Zero Emission Bus Pilot Commercial Deployment Project

Sacramento Regional Zero-Emission School Bus Deployment Project

Final Report

April 1, 2021

Prepared by

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

Report Number: Final Report

Project Title: *Sacramento Regional Zero-Emission School Bus Deployment Project*

Grantee: Sacramento Metropolitan Air Quality Management District

Report Submission Date: April 1, 2021

Grant Number: G16-ZBUS-02 **Execution Date**: February 27, 2017

project Timeframe: February 27, 2017 – June 30, 2021

CONTENTS

Appendices

Table of Figures

Table of Tables

LIST OF ACRONYMS

AQIP	Air Quality Improvement Program
CARB	California Air Resources Board
CCI	California Climate Investment
CEQA	California Environmental Quality Act
CHP	California Highway Patrol
CNG	Compressed Natural Gas
(CO_2e)/year	Carbon Dioxide Equivalent per Year
DAC	Disadvantaged Community
DMCA	Data Monitoring, Collection, and Analysis
DMS	Data Management System
EGUSD	Elk Grove Unified School District
E-BUS	Electric/Zero-Emission School Bus
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FPBS	First Priority Bus Sales
GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas Emission
HD	Heavy Duty
MD	Medium Duty
NOx	Nitrogen Oxide
PM	Particulate Matter
SCUSD	Sacramento City Unified School District
Sac Metro Air District	Sacramento Metropolitan Air Quality Management District
SMUD	Sacramento Municipal Utility District
TRUSD	Twin Rivers Unified School District
V2G	Vehicle-to-Grid
VGI	Vehicle-Grid Installation

ACKNOWLEDGEMENTS

The Sacramento Metropolitan Air Quality Management District (Sac Metro Air District) expresses immense gratitude and appreciation to the California Air Resources Board (CARB) for creating the solicitation for the Zero Emission Bus Pilot Commercial Deployment project. This solicitation enabled the Sac Metro Air District to apply, with assistance from partners, and implement the first and largest deployment of electric school buses in North America. Without this solicitation and funding from the Greenhouse Gas Reduction Fund (GGRF) and California Climate Investments (CCI), there would not be a successful integration of electric school bus adoption within these disadvantaged communities, where public health, specifically young children, are exposed to toxic air pollution from diesel engine exhaust emissions. This funding supports and prioritizes capital investments and allows for necessary resources and partnerships to enable an electric fleet of school buses, providing effective and efficient service.

The Sac Metro Air District is proud to showcase the success of this Sacramento Regional Zero-Emission School Bus Deployment Project. The deployment project provided twenty-eight electric buses to three school districts within Sacramento County, namely Elk Grove Unified School District (EGUSD), Sacramento City Unified School District (SCUSD), and Twin Rivers Unified School District (TWUSD). These school districts provided tremendous support and effort to be part of the founding movement toward electric vehicle and infrastructure adoption for potential widespread use throughout their district and by example, throughout California and now the United States.

The school districts face challenges in providing effective and efficient transportation for their students. With CARB's support using GGRF and CCI funds, a transportation solution was found that showcases the feasibility of electric school bus use and reductions in greenhouse gas emissions and criteria pollutants through deployment of clean, zero emission technologies. The Sac Metro Air District and our partners are sincerely appreciative of CARB's selection of this project to demonstrate the benefits of widespread usage of zero emission buses.

The Sac Metro Air District would like to recognize the following agencies and organizations for participation and contribution toward the success of the *Sacramento Regional Zero-Emission School Bus Deployment Project*, as well as the creation of this report showcasing that success. Full commitment, investment, and involvement from these partners (listed in alphabetical order) enabled opportunities for the project to flourish and assist in solving problems so other school districts have best practices to learn from in their pursuit.

- California Air Resources Board
- California Strategies & Advocacy
- ChargePoint (Kisensum and SunEdison)
- Elizabeth Cooper, LLC
- Elk Grove Unified School District
- EV Connect
- First Priority Bus Sales
- Lion Electric Company
- Motiv Power Systems
- Phil Haupt Electric
- Ricardo, Inc.
- Sacramento City Unified School District
- Sacramento Municipal Utility District (SMUD)
- Trans Tech Bus
- Twin Rivers Unified School District

PREFACE

Assembly Bill 118 (AB 118) known as the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007, was signed into law creating the Air Quality Improvement Program (AQIP) which provides incentives for clean vehicle and equipment projects. A CARB approved annual funding plan developed with public input is a necessary component within the AQIP Guidelines[1]. Within the funding plan, a blueprint for expending AQIP funds is appropriated to CARB in annual State Budgets. Focus is placed on development and deployment of advanced technologies meeting California's long-term air quality goals. Some of these projects include the Sacramento Regional Zero Emission School Deployment Project that the Sac Metro Air District applied for from CARB's solicitation released October 1, 2015.

Three bills established the GGRF to receive Cap-and-Trade auction proceeds; AB 1532 (Pérez, Chapter 807), SB 535 (De León, Chapter 830), and SB 1018 (Budget and Fiscal Review Committee, Chapter 39) were passed by Legislature and signed into law by Governor Brown in 2012. For the purposes of AB 32, these bills support the long-term efforts for improving public health and development of a cleaner energy economy, while providing the framework for auction proceeds.

A Low Carbon Transportation GGRF program implementing with AB 118 AQIP programs was established in 2014 with an appropriated amount of $200 million. In 2018, an additional budget of $500 million was proposed by Governor Brown for GGRF. A strong emphasis on benefitting disadvantaged communities by reducing greenhouse gas (GHG) emissions through AB 32 was furthered through programs funded under GGRF.

This call for projects benefitting disadvantaged communities was identified through the priority investments that facilitate GHG emission reductions under the development of the Cap-and-Trade Auction Proceeds Investment Plan. The acceleration of development and employment of advanced mobile source technologies meets the State's near-term and long-term GHG emission reduction goals. Fifty percent of the funding for GGRF is allocated to projects that will benefit disadvantaged communities, and ten percent invested directly in disadvantaged communities.

The Zero Emission Truck and Bus Pilot Commercial Deployment Project became prioritized when the FY 2016-2017 Funding Plan was scaled back by CARB accommodating the decrease in appropriated funds. Projects including the Sacramento Regional Zero Emission Bus Pilot Project were able to continue applying for the CARB solicitation. The solicitation was specific to pilot projects implementing new types of alternative technologies, especially meeting the disadvantaged communities' criteria.

In response to the District's application submittal, CARB notified the District that the project was selected for funding as preliminary grantee on February 25, 2016. The District and CARB executed their original grant agreement on February 27, 2017.

[1] https://ww3.arb.ca.gov/regact/2009/aqip09/aqipfro.pdf

EXECUTIVE SUMMARY

The Sacramento Regional Zero-Emission School Bus Deployment Project has provided a large-scale success story that proves commercially available zero-emission school buses have the best total cost of ownership, substantially improved maintenance and performance, and optimally serve the needs of school districts to sustainably transport California's children to and from school, as well as school activities.

The Sac Metro Air District, the project grantee, implemented the Sacramento Regional Zero-Emission School Bus Deployment Project, with the support of the California Air Resources Board, to accelerate the deployment of commercially available heavy-duty, zero-emission, school buses and benefit disadvantaged communities throughout the Greater Sacramento Metropolitan Area and as well as other new areas. The project reduced greenhouse gas (GHG) emissions and provided economic and environmental benefits to disadvantaged communities – and demonstrated the immediate scalability, practicality and economic viability of wide-spread adoption of purpose-built zero-emission school buses. Furthermore, the project helped eliminate mobile criteria pollutants and provides public health co-benefits to both schoolchildren and the greater community.

The Sacramento Regional Zero-Emission School Bus Deployment Project deployed zero-emission school buses throughout the Sacramento Region, including Elk Grove, Sacramento City, and Twin Rivers Unified School Districts. The school districts used the Type C manufactured by The Lion Electric Company and the smaller Type A manufactured by Trans Tech and Motiv Power Systems. EV Connect and Phil Haupt Electric provided, installed, and maintained the charging infrastructure. ChargePoint (Formerly Kisensum, and absorbed SunEdison) provided a Vehicle Grid Integration Study and along with Elizabeth Cooper, LLC, designed a Data Management System (DMS) to support data and reporting, and effective management of electricity costs and demand. Ricardo, Inc. contracted with California Air Resources Board for additional data collection.

The Sacramento Regional Zero-Emission School Bus Deployment Project deployed 28 state-of-the-art zero-emission school buses with associated charging ports in disadvantaged communities in the Greater Sacramento Region. The project included a $3,296,744 cash-match and $4,158,951 in-kind match from private, eligible state, and local funding to leverage the $7,584,459. Air Resources Board Investment, for a total project budget of $15,040,153.

Some lessons learned from this project include:

- Researching for electric school buses that fit the needs of school district bus routes and having flexibility and adaptability for route changes or bus driver fluctuations
- Electric buses should be outfitted with proper battery capability, especially for meeting high mileage routes
- Grant language needs to be more adaptable, especially for unforeseeable events such as bus, charger install, or maintenance delays

The success of this project paved the way to the current planned deployment of 138 battery electric school buses and associated charging infrastructure across seven local California counties: Butte, El Dorado, Placer, Sacramento, Solano, Yolo, and Yuba.

1.0 BACKGROUND AND INTRODUCTION

This final report provides an overview of the work performed by the Sac Metro Air District as part of the agreement with CARB under Grant Agreement G16-ZBUS-02, "*Zero Emission Bus Pilot Commercial Deployment Projects".* The *Sacramento Regional Zero-Emission School Bus Deployment Project* (hereafter, "project"), accelerated the deployment of fleets of commercially available, zero-emission, school buses throughout the Greater Sacramento Metropolitan Area between the February 2017 to June 2021 project timeline. State-of-the art zero-emission school buses were deployed throughout the Greater Sacramento region, including Elk Grove, Sacramento City, and Twin Rivers Unified School Districts.

Accelerating the deployment of zero-emission school buses, referred to as electric school buses (e-Bus), the project reduced GHG emissions, provided economic and environmental benefits to disadvantaged communities, and demonstrated the scalability, practicality and economic viability of wide-spread adoption of purpose-built zero-emission school buses. The HD battery electric technology used in these school buses are directly transferable to transit, freight, and goods movement applications. The project also reduced criteria pollutants, providing public health co-benefits to both schoolchildren and the greater community.

1.1 Project Objectives

The project accomplished the following objectives:

- Demonstrated that zero emissions, battery electric school buses are feasible and best serve school transportation needs as they substantially reduce GHG emissions and eliminate toxic emission exposures to children in disadvantaged communities.
- Deployed 28 zero-emission, battery-electric school buses, and 29 charging ports to serve as a large-scale zero emission school bus demonstration project in the Greater Sacramento region.
- Educated school district fleet operators and other commercial fleet operators about the viability of zero-emission HD vehicle technologies and accelerated the deployment of these technologies throughout California.
- Reduced GHG emissions by 311 metric tons of carbon dioxide equivalent (CO_2e)/year, and eliminated 0.23 tons/year of weighted criteria pollutants and PM emissions in disadvantaged communities.
- Demonstrated that fleets of zero-emission school buses can be managed to optimize charging design and minimize electricity demand charges, as well as to generate data for analyzing the potential of employing Vehicle to Grid Integration (VGI) technology.

1.2 Project Partners

The project benefited from the assistance of several partners who performed their roles with dedication, diligence, and professionalism. The following organizations and companies enabled the Sac Metro Air District to accomplish their objectives:

- **The State of California, California Air Resources Board (CARB)** — CARB provided the grant funding to the Sac Metro Air District, the Grantee, through the CCI program, which utilized Cap-and-Trade dollars from GGRF to deploy clean energy technology. As the project Grantor, CARB participated in regular meetings with the Sac Metro Air District to provide guidance on project administration. CARB also reviewed and approved all grant disbursements, ensured project compliance with funding requirements, maintained adherence to the project timeline, and coordinated data collection and analysis via its selected third party, Ricardo.

- **First Priority Bus Sales (FPBS)** – FPBS is a subsidiary of First Priority Global, one of the largest global suppliers of specialty vehicles in the United States. FPBS was responsible for deploying both the zero-emission, battery-electric Type A Trans Tech SSTe school bus with the Motiv Power Systems powertrain, and zero-emission, battery-electric Type C eLion school bus from Lion Electric Company, for this project. The specifications of these school buses are discussed in greater detail in Section 2.2. As the project vendor, FPBS presented the project holistically, providing all necessary subcontractors to implement the project. FPBS initially served as point contact for all transactions, service requirements, training, and support services required for the vehicles. FPBS pulled out of the partnership midway through the grant.

- **Motiv Power Systems (Motiv)** – Motiv is a California-based manufacturer of all-electric chassis, responsible for the modular electric powertrain that powers the California Trans Tech buses. Motiv, the technical and operational needs point of contact for their drive systems, aided FPBS with project management and administration related to bus deployment. Above all else their customer service, attention to detail, and persistence in overcoming obstacles proved invaluable.

- **EV Connect** – EV Connect was responsible for the installation and project management of zero-emission charging infrastructure for the project. Specifically, EV Connect coordinated software management, platform design, and connectivity related to charging infrastructure. They were also responsible for the design and development of energy management systems and worked with ChargePoint to support their VGI report. EV Connect worked collaboratively with school districts and Sacramento Municipal Utility District (SMUD) to establish the necessary permitting and approval for the new infrastructure.

- **Ricardo, Inc. (Ricardo**) – As part of the data collection commitment to the project, CARB provided Ricardo, a third-party tracking vendor, to conduct data collection and analysis. Ricardo worked with FPBS, bus manufacturers, and the school districts to set up and implement a data monitoring, collection, and analysis plan (DMCA) to fulfill reporting requirements and optimize electricity usage.

- **ChargePoint** – Formerly SunEdison and Kisensum, ChargePoint supported the gathering of data and reporting used to manage the electricity demand of the charging infrastructure by developing a data management system. Over the course of the project, ChargePoint provided two reports, including a VGI report to combine electric school bus charging with supporting the needs of the electrical grid and a renewable energy storage capability assessment to see if adding solar, renewable energy to the project would be economically, environmentally, and logistically feasible.

- **Elizabeth Cooper, LLC** – Subcontractor that contributed in providing information about optimal site infrastructure location, power management practices, usage, and electrical upgrades.

- **California Strategies & Advocacy** – Assisted in original application and grant writing.

- **Sacramento School Districts** – The Sac Metro Air District selected **Elk Grove, Sacramento City, and Twin Rivers Unified School Districts** as recipients of the zero-emission school buses and charging infrastructure. As such, the districts were the sole operators of the buses and were responsible for day-to-day care and maintenance of the buses with support from the project partners. The districts also provided additional funds to the total project budget to leverage CARB's investment.

1.3 Benefits to Disadvantaged Communities

A distinct goal of this project aligns with the support for long term, transformative efforts to improve public health, and develop a clean energy economy. Clean energy and climate change legislation adopted and implemented in California since 2005 emphasized the need to address disadvantaged communities. Specifically, allocation requirements in *SB 535 California Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund* require at least 25 percent of funding from the GGRF allocated toward projects that benefit disadvantaged communities, with at least 10 percent allocated toward projects located in disadvantaged communities, as identified by the California Environmental Protection Agency (Cal/EPA)[2].

Disadvantaged communities (DACs) all around the Greater Sacramento area are affected by pollutants from various sources, including tailpipe emissions from medium-duty (MD) and HD on-road trucks and buses. These vehicles produce significant emissions of GHGs, diesel particulate matter 2.5 microns or less ($PM_{2.5}$), and oxides of nitrogen (NOx) that contributes to ozone and secondary particulate matter formation. In California, the transportation sector is responsible for 39.9% of GHG emissions, and MD and HD on-road trucks and buses account for 8.2% of that percentage[3]. Individuals within DACs are often more disproportionately affected by NOx and $PM_{2.5}$ emissions which cause harm to human health, especially sensitive populations most vulnerable to adverse health effects.

To achieve long-term GHG emission reductions, protect public health, and attain stringent federal air quality standards, advancement of zero-emission technologies is essential, especially with early adoption. This can be done through higher volume commercialization, creating a demand for these technology types and encouraging economy-of-scale per-vehicle cost reductions, and ultimately consumer acceptance through high visibility applications, showcasing the variety and capability of these technologies. The *Sacramento Regional Zero-Emission School Bus Deployment Project* was a successful approach as a pilot project highlighting the potential for wide-ranging and far-reaching positive impact beyond the direct emission reduction benefits achieved. The project was specifically designated to benefit disadvantaged communities by ensuring that routes driven were within DACs, noted in Section 3.3 Bus Routes.

1.4 Grant Agreement and Amendment

The Sac Metro Air District's grant application for the project was selected to receive grant funds for project purposes after release of the CARB AQIP's FY 2016-2017 Funding Plan. In February of 2017, CARB and the Sac Metro Air District finalized the grant agreement. Within the first grant agreement, the project included cash-match and in-kind match from private and local funding to leverage the CARB investment.

In 2020, CARB and the Sac Metro Air District agreed on the only amendment to the original grant agreement, addressing the remaining project budget related to the departure of FPBS as

[2] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB535 Accessed March 2021.
[3] https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2018/ghg_inventory_trends_00-18.pdf

main project vendor. The amendment process considered how project sites could benefit from additional e-Buses. After consideration, CARB and the Sac Metro Air District agreed to the purchase of one additional e-Bus, eLion Type C bus, with a projected delivery date of April of 2020 to SCUSD. The Sac Metro Air District agreed to increase their cash-match to cover the remaining invoice cost after expending the GGRF funds.

The amendment removed two Trans Tech Type A buses from the EGUSD bus inventory established in the original grant and added the eLion Type C bus to SCUSD. To accommodate the new e-Bus projected delivery date, the amendment extended the project timeline, final reporting, and necessary emissions analysis to 2021.

