Report No: 18-134
Meeting Date: June 27, 2018

Alameda-Contra Costa Transit District

STAFF REPORT

TO:	**AC Transit Board of Directors**
FROM:	**Michael A. Hursh, General Manager**
SUBJECT:	**Progress Report on the District's Study on ZEB Expansion and Facilities Assessment**

BRIEFING ITEM

RECOMMENDED ACTION(S):

Consider receiving a progress report on the District's study on ZEB expansion and facilities assessment.

BUDGETARY/FISCAL IMPACT:

There are no budgetary impacts associated with this report. However, enactment of the California Air Resources Board proposed Innovative Clean Transit Regulation could result in regulations requiring purchase of zero emission buses that may have an impact on the Capital and Operating budget.

BACKGROUND/RATIONALE:

The District has commissioned two related studies. This report provides an update on the vehicle technology study. A companion facility readiness study is also underway. An update on both reports will be presented at the August Board Workshop.

The California Air Resources Board (CARB) has indicated during public workshops of their intent to update transit bus emissions regulations with development of the proposed Innovative Clean Transit (ICT) Regulation requiring all public transit bus fleets to be zero emission by 2040. Subsequently, the District engaged the Center for Transportation & the Environment (CTE) in November 2017 to conduct an assessment of the applicability of Zero Emission Buses (ZEBs) for AC Transit service and to develop a strategy and plan to transition AC Transit to a zero emission fleet. The study's zero emission transition goal is to have a 100% zero emission fleet in place by 2040 to be in compliance with the Innovative Clean Transit Regulation proposed by CARB. The results of the study will be used to inform AC Transit Board members and educate staff of estimated cost, benefits, constraints, and risks to guide future planning and decisions.

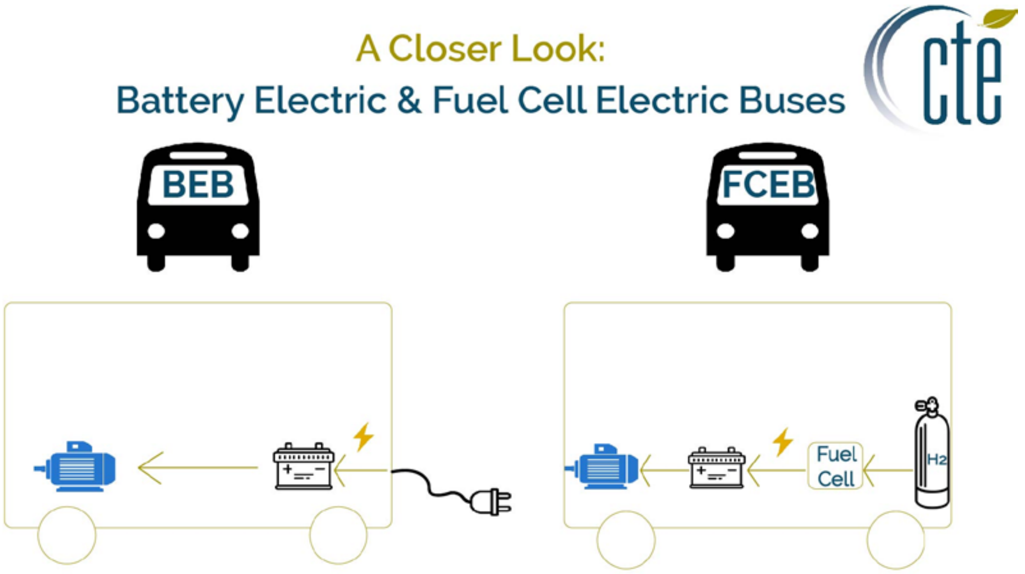
The underlying approach for the study is based on the creation and analysis of four scenarios:

1. No changes to current fleet composition (Baseline)
2. All Battery Electric Bus Fleet (All-BEB)
3. All Fuel Cell Electric Bus Fleet (All-FCEB)
4. Mixed Battery Electric Bus and Fuel Cell Electric Bus Fleet (Mixed-ZEB)

To date, CTE has completed a preliminary *Fleet Assessment* that analyzed the capabilities of current ZEB technologies to meet AC Transit service requirements under the All-BEB and All-FCEB scenarios. The analysis included an assessment of projected improvements in ZEB technology and impact on a potential ZEB procurement strategy consistent with AC Transit's fleet replacement plan. The Fleet Analysis also includes an assessment of projected fleet procurement cost and annual fuel costs over the transition lifetime.

