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TO: BOARD OF DIRECTORS

THROUGH: PHILLIP A. WASHINGTON PAW
CHIEF EXECUTIVE OFFICER

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SUBJECT: BOARD QUESTIONS REGARDING BATTERY ELECTRIC BUSES

ISSUE

At the October 27, 2016 Meeting of Metro's Board of Directors, staff was asked to respond to several questions regarding zero emission battery electric buses, electric batteries and other related topics.

The attached Electric Bus Program – Technology Overview document responds to the questions asked at Metro's Board Meeting, and includes responses that were compiled by both Metro staff and Ramboll/Environ, Metro's outside technical consultant.

This will be a "Living" document that is periodically updated to reflect new information about battery electric technologies and Metro's battery electric bus program.

Electric Bus Program – Technology Overview

November 15, 2016

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1) Electric Battery Bus Equipment and Technology

Buses:

- There are several USA based bus manufacturers selling 40' and 60' battery electric buses that are suitable for operation at LA Metro. Metro currently has an RFP (OP-28367) that was issued in July 2016, and includes options to purchase up to two hundred (200) 40' and 60' all electric zero emission buses (ZEB) for delivery between 2018-2022.

Battery Technologies:

- There are several manufacturers of advanced batteries that are suitable for transit applications. Battery technology is evolving very rapidly in terms of both cost and energy density. Metro's technical consultant projects that battery buses will have life cycle costs similar to CNG buses by the mid 2020's.
  Metro operates buses for approximately14 – 15 years. Several battery bus manufacturers now offer 12 year battery warranties, while other manufacturers offer a 5 year warranty and continue to recommend mid-life battery replacement.

2) Facilities & Infrastructure

En-Route Charging:

- For Metro's Orange and Silver Lines, the recommended approach is to use "En-route" or "Opportunity" charging stations that allow sustained daily operation without interrupting service for midday charging. This is similar to the approach used by Foothill Transit and others. En-route charging is a proven technology, uses Off-the-shelf systems and components, and is commercially available today. This technology approach is especially well suitable for fixed route BRT operations (i.e. Metro's Orange and Silver Lines).
- While en-route charging technology is well suited for fixed route BRT lines (such as Orange and Silver Lines), it is less flexible and not as well suited to broader application across multiple bus lines (e.g. Metro's Local and Rapid Services). In the future, the combination of lower cost batteries, better battery energy density, and lower cost charging systems should make battery electric buses more viable for use across more of Metro's Local and Rapid Bus routes.
- Division 8 (Chatsworth), Division 9 (El Monte), and Division 18 (Carson), the three divisions that serve the Orange and Silver BRT lines, all currently have capacity and equipment needed to handle these new electric buses. Several "Shop Chargers," lower voltage charging systems that can provide an option to charge buses slowly (i.e. overnight charging), will be installed at bus operating divisions, but there are no

other facility changes expected for operating electric buses at Metro operating divisions.

3) Maintenance and Training

Training:

- Although we expect to rely on the battery bus manufacturer for engineering and technical support, a key requirement of Metro's ZEB program is for Operations staff to be trained to support advanced technology electric buses.
- Electric bus systems do operate at high, potentially hazardous voltages not seen on current CNG buses. While new to Metro bus operations, high voltage safety is well understood in the transit industry. All of Metro's subway and light rail systems operate at similar voltages, and training programs are already available for Metro staff working with high voltage.
- In conjunction with the bus manufactures, Metro will develop maintenance procedures and protocols to address these potential high voltage hazards. Applicable Metro staff will be trained by the bus manufacturer in procedures for safely handling high voltage components and systems.

Technical Support and Warranty:

- For batteries and propulsion systems, bus manufacturers currently offer 5-12 year warranties. There is typically no scheduled maintenance required for batteries, and limited maintenance for propulsion systems. Individual battery modules would never be disassembled by Metro staff. In the case of warranty failures, individual battery modules and propulsion system components are typically exchanged under warranty by the bus manufacturer.
- Advanced batteries used in electric buses have gel or solid electrolytes, not the liquid "battery acid" used in older technology, lead-acid batteries. These electrolytes do not drip or leak even if batteries are damaged. Metro employees are very unlikely to be exposed to battery acid or hazardous materials from electric bus batteries.