Project timeline by quarter

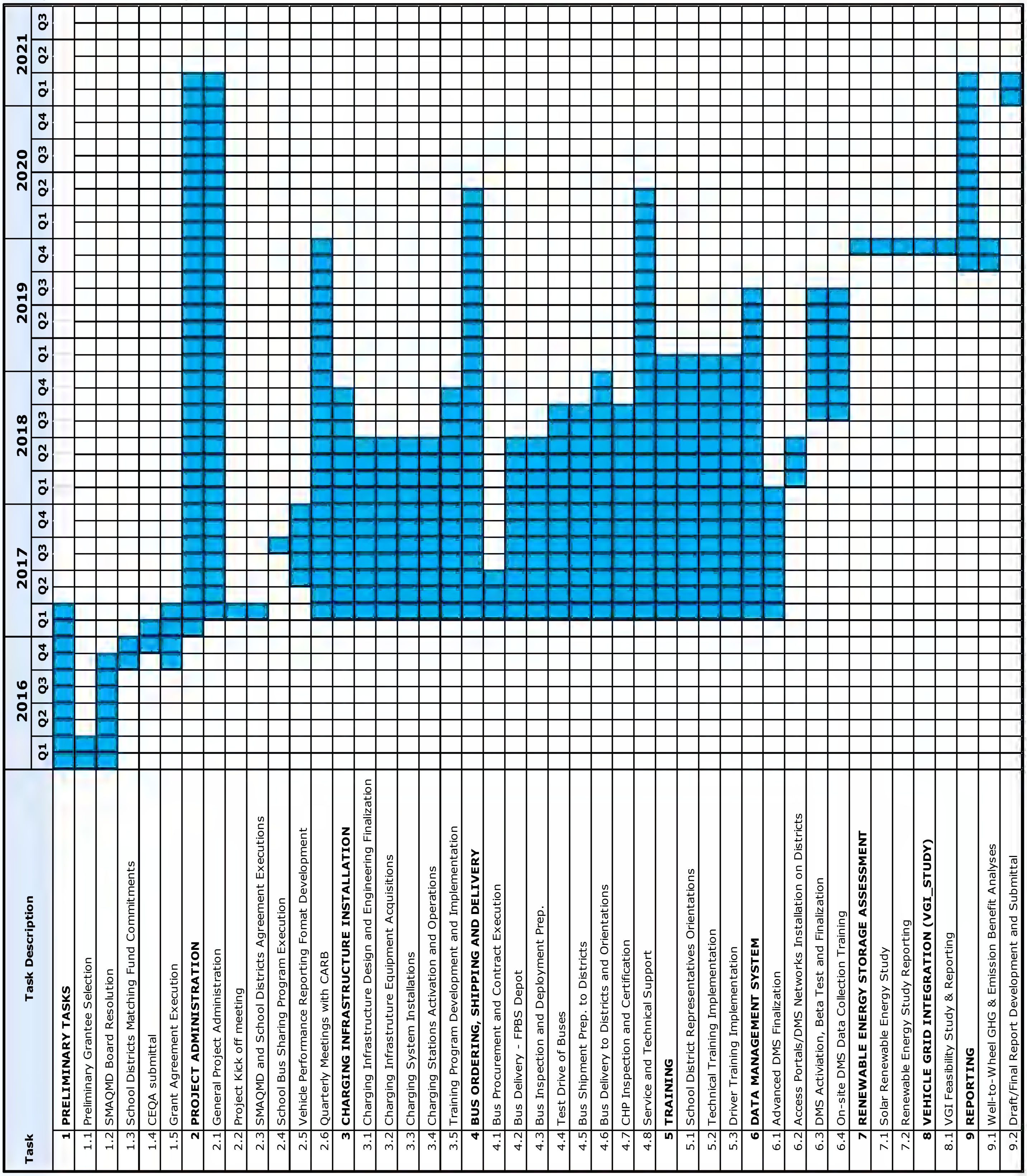


Figure 1: Project Timeline by Tasks

2.1 Grant Agreement, Site and Partner Selection

The project began with conversations held at a Sacramento School Bus Consortium (Consortium) meeting. The Consortium is an informal forum between Sacramento County school district transportation directors, lead mechanics, administrators, the Sac Metro Air District, and representatives from other school districts in the region. The meetings were held once a month and are used to exchange information and to speak on the nature of transportation and innovation in school bus transportation.

In 2015, the Sac Metro Air District was presented with the idea of applying for a grant for EVs during a competitive solicitation by CARB at the meeting. The Sac Metro Air District floated the opportunity at the Consortium to see if any would serve as sites for e-Bus deployment. After input and application, the Sac Metro Air District identified EGUSD, SCUSD, and TRUSD as the three school districts to participate in the project - the three districts were selected based on their ability to meet the disadvantaged community component of the grant, as well as interest.

All three school districts had experience with advanced vehicle technology operation, with TRUSD having operated compressed natural gas (CNG) school buses since 2002 and both EGUSD and SCUSD operating CNG buses in their districts as well[3]. EGUSD had maintained and operated several CNG refueling stations prior to its inclusion in the project.

At the time of project's pre-deployment stage, FPBS was the lead zero emission school bus sales company. FPBS presented the project and all subcontractors holistically, having worked together with Motiv and EV Connect previously to participate in the City of New York's initiative to launch a municipal electric fleet.

2.2 Budget and Management of Disbursements

The Sac Metro Air District was selected for the grant and put on track to accept grant funds for project purposes following the FY 2015-2016 Funding Plan. In February of 2017, CARB and the Sac Metro Air District finalized the grant agreement, with a project investment of $7,311,460 from CARB. The project included cash-match and in-kind match from private, state and local funding to leverage the CARB investment for a total project budget of $15,040,153. Funds for the project were deposited into an interest-bearing account, with interest being documented and reinvested into the project. Figures 2-5 summarize the total project budget by funding source, cash matching funds by source, and in-kind match by source. Figure 5 shows the CARB Grant expenditure by source. Detailed project budget information is included in Table A2 of Appendix A.

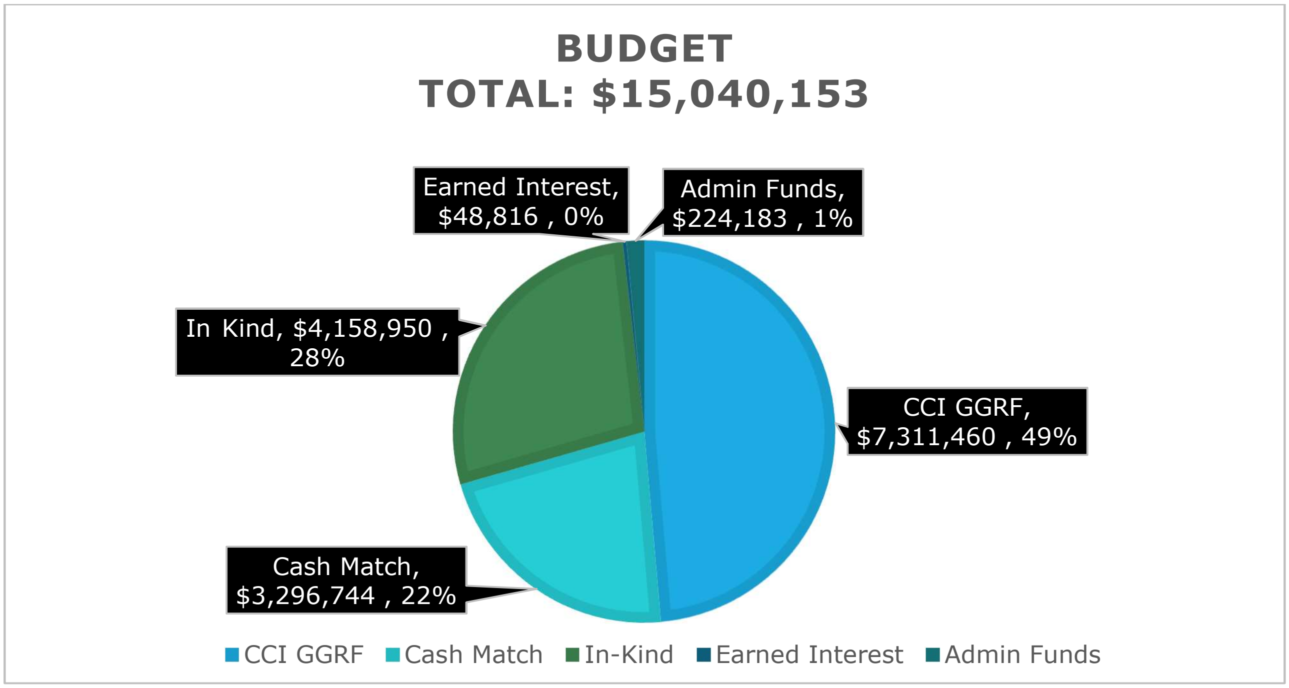


Figure 2: Total Project Budget by Funding Source

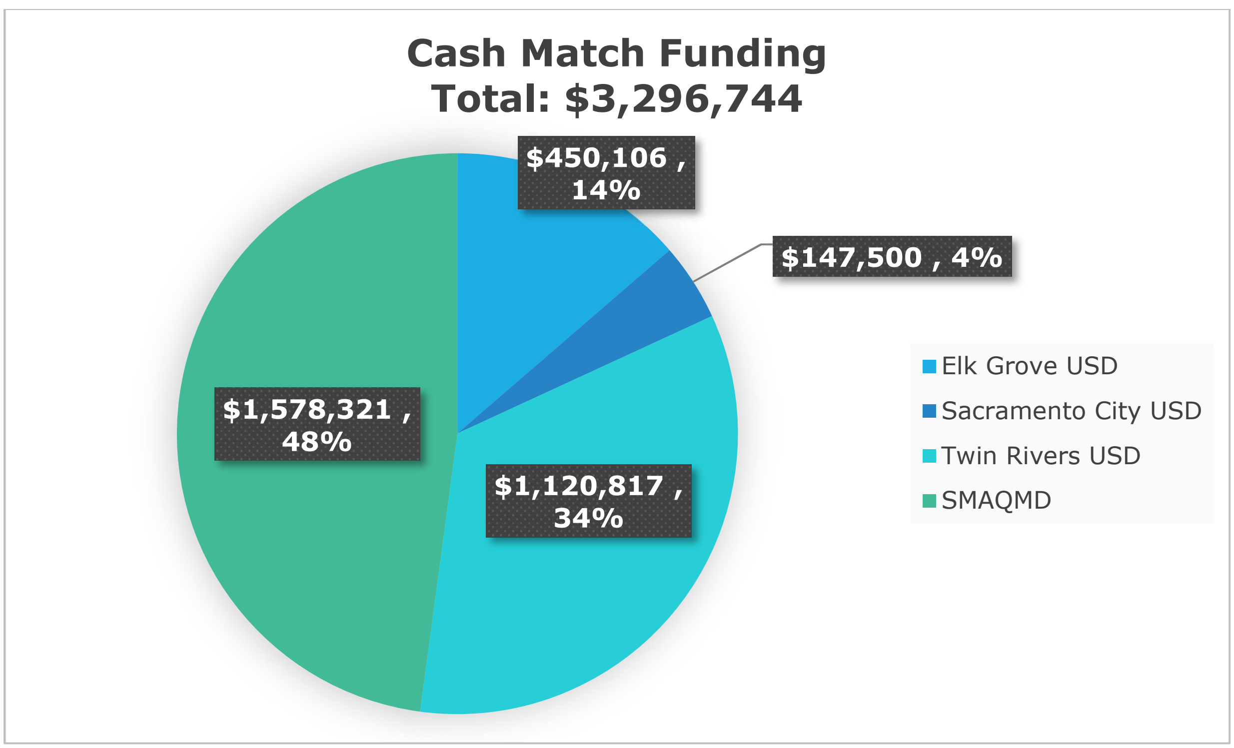


Figure 3: Total Project Cash Matching Funds by Source

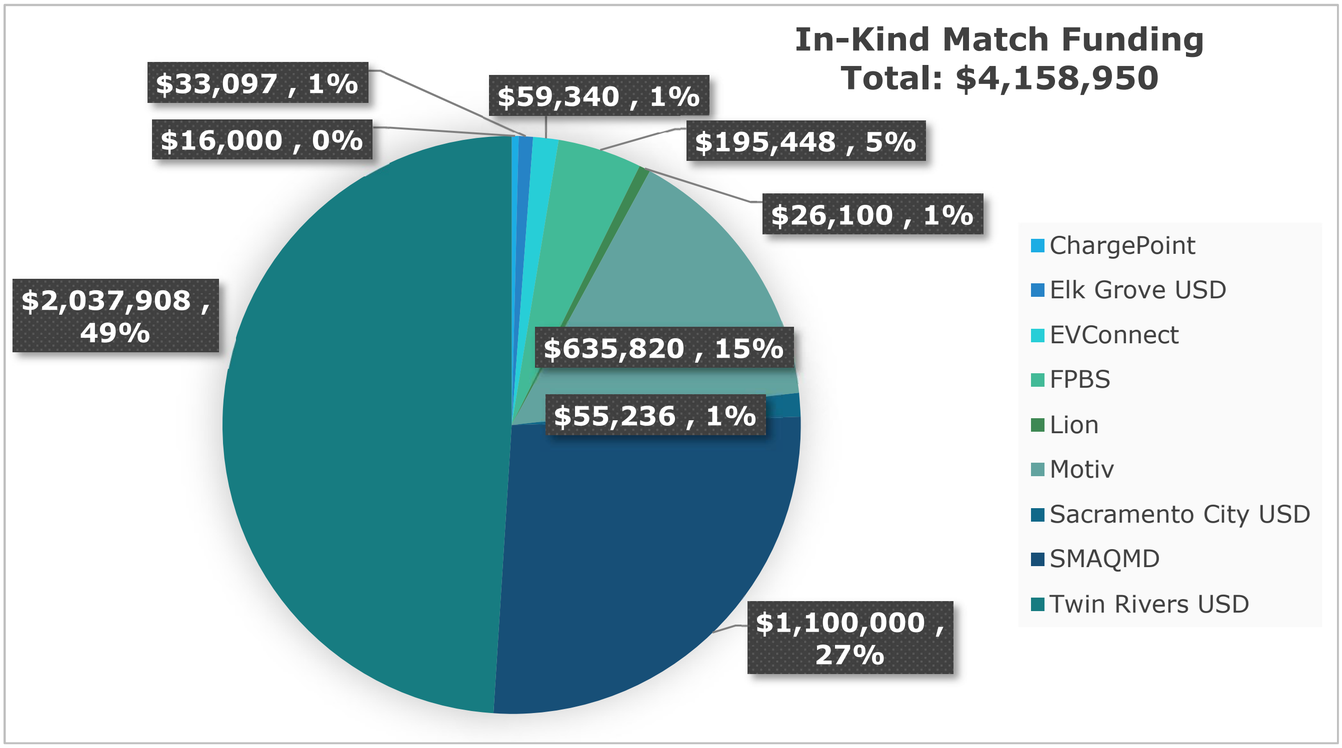


Figure 4: Total Project In-Kind Matching Funds by Source

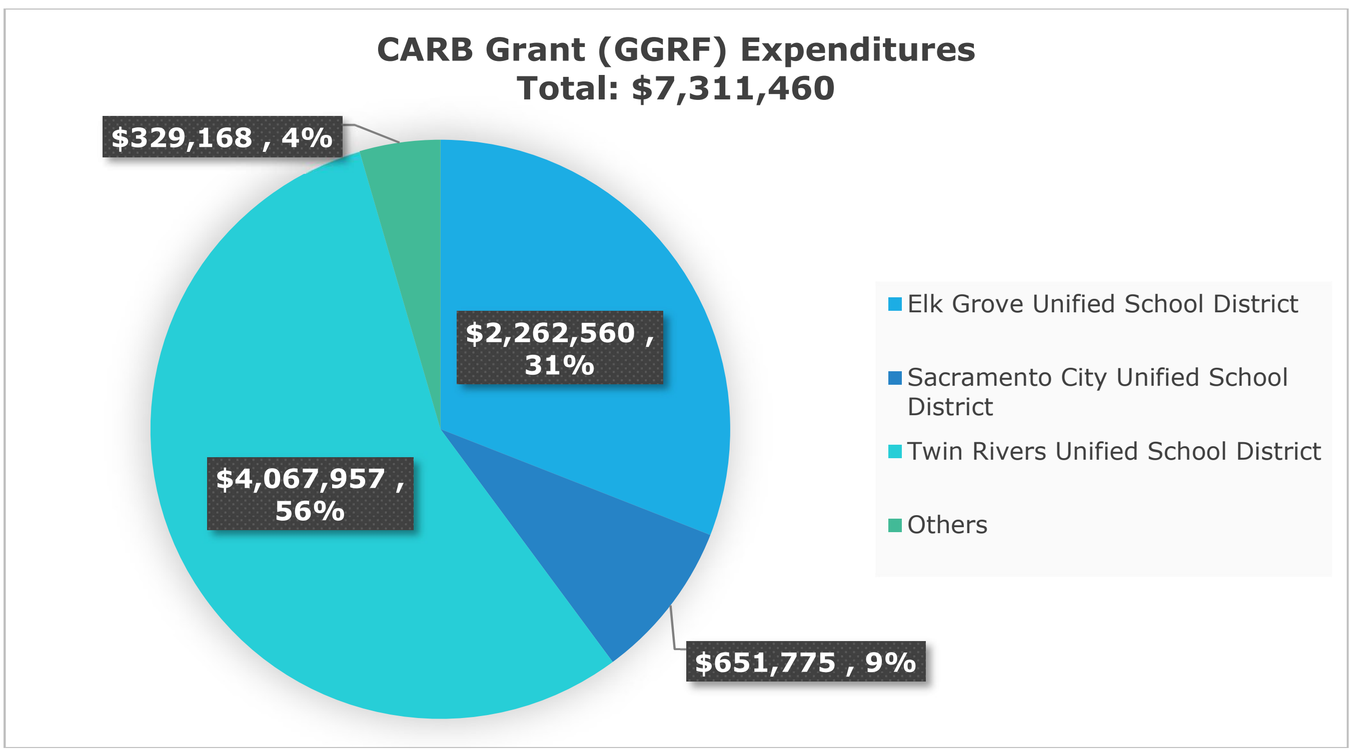


Figure 5: CARB Grant Expenditure by Source

Complying with the grant agreement requirements, FPBS provided invoices to school districts, who paid the vendors and subcontractors for services rendered. The Sac Metro Air District then worked with CARB on approving disbursements for the GGRF funds. Once approved, the Sac Metro Air District was able to provide approved reimbursements from the project account to the school districts upon receiving the invoices. The Sac Metro Air District was required to submit a Grant Disbursement Request with status reports covering activities. Upon receipt of the request and reports, a final payment was made to the Sac Metro Air District. For a complete breakdown of the budget, see Table A2, Project Budget.

