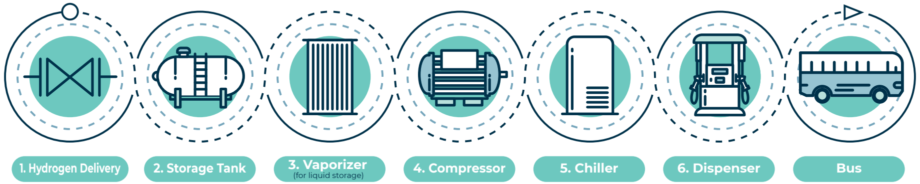
Fuel Cell Electric Buses (FCEB)

- Comparable range to diesel bus – 1:1 replacement ratio
- Fueling time comparable to diesel bus
- Fuel cost moderately higher than fossil fuel
- Bus cost significantly higher than diesel bus
- Infrastructure costs reduce per bus when scaled up
- Greater resilience
- Fewer entrants in market compared to BEB

BEB Fuel Delivery Pathway



FCEB Fuel Delivery Pathway



Factors Affecting BEB Range

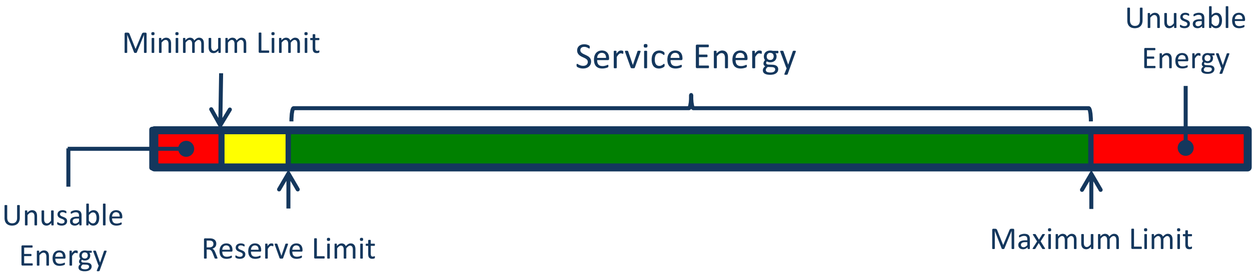
- **Route characteristics:** speed, stops, grade

- **Ridership**

- **Climate: Heating and cooling**

- **Operator Behavior**

- **Battery**



Battery at Start of Life

Preview

Preview: Assessment Conclusions

Scenario	ICT compliance	Total ZEB Fleet (2040)	TCO Over Transition Period
0. Baseline	No – For cost comparison only	8	$253 M
1. BEB Depot-only with diesels	No – Requires exemption to maintain diesels	77	$317 M
2. BEB Depot-only with expansion	Yes – Requires fleet expansion to maintain service	173	$456 M
3. BEB on-route & depot charging	Yes	125	$386 M
4. Mixed Fleet: BEB depot charging & FCEB	Yes	125	$373 M
5. FCEB-Only	Yes	125	$384 M

County Connection
ZEB Transition Study Approach

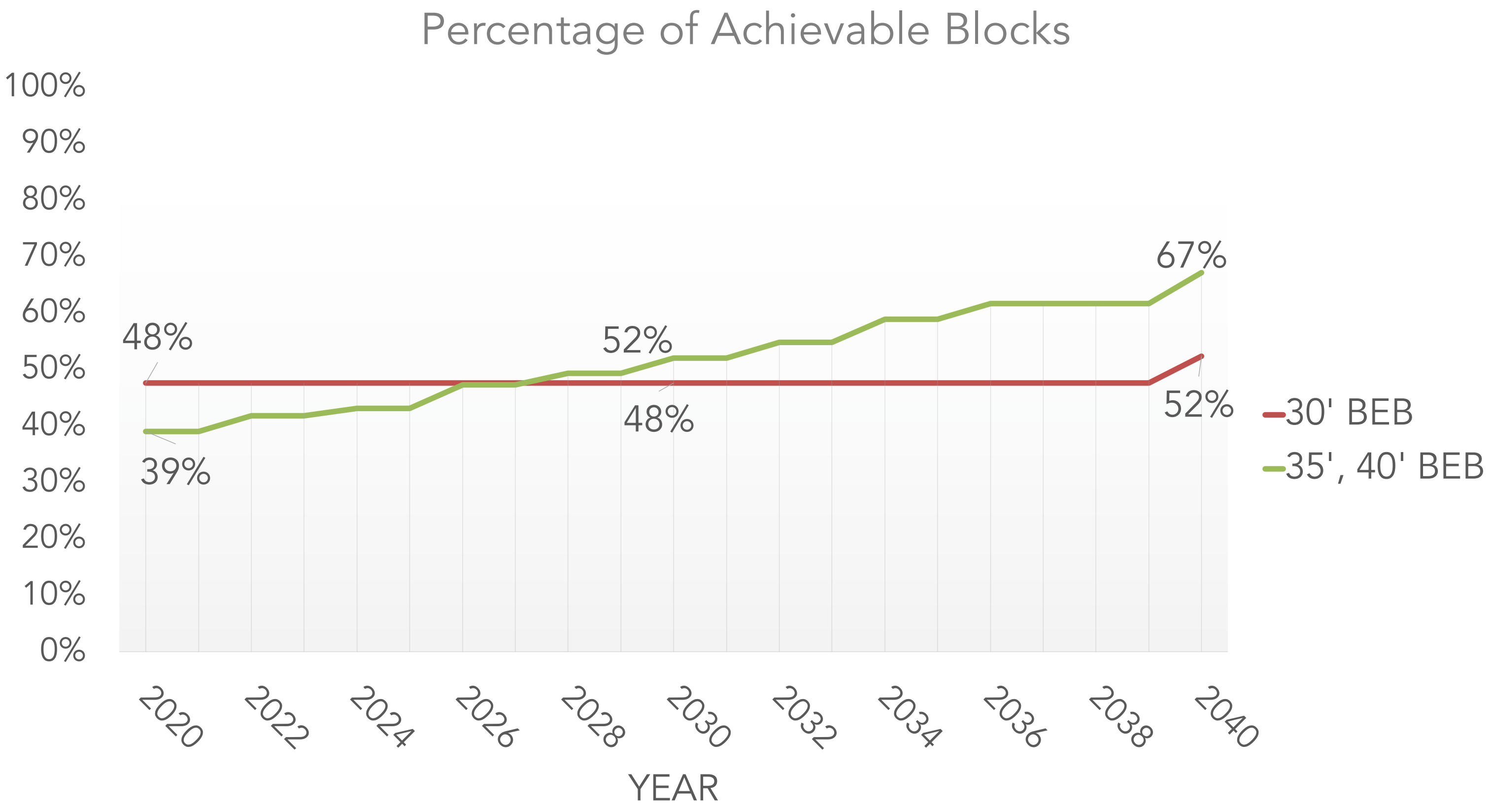
Key Assumptions

- County Connection will maintain service to similar destinations, which standardizes energy use estimates and block achievability throughout the transition period
- FCEBs can complete any block under 350 miles
- 12-year vehicle replacement cycle; FTA useful life
- Fuel and maintenance costs based on County Connection existing rates. OCTA costs were used to support hydrogen analysis
- Infrastructure identified to meet fleet’s evolving need over transition period
  - Assessment conducted in collaboration with AECOM and Fiedler Group

Financial Considerations

- Costs are subject to many variables and need not be the sole basis of transition scenario decision
- Aside from a fuel sensitivity analyses, all cost values are expressed in 2021 USD
- LCFS program engagement may reduce fuel costs
- Federal, State & Regional Cost Share is available
  - MTC expected to share 80% of vehicle purchase expense; not included in capital projections
  - Infrastructure: Federal grants offer up to 90% cost share; not included in capital projections

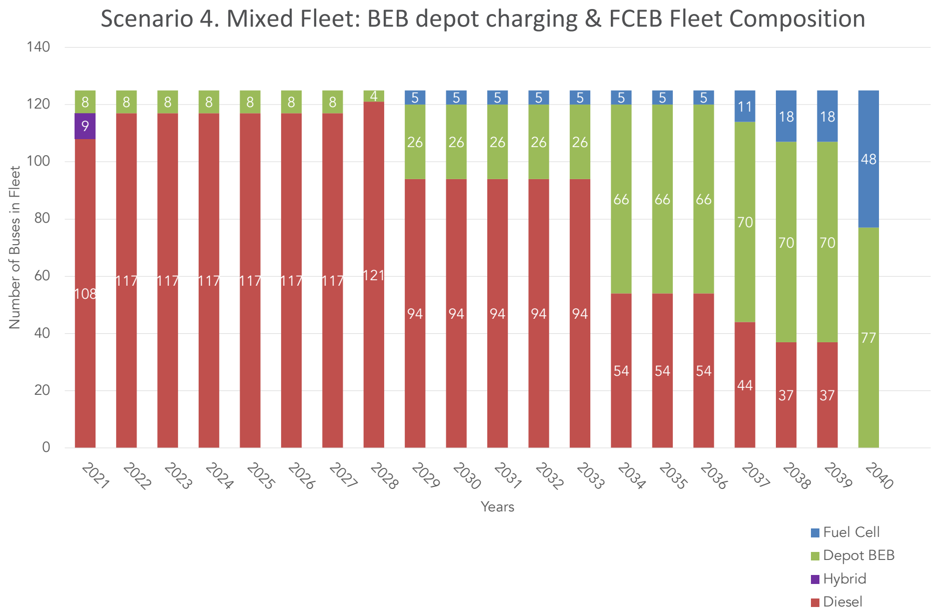
Overnight Depot-Charged BEB Service Feasibility



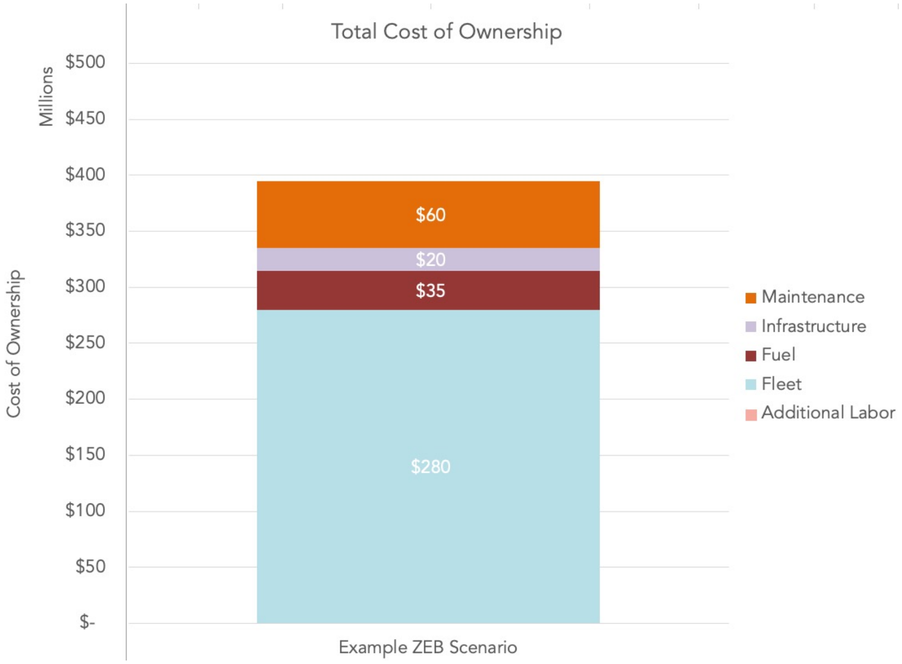
ZEB Transition Solutions

Scenarios Explored

0. Baseline (current technology)
1. BEB Depot-only with diesels
2. BEB Depot-only with expansion
3. BEB Fleet with on-route and depot charging
4. Mixed Fleet: BEB with depot-charging & FCEB
5. FCEB-Only Fleet



ZEB Transition Assessments



Maintenance: Projected maintenance costs based on County Connection actuals and regional agency FCEB reports

Infrastructure: Estimated capital cost for necessary facilities to support regular fueling

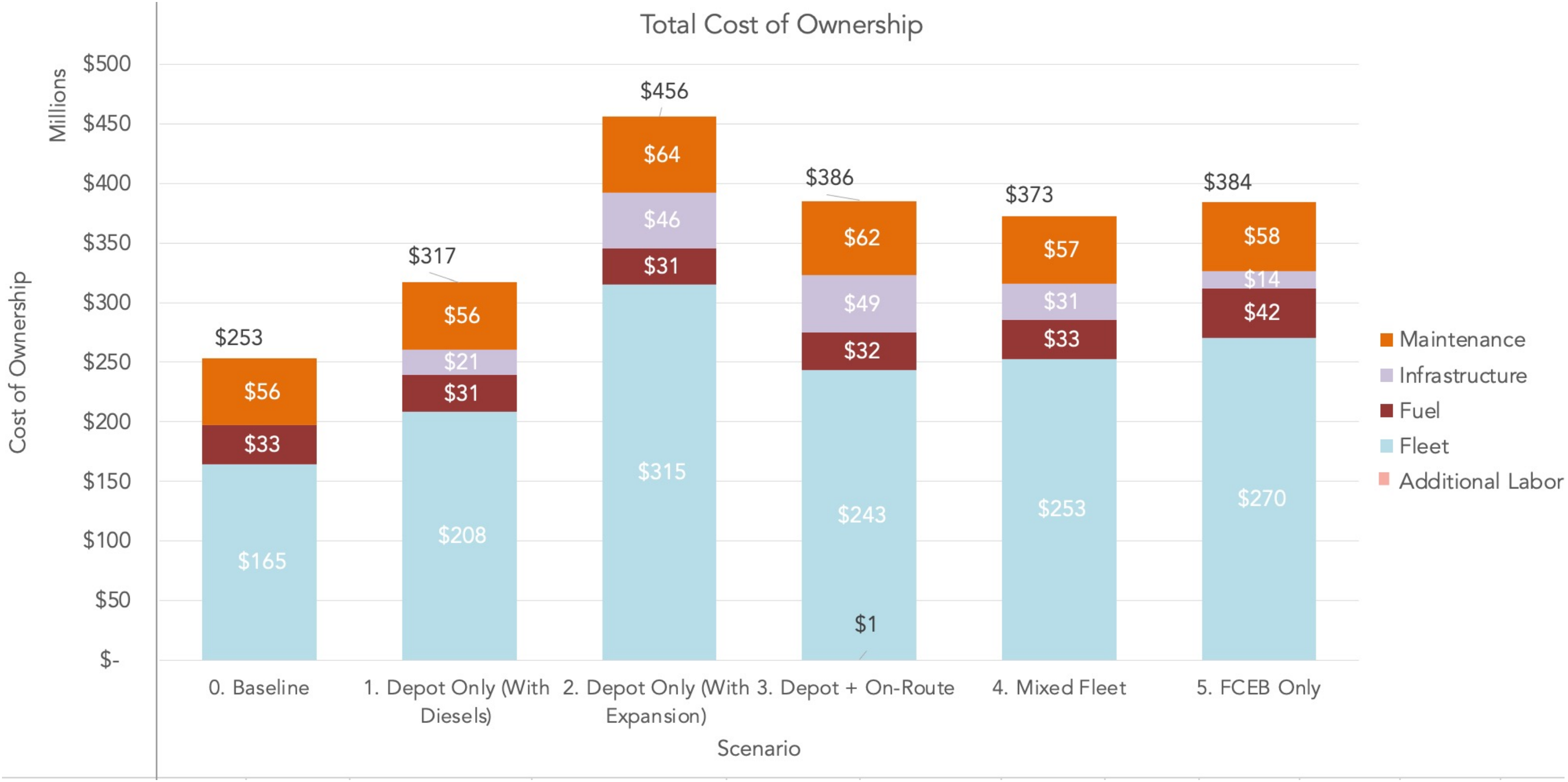
Fuel: Projected operating costs based on varied fuel pricing and energy costs

Fleet: Projected fleet capital costs to meet replace vehicles in fleet

Additional Labor: Applied to Scenario 3. Depot + On-Route to account for on-route charging time

Total Cumulative Capital & Operating Costs

All Scenarios, 2021-2040



Considerations for ZEB Transition Selection

0. Baseline	1. BEB Depot-only with diesels	2. BEB Depot-only with expansion
- Represents no change and maintains current technologies	- BEBs are purchased and deployed only on blocks within an achievable operating range and capable of meeting daily service requirement	+ Meets service requirements without added on-route charging infrastructure
- Used as a cost comparison	- Requires an exemption from CARB to retain diesel buses	- Requires expansion of fleet to meet service needs; 48 additional buses
- Not compliant with ICT Regulation	- Requires maintaining mixed propulsion fleet along with depot charging infrastructure	+ Uniform fueling infrastructure can streamline operations and maintenance

Considerations for ZEB Transition Selection

3. BEB Fleet, Depot & On-Route Charge	4. Mixed Fleet, Depot Charged BEBs & FCEBs	5. FCEB-Only Fleet
- Operationally challenging, may require schedule and/or service changes due to on-route charging requirement	+ Two technologies provide greater redundancy and resilience benefits; less reliant on the grid	+ Operationally similar to current fleet; no service or schedule changes are required due to the technology
- Acquisition costs for on-route charger location is unaccounted for in scenario costs	- Operationally challenging due to the creation of sub fleets by technology	○ Anticipated fuel price reduction due to regional renewable H_2 supply developments though current fuel price is costly
- Requires major infrastructure and operations restructuring in the depot	- Two different fueling infrastructures will be required at depot	+ Requires one-time major infrastructure investment & is scalable

County Connection
ZEB Transition Recommendations

Assessment Conclusions

Scenario	ICT compliance	Total ZEB Fleet (2040)	TCO
0. Baseline	No – For cost comparison only	8	$253 M
1. BEB Depot-only with diesels	No – Requires exemption to maintain diesels	77	$317 M
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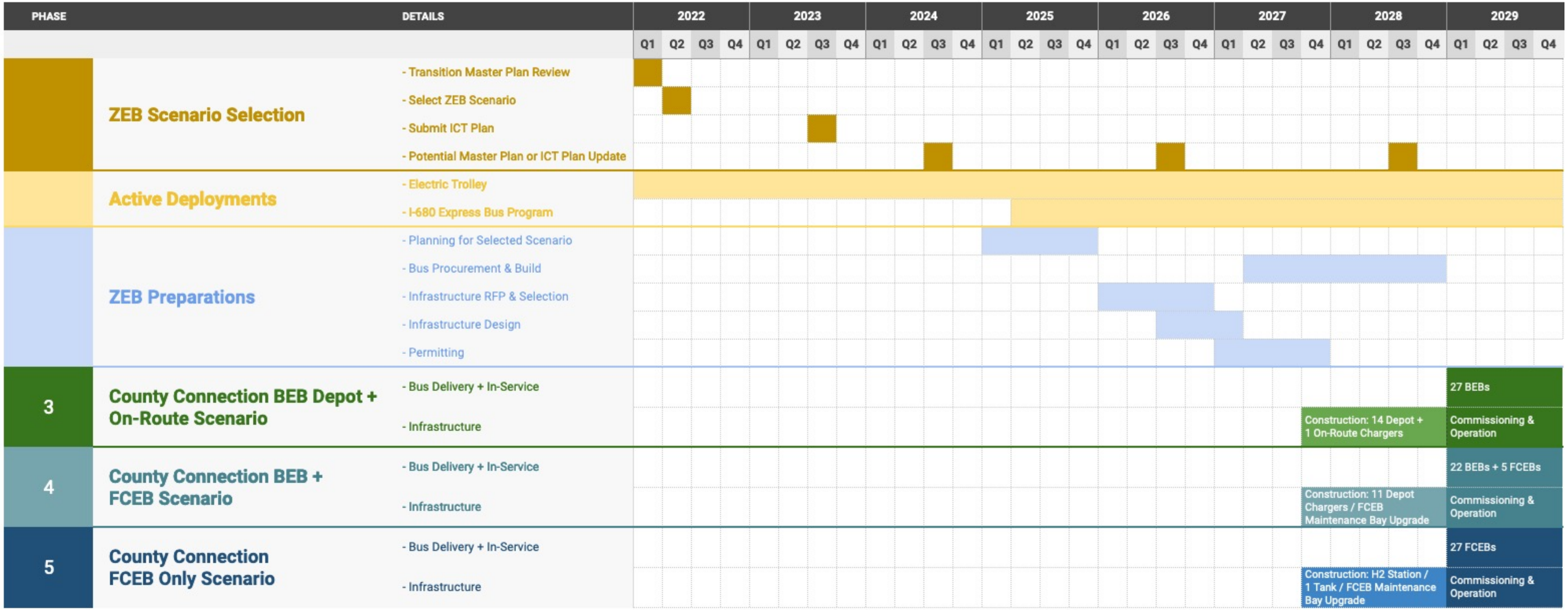
Considerations for ZEB Transition Selection

3. BEB Fleet, Depot & On-Route Charge	4. Mixed Fleet, Depot Charged BEBs & FCEBs	5. FCEB-Only Fleet
- Operationally challenging, may require schedule and/or service changes due to on-route charging requirement	+ Two technologies provide greater redundancy and resilience benefits; less reliant on the grid	+ Operationally similar to current fleet; no service or schedule changes are required due to the technology
- Acquisition costs for on-route charger location is unaccounted for in scenario costs	- Operationally challenging due to the creation of sub fleets by technology	○ Anticipated fuel price reduction due to regional renewable H_2 supply developments though current fuel price is costly
- Requires major infrastructure and operations restructuring in the depot	- Two different fueling infrastructures will be required at depot	+ Requires one-time major infrastructure investment & is scalable

Timeline



PHASE
DETAILS
2022
2023
2024
2025
2026
2027
2028
2029
Q1 Q2 Q3 Q4
ZEB Scenario Selection
- Transition Master Plan Review
- Select ZEB Scenario
- Submit ICT Plan
- Potential Master Plan or ICT Plan Update
Active Deployments
- Electric Trolley
- I-680 Express Bus Program
ZEB Preparations
- Planning for Selected Scenario
- Bus Procurement & Build
- Infrastructure RFP & Selection
- Infrastructure Design
- Permitting
3
County Connection BEB Depot + On-Route Scenario
- Bus Delivery + In-Service
- Infrastructure
27 BEBs
Construction: 14 Depot + 1 On-Route Chargers
Commissioning & Operation
4
County Connection BEB + FCEB Scenario
- Bus Delivery + In-Service
- Infrastructure
22 BEBs + 5 FCEBs
Construction: 11 Depot Chargers / FCEB Maintenance Bay Upgrade
Commissioning & Operation
5
County Connection FCEB Only Scenario
- Bus Delivery + In-Service
- Infrastructure
27 FCEBs
Construction: H2 Station / 1 Tank / FCEB Maintenance Bay Upgrade
Commissioning & Operation

Next Steps

April 1, 2022	Operating & Scheduling Committee Meeting: Follow-up Discussion
April 21, 2022	Board of Directors Meeting: Zero-emission transition scenario selection
Summer 2022	Board of Directors Meeting: ICT Rollout Plan Final and Approval by Board
July 1, 2023	CARB ICT deadline

Questions?

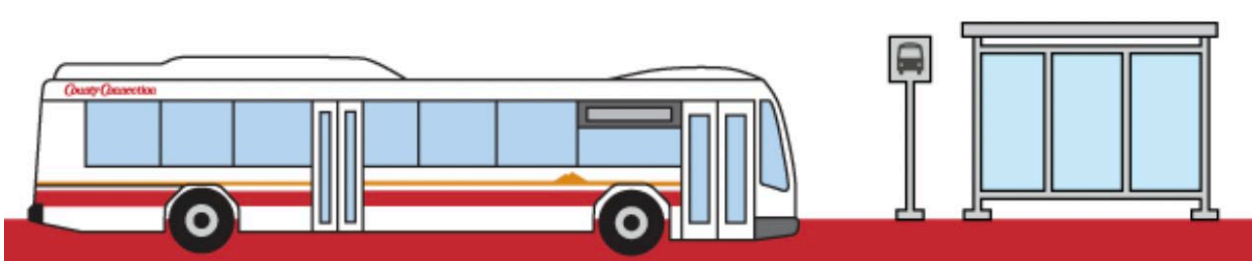
Attachment 2: Draft Zero Emission Bus Fleet Transition Study

COUNTY CONNECTION

DRAFT
Zero-Emission Bus
Fleet Transition Study

Presented by Center for Transportation and the Environment

March 4, 2022



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List of Acronyms

AC Transit	Alameda-Contra Costa Transit District
A&E	Architecture and Engineering
BEB	Battery Electric Bus
CARB	California Air Resources Board
CTE	Center for Transportation and the Environment
CI	Carbon Intensity
DOE	Department of Energy
DGE	Diesel Gallons Equivalent
dHEB	Diesel Hybrid
EPA	Environmental Protection Agency
EV	Electric Vehicle
ESS	Energy Storage System
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicles
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
kWh	Kilowatt Hour
kWh/mi	Kilowatt-hour/mile
LCFS	Low Carbon Fuel Standard
MW	Megawatt
MWh	Megawatt-hours
MTC	Metropolitan Transit Commission
NFPA	National Fire Protection Association
OCTA	Orange County Transit Authority
OEM	Original Equipment Manufacturer
ROW	Right-of-Way
SMR	Steam Methane Reformation
TOU	Time-of-Use
ZEB	Zero Emission Bus

Executive Summary

County Connection engaged the Center for Transportation and the Environment (CTE) to perform a zero-emission bus (ZEB) transition study to create a plan for a 100% zero-emission fleet by 2040 to comply with the Innovative Clean Transit (ICT) regulation enacted by the California Air Resources Board (CARB). The results of the study will inform County Connection Board members and County Connection staff of the estimated costs, benefits, constraints, and risks of the transition to a zero-emission fleet and will guide future planning and decision-making.

On December 14, 2018, CARB enacted the ICT regulation, setting a goal for California public transit agencies to have 100% zero-emission fleets by 2040. The ruling specifies the percentage of new bus procurements that must be zero-emission for each year of the transition period (2021– 2040). Those annual percentages are outlined in **Table ES-1** below.

Table ES-1: ICT ZEB Percentage Requirements

Starting January 1	Percent of New Bus Purchases for Small Agencies
2026	25%
2027	25%
2028	25%
2029	100%

This schedule lays out a pathway to reaching 100% zero-emission fleets in 2040 based on a 12-year projected lifespan for a transit bus. For ZEBs procured prior to 2018, County Connection would be eligible for credits that could be used to count toward CARB's ZEB procurement requirements. County Connection is entitled to eight ZEB credits for BEBs that were in service prior to the ICT Regulation's enactment and an additional four bonus credits for BEBs that were in service prior to January 1, 2018. This will allow County Connection to offset a total of 12 ZEB purchases. CTE recommends that County Connection's ICT Rollout Plan reflects the utilization of all of its bonus credits by the end of 2028, deferring any future ZEB purchases until 2029. This is a conservative approach that allows for ZEB technology to mature. County Connection always has the option to purchase ZEBs any time prior to 2029, regardless of what is documented in their ICT Rollout plan.

The ICT regulation also allows County Connection to request waivers that allow purchase deferrals in the event of economic hardship or if zero-emission technology has not matured enough to meet the service requirements of a given route, based on overnight depot charged battery electric buses. These concessions recognize that zero-emission technologies may cost more than current internal combustion engine (ICE) technologies on a lifecycle basis and that zero-emission technology may not currently be able to meet all service requirements.

Zero-emission technologies considered in this study include battery-electric buses (BEB) and hydrogen fuel cell electric buses (FCEB). BEBs and FCEBs have similar electric drive systems that feature a traction motor powered by a battery. The primary differences between BEBs and FCEBs are the respective amount of battery storage and the method by which the batteries are recharged. The electric drive components and energy source for a BEB and FCEB are illustrated in **Figure ES-1.**

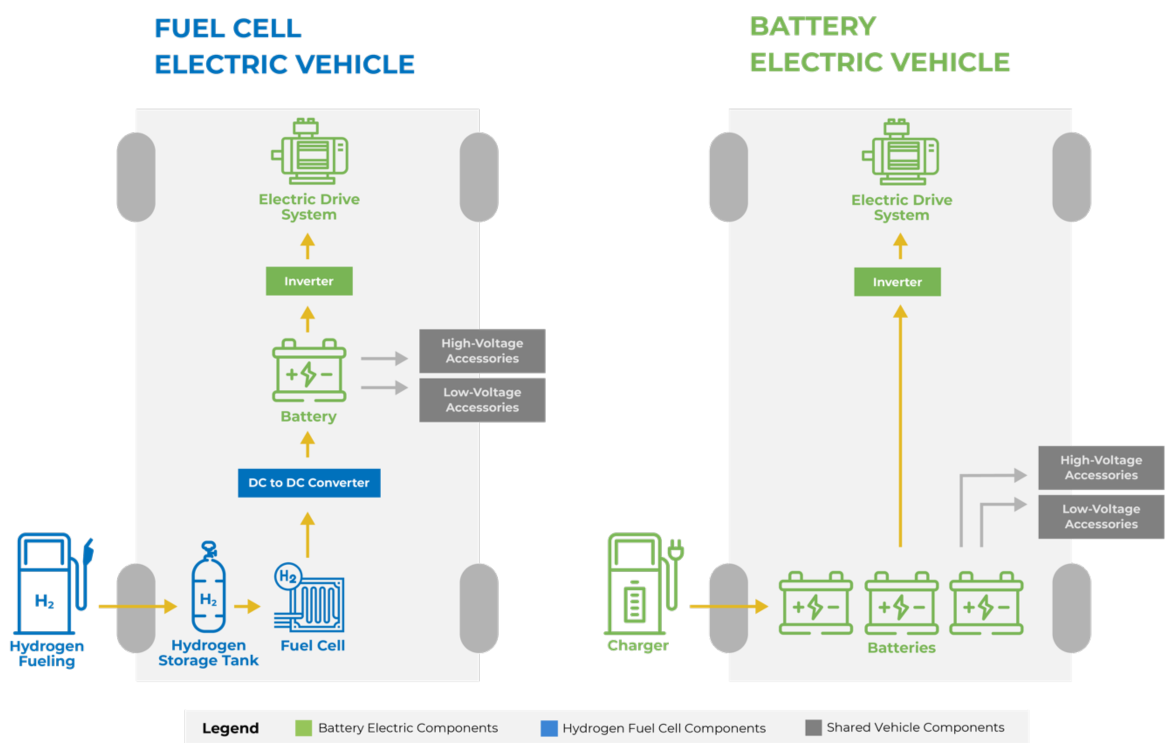


Figure ES-1: Battery and Fuel Cell Bus Schematic

CTE worked closely with County Connection staff throughout the project to develop an approach, define assumptions, and confirm the results. The approach for the study is based on analysis of five ZEB technology scenarios compared to a baseline scenario:

0. Baseline (current technology)
1. BEB with Depot-Only Charging (with Diesels)
2. BEB Depot-Only Charging + Fleet Expansion
3. BEB with Depot and On-Route Charging
4. Mixed Fleet: BEB Depot-Only Charging and FCEB
5. FCEB Only

To accurately forecast service feasibility for each of these zero-emission technologies, CTE then assessed the block achievability of County Connection's current service schedules. A block is the series of trips assigned to a single bus from the time of garage pull out to its return pull in, including deadhead, in-service hours, and layover. Block achievability is determined by comparing the estimated energy required to operate a BEB on a given block to the usable onboard energy storage capacity of the bus. If the block energy requirement exceeds the onboard storage capacity, the block is considered unachievable. If the block energy requirement does not exceed the usable onboard storage capacity, the block is considered to be achievable. Although not a zero-emission scenario, this study also includes a baseline scenario that is used to compare the cost of a ZEB transition to a “business-as-usual” case (i.e., without the need to transition the fleet).

The BEB-only scenarios were developed to model an option with a fleet consisting entirely of battery electric buses that can meet existing service range requirements. Fleets consisting of BEBs that only charge at a depot may not be able to meet the range requirements of many routes and would require additional time to return to the depot to charge. These constraints would necessitate maintaining a portion of diesel buses in the fleet. This would not be in compliance with the ICT regulation and would require an exemption, or the purchase of additional buses to cover the charging times. On-route charging mitigates the possible need to purchase additional buses, including diesel buses, by extending the range of in-service BEBs and reducing the time necessary to charge at the depot. On-route charging also allows a transit agency to focus on a single technology throughout the fleet and for the installation of a single fueling technology at the depot. The challenges of on-route charging are: finding space along the routes for chargers; additional costs of land acquisition, equipment, and infrastructure installation; operational costs; and the need to increase layover times for charging or accounting for the impact trip interruptions and/or delays on charging.

A Mixed Fleet: BEB and FCEB scenario was developed with the assumption that depot-charged BEBs would be deployed to all achievable blocks by 2040. These blocks would be complemented by FCEBs that would cover the blocks that exceed the range of the BEBs. Because FCEBs have a longer range than BEBs and are capable of completing blocks that BEBs cannot, FCEBs are more accommodating in dynamic changes to block patterns. Hydrogen fueling is also more similar to diesel fueling operations, and FCEBs are therefore modeled to replace diesel buses at a 1:1 ratio. Another advantage of a mixed fleet scenario is that it allows flexibility to use the less expensive depot charged BEB technology and infrastructure where possible and cover service needs with FCEBs used as needed. A mixed fleet is also more resilient to service interruptions if either fuel becomes temporarily unavailable. For agencies such as County Connection that operate only one depot, however, mixed fleets present the space challenge of hosting both infrastructure types in one depot.

The FCEB scenario was developed to help identify benefits and challenges associated with switching the entire fleet to fuel cell technology. A FCEB fleet could replace diesel buses on a 1:1 ratio and avoids the need to install two types of fueling infrastructure or purchase additional land for on-route charging. Additionally, hydrogen fueling infrastructure is less expensive at scale compared to a large-scale fleet transition to BEBs. While hydrogen is the most expensive fuel at current market prices, applying sensitivity to hydrogen costs shows that hydrogen may become more cost competitive compared to the cost of electricity in 2040. A FCEB only fleet may not provide the same resilience provided as having multiple technologies and fuel types in a mixed fleet. A good risk mitigation strategy for this scenario would be the use a diesel generator to power diesel pumps during a power outage. Current market prices for FCEBs are also currently higher than BEBs.

Improvements in technology are expected, but the timing of when or if BEB technology may improve to the point of one-for-one replacement of diesel buses or when the cost of FCEBs and hydrogen fuel will decrease to cost-competitive levels is impacted by numerous factors and unpredictable. Given these unknowns and the possible rapid changes in zero-emission technologies as interest in the field grows, this study is intended to present a range of estimated costs that can be expected for County Connection's ZEB fleet transition.

The underlying basis for the assessment is CTE's ZEB Transition Planning Methodology, a complete set of analyses used to inform agencies planning the conversion of their fleets to zero-emission technologies. The methodology consists of data collection of County Connection routes, analysis of energy efficiency and energy use of the buses, and evaluation of the associated costs, organized by scenario, over the transition lifetime.

The table and figure below provide a side-by-side comparison of the cumulative transition costs for each scenario. Additional labor costs are introduced to the Depot + On-Route scenario; the Baseline scenario is assumed to have all the necessary infrastructure to support the current fleet composition and therefore has no associated infrastructure costs.

Table ES-2 - Total Cost of Ownership, by Scenario

Assessment Type	0. Baseline (current tech-nology)	1. BEB Depot Only (With Diesels)	2. BEB Depot Only (With Expansion)	3. BEB Depot + On-Route	4. BEB Depot + FCEB	5. FCEB Only
Fleet	$165M	$ 208M	$ 315M	$ 243M	$253M	$ 270M
Additional Labor	$0	$0	$0	$ 1M	$0	$0
Fuel*	$ 33M	$ 31M	$ 31M	$ 32M	$ 33M	$ 42M
Maintenance	$ 56M	$ 56M	$ 64M	$ 62M	$ 57M	$ 58M
Infrastructure	$ 0	$ 21M	$ 46M**	$ 49M***	$ 33M	$ 14M
Total	$253 M	$317 M	$456 M	$386 M	$373 M	$384 M
% ZEB in 2040	0%	61%	100%	100%	100%	100%

*Excludes any potential Low Carbon Fuel Standard (LCFS) credit revenue; near-term costs with sensitivity analysis applied.
** Excludes costs for necessary yard expansion to accommodate expanded fleet.
***Excludes the cost of land acquisition for on-route charging stations.

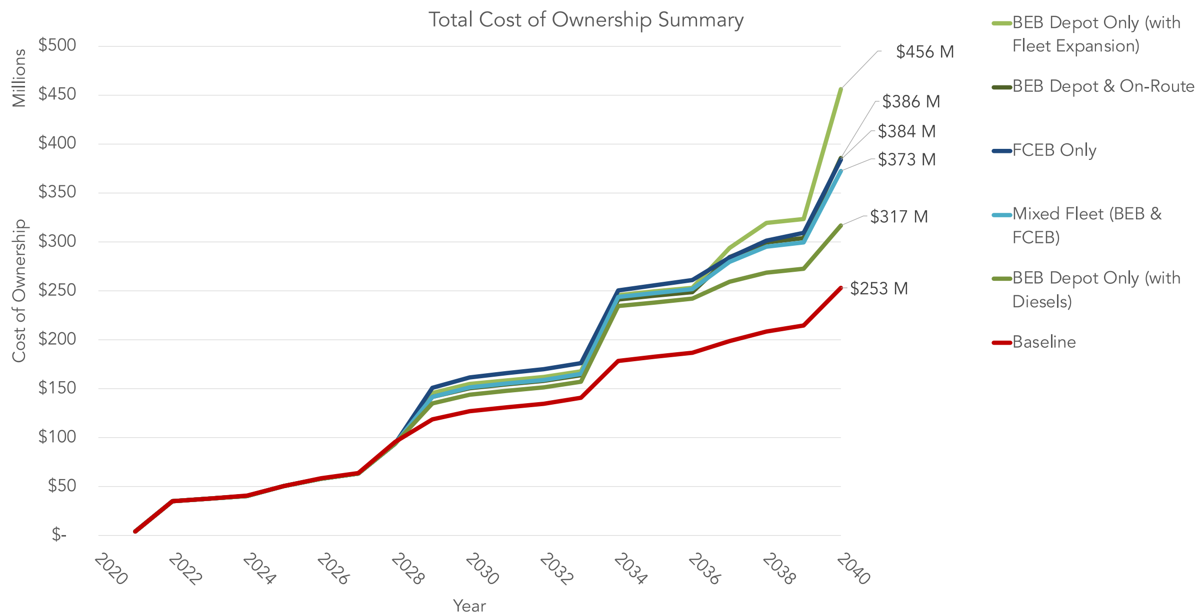


Figure ES-2: Total Cost of Ownership, by Scenario

ZEB Transition Scenario Overview

Battery Electric Bus (BEB) Depot Only with Diesel Scenario

For an all-BEB fleet that charges exclusively at the depot, ZEB fleet transition costs are likely to be $317 million, with 61% of County Connection's fleet is replaced with BEBs by 2040 without adding additional buses. A waiver will need to be requested from CARB as this would not meet ICT regulation. The difference in cost between the Baseline and BEB Depot Only scenario results from higher capital costs for battery electric buses compared to diesel buses and from the significant infrastructure investment necessary for charging infrastructure. This scenario was determined to be non-viable due to its non-compliance with the ICT Regulation.

BEB Depot Only with Fleet Expansion Scenario

In the BEB with Depot-Only Charging with Fleet Expansion scenario, a second BEB enters service to relieve a BEB deployed at the beginning of the service day when it reaches its energy capacity limit and cannot complete the block before charging. The objective of this scenario is to meet existing bus service requirements with an entirely BEB fleet without requiring on-route charging or mixed fueling technology at the depot, which can take up valuable yard space. In turn, County Connection's fleet would need to expand from a fleet consisting of 125 buses to 173 buses. CTE's initial estimate for the total cost to fully transition County Connection's entire fleet to BEBs by 2040 is $456 million. It is important to note that AECOM, this project's Architecture and Engineering (A&E) firm, found that the single depot in Concord does not have the adequate space to accommodate 173 buses, which currently renders this an unviable scenario for County Connection to pursue.

BEB Depot and On Route Scenario

In the BEB Depot and On Route scenario, on-route charging supplements depot charging in order to support an all-BEB fleet. For blocks that cannot be completed on a single overnight charge, on-route charging allows an agency to add energy to buses while in-service, providing the additional energy necessary to complete a block without having to travel the extra distance and take the extra time to return to a depot for charging. Buses are assumed to supplementally charge on-route in up to 15-minute increments. To accommodate extended layovers associated with on-route charging opportunities, this study applies a unit hourly rate of $29.05 to the additional operator time needed in service by on-route charged BEBs. This amounts to an estimated cost of $650,000 of additional operator time over the course of the transition period. The total combined cost of this scenario is approximately $386 million over the length of the transition from 2021 to 2040. This scenario estimates a complete BEB fleet in service by 2040.

Mixed Fleet: BEB and Fuel Cell Electric Bus Scenario

The Mixed Fleet: BEB and Fuel Cell Electric Bus scenario resulted in a total cost of approximately $373 million to replace County Connection's entire fleet with ZEBs by 2040. Though the costs are less for a mixed fleet deployment than for the FCEB Only deployment, there is the added complexity of installing infrastructure for both fuel types. Since County Connection has only one depot, the space constraint of installing both infrastructure types may be a challenge. Additionally, while County Connection maintenance staff are familiar with scheduled and unscheduled repairs associated with past BEB deployments, maintenance costs will vary with the introduction of new models of BEBs and a new technology with FCEBs.

Fuel Cell Electric Bus (FCEB) Only Scenario

In the FCEB Only scenario, ZEB transition costs are estimated at $384 million to replace 100% of County Connection's fleet with FCEBs by 2040. A primary assumption for the FCEB Only scenario is that 30-foot fuel cell electric buses will become available during the transition period. It is expected that, due to the limited deployment of FCEBs in service in the United States, capital costs for these buses and hydrogen fuel costs will remain high in the near-term due to low market competition. This is expected to change; however, more data is needed to adequately project these cost decreases. As such, this study uses current FCEB and infrastructure pricing for the entirety of the ZEB transition period.

For estimates of FCEB maintenance costs, CTE used data reported from Orange County Transit Authority's (OCTA) FCEB fleet of 10 New Flyer buses in their first year of operation. Fuel cell technology was new to OCTA and, as a result, the maintenance costs were higher than expected. OCTA does expect reductions in the long run. Given the necessary reliance on this early-adoption maintenance data, FCEB maintenance cost data has a wider margin of error than BEB cost estimates. More concrete data will become available, and costs will likely fall as a larger number of fuel cell electric buses and hydrogen infrastructure are deployed, however, significant investments in hydrogen infrastructure may take years to materialize.

Project Risks

In addition to the uncertainty of technology improvements, there are other operational risks to consider. Risk mitigation strategies may introduce additional costs over the 20-year transition period. Although current BEB range limitations may improve over time as a result of advancements in battery energy capacity and more efficient components, battery degradation may re-introduce range limitations, which is a cost and performance risk to an all-BEB fleet over time. In emergency scenarios that require the use of BEBs, agencies may face challenges supporting long-range evacuations and providing temporary shelters in support of fire and police operations. Furthermore, fleetwide energy service requirements, power redundancy, and resilience may be difficult to achieve at any given depot in an all-BEB scenario. Although FCEBs may not be subject to these same limitations, higher capital equipment costs and availability of hydrogen may constrain FCEB solutions.

