February 8, 2024

To: Transit Committee

From: Darrell E. Johnson, Chief Executive Officer

Subject: Zero-Emission Bus Pilot Update

Overview

On October 8, 2020, the Orange County Transportation Authority Board of Directors approved the purchase of ten hydrogen fuel-cell electric buses and ten plug-in battery-electric buses 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 pilot 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. On June 22, 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 plug-in 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 will allow OCTA to gain direct experience with operational effectiveness, maintenance, and cost. OCTA has initiated pilots using both technologies, discussed herein. 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 is partnering 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 is required to provide the BEB charging stations.

On June 14, 2021, the Board approved the purchase of ten, 150-kilowatt (kW) BEB charging stations that will 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.

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.

In December 2023, SCE completed the infrastructure upgrades required to install ten BEB charging stations. The charging stations were connected, energized, and made operational immediately following the SCE upgrades. However, 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 requires replacing the affected components to maintain the warranty. The procurement of replacement components is being expedited and the charging stations are expected to be operational in February 2024. In the interim, the BEBs are being charged using pay-per-use level III charging stations, designed to charge light-duty vehicles, installed at both directly-operated bus bases. This results in BEBs taking longer to charge limiting bus usage to four buses per day.

On August 16, 2022, the Federal Transit Administration (FTA) awarded OCTA $2.5 million in federal funding toward the purchase of ten battery-electric paratransit buses that will replace ten gasoline OC ACCESS cutaway buses. OCTA applied for and was awarded this funding through a competitive FTA grant program.

Discussion

The FCEBs have been in service for four years and the BEBs have been deployed sporadically for the last 18 months due to delays in infrastructure upgrades. The performance data included in this report covers the period beginning February 2020 through December 2023 (46 months). 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	FCEB	BEB	CNG
Number of Buses	10	10	10
Manufacturer/Model	New Flyer Xcelsior	New Flyer Xcelsior	New Flyer Xcelsior
Model Year	2018	2020	2016
Bus Cost Each	$1.3M	$1.1M	$580,000
Length	40 feet	40 feet	40 feet
Curb Weight	33,560 pounds	33,500 pounds	30,000 pounds
Propulsion System	Ballard Fuel Cell 85 kW	Siemens Electric Motor 210 kW	Cummins CNG Engine 280 hp
	Siemens Electric Motor 210 kW		Allison Transmission
Energy Storage	Five Composite Fuel Cylinders		Six Composite Fuel Cylinders
	Lithium-Ion Batteries 100 kW	Lithium-Ion Batteries 440kW	
Operating Range	300 miles	200 miles	400 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), regular scheduled maintenance, or required unscheduled repairs.

The OCTA performance standard for bus availability is 80 percent. However, for new bus technology, especially during a pilot, availability can be challenging as the system issues are analyzed and buses are out of service for a longer period. For 2023, both the FCEBs and BEBs fell below the target at 52 percent and 66 percent respectively, while CNG buses fell just below the goal at 78 percent.

The FCEBs did not achieve the goal mainly due to electrical issues. The FCEBs dropped slightly from 55 percent availability in 2022 to 52 percent availability in 2023. Most of the downtime was related to unscheduled maintenance related to batteries and electrical management systems. In addition, a growing number of supply chain issues heavily impacted the FCEB availability. It has become common to see FCEBs out of service for 60-100 days at a time waiting for parts.

The BEBs achieved 66 percent availability in the last year. The BEBs have also experienced electrical issues and long wait times for parts. As of this report, a replacement battery pack 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 declined in reliability as expected due to the engine and transmission reaching their end of useful life. A mid-life overhaul is scheduled for each of these buses, consistent with OCTA maintenance practices. Once the mid-life overhaul is completed, MBRCs are expected to improve. Last year, the CNG buses achieved 12,844 MBRCs but the average over the last four years remains above the goal at 24,581.

The FCEBs did not meet the standard, achieving only 4,717 MBRCs. 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.

In the early months of the pilot there were a variety of issues including software and calibration issues, but more recently most of the road failures are related to electrical components, like battery and electrical management system failures. In terms of the fuel cell performance, it is performing very well, and very little maintenance is required.

The BEBs also did not meet the standard, achieving 4,593 MBRCs. The BEBs are experiencing a variety of issues as expected for a bus under two years old, but the primary issues are 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 3.91 mpdge, while FCEBs have more than doubled that with an average of 8.92 mpdge. The BEBs are achieving the highest mpdge with an average of 17.05 mpdge.

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

The parts and labor CPM for FCEBs increased in 2023, exceeding that of CNG for the first time since the pilot began. The primary reasons for the increase are related to the buses being out of warranty and increasing parts cost. The parts and labor CPM for FCEBs is currently $1.84, compared to $1.65 for CNG buses. The BEB had a lower cost than both FCEBs and CNG buses at $1.40, bearing in mind that these buses have been in service for less than two years.

FCEB fuel cost significantly increased from 2022 to 2023 by 131 percent due to cost increases in the option year of the hydrogen fueling station operations and maintenance (O&M) agreement. O&M and the leasing of certain equipment was included in the first three years of the hydrogen fueling station agreement. In 2023, the first option year was exercised triggering a $300,000 annual O&M cost and $51,000 leasing cost. These costs were combined with the cost of liquid hydrogen fuel and estimated cost of electricity usage totaling $2.50 CPM. CNG CPM decreased from 2022 to 2023 by 64 percent mainly due to lower cost for renewable natural gas. CNG CPM in 2022 was $0.79, in 2023 $0.28. BEB remained steady at $0.41 CPM. However, 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. The BEB fuel CPM is expected to increase when all ten buses are in service.

Combining parts and labor cost and fuel cost results in the FCEB total CPM increasing 101 percent from 2022 to 2023. The total CPM in 2023 for the FCEB is $4.34, compared to CNG bus at $1.93, and BEB at $1.80. Since BEBs share many of the same components with the FCEBs and electricity rates will increase with increased usage, the BEB CPM is expected to increase.

Hydrogen Fuel Station Update

For the last two years, the hydrogen fueling station has performed consistently well, matching the performance of the CNG fueling station. Monthly meetings with the fueling station provider are held to ensure incidents are discussed and resolved immediately. Although the hydrogen fueling station is performing well, there are times when the station is out of service resulting in buses 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 fueling infrastructure, public or private, available for hydrogen. OCTA has plans to build a second hydrogen fueling station that will provide the infrastructure resiliency needed to ensure fuel is available for FCEB deployments and will support a larger fleet.

Summary

After four years, much has been gained in terms of knowledge and experience from the ZEB pilot program. Although the performance of the ZEBs does not match the performance of the CNG buses, there is a greater understanding of the differences between the technologies, what components need improvement to improve reliability, and where training can be developed to help mitigate issues. 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 electricity infrastructure.

The next steps are to expand the ZEB pilot program by procuring 40 additional FCEBs, ten additional BEBs, and ten battery-electric vans for paratransit service. This will require additional infrastructure, which will include procuring a second hydrogen fuel station, ten additional BEB charging stations, and charging stations for the battery-electric vans. The pilot expansion will allow OCTA to accelerate its operational and technological experience to shape and define the fleet mix required to meet the service demands of Orange County when utilizing ZEBs as well as move closer to transitioning the fleet to 100 percent zero-emission. Staff will continue to provide updates to the Board on the performance of the ZEB fleet and of any changes to the ZEB Pilot Program.

Attachment

None.

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