2.3 Electric Vehicles and Charging Infrastructure

Since the solicitation released by CARB was considered competitive, to make the Sac Metro Air District's application standout, grant writers suggested piloting two e-Bus types to showcase that electric vehicle technology has options that could fit varying school district needs. FPBS selected e-Buses from Trans Tech and The Lion Electric Co. The Trans Tech Type A bus, referred to by the company as the SST-e, was a Ford E450 chassis utilizing a Motiv Powertrain Control System. Passenger capacity for the bus is 32 students, or 24 students and 1 wheelchair. The chassis modification was similar to CNG modification of buses, and the bus was capable of holding four or five battery packs depending on desired range, with an advertised range of 80-100 miles[4]. Figure 6 shows a Trans Tech Type A bus.

The eLion Type C vehicles were 473 inches in length, with a seating capacity of up to 77 passengers and a range of 75 or 100 miles, depending on the installed battery capacity. The vehicle possessed high-performance batteries from LG Chem with a J1772 charging system standard in North America[5]. Figure 7 shows eLion Type C bus.

[4] https://www.motivps.com/news/trans-tech-bus-and-motiv-power-systems-partner-on-new-all-electric-school-bus/

[5] https://thelionelectric.com/en/products/electric, Accessed 3/13/2021.

Figure 6: Trans Tech Type A e-Bus

Figure 7: eLion Type C e-Bus

The charging infrastructure for the Type C Lion e-Buses was a ClipperCreek Model CS-100-3 for commercial vehicles, comprised of a 36-lb control box and cable length of 25 ft (see Figure 8). The standard plug J1772 was used for Lion e-Buses. A non-standard, 3-phase designed plug was used for the Trans Tech Type A e-Buses.

Figure 8: ClipperCreek Charging Station

3.0 PROJECT DEPLOYMENT

The Sac Metro Air District began deployment of e-Buses and construction of charging infrastructure in all three school districts in 2017. The following section details a timeline of deployment and establishment of the vehicles in use within the Sacramento school districts, as well as the many actions performed by the Sac Metro Air District and project partners ensuring a successful project deployment. Subsections detail challenges that arose during the project deployment and steps taken to address and overcome these challenges or issues.

3.1 EVSE Installation

The school districts began preparing for EVSE installation in March 2017. The school districts received and deployed their equipment in different timeframes which was a direct result of available resources for EVSE. The start of installation began prior to actual construction by conducting site visits at each school site within the district to determine charging infrastructure locations. All infrastructure construction required approval by FPBS; a finalization of design from an electrical contractor; a review by the Sac Metro Air District and participating school districts; and the proper certification and permitting from city officials.

In October 2017, each school district made strides in engineering design for EVSE infrastructure. However, these efforts varied based on site preparation needs. For instance, SCUSD indicated that their bus depot was being moved across the street and not ready for charging station installation to begin. SCUSD decided to use a high school in their district to house three of their e-Buses and associated EVSE in the school's parking lot, which could be locked for security purposes. Both SCUSD and EGUSD had similar time frames for infrastructure construction, which occurred toward late 2017 for SCUSD and early 2018 for EGUSD. Having increased staff involvement, TRUSD had site power upgrades and charging infrastructure installed and inspected prior to October 2017.

Delivered e-Buses were submitted by project partners for general inspection and California Highway Patrol (CHP) inspection. School districts received training when e-Buses were delivered, including technical trainings on maintenance and repair, vehicle operation, charging, and training for drivers. During the process of charging installation, some e-Buses were delivered to TRUSD prior to construction completion. TRUSD installed a few temporary chargers to allow for the first CHP inspection and technology debugging process.

EGUSD and SCUSD did not have site electrical power available for temporary chargers. EGUSD stipulated a need to have charging infrastructure installed prior to bus delivery, and SCUSD delayed their receipt of e-Buses until closer to the end of 2017 to due to the complexity of their new depot construction. PG&E ensured CNG lines remained safe during trench work for EVSE installation for both EGUSD and SCUSD. In March of 2018, EV Connect completed EVSE infrastructure at EGUSD, and eLion buses were delivered while CHP inspected the site following the completed installation. SCUSD still had no on-site development during this time-period and agreed to the installation at one of their nearby secured high school parking lots.

TRUSD received their first eight eLion buses during this same time-period. To alleviate stress of having e-Buses on site without permanent chargers in place, temporary charging was installed at sites where e-Buses were being housed while construction at the main sites continued so e-Buses training and usage could start upon delivery. TRUSD began an outreach component for their e-Buses, providing a brochure for parents and community, with special design t-shirts made for children that rode in the e-Buses. Figure 3.2 shows a group of Sacramento City officials posting with TRUSD faculty members and students in front of an eLion bus.

.

Figure 9: Sacramento City Officials, State Legislators, and the Sac Metro Air District Staff Posing with Twin Rivers' Students and Faculty in Front of an eLion Type C e-Bus

3.1.1 SMUD and Power Supply Permitting

FPBS managed purchase orders to subcontractor EV Connect, which in turn managed the design and construction of the charging infrastructure, working with SMUD to pull primaries, update transformers, and supply live power. Figure 10 shows a SMUD charging panel in use.

Permitting for new charging infrastructure required California Environmental Quality Act (CEQA) exemption documents from school districts, as well as SMUD applications, which needed assessment for the electrical requirements of the site. Assessments were focused on transformer capacity, providing power supply to the CS-100-3 charging stations. SMUD's application process can sometimes result in lengthy processing periods – in some cases requiring up to six months at a time to fulfill requests. Any delays in paperwork, which occasionally occurred during coordination between subcontractors and the school district, could result in a delay in installing infrastructure.

Figure 10: SMUD Charging Panel

3.2 E-Bus Delivery

Manufacturing and FPBS' unexpected departure from the project caused some delays in bus delivery. This resulted in EGUSD not taking delivery of two of the e-Buses. Additional delays occurred while they waited for final CHP inspections (CHP inspections are detailed in Table A3). Starting March 2019, e-Buses were in regular use. While riders and drivers reported liking the e-Buses, usage reflected that some of the e-Buses were not used as much. This was in part due to range, and the amount it took to charge the vehicle. Possible solutions to these challenges included finding e-Buses with a longer range and re-routing the current e-Buses onto shorter routes. EGUSD proposed moving their e-Buses to school districts that could utilize them. Despite repairs from Motiv and subcontractors, SCUSD reported at times that three of their e-Buses had chronic battery life issues and because requesting and getting service was time-consuming, the buses deemed unusable. Motiv added a fifth drivetrain battery free of charge to extend the range. The original buses were ordered with only 4 batteries to save money but all other Motiv buses were designed and built with 5 drivetrain batteries at the time. By this time, TRUSD had all their e-Buses in daily use and had begun to refine the bus routes for optimal use.

In September 2019, FPBS departed from the project as managing vendor, closing their business in California and leaving the subcontractors, bus manufacturers, and supporting project partners to manage the remaining project tasks. Despite this, FPBS reported that they had submitted the VGI report within the required project timeline. After their departure, SCUSD was left without a supported warranty at the end of the project timeline for their Type A e-Buses. However, Trans Tech and Motiv continued to support technology challenges and upgrades even after the warranty was no longer available from FPBS.

Two Trans Tech/Motiv Type A e-Buses were never delivered because manufacturers reported not receiving payment from FPBS. With the remaining budget, project partners were able to agree to make changes to the program and permit SCUSD to receive an eLion Type C e-Bus with long range battery capability, with deployment in 2020. SCUSD was completely satisfied with the Type C e-Bus range and capability. As discussed in Section 1.4, the Sac Metro Air District and CARB formulated an amendment to the original grant agreement to reinvest funds for purchase of the Type C e-Bus. Since multiple factors caused e-Bus delivery delays, the Sac Metro Air District also adjusted project timelines to minimize the impact delays had on other project tasks.

Table 1 shows the final e-Buses delivered to school districts. This table also included the average annual vehicle miles traveled (VMT) per vehicle, and annual fleet VMT calculated based on a year with the most complete actual vehicle mileage data.

Table 1: Final e-Bus Counts by District and Annual Vehicle and Fleet VMT Data

School Name	Final Vehicle Count	Average Annual Bus Miles*	Total Annual Fleet Miles
Elk Grove Unified School District	8	3663	29304
Sacramento City Unified School District	4	2966	11864
Twin Rivers Unified School District	16	8195	131127
Totals	**28**	**6153**	**172295**
* Average annual bus miles were based on the average annual mile data of a best year with most complete mileage data, from collected usage surveys. Also, the average annual mile data for SCUSD was lower at the 4th EV, which was the last EV delivered for the project, did not have any mileage data.			

3.2.1 E-Bus Maintenance

Power board defects that resulted in faulty relay switches caused EGUSD to wait nine weeks for two Lion e-Buses.[6] Some issues occurred before buses were even delivered or were part of the delivery, and then some maintenance issues occurred after operating some of the e-Buses. Furthermore, when an e-Bus battery was completely depleted, charging incompatibility caused some buses to not charge at all and sleep-mode caused some buses to only charge if the bus was powered on.

The Sac Metro Air District encouraged policies for alleviating maintenance issues. Upgrades to 12 V battery software became necessary maintenance tasks to reduce battery depletion from hill-hold or requiring a e-Bus to charge even when in sleep mode, so e-Bus does not need to be turned on. This proved successful when TRUSD worked with Motiv to replace draining 12 V batteries and conduct software upgrades solving the issue of range depletion from the hill-hold function.

Since electric vehicle technology is consistently upgrading, securing reliable maintenance became a necessary task that resulted in some e-Buses remaining offline for a few weeks at a time as schools were inundated with other staff capacity. If these issues were not resolved or technology service was not readily available or scheduled, then e-Buses would suffer from on-going battery malfunctions that prevented full charging. As buses came off the manufacturing line, some updates to software were missed because they were done at the factory thus resulting in some buses having persistent issues from missed updates. Three Type A e-Buses delivered to SCUSD had chronic battery-life and charge problems that did not allow normal use

[6] Ibid.

of the buses. As discussed in Section 1.4, the Sac Metro Air District worked with CARB to purchase a Type C, eLion bus.

3.3 Bus Routes

To meet the objective of substantially reducing GHG emissions and eliminating toxic emission exposures to children in disadvantaged communities, the Sac Metro Air District mapped bus routes within these communities. The original application submitted by the Sac Metro Air District outlined the routes that the electric e-Buses would be traveling through DACs. Through the course of the project period, e-Buses had continuous technology updates requiring some buses to be offline, which resulted in modifying routes based on efficient range to accommodate charging times. A main lesson learned in this pilot project was to shorten original bus routes accommodating mileage range for e-Bus battery capability (Appendix E). These items were under heavy consideration throughout the lifetime of the project because they were continuously changing and being modified so buses could be optimally utilized.

3.4 Lack of Drivers and Engine Silence Training

During the time of project deployment, most Northern California school districts experienced hardship with school bus driver shortages. EGUSD reported chronic shortage of available drivers and access to driver training during implementation of their bus routes. The Sac Metro Air District worked with project partners and school districts on initiatives for increasing the amount of e-Bus staff and drivers which included recruitment outreach. EGUSD also mapped out shorter, temporary routes to ensure that transportation access was still provided for their communities, partially resulting from a lack of drivers.

During training sessions, drivers reported that the biggest difference in the e-Buses vs. petroleum-fueled buses was the lack of engine or powertrain noise. The silent motor presented a challenge for districts to create new safety procedures. The Sac Metro Air District worked with districts to create new protocols to address the silent e-Bus powertrain. This process was especially aided by a TRUSD driving instructor who took personal initiative to train drivers and utilize the internet to present information to other fleet managers and interested parties.

3.5 Persistent Range Issues

Range anxiety is a particular concern for new electric vehicle drivers, but this was amplified with a concern over defining traveling times and distance required by the specific routes. School districts reported concern over the driving range of the vehicles. EGUSD communicated that their e-Bus routes required a longer range than what the available technology could handle during the project time period. Unforeseeable by the school districts was that drained batteries required a longer charging time than anticipated. In turn, this resulted in available range being impractical for certain routes leading to the need for route modification and education on available range capability (Lion Electric Bus Company, 2019).

As technology continued improving over the life of the project, based on route needs, researching e-Buses with 150 miles or more range became a recommendation for meeting specific routes and incorporating flexibility for changing conditions. EGUSD suggested moving their e-Buses to schools with shorter routes, and SCUSD was able to work with the drivetrain manufacturer through Motiv to upgrade all their e-Buses with another drivetrain battery free of charge to SCUSD for increased range. By September of 2019, EGUSD modified e-Bus routes to 60 miles, with other buses supporting the remaining 40 – 50 miles of the normal routes. SCUSD buses were upgraded to five battery packs, creating a 70-mile range.

Addressing the demand for creating a charging schedule, SMUD proposed for e-Buses to charge during times outside of the peak times which also addressed issues with drained batteries:

- Peak Winter Rate Time (October 1 – May 31): Weekdays Noon to 10 pm
- Peak Summer Rate Time (June 1 – September 30): Weekdays Noon – 2 pm; 8 pm – 10 pm
- Super Peak Summer Rate Time (June 1 – September 30): Weekdays 2 pm – 8 pm

This prompted FPBS to create a charging schedule to avoid over peak charges.

3.6 Data Collection

The original solicitation and grant agreement stated that tasks for data related to the project included the customization of a data management system installed concurrently with charging infrastructure; a study on the feasibility of solar energy integration into the project; and a VGI feasibility study to optimize electricity demand and reduce costs. FPBS and the Sac Metro Air District were also tasked to perform a well-to-wheel analysis to quantify GHG emission reductions and all criteria emissions associated with the project.

During the initial months of project deployment, Ricardo, Inc. began working with FPBS and school districts to formulate a data collection plan. At the end of 2017, Ricardo, FPBS, subcontractors, and the participating school districts discussed and finalized the data collection plan. The following year, the districts were requested to purchase HEM data loggers for their e-Buses and selected data baseline buses which were petroleum-fueled. The Sac Metro Air District ordered the remaining data loggers for the rest of the e-Buses.

The data management system collected bus telematics, charging station data, and SMUD utility rates. The data management system linked between all three school system networks and collated into EV Connect's cloud-based server. Following data monitoring, collection, and analysis (DCMA) plan, Ricardo selected some representative diesel engine buses as a source of baseline data. Some of the e-Buses were outfitted with the purchased HEM-supplied data loggers. School districts were provided data forms to manually collect the data that could not be collected by HEM data loggers. HEM data loggers collected electronic data. Manual data collection included vehicle information, maintenance, and costs, among others, and these data forms were submitted via email every two weeks.

In 2018, the project acknowledged compatibility issues with the data loggers and reassessed which e-Buses could be utilized for data loggers. In 2019, the Sac Metro Air District, CARB staff, Ricardo, and their subcontractor worked with school district to find a way for manufacturers to gather data despite irregular functionality with the data loggers. With the rapid developments in electric vehicle technology, some issues surrounding incompatibility were on-going and did not find resolution throughout the project lifetime. Data Logging was eventually rectified and continues to remain in place.

4.0 PROJECT OUTCOMES AND FUTURE OUTLOOK

The Sacramento Regional Zero-Emission School Bus Deployment Project is the largest zero-emission school bus initiative in the United States. Due to the efforts of CARB, the Sac Metro Air District, EGUSD, SCUSD, TRUSD, and participating project partners, this keystone project helped to encourage Northern California school districts to see EVs as an effective technology capable of meeting future transportation needs. The project was considered as a success story because of its lasting impact on California transportation infrastructure and industry, as well as the now widespread recognition of EVs as being capable of reducing greenhouse gas emissions and other pollutants. Per requirements of the project, the VGI study was submitted by ChargePoint, concluding that battery electric vehicle (BEV) charging could represent an asset to the grid, and that charging processes can meet the demands of the grid. Regarding renewable energy, such as wind and solar, the VGI report also concluded that implementation of renewable energy was not possible currently due to battery storage limitations and that production may not coincide with daily peak usage (Appendix C).

4.1 Project Outcomes

The outcome of implementing e-Buses delivered numerous benefits to the school districts and communities they serve, which includes:

- Eliminating diesel exhaust emissions, particulate pollution and pollutants that contribute to the formation of ground-level ozone.
- Significantly lower greenhouse gas emissions than diesel, and natural gas-powered buses.
- Financial benefits were reported from school district directors, including substantially reduced maintenance and fuel costs.
- Reducing air pollution, delivering significant societal benefits, including healthcare expenses resulting from cleaner air.

Well-to-wheel GHG emissions from the deployment of the 28 project e-Buses was calculated at 311 metric tons of CO_2 per year based on the total annual fleet VMT. In addition to GHGs, these e-Buses also reduced tailpipe criteria and toxic pollutant emissions. Specifically, the total emission reductions generated from these 28 e-Buses were 0.146 tons of NO_x/year, 0.018 tons of ROG/year, and 0.003 tons of PM_{10}/year. The combined weighted emission reductions for criteria pollutants were calculated to be 0.230 tons/year. Detailed calculations related to the emission reductions are provided in Appendix B.