Recommendations

CTE recommends that County Connection's ICT Rollout Plan reflects the utilization of all of its bonus credits by the end of 2028, deferring any future ZEB purchases until 2029. This is a conservative approach that allows for ZEB technology to mature. Given these considerations, general recommendations for County Connection are as follows:

1. **Select a preferred scenario to for County Connection's ICT Rollout Plan submission and remain proactive with ZEB deployment grants:** This Master Plan was developed to present County Connection with options for transitioning to a fully zero-emission fleet. Following County Connection's selection of a preferred ZEB Transition Scenario, the ICT Rollout Plan will be developed for submittal to CARB in compliance with the ICT Regulation. This document will put forth County Connection's vision for a ZEB Transition and will act as a living document to help the agency plan out grant funding requirements. As a greater proportion of County Connection's fleet converts to ZEB technology, auxiliary equipment, hardware, and software will be needed to ensure a successful fleet transition. County Connection should continue to remain proactive in the purchase and deployment of ZEBs and their associated systems by taking advantage of various grant and incentive programs.
2. **Apply learnings from early ZEB deployments in real time:** While ZEB technology continues to evolve, there is significant value in applying empirical data to deployment strategies. Results from early County Connection BEB deployments and other transit agency data have already informed this transition plan study and ongoing performance monitoring of ZEB technology will be key to ensuring the implementation of the best-fit technology at the appropriate time.
3. **Match the individual bus technology to the individual route and blocks:** County Connection should consider the strengths of given ZEB technologies and focus those technologies on routes and blocks that take advantage of their efficiencies and minimize the impact of the constraints related to the respective technologies. These technologies cannot follow a one-size-fits-all approach from either a performance or cost perspective. Matching the present technology to the present service levels will be a critical best practice.

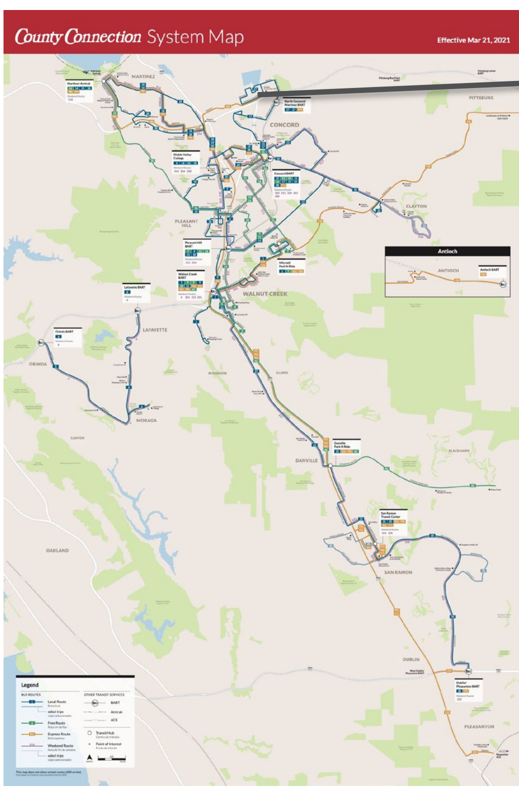
4. **Monitor local and regional developments:** In the zero-emission technology sector, developments at the local level can have the ability to catapult the industry forward. When local bus OEMs or fuel providers enter the zero-emission market, it can spark technological innovation or cost reduction. Neighboring transit agencies can also work together through group purchasing agreements and lobbying efforts to bring about reduced purchase costs or more funding opportunities.

The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission transportation sector. Widespread adoption of zero-emission bus technology has the potential to significantly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. County Connection is committed to implementing environmentally-friendly policies and reducing its carbon footprint.

Introduction

Central Contra-Costa Transit Authority (County Connection) was established in 1980 and is now popularly referred to as County Connection. It provides fixed-route and paratransit bus service for Contra Costa County and serves 10 cities and towns plus one county, for a total of 11 jurisdictions, in the East Bay. Communities served reside in Concord, Pleasant Hill, Martinez, Walnut Creek, Clayton, Lafayette, Orinda, Moraga, Danville, San Ramon, as well as unincorporated communities in Central Contra Costa County, California[1]. The service area covers approximately 200 square miles and contains more than 482,000 residents[2]. County Connection's fleet includes 125 transit buses (including twenty-nine 30-ft., thirteen 35-ft., and eighty-three 40-ft. buses) that operate daily and 63 cutaway vehicles that provide paratransit services. County Connection currently has one maintenance facility, located at 2477 Arnold Industrial Way, Concord, CA 94520 as shown in **Figure 1.**

As a transit agency in California, County Connection is subject to the Innovative Clean Transit (ICT) regulation, requiring all California transit agencies to develop a plan to achieve a zero-emission fleet by 2040. The ICT regulation is discussed in more detail in the following section. To explore its options for compliance, this Master Plan summarizes a baseline scenario plus 5 zero-emission fleet transition scenarios that is being considered by County Connection.



Bus Depot

Figure 1- County Connection System Map Highlighting Facility Location

[1] County Connection. (2021, December 5). About webpage. https://countyconnection.com/about/
[2] National Renewable Energy Laboratory (NREL). (2018, December). Zero-Emission Bus Evaluation Results: County Connection Battery Electric Buses (NREL/TP-5400-72864). https://www.nrel.gov/docs/fy19osti/72864.pdf

California Air Resources Board Innovative Clean Transit Regulation

On December 14, 2018, California Air Resources Board (CARB) enacted the Innovative Clean Transit (ICT) regulation, requiring all California public transit agencies to create a plan to achieve a 100% zero-emission fleet by 2040. County Connection engaged with CTE to perform a zero-emission bus (ZEB) transition study of its fleet and service. The results of the study will assist County Connection board members and staff in meeting their goal to transition to a zero-emission fleet.

The zero-emission technologies considered in this study are battery-electric buses (BEB) and hydrogen fuel cell electric buses (FCEBs). BEBs and FCEBs have similar electric drive systems that feature a traction motor powered by a battery. The primary differences between BEBs and FCEBs are the respective amount of battery storage and the method by which the batteries are recharged. The energy supply in a BEB comes from electricity provided by an external source, typically the local utility's electric grid, which is used to recharge the batteries. The energy supply for an FCEB is completely on-board, where hydrogen is converted to electricity within a fuel cell. The electricity from the fuel cell is used to recharge the batteries. The electric drive components and energy source for a BEB and FCEB are illustrated in **Figure 2.**

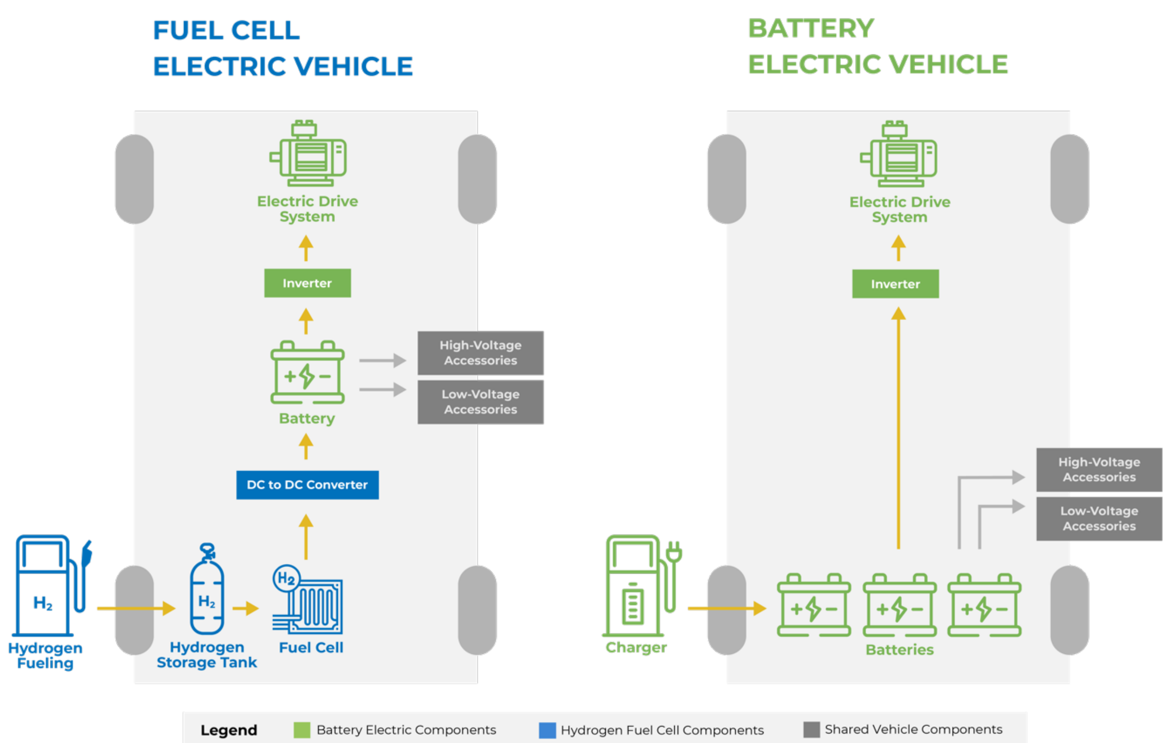


Figure 2- Battery and Fuel Cell Electric Bus Schematic

ZEB Purchase Requirements

CARB's ICT regulation requires all transit agencies to purchase only ZEBs from 2029 onward. Partial ZEB purchasing requirements begin in 2023 for large agencies and in 2026 for small agencies with the goal of transitioning all agencies to a 100% ZEB fleet by 2040.

CARB designates County Connection's fleet as a small fleet because the transit agency does not operate more than 100 vehicles at peak pullout. For small agencies, the ICT regulation requires that all new bus purchases include a specified percentage of ZEBs in accordance with the following schedule in **Table 1 .**

Table 1-CARB ICT ZEB Transition Timeline for Small Agencies

Starting January 1	Percent of New Bus Purchases
2026	25%
2027	25%
2028	25%
2029	100%

Agencies can defer the purchase of a cutaway bus, over-the-road bus, double-decker bus, or articulated bus until either January 1, 2026 or until a model of a given type has passed the Altoona bus testing procedure and obtained a Bus Testing Report, regardless of purchasing milestones. At the time of writing this report, a cutaway vehicle has passed Altoona testing but CARB has not revised its regulation regarding cutaway buses.

ZEB Bonus Credits

To recognize and incentivize early adopters of ZEBs, the ICT regulation has a credit system, which gives credits to agencies that deployed ZEBs before the regulation was enacted in 2018. Agencies are eligible for two credits for each fuel cell electric bus and one credit for each battery electric bus that was in their fleet as of January 1, 2018. Agencies may apply these credits to their future ZEB purchase requirements. Each credit has the same value as having one ZEB in their fleet but must be used by December 31, 2028.

The purchasing requirements outlined in **Table 1** can be met by any combination of ZEBs already in the fleet, bonus credits, and new purchases. In effect, County Connection will be able to submit the 8 ZEBs that are already part of their fleet and an additional 4 bonus credits for the BEBs that were in service prior to January 1, 2018, resulting in a total of 12 ZEB purchases that can be used to offset the ICT regulation purchase mandate before the end of the 2028 calendar year. CTE recommends that County Connection comply with ICT regulation and apply all of its bonus credits by the end of 2028 as depicted in **Table 2**, which outlines a schedule of how these credits and BEBs that are already in the fleet will be applied in this assessment in order to use all credits by the end of 2028.

Table 2-ZEB Bonus Credits Applied to CARB ICT Transition Schedule

Starting January 1	ZEB Percentage of Total New Bus Purchases	County Connection Scheduled Bus Purchases	Number of ZEBs to Purchase Per Requirement	Offsets Available	Offsets Used to Reduce ZEB Purchases	ZEBs Scheduled and Required to Purchase
2026	25%	7	2	12	2	0
2027	25%	0	0	10	0	0
2028	25%	37	10	10	10	0
2029	100%	26	26	0	0	26

Exemptions

Agencies may request exemptions from ZEB purchase requirements in a given year due to circumstances beyond the transit agency's control. Acceptable circumstances include:

- Delay in bus delivery caused by setback of construction schedule of infrastructure needed for the ZEB;
- Market-available depot-charged BEBs cannot meet a transit agency's daily mileage needs;
- Market-available ZEBs do not have adequate gradeability performance (i.e., unable to climb a slope at efficient speed) to meet the transit agency's daily needs;
- When a required ZEB type for the applicable weight class based on gross vehicle weight rating (GVWR) is unavailable for purchase because the ZEB has not passed the Altoona bus test; cannot meet ADA requirements; or would violate any federal, state, or local regulations or ordinances; and,
- When a required ZEB type cannot be purchased by a transit agency due to financial hardship.

ZEB Rollout Plan

County Connection is required to submit a ZEB Rollout Plan to CARB that has been approved by their governing board by July 1, 2023. Per CARB regulations, Rollout Plans must include all of the following components:

- A goal of full transition to ZEBs by 2040 with careful planning that avoids early retirement of conventional internal combustion engine (ICE) buses;
- Identification of the types of ZEB technologies a transit agency is planning to deploy, such as battery-electric or fuel cell electric buses;
- A schedule for construction of facilities, infrastructure modifications, or upgrades including charging, fueling, and maintenance facilities to deploy and maintain ZEBs.

This schedule must specify the general location of each facility, type of infrastructure, service capacity of an infrastructure, and a timeline for construction;

- A schedule for zero-emission and conventional ICE bus purchases and lease options. This schedule for bus purchase replacements must identify the bus types, fuel types, and number of buses;
- A schedule for conversion of conventional ICE buses to ZEBs, if any. This schedule for bus conversion must identify number of buses, bus types, the propulsion systems being removed and converted to;
- A description on how a transit agency plans to deploy ZEBs in disadvantaged communities as listed in the latest version of CalEnviroScreen at the time the Rollout Plan is submitted;
- A training plan and schedule for ZEB operators and maintenance and repair staff; and
- The identification of potential funding sources.

Findings outlined in this Master Plan are intended to inform County Connection in selecting a scenario to put forward in the ICT Rollout Plan that will be submitted to CARB.

Reporting Requirements

Starting March 31, 2021, and continuing every year thereafter through March 31, 2050, each transit agency must submit an annual ICT ZEB compliance report by March 31 for the prior calendar year. The initial report was to have been submitted by March 31, 2021, and must have included the number and information of active buses in the transit agency's fleet as of December 31, 2018.

Assessment Scenarios

For this study, CTE developed 5 scenarios to compare to a baseline scenario and analyze the feasibility and cost effectiveness of implementing each bus technology as well as co-implementation of both technologies. The scenarios are referred to by the following titles and described, in detail, below. A baseline scenario was developed to represent the typical "business-as-usual" case with retention of ICE buses for cost comparison purposes.

0. Baseline (current technology)
1. BEB with Depot-Only Charging (with Diesels)
2. BEB Depot-Only Charging + Fleet Expansion
3. BEB with Depot and On-Route Charging
4. Mixed Fleet: BEB Depot-Only Charging and FCEB
5. FCEB Only

In the **BEB with Depot-Only Charging** scenario, BEBs are purchased and deployed only on blocks that are within a BEB's achievable range as determined by CTE's modeling. If depot-charged BEBs are not capable of meeting a transit agency's daily service requirements, there is an exception in the ICT regulation that will allow the agency to request an exemption to retain ICE buses in their fleet. The regulation still requires that BEBs must be deployed for all blocks that can be completed by a BEB. The analysis in this plan recommends County Connection request an exemption to maintain 99 diesel buses in its fleet from 2030 to 2033; 59 diesel buses from 2034 to 2036; 55 diesel buses from 2037 to 2039; and 48 diesel buses in 2040 under this scenario.

Alternatively, blocks that exceed the modeled range for a single BEB may be serviced by two BEBs to replace the service of one ICE bus (i.e., 2:1 ratio). In this **BEB with Depot-Only Charging with Fleet Expansion** scenario, a second BEB enters service once the BEB that was deployed at the beginning of the service day reaches its energy capacity limit and cannot complete the block before charging. The objective of this scenario is to meet existing bus service requirements with an entirely BEB fleet without requiring on-route charging. A uniformly BEB fleet allows for the installation of a single fueling technology at the depot, which can be helpful for streamlining operations and depot configurations.

In the **BEB with Depot and On-Route Charging** scenario, on-route charging supplements depot charging to support a fully BEB fleet. For blocks that cannot be completed on a single overnight charge, on-route charging allows an agency to add energy to buses while in-service and provide the additional energy necessary to complete a block without having to travel the extra distance and take the extra time to return to a depot for charging. The costs for infrastructure and installation of on-route charging as well as added operator labor expenses are taken into account.

A **Mixed Fleet (BEB and FCEB) scenario** was developed to cover the range limitations and charging duration limitations of BEB technology. The range of FCEBs exceeds that of BEBs, so this assessment considers FCEBs capable of replacing diesel buses at a 1:1 ratio. FCEBs and hydrogen fuel, however, are more expensive than BEBs and electricity, so a mixed fleet allows an agency to use the less expensive BEB technology where possible and supplement service with FCEBs as needed. A mixed fleet is also more resilient as it would allow service to continue if either fuel became temporarily unavailable for any reason.

Finally, the **FCEB Only scenario** was developed to examine the costs for hydrogen fueling and transitioning to a 100% FCEB fleet. A fully FCEB fleet enables all ICE buses to be replaced at a 1:1 ratio. It also avoids the need to install two types of fueling infrastructure by eliminating the need for depot and on-route charging equipment. Fleets comprised entirely of fuel cell electric buses also offer the benefit of scalability compared to battery electric technologies. Adding FCEBs to a fleet does not necessitate large complementary infrastructure upgrades. Despite this benefit, the cost of FCEBs and hydrogen fuel are still more expensive than BEBs and electricity at current market prices.

CTE expects improvements in technology beyond the current state, but there is no indication of when the ZEB technology may improve to the point where BEBs can replace diesel buses one-for-one or when the cost of FCEBs or hydrogen fuel will decrease to cost-competitive levels. As a result, when considering the various scenarios, this study can be used to develop an understanding of the range of costs that may be expected for County Connection's ZEB transition, but ultimately, can only provide an estimate.

Terms and Definitions

- “Fuel” and “energy” are used interchangeably in this report, as ZEB technologies do not always require traditional liquid fuel. In the case of BEBs, “fuel” is electricity and costs include energy, demand, and other utility charges.
- The transition period is defined as achieving 100% ZEB fleet purchasing by 2040 to comply with the CARB ICT regulation.

Assessment Assumptions

This transition study uses multiple assumptions to model County Connection’s long-term fleet transition. The overarching assumptions are:

- Heavy-duty large buses have a normal service life of 12 years.[3]
    - This assumption follows FTA’s definition of vehicle useful life of 12 years as its retirement policy for their standard bus sizes.
- BEBs are modeled to have a battery capacity of 450 kwh (35’ & 40’) and 325 kwh (30’). FCEBs have fuel tank capacities of 37.5 kg (30’) and 40kg (35’ & 40’).
    - These figures are based on the average of the bus manufacturers’ specifications for the model compared with the Altoona Bus Testing and Research Center’s bus report at the time of analysis.[4]
- A 5% improvement in battery capacity occurs every two years, with a cap at 733 kWh.
    - For this study, considering the extended period of a complete fleet transition through 2040, CTE assumes a conservative 5% improvement of battery capacity every two years.[5] With this trend, buses will continue to increase the amount of energy they carry on-board without added onboard battery storage or reduction in passenger capacity.
    - The cap was determined based on a reasonable range of improvement that could be expected for battery capacity by 2040 given that the current (2021) top of the market nameplate capacity is 686 kWh.
    - With a starting battery capacity in this assessment at 450kWh, this cap will be reached in 2040 with the assumed 5% improvement every 2 years.
- A 5% improvement in hydrogen tank size occurs every two years.
    - This serves as a proxy for other component improvements such as battery capacity, motor efficiency, and fuel cell efficiency.
- FCEBs can more readily replace ICE buses one-for-one.
    - Alameda-Contra Costa Transit District (AC Transit) and OCTA have reported operational ranges for FCEBs up to 350 miles.

[3] Federal Transit Administration, “Useful Life of Transit Buses and Vans”. U.S. Department of Transportation. Retrieved on May 5, 2021, from https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Useful_Life_of_Buses_Final_Report_4-26-07_rv1.pdf
[4] Altoona Bus Research and Testing Center, Bus Tests. Penn State College of Engineering. Retrieved on May 5, 2021, from https://www.altoonabustest.psu.edu/bus-tests/index.aspx
[5] BloombergNEF, “Hitting the EV Inflection Point”. Bloomberg Finance L.P.2021. Retrieved on December 5, 2021, from https://www.transportenvironment.org/wp-content/uploads/2021/08/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

ZEB Transition Planning Methodology

This study uses CTE's ZEB Transition Planning Methodology. The methodology encompasses nine key phases; these stages are sequential and build upon findings in previous steps. The phases 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
9. ZEB Transition Plan – Document Creation

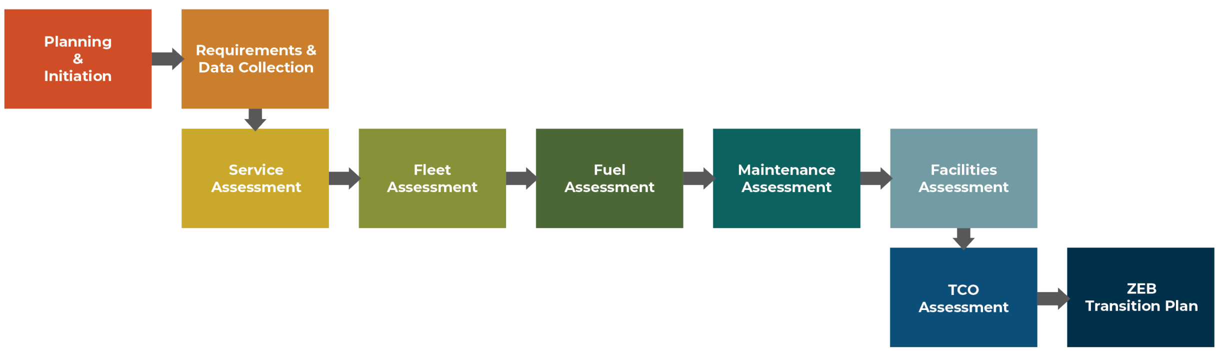


Figure 3 - CTE's ZEB Transition Study Methodology

The **Planning and Initiation** phase builds the administrative framework for the transition study. During this phase, the project team drafts the scope, approach, tasks, assignments and timeline for the project. CTE worked with County Connection staff to plan the overall project scope and all deliverables throughout the full life of the study.

For the **Requirements & Data Collection**, CTE collects GPS data on selected routes and utilizes software models to estimate ZEB performance. The results from this modeling are used to estimate achievability of every block in County Connection's network using BEBs and FCEBs.

The **Service Assessment** phase initiates the technical analysis of the study. The results from the Service Assessment are used to guide ZEB procurements in the Fleet Assessment and to determine energy requirements (depot charging, on-route charging, and/or hydrogen) in the Fuel Assessment. CTE met with County Connection to define assumptions and requirements used throughout the study and to collect operational data.

The **Fleet Assessment** develops a projected timeline for replacement of ICE buses with ZEBs that is consistent with the agency's fleet replacement plan. CTE creates multiple fleet composition scenarios using available ZEB technologies to assess the vehicle costs and procurement schedule of the transition. This assessment includes a projection of fleet capital cost over the transition lifetime and can be optimized with regard to any state mandates, like CARB's ICT regulation, or to meet 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 throughout the entire transition timeline for each scenario, including the agency's current fossil fuel buses. 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. The Facilities Assessment is calculated for each scenario used in the Fleet and Fuel Assessments. The assessment determines the required hydrogen and battery-electric infrastructure and calculates associated costs. Note that the infrastructure considered was only related to meeting regular fueling capabilities and did not include any backup power or emergency fueling components that might help provide redundancy or resilience to the agency as it was not within the scope of this study. As County Connection moves toward a fully zero-emission fleet, evaluating contingency plans may be an area of interest to explore further.

The **MAINTENANCE ASSESSMENT** calculates all projected fleet maintenance costs over the life of the project. These costs include those related to existing fossil fuel buses remaining in the fleet, as well as new BEBs and FCEBs, calculated for each scenario.

The **TOTAL COST OF OWNERSHIP ASSESSMENT** compiles results from the previous assessments and provides a comprehensive view of all associated costs, organized by scenario, over the transition lifetime.

Requirements Analysis

Baseline Data Collection

Understanding the key elements of County Connection's service is essential to evaluating the costs of a complete transition to a zero-emission fleet. County Connection staff provided key data on current County Connection service including:

- Current fleet composition including vehicle propulsion types and lengths
- Route and block information including distances and trip frequency
- Mileage and fuel consumption
- Maintenance costs

Fleet Composition

In 2021, the County Connection bus fleet included 9 diesel hybrid buses, 108 diesel buses, and 8 BEBs. A summary of the 2021 fleet by vehicle size, fuel type, and bus length is shown in **Table 3**. Bus service operates out of one depot in Concord. Operations, maintenance, and fueling functions are performed at the depot. County Connection's current service consists of 60 routes run on 167 blocks.

Table 3 - Fleet Summary by Depot, Length, and Fuel Type

Depot	Bus Length	Fuel Type			
		Diesel Hybrid (dHEB)	Diesel	BEB	Total
Concord	30'	--	21	8	29
	35'	--	13	--	13
	40'	9	74	--	83
	Total	9	108	8	125

Miles and Fuel Consumption

Data on County Connection's current fuel use is used to estimate energy costs throughout the transition period. This study assumes no cost escalation for fuel throughout the transition period. Average annual fleet mileage and fuel use are shown in **Table 4** and **Table 5**.

Table 4 - Average Annual Service Miles by Bus Length

Average Annual Miles per Bus				
Fuel Type / Length	Diesel	Electric	Hybrid	Total Average
30'	22,891	10,380	--	16,635
35'	28,247	--	--	28,247
40'	27,009	--	22,464	25,242
Total Average	26,386	10,380	22,464	22,375

Table 5 - Annual Diesel Consumption by Bus Length

Bus Length	Average of Annual Fuel Use (Diesel Gallon Equivalent DGE)
30'	24,908
35'	71,175
40'	110,127
Total Average	67,924

Service Assessment

The **Service Assessment** analyzes the feasibility of maintaining County Connection's current level of service with BEB and FCEB buses. The key component of the Service Assessment is the Block Analysis, which analyzes bus range limitations to determine if ZEBs can meet the service requirements of the blocks. The energy needed to complete a block is compared to the available energy for the prospective bus type that is planned for the block. If the prospective bus's available energy exceeds the block's required energy, then that block is considered achievable for that ZEB type. The Service Assessment also yields a timeline for when blocks become achievable for zero-emission buses as technology improves. This information is used to then inform ZEB procurements in the Fleet Assessment.

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, traffic conditions, deadhead), topography (i.e., grades), climate (i.e., temperature), driver behavior, and operational conditions (e.g., passenger loads and auxiliary loads). As such, the efficiency and range of a given ZEB model 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 County Connection's operating conditions.

The first task in the Service Assessment is to develop route and bus models to run operating simulations for typical County Connection routes. CTE obtained this data for routes 1, 5, 7, 9, 11 and 91X from County Connection's CTE-assisted BEB deployment in 2016. CTE uses a sampling approach for gathering data on an agency's service in which representative sample routes are identified based on topography and average speed characteristics. CTE collected GPS data—which includes time, distance, bus speed, bus acceleration, GPS coordinates, and roadway grade—from 15 County Connection routes that were identified with the sampling approach. Only routes selected for the analysis are included in **Table 6** below. County Connection's route map was used to categorize County Connection routes for the Service Assessment. Routes are classified by color to indicate the service type: blue signifies local routes; green signifies free routes; and yellow signifies express routes.

Table 6 - Selected Routes for Modeling

Route Classification	Route Number
Concord BART Blue	17, 19
Concord BART Green	11*
Concord BART Yellow	91X*
Concord School	616
Danville Blue	21
Danville Yellow	95X
Diablo Valley College Blue	9*
Dublin/Pleasanton BART Blue	35
Danville Park N Ride Yellow	97X
Lafayette Blue	6
Martinez Amtrak Blue	19
Martinez Amtrak Green	16
Martinez Amtrak Yellow	98X
Mitchell Park N Ride Blue	1*
Mitchell Park N Ride Green	7*
Mitchell Park N Ride Yellow	92X, 93X
North Concord Blue	17
Pleasant Hill BART Blue	9*
Pleasant Hill BART Green	7*, 11*
Pleasant Hill School	608
San Ramon School	623, 636

San Ramon Transit Center Yellow	95X
Walnut Creek Blue	1*, 9*, 21
Walnut Creek Green	5*
Walnut Creek School	602
Walnut Creek Yellow	93X, 98X

*Routes sampled in 2016 as part of a pilot BEB deployment data collection effort

CTE used component-level specifications for a generic electric bus and County Connection sample route data to develop a baseline performance model by simulating the operation of an electric bus on each route in Autonomie. Autonomie is a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE has modified software parameters in Autonomie to assess energy efficiencies, energy consumption, and range projections for ZEBs. The energy requirements of the sample routes were then applied to all routes and blocks that share the same characteristics as the sampled routes.

The **ROUTE MODELING** analyzes varying passenger loads, accessory loads, and battery degradation to estimate real-world bus performance, fuel efficiency, and range. The GPS data from routes and the specifications for each of the bus models are used to simulate operation on each type of route. The models were run under nominal and strenuous load conditions.

NOMINAL LOAD conditions assume average passenger loading and a moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditioning (HVAC) system. **STRENUOUS LOAD** conditions assume high or maximum passenger loading and near-maximum output of the HVAC system. These strenuous load conditions represent a hypothetical and unlikely worst-case scenario, but one that is necessary to establish an outer bound for the analysis. This nominal/strenuous approach offers a range of operating efficiencies—measured in kilowatt-hour/mile (kWh/mi)—to use for estimating average annual energy use (nominal) or planning maximum service demands (strenuous) shown in **Table 7** below. The projected nominal and strenuous efficiencies were then used to predict if the ZEB technology will be able to complete all blocks under various battery capacity assumptions and in subsequent assessments.

Table 7 - Modeling Results Summary

Route/Bus Length	Nominal Efficiency (kwh/mi)	Strenuous Efficiency (kWh/mi)
Antioch BART Yellow		
40'	2.2	2.5
Concord BART Blue		
30'	1.5	2.1
40'	2.1	2.7
Concord BART Green		
30'	2.0	2.9

40'	2.3	2.9
Concord BART Yellow		
30'	1.8	2.6
Concord School		
30'	1.7	2.4
40'	2.3	3.1
Danville Blue		
40'	2	2.6
Danville Yellow		
40'	2.1	2.5
Diablo Valley Blue		
30'	1.9	2.7
40'	2.1	3
Dublin/Pleasanton BART Blue		
40'	2.1	2.6
Dublin/Pleasanton BART Yellow		
40'	2.1	2.5
Lafayette Blue		
40'	1.9	2.4
Lafayette School		
30'	1.7	2.4
40'	2.2	2.9
Martinez Amtrak Blue		
30'	1.5	2.1
40'	2	2.6
Martinez Amtrak Green		
40'	2.3	2.9
Martinez Amtrak Yellow		
30'	1.8	2.2
40'	2.2	2.7
Mitchell Park N Ride Blue		
30'	2.0	2.9
40'	2.4	3.4
Mitchell Park N Ride Green		
30'	1.74	2.35
40'	1.9	2.5
Mitchell Park N Ride Yellow		
40'	2.15	2.5
North Concord Blue		
40'	2.1	2.8
North Concord Grey		
40'	3.3	4.1
North Concord Yellow		

30'	1.8	2.2
40'	2.2	2.7
Pleasant Hill Blue		
30'	1.9	2.7
40'	2.1	3
Pleasant Hill Green		
30'	2.0	2.9
40'	2.2	2.9
Pleasant Hill School		
30'	1.8	2.5
40'	2.4	3.2
San Ramon School		
40'	2.1	2.6
San Ramon Transit Center Blue		
40'	2.1	2.6
San Ramon Transit Center Yellow		
40'	2.1	2.5
Walnut Creek Blue		
30'	2.0	2.9
40'	2.4	3.4
Walnut Creek Green		
30'	2.2	3.5
Walnut Creek School		
30'	1.7	2.3
40'	2.3	2.9
Walnut Creek Yellow		
30'	1.8	2.2
40'	2.2	2.6

The **Block Analysis**, using the assumed 5% improvement in battery capacity or hydrogen storage capacity every two years, determines the timeline for when routes and blocks become achievable for BEBs and FCEBs. This information is used to inform ZEB procurement projections in the Fleet Assessment. Overall, the block analysis helps to determine when, or if, a full transition to ZEBs may be feasible and when there are requirements for supplemental energy solutions. Results from this analysis are also used to determine the specific energy requirements and develop the estimated costs to operate the ZEBs in the Fuel Assessment. Results from the block analysis are included in **Figure 4**.

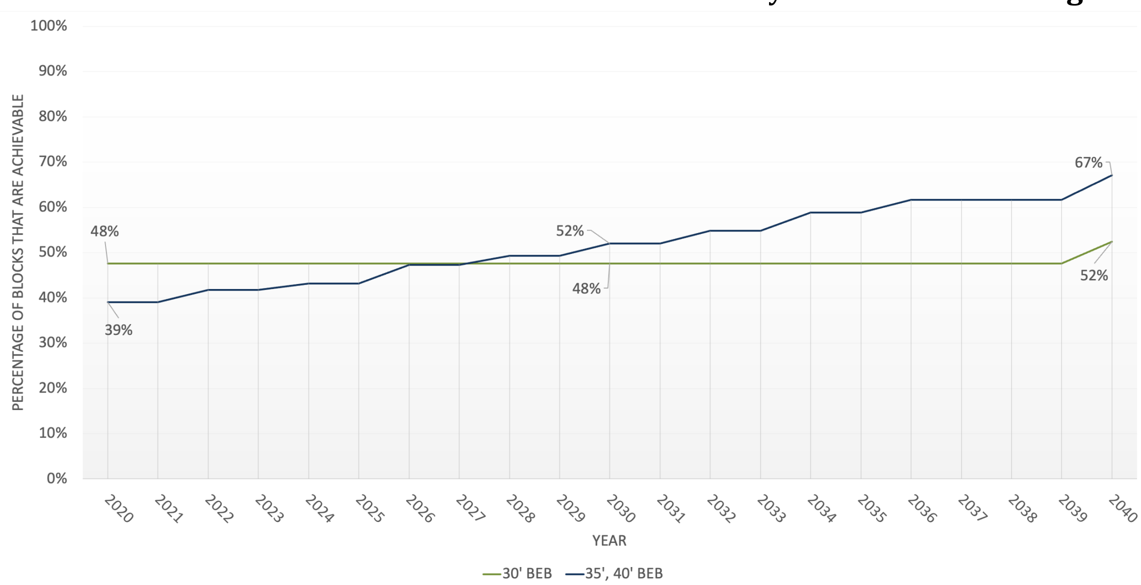


Figure 4 - 30', 35', 40' BEB Block Achievability Percentage by Year

The BEB achievability shows that, by 2040, 67% of County Connection's blocks can be completed under normal driving conditions when operating a 450-kWh usable battery capacity with 5% improvement every two years capped at 733 kWh for 35-foot and 40-foot BEBs. As covered in the **Introduction** of this report, this analysis assumes the following:

- FCEBs can complete any block under 350 total miles and therefore all blocks are achievable with FCEBs throughout the transition period.
- County Connection will maintain service to similar destinations within the Central Contra Costa region and therefore the blocks maintain a similar distribution of distance, relative speeds, and elevation changes throughout the transition period. This core assumption affects energy use estimates and block achievability in each year.

Another factor affecting block achievability is battery degradation. BEB range is negatively impacted by battery degradation over time. A BEB placed in service on a given block with beginning-of-life batteries may not be able to complete the entire block at some point during its life before the batteries reach end-of-life. End-of-life is typically defined as when batteries reach 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. County Connection can rotate the fleet to meet service energy demand, assuming there is a steady procurement of BEBs to match service requirements.

Fleet Assessment

The goal of the **Fleet Assessment** is to determine what type of ZEB technology solutions are required to transition an entire fleet to zero-emission vehicles. Results from the Service Assessment are integrated with County Connection's current fleet replacement plan and purchase schedule to produce two main outputs: 1) a projected bus replacement timeline through the end of the transition period and 2) the total capital costs of those replacements.

Cost Assumptions

CTE and County Connection developed cost assumptions for each bus length and technology type (e.g., CNG, gasoline hybrid, BEB, FCEB). Key assumptions for bus costs for the County Connection ZEB Master Plan Study are as follows:

- The base price for each type of bus is based on the 2022 Metropolitan Transit Commission (MTC) Pricelist. This includes estimate for configurable options.
- The local sales tax (9.25%) is applied to the base price.
- The standard labor inflation rate is assumed at 3% per year.
- Inflation rate for the bus and charger equipment is assumed at 1.5% based on the PPI index.
- The nominal cost of the bus capital remains level over the ZEB transition period.

For bus lengths that are not currently available in the market for a specific technology the costs in **Table 8** were used. Additional pertinent cost assumptions to note are as follows:

- The price for a 40' bus was used as an estimate for a 35' FCEB.
- Since the 2022 MTC Pricelist did not include a 30' FCEB option as there is not currently one available on the market, $200,000, which is the incremental cost difference between 40' BEBs and 40' FCEBs, was added to the 30' BEB MTC Price to generate an estimate for 30' FCEBs.

Table 8 - Fleet Assessment Cost Assumption based on Fiscal Year 2022 MTC Pricelist

Base Price Assumptions by Length and Fuel Type			
Length	Diesel	Electric	Fuel Cell
30'	$543,000	$934,000	$1,134,000*
35'	$600,000	$947,000	$1,264,000*
40'	$575,000	$1,130,000	$1, 264,000

*Bus size not currently available for this technology.

Baseline Scenario

In the Baseline scenario, County Connection continues to replace retired buses on a 12-year replacement cycle with buses of the same fuel type operating in its 2021 fleet. The fleet is primarily diesel powered and includes eight BEBs. This scenario illustrates the costs that County Connection would expect over the 20-year period if it maintained its current fleet composition including the same number of BEBs that are currently operating. **Figure 5** shows the number of diesel buses and BEBs that would be purchased each year through 2040 in this scenario.

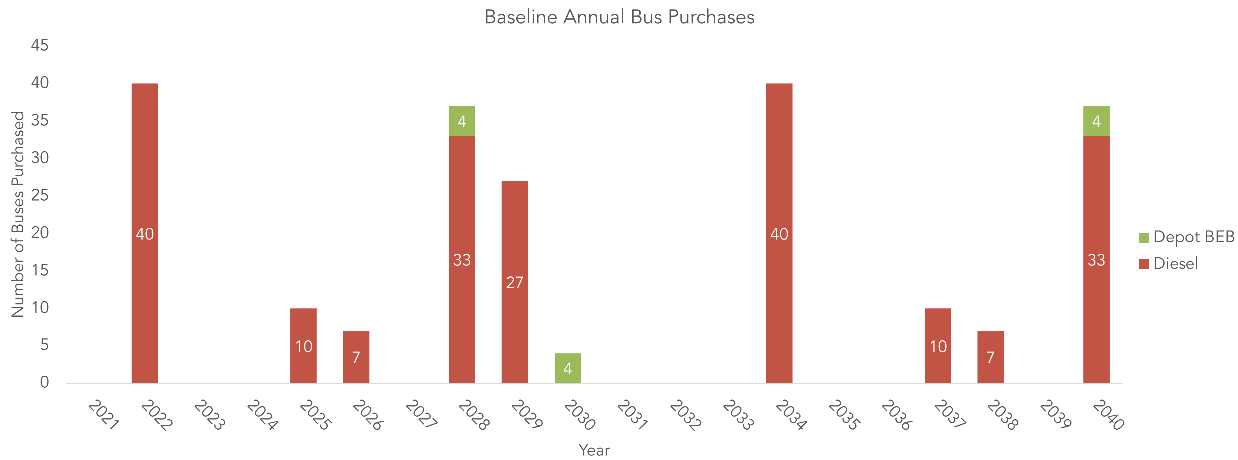


Figure 5 - Projected Bus Purchases, Baseline Scenario

Figure 6 depicts the annual fleet composition through 2040 for the Baseline scenario; the fleet remains composed of primarily diesel over the 20-year period. Note that the hybrid buses are scheduled to be replaced with diesel buses, which is why they are not carried over beyond 2021.

Figure 6 - Annual Fleet Composition, Baseline Scenario

Figure 7 shows the annual total bus capital costs for the diesel and battery electric buses purchased in each year in the Baseline scenario.

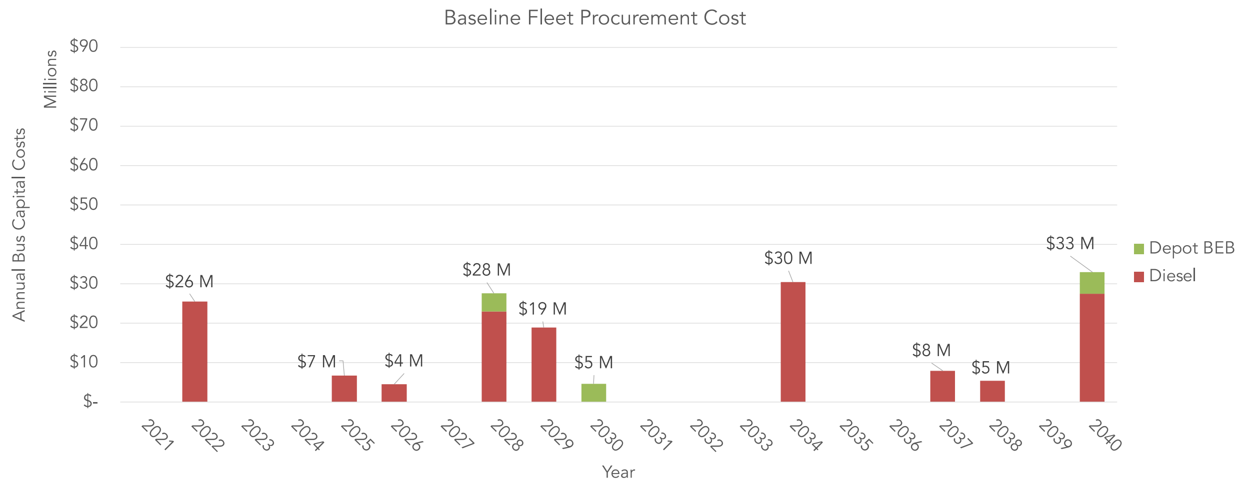


Figure 7 - Annual Capital Costs, Baseline Scenario

BEB Depot-Only Scenario

In the BEB Depot-Only scenario, diesel buses remain in County Connection's fleet to meet service requirements where BEBs cannot meet the necessary range. This scenario would only be allowable if County Connection applies for an exception to the ICT and CARB grants that exception. By 2029, County Connection will begin to procure new BEBs once all ZEB credits have been expended. The figures below show projected purchases, annual fleet composition, and annual total capital costs for the BEB Depot-Only scenario.

Figure 8 depicts the number of buses by type that are scheduled to be purchased per year in the BEB Depot-Only scenario. 2029 is a major procurement year with 27 buses scheduled for purchase—22 BEBs and 5 diesel buses. Note that diesel buses are kept in the fleet composition and will run in blocks that cannot be completed by a BEB. As these diesel buses reach their end-of-life service year, they will be replaced with the technology that can meet County Connection's current service requirement. With the assumption of a 5% improvement in battery capacity every two years, by 2040, it is projected that only 61% of County Connection's blocks can be met with a BEB on a single depot charge. Therefore, in this scenario, diesel buses will still be replaced by new diesel buses in the latter years of the transition period.