ZEB Technology

Zero emission bus technologies range from battery-electric depot charge to battery-electric on-route fast charge (inductive and/or conductive) to hydrogen fuel cell-electric hybrid. Battery Electric Buses (BEB) and Fuel Cell Electric Buses (FCEB) have similar electric-drive systems that include a traction motor that is driven with electricity from a battery. The primary difference between BEBs and FCEBs is the amount of battery storage and how the batteries are recharged. The energy supply for a BEB comes from electricity provided by an external source, typically the local utility's grid, which is used to recharge the batteries. The energy supply for an FCEB is completely on-board where hydrogen is converted to electricity using a fuel cell. The electricity from the fuel cell is used to recharge the batteries. Illustrated below is the electric drive components and energy source for a BEB and FCEB.



Fleet Assessment

The first task in the Fleet Assessment is to develop route models and generic BEB models to run operating simulations on AC Transit routes. CTE uses Autonomie, a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE modified software parameters specifically for ZEBs to assess energy efficiencies, energy consumption, and range projections. Since ZEBs all share a common electric-drive architecture, we can use CTE's route modeling software to estimate the amount of energy required to power the traction motors for a given bus on a given route. Once energy requirements are known, we can calculate the amount of electricity needed from the grid to charge the batteries, or the amount of hydrogen needed to generate electricity through a fuel cell to charge the batteries.

A sampling approach was used to model in-service sample routes that are representative of all routes in the system with respect to topography and operating profile. The modeling results of the sample routes can then be applied to routes and blocks that share the same characteristics. Data was collected on the "V" trans-bay commuter route, as well as routes 54 and 73.

Route	Avg. Speed	Gross Elevation Gain	Route Category
V	23.3 mph	4,027	Transbay
54	11.4 mph	16,026	Hilly
73	11.2 mph	2,612	Flat


Route V Route 54 Route 73

The data from these routes, as well as the specifications for each type of generic electric-drive bus, (30-foot, 40-foot, 45-foot, and 60-foot) were inserted into CTE's modeling software to simulate operation of each type of bus on each type of route. As a result, the estimated nominal and strenuous energy efficiency for each type of bus and for each type of route was established:

Length (feet)	Route Category	Nominal Efficiency (kWh/mi)	Strenuous Efficiency (kWh/mi)
26	Flat	1.4	1.6
26	Hilly	1.5	1.7
26	Transbay	1.3	1.5
30	Flat	2.0	2.6
30	Hilly	2.1	2.5
30	Transbay	1.8	2.1
40	Flat	2.5	3.2
40	Hilly	2.6	3.6
40	Transbay	2.2	2.5
45	Flat	2.9	3.6
45	Hilly	3.1	3.8
45	Transbay	2.5	2.8
60	Flat	3.4	4.5
60	Hilly	3.4	4.9
60	Transbay	3.0	3.5

This information can be then used to calculate range and either grid energy or hydrogen requirements for battery electric and fuel cell electric buses, respectively.

As a result of the block analysis, it was determined that buses operating on 20% of AC Transit blocks could be replaced with battery electric buses on a 1:1 basis with a single overnight charge. We expect this percentage to improve over time as energy density increases with advancements in battery technology. In the event that an agency desires to place BEBs on routes where the range is less than block distance, they must: a) modify the block distance and duration, or b) use a 2:1 (or higher) replacement ratio and expand the fleet, or c) add on-route charging.