Making changes to school buses' fuel sources drastically reduces their effects on the environment. There are important environmental considerations beyond fuel consumption, including GHG emissions. Higher concentrations of GHGs in the atmosphere contribute to global warming. Despite their differences in petroleum use, the latest diesel, propane, and CNG school bus models emit similar amounts of GHGs — about 40 to 50% more than electric options.

The e-Buses met 60% of their expected usage during the first year of the pilot demonstration. The factors stated above contributed to lower data outcomes for the e-Buses compared to the Sac Metro Air District's initial projections in the original application. Despite dealing with significant issues associated with the e-Bus deployment and usage, the project partners diligently addressed these issues throughout the program, and school districts consistently attempted to deploy their e-Buses with full participation. The diligence and determination by all project partners lead to the success of this pilot project.

4.2 Impact on Participating School Districts

Buses and charging infrastructure remain at the three participating school districts, although EGUSD attempted to move their e-Buses to other districts and SCUSD stopped utilizing their Trans Tech Buses following the loss of warranty after the FPBS departure from the state of California. There is a consensus among the districts that the range of these e-Buses and their battery issues were consistent problems. Therefore, e-Buses are operating congruently with diesel powered buses. Increases in battery capacity and more efficient electric vehicle technology since project start, e-Buses are becoming the leading choice in replacing old combustion engines and more funding is becoming available to subsidize the purchase of e-Buses.

Overall, the participating school districts have reached the consensus, based on their involvement in the project, that e-Buses are the best possible option for zero-emission vehicles that provide transportation while lowering GHG emissions, thus reducing exposure from emissions to children – especially those living within disadvantaged communities. Furthermore, all three districts have taken the initiative to expand their electric vehicle fleets with contracts for new buses following the conclusion of their participation in the project. This major decision supports that early adoption of electric vehicles, although early versions of technology may have upsides and downsides to work through, is a viable option for communities looking to improve their air quality and serve the needs of the school district's transportation. The pilot project clearly demonstrated that electric school buses can transport children to and from school safely and effectively while exhibiting a lower total cost of ownership based off testimonials from transportation directors at the school districts compared to conventional school buses, and while emitting zero emissions.

4.3 Media Coverage

One of the benefits of a media presence is that the public can view, comment, ask questions, and get direct answers. Media has demonstrated the actual work that was being done within this project. As noted in the appendix with a list of article titles, there was significant media coverage on this project since at time of the application, this was the largest deployment of electric school buses. Some of the articles were released from local news sources, such as KCRA 3, CBS 13 Sacramento, and Capital Public Radio. Other recognition for this pilot project came from New York Times, San Francisco Gate, and Chicago News Journal. Media presence reached across the nation and throughout the state of California shedding light on the benefits and success of transporting students on e-Buses as a way to adopt more alternative modes of technology for transportation.

Figure 11: Twin Rivers Students All Charged Up!

4.4 Impact on Northern California and Transportation Infrastructure

The impact of the project on the transit industry and transportation infrastructure in Northern California expanded services and proved that EV technology for mass transit is not only possible, emissions data clearly show that electric school buses are the most environmentally friendly option, as they don't use traditional fuels, emit fewer GHSs, and create little pollution. The project has accelerated adoption of e-Buses in school districts while expanding demand for the industry. The outcomes and perseverance of school districts to utilize the e-Buses to full potential when possible is proof that the project was successful in demonstrating e-Buses and providing opportunity for educating school districts about EV viability.

During the project timeline, the Sac Metro Air District continued to attend the Sacramento Bus Consortium meetings, providing regular updates and presentations to share knowledge with manufacturers and transportation officials. The Sac Metro Air District is now working toward a long-term goal of deploying one e-Bus for every Sacramento County school district. Currently, the Sac Metro Air District has received applications from every district and continues to work with interested parties on electric vehicle fleet deployments. Nationwide, there are now hundreds of e-Buses being deployed in multiple school districts.

TRUSD directors acted as a continual advocate for zero-emissions school buses during the project, going so far as to create a website to provide information to interested parties. TRUSD committed to electric vehicle advocacy, remains a pioneer of hosting the largest fleet of electric school buses in the nation.

Key relationships were formed during this pilot project, such as SMUD joining in the Sacramento Bus Consortium as a regular meeting attendee starting in 2018. During the project, SMUD identified the need for a rebate program as a utility to incentivize the electrification of bus fleets for school districts. In pursuit of this endeavor, SMUD is in process of creating this program. SMUD acknowledges electric infrastructure as the next technology of the transit industry, going so far as to change energy-efficiency metrics to encourage electrification.[7]

[7] https://www.greentechmedia.com/articles/read/this-california-utility-is-now-measuring-building-electrification-in-avoided-carbon

Lion Electric, a Canadian company, took steps to certify products as American made during the project timeline. In December of 2019, Lion Electric opened an 18,000 square-foot facility in McClellan Park in Sacramento, California. The facility is fully dedicated to heavy-duty e-Buses. Since opening, Lion Electric has delivered more than 200 zero-emissions school buses in the United States, with California leading with largest number of active e-Bus fleets. Lion Electric's establishment as an EV manufacturer in the state of California represents a growing number of electric sales and manufacturing companies in the state of California, including AZ Bus Sales, Proterra, and BYD.

4.5 Considerations for Future e-Bus Deployment Projects

The high up-front costs associated with electric school buses - including the price of the vehicles and charging infrastructure - continue to limit districts' ability to include them in their school transportation operations. As e-Buses represent a new and emerging technology in California, there is emphasis on considering the implementation costs for future projects geared toward e-Bus and electric vehicle fleet deployments. Although the technology is rapidly improving, e-Buses are more expensive to purchase relative to conventional school buses and vehicles. To ensure that e-Buses are optimally utilized and efficient for optimal cost-effectiveness, the overarching best practice recommended by the Sac Metro Air District and partners would be to modify routes with appropriate mileage for e-Bus battery range. Optimized routes and efficient charging schedules will aid in initial cost justification. In addition, costs associated with charging infrastructure will need to be factored into initial deployment, but can be accommodated through several rebate and incentive programs that have been created as part of identified needs from this pilot project and by leading energy companies like SMUD.

As EV technology grows, California may continue promoting industry competition and larger EV supply. This can advance EV development and lower prices, and ultimately position e-Buses as a legitimate alternative to conventional vehicles. In this interim, California must continue advocating for support of EV technology and e-Bus deployment, especially initiatives reducing barriers that can prevent adoption of EV fleets. SMUD's creation of a rebate program and cooperation with Plug In America to educate consumers on the options available for EVs, the ongoing support of pilot projects through CCI and the GGRF, and CARB's Low Carbon Fuel Standard Credit (LCFS) Program all represent supportive government initiatives that will assist school districts in meeting their demand for EV fleets.

Vehicle grid (VGI) integration are currently in demonstration phase and projects are being conducted for optimizing the electric grid with EV charging, but ongoing improvements to battery capacity and electric infrastructure will eventually realize this important technology innovation. Public fleet vehicles may more successfully support VGI applications given they have predictable routes of limited range and are not in use for extended periods of time. After public fleet vehicles conduct their typical routes, they can be plugged in providing energy back onto the electric grid for the entirety of the time they are not in use, enabling them to collect revenues for VGI services for several hours per day – although regulatory and technical obstacles will need to be overcome before VGI application is at full potential. Charging times for e-Bus and other EV fleets must be supported by energy utility companies for optimal charging schedules that align with the school district's transportation schedules. In effort to keep charging costs low, utility companies should continue educating school districts on affordable charging times, such as off-peak hours.

5.0 LESSONS LEARNED AND RECOMMENDATIONS

The project, despite its successes, faced numerous obstacles and setbacks during its deployment phase that offer important insight and wisdom for similar initiatives. The following chapter represents a reflective look at the project in hindsight from the Sac Metro Air District staff, detailing three of the biggest lessons learned and recommendations to address similar project challenges.

5.1 Grant Language and Adaptability

The initial grant language for the project was very specific related to timeline tasks and budget disbursements. This generated multiple challenges over the course of the project, further exacerbating project delays and creating a compounding effect any time a project challenge occurred. Feedback from school districts, project partners, and the Sac Metro Air District project leaders agree on the need for more flexible grant language to adapt to these issues. Having learned from this experience, project participants propose the following recommendations:

- **Ensure that budget disbursements are approved by completion of individual task on a site-by-site basis.** The grant language initially established that task specific disbursements occur only if all partnering school districts had completed the same task over the course of the project timeline. As project sites often moved on different schedules due to individual project pace and resources for permitting, installing infrastructure, completing driver training, and maintaining the buses, all project sites would be delayed for financial reimbursements due to individual site issues. This resulted in school districts often shouldering the burden of financial strain related to the project. Later, project managers wisely agreed on a plan for grant disbursements and associated participant reimbursements to be approved by completion of individual task and participant site, and this approach should serve as a baseline for future budget management. Future contract agreement language should support project partners to be paid based on their individual project completions and associated passing inspections to support real world project and budget needs.

- **Assist managing vendors and project partners in drafting paperwork processes that adhere strictly to grant requirements.** A continual issue for the project was FPBS's invoicing process, which often failed to itemize project tasks, resulting in the Sac Metro Air District having to repeatedly work with the company to rework their invoices. This again caused hardship for the school districts, as there were numerous delay periods between when they paid FPBS for rendered services and when they received a project task reimbursement. Project managers should either draft additional paperwork for vendors to provide necessary project information or develop a system to hold vendors accountable for delayed invoices so as not to put strain on school district resources and allow them to continue to deploy the project smoothly.

5.2 Communications and Advocacy for Adoption

Tim Shannon, Transportation Director for TRUSD, shared a particular anecdote at a bus consortium meeting, a student within the school mentioned that their father expressed surprise in the project's existence during deployment, stating, "There's no such thing as an electric bus." This statement sheds light on the necessity for more advocacy and outreach programs encapsulating the viability of electric vehicle technologies, especially at a heavy-duty application. More advocacy and education presented to decision-makers and importantly the public will ensure projects can develop smoothly and assists in fulfilling needed participation for meeting project requirements. Effective communication between managers and project partners is key; continual dialogue will alleviate the creation of an “instantaneous challenge” due to a communication failure. In response to these considerations, the Sac Metro Air District recommends:

- **Build a communications and advocacy plan for your community during project deployment**. The project was repeatedly aided by countless district and transportation professionals that developed a personal passion and understanding of the project objectives. These professionals responded to challenges that occurred with driver training, communication to interested parties, and management of technology and data reporting. Many of these challenges were unforeseeable, but they still managed to be addressed due to the community response. Furthermore, the solution to addressing driver shortages was an outreach and recruitment campaign that presented a need to the community. By continually reaching out and speaking to the project community in mediums such as meetings, digital campaigns, and school projects will increase total project awareness and generate a knowledgeable and engaged population of professionals able to help success of a project.

- **Ensure that project partners are aware of developments between all parties.** The sudden departure of FPBS from the project resulted in many unfortunate outcomes, including undelivered EVs to project sites, buses without warranties, and unfulfilled subcontractor requests. Were it not for open communication and constant quarterly updates amongst project partners, such a departure could have resulted in project failure. Project subcontractors like Motiv and Trans Tech, however, continued to communicate and support the project and technology challenges despite FPBS’s departure. Future project communication should ensure that managing vendors and subcontractors have their needs addressed so that such project departures can be foreseen and accommodated over the course of the project.

5.3 Technology that Meets Both Project and Partner Needs

Certain buses and data collection technologies that were deployed during the project failed, which is an unfortunate but not unexpected outcome during pilot projects. In the project’s case, continued technology failures negatively affected data related to project usage. Having faced this challenge, project participants propose the following recommendations to ensure that projects are successful despite technology challenges:

- **Do not be conservative in estimating technology-based needs.** Based on initial project research and consideration of bus routes and daily mileage needs, project partners and vendors considered Trans Tech 75 EV buses to have enough capacity to cover bus routes; this was, however, too conservative of an estimation and did not consider issues associated with continual use, charging times, depletion related to the hold-hill function, and temperature control for the batteries and vehicle chassis. As such, the capacity of the vehicle strongly underperformed, to such an extent that SCUSD’s reported usage data reflected training, troubleshooting, and repair usage — not student transportation. Battery capacity was continually increased during the project, and SCUSD reported that the eLion Type C EV bus managed transportation needs with its longer range and capacity. It is important to assume, therefore, that an EV may underperform relative to its advertised capacity. Projects should consider this and determine whether to increase their initial investments and purchase more capable, higher performing technology.

- **Perform an optimal amount of research to ensure that data collection technology can accommodate your deployed technology.** An obvious issue in the deployment of data technology was the fact that HEM data loggers were not compatible with Trans Tech EV buses. This required additional support from the school and project partners to address data collection needs, pulling away time and resources from other aspects of the project deployment. When determining the technology needed for data collection, it is important to consider if a data technology is compatible with the other technology being deployed in the project.

- **Understand that pilot projects are an early technology innovator and prepare for delays.** The adoption of early technology will usually result in hardships related to deployment and use. Novel technology results in novel challenges, and these will require novel solutions. This was absolutely the case with this project's EVs, which required continual repair and maintenance as well as training related to interesting new challenges like the silent engine feature. These novel challenges are a part of any pilot project. Ample time should be appropriately budgeted, assuming that delays are inevitable and a natural part of the project process. Budgets should also consider ordering beyond the minimum requirement for battery storage and operation for e-Buses to alleviate risk of chronic battery problems or low utilization from batteries draining too quickly.

APPENDICES

Appendix A: TABLES

Table A2: Project Budget

Grant Budget and Total Fund Expenditures

Costs	CARB Grant	Project Team Match Funding		Total
		Cash	In-Kind	
1. Project Funds	$7,311,460	$3,296,744	$4,158,951	$14,767,154
2. Administrative Funds	$224,183	N/A	N/A	$224,183
3. Earned Interest	$48,816	N/A	N/A	$48,816
Total	$7,584,459	$3,296,744	$4,158,951	**$15,040,153**

Cash Match Funding	
Company/School/Agency	**Amount**
Elk Grove USD	$450,106
Sacramento City USD	$147,500
Twin Rivers USD	$1,120,817
SMAQMD	$1,578,321
Total	**$3,296,744**

In-Kind Match Funding	
Company/School/Agency	**Amount**
ChargePoint	$16,000
Elk Grove USD	$33,097
EVConnect	$59,340
FPBS	$195,448
Lion	$26,100
Motiv	$635,820
Sacramento City USD	$55,236
SMAQMD	$1,100,000
Twin Rivers USD	$2,037,908
Total	**$4,158,950**

CARB Grant (CCI GGRF) Expenditure	
School District	**Amount**
Elk Grove Unified School District	$2,262,560
Sacramento City Unified School District	$651,775
Twin Rivers Unified School District	$4,067,957
Others	$329,168
Total	**$7,311,460**

Table A3: CHP Inspections

EV Bus - CHP Inspections			
District Bus or INF	SMQV	Technology Type	Date
SC1	SMQV007034	Trans Tech, Type A	10/19/2018
SC2	SMQV007035	Trans Tech, Type A	10/19/2018
SC3	SMQV007036	Trans Tech, Type A	2/20/2019
SC4	SMQV008811	eLion, Type C, 125mi Range	7/29/2020
SC-INF	SMQV007037	Infrastructure or Baseline Bus Data Logger	NA
TR1	SMQV006873	eLion, Type C, 100mi Range	5/3/2017
TR2	SMQV006874	eLion, Type C, 100mi Range	5/3/2017
TR3	SMQV006875	eLion, Type C, 100mi Range	5/3/2017
TR4	SMQV006876	eLion, Type C, 100mi Range	5/3/2017
TR5	SMQV006877	eLion, Type C, 100mi Range	12/22/2016
TR6	SMQV006878	eLion, Type C, 100mi Range	5/3/2017
TR7	SMQV006879	eLion, Type C, 100mi Range	5/3/2017
TR8	SMQV006880	eLion, Type C, 100mi Range	5/3/2017
TR9	SMQV006881	Trans Tech, Type A	2/22/2018
TR10	SMQV006882	Trans Tech, Type A	3/26/2018
TR11	SMQV006883	Trans Tech, Type A	2/22/2018
TR12	SMQV006884	Trans Tech, Type A	2/22/2018
TR13	SMQV006885	Trans Tech, Type A	6/5/2018
TR14	SMQV006886	Trans Tech, Type A	6/5/2018
TR15	SMQV006887	Trans Tech, Type A	6/6/2018
TR16	SMQV006888	Trans Tech, Type A	6/5/2018
TR-INF	SMQV006889	Infrastructure or Baseline Bus Data Loggers	NA
EG1	SMQV007017	eLion, Type C, 75mi Range	3/16/2018
EG2	SMQV007018	eLion, Type C, 75mi Range	3/16/2018
EG3	SMQV007019	eLion, Type C, 75mi Range	3/16/2018
EG4	SMQV007020	eLion, Type C, 75mi Range	3/16/2018
EG5	SMQV007021	eLion, Type C, 75mi Range	3/16/2018
EG6	SMQV007022	eLion, Type C, 75mi Range	3/30/2018
EG7	SMQV007023	eLion, Type C, 75mi Range	3/30/2018
EG8	SMQV007024	eLion, Type C, 75mi Range	4/4/2018
EG9	SMQV007025	Trans Tech, Type A	Not Delivered
EG10	SMQV007026	Trans Tech, Type A	Not Delivered
EG-INF	SMQV007027	Infrastructure or Baseline Bus Data Loggers	NA

APPENDIX B

Emissions Report

APPENDIX B. Emission Reduction Calculation Report

Emission Reductions

Based on the methodology in Attachment D from the original application (see attached), the well-to-wheel GHG emissions avoided from the deployment of 28 zero-emission school buses is calculated to be 311 MT CO_2/year.

