February 13, 2025

To: Transit Committee

From: Darrell E. Johnson, Chief Executive Officer

Subject: Zero-Emission Bus Program Update

Overview

The Orange County Transportation Authority Board of Directors approved the purchase of zero-emission buses and infrastructure to gain necessary operational and technological experience in preparation for transitioning the Orange County Transportation Authority's bus fleet to zero-emission technologies. This report provides an update on the zero-emission bus program performance and deployment efforts.

Recommendation

Receive and file as an information item.

Background

In 2018, the California Air Resources Board (CARB) passed the Innovative Clean Transit (ICT) rule requiring all public transit agencies to transition their bus fleets to zero-emission technologies by the year 2040. Transit agencies were required to develop and submit a rollout plan that describes how the agency will transition to a zero-emission bus (ZEB) fleet by 2040, with purchasing requirements beginning in 2023. In June 2020, the Orange County Transportation Authority (OCTA) Board of Directors (Board) approved the OCTA ZEB Rollout Plan, which included the deployment of a mix of hydrogen fuel-cell electric buses (FCEB) and battery-electric buses (BEB) to prepare for compliance with the ICT rule.

In anticipation of the ICT rule, OCTA developed a strategy to pilot both FCEB and BEB technologies using available grant funding. Piloting both technologies allows OCTA to gain direct experience with operational effectiveness, maintenance, and cost. In 2017, OCTA entered into an agreement to utilize grants provided by CARB and the South Coast Air Quality Management District to purchase ten

FCEBs in lieu of compressed natural gas (CNG)-powered buses to replace buses that had reached their useful life. The grant also funded the required supporting infrastructure, including the hydrogen fueling station and maintenance shop upgrades.

On February 9, 2020, OCTA initiated the FCEB pilot, which included ten, 40-foot FCEBs operating in OC Bus fixed-route service, and a hydrogen fueling station, located at the Santa Ana Bus Base, capable of fueling up to 50 buses per day.

On October 12, 2020, the Board approved the purchase of ten plug-in BEBs as a pilot for operation in OC Bus fixed-route service. To support the charging of these vehicles, OCTA partnered with Southern California Edison (SCE) and the Charge Ready Transport Program to provide electrical infrastructure at the Garden Grove Bus Base. In addition to the equipment being provided by SCE, OCTA provided the BEB charging stations.

On June 14, 2021, the Board approved the purchase of ten, 150-kilowatt (kW) BEB charging stations that provide power to ten depot charging stations. The chargers can supply power evenly or sequentially to the charging stations. This allows buses to be intelligently charged in a manner tailored to the power and logistical needs of each bus. BEBs can be fully charged in less than four hours. However, the chargers were not fully operational until December 2023, due to delays from SCE completing the infrastructure upgrades required to install ten BEB charging stations and equipment issues. During the commissioning and testing of the charging stations, certain equipment components were identified as having water corrosion. Due to the high voltage and risk of malfunctioning, the charging station manufacturer recommended replacing the effected components. The charging stations were connected, energized, and made operational immediately following the component replacement and SCE upgrades. Prior to the installation of dedicated charging stations, the BEBs were charged using pay-per-use level III charging stations located at both directly operated bases. This resulted in BEBs taking longer to charge limiting bus usage to four buses per day.

The first two BEBs arrived in December 2021. After acceptance testing and working through supply chain issues, the buses went into OC Bus fixed-route service in July 2022. The remaining eight buses arrived in December 2022. Delays in receiving the remaining eight BEBs were related to electronic parts shortages and other supply chain issues.

On June 24, 2024, the Board approved the purchase of ten battery-electric paratransit vans that will replace ten gasoline OC ACCESS cutaway buses. OCTA applied for and was awarded funding through a competitive FTA grant

program. Ten battery-electric vans and charging equipment are on order and expected to arrive in July 2025.

On November 14, 2024, the OCTA Board approved the purchase of an additional 40 FCEBs, ten BEBs, and battery chargers to accelerate the operational and technological experience necessary to operate and maintain a ZEB fleet. In addition, the 50 ZEBs in this procurement will replace compressed natural gas buses that have met their useful life, moving OCTA closer to converting the bus fleet to 100 percent zero-emission.

Discussion

The ten FCEBs have been in service for five years and all ten BEBs have been deployed consistently for two years. The performance data included in this report covers the period beginning February 2020 through December 2024. The performance of the ten FCEBs and ten BEBs is measured against the performance of ten CNG buses that were selected during the onset of the pilot to provide comparative performance analytics. General vehicle information on all three bus types is provided in the following chart.

