Final Report

Metro Orange Line – Fleet Electrification - Battery Electric Vehicle Conversion

Los Angeles County Metropolitan Transportation Authority (LA Metro)

Prepared for the Mobile Source Air Pollution Review Committee (MSRC) under the AB 2766 Discretionary Fund Work Program

Contract number MS 18073

Table of Contents

1. Purpose

This document is the final report for contract number MS18073, as per provisioned on Attachment 1, Item 5:
a) an executive summary;
b) a detailed discussion of the results and conclusions about this project.

2. Acknowledgements

The project team would like to thank the following for their enormous contributions in bringing this project from a grant application to successful operation of LA Metro's most successful Bus Rapid Transit Line:

- New Flyer of America, supplier of vehicles and charging equipment
- Andi Wang, Executive Officer, LA Metro, for her oversight of the construction activities at four locations
- Reynaldo Tolibas, Director of Engineering, LA Metro, for his design and expertise in electrical site development
- Michael Samulon, Director of Vehicle Electrification and City Projects, Mayor's Office of Sustainability, City of Los Angeles, for his expertise in facilitation of expediting power delivery and navigation of city building departments
- Phil Rabottini, Senior Engineer, LA Metro, for his expertise in vehicle design and criteria necessary to LA Metro
- Elizabeth Hernandez, Principal Contract Administrator, LA Metro, for her dedication and expertise in managing the procurement process for four concurrent vehicle contracts and never missing a deadline
- Steve Schupak, Senior Manager - Project Control, LA Metro, for leading the project forward and not letting anything stand in the way of progress to meeting the goals of the project
- Gustavo Cerochi, Senior Manager – Project Control, LA Metro, for supporting on the vehicle's validation, acceptance, and warranty

This report was submitted in fulfillment of contract MS18703 for the Metro Orange Line Battery Electric Vehicle Conversion project, by LA Metro under the partial sponsorship of the Mobile Source Air Pollution Reduction Review Committee (MSRC). Work was completed as of March 31, 2022.

3. Disclaimer

The statement and conclusions in this report are those of the contractor and not necessarily those of the Mobile Source Air Pollution Reduction Review Committee (MSRC) or the South Coast Air Quality Management District (SCAQMD). The mention of commercial products, their sources or their uses in connection with material reported is not to be construed as either an actual or implied endorsement of such products.

4. Project Description and Work Performed

4.1. Introduction

Originally opened in 2005 and expanded in 2012, the Metro Orange Line (Now G Line) is an 18-mile Bus Rapid Transit (BRT) line running on a dedicated right-of-way with eighteen stations between North Hollywood and Chatsworth stations serving the North San Fernando Valley.

The line started operations with a newly designed fleet of 60-foot Clean Natural Gas (CNG) powered articulated buses, fare collections at the stations, stops at every station (every mile) and traffic signal synchronization. The Orange Line has two runs, one from North Hollywood to Chatsworth station, and the other from North Hollywood to Canoga station. Runs alternate between the two northern endpoints creating a shorter and longer run.