In addition to GHGs, the proposed vehicles will reduce tailpipe criteria and toxic pollutant emissions. Specifically, the total emission reduction for 28 zero-emission transit buses is 0.146 tons of NO_x/year, 0.018 tons of ROG/year, and 0.003 tons of PM_{10}/year. The combined weighted emission reductions for criteria pollutants is 0.230 tons/year.

The values and calculations are shown in Table A3 below.

Cost-Effectiveness Calculations

Using the methodology in Attachment D from the original application, the estimated cost-effectiveness of the project dollars per ton of GHG emissions reduced and dollars per ton of weighted emissions reductions during a 2-year demonstration and during a 10-year period of project vehicle operation were calculated. These cost-effectiveness values are shown in Table A3 below.

The buses met 60% of the expected usage during the two-year pilot demonstration. The reasons behind the lower usage are noted within other sections in this final report.

Table A4: Emission Reduction Calculations

School Name	Final Vehicle Count	Average Annual Bus Miles*	Total Annual Fleet Miles
Elk Grove Unified School District	8	3663	29304
Sacramento City Unified School Distri	4	2966	11864
Twin Rivers Unified School District	16	8195	131127
Totals	**28**	**6153**	**172295**

* Average annual bus miles were based on the average annual mile data of a best year with most complete mileage data. Also, the average annual mile data for SCUSD was lower as the 4th EV, which was the last EV delivered for the Project, did not have any mileage data.

Application VMT Data	
Mileage Assumptions	**Total Miles**
13 type A buses @ 14,302 mi/yr	185926
16 type c buses @ 6,993 mi/yr	111888
Grand Total mi/yr	**297814**
Revised Total mi/yr @ 28 Buses	**287545**

Application Total Annual Fleet Miles	287545
Project Total Annual Fleet Miles	172295
Project Annual Fleet Mile % Met	60%

Emissions	Calculated Emission Reductions	
	Project Actual (tons/yr)	Application Value (tons/yr)
GHG	311	519
NOx	0.146	0.243
ROG	0.018	0.030
PM10	0.003	0.006
Combined Weighted Criteria Pollutant	0.230	0.384

GHG CE Value	2 Year Project Life ($/ton)	10,902	6,532
	10 Year Project Life ($/ton)	2,336	1,400
Criteria Pollutant CE Value	2 Year Project Life ($/ton)	14,626,826	8,764,308
	10 Year Project Life ($/ton)	3,152,601	1,889,020

Below is the supporting Appendix D calculation methodology from the original application.

Attachment D: Emission Reductions and Cost-Effectiveness Calculations

Emission Reductions

Based on the methodology in Appendix D, the well-to-wheel GHG emissions avoided from the deployment of 29 zero-emission school buses is calculated to be 518.87 MT CO_2/year.

In addition to GHGs, the proposed vehicles will reduce tailpipe criteria and toxic pollutant emissions. Specifically, the total emission reduction for 29 zero-emission transit buses is 0.2429 tons of NO_x/year, 0.0295 tons of ROG/year, and 0.0056 tons of PM_{10}/year. The combined weighted emission reductions for criteria pollutants is 0.3841 tons/year.

Cost-Effectiveness Calculations

Using the methodology in Appendix D, the estimated cost-effectiveness of the project dollars per ton of GHG emissions reduced and dollars per ton of weighted emissions reductions during a 2-year demonstration and during a 10-year period of project vehicle operation are as following:

Dollars per MT of GHG emissions (in CO2 equivalent) reduced during the actual proposed project over a 2-year demonstration	**GHG $C/E_{2\ years}$ = \$6, 532. 41/MT CO_2e reduced**
Dollars per MT of GHG emissions (in CO2 equivalent) reduced once deployed into the marketplace, one year post proposed demonstration and based on a10-year vehicle/equipment useful life	**GHG $C/E_{10\ years}$ = \$1,399.82/MT CO_2e reduced**
Dollars per ton of combined criteria pollutant and weighted PM emissions reduced during the actual proposed project over a 2-year demonstration	**Criteria Pollutant $C/E_{2\ years}$ = \$8,764,308/ton criteria pollutants reduced**
Dollars per ton of combined criteria pollutant and weighted PM emissions reduced once deployed into the marketplace, one year post proposed demonstration and based on a 10-year vehicle/equipment useful life	**Criteria Pollutant $C/E_{10\ years}$ = \$1,889,020/ton criteria pollutants reduced**

Assumptions

The potential greenhouse gas emissions in this project were calculated using a well-to-wheel analysis and formulas provided by CARB, in Appendix D of the solicitation, to ensure consistency.

Baseline Type A School Bus:

- 1996 Thomas Vista with International T444 diesel engine. This vehicle is one of the newer vehicles of those identified to be replaced by Twin Rivers with older vehicles including 1990 to 1997 models.

- Emission standard of 10.51 g NO_x/ mile, 0.20 g ROG/mile, and 0.226 g PM10/mile.
- Gas mileage is 6 mpg in a vehicle operating 180 school days per year, approximate yearly mileage of 14,302.
- Vehicle cost at demonstration: $80,000.00

All-Electric Motiv Powered Type A School Bus:

- Motiv Powered Type A School Bus with 5 battery system, 106 kWh nominally, with 20% reserve power to maintain optimal battery health.
- All-Electric Type A School Bus cost at demonstration: $261,981.00

Baseline Type C School Bus:

- The buses being replaced range from 1988 to 1999 vehicles manufactured by both Thomas and Bluebird.
- Fuel usage is 6 miles per gallon with yearly estimates based upon the average miles per year of 6,993 based upon the average routes for bus replacement as supplied from the school districts.
- Equivalent Diesel Vehicle cost at demonstration: $150,000.00

All-Electric Type C School Bus:

- eLion with 106 kWh nominally, with 20% reserve power to maintain optimal battery health.
- All-Electric Type C School Bus cost at demonstration: $411,106.00

Carbon Intensity	Diesel	102.76 gCO_2e/MJ	Table ZET&B App D2
	Electricity	105.16 gCO_2e/MJ	
Energy Density	Diesel	134.47 MJ/gal.	Table ZET&B App D1
	Electricity	3.60 MJ/kWh	
Energy Efficiency Ratio	Diesel	1.0	Table ZET&B App D3
	Electricity	4.2	

Greenhouse Gas Emission Reductions

Potential GHG emission reductions are determined on a well-to-wheel basis and the electricity used will be 100% average California electricity.

GHG emissions that are attributed to the base case diesel Type A School Bus

$$GHG_{Base\ Type\ A} = \frac{102.76\ gCO2e}{MJ} \times \frac{134.47\ MJ}{DGE} \times \frac{14{,}302\ mi}{year} \times \frac{DGE}{6} \times \frac{1\ metric\ ton\ CO2e}{1{,}000{,}000\ g}$$

$$= 32.94 \frac{metric\ tons\ CO2e}{bus - year}$$

GHG emissions that are attributed to the all-electric Motiv Powered Type A School Bus

$$GHG\ EF_{Electric\ Type\ A} = \frac{14{,}302\ mi}{year} \times \frac{DGE}{6\ mi} \times \frac{134.47\ \mathrm{MJ}}{DGE} \times \frac{1}{4.2} \times \frac{105.16\ gCO2e}{MJ} \times \frac{1\ metric\ ton\ CO2e}{1{,}000{,}000\ grams}$$

$$= 8.03\ \frac{metric\ tons\ CO2e}{bus - year}$$

GHG emissions reduced per Type A School Bus

$$GHG\ Reduced = GHG\ EF_{Base\ Van} - GHG\ EF_{Electric\ Van}$$

$$= 32.94\ \frac{metric\ tons\ CO2e}{year} - 8.03\frac{metric\ tons\ CO2e}{year}$$

$$GHG\ Reduced\ = 24.91\ \frac{metric\ tons\ CO2e}{bus - year}$$

GHG emissions that are attributed to the base case diesel Type C School Bus

$$GHG\ EF_{Base\ Type\ C} = \frac{102.76\ gCO2e}{MJ} \times \frac{134.47\ MJ}{DGE} \times \frac{6{,}993\ mi}{year} \times \frac{DGE}{6\ mi} \times \frac{1\ metric\ ton\ CO2e}{1{,}000{,}000\ grams}$$

$$= 16.11\frac{metric\ tons\ CO2e}{bus - year}$$

GHG emissions that are attributed to the All-Electric Type C School Bus

$$GHG\ EF_{Electric\ Type\ C} = 6{,}993 \times \frac{DGE}{6\ mi} \times \frac{134.47\ MJ}{DGE} \times \frac{1}{4.2} \times \frac{105.16\ gCO2e}{MJ} \times \frac{1\ metric\ ton\ CO2e}{1{,}000{,}000\ g}$$

$$= 3.92\frac{metric\ tons\ CO2e}{bus - year}$$

GHG emissions reduced per Type C School Bus

$$GHG\ Reduced = GHG\ EF_{Base\ Type\ C} - GHG\ EF_{Electric\ Type\ C}$$

$$= 16.11\ \frac{metric\ tons\ CO2e}{year} - 3.92\frac{metric\ tons\ CO2e}{year}$$

$$GHG\ Reduced\ = 12.19\frac{metric\ tons\ CO2e}{bus - year}$$

Annual GHG emissions reduced by project vehicles

$$GHG\ Reduced = 13\ buses \times\ GHG\ Reduced_{Type\ A\ Bus} +\ \ 16\ buses \times\ GHG\ Reduced_{Type\ C\ Bus}$$

$$= 13\ buses \times 24.91\ \frac{metric\ tons\ CO2e}{bus{-}year} + 16\ buses \times\ 12.19\ \frac{metric\ tons\ CO2e}{bus{-}year}$$

$$GHG\ Reduced\ = 518.87\ \frac{metric\ tons\ CO2e}{year}$$

Criteria Pollutant Reductions

All criteria pollutant reduction numbers are based on 2010, per ARB instructions in Appendix D. Actual criteria pollutant reductions are expected to be higher because the zero-emission electric vehicle demonstration will replace buses from 1988 to 1999. Emissions factors are sourced from the Moyer Guidelines Appendix D, Table D-3.

NO_x = 0.74 gNO_x/mile

ROG = 0.09 gROG/mile

PM_{10} = 0.017 gPM_{10}/mile

Baseline Type A School Bus:

$$Baseline\ Type\ A\ Bus\ EM_{NOx} = 0.74 \frac{gNO_x}{mile} \times\ 14{,}302 \frac{miles}{year} \times \frac{1\ ton}{907{,}200g} = 0.0117\ \frac{tons\ NO_x}{bus - year}$$

$$Baseline\ Type\ A\ EM_{ROG} = 0.09 \frac{gROG}{mile} \times\ 14{,}302 \frac{miles}{year} \times \frac{1\ ton}{907{,}200g} = 0.00142\ \frac{tons\ ROG}{bus - year}$$

$$Baseline\ Type\ A\ EM_{PM10} = 0.017 \frac{gPM_{10}}{mile} \times\ 14{,}302 \frac{miles}{year} \times \frac{1\ ton}{907{,}200g} = 0.000268\ \frac{tons\ PM_{10}}{bus - year}$$

Baseline Type C School Bus:

$$Baseline\ Type\ C\ EM_{NOx} = 0.74 \frac{gNO_x}{mile} \times 6{,}993 \frac{mile}{year} \times \frac{1\ ton}{907{,}200g} = 0.0057\ \frac{tons\ NO_x}{bus - year}$$

$$Baseline\ Type\ C\ EM_{ROG} = 0.09 \frac{gROG}{mile} \times\ 6{,}993 \frac{miles}{year} \times \frac{1\ ton}{907{,}200g} = 0.000694\ \frac{tons\ ROG}{bus - year}$$

$$Baseline\ Type\ C\ EM_{PM10} = 0.017 \frac{gPM_{10}}{mile} \times\ 6{,}993 \frac{miles}{year} \times \frac{1\ ton}{907{,}200g} = 0.000131\ \frac{tons\ PM_{10}}{bus - year}$$

Because the proposed technologies are Zero-Emission Battery-Electric Vehicles, there are no tailpipe emissions associated with operation. Therefore, all emissions associated with the baseline Type A School Buses and Type C School Buses are eliminated. There are greenhouse gases associated with the electric usages as previously quantified but there are no further emissions of NOx, ROG, or PM_{10} associated with operation.

The total emission reduction for 13 Type A School Buses and 16 Type C School Buses is thus:

- $0.2433\ tons\ NO_x/year$
- $0.0296\ tons\ ROG/year$
- $0.0056\ tons\ PM_{10}/year$

Weighted Emission Reductions

*NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * (PM reductions (tons/yr)]*

WER is the Weighted Emission Reductions

Type A School Bus Emission Reductions

$$WER = 0.0117\ \frac{tons\ NO_x}{bus - year} + 0.00142\frac{tons\ ROG}{bus - year} + 20 \times 0.000268\frac{tons\ PM_{10}}{bus - year}$$

$$= 0.0185\, {}^{tons\ criteria\ pollutants\ reduced}/_{bus - year}$$

This number reflects the emission reductions from one year of operation for one vehicle. For the total 13 Type A School Buss:

$$WER = 13\ buses\ x\ 0.0185\, {}^{tons\ criteria\ pollutants\ reduced}/_{bus - year}$$

$$WER = 0.2405\, {}^{tons\ criteria\ pollutants\ reduced}/_{year}$$

Type C School Bus Emission Reductions

$$WER = 0.0057\ \frac{tons\ NO_x}{bus - year} + 0.000694\ \frac{tons\ ROG}{bus - year} + 20 \times 0.000131\ \frac{tons\ PM_{10}}{bus - year}$$

$$= 0.0090\, {}^{tons\ criteria\ pollutants\ reduced}/_{bus - year}$$

This number reflects the emission reductions from one year of operation for one vehicle. For the total 16 Type C School Buss:

$$WER = 16\ buses\ x\ 0.0090\, {}^{tons\ criteria\ pollutants\ reduced}/_{bus - year}$$

$$WER = 0.1440\, {}^{tons\ criteria\ pollutants\ reduced}/_{year}$$

TOTAL Project Weighted Emission Reduction

$$WER = 0.2405 + 0.1440\, {}^{tons\ criteria\ pollutants\ reduced}/_{year}$$

$$WER = 0.3845 \, {}^{tons\ criteria\ pollutants\ reduced}/_{year}$$

Cost-Effectiveness

Incremental Costs:
Baseline Type A School Bus:

- Type A School Bus cost at demonstration: $80,000.00

All-Electric Type A School Bus:

- All-Electric Type A School Bus cost at demonstration: $261,981.00

$$Incremental\ Cost = \$261{,}981.00 - \$80{,}000.00 = \$181{,}981.00$$

Baseline Type C School Bus:

- Type C School Bus cost at demonstration: $150,000.00

All-Electric Type C School Bus:

- All-Electric Type C School Bus cost at demonstration: $411,106.00

$$Incremental\ Cost = \$411{,}106.00 - \$150{,}000.00 = \$261{,}106.00$$

Project Incremental Costs:

$$Project\ Incremental\ Cost = 13 \times \$181{,}981.00 + 16\ x\ \$261{,}106.00 = \$6{,}543{,}449.00$$

GHG Cost Effectiveness:

The GHG emission reduction cost effectiveness for the proposed project calculated using the Capital Recovery Factor of .515 for 2 years and .111 for 10 years as required:

$$GHG\ C/E_{2\ years} = \frac{0.515 \times \$6{,}543{,}449.00}{518.87\ metric\ tons\ CO2e} = \$6{,}532.41\ /_{metric\ tons\ CO2e\ reduced}$$

$$GHG\ C/E_{10\ years} = \frac{0.111 \times \$6{,}543{,}449.00}{518.87\ metric\ tons\ CO2e} = \$1{,}399.82\ /_{metric\ tons\ CO2e\ reduced}$$

Criteria Pollutant Cost Effectiveness:

$$CP\ C/E_{2\ years} = \frac{0.515 \times \$6{,}543{,}449.00}{0.3845\ WER} = \$8{,}764{,}308/_{tons\ criteria\ pollutants\ reduced}$$

$$CP\ C/E_{10\ years} = \frac{0.111 \times \$6{,}543{,}449.00}{0.3845\ WER} = \$1{,}889{,}020 /_{tons\ criteria\ pollutants\ reduced}$$

APPENDIX C

ChargePoint VGI Report

APPENDIX C. ChargePoint VGI Report

Vehicle Grid Integration (VGI) Study

This report will focus on the opportunity to combine electric school bus charging with supporting the needs of the electrical grid. We will use the detailed data that we have from two years of charging electrical school buses in the Sacramento area as a base case for this study. This report will be divided into three main sections: Background, Current Environment, and Charging Pattern and Optimization.

Background

VGI technology can be defined as a system in which there is capability of controllable, bi-directional electrical energy flow between a vehicle and the electrical grid. The electrical energy flows from the grid to the vehicle in order to charge the battery. It flows in the other direction when the grid requires the energy, for example, peak load leveling, grid stability and regulation services.

The parties that are involved in a VGI operation include the vehicle supplier (Lion), the vehicle owner (the school), the electric vehicle supply equipment owner (EV Connect/BTC Power), and the electrical utility (SMUD).

From the grid perspective, the electric utility has two primary obligations: it must supply electricity on a reliable basis and maintain profitability. Additionally, utilities are asked to provide "cleaner" power through higher usage of renewable energy. These goals intersect with the need for load control to cost effectively manage periods of peak load. Utilities are likely to find bi-directional power flow of Battery Electric Vehicles (BEVs) in a VGI system attractive as a storage medium and load-leveling sink for intermittent renewable energy and as a means of fulfilling their grid support.