4) Operations

Bus Assignments:

- Battery electric buses will operate similar routes and schedules to conventional CNG buses currently assigned to Metro's Orange and Silver Lines. The one difference is that approximately 5-10 minutes of *layover* time will need to be planned into each run to allow for opportunity charging.
- Metro Operations does not currently plan to expand the number of buses on the Orange or Silver Lines. However, for the Silver Line, the tentative plan may consider replacing current 45' CNG buses with a like number of 60' articulated buses; this could provide additional passenger capacity on this corridor.

5) Financial Impacts

Operating Costs:

- Battery electric buses today (2016) are more expensive to purchase and operate than conventional CNG buses. Longer term, Metro's technology consultant projects that costs for electric buses will drop significantly by 2025.
- On a total life cycle cost basis, future costs for electric buses are projected to eventually drop to ~2-5% more than conventional CNG buses.
- Metro's zero emission electric bus deployment plans are being developed to fit within available financial resources, especially as life cycle costs between battery electric & CNG buses approach parity.

Ownership Costs and Alternatives:

- As part of Metro's current RFP for battery electric buses (RFP OP28367), Metro expects to consider proposals for alternate vehicle financing and ownership options. This may include 12 year warranties on batteries/propulsion systems, and/or alternative vehicle or battery lease options.
- Metro will also be evaluating options to have third party operation of en-route charging systems (such as is done now with Metro's CNG fueling facilities).

6) Power Infrastructure

Power Supply/Grid Power:

- Regionally, power supply issues are not anticipated on either the Orange or Silver lines. Staff is already communicating with LADWP (DWP) and So Cal Edison (Edison) staff. There may be local power supply challenges associated with bringing new power connections to specific charging locations. At least in preliminary discussions with DWP and Edison, they suggest that these issues can be addressed in the course of our project.
- In 2014 DWP and Edison together sold 99.3 million MWh of electricity.[i] If the entire Metro fleet were converted to electric buses it would consume approximately 224,000 MWh of electricity annually, which would add approximately 0.2% to DWP and Edison's annual electric sales.

7) Other Issues

Carbon Footprint for Battery Technologies:

- Even when older batteries have insufficient capacity to provide the necessary daily range for buses, the batteries are expected to still be usable in other applications. Several battery manufacturers project that batteries used for transit buses will have a second life in stationary power applications. At the ultimate end of battery life (which may be 20-25 years), depending on specific battery chemistries, some batteries will have major elements that can be recycled and re-used in new battery production. For

example, Tesla is projecting that up to 70% of their battery materials will be recyclable.

- The ability to recycle a battery is largely dependent on materials and processes used in battery construction, and the handling of the battery once it is beyond useful life. For example, lithium-ion batteries (such as those employed in Tesla vehicles) contain valuable rare-earth metals, for which mining and processing activities are very carbon intensive. Opportunities for battery reuse and recycling can significantly reduce end-of-life impacts. Efforts are still underway to quantify the net impact of batteries in electric vehicles.
- According to the Energy information administration, 11.5% of the electricity generated by DWP in 2015 was generated from renewable sources (solar, wind) and the remaining 88.5% was generated with natural gas. In 2015, 17% of the electricity generated by Edison was generated from renewable sources and the remaining 83% was generated with natural gas[ii].

Conclusion

This is a living document that will be updated periodically to reflect changes and updates in battery electric bus technologies. This document will also be updated to reflect changes in Metro's electric bus implementation plans. We will provide periodic updates when new information or updated plans are released.

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[i] Energy Information Administration, Form EIA-861, Annual Electric Power Industry Report, 2014

[ii] Energy Information Administration, Form EIA-923, Monthly Generation and Fuel Consumption Time Series File, 2015 Final Release