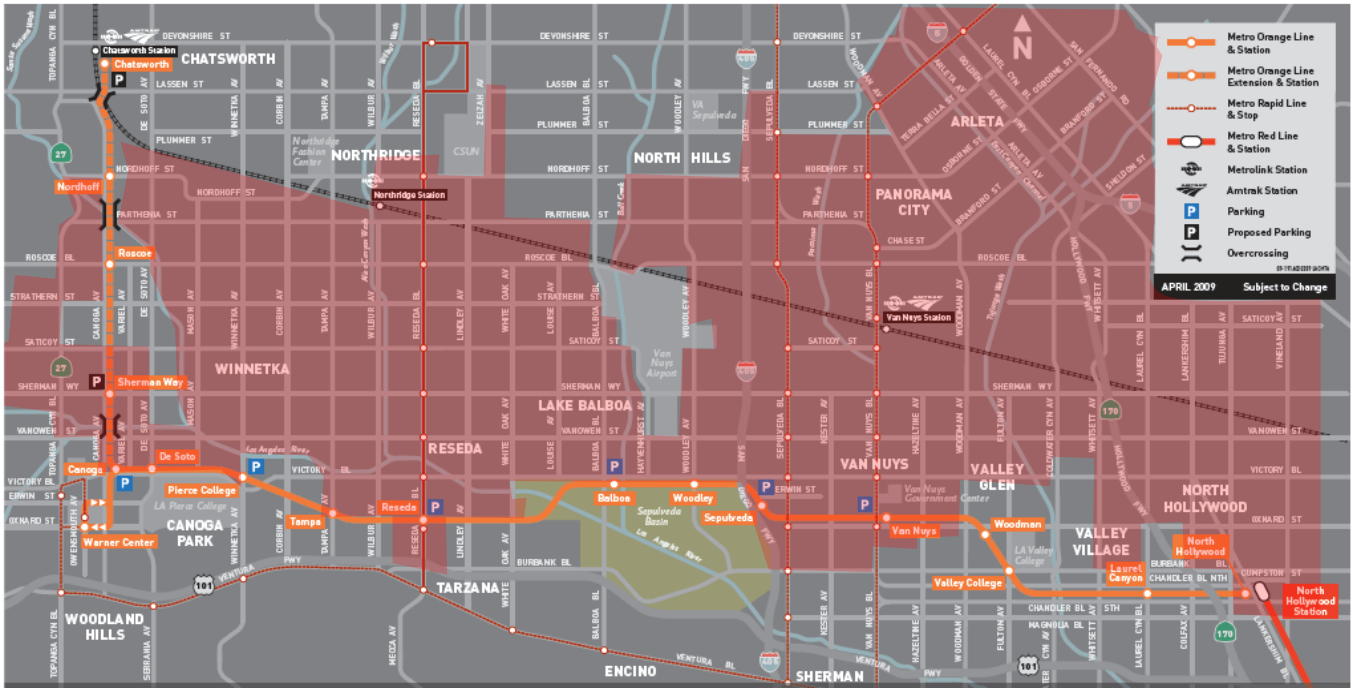

Figure 1 - Los Angeles Metro G Line (Orange) serves 114 disadvantaged communities[1], as indicated on red areas

The electrification of the line was the agency' first step on the conversion of the fleet from CNG to Battery Electric Buses (BEB), to be achieved by 2030. The main purpose was to gain experience in operating and maintaining BEBs, validating the viability of fully electrifying Metro's bus system, and determining the suitability and direct replacement for CNG vehicles.

The project started with a 2016 Federal Transit Administration Low or No Emission Grant award for the implementation of five zero emission vehicles (ZEV), on-route charging at North Hollywood and Chatsworth stations, and backup depot charging at Division 8. In 2017, an LA Metro directive called to convert the entire line to zero emission operation by 2020.

[1] California Office of Environmental Health Hazard Assessment
https://oehha.ca.gov/calenviroscreen/sb535

Thirty-five additional vehicles were ordered from New Flyer along with construction, installation, and commissioning of four 450kW on-route charging stations at North Hollywood, two 600KW at Canoga, and two more (600kW) at Chatsworth. Ten 150KW depot chargers were also installed at Division 8. These quantities were anticipated to be sufficient to convert the entire line to Zero Emission Bus (ZEB) operation.

The installation of the on-route chargers entailed digging foundations for both the pantograph masts and charger pads. Additionally, concrete pads were poured for the switch gear for LA Metro and Los Angeles Department of Power (LADWP). Finally, conduits were trenched to feed power from the components in the power stream. Installation of the depot chargers at Division 8 followed the same series of activities, though all within the walls of Division 8 along the back fence of the bus parking area.

Table 1 shows a summary of the charging infrastructure installed as of April 2023.

Figure 2 shows ridership since inauguration. Red bars represent fleet fully electrified.

	Charging Equipment				
Location	**Type**	**Make**	**Model**	**Power (KW)**	**QTY**
Canoga	on-route	Siemens	VersiCharge Go 600	600	2
Chatsworth			VersiCharge Go 600		2
North Hollywood			VersiCharge Go 450	450	4
Division 08	depot	ABB	HVC150 Depot charge Box	150	10