From the end-user perspective, the vehicle needs to be charged to a sufficient state-of-charge (SOC) so that it meets the driving needs of the owner when the owner wants to use it. Additionally, the owner can benefit from incremental revenue through energy arbitrage from every kWh of electricity that is discharged from their vehicle's energy storage system (high capacity batteries) to the electrical grid or for simply making its capacity to discharge available for such action.

Many of the grid-scale benefits of VGI can be accomplished with unidirectional managed charging services, also known as V1G or "smart charging" which is the configuration at use by the three Sacramento School Districts. V1G involves varying the time or rate at which an electric vehicle is charged in order to provide ancillary services to the grid, while V2G also includes reverse power, or bi-directional flow. V1G includes applications such as timing vehicles to charge in the middle of the day or varying the charge rate of electric vehicles to provide schools with the lowest possible electrical rates and provide frequency response services or load balancing services for the grid. V1G is the best option to begin integrating BEVs onto the electric grid followed by V2G which requires more sophisticated technology and a greater upfront investment.

Lack of cost-effective electricity storage is seen as one of the barriers currently inhibiting faster adoption of renewable energy. Power produced from an intermittent renewable source (such as wind or solar) is not a consistent source and its production may not coincide with daily peak usage. By leaving BEVs plugged into the power grid during times when the vehicle is not being driven, the vehicle batteries can act as distributed storage to these states of surplus/deficit renewable energy. If BEVs with surplus energy capacity are left connected to the grid during daily peak energy demand periods, this stored renewable energy can be supplied to the vehicles or the grid at a rapid rate, potentially reducing the need for incremental power peaking. If the power is stored during periods of low usage, such as at night, the energy consumption can be deferred to offset periods of higher demand, thus flattening the system load curve.

Current Environment

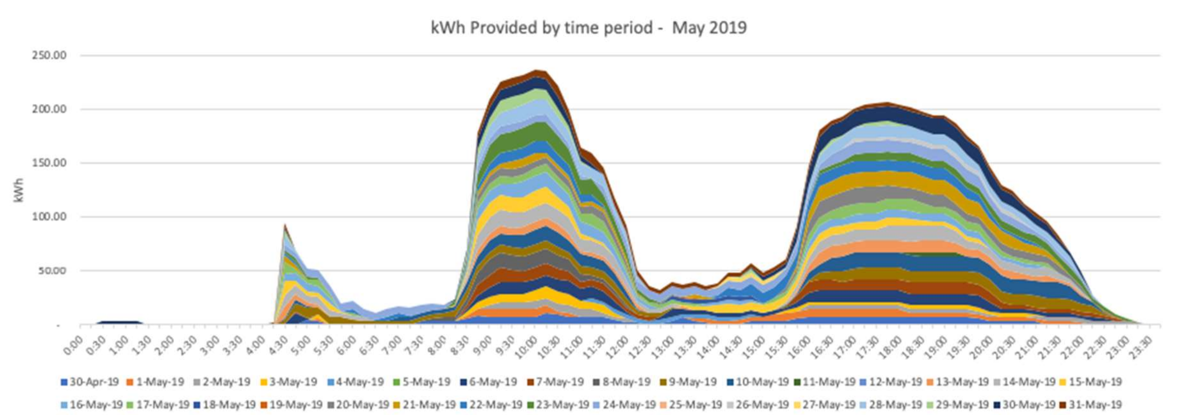
As detailed on the California Climate Investments website:
http://www.caclimateinvestments.ca.gov/press-releases/2017/5/12/sacramento-aqmd-unveils-nations-largest-zero-emission-electric-school-bus-deployment

The Sacramento Air Quality Management District deployed the largest electric school fleet in the United States, as of May 2017. The 29 bus fleet (presently at 27 with two more Type A buses due at Elk Grove) runs primarily through disadvantaged communities and reduces pollution generated to protect children's health. The school buses were deployed at the Twin Rivers, Sacramento City and Elk Grove Unified School Districts.

School District	Lion C Electric School Buses	Trans Tech Type-A School Buses
Twin Rivers	8	8
Elk Grove	8	2 pending
Sacramento City	0	3

Charging Pattern

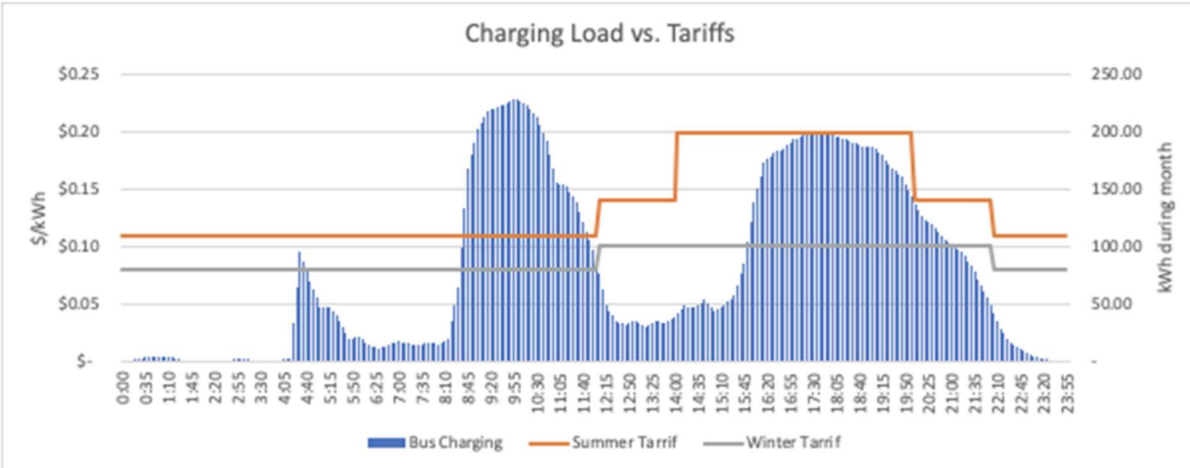
The pattern of charging the electric school buses is very consistent throughout the school week and is not surprising considering the driving schedule. When the vehicles operations team first starts their shift at 4:30 AM, they plug in any vehicles that were returned to the depot and inadvertently, or purposefully not plugged into chargers. There is a charging mini-peak created by that first charge before the vehicles leave for their first pickup in the morning from 4:00 AM until about 6:30 AM. The vehicles pick up children and drop them off at school from 6:30 AM until 8:00 AM. At 8:00 all the vehicles plug back in at the depot and that creates the largest peak charging event of the day. The charging remains strong until about 12:30PM when the vehicles begin to fill up their batteries. From 2:00PM until about 3:30 PM, the vehicles are sent to school to pick up children and deliver them back home. When they return to the depot, they plug in and begin charging at 3:30 PM and will complete the charging process by around 10:00 PM. There is almost no charging between 10:30 PM and 4:30 AM the next morning. Below is a graph that shows this pattern from May 2019 at Twin Rivers.



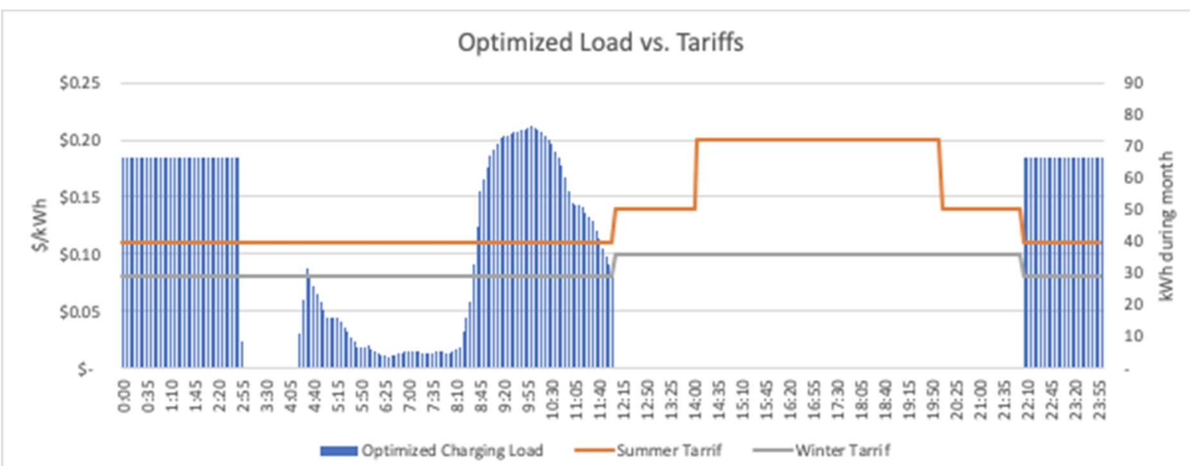
The absolute scale of this graph is not necessarily relevant since it sums up the kilowatt hours for each of the 15 minute time segments during the month, but the shape of the curves and the gaps are absolutely relevant.

Charging Optimization

The first analysis that we can do is to compare the charging patterns to the tariffs to see if the charging can be shifted to better fit the tariff schedules and therefore save money. The tariffs have been designed to affect consumption behavior to better match grid generation and demand.

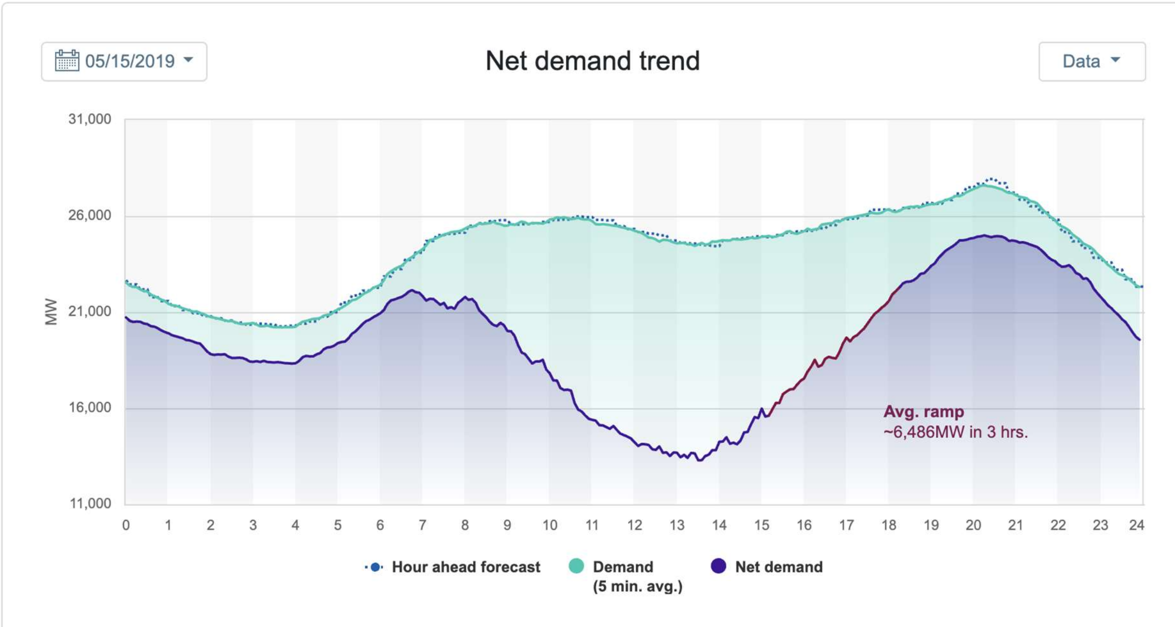


In the graph above, you can observe that all the morning charging between 7:35 AM and noon takes place at the lowest electrical rates. That indicates that even if buses do not need additional charges to meet the afternoon route requirements, it is good that they are charging after their morning run, because it takes advantage of the lowest rates offered by SMUD. The rate design would indicate that SMUD is able to acquire lower cost energy during the midnight-to-noon time period. There is still some charging taking place from noon until 3:00 PM when the rates go up, but you can see that the charging is less than 20% of the 10:00 AM peak. The afternoon charging is the problem in this charging pattern. There is a lot of afternoon charging taking place when the vehicles are returned after the afternoon school runs. Almost all the charging in the afternoon takes place in at the high rates and does not take advantage of the lower SMUD rates.



This graph shows what an optimal charging plan would look like to take advantage of the lower SMUD rates and avoid the CA peak demand period of 7 to 9 PM. As you can see above, no charging takes place when the rates are higher from noon to10 PM. There is still plenty of time to charge the vehicles well before they are needed in the morning. There is also plenty of slack to charge the buses not plugged in the previous night before they are needed for the morning school bus run.

Grid demand curves



Source: CAISO website: http://www.caiso.com/TodaysOutlook/Pages/emissions.aspx

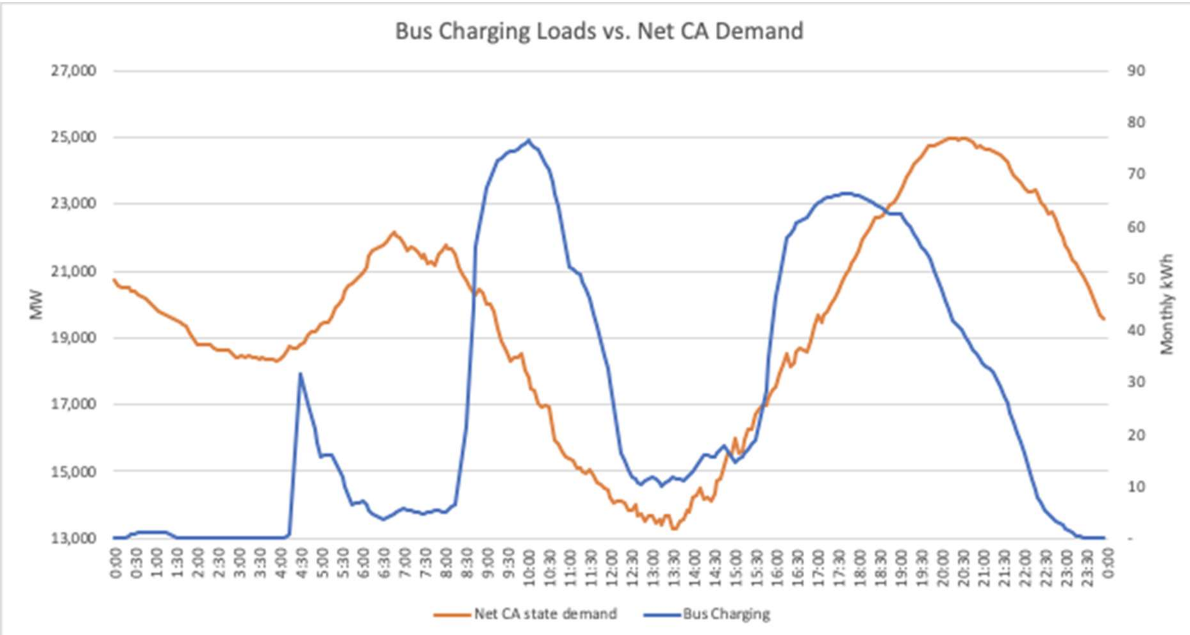
This is a sample demand curve from the California Independent System Operator (CAISO). California has a high penetration of solar power which leads to this net demand curve that is often described as the "duck curve" because of its shape. This is the actual demand seen in CA on May 15, 2019 and corresponds to the charging data that we have selected to highlight in the Charging Pattern and Optimization portion of this report. The light blue curve represents the total energy demand in California, and you can see that the lowest demand is around 4 AM and it increases throughout the morning. There is a slight dip around noon and then it goes back to increasing straight through until around 9 PM. At this point many businesses are shutting down and residences are closing for the night. The lowest demand in the state is around 20 GW and the peak consumption is around 28 GW on this day. Before the addition of renewable energy into the CAISO grid, this was the narrow range that had to be managed by the grid operator.

Renewable energy dramatically changes this as demonstrated in the net demand purple curve. The peak net demand is reduced by a small amount down to about 24 GW from the 28 GW, but the minimum is reduced to 13 GW at a time when the total demand is almost at its peak. This reduction is because of the large solar production in the state. The other challenge for the grid is not just the absolute peaks and valleys but the sharp reduction and later increase slopes of the net demand. The grid must plan to quickly remove energy generation assets to accommodate the lower net demand. At the bottom of the net demand curve, the CAISO needs to almost immediately bring on a large amount of assets to support the sharply increasing demand.

BEV charging can be an asset to the grid because it is a flexible load that can be modified to fit into the net demand curve. Because of the unpredictability of the net demand at any given moment, BEV charging loads can be curtailed to match the actual net demand. There can be a baseload of charging that is permanently shifted through intelligently designed tariffs. Additional charging load can be shifted to increase or decrease based on real time, net energy demand through the implementation of programs and ancillary services provided by BEV fleet charging software.