The following chart depicts the percentage of blocks where BEBs can be deployed on a 1:1 basis by bus length, based on range limitations of current BEB technologies. For example, 23% of blocks that are currently served by 40-foot buses can be served by 40-foot depot charged BEBs with a single overnight charge. The other 73% of the blocks served by current 40-foot buses would require modification to the block, or multiple BEBs to provide the same level of service.

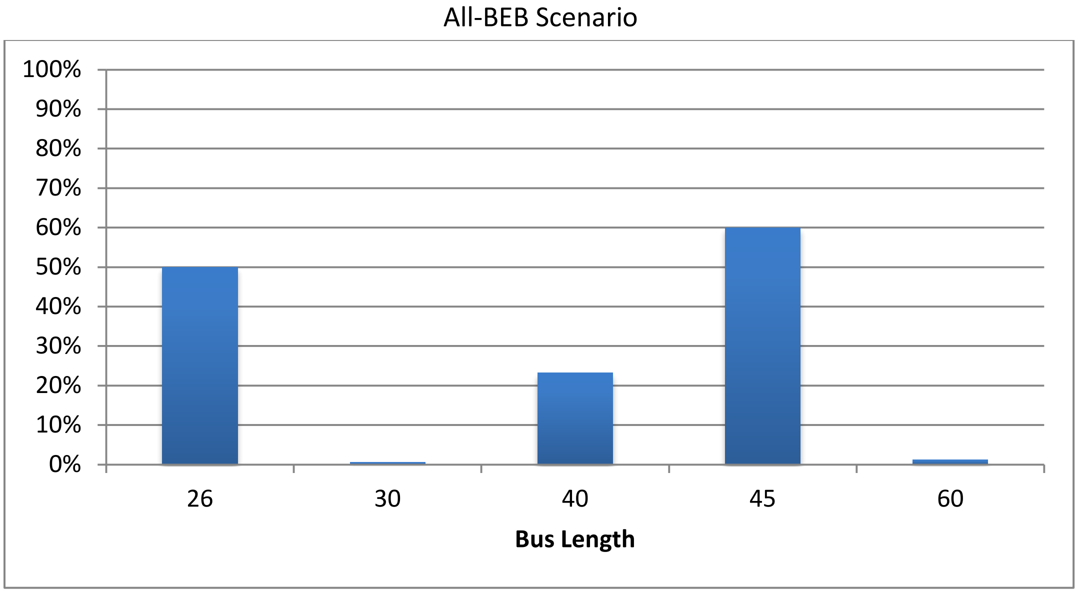


Figure 1: Percentage of AC Transit blocks where buses can be replaced 1:1 with BEBs, by bus length

BEBs are currently close to their limit for optimizing energy storage, passenger load, gross vehicle weight rating (GVWR), and axle weight ratings. However, battery density has improved by an average 5% per year. If this trend continues, we would expect that buses might carry more energy storage without increasing weight or limiting passenger loads. Over time, we can expect that BEBs may be deployed on an increasing number of routes.