Table 1 - Installed Charging Infrastructure

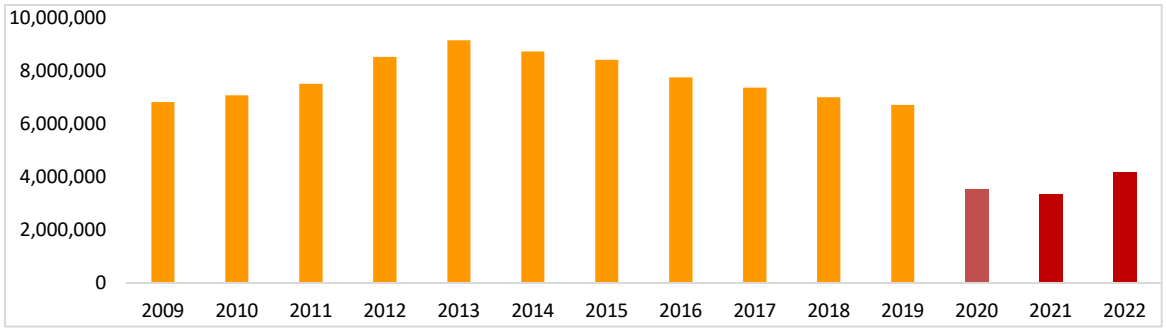

Figure 2 - Los Angeles Metro G Line (Orange) ridership. Red bars indicate fleet electrification

5. Problems Encountered

Problems and challenges encountered are grouped into four categories: environmental (rain, fire, flood), geographical (issues with construction sites), societal (covid-19, labor) and technical (issues with vehicle availability and reliability).

The first major environmental challenge surfaced when the depot charging equipment was nearing completion, and the switch gear from LADWP was scheduled to be delivered and installed. In the fall of 2018, there were major brush fires in Los Angeles County, and an emergency need for replacement switch gear preempted the installation of the equipment slated for LA Metro. Several months later, flooding caused further delay in delivering equipment to LA Metro. Ultimately, the depot chargers and infrastructure were completed in June 2019, approximately one year behind schedule.

The next major geographical challenge revolved around the on-route charging locations. LA Metro owned the property, developed the stations, and maintained as-built drawings. However, at all three locations, when excavation began, unknown electrical and plumbing conduits were discovered. In each instance construction work was halted, the discovery was identified, and a new routing solution was developed. Then a change order was necessary with the contractor for the new change in construction scope. These discoveries led to schedule delays and cost increases.

An unprecedent societal impact was felt starting by January-March 2020 when the entire world experienced disruptions in supply, labor, and productivity due to COVID-19 pandemic. This project was no stranger to those stresses. The biggest factors included materials shortages and labor. Parts and supplies were difficult to acquire and coupled with a complete disruption in transportation and distribution services, delays in construction of the on-route charging stations became the norm. On the vehicle manufacturing front, New Flyer was challenged with not only parts limitations, but also had periodic complete factory shutdowns due to covid outbreaks. When the main production facility manufacturing LA Metro's BEBs was shut down due to COVID-19 for an unknown closure period, they made the decision to move the vehicles in production to another facility for completion to maintain some semblance of schedule adherence. Ultimately, the on-route chargers delays and vehicle delivery delays balanced out well.

As for reliability, Metro's electric buses fleet seems to alternate between high and low performance while the CNG counterparts tend to perform stably over time. There were instances of electric buses significantly overperformed CNG for eight months in a row, until a sudden underperformance, later found to be a combination of summer elevated temperature and fleet defects.

The overall fleet availability ranged from 70% to 85% until mid-2022, when it reached 60% due to a fleet defect. A quick recovery followed and since then the availability trended down again to minimum 60% by April 2023.

6. Emissions Benefits

Population

LA Metro G Line (Orange) electrification cut line's vehicles emissions to almost zero, bringing a smooth ride and cleaner air to four million riders and 114 disadvantages communities along the line.

Noise

The new buses also have lower interior and exterior noise emissions than their CNG counter parts. The electric propulsion has almost no moving parts, thus reducing internal and external noise. One can barely notice noise coming from the bus when it is on or even when it is moving. On the interior there is no tailpipe noise or engine vibration, making the ride more enjoyable for passengers.

Carbon Dioxide Emissions

The fuel consumption on electric vehicles – including buses – is measured in the equivalent of miles per gallon of gasoline (MPGe), which represents the miles the vehicle can travel using the energy content of a gallon of gasoline (33.7 KWh). It can also be measured in Kilowatts-hours per mile (KWh/mile).