Charging Pattern and Optimization

Actual Charging loads compared with grid net demand

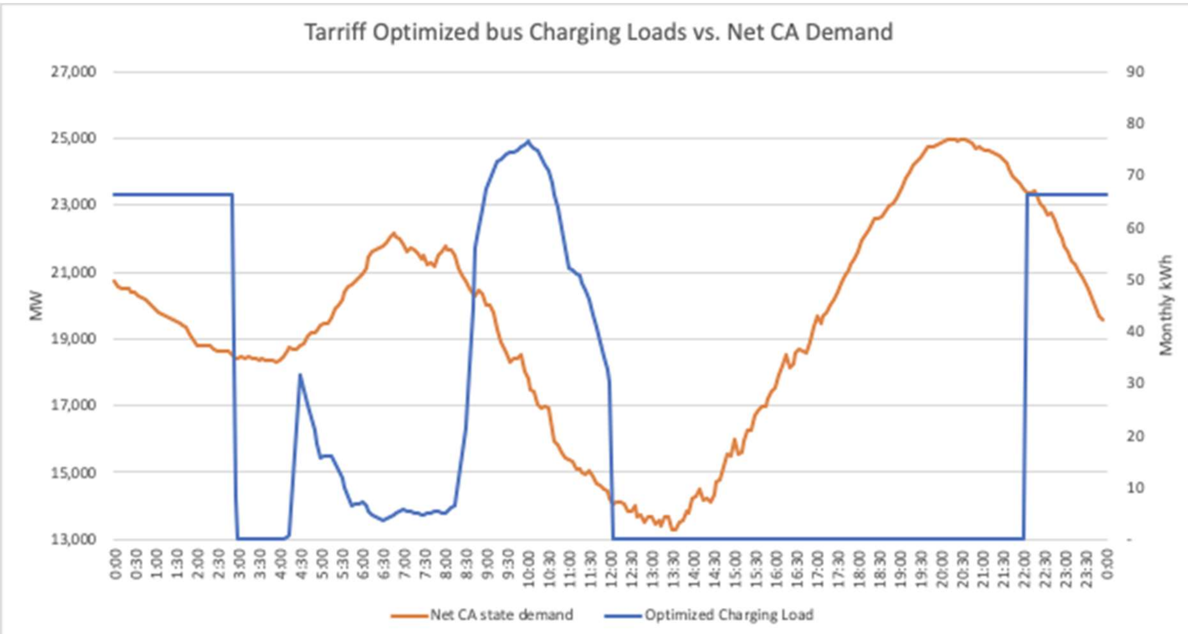


This graph shows the timing of the vehicle charging compared to the statewide net demand. This is useful to determine the influence that charging has on the grid net demand peaks and values. Of primary interest is observation of the charging fit of the two graphs to see where BEV charging is helping to stabilize the grid where it is exacerbating the problem. We expect the number of BEVs to increase sharply over the next 20 years and want to see what effect this will have on the net demand of the grid.

The first morning peak at 4:30 AM occurs at a time where the net demand is at a localized low point. The grid is about to support increased demand as businesses and homes start to energize. It would be better to avoid this morning charging peak if possible. To avoid this peak might require operational changes at the school bus depot to ensure that all buses are plugged in at night, or maybe the school needs a few more working chargers to avoid this early morning plug in. This is a relatively small peak, so it is not viewed as a major problem. The second peak from 9:30 to 11:30 AM is extra load exactly where it is needed in the CA grid. The net load is decreasing starting at 8:00 AM, exactly when the buses are beginning to return from the morning school routes. The charging continues to increase as the solar power brings down the net load on the grid. The more morning and mid-day charging we can add to the CA grid the better. The floor of the charging occurs as the vehicles are doing their afternoon routes. This is, unfortunately, when the net load is lowest, and we could use some extra load on the grid. The next peak after the buses return from school actually occurs at the worst time and follows the steep neck of the duck curve. As the sun begins to move lower in the sky, the solar production is reduced and at the same time the demand increases as both homes and businesses are operating. The afternoon charging is contributing to that increased demand. The optimized charging can avoid that.

Optimized Charging loads compared with grid net demand
If we take the optimized charging curve based on the SMUD tariffs, we can see that there is much better support for the CA grid peaks. The first two peaks are unchanged, but the afternoon peak is shifted from the afternoon to 10 PM. The benefits of this shift is that there is no charging as the

demand increase. The school bus charging does not contribute to the steepness of the net demand curve. All the third peak charging is done after the grid has reached its peak demand and the bus charging begins as the net demand drops to its evening lows. The charging could even be started later as there is enough slack to move into the 2:00 AM to 4:00 AM low demand periods. A change in Tariff could encourage this shift.



Conclusion

Battery Electric Vehicles have always been identified as excellent "shiftable" loads which fit nicely into a grid environment – especially one that has many renewable resources such as wind and solar. As we can see from the actual charging data at the Sacramento School Districts, the BEV charging can be a positive asset to the grid and support the reduction of the effects of the duck curve. If additional charging patterns from other vehicle classes are added, BEV loads can be an excellent controllable load.

Ideally, the charging process at all locations should be optimized to match the demands of the grid. Currently all of the morning charges take place at the lowest electrical rates which greatly benefits the school districts. However, the afternoon charging is the problem. There is a lot of charging occurring when the buses are returned after the afternoon school runs, and almost all the charging in the afternoon takes place at the high rates. The intention of V1G integration is to create usage patterns in which schools can optimize charging cycles and sync with the lowest demands on the grid. The schools using Lion buses were provided "smart" charges in order to automatically regulate grid-to-bus charging and benefit from the savings of reduced rates. Manual charge management can be accomplished using "dumb" Clipper Creek chargers, but the chargers must be manually turned on/off. In summary, the schools are integrated with the grid on a V1G basis, but not fully benefitting from smart grid management.

V2G is bi-directional charging in which schools can arbitrage (buy low, sell high) electricity to the utilities and benefit from low purchase rates as well as incremental revenue from the sale of electricity back to the utility. This level of grid integration is best suited for fleets with at least 1 megawatt of electricity storage capacity. The Lion buses deployed in Sacramento range from 98 to 135 kWh, so a fleet of 8 Lion buses represents significant standby capacity that is also mobile if needed and provides the most time responsive asset for use in grid balancing. V2G integration is still under development in the U.S. There are several demonstration projects being conducted by major utilities including Con Edison of New York and San Diego Gas and Electric in partnership with Lion. The buses in New York are scheduled to be V2G operational before the end of 2019. V2G level grid integration testing requires participation and sponsorship by the regional utility and approval by the state Public Utilities Commission. While both the Elk Grove and Twin River electric school bus fleets represent ideal testing venues, a demonstration project would require participation by the Sacramento Metropolitan Utility District (SMUD). SMUD declined to participate in a demonstration project when approached in June of 2019. Further inquiries to SMUD may be warranted.

APPENDIX D

ChargePoint Final Report Presentation

APPENDIX D. ChargePoint Final Report

chargepoint

Q4-2019 and final Report for Twin Rivers USD, Elk Grove USD and Sacramento USD Data Collection Report for Sacramento AQMD

1

Data Collection Status

chargepoint

- Data collected for October 2019 through December 2019
- Data includes:
  - 16 charging stations and 8 eLion buses and 8 Transtech buses in use at Twin Rivers School District
  - 8 eLion buses at Elk Grove school district
  - 3 Trantech buses at Sac City
- 3 data sources were used for TRUSD:
  - GPS logs from MyGeotab application
  - Log information from charging stations via EVConnect
  - Meter data from SMUD
- Data sources for Elk Grove includes EVConnect log information and extracts from the GPS system on the Elk Grove buses
- Sacramento school district data will be derived from the Dedicated SMUD meter data

2

TwinRivers
UNIFIED SCHOOL DISTRICT

chargepoint

Twin Rivers EV bus usage data

Q4 2019

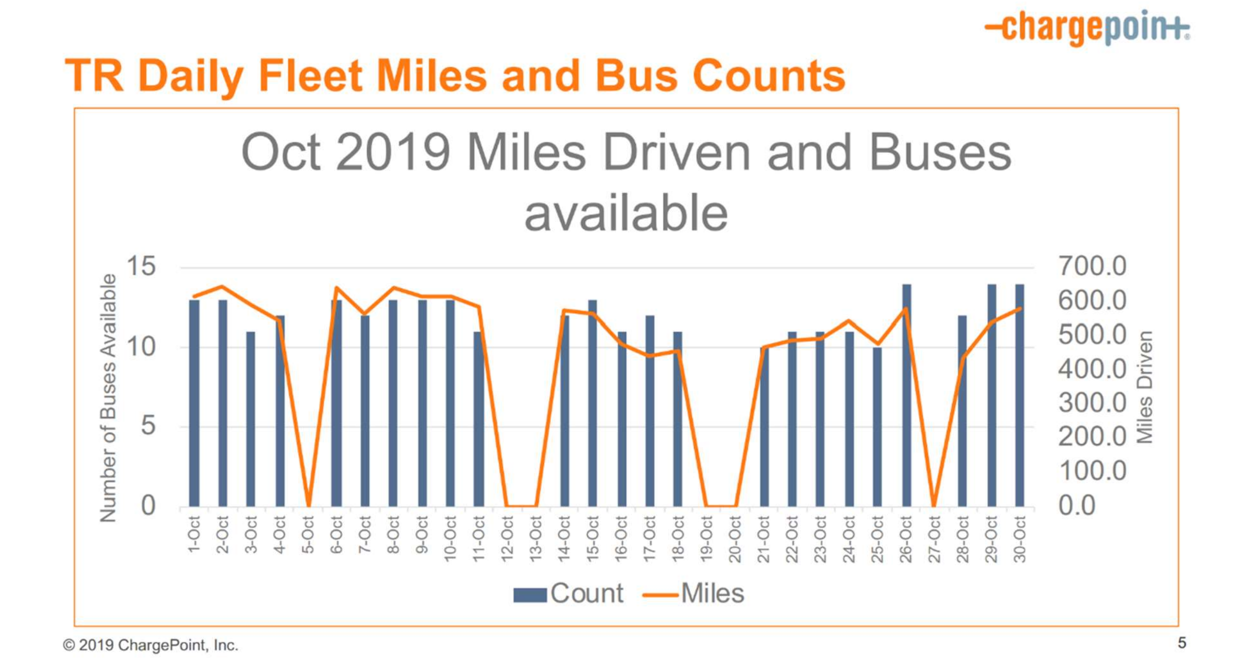
3

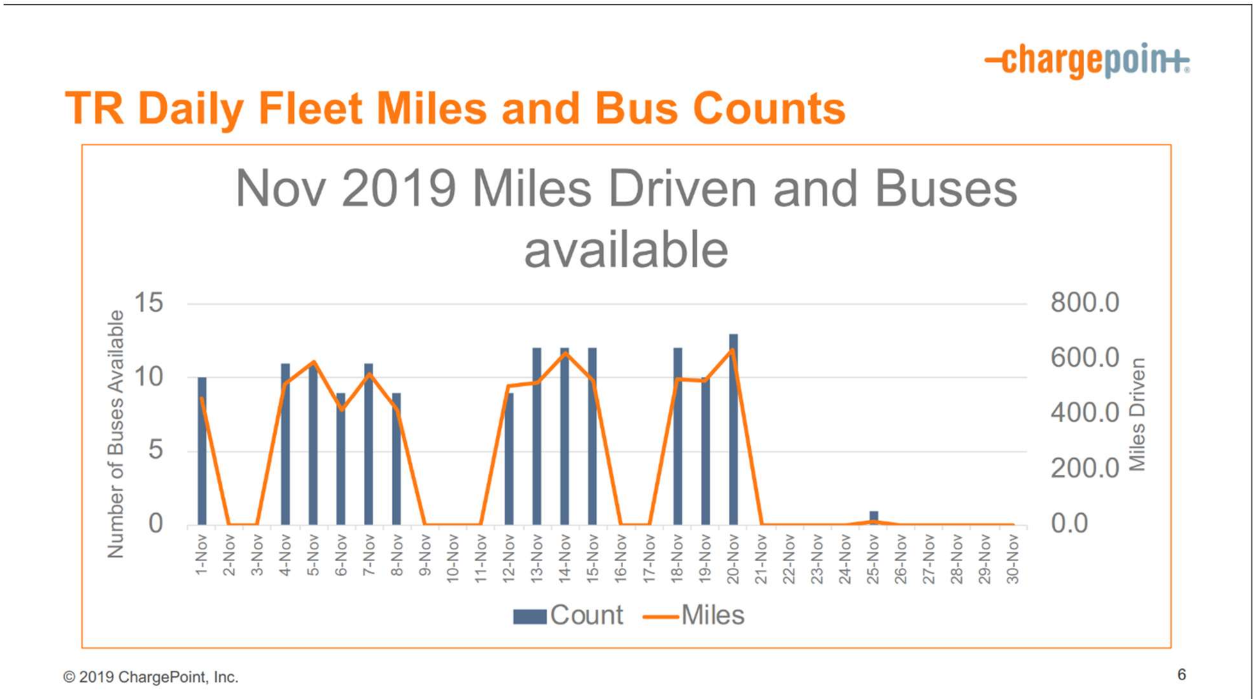
Twin Rivers Data Collection Summary

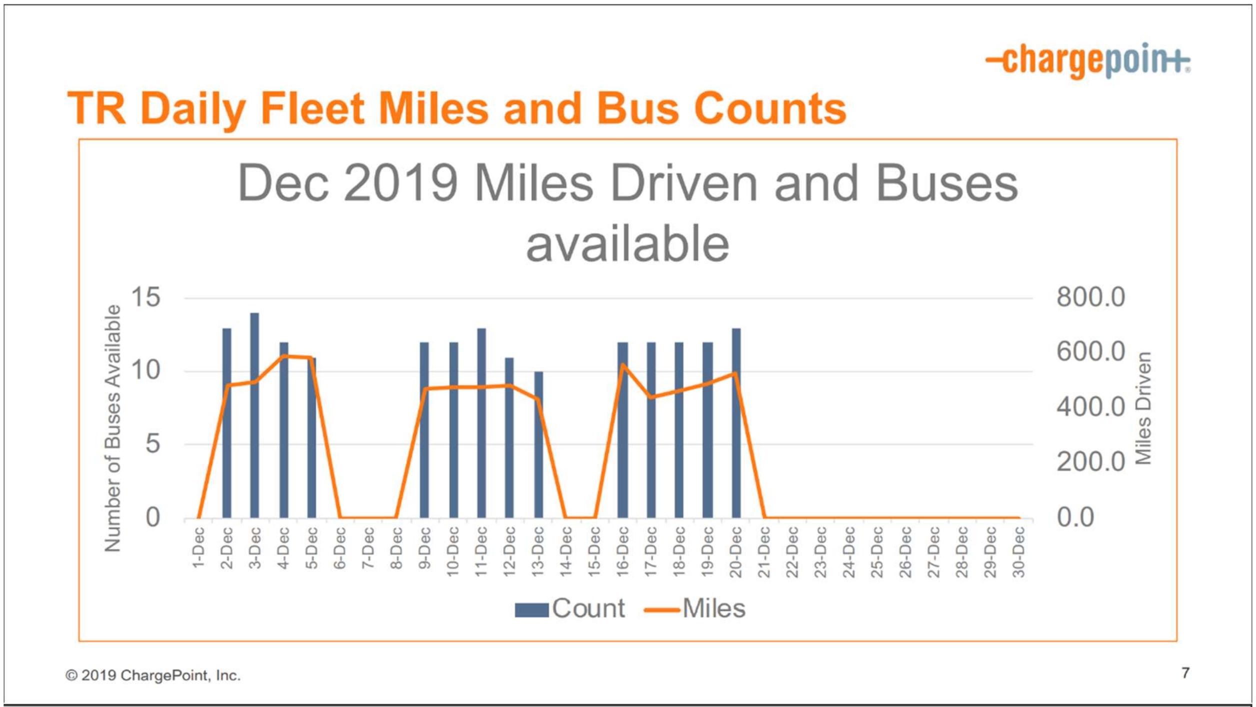
chargepoint

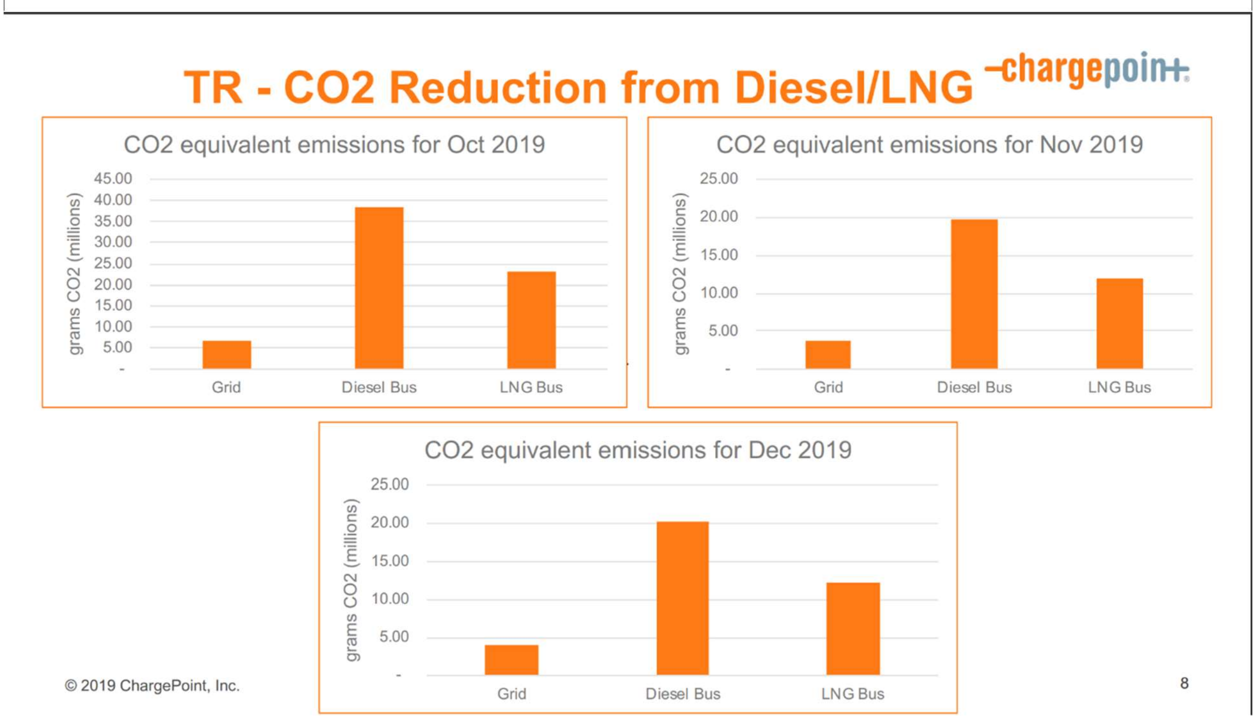
Twin Rivers	Oct 2019	Nov 2019	Dec 2019
Average number of buses dispatched	12.1	10.1	12.1
Miles Driven	13,195	6,805	6,958
Average Route	45.6 miles	45.8 miles	41.4 miles
Average kWh/mile	2.0	2.15	2.31
Charging Cost	$2,483	$1,402	$1,628
Charging cost/mile	$0.188	$0.206	$0.234
Dollars Diesel equivalent	$8,924	$4,603	$4,706
Dollar Savings	$6,441	$3,201	$3,078