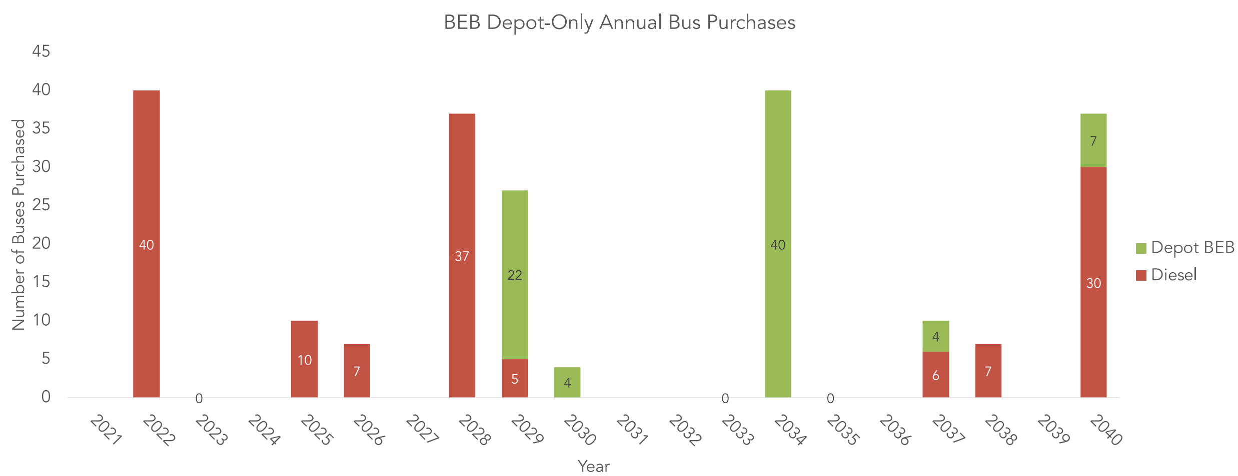


Figure 8 -Projected Bus Purchases, BEB Depot-Only Scenario

Figure 9 shows the fleet composition year-by-year. Per ICT regulation, ZEB credits reduce the number of ZEBs required to be purchased in a given year on a 1:1 basis. In 2028, there is a 25% ZEB purchase requirement in place. County Connection is scheduled to replace 37 buses that have reached the end of their service life. Instead of being required to purchase 10 ZEBs, which is 25% of 37 rounded up, County Connection will use the remaining of its ZEB credits to offset the purchase mandate in favor of purchasing ZEB technology in the future years when the technology further matures. However, while diesel buses are still being procured throughout the transition period, by 2034, BEBs begin to make up the majority of County Connection's fleet.

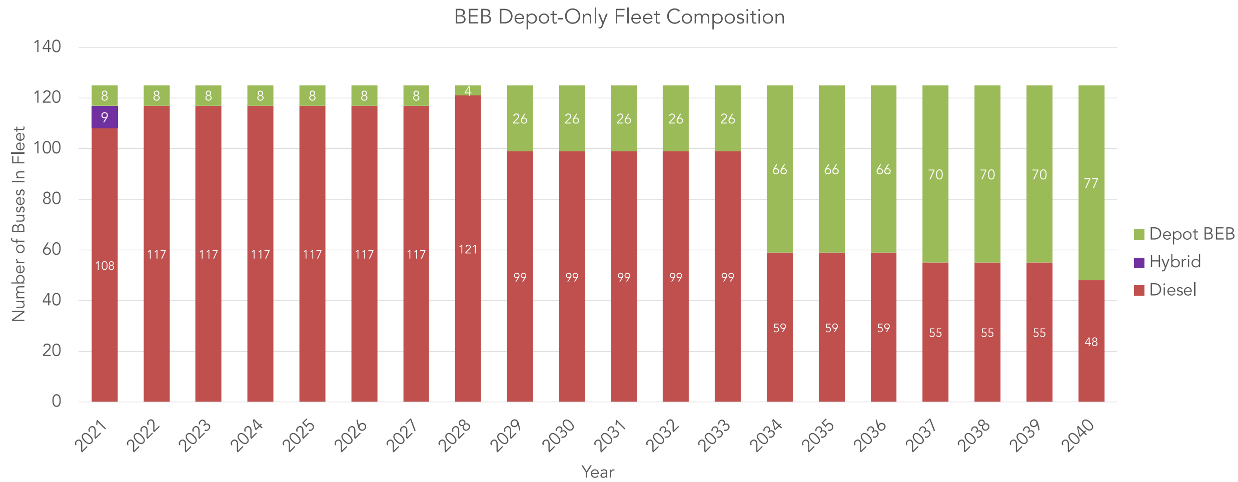


Figure 9 – Annual Fleet Composition, BEB Depot-Only Scenario

Figure 10 shows the annual total bus capital costs for the diesel and battery electric buses purchased in each year in the BEB Depot-Only scenario. 2029 and 2034 are a major purchase years, with 22 BEBs and 5 diesles expected in 2029 for an estimated $29 million and 40 BEBs in 2034 at an expenditure of $60 million.

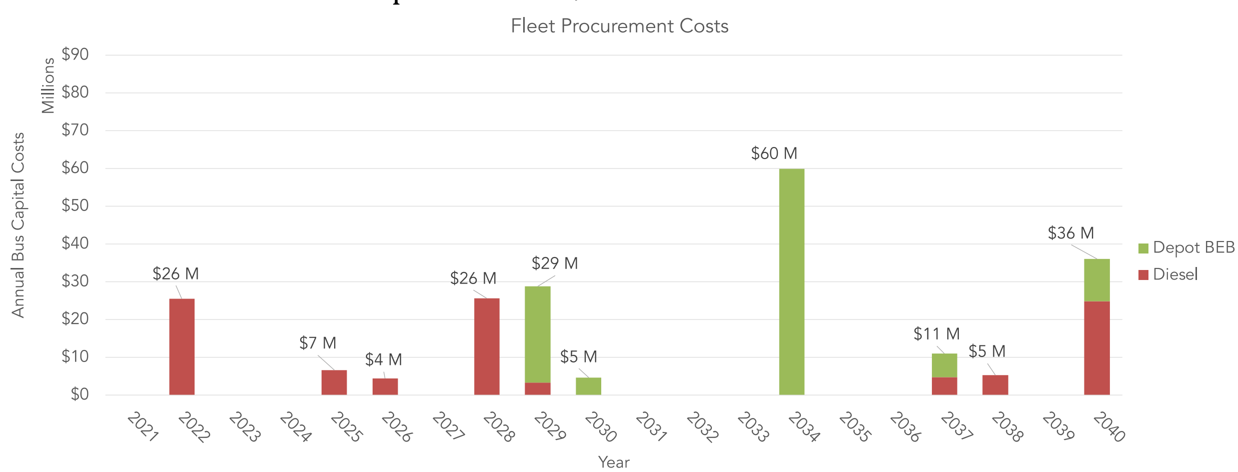


Figure 10 – Annual Capital Costs, BEB Depot-Only Scenario

BEB Depot-Only + Expanded Fleet Scenario

This scenario assumes that County Connection will expand its fleet from a total of 125 buses to 173 buses by year 2040 in order to fully electrify all of County Connection's current blocks and maintain current service levels with depot charging. From CTE's block analysis, 48 diesel buses would need to be replaced with a BEB at a 2:1 ratio. This would allow a vehicle swapping scenario where one BEB runs on a block until it reaches its range limitation and a second BEB is dispatched to act as a relief in order to complete the block. All BEBs would run on a single depot charge. While this scenario fully complies with the ICT regulation and avoids filing an exemption with CARB, higher operator and maintenance staffing are needed.

Figure 11 shows the number of BEBs that would be purchased each year from 2029 through 2040 in this scenario.

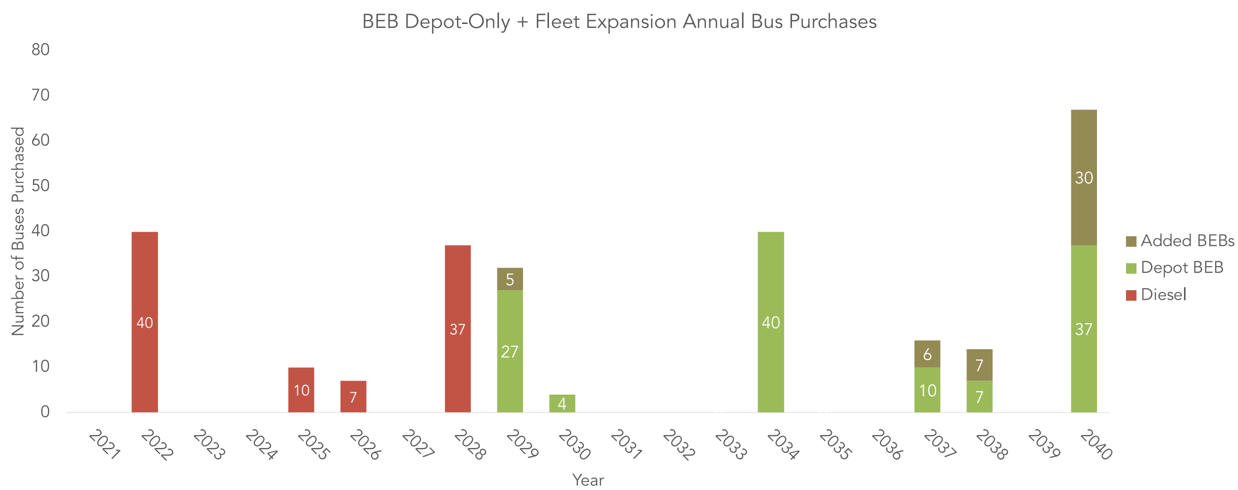


Figure 11 – Projected Bus Purchases, BEB Depot + Fleet Expansion

Figure 12 depicts the annual fleet composition through 2040 for the BEB Depot Only + Fleet Expansion scenario; the fleet remains composed of diesel buses and BEBs until the diesels are fully phased out in 2040.

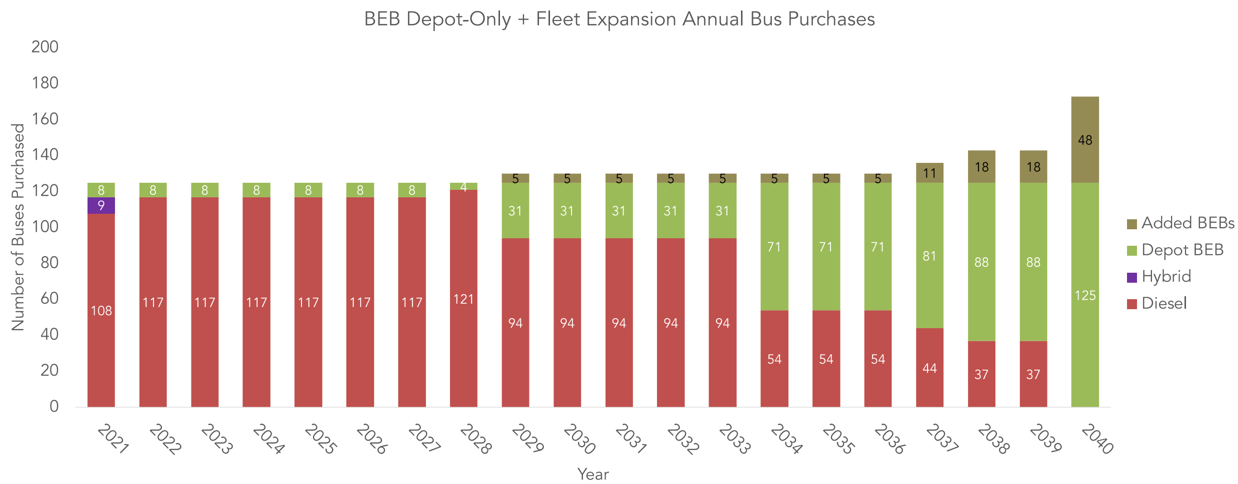


Figure 12 – Annual Fleet Composition, BEB Depot + Fleet Expansion

Figure 13 shows the annual total bus capital costs in the BEB Depot-Only + Fleet Expansion Scenario.

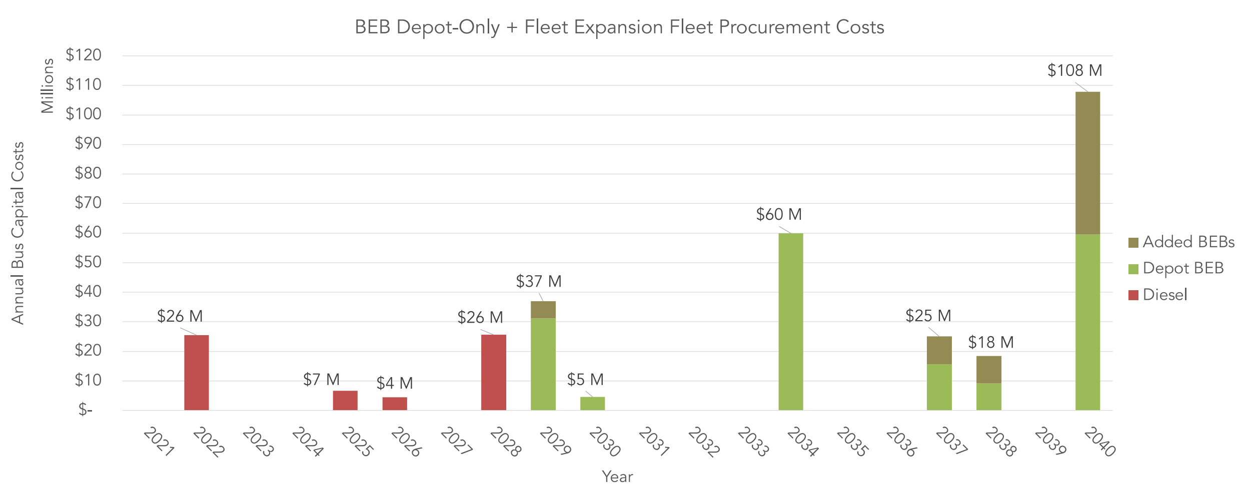


Figure 13 – Annual Capital Cost, BEB Depot + Fleet Expansion

BEB Depot + On-Route Charging Scenario

The BEB with Depot and On-Route Charging scenario builds on the analysis completed for the BEB with Depot-Only scenario. There may be instances where block coverage is insufficient and depot-charged BEBs cannot meet service requirements. In these cases, on-route charging can fill the gap. On-route charging allows an agency to add energy to buses while the bus is in service, providing the energy necessary to complete a block without having to return to the depot for charging or deploying an additional bus. Buses are assumed to supplementally charge on-route in up to 15-minute increments. CTE accounted for two 15-minute increments of layovers to blocks that will be serviced by on-route charged BEBs. An hourly labor rate of $29.05 was applied to operator time resulting in approximately $650,000 of added labor cost throughout the entire transition period. This additional labor cost is uniquely applied to the capital cost of this scenario.

The following figures show projected purchases, annual fleet composition, and annual total capital costs for the BEB with Depot and On-Route Charging scenario. On-route BEBs are distinguished from depot-charged BEBs only to indicate the number of BEBs that would require on-route charging to complete the total number of County Connection blocks; however, County Connection may choose to procure a single vehicle type that meets the needs of both depot and on-route charging.

Figure 14 shows the number of BEBs that would be purchased each year from 2029 through 2040 in this scenario. With the option of on-route charging, a greater proportion of County Connection's blocks can be serviced with BEBs over time and by 2040, all of County Connection's blocks can be completed with a BEB. Unlike in the BEB Depot-Only scenario in 2029, 2037, 2038, and 2040, where diesel buses that reach the end of their service life are replaced with another diesel bus, in this scenario, they are instead replaced with BEBs. For specificity, BEBs that would require on-route charging are shown in the graph as the dark green bar and indicated in the legend as "On-Route BEB".

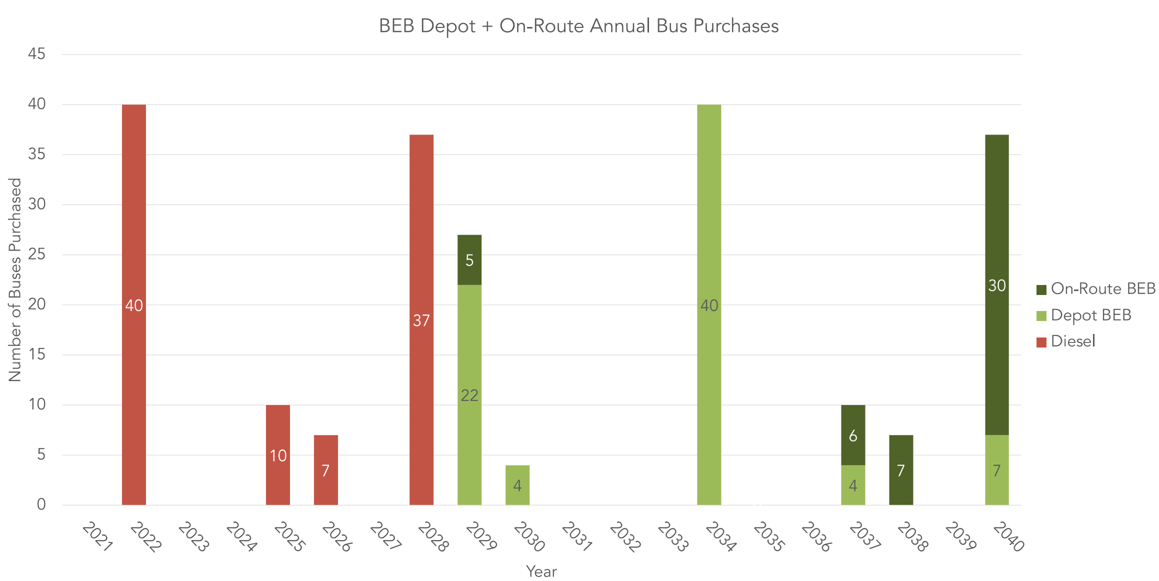


Figure 14 – Projected Bus Purchases, BEB Depot + On-Route Charging

Figure 15 depicts the annual fleet composition through 2040 for the BEB Depot Only + On-Route scenario. In comparison to the BEB Depot-Only scenario, on-route charging allows for a full replacement of diesel buses and conversion to zero-emission technology without fleet expansion. Additionally, diesel buses that run on blocks that go beyond a BEB's single depot-charge range limitation can, under this scenario, be replaced with BEBs at a 1:1 ratio.

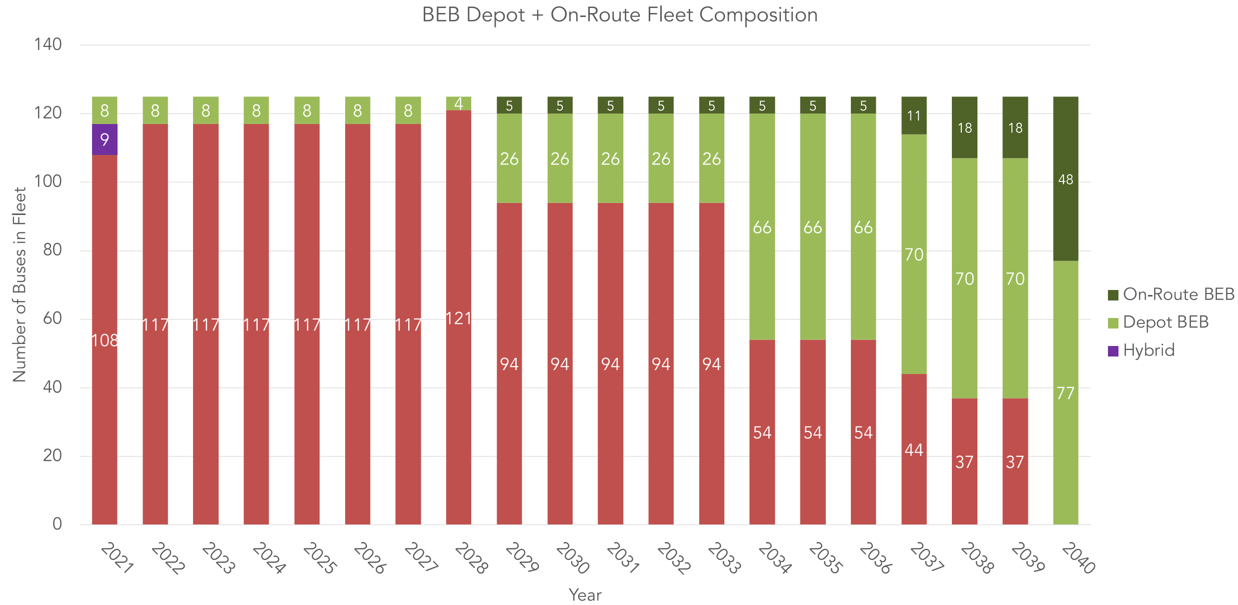


Figure 15 – Annual Fleet Composition, BEB Depot + On-Route Charging

Figure 16 shows the annual bus capital cost for the BEB Depot + On-Route Charging scenario. While the same number of diesel buses are being replaced in this scenario as in the BEB Depot-Only scenario, the bus capital cost is increased due to higher prices for BEB technology and associated costs related to additional labor for on-route charging. 2034 and 2040 are major purchase years with estimated annual expenditures of $60 million.

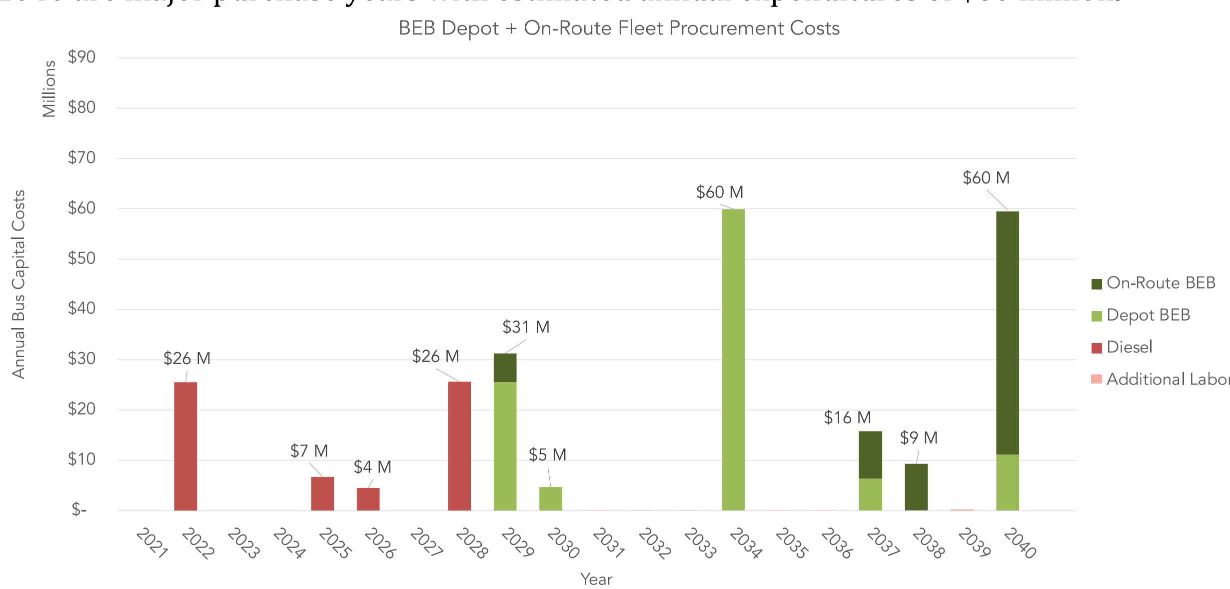


Figure 16 - Annual Capital Cost, BEB Depot + On-Route Charging

Mixed Fleet (BEB and FCEB) Scenario

In the Mixed Fleet (BEB and FCEB) scenario, County Connection operates a mixed-technology depot and fleet. Deploying both battery electric and hydrogen fuel cell technologies makes it possible to achieve an entirely zero-emission fleet and leverage the strengths of each technology. Battery electric buses can perform the shorter blocks while FCEBs, given their longer range, can be deployed on longer blocks. In this case, County Connection only incurs the higher costs of FCEBs where necessary to maintain full block achievability. The mixed fleet approach also avoids incurring the additional infrastructure costs of on-route charging required in the BEB Depot + On-Route Charging scenario. The figures below show projected purchases, annual fleet composition, and annual total capital costs for the Mixed Fleet (BEB and FCEB).

By 2040, County Connection would be able to replace 100% of its fleet with BEB and FCEBs.

Figure 17 shows the number of buses scheduled for purchase per year in the Mixed Fleet (BEB and FCEB) scenario. Diesel buses that would have been replaced with On-Route BEBs in the BEB Depot + On-Route Charging scenario are instead replaced with FCEBs.

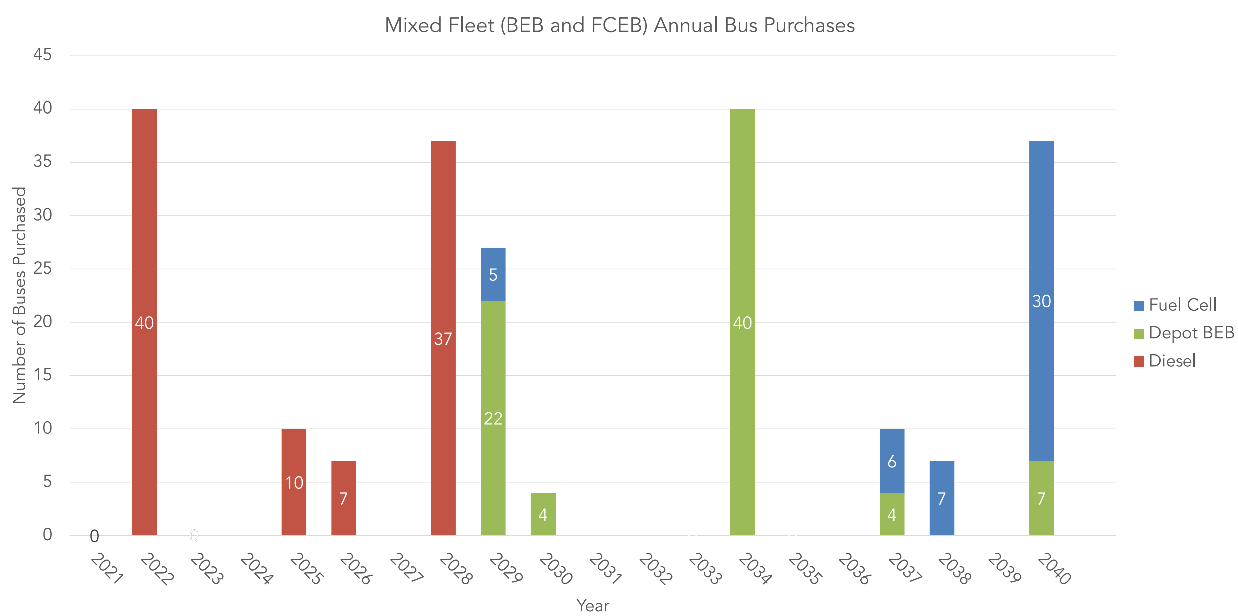


Figure 17 - Projected Bus Purchases, Mixed Fleet Scenario

Figure 18 provides a breakdown of the technology of the fleet composition per year in a Mixed Fleet scenario. FCEBs are slowly introduced with 5 buses scheduled for purchase in 2029, then 11 in 2037, 18 in 2038, and 48 in 2040.

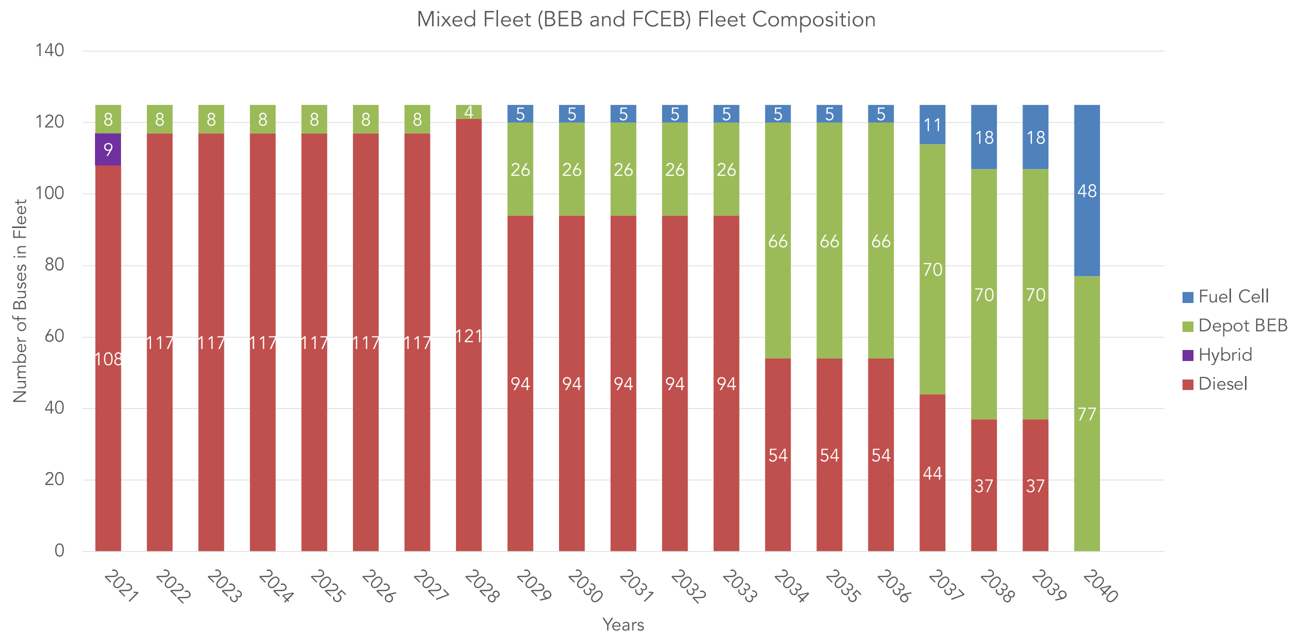


Figure 18 – Annual Fleet Composition, Mixed Fleet Scenario

Figure 19 shows the annual bus capital cost for the Mixed Fleet scenario. 2034 and 2040 are major purchase years with estimated annual expenditures of $60 million and $66 million respectively.

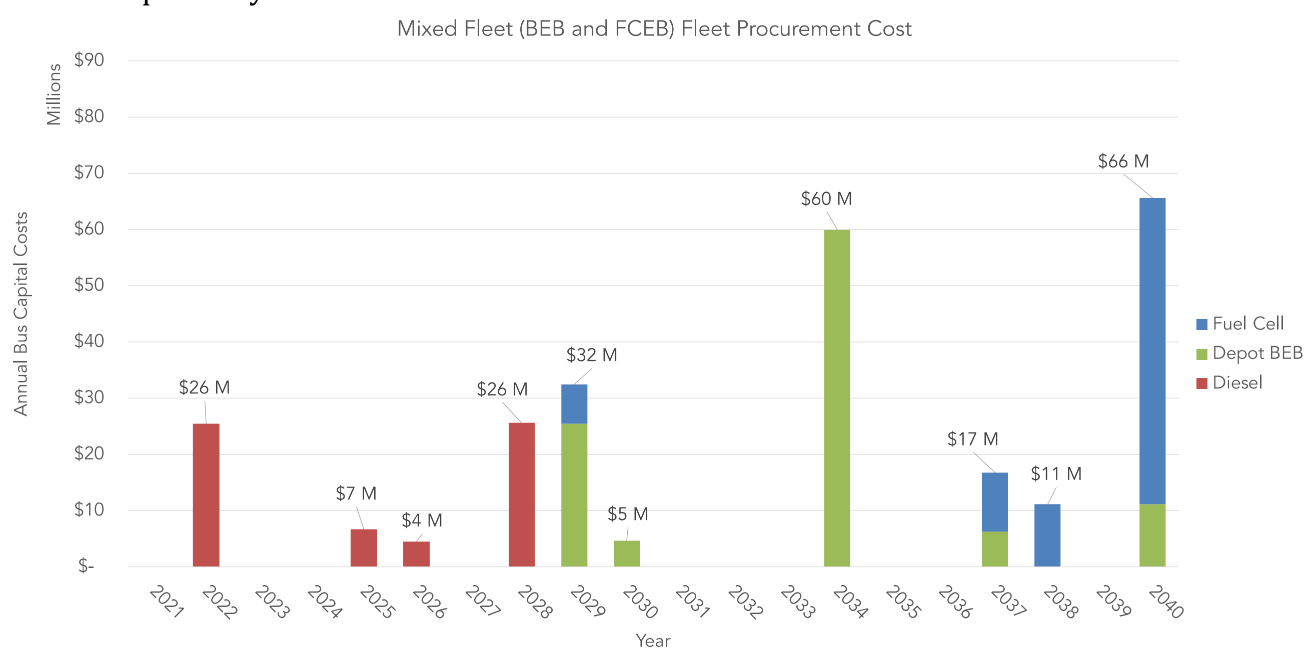


Figure 19 - Annual Capital Costs, Mixed Fleet Scenario

FCEB Only Scenario

Unlike BEBs, FCEBs do not have the same range constraints and is expected to service any block that is up to 350 miles long in nominal conditions. Analysis results show that all of County Connection's blocks can be served by an FCEB on a one-for-one replacement basis to diesel buses by the end of the transition period. Additionally, maintenance costs are highly dependent on the size and complexity of the vehicle fleet being supported. There are efficiencies gained in maintaining a single technology versus in a mixed fleet scenario where maintenance of both hydrogen equipment and charging infrastructure will need to be considered. The figures below show projected purchases, annual fleet composition, and annual total capital costs for the FCEB Only scenario.

By 2040, County Connection is able to replace 100% of its fleet with FCEBs.

Figure 20 shows the number of buses scheduled for purchase per year in the FCEB Only scenario. The initial procurement of an FCEB in this scenario begins in 2029 after all of County Connection's BEB purchases and bonus credits have been applied to offset the ICT regulation purchase mandate before the end of the 2028 calendar year.

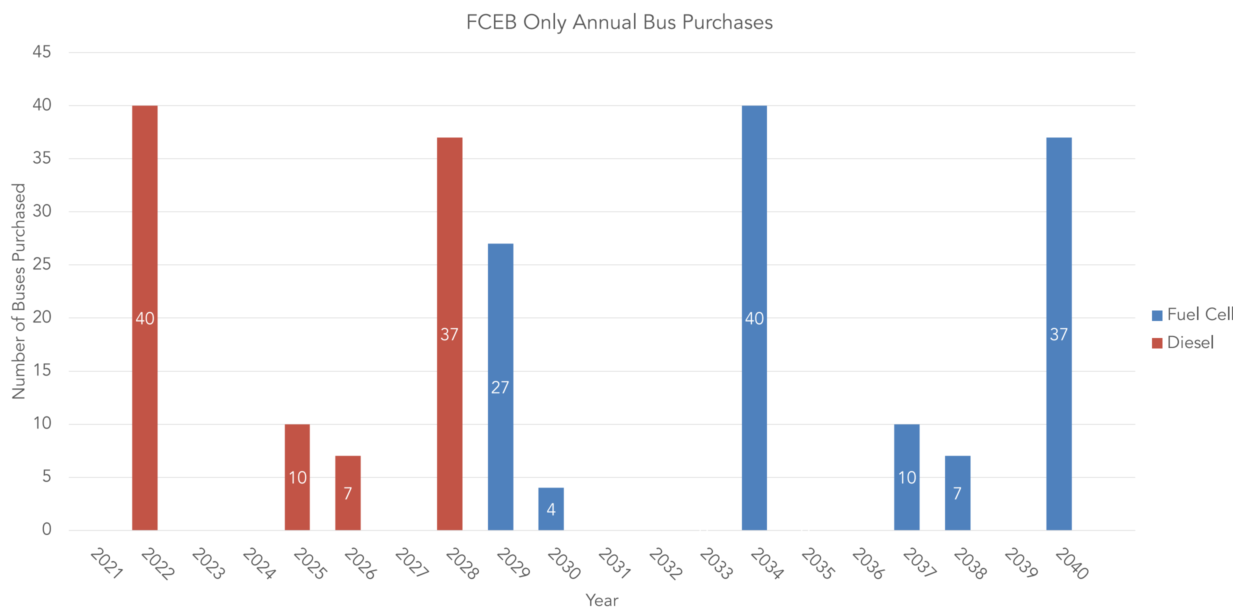


Figure 20 – Projected Bus Purchases, FCEB Only Scenario

Figure 21 shows the annual fleet composition a FCEB Only scenario. Given that FCEBs do not have the same range limitations as BEBs, diesel buses are replaced with FCEBs at a 1:1 ratio starting in 2029. BEBs are fully phased out by 2030 and diesel buses by 2040.

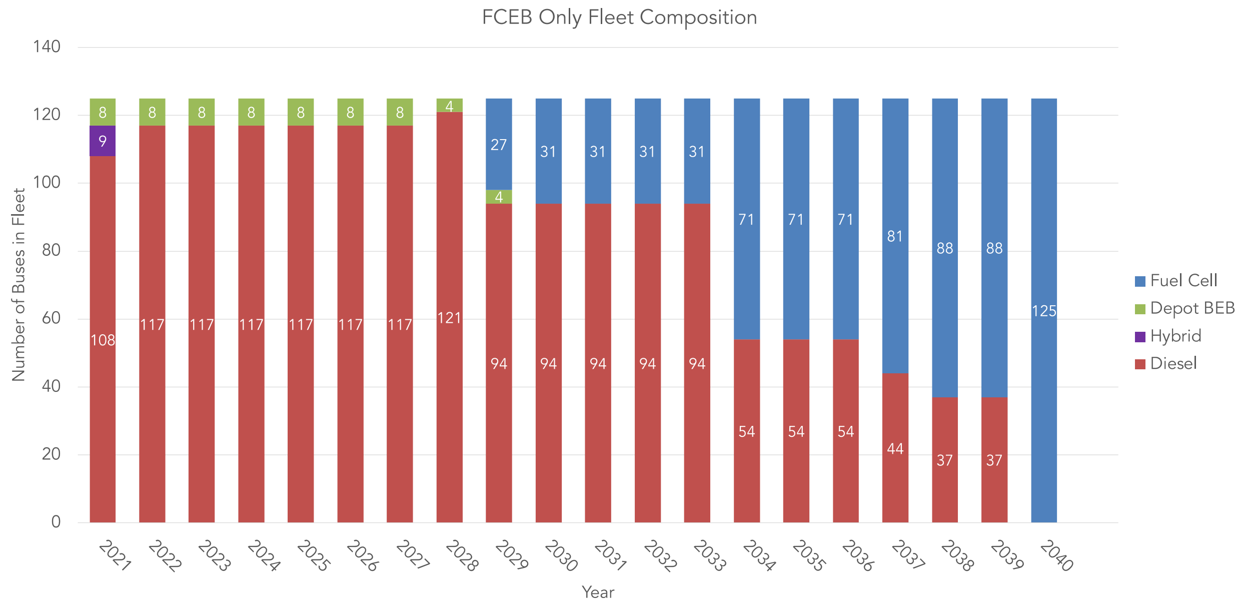


Figure 21 – Annual Fleet Composition, FCEB Only Scenario

Figure 22 shows the annual bus capital cost for the FCEB Only scenario. 2034 and 2040 are major purchase years with estimated annual expenditures of $67 million.

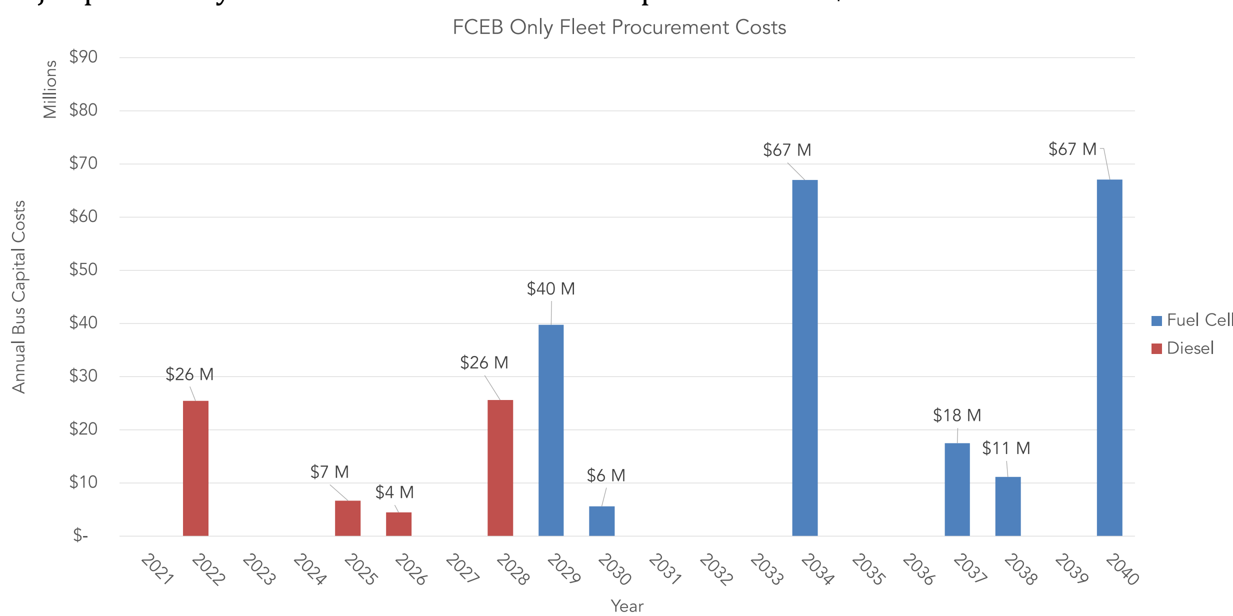


Figure 22 - Annual Capital Costs, FCEB Only Scenario

Fleet Assessment Cost Comparison

The transition and fleet composition schedules were used to develop the total capital cost for bus purchases through the transition period. **Figure 23** shows the cumulative bus purchase capital costs for each scenario.

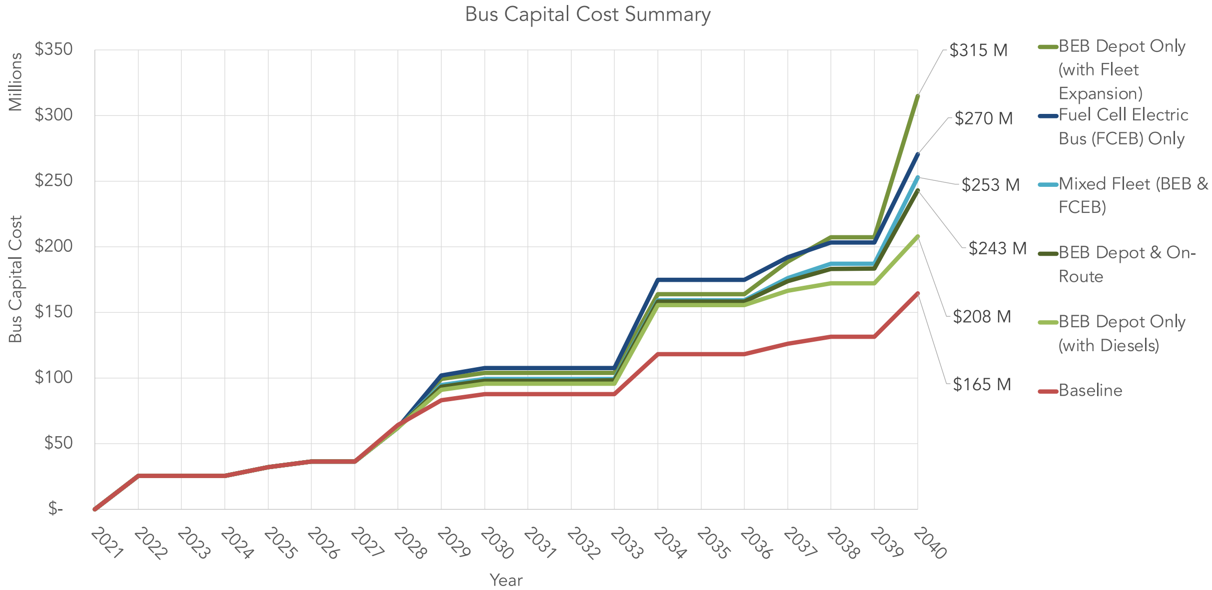


Figure 23 - Cumulative Bus Capital Costs, Fleet Assessment

By the end of the transition period, the cumulative bus capital costs vary substantially according to the technology selected. Four out of the six scenarios—the BEB Depot Only with Fleet Expansion, the BEB Depot and On-Route Charging, the Mixed Fleet, and the FCEB Only scenarios—achieve 100% zero-emission status by 2040. The Baseline and BEB Depot-Only scenarios do not achieve a fully zero-emission fleet by 2040.

Table 9 provides the combined total costs for each transit scenario and the percentage of ZEBs present in the fleet in 2040 for the scenario.