Vehicle Information	CNG Bus	FCEB	BEB
Number of Buses	10	10	10
Manufacturer/Model	New Flyer Xcelsior	New Flyer Xcelsior	New Flyer Xcelsior
Model Year	2016	2018	2020
Deployment Date	Aug-18	Feb-20	Dec-22
Bus Purchase Price	$580,000	$1.3M	$1.1M
Length	40-foot	40-foot	40-foot
Curb Weight	30,000 pounds	33,560 pounds	33,500 pounds
Propulsion System	CNG Engine 280 hp (209 kW)	Electric Motor 210 kW	Electric Motor 210 kW
	Transmission	Fuel Cell 85 kW	
Energy Storage	Six Composite Fuel Cylinders	Five Composite Fuel Cylinders	
		Lithium-ion Batteries 100 kW	Lithium-ion Batteries 440kW
Total Operating Range	400 miles	300 miles	200 miles
Usable Operating Range	350 miles	250 miles	150 miles

The key performance indicators for the pilot include bus availability, miles between road calls (MBRC), fuel economy, and cost per mile (CPM).

Bus availability, which is a measure of reliability, is the percentage of days the buses are available compared to the total number of days that the buses are planned for revenue service. Buses available for service may be used in revenue service, training, special events, or they may be available but not used. Buses unavailable for service may have had mechanical issues with the propulsion system (fuel-cell system, electric drive system, engine), regularly scheduled maintenance, or required unscheduled repairs.

The OCTA performance standard for bus availability is 80 percent. However, for new bus technology, availability can be challenging as the system issues are analyzed and buses are out of service for a longer period. For 2024, both the FCEBs and BEBs fell below the target at 49 percent and 58 percent respectively, while CNG buses achieved the goal at 84 percent.

The FCEBs did not achieve the goal mainly due to electrical issues. The FCEBs dropped from 52 percent availability in 2023 to 49 percent availability in 2024. Most of the downtime was related to unscheduled maintenance due to batteries and electrical management systems. In addition, supply chain issues continue to heavily impact FCEB availability. It has become common to see FCEBs out of service for 60-100 days at a time waiting for parts. In one case, a bus was out of service waiting for parts for over one year.

The BEBs also dropped in availability, achieving 58 percent availability in 2024, down from 66 percent in 2023. The BEBs have also experienced electrical issues and long wait times for parts. A replacement battery pack currently has a lead time of 135 days.

MBRC is a measurement of bus reliability. A road call is defined as a revenue vehicle mechanical or system failure that causes the bus to be replaced in route or causes a significant delay in the bus schedule.

The OCTA performance standard for MBRC is 14,000 miles. The ten CNG buses exceeded the goal in 2024, achieving 20,964 MBRC. This improvement over 2023 is primarily due to completing a scheduled mid-life overhaul, which included replacing the engine.

The FCEBs did not meet the standard, achieving 8,399 MBRC in 2024. However, this is an improvement over 2023 with only 4,717 MBRC. Taking into consideration that this is new technology and only 30 FCEBs were built by this manufacturer at the time of delivery, peak performance may not yet be realized. However, the MBRCs appear to be in line with other agencies operating FCEBs.

Most of the road failures are related to electrical components, such as batteries and electrical management system failures. In terms of the fuel cell performance, it is performing well but showing signs of degradation, which will require overhauls to return to peak performance.

The BEBs also did not meet the standard, achieving 4,923 MBRC in 2024. This is a slight improvement over 2023 with 4,593 MBRC. The BEBs are experiencing a variety of issues but primarily battery-related, such as battery failures and electrical management system failures.

Fuel economy is a measurement of how efficiently the fuel is being used by the propulsion system. Because CNG is measured in Therms, hydrogen is measured in kilograms, and battery power in kW, fuel types are converted to a common measurement. In this case, all three technologies are measured in miles per diesel gallon equivalent (mpdge). CNG buses are averaging 3.19 mpdge. The FCEBs are averaging 7.57 mpdge which is a decrease from 2023 at 8.92 mpdge. This is related to fuel cell degradation causing the bus to consume more fuel to meet the electrical demands of the batteries. The BEBs are achieving the highest mpdge with an average of 18.14 mpdge. This is a slight decrease from 2023 at 18.71 mpdge.

OCTA calculates total CPM for each technology by tracking parts and labor and fuel cost. CPM is used due to being the lowest common denominator. Assigning a daily, weekly, or monthly cost value can vary due to buses being assigned to various routes with varying miles.