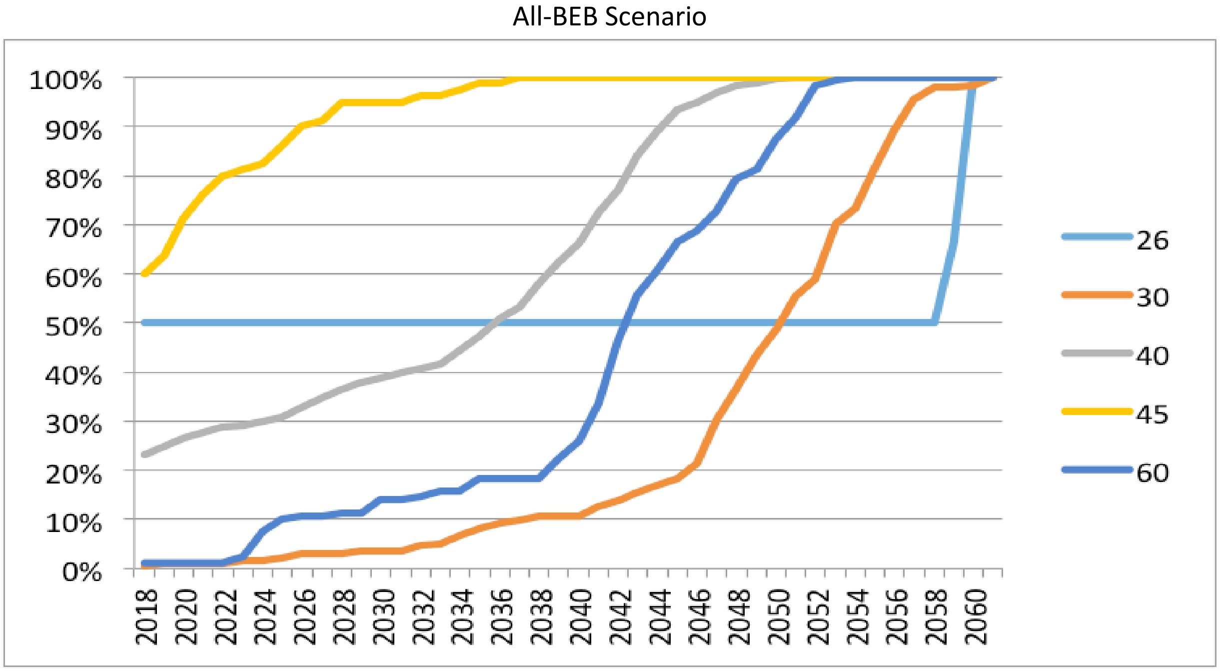


Figure 2: Percentage of AC Transit Routes where BEBs may be used on a 1:1 basis

Based on this analysis, the District should focus initial BEB procurements on 45-foot and 40-foot buses as these can be deployed on more blocks earlier in the transition life cycle. The ZEB transition plan shall consider the timing of expected range improvements to maintain a 1:1 replacement ratio.

It should be noted that BEB range is negatively impacted by battery degradation over time. A BEB may be placed in service on a given block with beginning-of-life batteries. However, it may not be able run the entire block at some point in the future before the batteries are at end-of-life. Conceptually, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding buses. The District can rotate the fleet to meet the demand assuming there is a steady procurement of BEBs each year to match service requirements. An alternative would be to replace the batteries strategically at some point during the mid-life of the BEB between 6-7 years.

FCEBs do not have the same range constraints as BEBs. 95% of all blocks can be served by FCEBs on a 1:1 replacement basis.