Table 9 - Total Bus Capital Costs, Fleet Assessment

Scenario	Cost	% ZEB in 2040
0. Baseline (current technology)	$165M	0%
1. BEB Depot-Only (with Diesels)	$208M	61%
2. BEB Depot-Only + Expanded Fleet	$315M	100%
3. BEB Depot + On-Route Charging	$243M	100%
4. Mixed Fleet: BEB and FCEB	$253M	100%
5. FCEB Only	$270M	100%

Fuel Assessment

The Fuel Assessment estimates fuel consumption and costs for each of the technologies—diesel, electric, and hydrogen—studied in the relevant scenario. This assessment calculates fuel costs using 2021 prices adjusted for future value based on the U.S. Energy Information Administration's (EIA) outlook for energy markets which gives prices as dollars per gallon.[6]

Using ZEB performance data from the route simulation, CTE analyzed expected bus performance on each block in County Connection's service catalog to calculate the daily fuel required for that block's completion. CTE completed this analysis for each of the five zero-emission fleet transition scenarios and the baseline scenario. The analysis produced estimates of the fuel costs for each projected fleet composition through the transition period. Operation and maintenance costs for BEB and FCEB fueling infrastructure are also included. Fuel cost estimates are based on the assumptions shown in **Table 10** below.

Table 10 - Fuel Cost Assumptions

Fuel	Cost	Source
Diesel	$2.06/DGE	County Connection-contracted rate. Cost includes fueling infrastructure maintenance costs.
Hydrogen (liquid)	$8.50/kg	Based on AC Transit's current fuel costs. Cost is inclusive of H2 fueling station maintenance by provider.
Electricity	$0.13/kWh (Off-Peak) $0.14/kWh (On-Route Charge)	PG&E Commercial EV Tariff Schedule*
Electricity	$3,500 per charger per year	Based on County Connection's current charger contract. All electricity cost includes maintenance cost, which is estimated $3,500 per charger per year

*This is not County Connection's current rate; work with PG&E to transition.

The primary source of energy for a BEB is the local electrical grid. Utility companies typically charge separate rates for electrical energy consumption [kilowatt-hours (kWh) or megawatt-hours (MWh)] and for peak power demand [kilowatts (kW) or megawatts (MW)] on a monthly basis. These separate charges are then totaled to produce an agency's electricity bill for the month.

[6] Annual Energy Outlook. 2021. Washington, DC: U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2021&cases=ref2021&sourcekey=0

Pacific Gas & Electric (PG&E) is the electricity provider, or utility, for County Connection. PG&E charges customers for energy consumption, measured in kWh, using a time-of-use (TOU) rate. Under a TOU rate, the cost per kWh of electricity varies by time of day.

Demand charges are the costs incurred by an agency's peak power demand. Peak demand is defined as the maximum amount of energy that a customer pulls from the grid for any 15-minute window within a month. Demand charges are then applied on a per-kW basis to that maximum demand. Demand charge is considered for depot and on-route charging.

As a transit agency adds more buses and chargers, the agency's energy consumption and the peak power demand both increases. Electricity rates also vary throughout the year and throughout the day, making costs highly variable if charging is not managed. Charge management strategies aim to minimize charging costs by taking advantage of this variability. Charge management strategies include charging buses during times of day at which rates are lower and avoiding demand charges by spreading out the number of buses charging at once to minimize increases in peak power demand. In the scenarios presented in this Master Plan, all buses would depot charge in the off-peak times to help reduce overall fuel cost, which the buses at County Connection can achieve by charging at night. On-route charged buses would incur some additional fees for charging at on-route stations while the buses are in service, which may occur outside of the off-peak window.

Table 11 shows a summary of the **PG&E's Electric Schedule BEV-2-S Commercial Electric Vehicles (EV) for Secondary Voltage**, which was used in the Fuel Assessment to estimate electricity costs for BEBs. These rates are averaged from monthly rates and are a summarized version of PG&E's full rate schedule. Because this is a TOU rate, the rate per kWh changes based on the time of day and year that the kWh is consumed. Depot-charged buses are assumed to charge entirely during the off-peak hours between 9:00 pm and 9:00 am. The depot charge rate is therefore the same as the off-peak rate ($0.13 per kWh). Buses that charge on-route will operate partially during on-peak hours, which incurs a slightly higher average per kWh rate ($0.14 kWh) while those buses are in service.

Most TOU rates also include a demand charge, which depends on the maximum demand that the meter measures in a given month. Fortunately, PG&E's Commercial EV Rate allows agencies to subscribe to a set fee of $95.56 per 50 kW of power demand in lieu of traditional demand charges. This standard fee rate applies to the demand at the depot as well as the demand at each of the on-route charging stations. County Connection will be moved to the new Commercial EV rate structure when their demand exceeds the current rate. The Depot Charge Rate and On-Route Charge Rate included in the table below represent the average cost per kilowatt-hour expected for County Connection.

Table 11 - PG&E's Electric Schedule BEV-2-S Commercial Electric Vehicles for Secondary Voltage

Electric Utility Rates	Per meter charge	Average monthly rates		
		summer	winter	annual
	On Peak (per kWh)	$0.34	$0.34	$0.34

	Off-Peak (per kWh)	$0.13	$0.13	$0.13
	Super Off (per kWh)	$0.11	$0.11	$0.11
	Depot Charge Rate	$0.13		
	On-Route Charge Rate	$0.14		
	Depot Demand Charge (per 50kW/month)	$95.56		
	On-Route Demand charge (per 50kW/month)	$96.56		

Charging Analysis

To accurately estimate energy consumption, peak power demand, and resultant costs, CTE conducted simulations of charging at the depot for each year of the transition. Electrical energy consumption and peak power demand were estimated based on current block schedules and projections of BEB purchases. CTE then used PG&E tariff schedules to calculate the annual cost of charging. This annual cost is evaluated for each year of the study (2021–2040) to obtain a total charging cost of BEBs with depot charging for the transition period. This estimate of total charging cost is used as the total fuel cost for the BEB-Only scenarios and is used in the other fleet scenarios, where relevant, in addition to on-route charging costs, hydrogen fuel costs, or fossil-fuel costs.

Hydrogen Pricing, Electricity Pricing, and Sensitivity Analyses

A sensitivity analysis was conducted for County Connection regarding hydrogen pricing because it is widely believed that these prices will fall over time. The high end of the expected price is the current price paid by AC Transit ($8.50/kg), a transit agency in California, and the bottom rate was estimated based on NREL and Department of Energy (DOE) projections at $5.50.[7,8] This pricing sensitivity is shown in the summary and total estimates for the fuel cell scenarios. In contrast, electricity prices are likely to rise in the future, in part due to PG&E's necessary fire safety upgrades to older electrical infrastructure. The electricity price increases are expected to translate into an increase in cost of 3.2% per year.[9] This price was included as part of a sensitivity analysis for electricity pricing. Because hydrogen and electricity pricing are expected to move in opposite directions, the near-term electricity price is the least expensive whereas the near-term hydrogen price is the most expensive.

[7] Melaina, M. and Penev, M. 2013. Hydrogen Station Cost Estimates Comparing Hydrogen Station Cost Calculator Results with Recent Estimates. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-56412 https://www.nrel.gov/docs/fy13osti/56412.pdf

[8] Hydrogen Production Tech Team Roadmap. 2017. U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability). Washington, DC: Department of Energy. https://www.energy.gov/sites/prod/files/2017/11/f46/HPTT%20Roadmap%20FY17%20Final_Nov%202017.pdf

[9] Utility Costs and Affordability of the Grid of the Future. 2021. California: California Public Utilities Commission. https://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Reports_and_White_Papers/Feb%202021%20Utility%20Costs%20and%20Affordability%20of%20the%20Grid%20of%20the%20Future.pdf

Low Carbon Fuel Standard Credits (LCFS)

The LCFS program aims to reduce carbon emissions by setting annual carbon intensity (CI) standards, or benchmarks, for the transportation sector. All transportation fuels have CI scores that are predetermined by CARB by taking into account all of the steps of fuel production, transportation, and consumption—also known as a complete lifecycle (Board, 2020). Low carbon fuels below the CI benchmark generate credits while fuels above the CI benchmark generate deficits. In the LCFS program, one credit is equivalent to one metric ton of carbon dioxide reduction. The current program extends through 2030 but is expected to be renewed within the next few years.

CTE included an estimation of the fuel cost reductions that County Connection would receive if it engages in CARB's LCFS credit program. Engagement with LCFS and ensuing credit revenue associated with certain zero-emission fuels would allow County Connection to greatly reduce their expected fuel costs. Graphics illustrating an estimate of the potential for each scenario to generate LCFS credits will follow the Fuel Assessment graphs for each scenario; however, since the exact credit revenue would be difficult to predict at this stage, especially considering the uncertainty of potential hydrogen fuel pathways for County Connection, only the fuel costs were included in the Total Cost Analysis. The discussion of LCFS credits is included to illustrate the financial impact participating in the LCFS credit trading program could have on County Connection's fuel costs.

Methodology and Cost Assumptions

- For fueling BEBs, it is assumed that County Connection will continue to use standard PG&E delivered power with an application for a Renewable Energy Sourcing Credit Benefit (REC) to make it 100% renewable.
- A 2% per year reduction is applied to the LCFS credit gross value.
- A broker service fee of 10% is subtracted from the gross credit value.
- The current LCFS credit program only extends through 2030. Speculating on how the pricing will trend after the program renewal is challenging, therefore, the LCFS credit revenue remains at 2030 values through 2040. Although, credit revenue depreciation is expected as adoption and market maturity increase.
- For FCEB fueling options, three hydrogen production processes were considered:
    1. Fossil Fuel Steam Methane Reformation (SMR). This means of production has the highest CI for hydrogen production and is the most common source that is currently on the market. It is not considered green hydrogen.
    2. Electrolysis. This is via 100% renewable electricity pathways.
    3. Dairy Gas SMR. County Connection may pay particular interest to dairy gas SMR as there are plans to develop a distribution center for hydrogen produced through this method in nearby Livermore, CA.

Baseline

In the Baseline scenario, the fleet remains composed primarily of diesel buses with just eight BEBs. **Figure 24** depicts energy consumption by fuel type over the transition period for the Baseline scenario. Fleet energy use remains constant over the entire period at around 0.6 million diesel-gallon-equivalent (DGE).

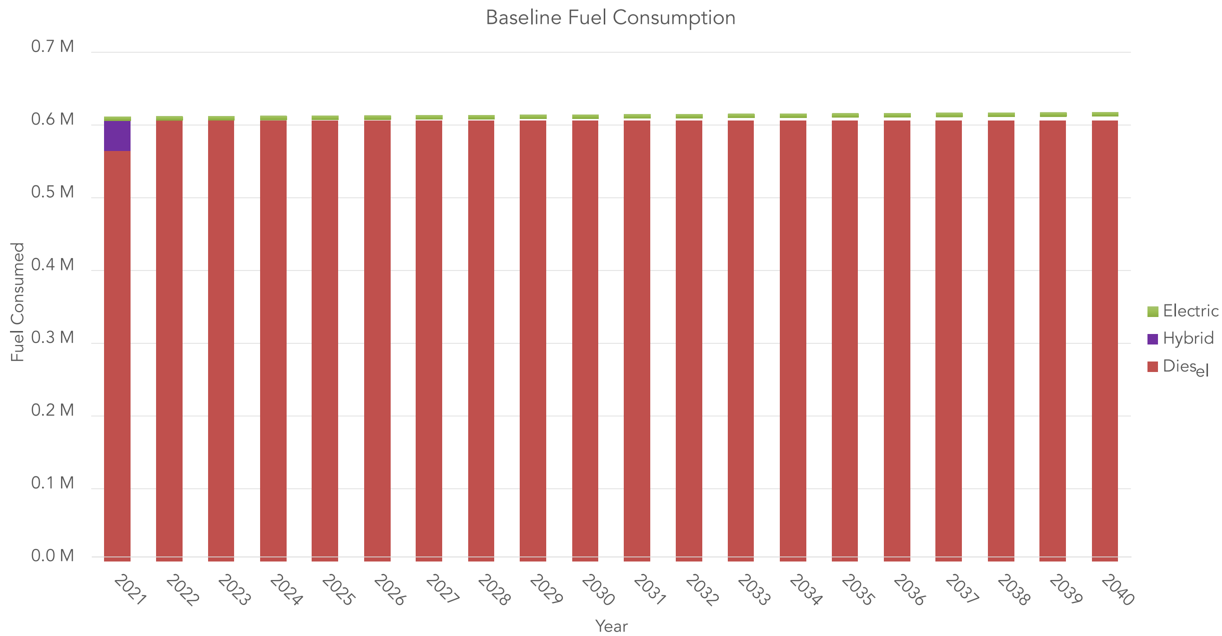


Figure 24 - Annual Fuel Consumption, Baseline Scenario

Figure 25 shows the annual fuel costs for each fuel type in the Baseline scenario, based on the consumption quantities (in DGE) shown in **Figure 24**. To estimate fuel costs, CTE multiplied the annual fuel consumption of the relevant fleet composition (in gallons or gallons-equivalent) by County Connection's reported annual miles traveled per vehicle type. This quantity was then multiplied by the average fuel price per gallon at County Connection's contracted rate of $2.06 per gallon for diesel. In the Baseline scenario, the fleet is primarily composed of diesel buses. While the fleet size, frequency of trips per route, and associated annual mileage are sustained throughout the analysis period, the annual fuel cost increases over time, since it has been adjusted for inflation. The total estimated fuel costs in 2040, approximately $1.8 million, are therefore greater than in 2021.

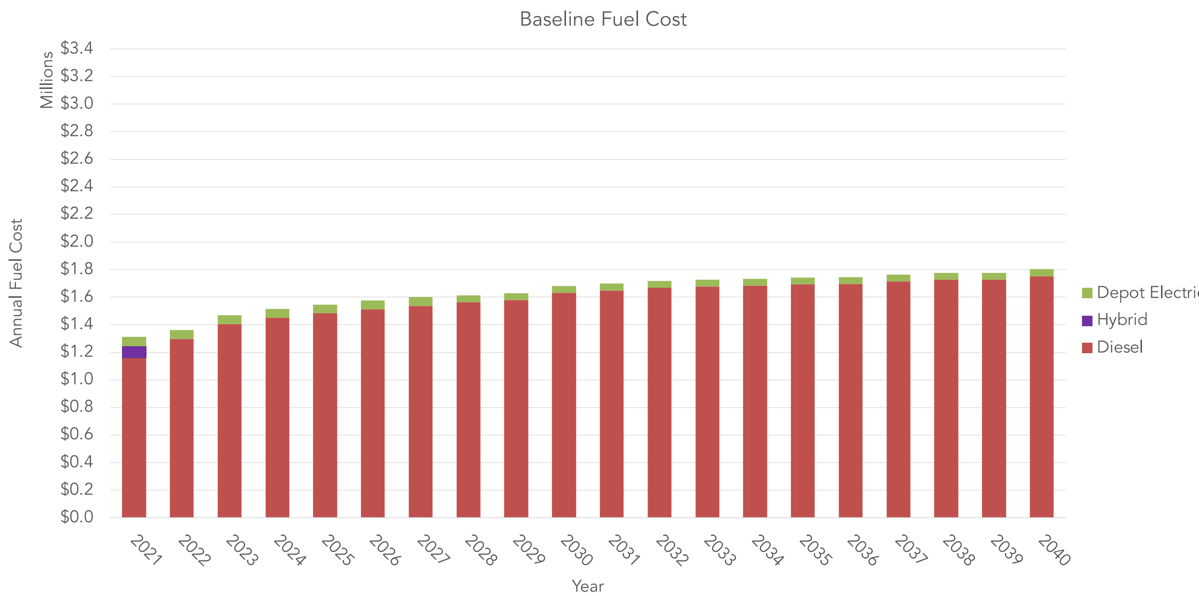


Figure 25- Annual Fuel Costs, Baseline Scenario

BEB Depot Only

The BEB Depot Only scenario models a transition to a partially-BEB fleet in which the BEBs are powered entirely by electricity delivered via depot-charging. **Figure 26** depicts energy consumption for each fuel type over the transition period. Legacy fuels are phased out as electricity consumption increases, reflecting an increasing number of BEBs in the fleet. Fleet energy use is thus reduced from about 0.6 million DGE in 2020 to about 0.3 million DGE in 2040.

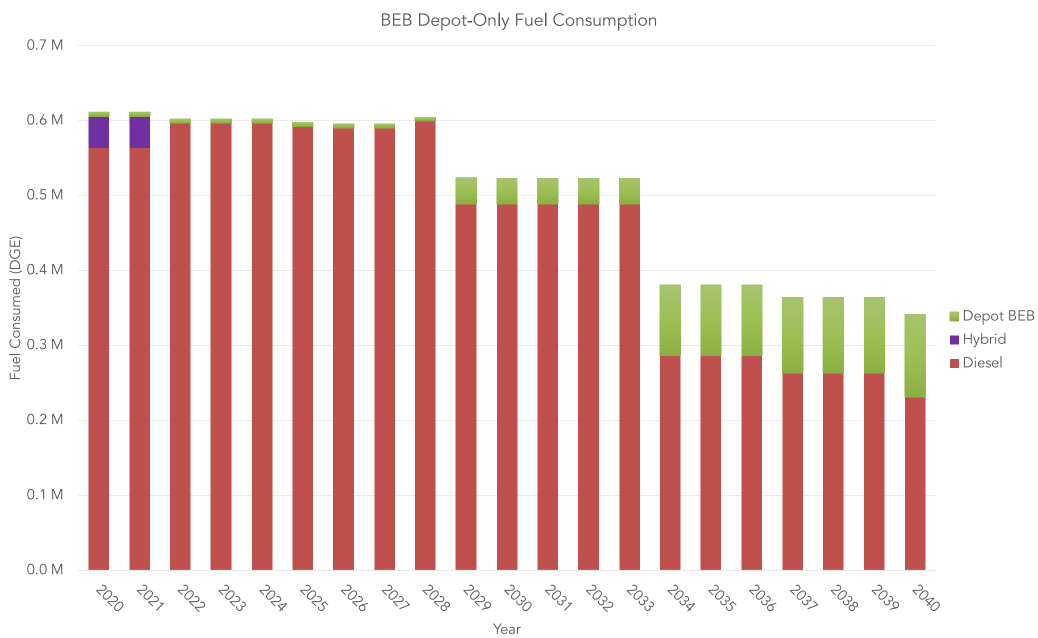


Figure 26 – Annual Fuel Consumption, BEB Depot-Only

Figure 27 shows the annual costs for each fuel type based on the quantities in **Figure 26**. Electricity consumption increases as diesel fuel consumption decreases. The total estimated fuel costs in 2040, approximately $1.6 million, is less than that of the Baseline scenario.

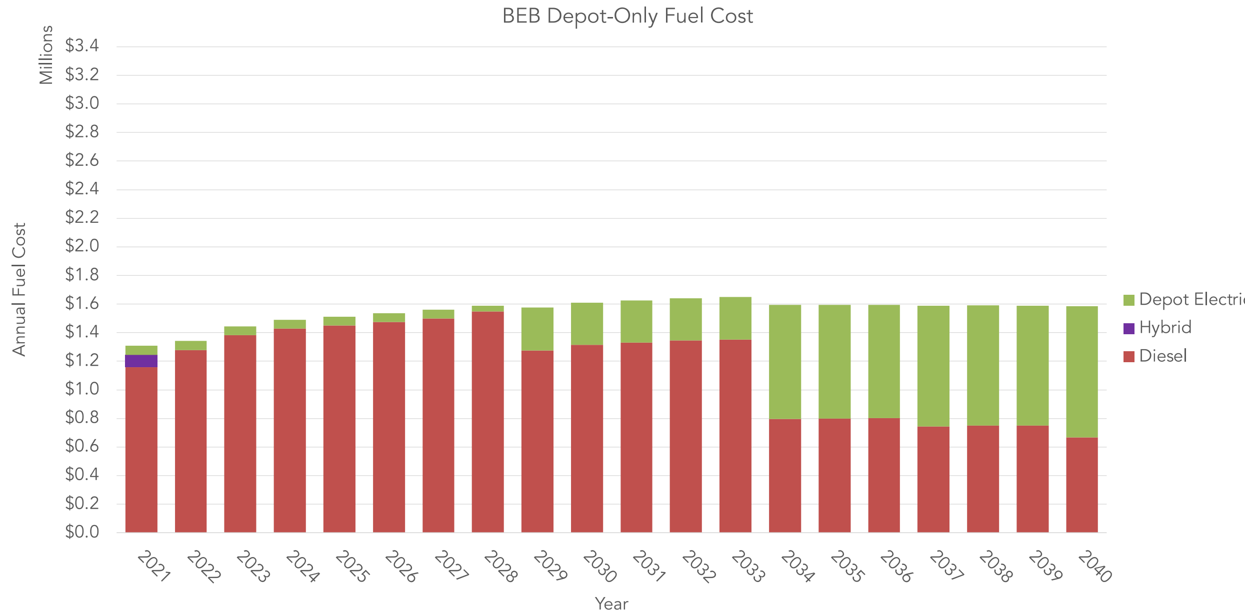


Figure 27 - Annual Fuel Costs, BEB Depot-Only

Operating BEBs would also make County Connection eligible for LCFS credit revenue. Procuring electricity from 100% renewable energy would generate the most credits for County Connection. Purchasing REC is a pathway to obtain renewable energy and would enable County Connection to qualify for LCFS credits while still receiving its energy from PG&E.

illustrates the credit revenue estimates through 2030, which is the date of when the current program will sunset. Although the program is expected to be extended through 2040 shortly, it is hard to estimate how the credit values may change in the next iteration of the program. The cost estimate over time shown in **Figure 28** shows an estimate through 2040, to demonstrate that increasing the number of ZEBs in the fleet will increase LCFS credit revenue, but since predicting LCFS Credit Value changes past 2030 is challenging, 2030 values are maintained through 2031-2040.

Table 12- LCFS Credit Revenue Estimates by Year, BEB Depot-Only

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	26	26
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$510K	$492K

*Calculated using analysis from SREC Trade.

Figure 28 depicts projected revenue from LCFS credits, estimated annual cost by fuel type, and the net fuel cost after summing the previous categories. In 2033 and onward, more LCFS credit revenue is generated due to the increased number of BEBs in the fleet versus net fuel cost.

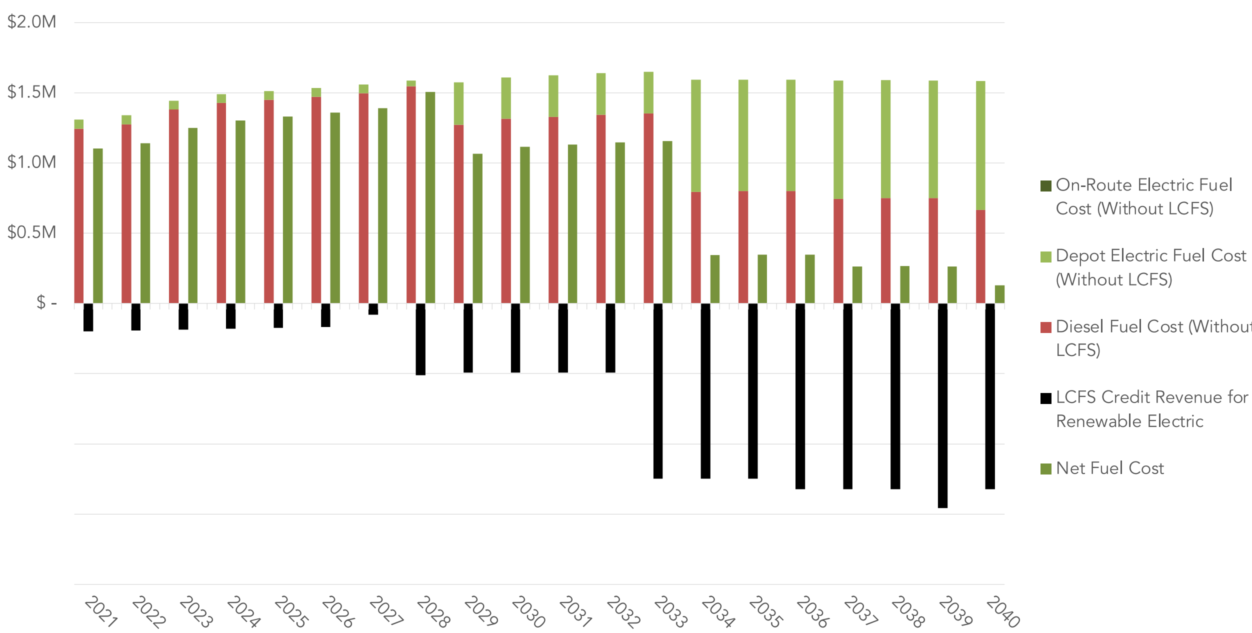


Figure 28 - Potential LCFS Credit Revenue for 100% Renewable Electric, BEB Depot-Only

BEB Depot Only + Expanded Fleet

The BEB Depot Only with Expanded Fleet scenario models a transition to an all-BEB fleet that is larger than County Connection's current fleet and relies entirely on depot-charging infrastructure. Achieving this scenario results in compliance with CARB's ICT regulation. **Figure 29** depicts energy consumption for each fuel type over the transition period, assuming depot-charged BEBs. Legacy fuels are phased out as electricity consumption increases, reflecting an increasing number of BEBs in the fleet. Fleet energy use is thus reduced from about 0.6 million DGE in 2020 to about 0.15 million DGE in 2040.

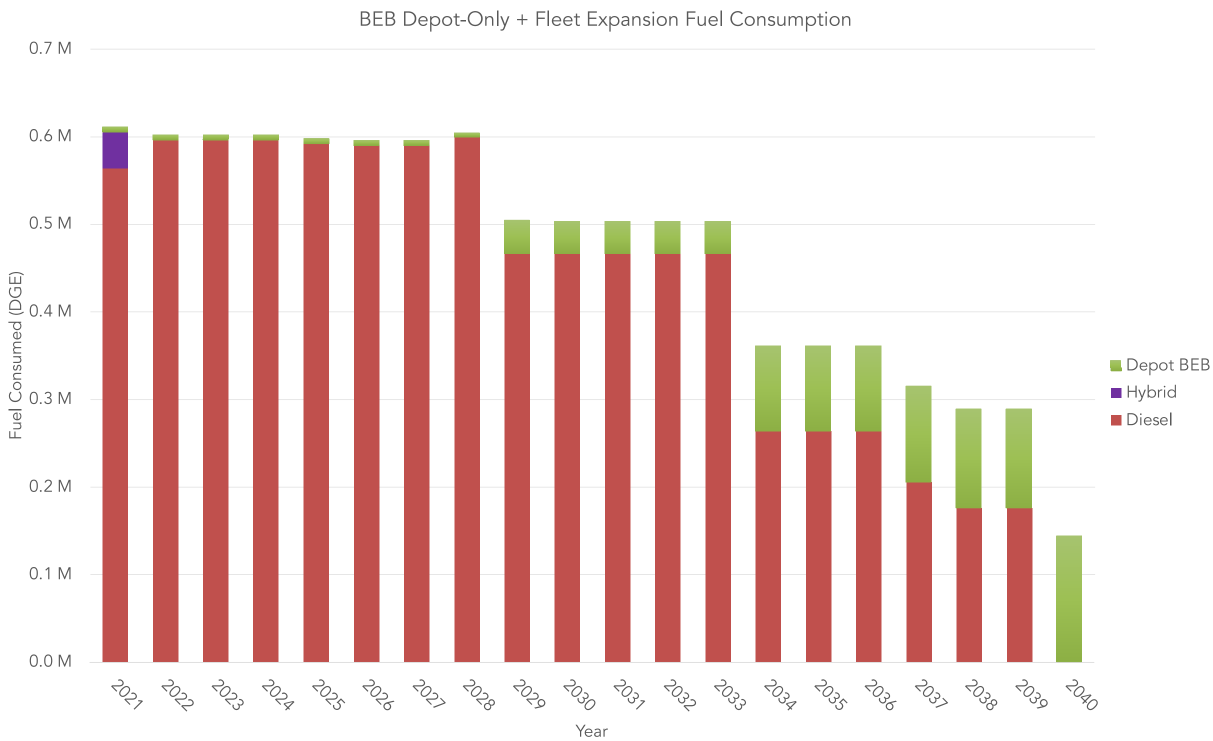


Figure 29 - Annual Fuel Consumption, BEB-Depot Only + Fleet Expansion

Figure 30 shows the annual costs for each fuel type based on the quantities in the above.

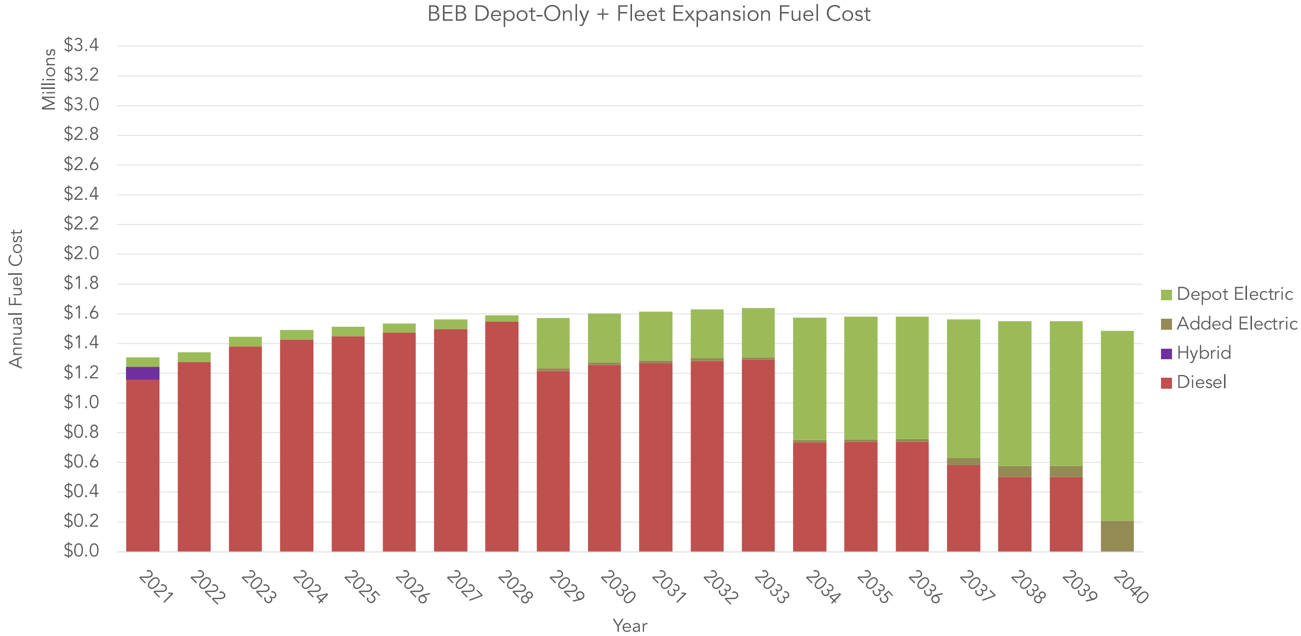


Figure 30 - Annual Fuel Costs, BEB-Depot Only + Fleet Expansion

According to the calculations used in the table below, $705,000 and $681,000 in LCFS credit revenue can be generated through the operation of 31 BEBs in 2029 and 2030, respectively. **Table 13** illustrates the LFCS credit value and revenue generation potential through 2030, which is the date of the current program sunset.

Table 13- LCFS Credit Revenue Estimates by Year, BEB Depot-Only + Fleet Expansion

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	31	31
No. of added BEBs in Fleet	0	0	0	0	0	0	0	0	5	5
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$705K	$681K

*Calculated using analysis from SREC Trade.

In **Figure 31**, County Connection stands to gain more LCFS credit revenue than projected fuel cost beginning in year 2034.

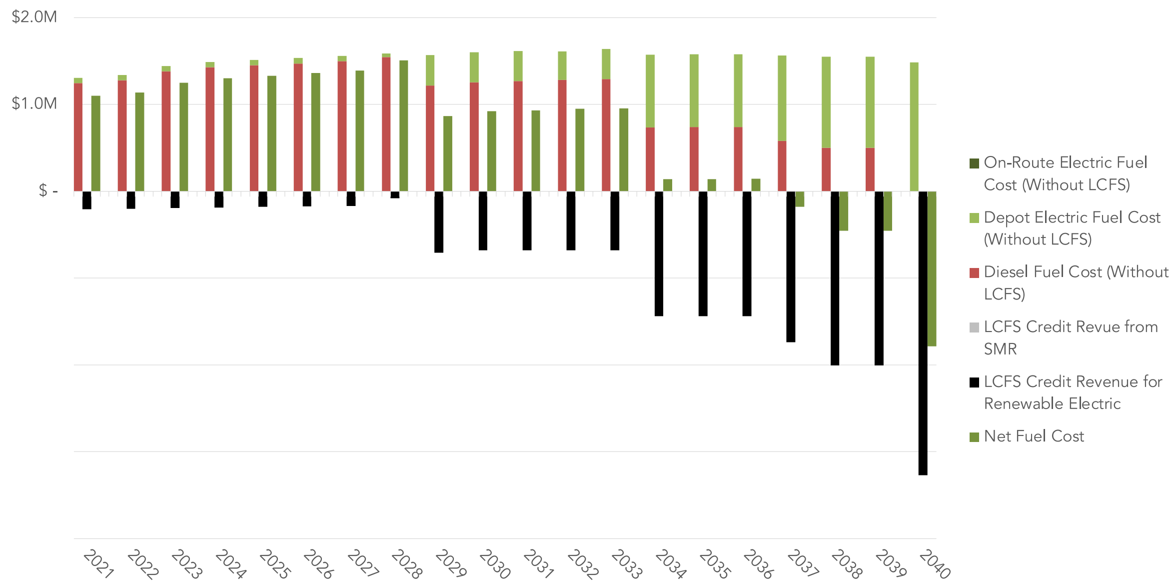


Figure 31 - Potential LCFS Credit Revenue for 100% Renewable Electric, BEB Depot-Only + Fleet Expansion

BEB Depot + On-Route Scenario

The BEB Depot and On-Route Charging scenario models a transition to an all-BEB fleet but achieves compliance with the ICT regulation through the addition of on-route charging infrastructure. The figures below show energy consumption for each fuel type over the transition period and the annual costs for each fuel type within the BEB Depot and On-Route Charging scenario.

In **Figure 32**, fleet energy use is shown to reduce by 71% in 2040 compared to 2021 fuel consumption levels due to the efficiencies of BEB technology.

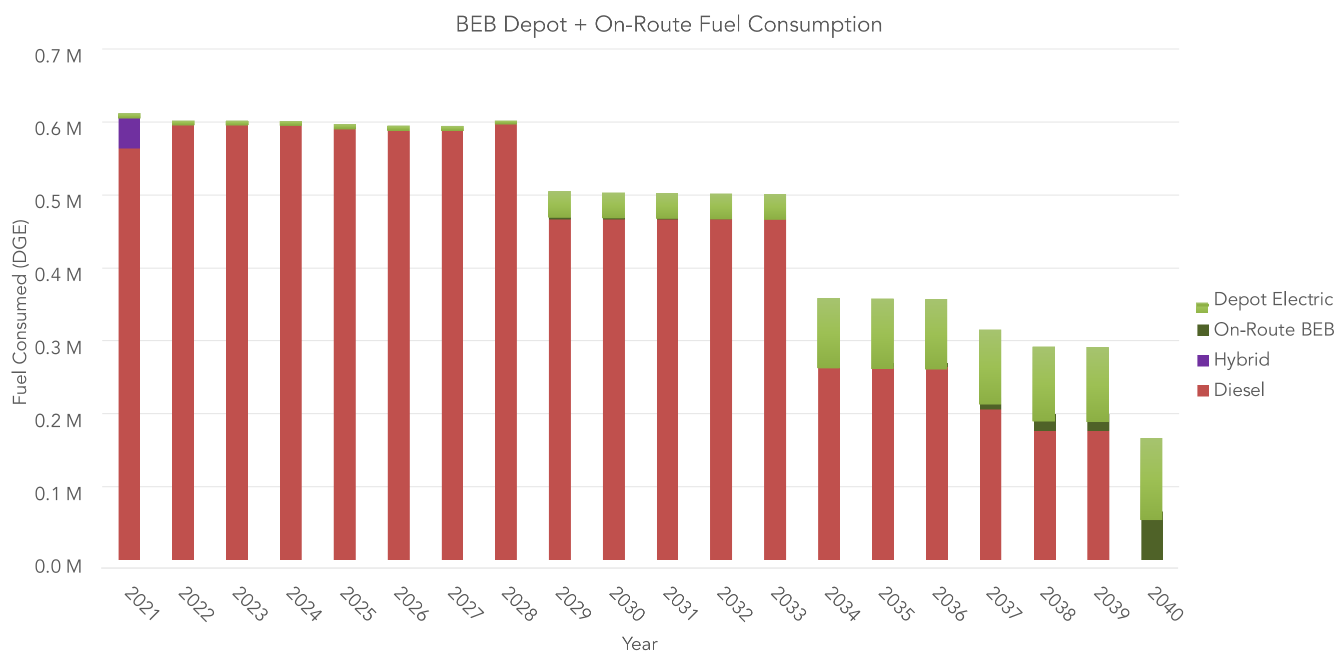


Figure 32 - Annual Fuel Consumption, BEB Depot + On-Route Charging

Although the total amount of energy consumed by the fleet decreases over the fleet transition period, as shown in **Figure 33**, the total fuel costs increase over time. Annual fuel costs increase by the end of the transition period partly because of inflation but also because on-route charging costs are incurred during on-peak electricity rate hours and thus incur on-peak rate charges and demand charges. These costs increase as fleet electrification progresses, and the fleet becomes fully electrified in 2040.

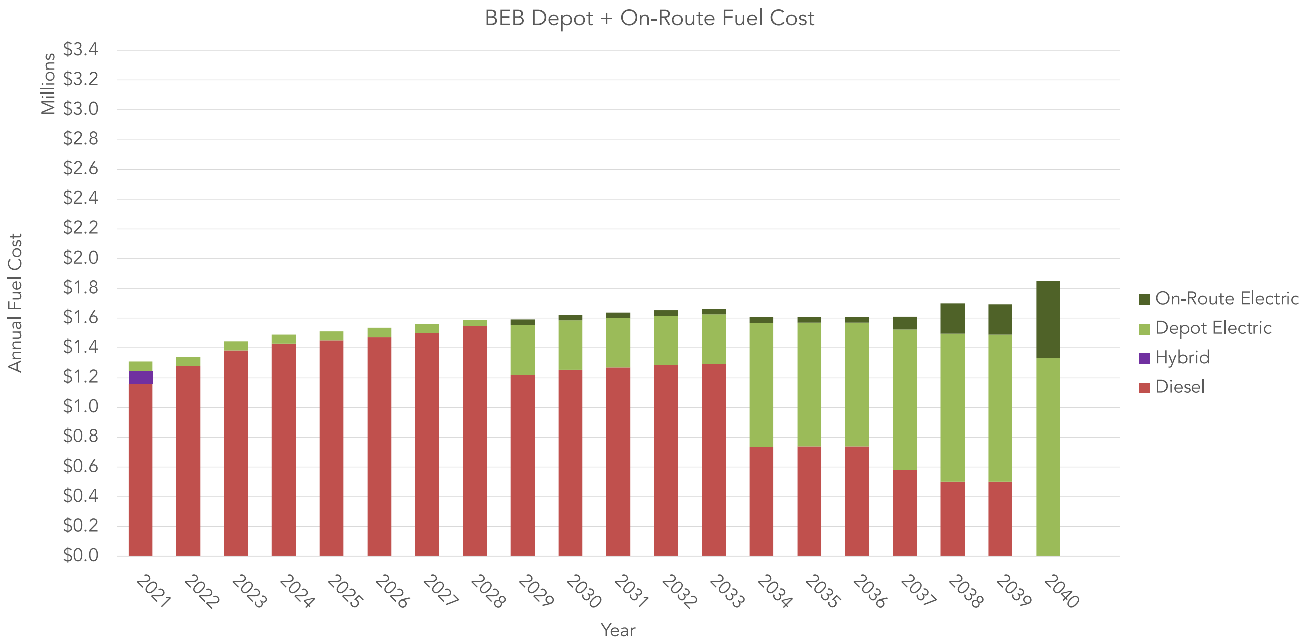


Figure 33 - Annual Fuel Costs, BEB Depot + On-Route Charging

According to the calculations used in the table below, $607,000 and $586,000 in LCFS credit revenue can be generated through the procurement of 26 BEBs in 2029 and 2030, respectively. **Table 14** illustrates the LFCS credit value and revenue generation potential through 2030, which is the date of the current program sunset.

Table 14 - LCFS Credit Revenue Estimates by Year, BEB Depot + On-Route Charging

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet for Dep. Charging	8	8	8	8	8	8	8	4	26	26
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$607K	$586K

*Calculated using analysis from SREC Trade.

In **Figure 34**, County Connection stands to gain more LCFS credit revenue than projected fuel cost beginning in year 2038.

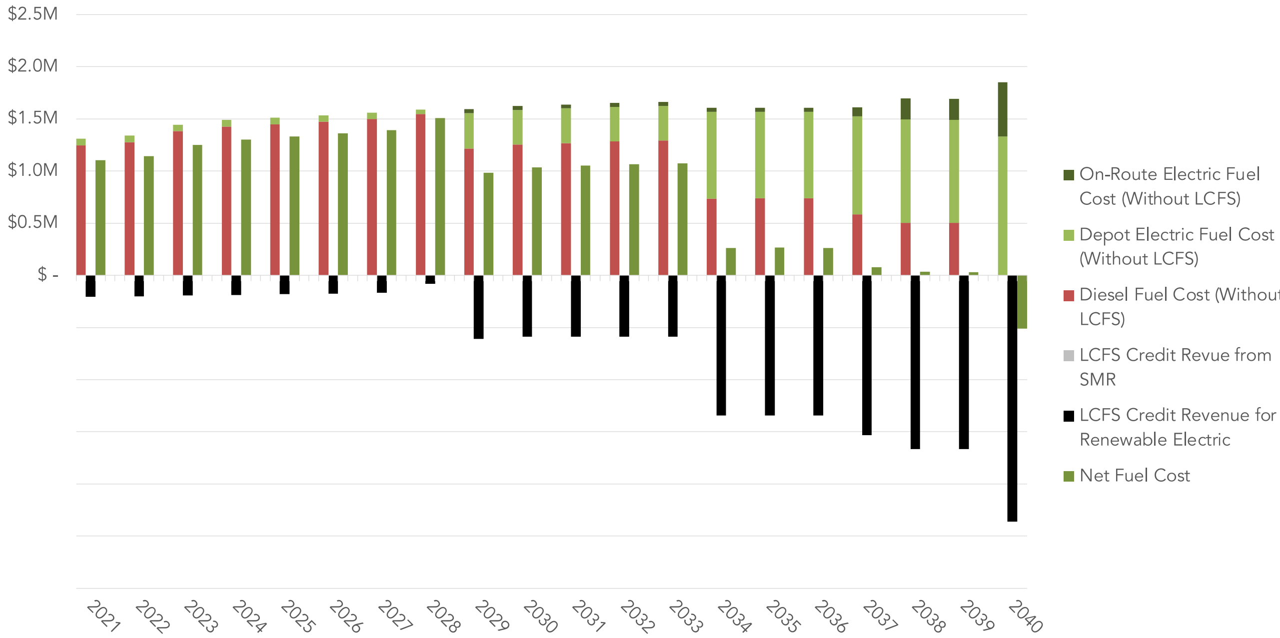


Figure 34 - Potential LCFS Credit Revenue for 100% Renewable Electric, BEB Depot + On-Route Charging

Mixed Fleet BEB and FCEB

In the Mixed Fleet: BEB and FCEB scenario, BEBs replace diesel buses on all achievable blocks. FCEBs supplement the BEB fleet to cover the blocks that are not achievable with battery-electric technologies. Building the fleet composition in this way ensures that all routes are achievable while minimizing expenditure on higher cost FCEBs.