LA Metro's buses energy consumption varies depending on speed, payload, and ambient temperature. It had averaged 3.0 KWh/mile (106 miles) while minimum and maximal values recorded were 2.5 and 3.6KWh/mile, resulting in ranges of 128 and 89 miles, respectively.

As of April 2023, the buses have accumulated 3.3 million miles, averaging 91 miles per bus per day.

The table below shows a comparison between different fuels and energy content and consumption. It also shows an estimate[2] for the associated emissions.

Fuel	Energy	Consumption		Emission	Mileage	Total Emissions
	(KWh/gallon)	*MPGe*	KWh/mile	lb. CO2/mile		Million lb. CO2
Diesel	36	3.16	11.4	6.6	3,330,000	22
CNG	33	2.51	13.2	6.1		20
Electricity	1.7	11.23	3.0	1.4		4.6

Table 2 – Comparison between fuels for a 60-foot bus: energy content, consumption, and emissions

[2] US Department of Transportation
https://www.transportation.gov/sites/dot.gov/files/pictures/Zero-Emission%20Bus%20Information.pdf

7. Photographs and Outreach

LA Metro is required to provide a public outreach plan or summary of activities to promote MSRC's co-funding of the vehicles. Below are listed some of Metro's G Line (Orange) that had impact on the awareness of project and agency clean-air project promotion.

News Broadcast

- LA Announces First 100% Electric Bus Line – CBS News - October 13, 2021
  https://www.cbsnews.com/losangeles/news/la-announces-first-100-electric-bus-line/

Articles

- Los Angeles Daily News
  https://thesource.metro.net/2021/10/13/metro-announces-fully-electric-bus-fleet-on-the-g-line-orange/
- Mass Transit Magazine, October 14, 2021 - L.A. Metro's G Line now fully electric
  https://www.metro-magazine.com/10153936/l-a-metro-now-running-all-zero-emission-electric-buses-on-the-g-orange-line

Corporate Website

- L.A. Metro Now Running all Zero-Emission Electric Buses on the G (Orange) Line in the San Fernando Valley
  https://www.metro.net/about/l-a-metro-now-running-all-zero-emission-electric-buses-on-the-g-orange-line-in-the-san-fernando-valley/

Ribbon-cutting events

- G Line (Orange) now 100% electric! – LA Metro corporate social media page, October 13, 2021
  https://www.facebook.com/losangelesmetro/videos/g-line-orange-now-100-electric/1024166491714729/
- Mayor Garcetti celebrates first electric bus deployed on the G Line - Los Angeles Mayor page, July 27, 2020
  https://www.lamayor.org/mayor-garcetti-celebrates-first-electric-bus-deployed-g-line

8. Summary and Conclusions

Public Transit buses propulsion and fuel technologies have not changed significantly in the last few decades, being limited to internal combustion engines fueled by Diesel or CNG. Transit vehicle maintainers have become specialized in tools and resources to support the technology.

Transit operators are required to provide daily reliable safe service in all weather, health, and civil environments, which ultimately results on heavy reliance on service proven standards, procedures, and technologies.

Usually, the introduction of a new technology is piloted and later validated in terms of reliability. The switch from diesel to CNG in the late 1990's was a prime example of introducing a new propulsion into public transit. Initially, the engines were expensive and unreliable compared to the service proven diesel engines. As the engine market matured, costs came down, reliability increased, and now it is the recognized propulsion platform for reduced emissions in public transit vehicles.

The political and environmental shift to ZEVs is no different in the introduction of new un-proven technologies. The increased cost per unit for early generation vehicles is paving the way for larger scale production runs in the future that promise to bring prices closer to parity with existing propulsion systems. Since early adoption comes at a higher per unit cost, the funding provided by sources like the MSRC AB 2766 program provided vital funds necessary to bridge the gap between regular replacement vehicles and newer ZEV technologies.

The funding provided to LA Metro has been a key factor in bringing in the complete conversion of the Metro Orange Line to zero emission operation.

As of the writing of this report, the 40 New Flyer 60' articulated BEB fleet has amassed over three million miles and is growing every day.

Therefore, LA Metro's first line conversion to zero emission operation has been a great success, and the insight and experience gained through it will be leveraged as additional ZEVs are purchased and put into service. The continued supply of dedicated zero emission funds will help accelerate the implementation going forward.