The parts and labor CPM for FCEBs remained close to the previous year at $1.30 in 2024 versus $1.25 in 2023. The BEBs increased in 2024 to $1.26 versus $0.83 in 2023. The primary reasons for the increase are related to the buses being out of warranty and increasing parts cost. The CNG buses had a lower CPM in parts and labor in 2024 at $0.99 compared to 2023 at $1.65. CPM in 2023 was much higher due to the mid-life overhaul project. Costs are expected to decrease after a mid-life overhaul and did so in this case.

FCEB fuel costs increased slightly from 2023 to 2024 due to cost increases in the option year of the hydrogen fueling station agreement. The cost of hydrogen increased from $9.16/kg to $9.44/kg resulting in an increase in the CPM from $1.16 in 2023 to $1.23 in 2024. BEB fuel cost (electricity cost) decreased from $0.41 in 2023 to $0.32 in 2024 due to completing the installation of bus depot chargers which provide access to energy management tools that optimize energy use. It is important to note that with electricity, cost is based on kW usage, and due to current rate structures, as that usage increases the cost per kW also increases, which will affect the CPM. CNG CPM increased from $0.28 in 2023

to $0.37 in 2024 due to price increases in renewable natural gas and electricity rates.

Total CPM includes combining parts, labor, and fuel costs. The total CPM for FCEBs increased slightly from $2.41 in 2023 to $2.53 in 2024 due to cost increases in all areas. The total CPM for BEBs also increased from $1.23 in 2023 to $1.58 in 2024 primarily due to parts and labor cost increases. Finally, the total CPM for CNG buses decreased from $1.93 in 2023 to $1.37 in 2024 primarily due to completing the mid-life overhaul project. A summary of the CPM trends for the three technologies is provided in the table below:

Cost Per Mile (CPM)	**FCEB**			**BEB**			**CNG**		
Year Over Year Comparison	2024	2023	Trend	2024	2023	Trend	2024	2023	Trend
CPM - Parts and Labor	$1.30	$1.25	▲	$1.26	$0.83	▲	$0.99	$1.65	▼
CPM - Fuel Costs	$1.23	$1.16	▲	$0.32	$0.41	▼	$0.37	$0.28	▲
CPM Total	$2.53	$2.41	▲	$1.58	$1.23	▲	$1.37	$1.93	▼

Infrastructure Update

The hydrogen fueling station has performed consistently well in 2024, matching the performance of the CNG fueling station. Monthly meetings with the fueling station provider are held to ensure maintenance activities are discussed and resolved immediately. Although the hydrogen fueling station is performing well, there are rare occasions when the station is out of service resulting in FCEBs not being fueled and not deployed into service. The CNG fueling station also goes down at times; however, fueling can be accomplished by sending buses to another base. Currently there is no backup hydrogen fueling infrastructure, public or private, that can accommodate OCTA's fuel demand; however, on January 13, 2025, the Board approved the Release of Request for Proposals for Design-Build of Hydrogen Fueling Station and Facility Modifications at Garden Grove Bus Base. This second hydrogen fueling station will provide the infrastructure redundancy needed to deploy larger FCEBs more consistently.

The battery charging stations located at the Garden Grove Base are fully installed and operate reliably. The energy management software provides a means to control when buses will be charged, reducing the fuel (energy) cost to operate BEBs.

On November 14, 2024, the Board approved the purchase of additional depot battery charging stations to be located at the Santa Ana Base to accommodate additional BEBs on order. Having charging stations at both directly operated bases provides infrastructure redundancy in the event of a power outage and flexibility to deploy BEBs throughout Orange County.

Summary

After five years of operating FCEBs and more than two years of operating BEBs, much has been gained in terms of knowledge and experience with buses and infrastructure. Although the performance of the ZEBs does not match the performance of CNG buses, there is a greater understanding of the differences between the technologies, which components need improvement to become more reliable, and how to build a sustainable fueling infrastructure. Understanding the various costs to operate and maintain ZEBs helps drive financial planning and advocacy for funding and lowering costs, such as the need to find solutions to lower the cost of hydrogen fuel and building electricity infrastructure.

The next steps in OCTA's ZEB program are to complete the procurement for 40 additional FCEBs, ten additional BEBs, and ten battery-electric vans for paratransit service, as well as complete procurements to install a second hydrogen fueling station and additional charging stations to support the ZEB fleets. In addition, procurement for six 60-foot FCEBs will be initiated later this year. Staff will continue to provide updates to the Board on the performance of the ZEB fleet and of any changes to the ZEB Program.

Attachment

None.

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