Figure 35 depicts energy consumption for each fuel type over the transition period for the Mixed Fleet: BEB and FCEB scenario. Legacy fuels are phased out as electricity and hydrogen consumption increases, reflecting an increasing number of BEBs and FCEBs in the fleet. Fleet energy use is reduced from about 0.6 million DGE in 2021 to under 0.3 million DGE in 2040.

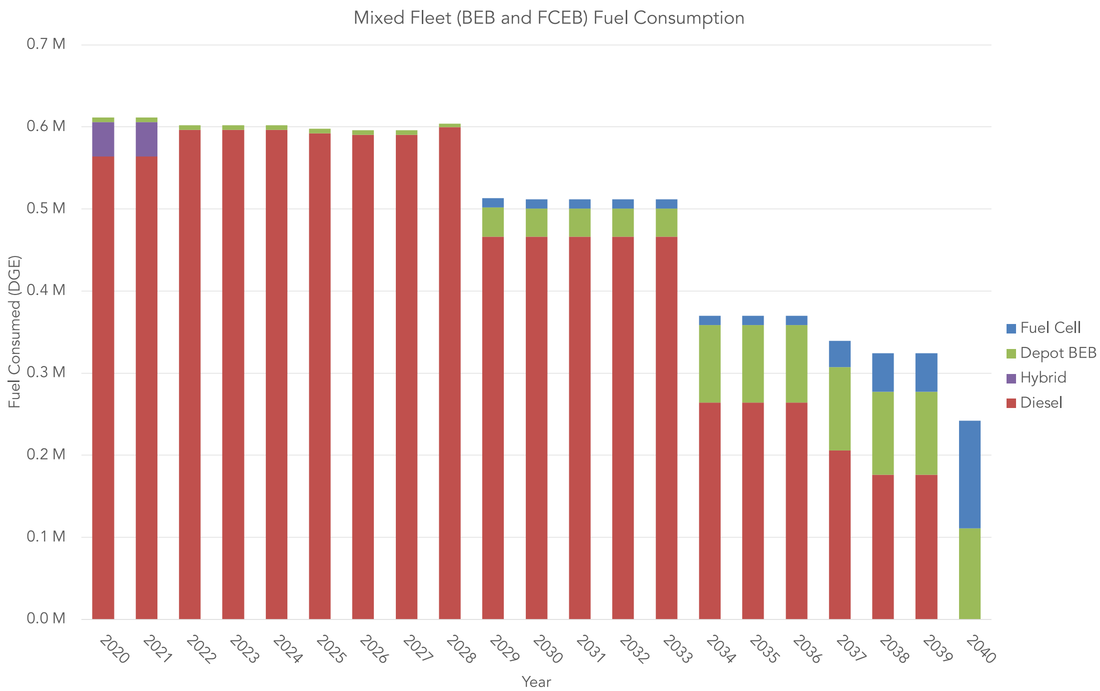


Figure 35 - Annual Fuel Consumption, Mixed Fleet

Figure 36 shows the estimated annual costs for each fuel type based on the quantities consumed, as shown in **Figure 35**. Total estimated fuel costs in 2040 are approximately $1.9 million, which are incurred from electricity use for BEBs and hydrogen fuel for FCEBs. Although the total amount of energy consumed decreases over the fleet transition period (**Figure 35**), the total fuel costs increase over that timeframe. These trends reflect hydrogen and electricity's greater efficiency but also its higher costs compared to diesel fuel.

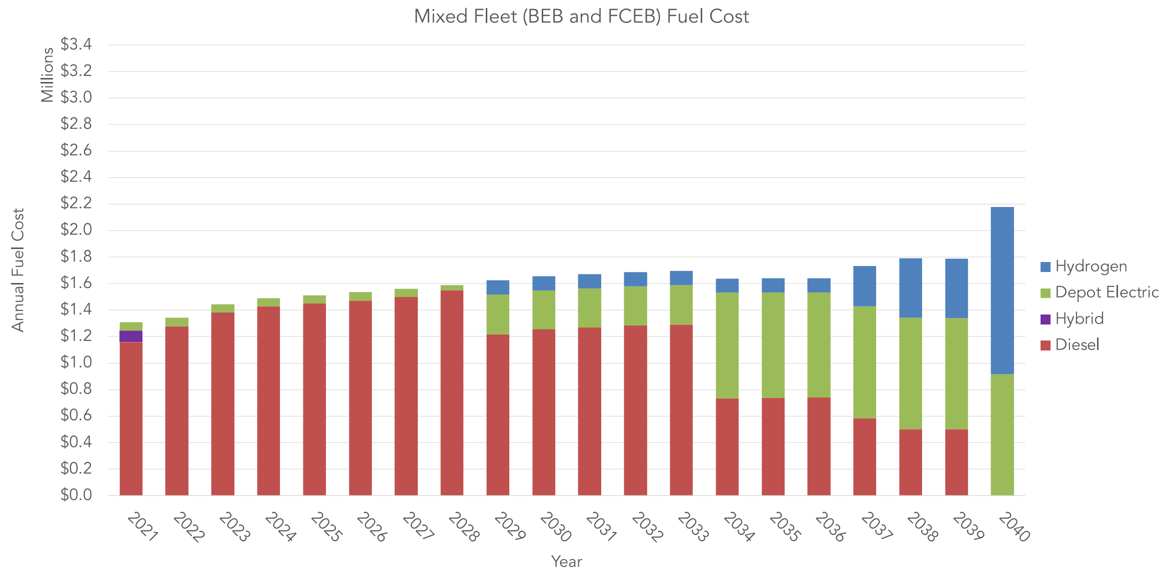


Figure 36 - Annual Fuel Costs, Mixed Fleet

The Mixed Fleet Scenario is also eligible for participation in the LCFS Credit Program. Revenue potential for hydrogen is highly variable depending on how the fuel is produced. CTE therefore explored three potential hydrogen fuel production pathways for the LCFS credit assessment. The first pathway, fossil fuel SMR, is currently the most commonly available hydrogen but this method is not incentivized in the LCFS market given that fossil fuels are used as to produce the hydrogen. The tables below illustrate the LFCS credit value and revenue generation potential through 2030, which is the date of the current program sunset.

Table 15 - LCFS Credit Revenue Estimates by Year for Fossil Fuel SMR Hydrogen, Mixed Fleet Scenario

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	26	26
No. of FCEBs in Fleet	0	0	0	0	0	0	0	0	5	5
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value per FCEB - SMR	$1.4K	$1.1K	$900	$650	$400	$200	$0	$0	$0	$0
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$510K	$492K

*Calculated using analysis from SREC Trade

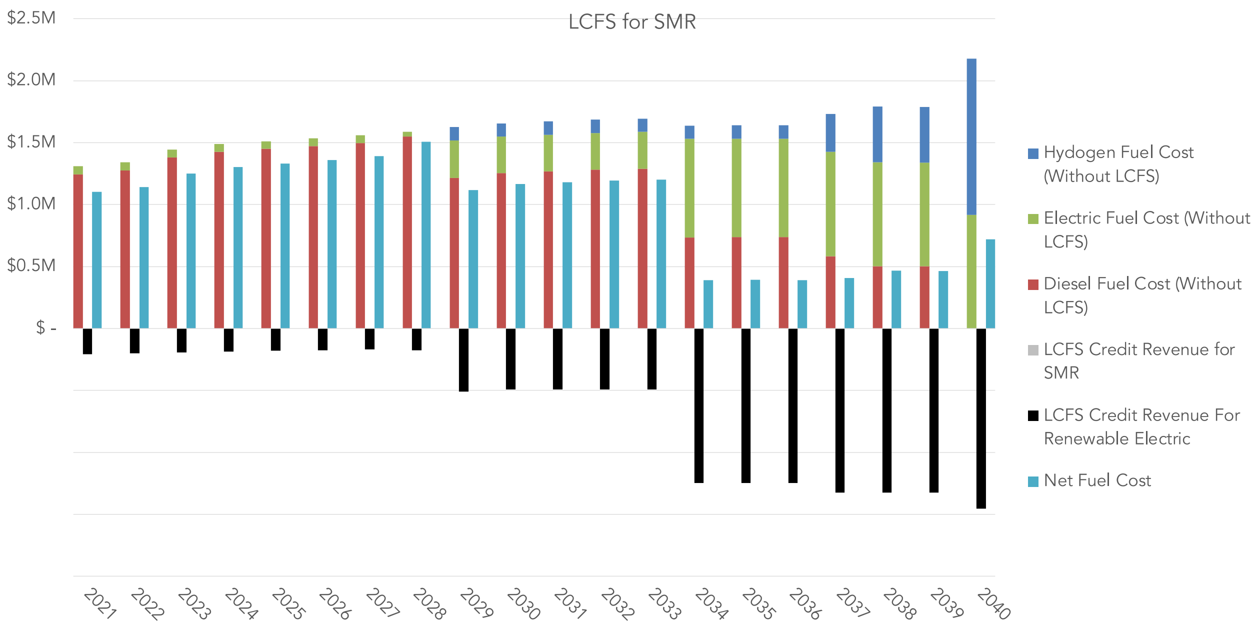


Figure 37 - Potential LCFS Credit Revenue for Fossil Fuel SMR Hydrogen, Mixed Fleet

The second pathway, electrolysis using 100% renewable energy, generates a greater LCFS credit generation per FCEB than fossil fuel SMR.

Table 16 - LCFS Credit Revenue Estimates by Year for 100% Renewable Electrolysis Hydrogen, Mixed Fleet

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	26	26
No. of FCEBs in Fleet	0	0	0	0	0	0	0	0	5	5
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value per FCEB - Electrolysis	$16K	$15K	$15K	$14K	$13K	$13K	$13K	$12K	$12K	$11K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$564K	$541K

*Calculated using analysis from SREC Trade.

In **Figure 38**, electric and renewable electrolysis hydrogen pathways generate a significant amount of LCFS credit revenue and the net fuel costs are lower than in the SMR pathway. It is worth noting that in this model, the hydrogen fuel price is based on cost data from AC Transit, which uses hydrogen produced from fossil fuel SMR with a 33% renewable supply stream. Contract prices for electrolysis and dairy gas SMR are not yet available and therefore could not inform the model.

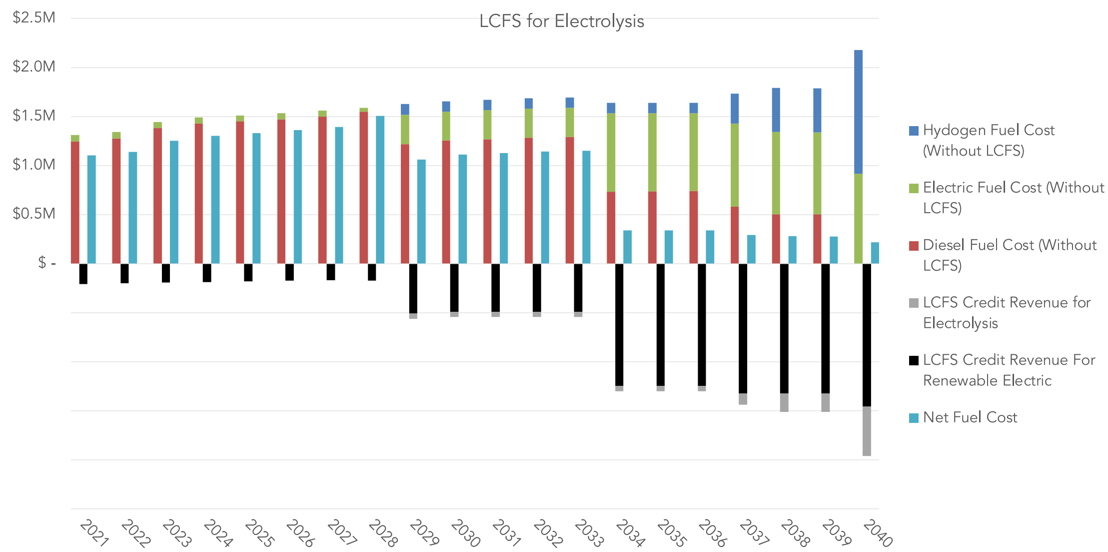


Figure 38 - Potential LCFS Credit Revenue for 100% Renewable Electrolysis H2, Mixed Fleet

The third pathway, dairy gas SMR, has a negative carbon intensity and generates the most LCFS credits of any of the pathways explored including electricity.

Table 17 - LCFS Credit Revenue Estimates by Year for Dairy Gas SMR Hydrogen, Mixed Fleet

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	26	26
No. of FCEBs in Fleet	0	0	0	0	0	0	0	0	5	5
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value per FCEB – Dairy Gas	$42K	$41K	$40K	$39K	$38K	$37K	$36K	$35K	$34K	$33K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$662K	$640K

*Calculated using analysis from SREC Trade.

In **Figure 39**, LCFS credit revenues from electric hydrolysis and dairy gas SMR are sufficient to cover net fuel costs by 2034.

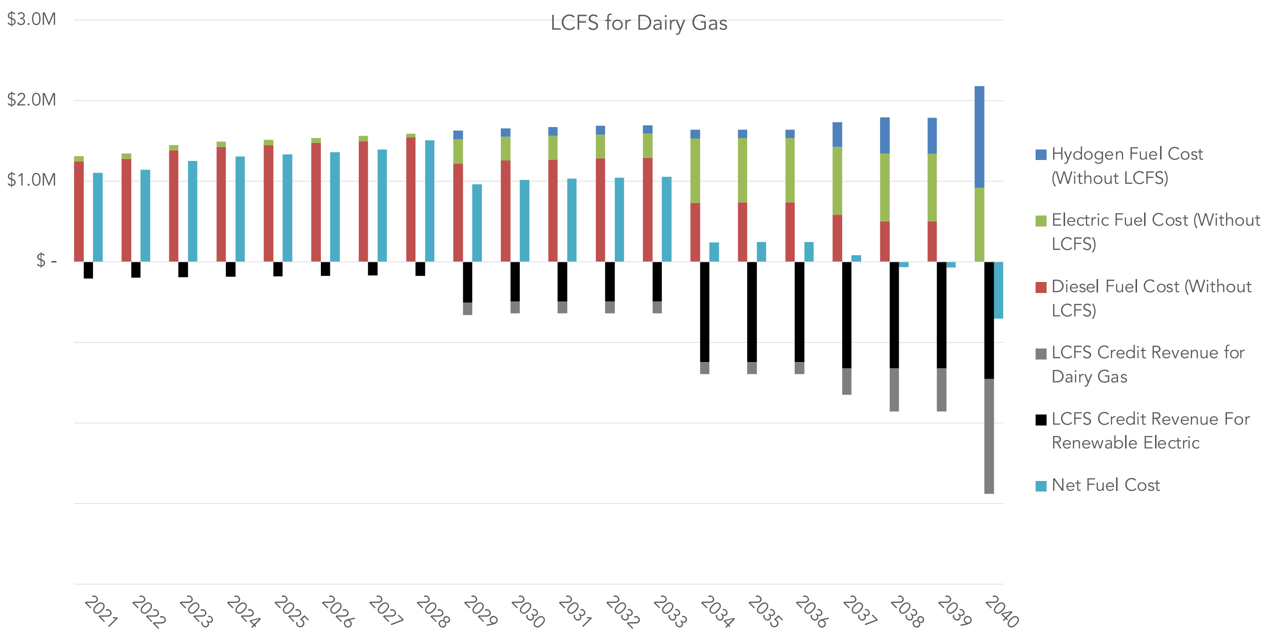


Figure 39 - Potential LCFS Credit Revenue for Dairy Gas SMR Hydrogen, Mixed Fleet

FCEB Only

Fuel cell electric buses are able to complete all of County Connection's blocks by the end of the transition period in 2040. **Figure 40** depicts fuel consumption for each fuel type over the transition period for the FCEB Only scenario. Legacy fuels are phased out as hydrogen consumption increases, reflecting an increasing number of FCEBs in the fleet. Fleet energy use is reduced by one-third, from about 0.6 million DGE in 2021 to just under 0.4 million DGE in 2040.

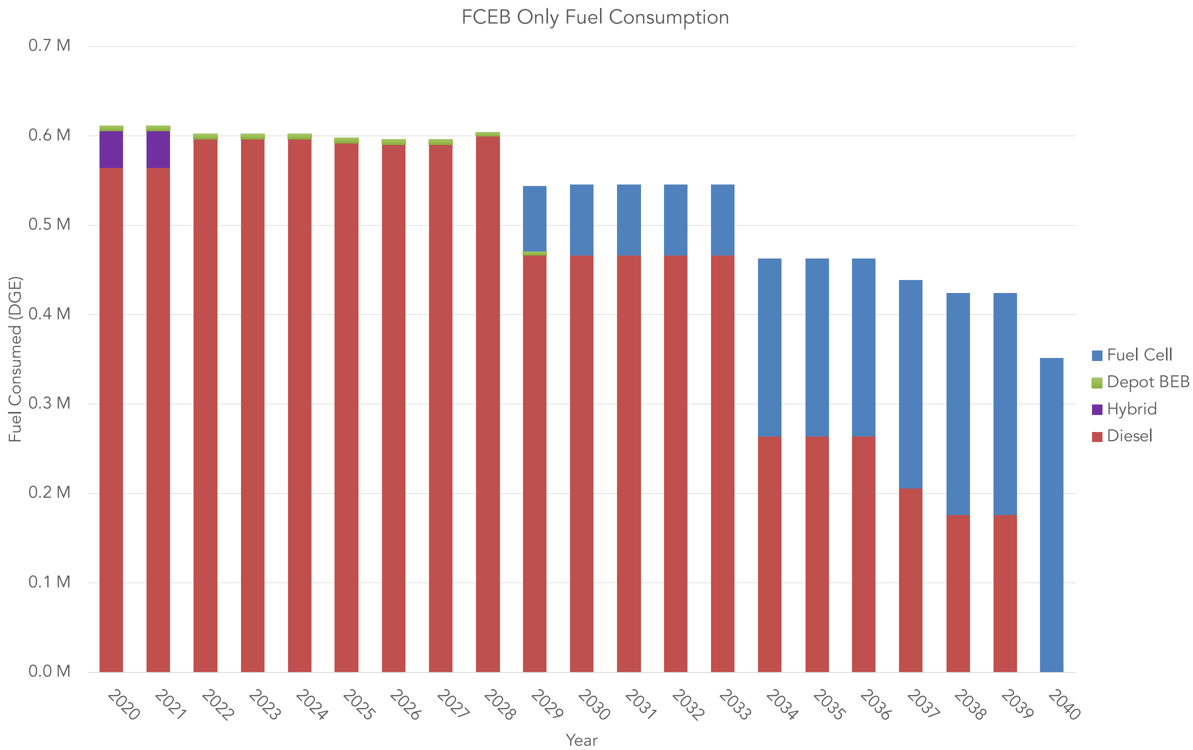


Figure 40 - Annual Fuel Consumption, FCEB Only

Figure 41 shows estimated annual costs for each fuel type based on the quantities consumed, as shown in **Figure 40**. Total estimated fuel costs, entirely from hydrogen fuel, in 2040 are approximately $3.4 million. As in the Mixed Fleet scenario, the fuel costs increase over the transition period while the DGE consumption decreases. These trends reflect hydrogen's greater efficiency but also its higher costs compared to diesel fuel.

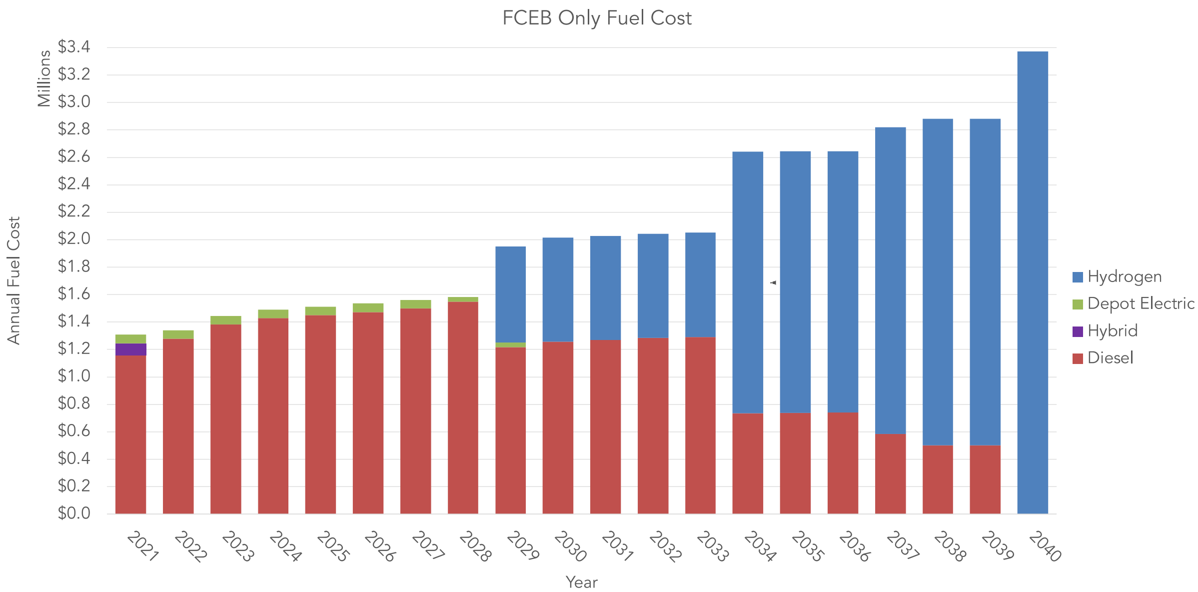


Figure 41 – Annual Fuel Costs, FCEB Only

The LCFS credit revenue in this scenario also depends largely on the method of hydrogen production for the fuel that County Connection purchases. Fossil fuel SMR generates the least LCFS credits, and dairy gas SMR generates the most. For the FCEB Only Scenario, LCFS credit values for all three hydrogen pathways were again reviewed. With fossil fuel SMR, slight credit revenues are generated from 2021 to 2026. The value per FCEB drops to $0 in 2027. The tables below illustrate the LFCS credit value and revenue generation potential through 2030, which is the date of the current program sunset.

Table 18 - LCFS Credit Revenue Estimates by Year for Fossil Fuel SMR Hydrogen, FCEB Only

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	4	0
No. of FCEBs in Fleet	0	0	0	0	0	0	0	0	27	31
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value* per FCEB - SMR	$1.4K	$1.1K	$900	$650	$400	$200	$0	$0	$0	$0
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$78K	$ -

*Calculated using analysis from SREC Trade.

In **Figure 42**, the LCFS credit revenues are marginal from years 2021-2029.

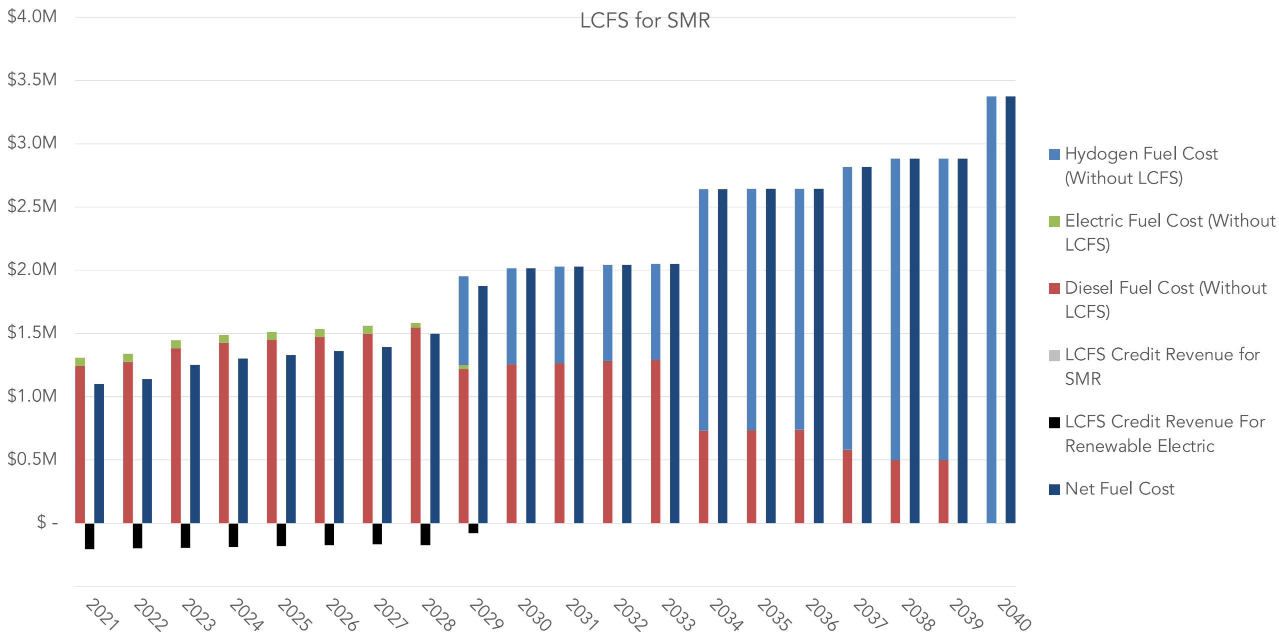


Figure 42 - Potential LCFS Credit Revenue for Fossil Fuel SMR Hydrogen, FCEB Only

In **Table 19**, the LCFS credit revenues range from $12,000 to $16,000 from 2021 to 2030.

Table 19 – LCFS Credit Revenue Estimates by Year for 100% Renewable Electrolysis Hydrogen, FCEB Only

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
No. of BEBs in Fleet	8	8	8	8	8	8	8	4	4	0
No. of FCEBs in Fleet	0	0	0	0	0	0	0	0	27	31
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value* per FCEB - Electrolysis	$16K	$16K	$15K	$14K	$14K	$13K	$13K	$13K	$12K	$12K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$372K	$325K

*Calculated using analysis from SREC Trade.

In the electrolysis hydrogen pathway, enough credit revenue is generated to offset the annual fuel expense by about one-third by year 2040, as shown in **Figure 43**.

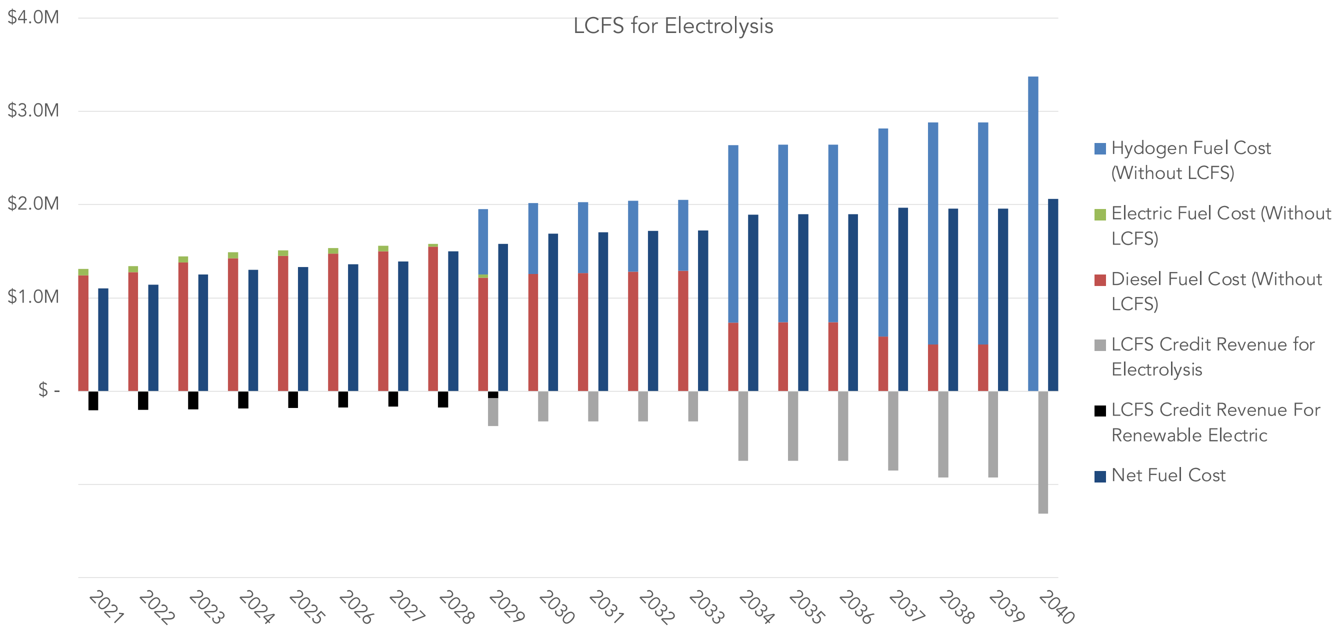


Figure 43 - Potential LCFS Credit Revenue for 100% Renewable Electrolysis H2, FCEB Only

In the FCEB Only scenario for the Dairy Gas SMR pathway, more LCFS credit revenues are earned compared to electric. This final option generates the most LCFS credit revenues, with a peak value of $921,000 in year 2030 as shown in **Table 20.**

Table 20 - LCFS Credit Revenue Estimates by Year for Dairy Gas SMR Hydrogen, FCEB Only

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Number of BEBs in Fleet	8	8	8	8	8	8	8	4	4	0
Number of FCEBs in Fleet	0	0	0	0	0	0	0	0	27	31
LCFS Credit Gross Value* per BEB	$29K	$28K	$27K	$26K	$25K	$24K	$23K	$23K	$22K	$21K
LCFS Credit Gross Value* per FCEB – Dairy Gas	$42K	$41K	$40K	$39K	$38K	$37K	$36K	$35K	$34K	$33K
Credit Processing Fee	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
County Connection LCFS Credit Revenue	$207K	$200K	$193K	$187K	$180K	$174K	$168K	$81K	$902K	$921K

*Calculated using analysis from SRECTrade.

Figure 44 serves to illustrate that while hydrogen fuel is more costly than electricity, LCFS credit revenue generated from the FCEB Only scenario for the dairy gas SMR pathway may still able to completely offset annual fuel expenses by year 2034.

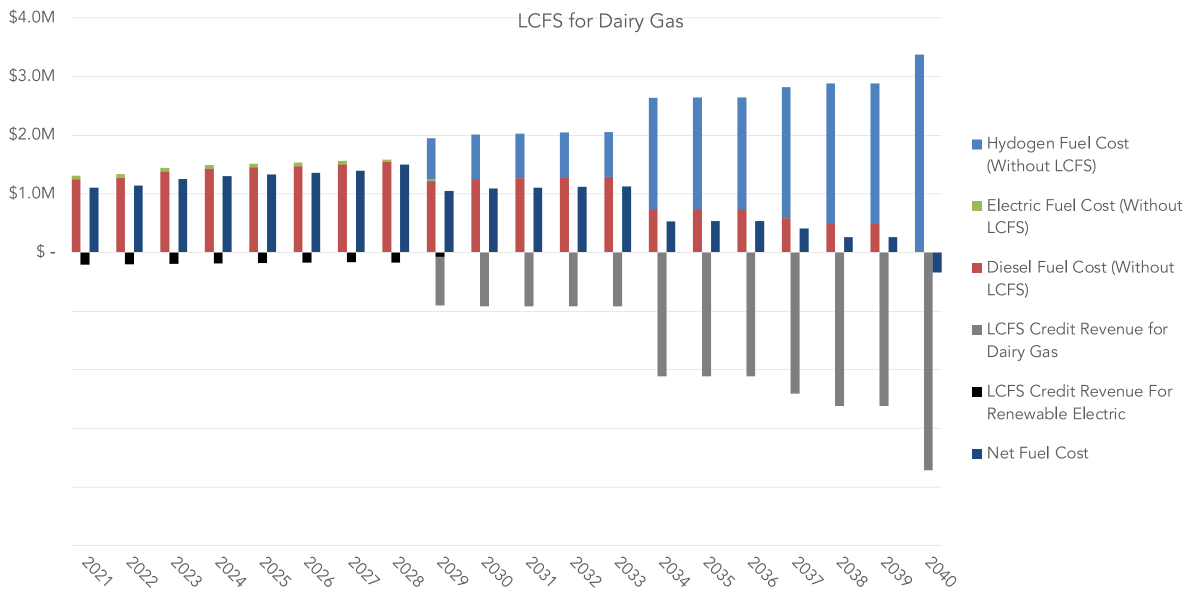


Figure 44 - Potential LCFS Credit Revenue for Dairy Gas SMR Hydrogen, FCEB Only Scenario

Fuel Assessment Cost Comparison

The Fuel Assessment includes all fuel costs over the transition for each scenario. **Table 21** shows the combined total costs based on a sensitivity analysis. There is no upper bound cost for the baseline scenario because the cost per mile for diesel in County Connection's current fleet is normalized throughout the analysis period. For electricity and hydrogen, the projected costs per mile are more variable. Hydrogen is the most expensive fuel in the near-term because of its high cost of production. Future technology and policy advancements may reduce the production cost for hydrogen and the resulting price. Therefore, a lower bound estimate is shown to reflect the potential decrease in hydrogen in the future. In reverse, electricity prices are likely to rise in the future in California, which is predominantly served by PG&E. County Connection receives electricity from PG&E and will be affected by increases in electricity costs should PG&E decide to bundle costs to upgrade their infrastructure with end user pricing. Therefore, a projected upper bound estimate is shown for the BEB scenarios to reflect the potential increase in electricity cost in the future.

Table 21 - Total Fuel Costs Over Entire Transition Period, Fuel Assessment

Scenario	Lower Bound	Upper Bound
0. Baseline (current technology)	$32,787,000	
1. BEB Depot-Only (with Diesels)	$31,015,000*	$35,483,000**
2. BEB Depot-Only Charging + Fleet Expansion	$30,716,000*	$36,763,000**
3. BEB Depot and On-Route	$31,621,000*	$34,866,000**
4. Mixed Fleet: BEB Depot-Only & FCEB with Electricity Sensitivity	$32,522,000*	$36,990,000**
4. Mixed Fleet: BEB Depot-Only & FCEB with Hydrogen Sensitivity	$31,490,000**	$32,522,000*
5. FCEB Only	35,966,000**	$41,749,000*

*Near term
**Projected future costs

Maintenance Assessment

The Maintenance Assessment examines the changes to fleet maintenance costs for each fleet composition scenario over the transition period. The different vehicle technologies incur differing labor and parts costs for maintenance and warranty terms that can impact the overall maintenance costs for a fleet. Most manufacturers offer six-year warranties on their batteries with an option to extend to 12 years.[10]

ZEBs offer the opportunity to lower some maintenance costs while others may increase. Similar to diesel buses, the amount of maintenance required for ZEBs are highly dependent on the size and complexity of each vehicle and the local conditions and operating profile of each transit agency. While early adopters of ZEB technologies have reported that a transit agency may save 30% in maintenance cost per mile after transitioning from a diesel vehicle to a BEB[11], County Connection has experienced several issues with their early pilot model BEBs and have not observed such a significant reduction. Of note, County Connection has had to replace multiple battery strings. Given maintenance costs reported by transit agencies are variable and have a wide range, CTE applied County Connection's actual costs based on their historical fleet data.

Cost Assumptions

CTE's maintenance cost assessment includes labor, materials, and midlife overhaul costs. This assessment applied unit maintenance cost per mile by vehicle type with total costs based on average annual vehicle mileage as reported by County Connection. Total costs are based on the following assumptions:

- Maintenance costs for diesel buses and BEBs are based on data from County Connection's current fleet.
    - It is important to keep in mind that maintenance costs are hard to predict. Compared to conventional diesel and gasoline fueled vehicles, BEBs have different maintenance needs that vary based on manufacturer and operating environment. In addition, some equipment for BEBs is covered by warranty so costs in the first few years for maintenance are significantly lower than in the latter half of their service lives. County Connection provided current cost data on maintaining early model BEBs to inform this assessment. Long-term maintenance costs are still to be determined and should be carefully considered as County Connection implements their transition plan.
- Hydrogen maintenance costs were based on OCTA's reported labor and maintenance costs.

[10] Blanco, Sebastian. April 18, 2019. "Proterra Ready For Electric Bus Battery Leasing With $200- Million Credit Facility. Forbes. www.forbes.com/sites/sebastianblanco/2019/04/18/proterraready-for-electric-bus-battery-leasing-with-200-million-credit-facility/#3b81b5b52314

[11] Eudy, Leslie and Matthew Jeffers. 2019. Foothill Transit Agency Battery Electric Bus Progress Report: Data Period Focus: Jul.2018 through Dec. 2018. Golden, CO: National Renewable Energy Laboratory. NREL/PR-5400-72209. https://afdc.energy.gov/files/u/publication/foothill_transit_beb_progress_rpt_5-2019.pdf

- This FCEB maintenance per mile value is based on the costs for the first year of service at OCTA. Therefore, this cost is likely high and will eventually trend downward since this is a first-generation vehicle. Long-term FCEB maintenance costs for US manufactured buses are still to be determined and should be carefully considered as County Connection implements their transition plan.

Table 22 is a summary of the estimated combined costs for scheduled and unscheduled labor and maintenance for each type of bus explored in this study.

Table 22 – Labor and Materials Cost Assumptions

Type	Estimate (Per Mile)	Source
30’, 35’, 40’ Diesel	$ 0.43	County Connection
30’, 35’, 40’ BEB	$ 0.45	County Connection
30’, 35’, 40’ FCEB	$ 0.59	OCTA

This assessment also estimates the cost impact of midlife overhauls for major components in each type of bus, as summarized in **Table 23.** In a midlife overhaul, technicians look for signs of corrosion and install more durable parts. The costs in **Table 23** are the starting values for midlife overhaul costs. The estimated 1.5% inflation rate per year for parts and a 3% inflation rate for labor based on PPI and standard labor inflation rates are taken into account in the assessment.

Table 23 - Midlife Overhaul Cost Assumptions

Type	Overhaul Scope	Estimate	Source
Diesel	Engine/Transmission Overhaul	$50k per bus	County Connection
BEB	Extended Warranty Cost	$75k per bus	Bus OEM experience
FCEB	Battery Replacement Warranty	$17k per bus	Prorated from BEB extended battery warrant price incurred in year of purchase estimate
	Fuel Cell Overhaul	$40k per bus	Fuel Cell Provider

Baseline

The 12-year replacement cycle creates a cyclical pattern in maintenance costs every six years due to midlife overhauls. As a result, expected maintenance costs spike every six years after a large number of buses are purchased, such as in 2022 and in 2034. Since this scenario represents a fleet that stays entirely composed of diesel buses, the peaks consistently repeat every 12 years at the midlife of large purchases. In non-midlife and replacement years, the average annual maintenance cost is approximately $1.3 million.

Figure 45 shows the combined labor, materials, and midlife overhaul costs for the Baseline scenario for each year of the transition.

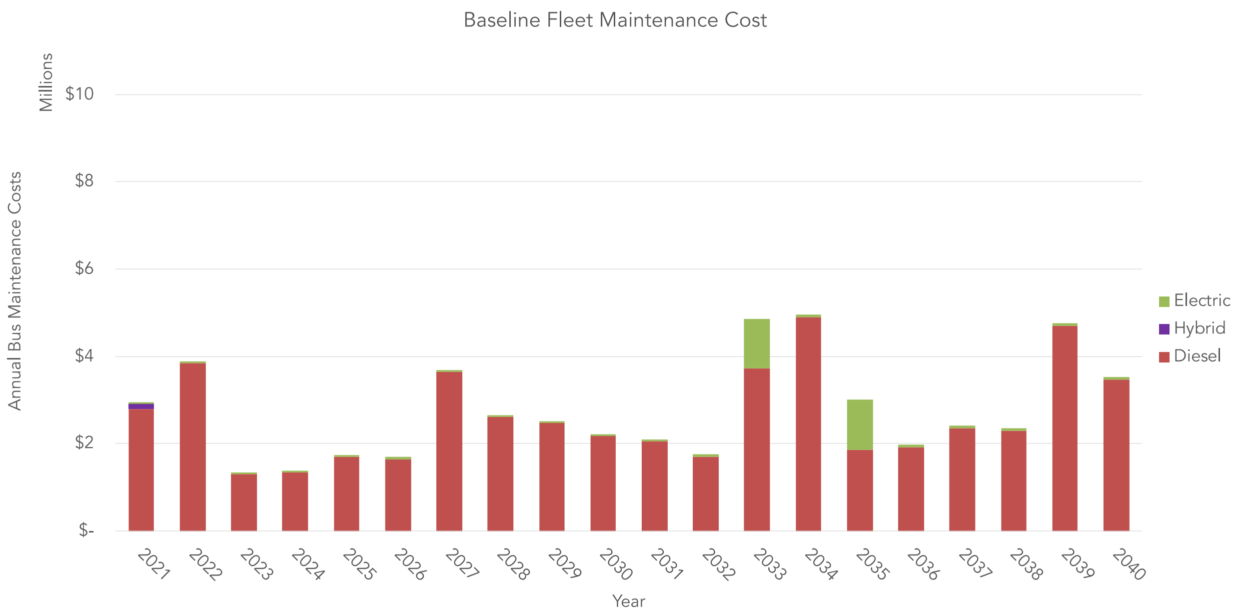


Figure 45 - Annual Fleet Maintenance Costs, Baseline

BEB Depot-Only

Figure 46 shows the combined labor, materials, and midlife overhaul costs for the BEB Only scenario for each year of the transition. For the BEB Depot-Only scenario, the cost of the battery warranty is used to reflect the midlife battery replacement. In the assessment, these warranty costs are incurred at the time of the bus purchase. The spikes in expected maintenance costs for this scenario therefore occur in the same years that large bus procurements take place, such as in 2029 and 2024. In this scenario, the 12-year replacement cycle shifts the cyclical pattern in maintenance costs from non-purchasing years to purchasing years because of the warranty costs incurred during procurements.

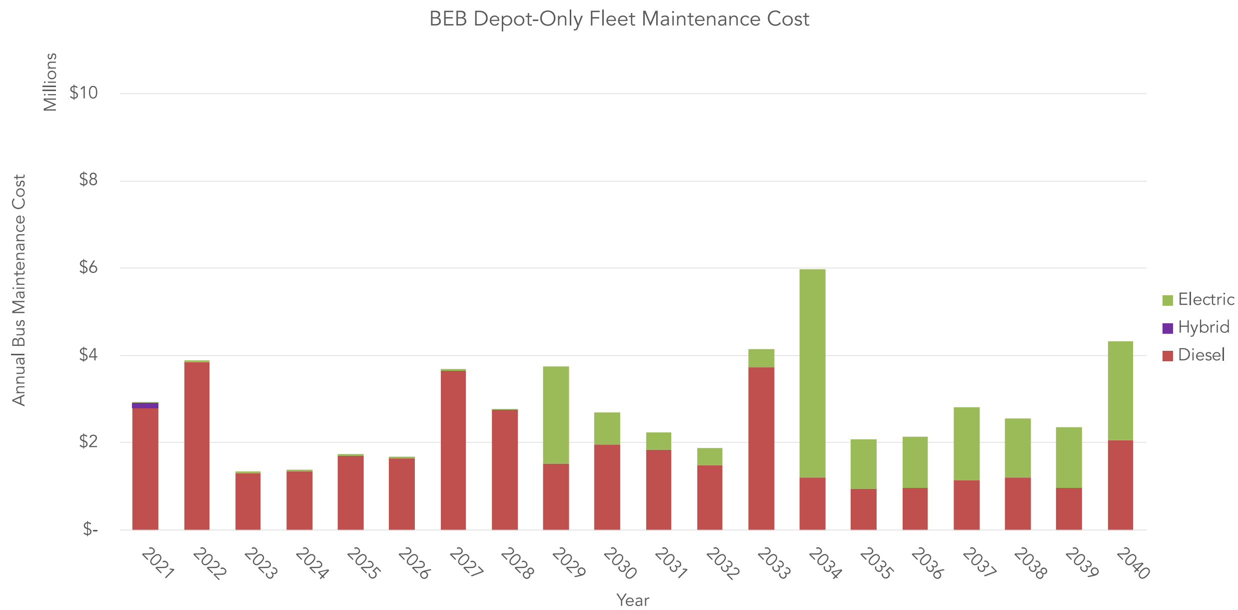


Figure 46 - Annual Fleet Maintenance Costs, BEB Depot-Only

BEB Depot-Only + Fleet Expansion

Figure 47 shows the combined labor, materials, and midlife overhaul costs for the BEB Depot + Fleet Expansion scenario for each year of the transition. Similar to the above scenario, anticipated midlife battery replacements for BEBs are covered in warranty in the year of purchase or in the first service year. As with the BEB Depot Only scenario, the years that show the highest maintenance costs correlate with BEB procurement years. In this scenario, the largest procurement of BEBs, 67 in total, is expected to take place in 2040. As such, year 2040 also incurs these warranty costs. As expected with an increased number of vehicles in the fleet, the maintenance costs are proportionally higher.