All-FCEB Scenario

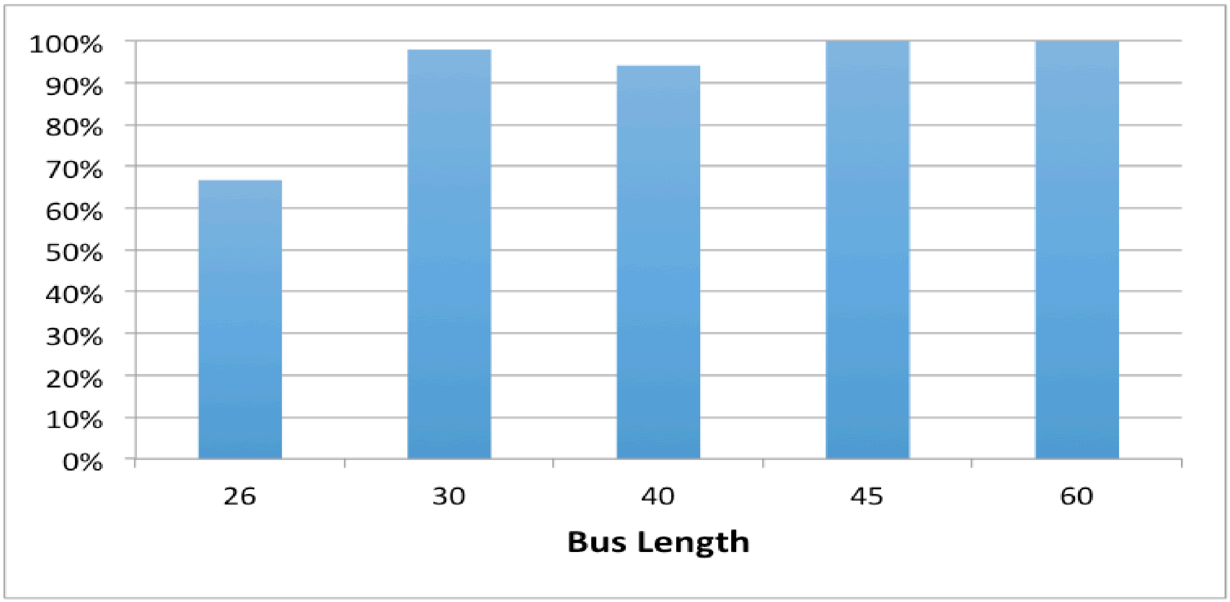


Figure 3: Percentage of AC Transit blocks where buses can be replaced 1:1 with BEBs, by bus length

Furthermore, improvements in hydrogen compression and storage technologies in the near future will easily allow for all routes to be served by FCEBs during the transition period. Staff worked with Linde, LLC to develop an improved hydrogen fuel station design that increases throughput and scales up capacity to fuel up to 30 buses back-to-back. Research in cryogenic pumping of hydrogen, improvements of hydrogen storage on vehicles and fuel dispensers are expected to be available on the market within the next five years. However, currently FCEBs, fueling infrastructure and hydrogen fuel is very expensive to purchase and operate. There has been a reduction in FCEB price since 2006 but fueling station and cost of hydrogen fuel continues to be more than twice as compared to diesel equivalent.

All-FCEB Scenario

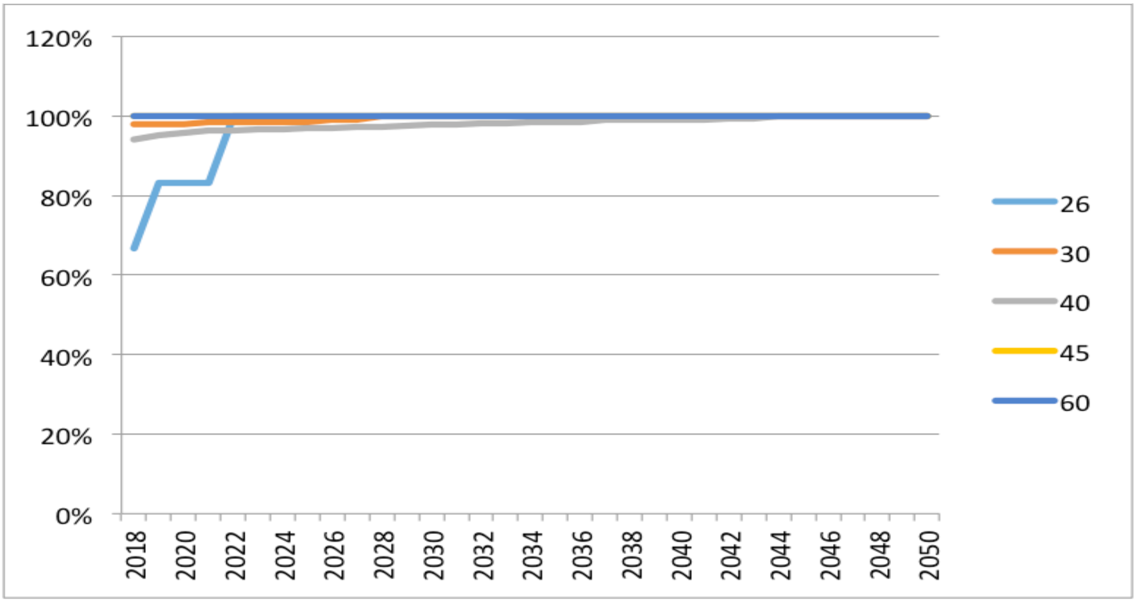


Figure 4: Percentage of AC Transit Routes where FCEBs may be used on a 1:1 basis, by year