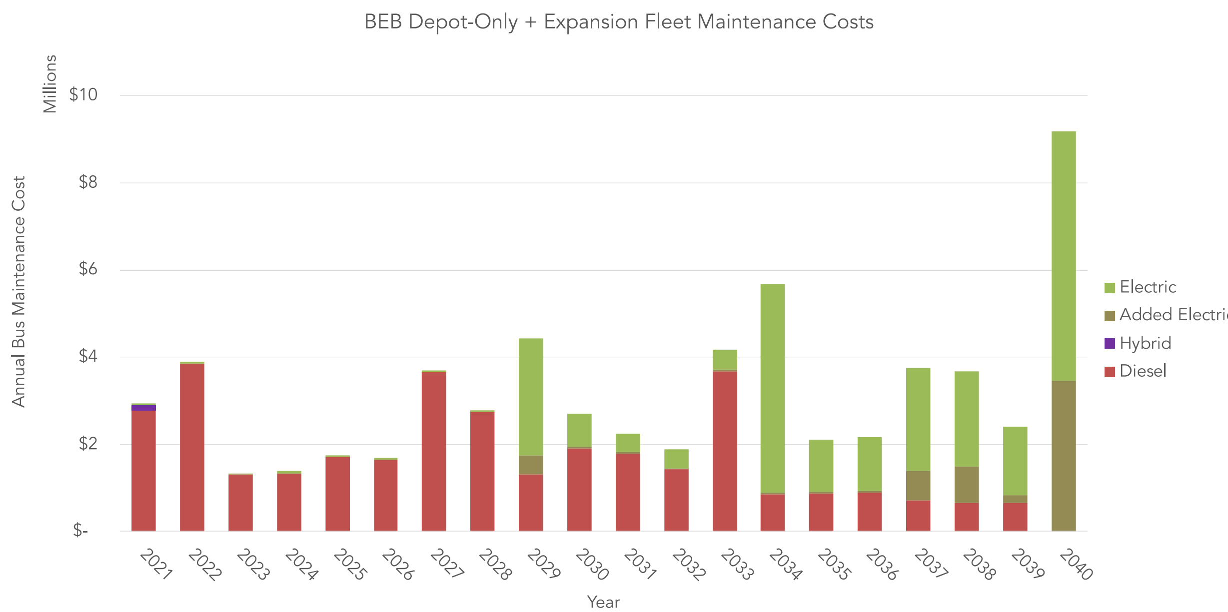


Figure 47 - Annual Fleet Maintenance Costs, BEB Depot-Only + Fleet Expansion

BEB Depot-Only and On-Route

Figure 48 shows the combined labor, materials, and midlife overhaul costs for the BEB Depot + Fleet Expansion scenario for each year of the transition. The maintenance cost is higher in 2040 because the extended battery warranty cost is incurred in the year of purchase.

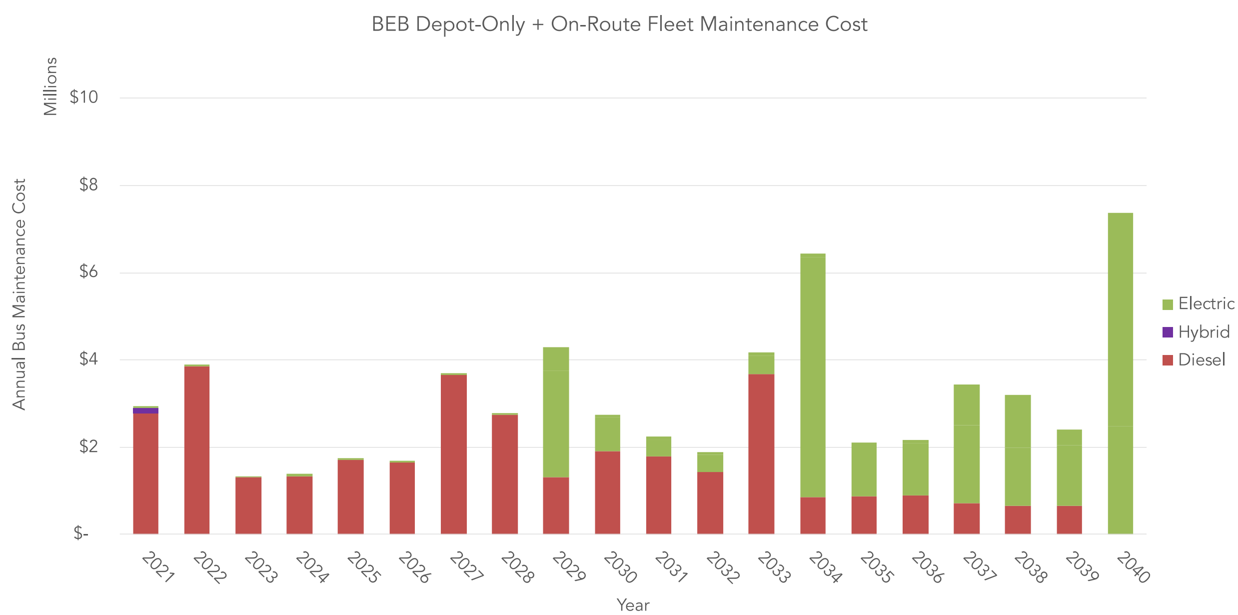


Figure 48 - Annual Fleet Maintenance Costs, BEB Depot + On-Route

Mixed Fleet: BEB and FCEB

Figure 49 shows the combined labor, materials, and midlife overhaul costs for the Mixed Fleet: BEB and FCEB scenario for each year of the transition. This scenario incurs the largest maintenance costs in 2034 due to a large procurement of BEBs and related extended battery warranties. FCEBs have a smaller extended battery warranty cost—$17,000 as opposed to $75,000 for BEBs—because FCEBs have a significantly smaller battery on board, while also incurring a mid-life fuel cell overhaul cost of $40,000. The FCEB battery warranty cost is also applied in the vehicle purchase year, as shown in 2040.

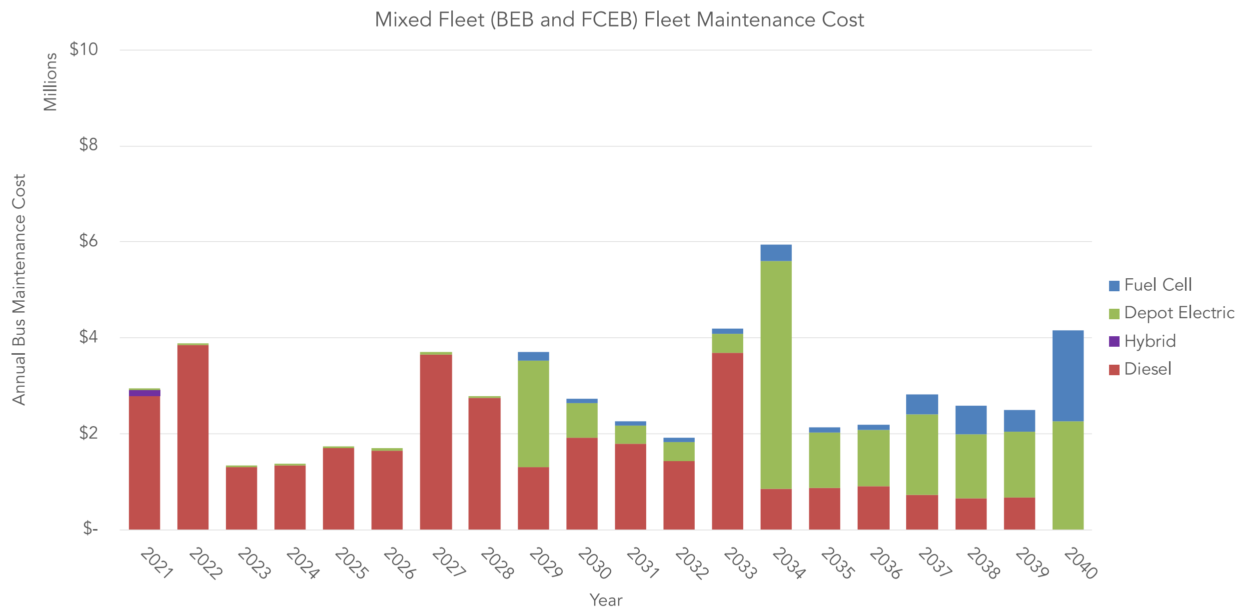


Figure 49 -Annual Fleet Maintenance Costs, Mixed Fleet

FCEB Only

Figure 50 shows the combined labor, materials and midlife overhaul costs for the FCEB Only scenario for each year of the transition. Maintenance costs for fuel cells were calculated using industry-reported maintenance costs per mile and maintenance costs reported by OCTA. The estimated cost for one fuel cell overhaul ($40,000) was based on the average cost for this activity as reported by bus and fuel cell manufacturers. The 12-year extended battery warranty price of $17,000 (prorated from the BEB extended battery warranty price) is also included in this analysis. Because the warranty is paid for at the same time the bus is procured, maintenance costs spike in years 2034 and 2040 because of the purchase of 40 and 37 FCEBs, respectively. The spike in 2039 is the result of mid-life fuel cell replacement.

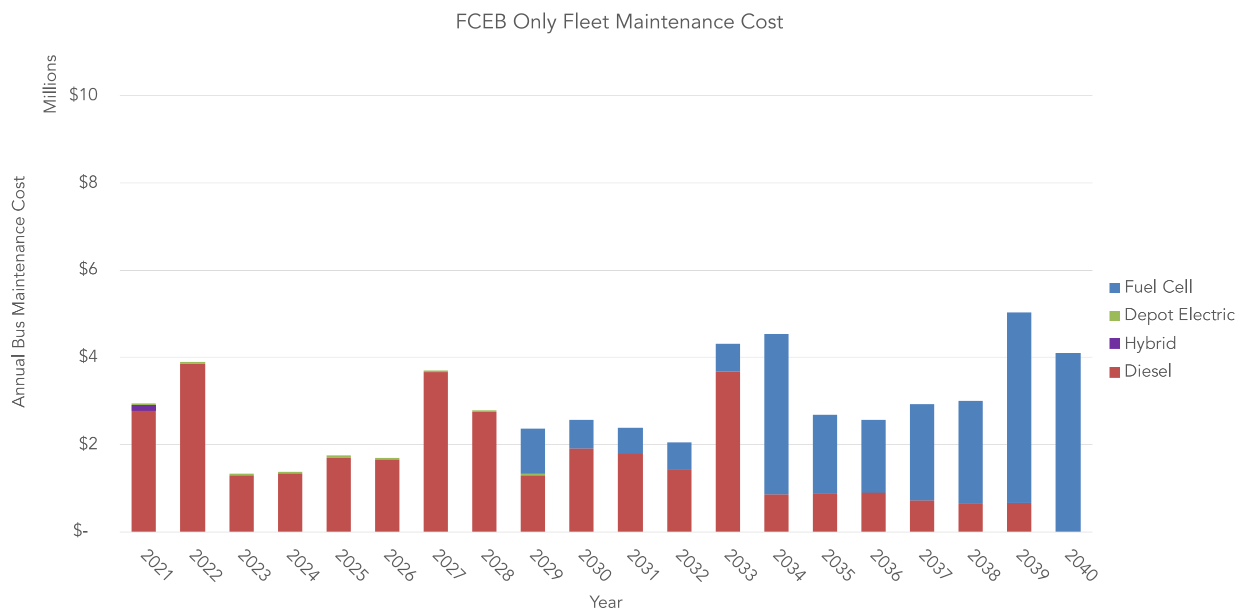


Figure 50 -Annual Maintenance Costs, FCEB Only

Maintenance Assessment Cost Comparison

Figure 51 shows the cumulative maintenance costs for each scenario.

Table 24 shows the total maintenance costs for each scenario at the end of the 20-year transition period. The total maintenance cost for the BEB Depot Only + Fleet Expansion scenario is shown to be the costliest because of its greater total number of buses and its sensitivity to the cost per mile. Overall, the zero-emission scenarios' maintenance costs are comparable with the Baseline scenario, all of which are within $1 million to $8 million of the other.

Despite BEBs having a higher price for battery warranty at $75,000 as compared to the price of a mid-life fuel cell replacement and extended battery warranty for a FCEB ($57,000 in total), savings in warranty for the FCEB scenarios are largely offset by the FCEB's higher maintenance cost per mile of $0.59.

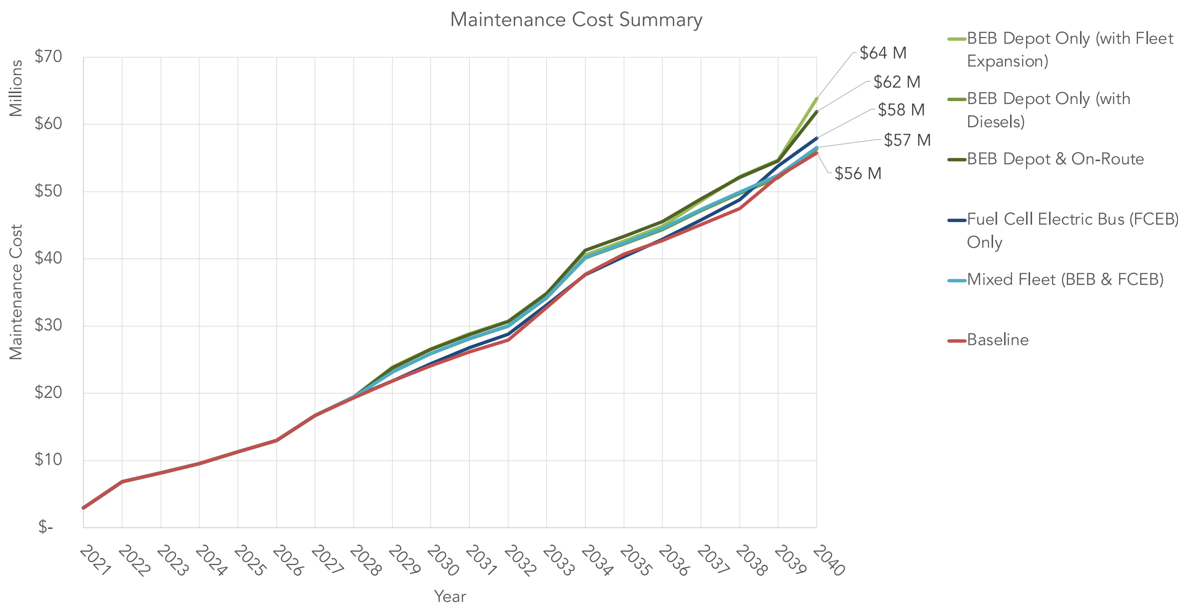


Figure 51- Total Costs, Maintenance Assessment

Table 24- Total Costs, Maintenance Assessments

Scenario	Cost	% ZEB
0. Baseline (Current Technology)	$56M	0%
1. BEB Depot-Only (With Diesels)	$56M	61%
2. BEB Depot + Fleet Expansion	$64M	100%
3. BEB Depot + On Route	$62M	100%
4. Mixed Fleet: BEB and FCEB	$57M	100%
5. FCEB Only	$58M	100%

Facilities Assessment

The Facilities Assessment determines the scale of fueling infrastructure (charging stations for BEBs and hydrogen fueling stations for FCEBs) that is needed to meet the projected energy use for each scenario. It is informed by the Fleet and Fuel Assessments. Facility costs are estimated based on the assessed infrastructure requirements for the given fleet and the selected fueling technology. The information in this section is organized according to the fueling technology explored in this transition plan: depot-charging; on-route charging; and hydrogen storage and fueling station. A diesel fueling strategy is not included in this assessment because the Baseline scenario assumes that County Connection already has the facilities necessary to support their diesel fleet.

Depot-Charging Infrastructure

Scaling to a fleetwide BEB deployment requires a significantly different approach to charging and substantial infrastructure upgrades compared to smaller pilot deployments. With small BEB pilot deployments, charging requirements are met relatively easily with a handful of plug-in pedestal chargers and minimal infrastructure investment. For fleetwide BEB transitions, plug-in charging is impractical because charger dispenser cables can create hazards in the bus yard. Instead, the preferred approach is to use overhead pantograph or mounted-reel dispensers attached to gantries installed above bus parking lanes.

In addition to the installation of charging stations, improvements to existing electrical infrastructure, such as upgrades to switchgear or service connections, are required to support the deployment of BEBs. Planning and design work including development of detailed electrical and construction drawings required for permitting is necessary once specific charging equipment has been selected. To define the installation timeline and costs for charging equipment for each scenario, the scope of work is broken into four key project types:

These projects are typically sized and scheduled to meet near-term charging requirements rather than immediately building out all necessary infrastructure for a full fleet transition.

The following key assumptions were applied in County Connection's Facilities Assessment for BEB deployments:

- Gantry structures are used at each depot;
- One plug-in reel or overhead pantograph per bus;
- Two buses per 120 kW charger;
- Two charge windows;
- Off-peak, overnight charging with automated charge management software; and
- Dispenser capacity to serve up to 80% of the fleet at a time; no movement of buses overnight.

BEB Depot-Only Charging Infrastructure Projects

1. Planning | 2. Structural | 3. Power Upgrades | 4. Charger Installation

Infrastructure Planning Project

Charging infrastructure for a large BEB fleet has significant power and space requirements. Large-scale fleets may require bus depot redesigns to accommodate the additional equipment. Planning is an essential step in understanding the best solutions to keep electricity costs down while meeting service requirements. Each planning project is estimated to cost $200,000 per depot per ZEB technology. The estimated planning cost for the infrastructure transition at the Concord depot is $200,000, which is scheduled to occur in 2028.

1. Planning | **2. Structural** | 3. Power Upgrades | 4. Charger Installation

Structural Projects

Structural projects include (1) trenching and the build out of duct banks from the switchgear to the charger pads, (2) the construction of charger pads (i.e., foundation for charging equipment), (3) the construction of gantry foundations and overhead gantry structures that hold the dispensers, and (4) installation of conduit from switchgear to charger pads and gantries. **Table 25** shows the detailed cost assumptions for structural projects. These cost assumptions also apply to other projection scenarios. Duct bank cost is incurred only once per depot, other costs are on a per gantry basis.

Table 25 – Structural Project Cost Assumptions

Item	Cost	Unit
Initial Duct/Bank	$ 300,000	per depot
Gantry & Foundation	$ 450,000	per gantry
Incremental Duct Bank/Conduit	$ 22,000	per gantry
Charger Pad (3 chargers per gantry)	$ 25,000	per gantry
Contingency	20%	on project costs
Design Engineering	7%	on project costs and contingency

1. Planning | 2. Structural | 3. Power Upgrades | 4. Charger Installation

Power Upgrade Projects

Power upgrade projects include construction of transformer foundations and installation of transformers. It is assumed that transformers will be modular and that incremental power requirements are met over time. The total estimated power upgrade costs over the project life are approximately $420,000. **Table 26** shows the estimated costs for depot power upgrade projects.

Table 26 - Depot Power Upgrade Cost Assumptions, BEB Only Scenario

Transformer/Switchback Pad	Cost	Unit
Transformer	Covered by PG&E	
Trench and Duct bank	$ 30,000	per project
Construction, Equipment (1 MW)	$ 200,000	per project
Construction, Equipment (2 MW)	$ 300,000	per project
Construction, Equipment (3 MW)	$ 350,000	per project
Construction, Equipment (4 MW)	$ 375,000	per project
Construction, Equipment (5 MW)	$ 400,000	per project
Contingency	20%	on project costs
Design Engineering	7%	on project costs and contingency

Power upgrades are consolidated to occur in selected years, in accordance with the required demand in **Table 26.**

1. Planning | 2. Structural | 3. Power Upgrades | 4. Charger Installation

Charger Installation Projects

Charging projects include purchase and installation of 120 kW chargers. Every two buses (40-foot and larger) will require one charger. **Table 27** provides the costs assumed for charger installs. In total, 36 chargers are needed to accommodate the entire fleet of 77 BEBs. Should the BEB fleet grow, the ratio of buses to charger will be the same. For example, if all 125 buses were converted to BEBs, 63 chargers will be needed.

Table 27 - Charger Project Cost Assumptions

Item	Cost	Unit
Charger	$ 120,000	per 120 kW charger
Charger Installation	$ 12,000	per 120 kW charger
Contingency	20%	on project costs

BEB Depot Only Infrastructure Cost Summary

Figure 52 shows the cumulative total cost breakdown. The estimated total infrastructure costs for the BEB Only scenario is approximately $21 million. This total cost includes all gantry structural projects, all power upgrade projects, all charger and dispenser installations, all planning projects, design engineering costs and the added 20% contingency on all costs, as well as the design and equipment costs for charging infrastructure.

- **GANTRIES.** A total of 13 gantries will be needed at County Connection's Concord depot in this scenario, which will leave 48 diesel buses in the fleet that will not require gantries. Each gantry will be able to serve up to eight buses.
- **CHARGERS.** In total, this scenario would require 36 chargers (72 dispensers). Charging projects include purchase and installation of 120 kW chargers and dispensers.
- **MW SERVICE UPGRADE.** County Connection will need to add an estimated additional 5 MW of power to its system by 2040 to accommodate charging for 77 BEBs. Each entry in the figure below indicates the minimum amount of power that must be added in a given year to meet the growing demand at a given facility as more BEBs are purchased. To meet the growing demand of electricity, the Concord depot will need to upgrade its system to at least 2 MW of capacity by 2029 and to 3 MW of capacity by 2034.
- **CONTINGENCY.** A 20% contingency is added on all project costs.
- **DESIGN ENGINEERING.** 7% is added on all project costs and contingency.

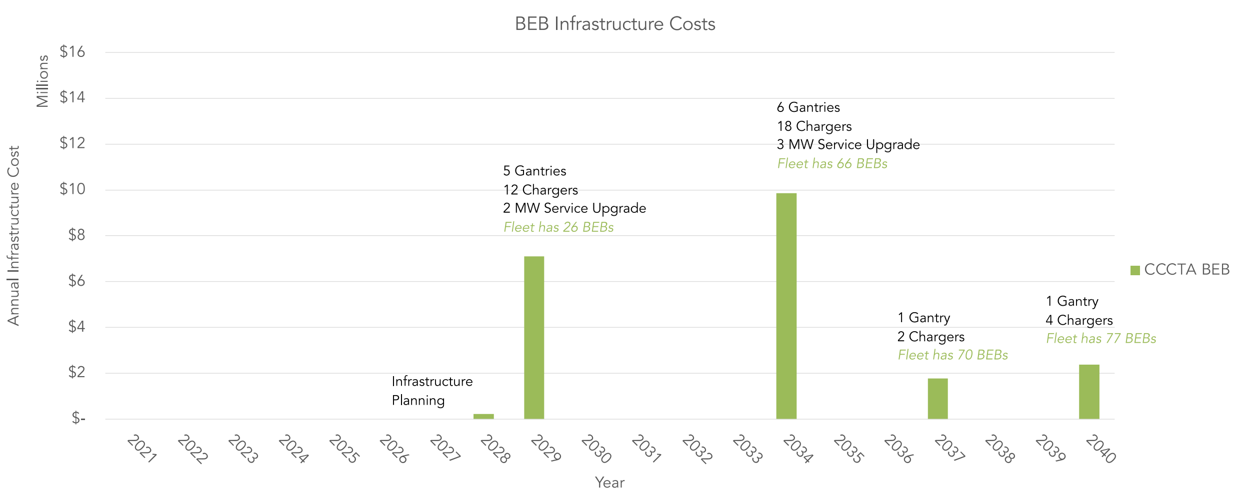


Figure 52 - Infrastructure Costs, BEB Only Scenario

BEB Depot + Fleet Expansion Infrastructure Cost Summary

Figure 53 shows the cumulative total cost breakdown. The estimated total infrastructure costs for the BEB Only with Fleet Expansion scenario is approximately $46 million. This total cost includes all gantry structural projects, all power upgrade projects, all charger and dispenser installations, all planning projects, design engineering costs and the added 20% contingency on all costs, as well as the design and equipment costs for charging infrastructure. This total cost does not include estimates for a new facility, land acquisition, or expansion of the existing facility in order to accommodate all 173 BEBs.

- **GANTRIES.** A total of 29 gantries will be needed at County Connection to support BEB charging during the transition period. Each gantry will be able to serve up to eight buses.
- **CHARGERS.** In total, this scenario would require 81 chargers (162 dispensers). Charging projects include purchase and installation of 120 kW chargers and dispensers. AECOM, the A&E firm contracted for this project, suggests 87 chargers for this scenario; however, AECOM did not expand on its analysis because the Concord depot cannot accommodate the total number of buses.
- **MW SERVICE UPGRADE.** County Connection will need to add an additional estimated 11 MW of power to its system by 2040 to accommodate charging for 173 BEBs. Each entry in the figure below indicates the minimum amount of power that must be added in a given year to meet the growing demand at a given facility as more BEBs are purchased.
- **CONTINGENCY.** A 20% contingency is added on all project costs.
- **DESIGN ENGINEERING.** 7% is added on all project costs and contingency.

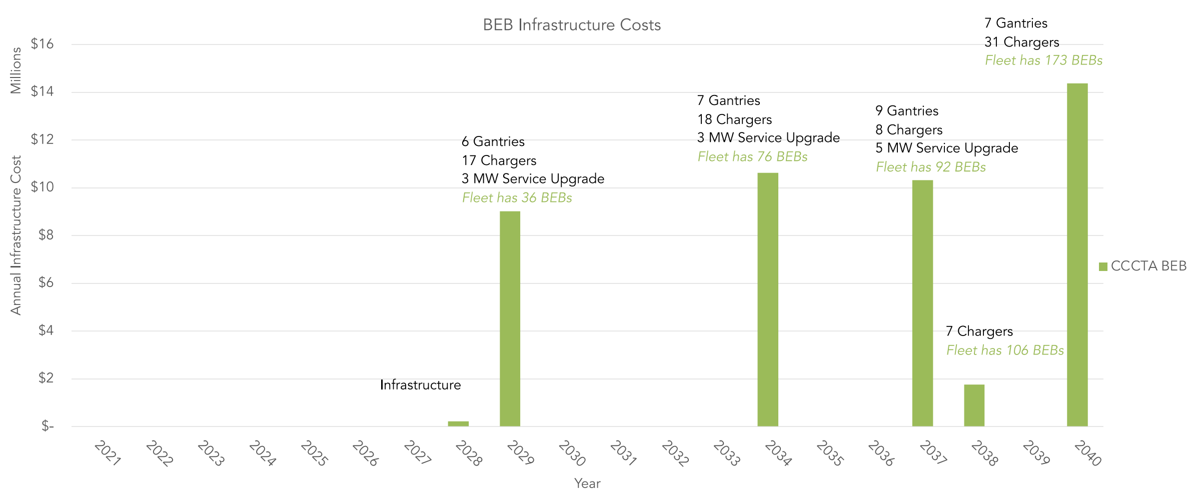


Figure 53 - Cumulative Total Infrastructure Costs, BEB Depot + Fleet Expansion

BEB Depot + On-Route Infrastructure Cost Summary

On-Route Charging Infrastructure

In addition to the depot charging infrastructure already developed and presented in the previous section, on-route charging will support 48 electric buses before 2040. In this section, the on-route infrastructure costs are summarized along with the depot infrastructure costs. In some circumstances, on-route chargers may not require additional support structures, such as gantries, to be built and may not require any structural project planning, as depot chargers do. On-route chargers will, however, require planning, power upgrades, and charger purchase and installation, which can be summarized as design costs and equipment costs. **Table 28** shows the cost assumptions used in the following sections to estimate costs for on-route charging infrastructure. This assessment did not include the costs of land acquisition for on-route charging sites and impacts to Right-of-Way (ROW).

Table 28 – On-Route Infrastructure Project Cost Assumptions

Project	Cost Estimate Metrics	Source
Structural Projects (Gantries, Conduit, duct banks, etc.)	Design/Construction: $30k per bus (avg.)	Engineer's estimate, includes 20% contingency
Power Upgrade Projects	Design, Construction, & Equip: $264k per MW	Engineer's estimate, includes 20% contingency
Charging Projects	Charging Equipment & Installation: $39k per bus	Quotes and estimates, includes 20% contingency

It is assumed that each on-route charging project will cost around $2.7 million per site. The number of on-route projects occurring in a given year is shown in **Figure 54**, below. A total of six on-route charging sites will be required to serve the additional 48 on-route-charged buses, which is expected to cost around $16.8 million. The East Dublin Pleasanton BART Station has been identified as a potential site for on-route stations. Site designs for the potential on-route station can be found in **Appendix A9**. An additional five locations would need to be selected by County Connection.

Figure 54 shows the cumulative total cost breakdown. The estimated total infrastructure costs for this scenario are approximately $49 million. This total cost includes all gantry structural projects, all power upgrade projects, all charger and dispenser installations, all planning projects, design engineering costs and the added 20% contingency on all costs, as well as the design and equipment costs for charging infrastructure.

- **Gantries.** A total of 21 gantries will be needed at County Connection to support BEB charging during the transition period. Each gantry can serve up to eight buses.
- **Chargers.** In total, this scenario would require 58 depot chargers (116 dispensers) and six on-route chargers. Charging projects include purchase and installation of 120 kW chargers and dispensers.
- **MW Service Upgrade.** County Connection will need to add an additional estimated 8 MW of power to its system by 2040 to accommodate charging for 125 BEBs. Each entry in the figure below indicates the minimum amount of power that must be added in a given year to meet the growing demand at a given facility as more BEBs are purchased.
- **Contingency.** A 20% contingency is added on all project costs.
- **Design Engineering.** 7% is added on all project costs and contingency.

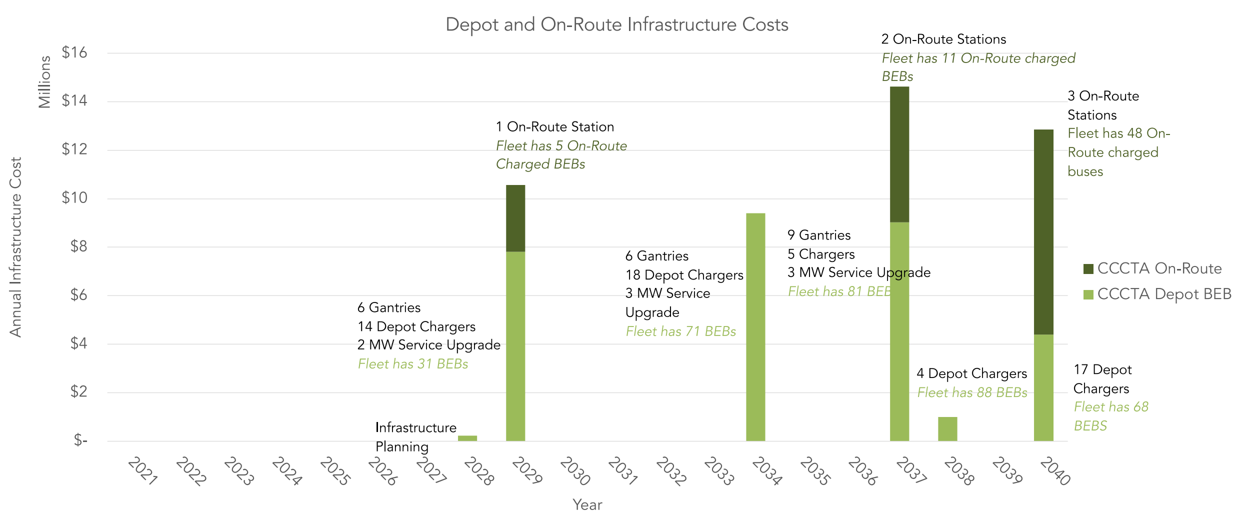


Figure 54 - Infrastructure Costs, BEB Depot + On-Route

Mixed Fleet: BEB and FCEB Scenario

In the Mixed Fleet: BEB and FCEB scenario, charging infrastructure is required to service a total of 77 BEBs and additional hydrogen fueling infrastructure for 48 FCEBs to support a completely zero-emission bus fleet by 2040. Because there are separate costs associated with each type of ZEB technology, the facilities assessment for this scenario is broken down by each bus type beginning with BEB.

BEB Cost Assumptions

Structural projects include (1) trenching and build out of duct banks from the switchgear to the charger pads, (2) construction of charger pads (i.e., foundation for charging equipment), (3) construction of gantry foundations and overhead gantry structures that hold the dispensers, and (4) installation of conduit from switchgear to charger pads and gantries. See **Table 29** for the detailed cost assumptions for structural projects. Duct bank costs are incurred only once per depot; other costs are on a per gantry basis.

Table 29 - Structural Project Cost Assumptions

Item	Cost	Unit
Initial Duct/Bank	$300K	per depot
Gantry & Foundation	$450K	per gantry
Incremental Duct Bank/Conduit	$22K	per gantry
Charger Pad (3 chargers per gantry)	$25K	per gantry
Contingency	20%	on project costs
Design Engineering	7%	on project costs and contingency

BEB Charging Infrastructure Cost Summary

The estimated total BEB infrastructure costs for the Mixed Fleet scenario are approximately $20 million (see **Figure 55**). The estimated infrastructure costs for the BEB technology & infrastructure includes the following costs:

- **Infrastructure Planning.** Each planning project is estimated to cost $200,000 per depot per ZEB technology. Planning for infrastructure at the Concord depot is estimated to cost $200,000 to be incurred in 2028.
- **Gantries.** A total of 13 gantries will be needed at County Connection to support BEB charging during the transition period. Each gantry can serve up to eight buses.
- **Chargers.** In total, this scenario would require 39 chargers (78 dispensers). Charging projects include purchase and installation of 120 kW chargers and dispensers. Every two buses (30-foot and larger) will require one charger with two dispensers. Dispensers are expected to be either overhead reel or pantograph style.
- **MW Service Upgrade.** County Connection will need to add an additional estimated 5 MW of power to its system by 2040 to accommodate charging for 77 BEBs. Each entry in the figure below indicates the minimum amount of power that must be added in a given year to meet the growing demand at a given facility as more BEBs are purchased.
- **Contingency.** A 20% contingency is added on all project costs.
- **Design Engineering.** 6% is added on all project costs and contingency.

Hydrogen Fueling Infrastructure

To define the timeline and costs to build hydrogen fueling infrastructure, for each scenario, CTE breaks the scope of work into four key project types: (1) Planning, (2) Structural, (3) Maintenance Bay Upgrades, and (4) Fueling. Rather than building out the infrastructure all at once, projects are sized and scheduled to meet near-term fueling requirements.

The cost estimates that Fiedler Group provided for FCEB infrastructure were integrated into CTE's Facilities Assessment and are summarized in **Table 30.** These estimates are based on the 50-bus increments employed by Fiedler Group.

Table 30 – FCEB Infrastructure Planning Assumptions

Project	Cost Estimate	Source
Infrastructure Planning	$200,000 per depot	Engineer's estimate
50-Bus Incremental Mechanical Equipment and Installation Package	Varies by facility; Includes design, permitting, and installation for two (2) dispensers; all mechanical process equipment; electrical utilities and switchgear. Excludes storage tanks.	Engineer's estimate, vendor quotes
Incremental Addition of 15,000 Liquid Hydrogen Tank	$300,000 per tank for installation	Engineer's estimate, vendor quotes
Maintenance Upgrades	Electrical, Lighting, Ventilation, and Gas Detection $200,00 to upgrade each of County Connection's maintenance bays	Engineer's estimate

Storage Capacity Projects include the incremental addition of one or more 15,000-gallon liquid hydrogen storage tanks. Tanks are sized at 15,000 gallons to accommodate one truckload of liquid hydrogen, or approximately 3,000 kilograms. Storage capacity projects are planned in conjunction with bus mechanical projects to reduce disruptions for construction projects. This practice is standard and has been successfully implemented at OCTA and AC Transit and was recommended by Fiedler Group to San Diego Metropolitan Transit System and Long Beach Transit. The required capacity of hydrogen storage at a given depot is sized to accommodate an approximately four-day supply of average daily fuel use.

Mixed Fleet FCEB Charging Infrastructure Cost Summary

In addition to BEB charging, hydrogen fueling is required to support the Mixed Fleet: BEB and FCEB scenario. Infrastructure is built out over time as necessary to support FCEB deployment. **Figure 55** shows the estimated infrastructure costs for the FCEB technology, which includes the following costs and reaches a sum of $10M:

- **Infrastructure Planning.** Building hydrogen infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 occurs only once per depot. The total cost of planning projects for County Connection's single depot is approximately $200,000.
- **Storage Capacity Projects.** The total cost for storage capacity projects at County Connection is approximately $300,000 over the transition period.
- **Maintenance Bay Upgrades.** Maintenance bay upgrades are required to make the bays compliant with hydrogen safety regulations. At County Connection, CTE integrated Fiedler Group's estimated cost for each bay upgrade at $200,000. This cost estimate stems from the requirement of additional ventilation systems and sensors necessary for hydrogen detection. These costs are estimates of the anticipated expenditure required to retrofit and upgrade a diesel maintenance bay for hydrogen gas detection. Retrofitting is more expensive than the incremental cost of adding hydrogen detection to a new facility. For 14 maintenance bay upgrade projects, the total estimated cost is $2.8 million to be incurred in 2029.
- **H2 Fueling Infrastructure.** When the permanent station is installed, CTE estimated the 50-bus incremental design cost at around $4.2 million. The Fiedler Group's estimate presents an upper bound cost of $5 million. The storage capacity incremental cost estimate is $300,000.
- **Mobile Fueler.** Fiedler Group recommends using a mobile fueler until the number of FCEBs meets or exceeds 11 buses. The infrastructure for a mobile fueler is expected to cost around $72,000 per year for eight years.
- **Contingency.** A 20% contingency is added on all project costs.

Design Engineering. 7% is added on all project costs and contingency.

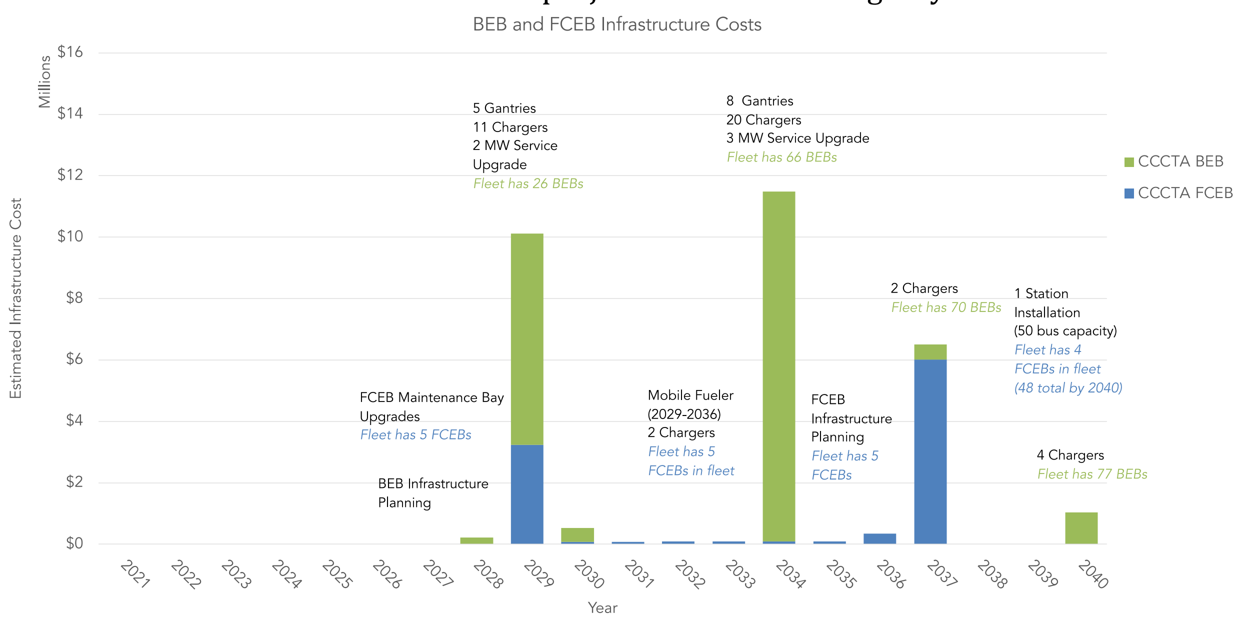
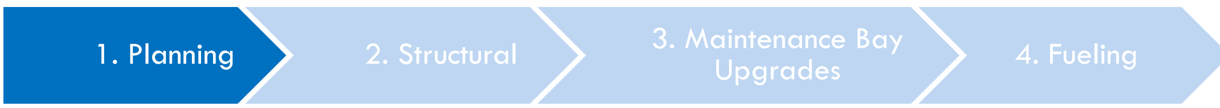


Figure 55– Infrastructure Costs, Mixed Fleet Charging Scenario

FCEB Only

The FCEB Only scenario assumes that FCEBs run on all of County Connection's routes by 2040. The Facilities Assessment for this scenario calculates the hydrogen infrastructure costs necessary to support the initial bus deployment. The initial deployment will put 27 buses into service in 2029 with the full deployment of 125 buses in 2040. The scope of work is broken into four key project types: (1) Planning, (2) Structural, (3) Maintenance Bay Upgrades, and (4) Fueling.



Infrastructure Planning Project

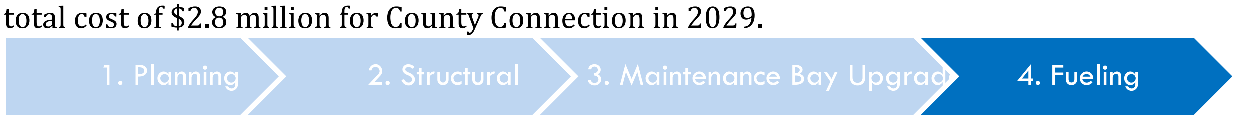
Building hydrogen infrastructure requires planning at each depot. It is assumed that each planning project will cost $200,000, occurring as shown in **Figure 56** and only once per depot. The total projected cost of planning for County Connection's project is $200,000.

H2 Fueling Infrastructure Project

The total cost for permanent hydrogen fueling infrastructure project is approximately $9.3 million over the transition period. The first project is scheduled in 2029, which will add the initial 100-bus capacity tank. Another 50-bus capacity tank installation is scheduled in 2040 to support the entire fleet of 125 FCEBs.

Maintenance Bay Upgrade Projects

Maintenance bays at each depot will require hydrogen detection and exhaust equipment to ensure safety. A total of 14 maintenance bays will require upgrades. CTE assumes about $200,000 per bay for the required upgrades. This cost comes from the requirement of additional ventilation systems. For maintenance bay upgrade projects, CTE estimates a total cost of $2.8 million for County Connection in 2029.



For hydrogen fueling equipment, it is economical to package projects in 50-bus increments with all necessary mechanical and fueling components included except for liquid hydrogen storage tanks. Storage tanks can be added in a modular fashion as demand increases, separately from other fueling components. The 50-bus mechanical projects include:

1. Two dispensers (additional dispensers may be added);

2. All mechanical process equipment and hydrogen wetted components;
3. Design, engineering, and permitting;
4. Construction;
5. Demolition of existing pavement, and excavation;
6. Installation of new equipment foundations;
7. All electrical conduit, conductors, and termination;
8. Emergency shut down and notification system;
9. Mechanical installation; and
10. Electrical utilities and switchgear.