Vehicle Purchase Costs

When considering conversion to an all zero emission fleet vehicle purchases and support infrastructure costs are a concern. The most recent pricing for a FCEB is $1.2M. Most recent data for BEB purchases range from $750K to $900K. In addition to vehicle costs the fueling infrastructure for FCEBs is estimated to be $4M to $6M per facility. Costs for charging infrastructure are difficult to ascertain as civil work and availability of electrical distribution network vary widely. More information will be presented in the facility study.

CARB's Innovative Clean Transit Regulation

While CARB's proposed Innovative Clean Transit (ICT) Regulation has not been adopted and is subject to change, it was used to guide a ZEB transition procurement strategy. AC Transit's fleet exceeds 100 buses. As a result, all new bus purchases must include a specified percentage of ZEBs in accordance with the following schedule.

Starting	Percent of Bus Purchases
2020	25%
2023	50%
2026	75%
2029	100%

Any ZEBs purchased prior to 2020 earns a purchase credit that may be used against future compliance requirements. In addition to purchase credits, AC Transit shall earn bonus credits for early adoption of ZEBs according to the following schedule. These credits may also be used to meet ZEB percentages for new procurements.

Technology	Placed in Service	Bonus ZEB Credit
FCEB	January 1, 2018 to January 1, 2023	1
BEB	Before December 31, 2017*	1
FCEB	Before December 31, 2017*	2

As a result of AC Transit's previous ZEB procurements, AC Transit may have up to 64 credits to apply to future procurements.

Procurement	Purchase Credit	Bonus Credit	Total Credits
2013 Van Hool FCEB	13	26	39
2018 New Flyer FCEB	10	10	20
2018 New Flyer BEB	5		5
Totals	**28**	**36**	**64**

Transition Plan

AC Transit's ZEB Transition Plan is based on the following assumptions:

- 100% Zero Emission Fleet by 2040
- Compliance with CARB's Innovative Clean Transit Regulation
- 14-year replacement schedule on 30-foot to 60-foot buses.
- 630-bus fleet remains constant through the transition period
- Service levels remain constant through the transition period
- Account for currently planned procurements

The following chart depicts the annual fleet composition resulting from the preliminary transition plan for the All-BEB scenario. Note that BEB procurements are deferred to later years as a result of the ICT purchase and bonus credits.