FCEB Only Infrastructure Summary provides the total infrastructure costs for the FCEB Only scenario for the entire transition period. The total build of required FCEB infrastructure will require approximately $14 million for the FCEB Only scenario**.**

Table 31 - Total Costs, Infrastructure Costs

Project	Cost $	%
Inflation rate for the bus and charger equipment (1.5% per year per PPI index)	$1.6M	12%
Master Planning	$200K	1%
H2 Fueling Infrastructure Project	$9.3M	67%
Maintenance Bay & Gas Detection Upgrades	$2.8M	20%
Total	$13.9M	100%

Figure 56 shows a cumulative summary of infrastructure costs by year at the depot.

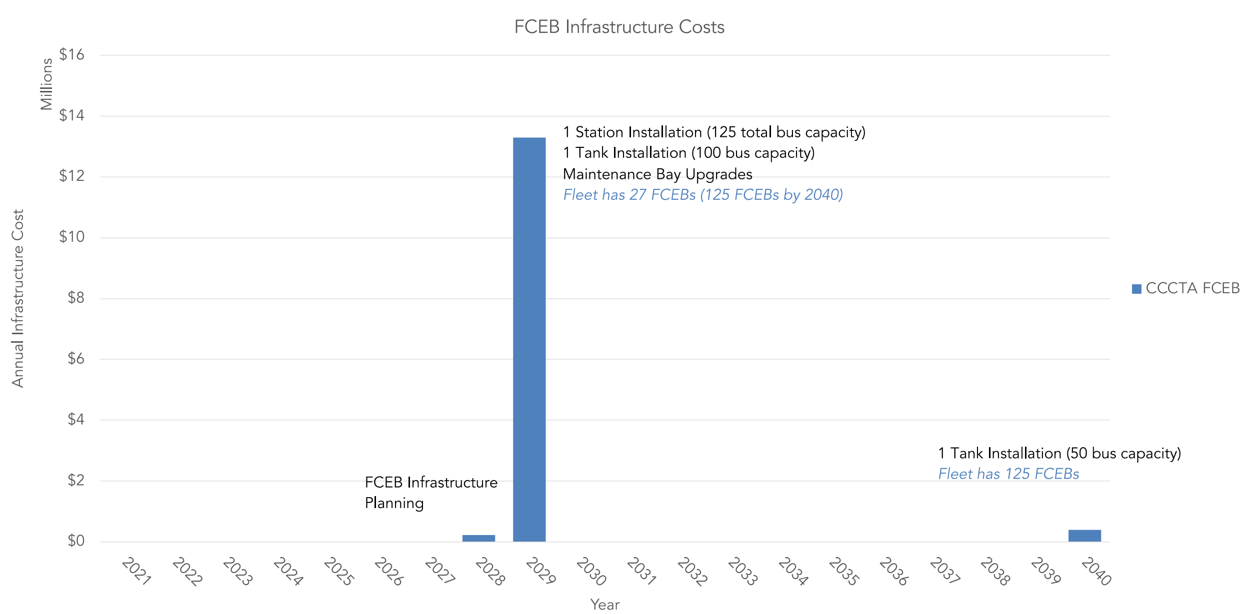


Figure 56 – Infrastructure Costs, FCEB Only Scenario

Facilities Assessment Cost Comparison

The Facilities Assessment includes all infrastructure-related costs over the transition for each scenario. **Figure 57** shows the cumulative infrastructure costs for each scenario.

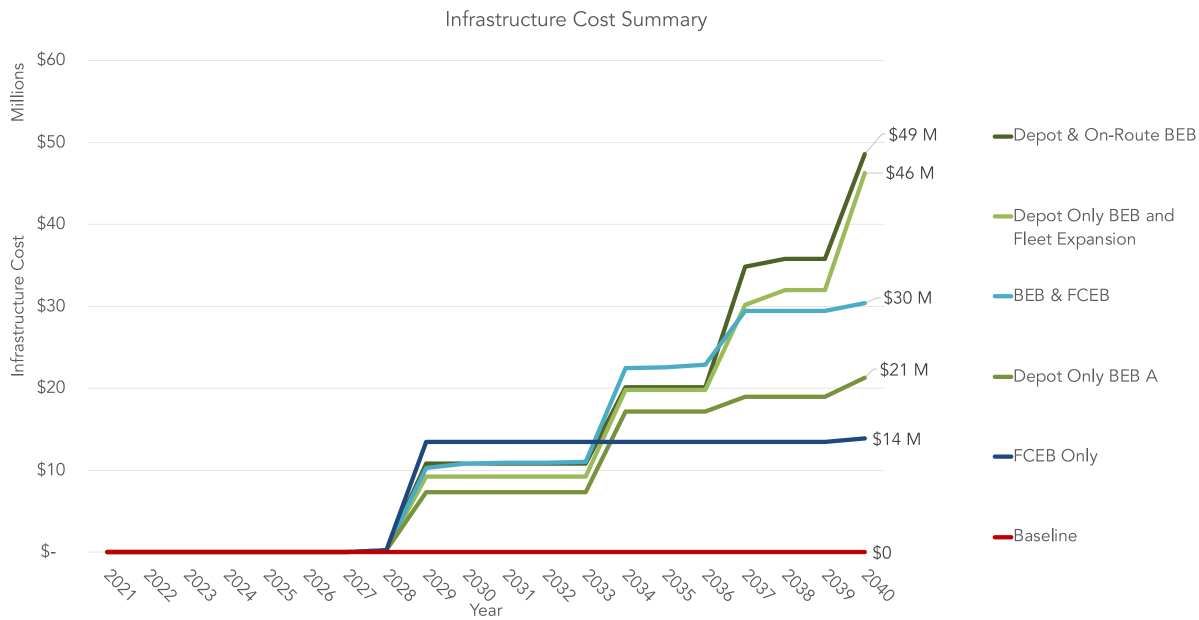


Figure 57 - Total Cumulative Costs, Facilities Assessment

Assessment Conducted in Collaboration with Architecture & Engineering Partner

AECOM

CTE and AECOM developed estimates for components of the BEB infrastructure. County Connection has eight BEBs in their current fleet with existing infrastructure already in place to accommodate the existing BEBs. The charging infrastructure estimates in this Facilities Assessment therefore do not include costs for installation of new charging infrastructure until the new battery electric buses are procured in 2029 and 2030. This is the case in all of the scenarios deploying BEBs.

AECOM prepared conceptual layouts for the BEB Scenarios (e.g., Depot Only, Depot + On-Route Charging) and Mixed Fleet Scenario, and they are provided in **Appendix A1-A9 – County Connection Depot Site Plans.** When County Connection begins its ZEB transition in 2029, the Concord depot will require modifications or re-purposing. AECOM also supplied a report including the power requirements, equipment and raceway routing, gantries, and phasing to convert the Concord depot to an electric charging depot for the BEB Depot and On-Route scenario and the Mixed Fleet: BEB and FCEB scenario. AECOM did not assess Scenario 1A – BEB Depot Only Without Fleet Expansion because County Connection determined this scenario would be unappealing to their board and did not want to investigate this option further.

For the BEB Depot Only with Fleet Expansion scenario, AECOM predicts that the Concord property cannot accommodate the required area to park and charge the entire fleet of 173 total buses required in this scenario.

For the Mixed Fleet: BEB and FCEB Scenario, AECOM expects that 5 gantries will be installed for the first 26 buses deployed in 2029. To accommodate the demand resulting from the addition of this series of 120kW chargers, a new 480/ 277V switchgear, 3-phase service, and a new 2500kVA transformer will be required. See **Appendix A6** for 2029-30 phasing plan. In that same year, the BEB infrastructure projects and service upgrades would commence concurrently with the hydrogen fueling infrastructure being installed. See **Appendix A7** for 2034 phasing plan.

The final site plans for the completed transition can be seen in the 2035 site layouts in **Appendix A9** for Depot and On-Route Charging Scenario and **Appendix A10** for the Mixed Fleet.

Although some of the costs that AECOM supplied such as the power upgrade costs were estimated as part of CTE's analysis in this Master Plan, it is recommended that more detailed cost analysis be done before committing to plans or funding obligations.

FIEDLER GROUP

For County Connection, Fiedler Group conducted an assessment of the FCEB infrastructure requirements at this facility for the Mixed Fleet: BEB and FCEB Only scenario and the FCEB Only Scenario. Fiedler Group has over 60 years of experience working on innovative engineering and design projects and is widely viewed as the industry expert on hydrogen fueling station design. The Mixed Fleet scenario will have an initial deployment of five buses. A mobile hydrogen fueling unit with tube trailer supply will be utilized until the fleet size is increased to 11 buses. The estimated cost for a mobile hydrogen fueling unit per year is $72,000. In the Mixed Scenario, this annual cost is incurred for a total of eight years, from 2029 to 2036, for a total cost of $576,000. In the FCEB Only scenario, the initial bus deployment is planned to be 27 buses. Fiedler Group proposes the initial build-out of fueling infrastructure that will accommodate the full deployment of 125 buses, which is estimated to be $5.3 million.

Maintenance bay upgrades are also required to be hydrogen safety compliant. The total estimate costs to upgrade all 14 bays at the Concord depot is $2.8 million, or $200,000 for each bay retrofit. It is assumed that a new exhaust fan will be required for the maintenance bay area and gas detectors will need to be installed in each of the maintenance bays and a gas detection panel be added. Hydrogen storage must comply with safety distance requirements outlined by the National Fire Protection Association (NFPA), which have been reviewed by Fiedler Group.

Total Cost of Ownership Assessment

The Total Cost of Ownership Assessment compiles the results from the Fleet, Fuel, Facilities, and Maintenance Assessments to show cumulative and annual costs throughout the transition period for each scenario. It includes selected capital and operating costs of each fleet scenario over the transition timeline. Other costs may be incurred (e.g., incremental operator and maintenance training) during a fleet transition; however, these four assessment categories are the key drivers in ZEB transition decision-making.

This study assumes no cost escalation or any cost reduction due to economies of scale for ZEB technology because there is no historical basis for these assumptions. Future changes to County Connection's service level, depot locations, route alignments, block scheduling, or other operations are unknown. The analyses below provide best estimates using the information currently available and the assumptions detailed throughout this report. As a reminder, these costs include inflation, but do not include the sensitivity analysis or LCFS credit value explored in the Fuel Assessment.

The following sections show total costs per scenario, broken down by assessment type.

Baseline

Figure 58 shows the combined fleet, fuel, facilities, and maintenance costs for the Baseline scenario. Since bus capital costs represent the most expensive cost examined, the peaks in these expenses occur during large purchasing years. Compared to bus costs, the fluctuations in fueling and maintenance cost are minimal and appear fairly stable from one year to the next. Since this scenario assumes that the necessary infrastructure is already present at the depot, there are no infrastructure costs associated with the Baseline scenario. The total combined cost is approximately $253 million from 2021 to 2040. This scenario estimates a total of 125 diesels in service in 2040 and will not comply with ICT regulation.

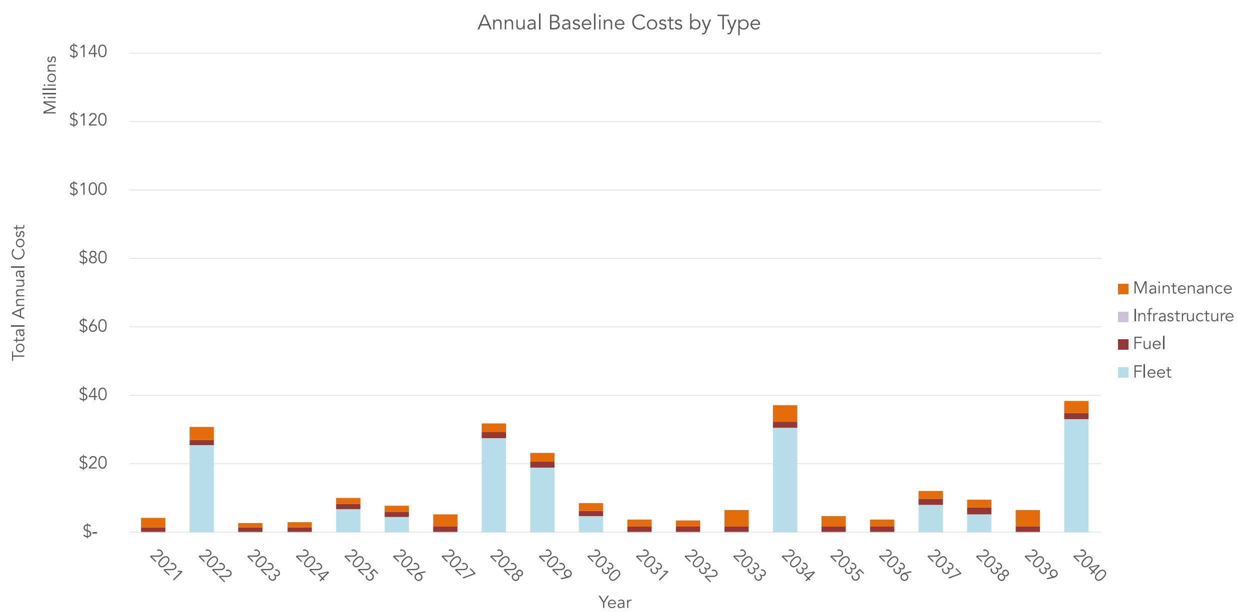


Figure 58 – Total Costs by Type, Baseline Scenario

BEB with Depot Only

Figure 59 shows the combined fleet, fuel, facilities, and maintenance costs for the BEB Only scenario in 2021 dollars. The total combined cost is approximately $317 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 77 total BEBs and 48 ICE buses in the fleet in 2040. The trends in the total cost fluctuations between years are largely the same as the Baseline scenario, with costs peaking in years with large bus procurements. Bus capital costs are the main component of yearly costs with a large spike of bus capital costs occurring in 2034 due to the purchase of 40 BEBs. Infrastructure costs factor in towards the middle and latter half of the transition period while maintenance and fueling costs remain relatively stable from year to year. The costs of this scenario are significantly lower than any other zero-emission scenario because of less infrastructure costs for fewer ZEBs and the lower fuel cost of diesel compared to electricity or hydrogen. However, this scenario was deemed nonviable for the agency because it does not result in a full fleet transition to zero emissions and would not comply with the ICT Regulation.

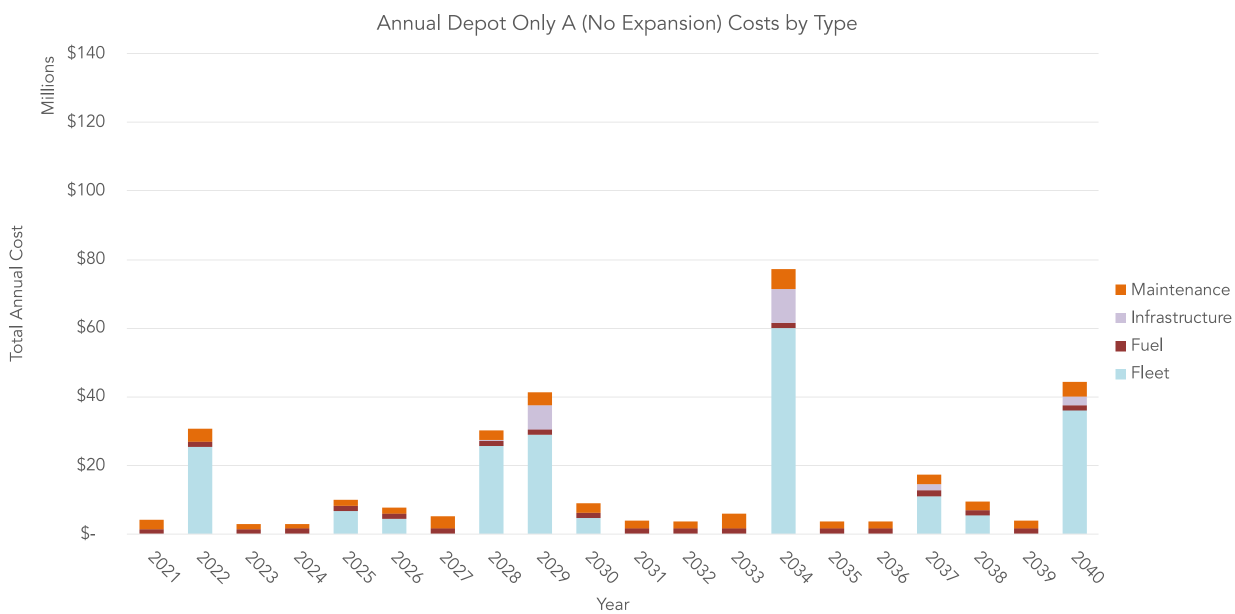


Figure 59– Total Costs by Type, Depot Only

BEB with Depot Only + Fleet Expansion

Figure 60 shows the combined fleet, fuel, facilities, and maintenance costs for the BEB Depot-Only + Fleet Expansion scenario. The total combined cost is approximately $456 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 173 total BEBs in service by 2040 in order to achieve all County Connection blocks, which expands the current fleet level from 125 buses to 173 buses. The spikes seen here correlate with the procurement schedule for this scenario. In 2034, 40 BEBs are scheduled for purchase. In 2040, 67 BEBs are scheduled for purchase. AECOM determined that this many buses and associated charging infrastructure would not fit in the current footprint of the Concord yard and this scenario was therefore deemed operationally non-viable under existing conditions.

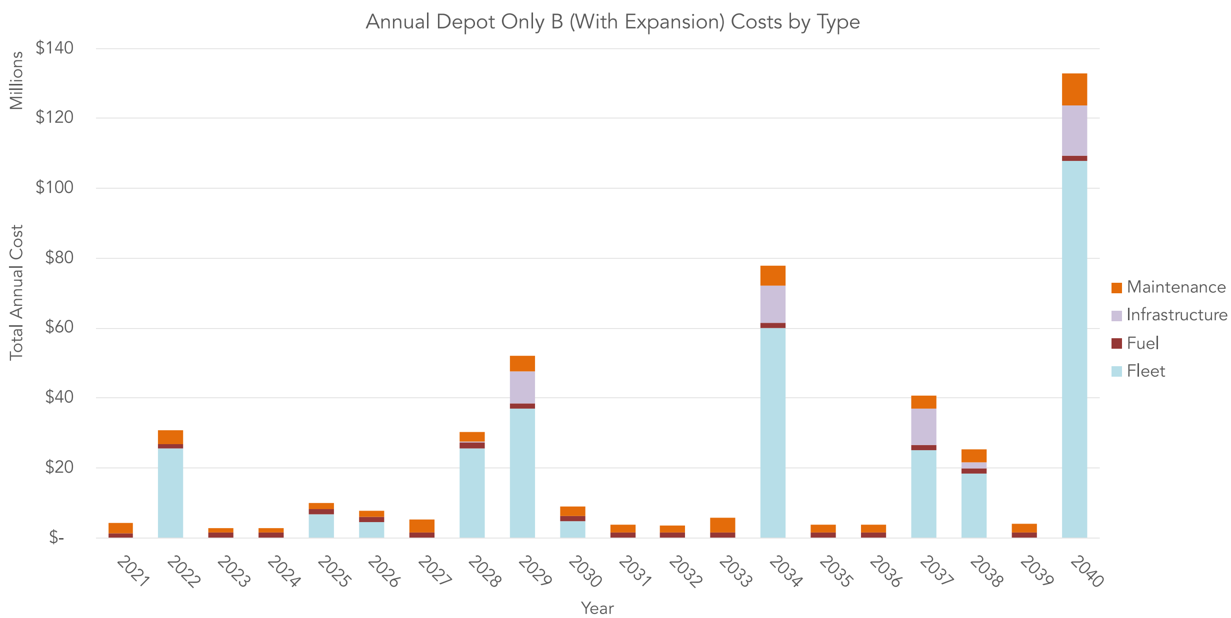


Figure 60– Total Costs by Type, Depot + Fleet Expansion

BEB with Depot & On Route Charging

Figure 61 shows the combined fleet, fuel, facilities, and maintenance costs for the BEB Depot & On-Route scenario. The total combined cost is approximately $386 million over the length of the transition, from 2021 to 2040. This scenario estimates a complete BEB fleet in service by 2040. Similarly, as above, the spikes seen here correlate with the procurement schedule for this scenario. In 2034, 40 BEBs are scheduled for purchase. In 2040, 37 BEBs are scheduled for purchase. Additional labor costs associated with layover charging time are applied to this scenario.

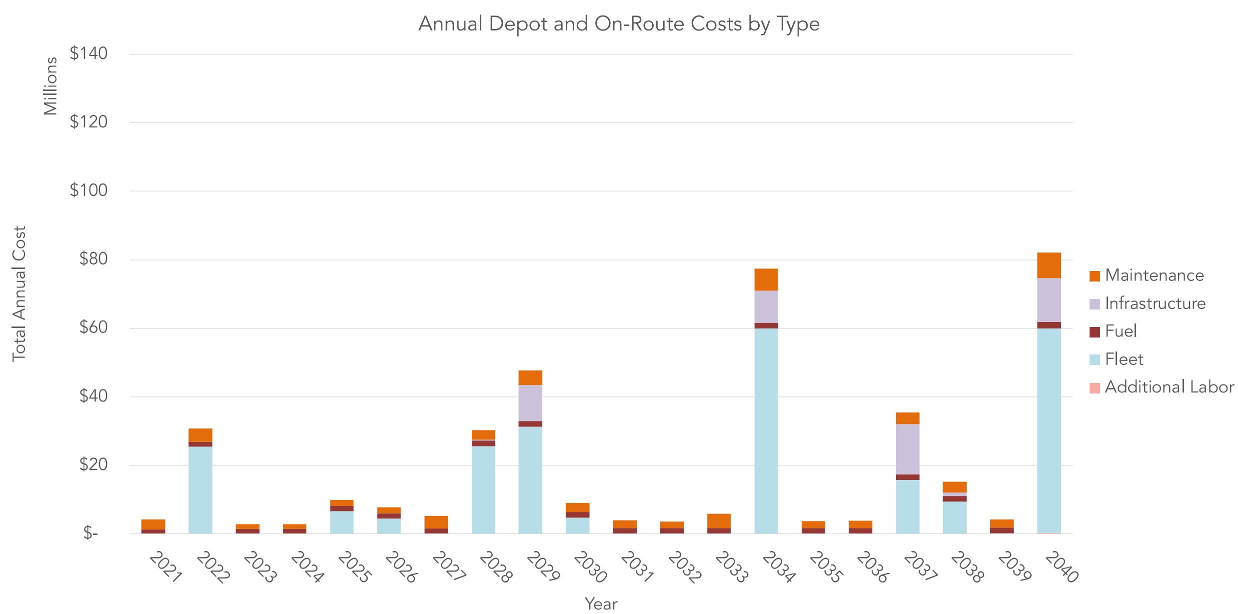


Figure 61– Total Costs by Type, Depot & On-Route

Mixed Fleet: BEB and FCEB

Figure 62 shows the combined fleet, fuel, facilities, and maintenance costs related to the Mixed Fleet: BEB and FCEB scenario in 2021 dollars. The total combined cost is approximately $373 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 77 BEBs and 48 FCEBs (125 total ZEBs) in service by 2040. The patterns of this scenario's bus purchasing, maintenance costs, and fueling costs are similar to those of the previously discussed scenarios with the infrastructure costs starting in 2029 and continuing until 2040.

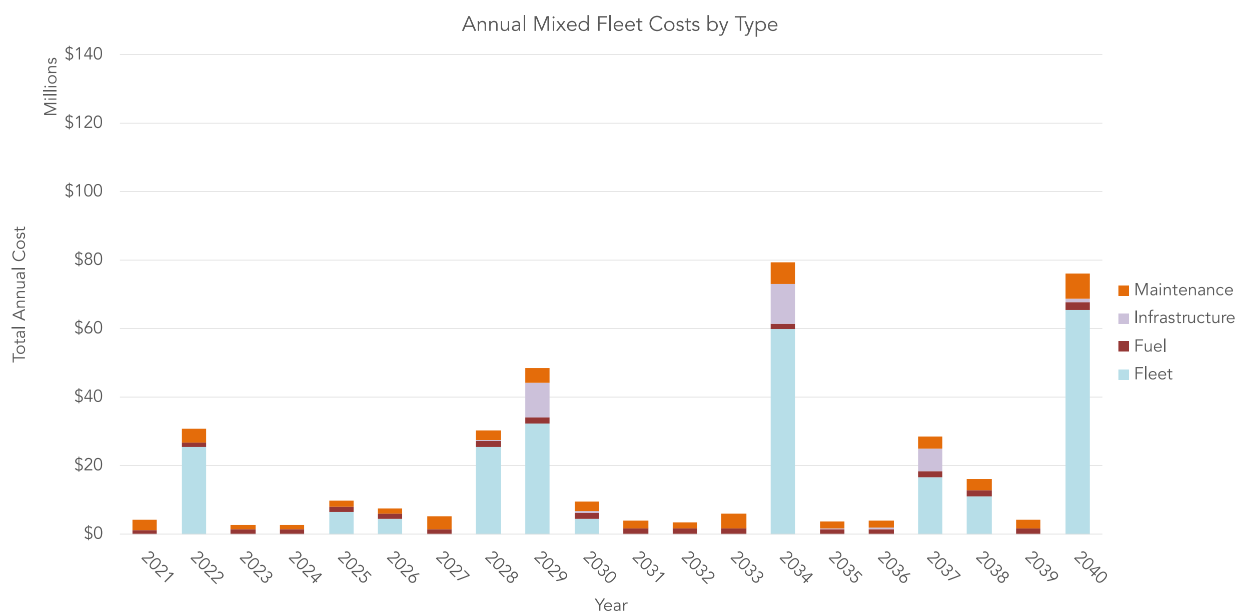


Figure 62– Total Costs by Type, Mixed Fleet: BEB and FCEB Scenario

FCEB Only

Figure 63 shows the combined fleet, fuel, facilities, and maintenance costs related to the FCEB Only scenario in 2021 dollars. The total combined cost is approximately $384 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 125 FCEBs in service by 2040. The general trends of this scenario are similar to the previous ZEB scenarios discussed. The annual expenses for the FCEB Only scenario never exceed $75 million, because the infrastructure costs for hydrogen fueling are lower than the costs for charging infrastructure. In comparison, the highest annual expense for BEB Depot & On-Route Charging is close to $82 million.

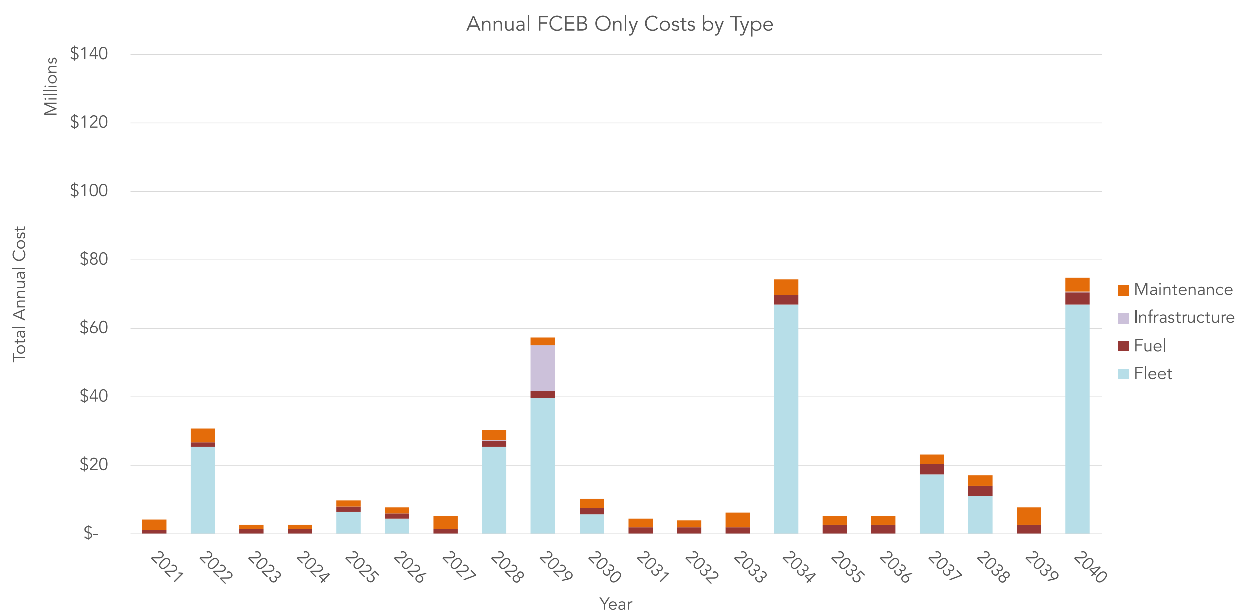


Figure 63– Total Costs by Type, FCEB Only Scenario

Total Estimated Costs

Figure 64 shows the combined total costs from the assessments above, broken down by scenario. **Table 32** shows the detailed cost totals.

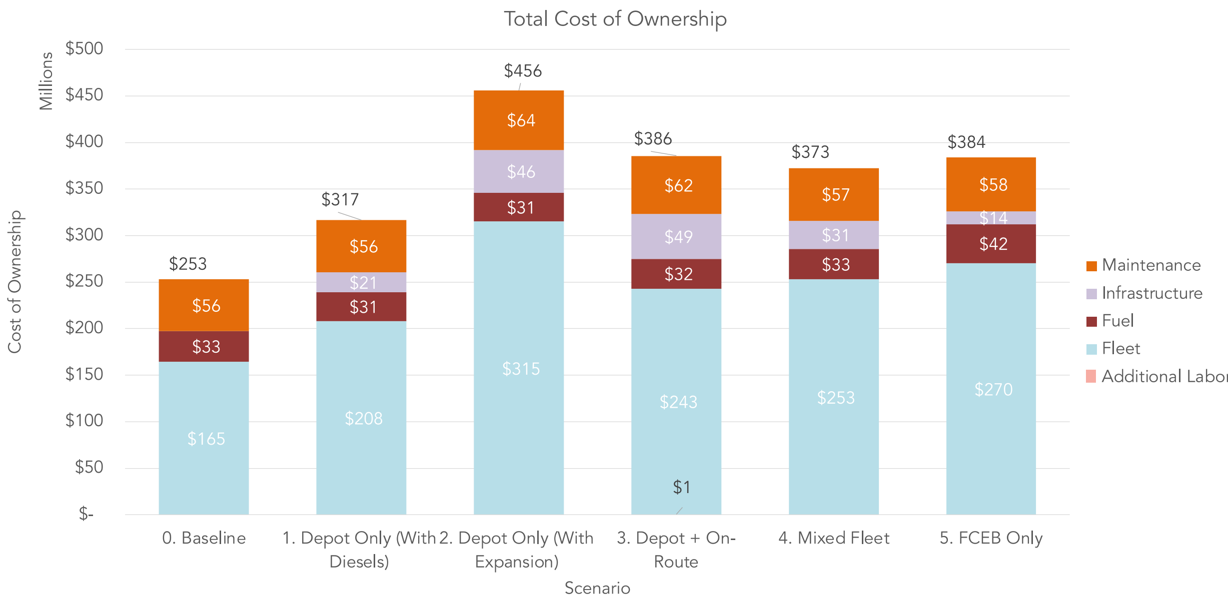


Figure 64– Total Cost of Ownership, by Scenario

Table 32–Total Cost of Ownership, by Scenario

	0. Baseline (Current Tech-nology)	1. Depot Only (With Diesels)	2. Depot Only (With Expansion)	3. Depot + On-Route	4. Mixed Fleet	5. FCEB Only
Fleet	$165M	$ 208M	$ 315M	$ 243M	$253M	$ 270M
Additional Labor	--	--	--	$ 1M	--	--
Fuel*	$ 33M	$ 31M	$ 31M	$ 32M	$ 33M	$ 42M
Maintenance	$ 56M	$ 56M	$ 64M	$ 62M	$ 57M	$ 58M
Infrastructure	$ 0	$ 21M	$ 46M**	$ 49M***	$ 30M	$ 14M
TOTAL	**$ 253M**	**$ 317M**	**$ 456M**	**$386M**	**$ 373M**	**$ 384M**

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.
** Excludes costs for necessary yard expansion to accommodate expanded fleet.
***Excludes the cost of land acquisition for on-route charging stations.

Conclusions and Recommendations

ZEB technologies are in a period of rapid development. While the technologies have been proven in many pilot deployments, they are not yet matured to the point where they can easily replace current fossil-fuel technologies on a large scale. BEBs require significant investment in facilities and infrastructure and may require changes to service and operations to manage their energy constraints. On the other hand, FCEBs can provide an operational equivalent to diesel buses but the cost of buses, fueling infrastructure, and fuel remain a significant barrier to mass adoption.

CARB's ICT regulation is an achievement in addressing the challenges of climate change and improving local air quality through the goal of 100% zero-emission transit fleets by 2040. However, as demonstrated in this analysis, there will be substantial costs and technical challenges to overcome. Transit agencies may be challenged to meet this goal while maintaining the same level of passenger service.

The BEB Only scenario meets the CARB ICT regulation, but does not result in a fully zero-emission fleet by 2040. The transition cost of this scenario is estimated to be around $317 million, not including LCFS credit revenue to offset fuel costs. The difference in cost between this scenario and the Baseline scenario is largely the result of the price difference between diesel buses and BEBs and up-front capital costs for new fueling infrastructure. The 35-foot and 40-foot BEBs have completed Altoona testing and are acceptable under the CARB ICT regulation.

In a BEB Depot Only with Fleet Expansion scenario, AECOM, this project's A&E firm, found that the single depot in Concord does not have the adequate space to accommodate 173 buses, therefore, rendering this scenario unviable. For this transition plan, CTE reviewed expanding the fleet from 125 buses to 173 buses that will maintain service levels while also fully transitioning the entire fleet to BEB technology and infrastructure. This scenario will cost around $456 million and does not include the cost of land acquisition.

In the BEB Depot and On-Route scenario, the total estimated cost is approximately $386 million over the transition from 2021 to 2040. This scenario estimates a complete BEB fleet in service by 2040, with 40 BEBs are scheduled for purchase in 2034 and 37 BEBs scheduled for purchase in 2040. By adding on-route charging, County Connection could achieve a transition to a 100% battery-electric fleet without increasing fleet size or sacrificing block achievability.

The Mixed Fleet: BEB and FCEB scenario achieves the transition of County Connection's fleet to 100% zero-emission by 2040 with an estimated total cost of $373 million, not including LCFS credit revenue on fuel. Though this total cost is comparable to the BEB Depot + On-Route Charging scenario, managing a mixed fleet through a transition presents its own complexities such as installing new BEB charging infrastructure and new FCEB fueling infrastructure in a time frame that does not disrupt service or depot access. In this scenario, the depot would also need to have the capacity to fit both kinds of fueling infrastructure.

Total costs for the FCEB Only scenario are estimated at approximately $384 million (not including LCFS credit revenue on fuel) and result in an entirely fuel cell electric bus fleet by

2040. FCEB technology would allow service to continue unaltered without increasing fleet size. A primary assumption for the FCEB analysis is that FCEBs will be available for all bus types and lengths during the transition period. Due to the lack of market diversity of FCEBs and hydrogen availability in the United States, fuel costs and bus capital costs remain high. These costs are largely expected to decrease in the future as more buses are deployed; however, more data is needed to understand how much they may decrease. Additionally, data for FCEB maintenance costs reflect higher costs than what might be expected as agencies become more familiar with the technology. As such, there are more unknowns associated with costs for the FCEB Only scenario, and costs are more subject to change.

Given these considerations, the recommendations for County Connection are as follows:

1. **Select a preferred scenario to refine in ICT Plan development and remain proactive with ZEB deployment grants:** This Master Plan was developed to present County Connection with options for transitioning to a fully zero-emission fleet. Following County Connection's selection of a preferred ZEB Transition Scenario, the ICT Rollout Plan will be developed for submittal to CARB in compliance with the ICT Regulation. This document will put forth County Connection's vision for a ZEB Transition and will act as a living document to help the agency plan out grant funding requirements. As a greater proportion of County Connection's fleet converts to ZEB technology, auxiliary equipment, hardware, and software will be needed to ensure a successful fleet transition. County Connection should continue to remain proactive in the purchase and deployment of ZEBs and their associated systems by taking advantage of various grant and incentive programs.
2. **Apply learnings from early ZEB deployments in real time:** While ZEB technology continues to evolve, there is significant value in applying empirical data to deployment strategies. Results from early County Connection BEB deployments and other transit agency data have already informed this transition plan study and ongoing performance monitoring of ZEB technology will be key to ensuring the implementation of the best-fit technology at the appropriate time.
3. **Match the individual bus technology to the individual route and blocks:** County Connection should consider the strengths of given ZEB technologies and focus those technologies on routes and blocks that take advantage of their efficiencies and minimize the impact of the constraints related to the respective technologies. These technologies cannot follow a one-size-fits-all approach from either a performance or cost perspective. Matching the present technology to the present service levels will be a critical best practice.
4. **Monitor local and regional developments:** In the zero-emission technology sector, developments at the local level can have the ability to catapult the industry forward. When local bus OEMs or fuel providers enter the zero-emission market, it can spark technological innovation or cost reduction. Neighboring transit agencies can also work together through group purchasing agreements and lobbying efforts to bring about reduced purchase costs or more funding opportunities.

The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission public transit. Widespread adoption of zero-emission bus technology has the potential to significantly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. County Connection is committed to implementing environmentally-friendly policies and reducing its carbon footprint.

This ZEB transition plan describes several factors considered for each of the scenarios that were explored by County Connection. Costs, benefits, and limitations of each scenario are summarized below to help transit management and other decision makers in evaluating the impacts of ZEB deployment in the subsequent years.

1.Depot Only (With Diesels)

Assessment Type	1. Depot Only (With Diesels)
Fleet	$ 208M
Additional Labor	$0
Fuel*	$ 31M
Maintenance	$ 56M
Infrastructure	$ 21M
Total	$317 M
% ZEB in 2040	61%

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.

This scenario results in the lowest total cost of ownership with the exception of the Baseline scenario. However, it does not result in a fully zero-emission fleet by 2040. Should this scenario be chosen, a waiver will need to be requested from CARB as this would not meet ICT regulation.

2.Depot Only (With Expansion)

Assessment Type	2. Depot Only (With Expansion)
Fleet	$ 315M
Additional Labor	$0
Fuel*	$ 31M
Maintenance	$ 64M
Infrastructure	$ 46M**
Total	$456 M
% ZEB in 2040	100%

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.
** Excludes costs for necessary yard expansion to accommodate expanded fleet.

While expanding the fleet from 125 buses to 173 buses will maintain service levels and fully transition the entire fleet to BEB technology, this scenario requires the highest capital expenditure. Additionally, this transition plan does not cover the costs associated with related depot expansion.

3.Depot + On-Route

Assessment Type	3. Depot + On-Route
Fleet	$ 243M
Additional Labor	$ 1M
Fuel*	$ 32M
Maintenance	$ 62M
Infrastructure	$ 49M***
Total	$386 M
% ZEB in 2040	100%

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.
***Excludes the cost of land acquisition for on-route charging stations.

Through on-route charging, this scenario allows County Connection to fully achieve a 100% BEB fleet. However, fiscal impacts related to land acquisition for on-route charging are cost-intensive and additional resources are needed to mitigate risks related to ROW issues. Moreover, there are operational considerations such as added labor costs related to extended layovers.

4.Depot + FCEB

Assessment Type	4. Depot + FCEB
Fleet	$253M
Additional Labor	$0
Fuel*	$ 33M
Maintenance	$ 57M
Infrastructure	$ 31M
Total	$373 M
% ZEB in 2040	100%

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.

This scenario allows County Connection to take advantage of both ZEB technology—BEB and FCEB—in order to maintain current levels of service and increase resilience in the event of power outage. However, installing new BEB infrastructure and new FCEB fueling infrastructure will create space constraints at the depot. Additionally, careful planning of charging and fueling installation is needed in order to avoid service disruption and depot access.

5.FCEB Only

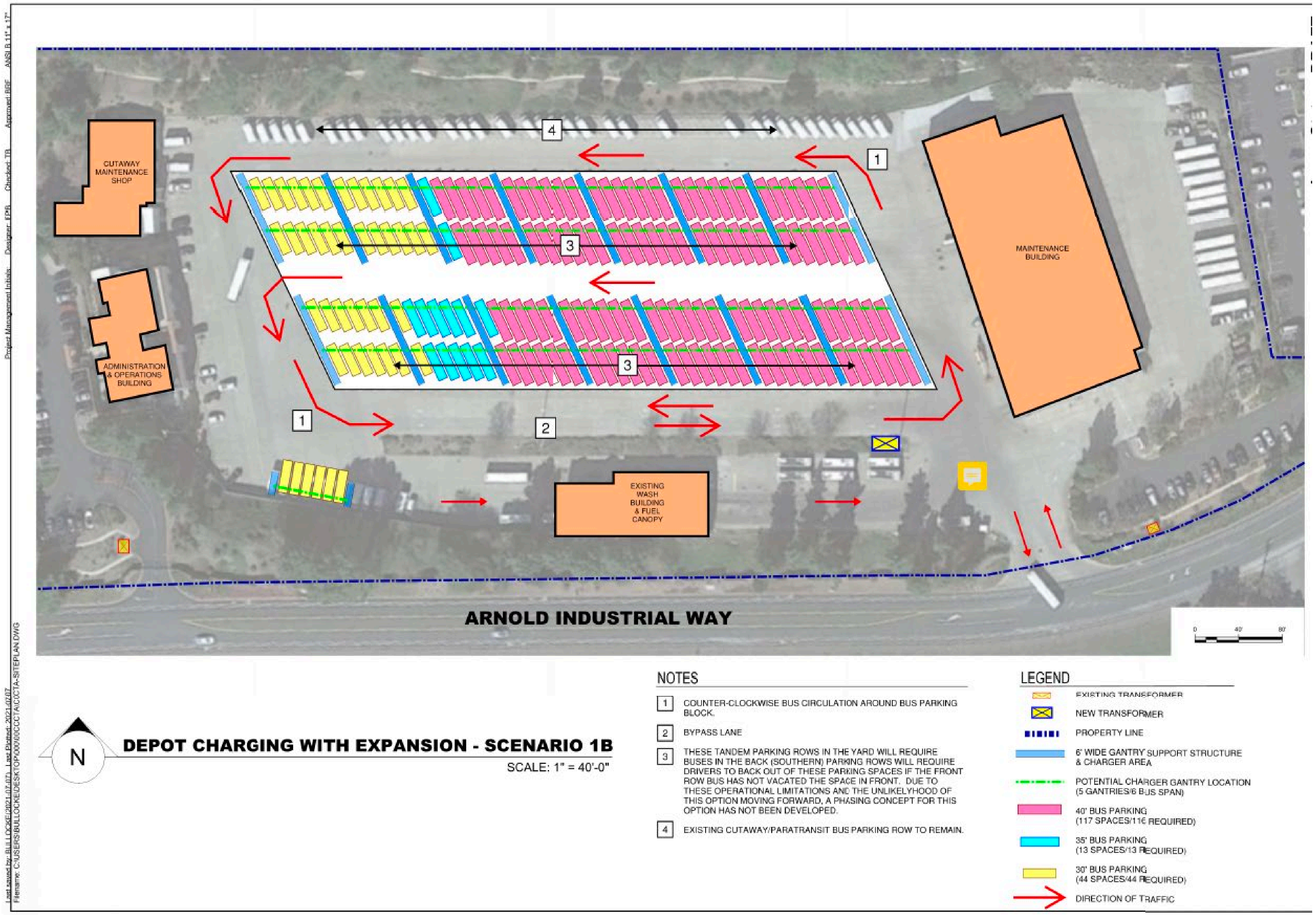
Assessment Type	5. FCEB Only
Fleet	$ 270M
Additional Labor	$0
Fuel*	$ 42M
Maintenance	$ 58M
Infrastructure	$ 14M
Total	$384 M
% ZEB in 2040	100%

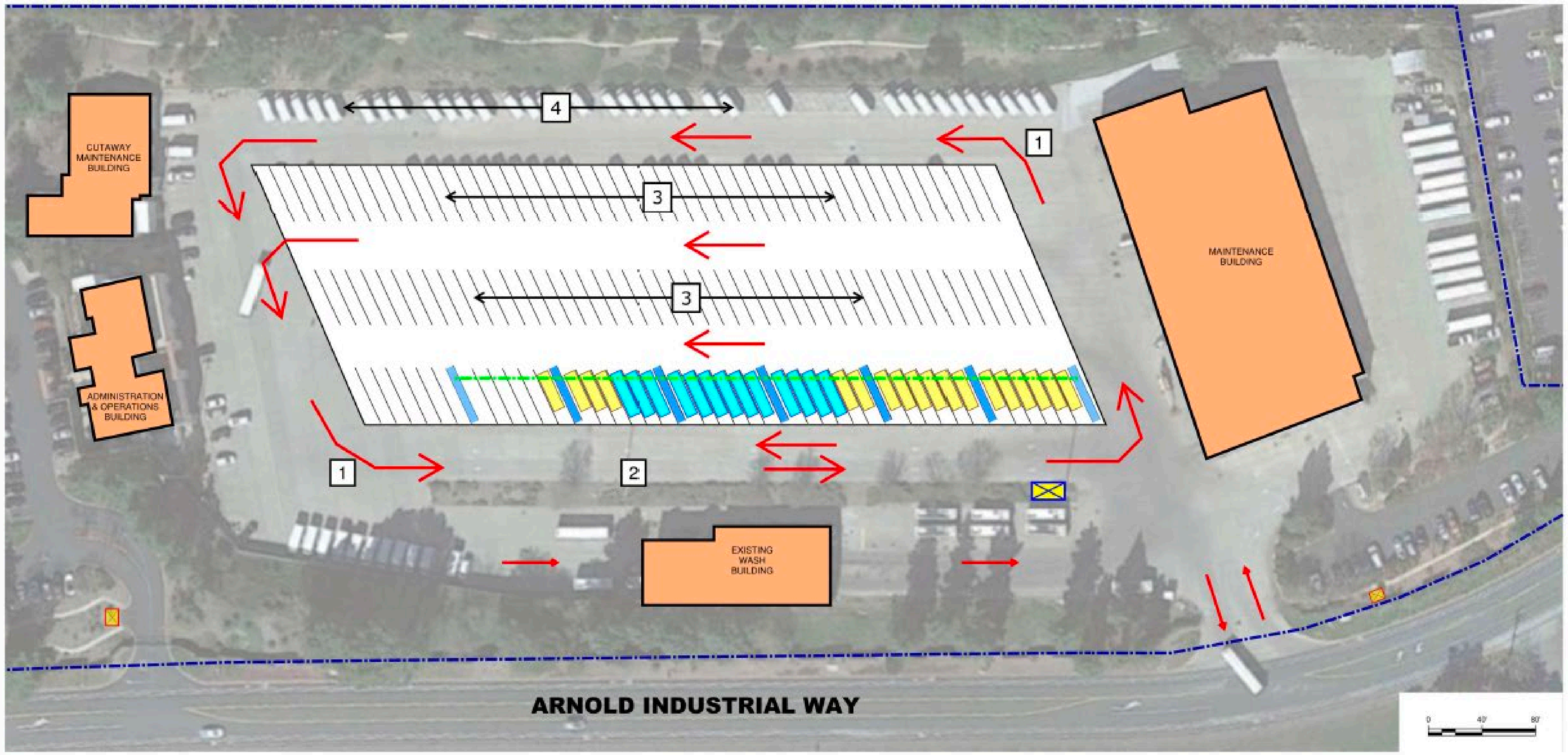
*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.