All-BEB Scenario

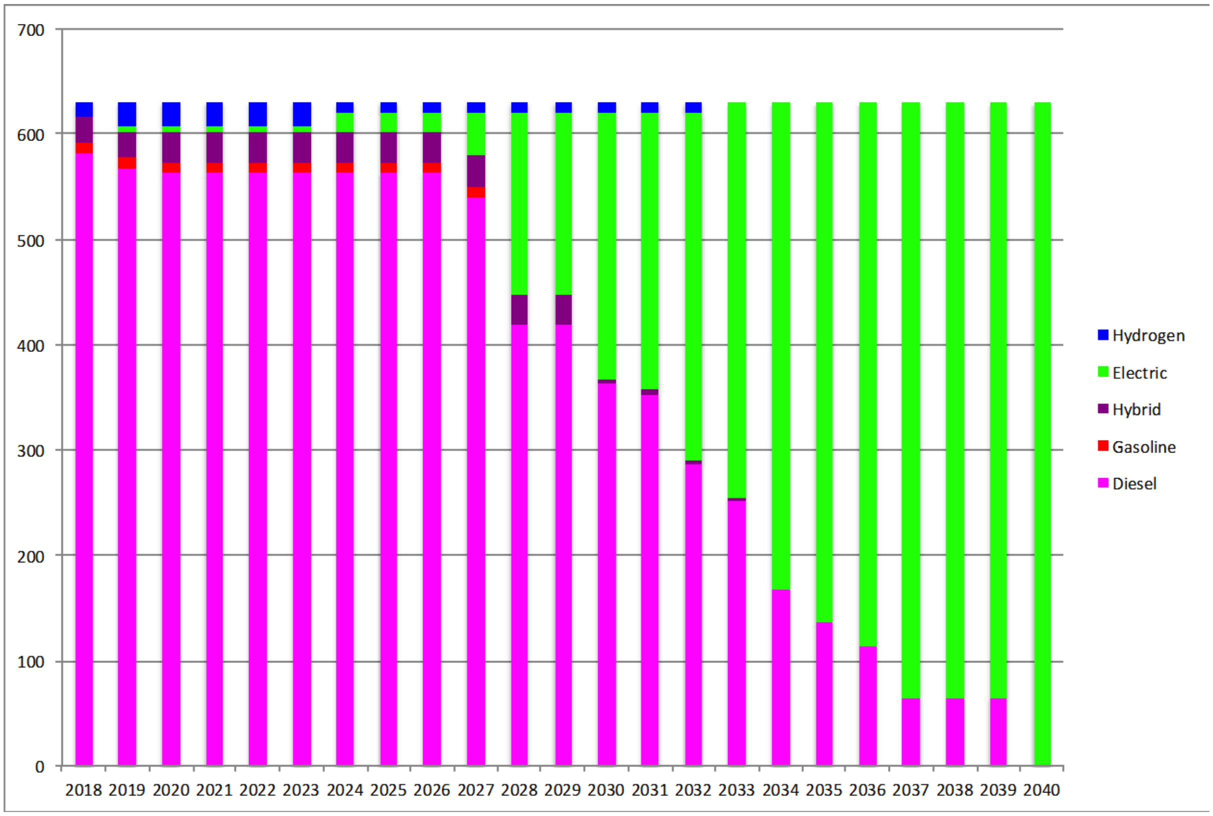


Figure 5: Fleet Composition using All-BEB Scenario Transition Plan

The following chart depicts the annual fleet composition resulting from the preliminary transition plan for the All-FCEB scenario. Note that FCEB procurements are deferred to later years as a result of the ICT purchase and bonus credits.