A 100% FCEB allows for a 1:1 replacement of diesel buses and full compliance with ICT regulation. However, hydrogen from an external source may be subject to supply and demand market volatility.

Appendix A1-A9 – County Connection Depot Site Plans

Appendix A1, Depot Charging with Fleet Expansion Scenario





N

DEPOT & ON-ROUTE SCENARIO 2 / PHASE 1

SCALE: 1" = 40'-0"

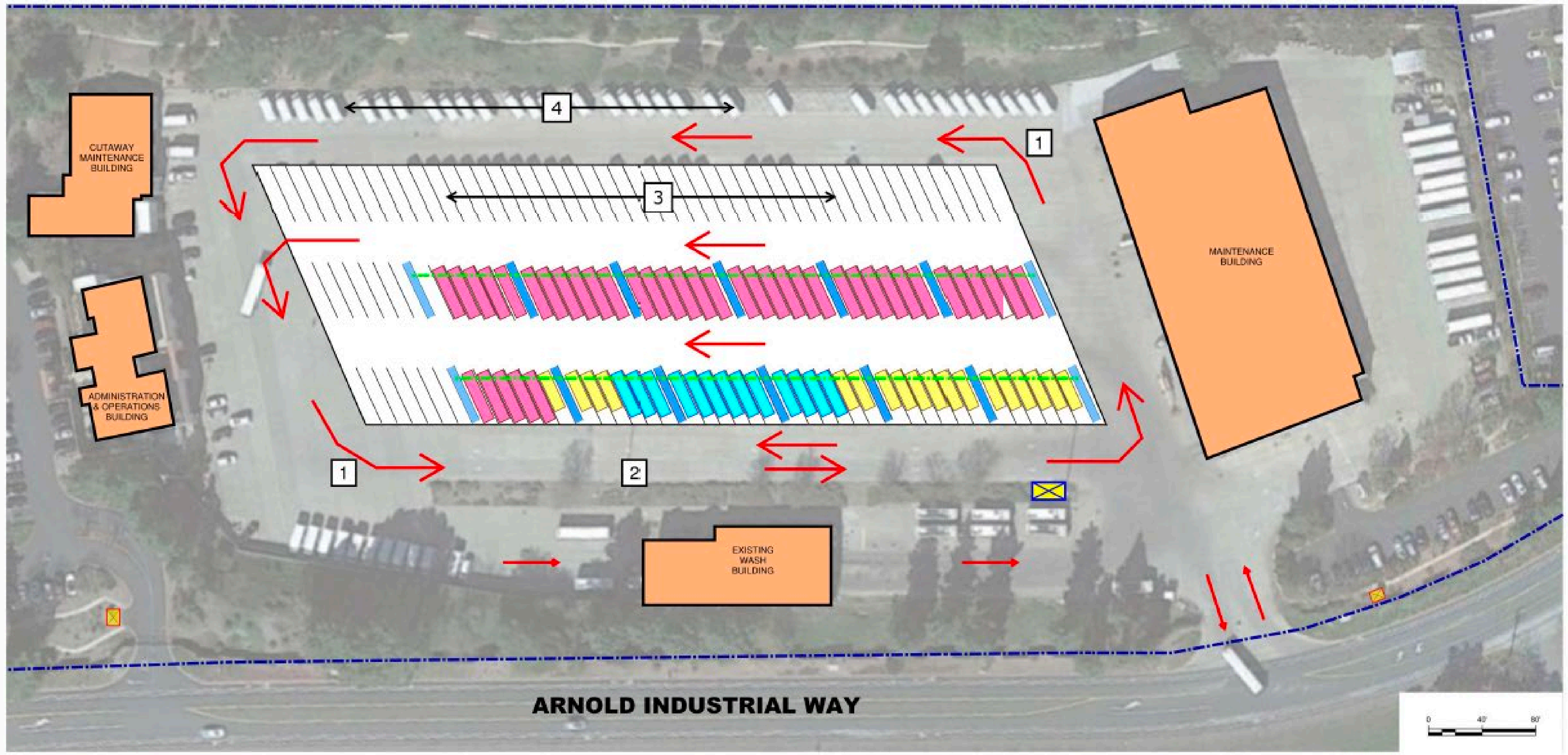
BEBs ADDED BY PHASE BY DIVISION & LENGTH						
DIVISION	BUS	PHASE 1 (2029-2030)	PHASE 2 (2033)	PHASE 3 (2036-2037)	PHASE 4 (2039)	TOTAL
CCCTA	30	18		7	4	29
CCCTA	35	13				13
CCCTA	40		40	10	33	83
TOTAL		31	40	17	37	125

NOTES

1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. THESE TANDEM PARKING ROWS IN THE YARD WILL REQUIRE BUSES IN THE BACK (SOUTHERN) PARKING ROWS WILL REQUIRE DRIVERS TO BACK OUT OF THESE PARKING SPACES IF THE FRONT ROW BUS HAS NOT VACATED THE SPACE IN FRONT. DUE TO THESE OPERATIONAL LIMITATIONS AND THE UNLIKELYHOOD OF THIS OPTION MOVING FORWARD, A PHASING CONCEPT FOR THIS OPTION HAS NOT BEEN DEVELOPED.
4. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN.

LEGEND

- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER AREA
- POTENTIAL CHARGER GANTRY LOCATION (21 GANTRIES/6 BUS SPAN)
- 40' BUS PARKING
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC



N

DEPOT & ON-ROUTE SCENARIO 2 / PHASE 2

SCALE: 1" = 40'-0"

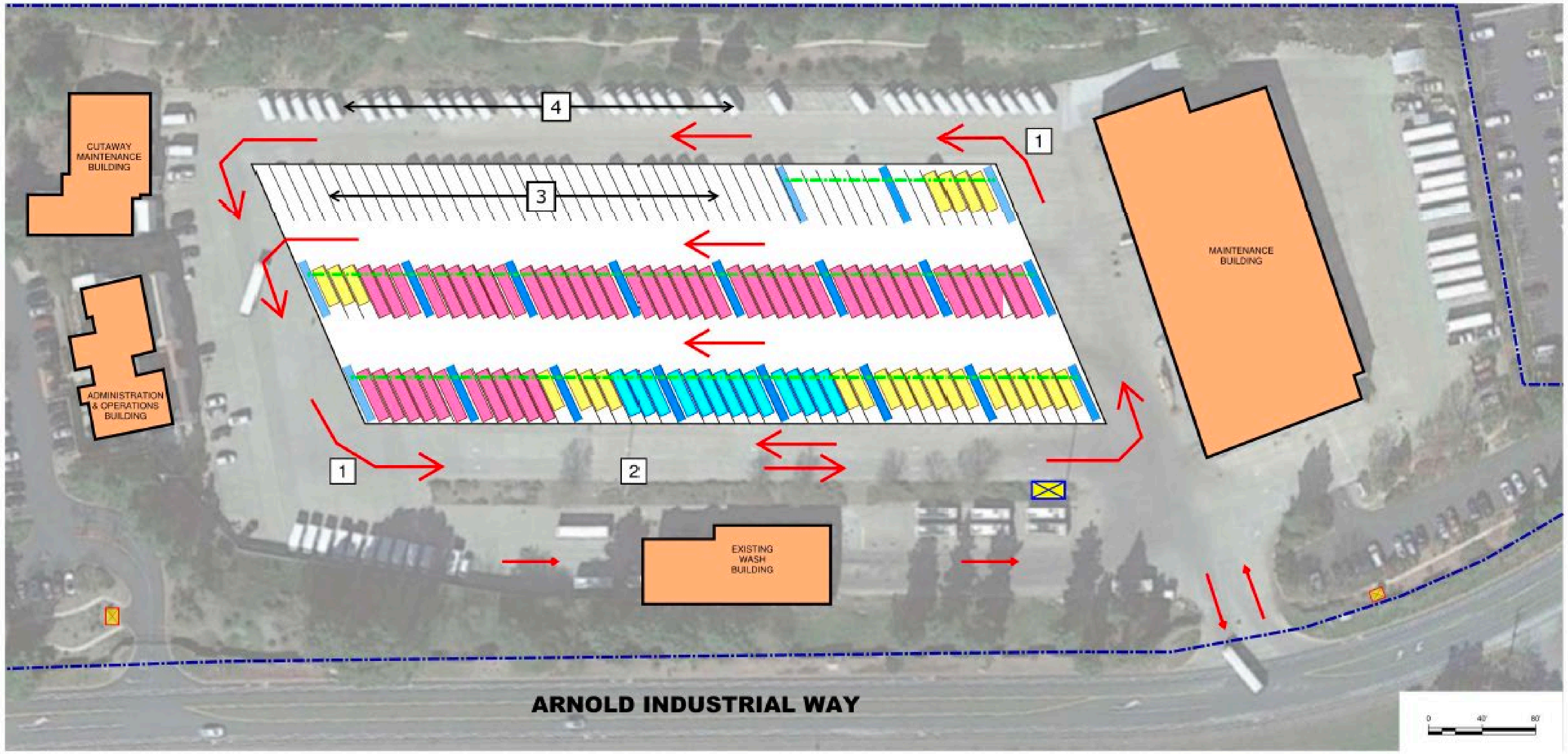
BEBs ADDED BY PHASE BY DIVISION & LENGTH						
DIVISION	BUS	PHASE 1 (2029-2030)	PHASE 2 (2033)	PHASE 3 (2036-2037)	PHASE 4 (2039)	TOTAL
CCCTA	30	18		7	4	29
CCCTA	35	13				13
CCCTA	40		40	10	33	83
TOTAL		31	40	17	37	125

NOTES

1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. THESE TANDEM PARKING ROWS IN THE YARD WILL REQUIRE BUSES IN THE BACK (SOUTHERN) PARKING ROWS WILL REQUIRE DRIVERS TO BACK OUT OF THESE PARKING SPACES IF THE FRONT ROW BUS HAS NOT VACATED THE SPACE IN FRONT. DUE TO THESE OPERATIONAL LIMITATIONS AND THE UNLIKELYHOOD OF THIS OPTION MOVING FORWARD, A PHASING CONCEPT FOR THIS OPTION HAS NOT BEEN DEVELOPED.
4. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN.

LEGEND

- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER AREA
- POTENTIAL CHARGER GANTRY LOCATION (21 GANTRIES/6 BUS SPAN)
- 40' BUS PARKING
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC



N

DEPOT & ON-ROUTE SCENARIO 2 / PHASE 3

SCALE: 1" = 40'-0"

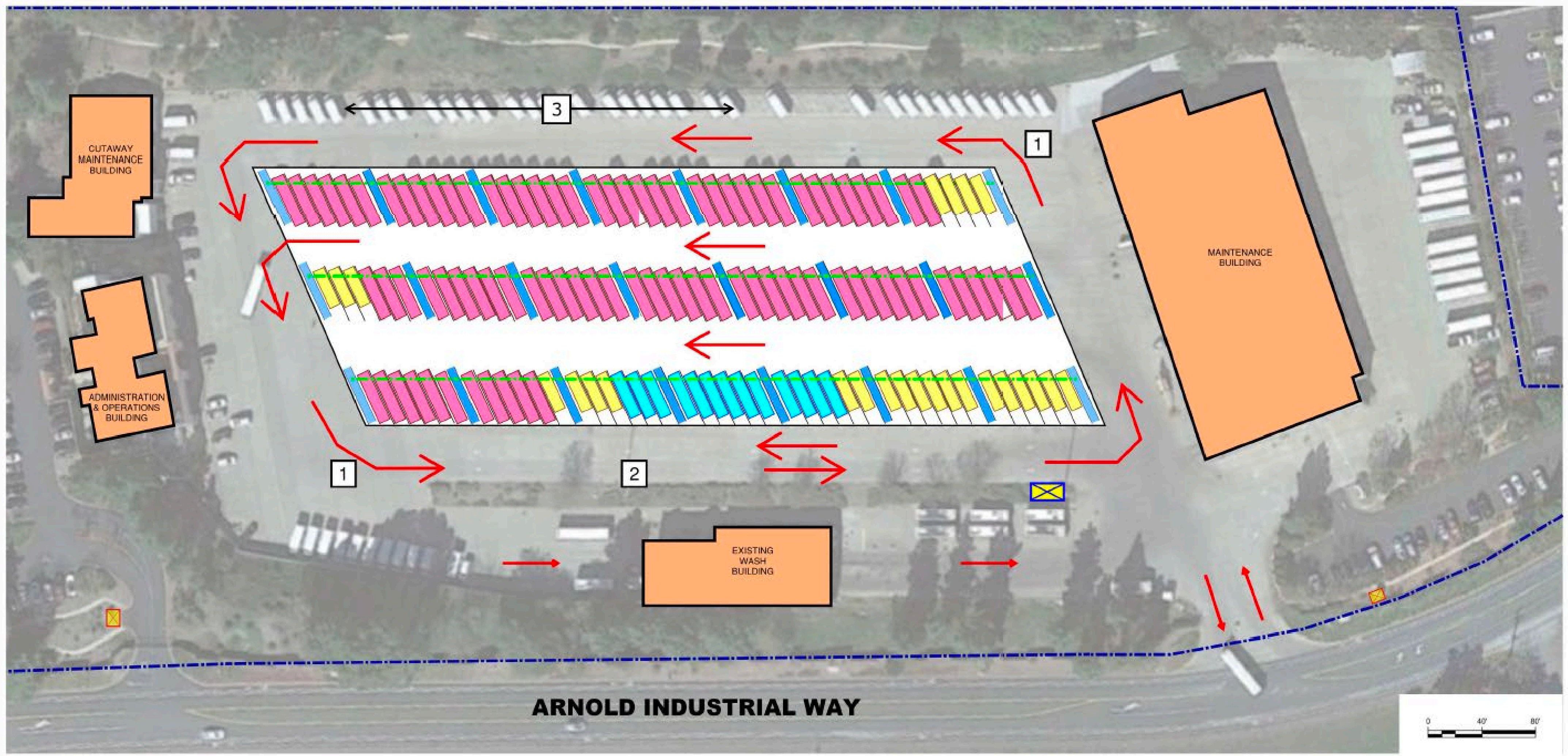
BEBs ADDED BY PHASE BY DIVISION & LENGTH						
DIVISION	BUS	PHASE 1 (2029-2030)	PHASE 2 (2033)	PHASE 3 (2036-2037)	PHASE 4 (2039)	TOTAL
CCCTA	30	18		7	4	29
CCCTA	35	13				13
CCCTA	40		40	10	33	83
TOTAL		31	40	17	37	125

NOTES

1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. THESE TANDEM PARKING ROWS IN THE YARD WILL REQUIRE BUSES IN THE BACK (SOUTHERN) PARKING ROWS WILL REQUIRE DRIVERS TO BACK OUT OF THESE PARKING SPACES IF THE FRONT ROW BUS HAS NOT VACATED THE SPACE IN FRONT. DUE TO THESE OPERATIONAL LIMITATIONS AND THE UNLIKELYHOOD OF THIS OPTION MOVING FORWARD, A PHASING CONCEPT FOR THIS OPTION HAS NOT BEEN DEVELOPED.
4. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN.

LEGEND

- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER AREA
- POTENTIAL CHARGER GANTRY LOCATION (21 GANTRIES/6 BUS SPAN)
- 40' BUS PARKING
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC



NOTES

1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN.

LEGEND

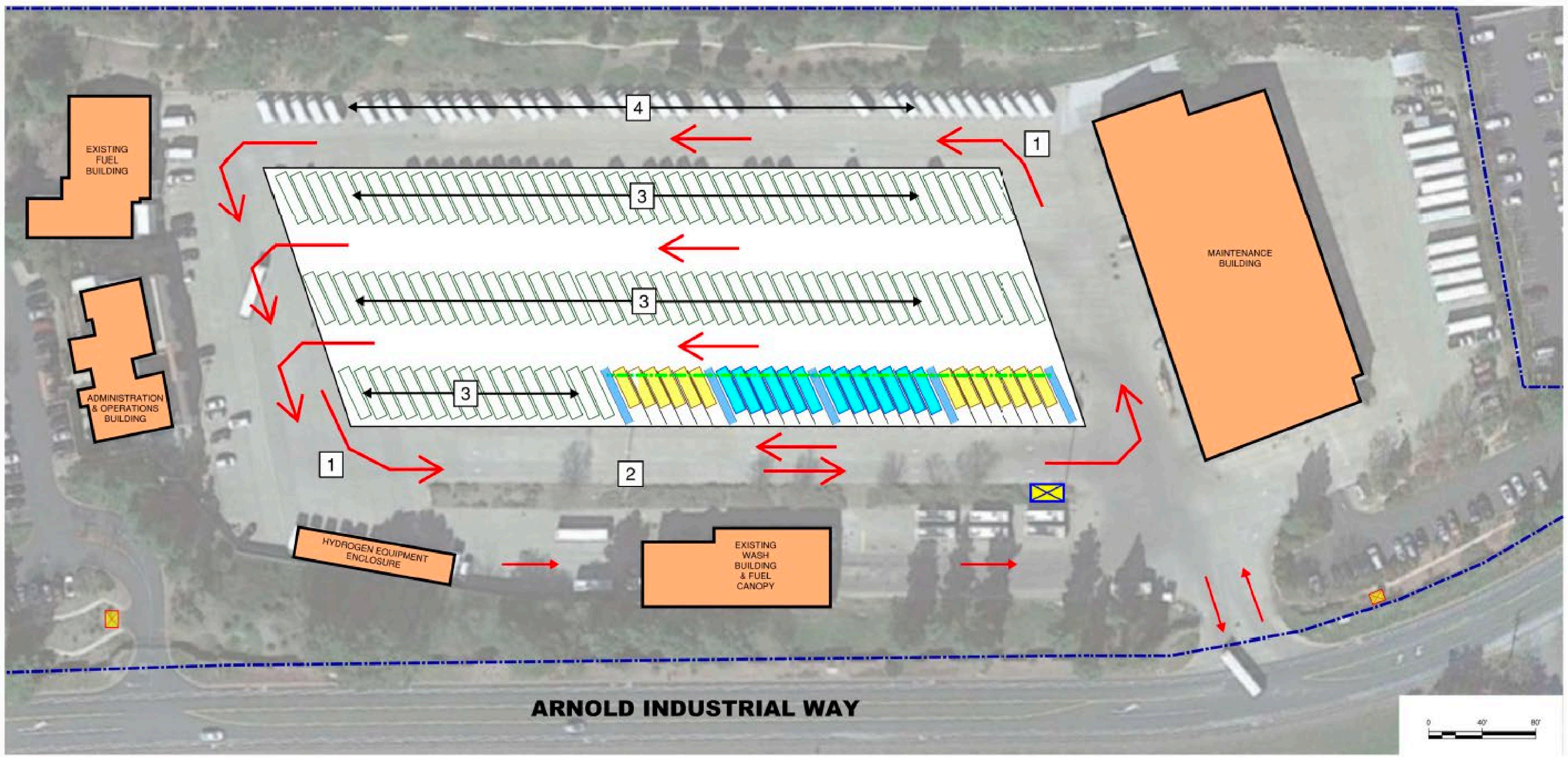
- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER AREA
- POTENTIAL CHARGER GANTRY LOCATION (21 GANTRIES/6 BUS SPAN)
- 40' BUS PARKING
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC

N

DEPOT & ON-ROUTE SCENARIO 2 / PHASE 4

SCALE: 1" = 40'-0"

BEBs ADDED BY PHASE BY DIVISION & LENGTH						
DIVISION	BUS	PHASE 1 (2029-2030)	PHASE 2 (2033)	PHASE 3 (2036-2037)	PHASE 4 (2039)	TOTAL
CCCTA	30	18		7	4	29
CCCTA	35	13				13
CCCTA	40		40	10	33	83
TOTAL		31	40	17	37	125



N

MIXED BEB-FCEB FLEET - SCENARIO 3 / PHASE 1

SCALE: 1" = 40'-0"

NOTES

1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. 40' PARKING SLOTS FOR REMAINING DIESEL/FUEL CELL BUSES
4. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN.

LEGEND

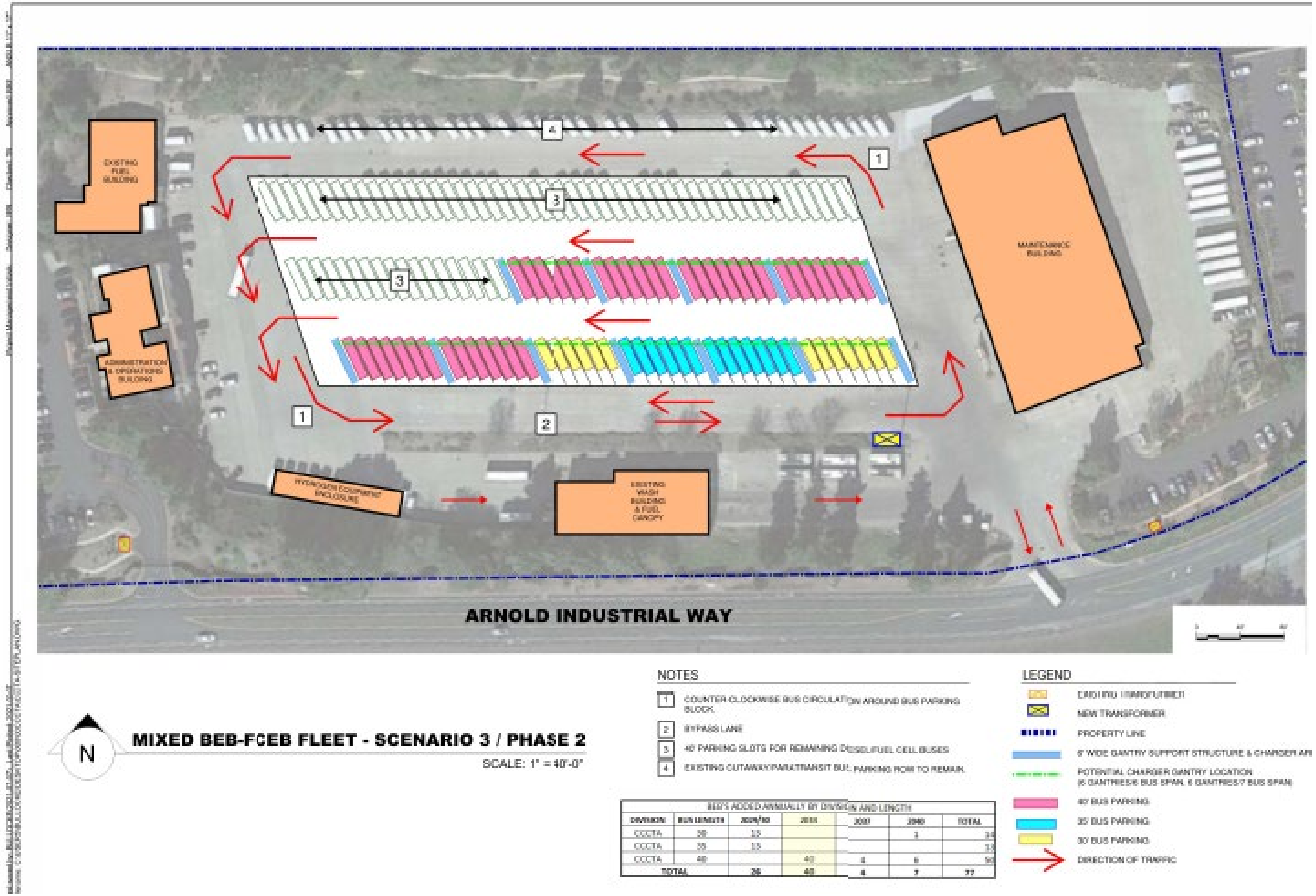
- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER ARE
- POTENTIAL CHARGER GANTRY LOCATION (2 GANTRIES/6 BUS SPAN, 2 GANTRIES/7 BUS SPAN)
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC

BEB'S ADDED ANNUALLY BY DIVISION AND LENGTH

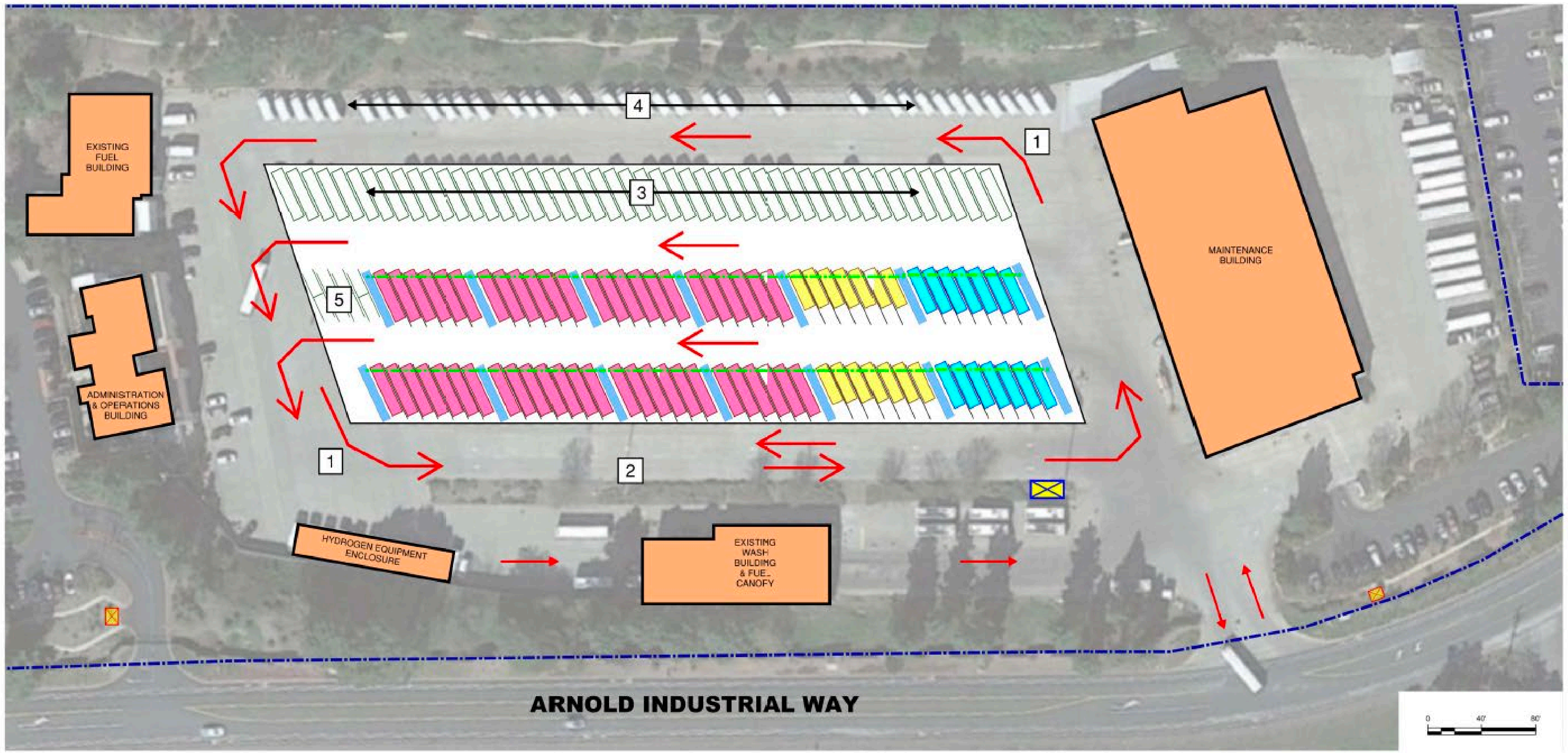
DIVISION	BUS LENGTH	2029/30	2034	2037	2040	TOTAL
CCCTA	30	13			1	14
CCCTA	35	13				13
CCCTA	40		40	4	6	50
TOTAL		26	40	4	7	77

Project Management Initials: Designer: EPR Checked: TB Approved: BRF ANSI B 11" x 17"

Last saved by: BULLOCKE(2021-07-07) Last Plotted: 2021-07-07
Filename: C:\USERS\BULLOCKE\DESKTOP\000\CCCTA\CCCTA-SITEPLAN.DWG



BEB'S ADDED ANNUALLY BY DIVISION AND LENGTH						
DIVISION	BUS LENGTH	2029/30	[illegible]	2037	2040	TOTAL
CCCTA	30	13			1	14
CCCTA	35	13				13
CCCTA	40		40	4	6	50
TOTAL		26	40	4	7	77



MIXED BEB-FCEB FLEET - SCENARIO 3 / PHASE 3

SCALE: 1" = 40'-0"

NOTES

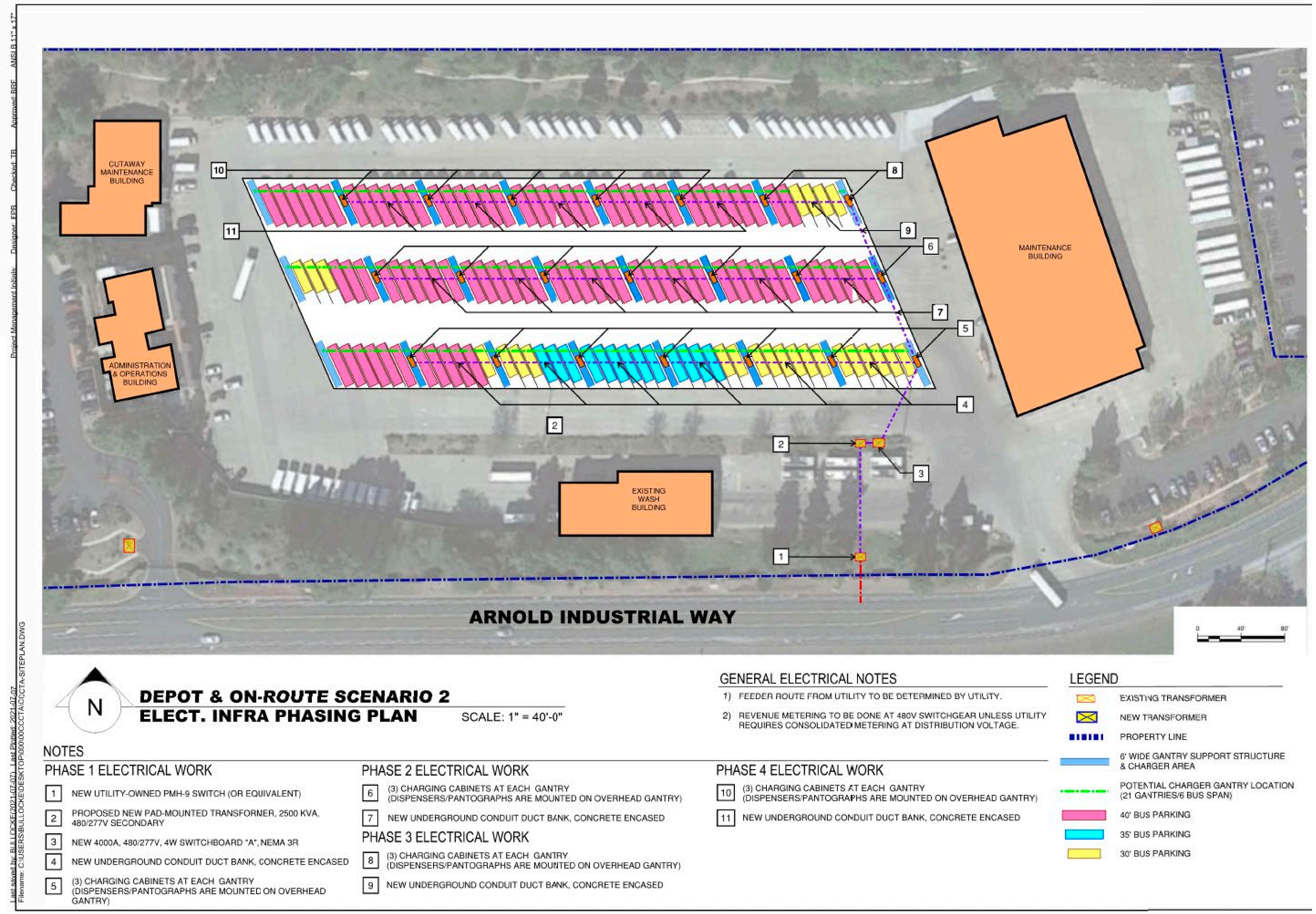
1. COUNTER-CLOCKWISE BUS CIRCULATION AROUND BUS PARKING BLOCK.
2. BYPASS LANE
3. 40' PARKING SLOTS FOR FUEL CELL BUSES (48 SPACES)
4. EXISTING CUTAWAY/PARATRANSIT BUS PARKING ROW TO REMAIN
5. YARD VEHICLE PARKING

BEB'S ADDED ANNUALLY BY DIVISION AND LENGTH						
DIVISION	BUS LENGTH	2029/30	2034	2037	2040	TOTAL
CCCTA	30	13			1	14
CCCTA	35	13				13
CCCTA	40		40	4	6	50
TOTAL		26	40	4	7	77

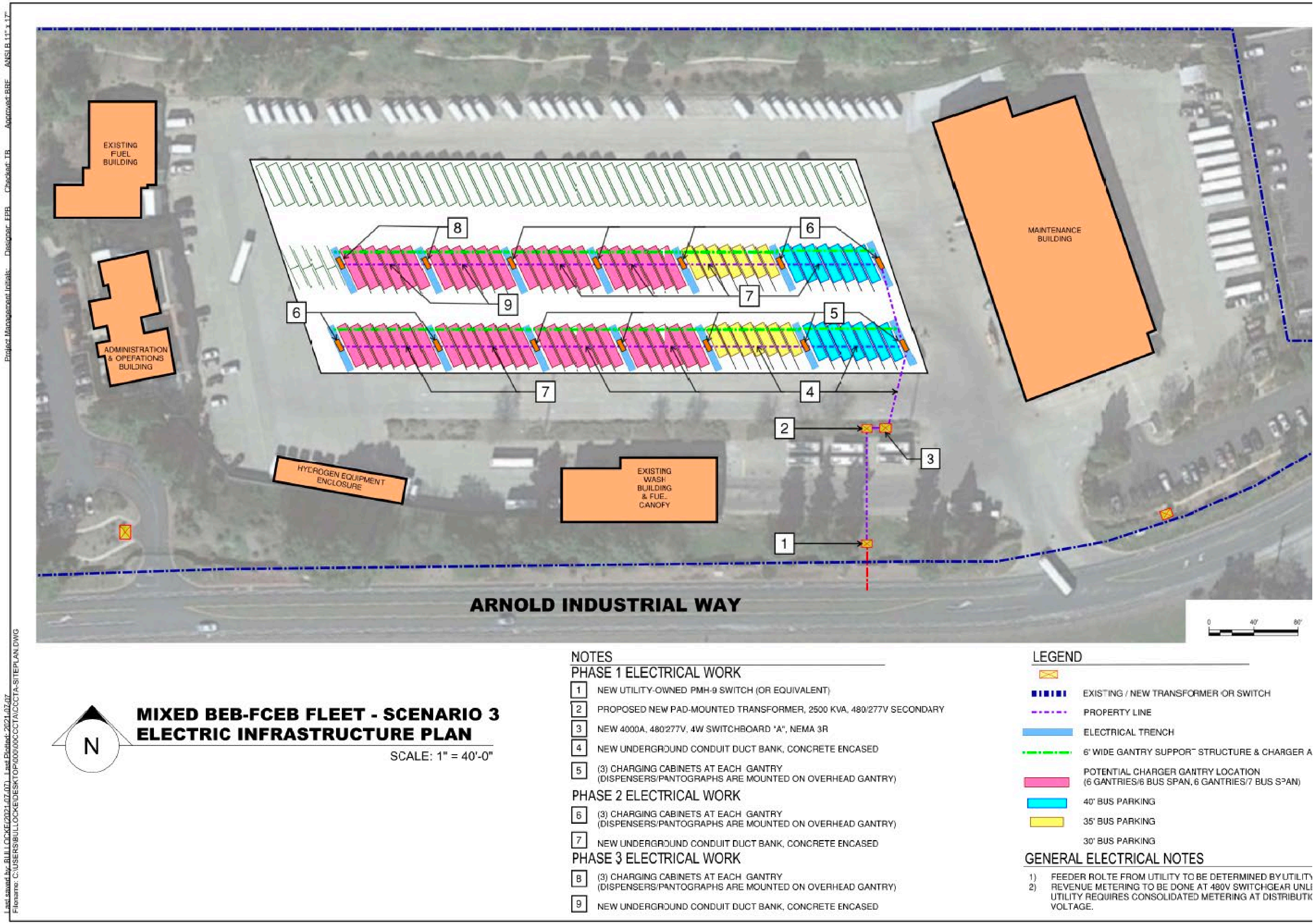
LEGEND

- EXISTING TRANSFORMER
- NEW TRANSFORMER
- PROPERTY LINE
- 6' WIDE GANTRY SUPPORT STRUCTURE & CHARGER AREA
- POTENTIAL CHARGER GANTRY LOCATION (6 GANTRIES/6 BUS SPAN, 6 GANTRIES/7 BUS SPAN)
- 40' BUS PARKING
- 35' BUS PARKING
- 30' BUS PARKING
- DIRECTION OF TRAFFIC

Appendix A9 – County Connection Depot and On-Route Charging Scenario, Electrical Infrastructure Phasing Plan

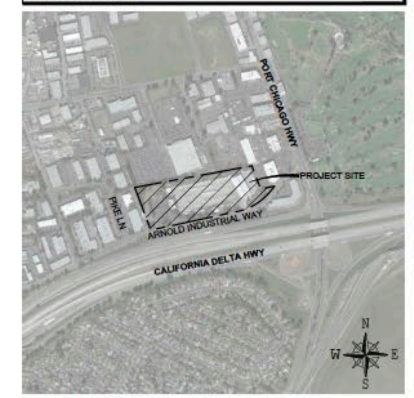


Appendix A10 – County Connection Mixed Fleet Charging Scenario, Electrical Infrastructure Phasing Plan



Appendix A11 – County Connection Mixed Fleet Charging Scenario, Fuel Cell Bus Infrastructure Phasing Plan

VICINITY MAP



SITE NOTES

(#) NOTE

EXISTING ITEMS
- 0.1 (E) ADMINISTRATION
- 0.2 (E) SERVICE ISLAND / BUS WASH
- 0.3 (E) MAINTENANCE BUILDING
- 0.4 (E) PLANTER
- 0.5 (E) UNDERGROUND TANKS
- 0.6 (E) STORAGE AREA
- 0.7 (E) TRASH ENCLOSURE
- 0.8 (E) WALL

NEW ITEMS
- 1.0 (N) HYDROGEN DISPENSER
- 1.1 (N) HYDROGEN EQUIPMENT COMPOUND
- 1.2 (N) OFFLOAD CABINET
- 1.3 (N) MOBILE FUELER

PARKING INFORMATION

	PHASE 1		PHASE 2	
	CAR	BUS	CAR	BUS
EXISTING REMOVED	0	-1	0	-14
PROPOSED	0	0	0	0
NET CHANGE	0	-1	0	-14

HYDROGEN EQUIPMENT INFORMATION

	PHASE 1	PHASE 2
TOTAL COMPOUND SIZE:	MOBILE FUELER 20' X 75'	25' X 121'
TOTAL # OF FUELING POSITION:	1	2
TOTAL # OF 15,000-GAL LH2 VESSELS	0	1

LEGEND

- PROPOSED PHASE 1 MOBILE FUELER
- PROPOSED PHASE 2 HYDROGEN COMPOUND
- PROPOSED PHASE 2 HYDROGEN DISPENSER
- PROPOSED PHASE 2 OFFLOAD CABINET
- PROPOSED VEHICLE PARKING SETBACK LINE
- APPROX. LOCATION OF PROPERTY LINE
- APPROX. LOCATION OF DISPENSING BUS
- APPROX. LOCATION OF OFFLOAD TRUCK

County Connection

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NO.	DATE	REVISION DESCRIPTION

DEVELOPMENT INFORMATION:

COUNTY CONNECTION
CENTRAL
CONTRA COSTA
TRANSIT AUTHORITY
(CCCTA)

SITE ADDRESS:

2477 ARNOLD INDUSTRIAL WAY
CONCORD, CA 94520

DESIGNED BY: KB	FG PM: PCF
CHECKED BY: TH	MEP PM: -
DRAWN BY: KB	CONSULTANT PM: -
DATE: 07/07/2021	PROJECT NO.: 16621

DRAWING TITLE:

PRELIMINARY
SITE PLAN
SCENARIO #3 - 48 FCEB

SHEET NO.:

SP-1A

Appendix A12 – County Connection FCEB Only Charging Scenario, Fuel Cell Bus Infrastructure Phasing Plan

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