All-FCEB Scenario

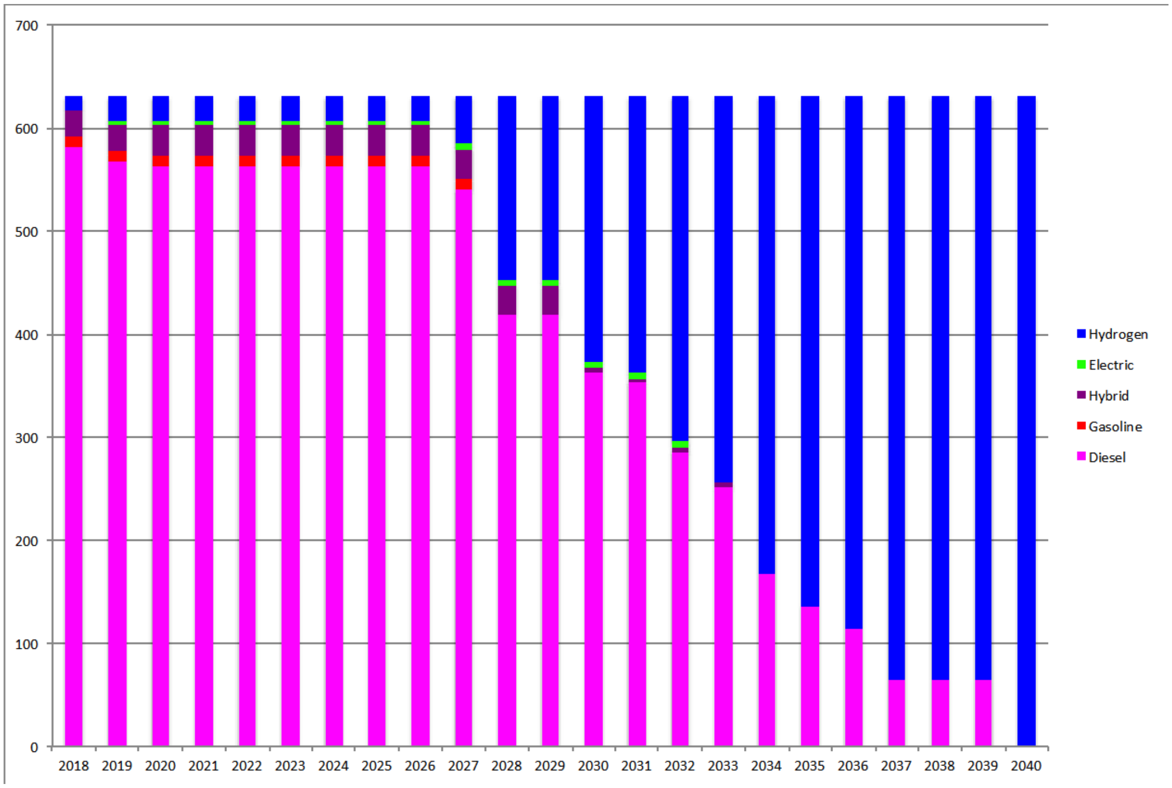


Figure 6: Fleet Composition using All-BEB Scenario Transition Plan

Next Steps

The next phase of the AC Transit ZEB Study is to focus on the *Facilities Assessment*. The facilities team has been provided with estimates of total electricity and hydrogen consumption on which they can use to estimate equipment and space requirements. The ZEB Study team has been coordinating with the Facilities Utilization Plan team (led by WSP) in determining site requirements, cost and phasing. The Facilities Utilization Plan will incorporate infrastructure needs identified by the ZEB Study in short- and long-term facilities utilization strategies.

Once the facilities assessment is complete, the team will refine the transition plan to coordinate fleet procurements and facility upgrade projects, then assemble costs and benefit profiles associated with each transition project. The team will then weigh cost, benefits, and constraints to establish the final Mixed-ZEB scenario. This will include capital cost, operations and maintenance cost and remaining unaddressed challenges with scaling up each technology.

The final results of this analysis will be presented to the AC Transit Board of Directors to better inform their decision making on the transition to a zero emission bus fleet.

ADVANTAGES/DISADVANTAGES:

The advantages of this analysis are to identify the economic costs, performance issues, risks, and recommended timeline associated with transition to a zero emission transit bus fleet. The analysis will consider financial and operational impacts of various zero emission transit bus technologies that are considered commercially available during the time period of this study. The results of this analysis will inform AC Transit decision making in the areas of policy, procurement and technology.

Staff could not identify a disadvantage with this report.

ALTERNATIVES ANALYSIS:

This report does not recommend an alternative analysis.

PRIOR RELEVANT BOARD ACTION/POLICIES:

16-072 Zero Emissions Meeting Report

15-017 Update on Zero Emission Bus Technologies

14-013 Update on the Status of AC Transit's Fuel Cell Program and Discussion of Path Forward for Zero Emission Bus Procurements

ATTACHMENTS:

None

Approved by: Salvador Llamas, Chief Operating Officer
Reviewed by: Ramakrishna Pochiraju, Executive Director of Planning & Engineering
Mika Miyasato, Senior Transportation Planner
Prepared by: Salvador Llamas, Chief Operating Officer