4

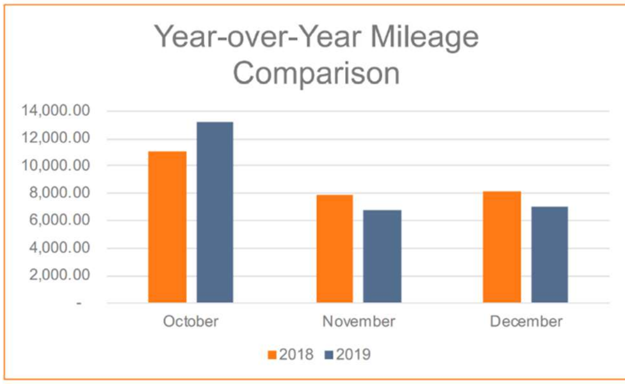

chargepoint
TR Daily Fleet Miles and Bus Counts
Oct 2019 Miles Driven and Buses available
Number of Buses Available
Miles Driven
Count
Miles
© 2019 ChargePoint, Inc.
5

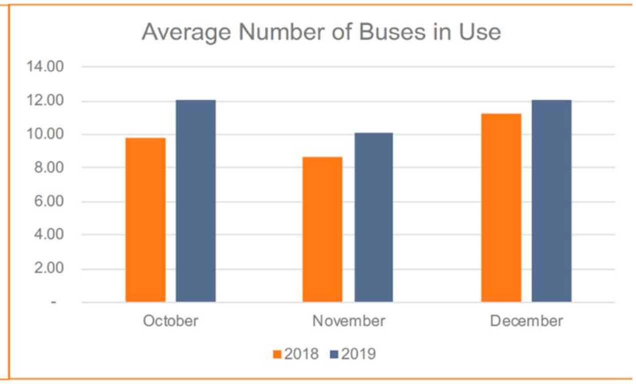

chargepoint
TR Daily Fleet Miles and Bus Counts
Nov 2019 Miles Driven and Buses available
Number of Buses Available
Miles Driven
Count
Miles
© 2019 ChargePoint, Inc.
6


chargepoint
TR Daily Fleet Miles and Bus Counts
Dec 2019 Miles Driven and Buses available
Number of Buses Available
15
10
5
0
800.0
600.0
400.0
200.0
0.0
Miles Driven
1-Dec 2-Dec 3-Dec 4-Dec 5-Dec 6-Dec 7-Dec 8-Dec 9-Dec 10-Dec 11-Dec 12-Dec 13-Dec 14-Dec 15-Dec 16-Dec 17-Dec 18-Dec 19-Dec 20-Dec 21-Dec 22-Dec 23-Dec 24-Dec 25-Dec 26-Dec 27-Dec 28-Dec 29-Dec 30-Dec
Count
Miles
© 2019 ChargePoint, Inc.
7


TR - CO2 Reduction from Diesel/LNG
chargepoint
CO2 equivalent emissions for Oct 2019
grams CO2 (millions)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
-
Grid
Diesel Bus
LNG Bus
CO2 equivalent emissions for Nov 2019
grams CO2 (millions)
25.00
20.00
15.00
10.00
5.00
-
Grid
Diesel Bus
LNG Bus
CO2 equivalent emissions for Dec 2019
grams CO2 (millions)
25.00
20.00
15.00
10.00
5.00
-
Grid
Diesel Bus
LNG Bus
© 2019 ChargePoint, Inc.
8

Twin Rivers Year over Year Comparison





9

Twin Rivers Summary for Q4 2019

+ Twin Rivers has settled into a consistent use of EV buses for a percentage of the total miles driven. Year over Year, Q4 is within 0.5% of the miles driven in Q4 last year and totaled 26,958 miles. The differences by month is exactly related to the school calendar. October had 2 more days in 2019, November 1 less and December 1 less when compared to 2018.
+ The best news from the Q4 data is that more buses where put into service during the month. October and December averaged slightly over 12 buses in operations.

10

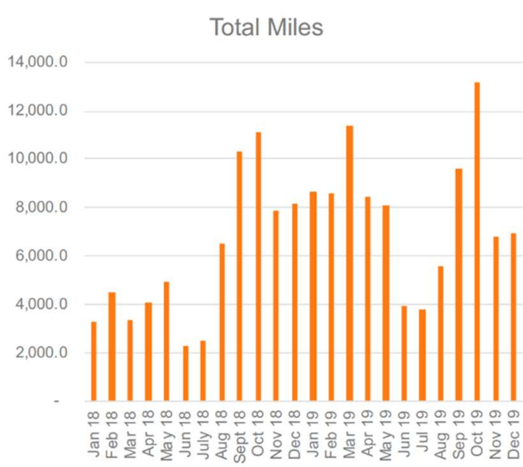
Project Totals for Twin Rivers

+ Based on data recorded from Jan 1, 2018 to Dec 31, 2019

Category	Totals	Monthly Average
Total Miles	164,167	6,840
Dollar Savings	$81,952	$3,414
Vehicles in Use	12.1(highest month)	8.2
Days routes driven	466	19.4
Average Miles/day	550(highest month)	352.3
kWh/mile		1.7
Trip Length		42.4

11

Total Miles Driven

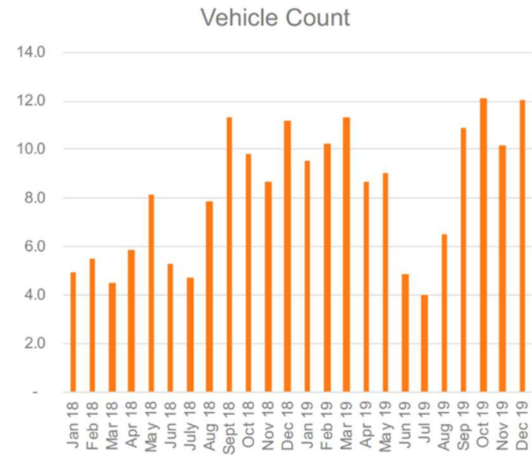


+ Highest month for miles driven was October 2019 13,195
+ Summer months show large drop in miles as less routes are run for summer school
+ Total miles driven shows a steady increase since the start of the program

12

chargepoint

Vehicles in Service

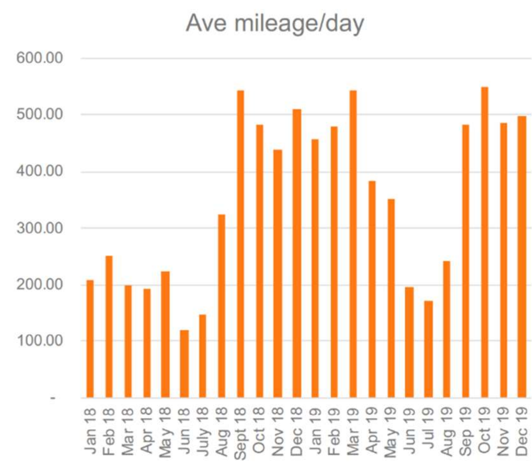


- The program finished the date range strong with 10-12 vehicles in use from September through December 2019.
- It took until September 2018 to get more than 10 vehicles running routes, but then stayed above 8 vehicles except for the summer break when less miles and routes were run

 13

chargepoint

Average Miles per day Driven

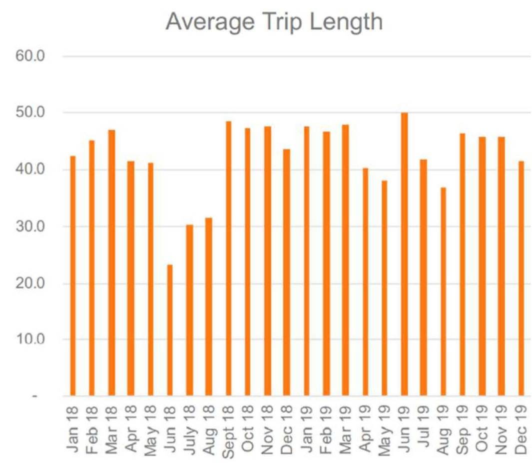


- The peak miles per day was in October 2019 at 550 miles.
- The average remained high during the non summer months starting in September 2018

 14

chargepoint

Average Trip Length



+ The average trip length did not vary much during the year and was consistently in the mid 40 mile range, except for the first summer when it was between 22 and 30 miles.

15

chargepoint

EGUSD ELK GROVE UNIFIED SCHOOL DISTRICT

Elk Grove EV Bus usage data

Q4 2019

16

-chargepoint+

Elk Grove Data in Q4 2019

+ The data logs received from Elk Grove did not match the EVConnect data.
  - EvConnect data showed energy to drive approximately 650 miles vs. the log data that only showed 50 miles driven. We used the EVConnect data to estimate the number of miles driven.
  - The number of vehicles and the length of routes were also estimates from the kWh data that was available.
+ The usage of the fleet seemed to drop dramatically Q4 of 2019

17

Elk Grove Data Collection Summary

-chargepoint+

Elk Grove	Oct 2019	Nov 2019	Dec 2019
Average number of buses dispatched	1.1	1.7	1
Miles Driven	342	204	99
Average Route	17	4.6	5.8
Average kWh/mile	1.7	1.7	1.7
Charging Cost	$ 52	$31	$15
Charging cost/mile	$0.253	$0.15	$0.15
Dollars Diesel equivalent	$192	$138	$67
Dollar Savings	$140	$107	$52

18

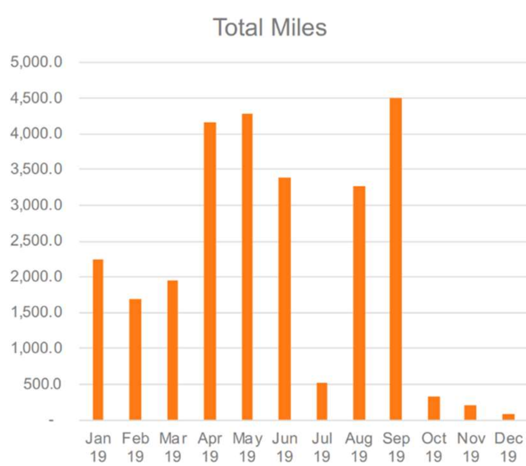
Project Totals for Elk Grove

+ Based on data recorded from Jan 1, 2019 to Dec 31, 2019

Category	Totals	Monthly Average
Total Miles	26,671	6,840
Dollar Savings	$14,232	$1,186
Vehicles in Use		2.8 (estimate)
Days routes driven	221	18.4
Average Miles/day	225(highest month)	120
kWh/mile		1.7 (estimate)
Trip Length		29.6 (estimate)

19

Total Miles Driven

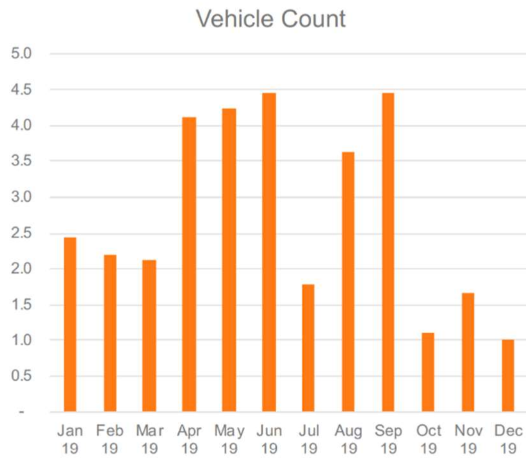


+ Highest month for miles driven was September 2019: 4,499 miles
+ Mileage drops off sharply in the final quarter of the year.

20

chargepoint

Vehicles in Service

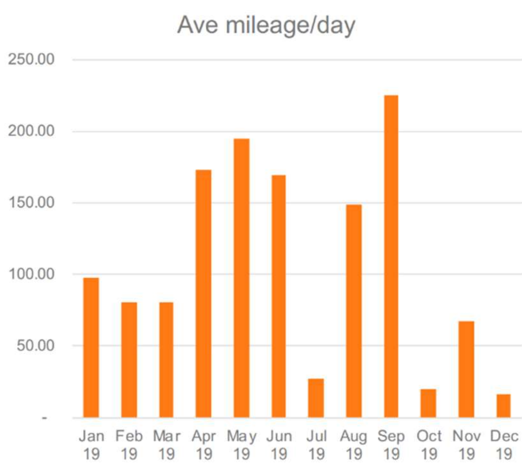


+ The site has 8 Elion buses available and at their peak used 5 of those buses
+ Either 1 or maybe 2 buses were in service in the final quarter of the year.

21

chargepoint

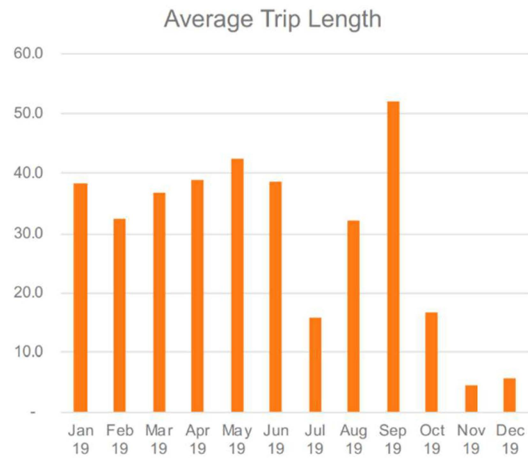
Average Miles per day Driven



+ This is consistent with not utilizing the buses in the 4th quarter.

22

Average Trip Length



+ It appears that the average trip length was consistently between 30-40 miles until the final quarter of the year.

 23

Sacramento City UNIFIED SCHOOL DISTRICT

chargepoint

Sacramento EV bus usage data

Data collected from May-Dec 2019

 24

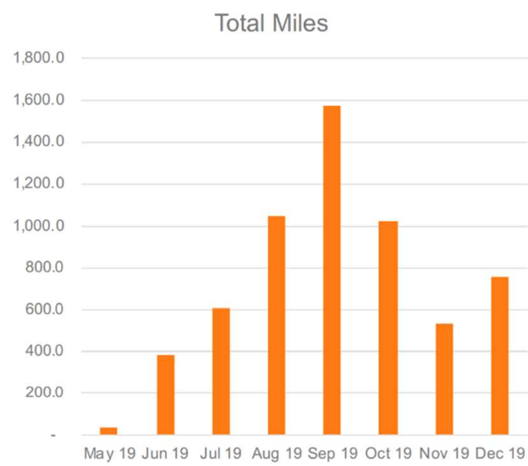
Project Totals for Sac City

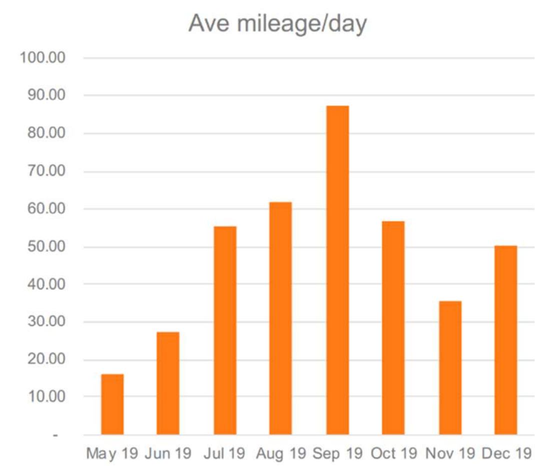
+ Based on data recorded from May 1, 2019 to Dec 31, 2019

Category	Totals	Monthly Average
Total Miles	5,970	746
Dollar Savings	$2,039	$255
Vehicles in Use		1.5 (estimate)
Days routes driven	110	13.8
Average Miles/day	87(highest month)	54
kWh/mile		1.5 (estimate)
Trip Length		30.1 (estimate)

25

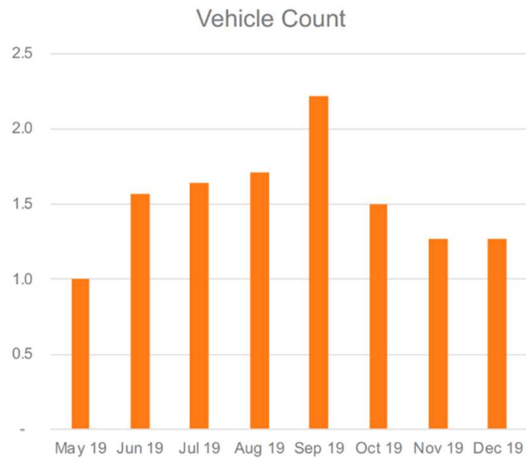
Total miles and average daily miles

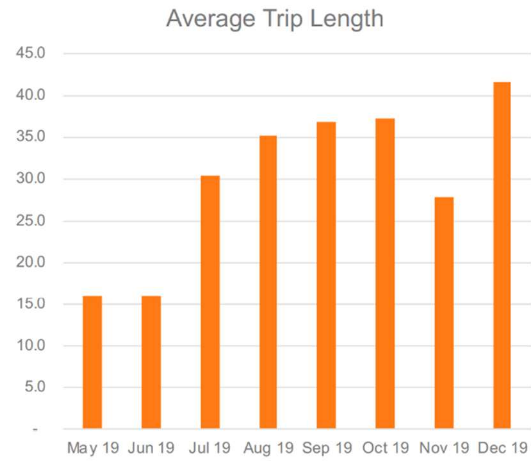




26

Vehicles counts and trip length





27

Sacramento City data collection summary

+ Only data source was dedicated charging meter
+ Data would be improved with vehicle logs
+ Some of the high meter days were weekends. This implies that the buses were run on the weekends, or at least charged during the weekends.
+ Vehicle usage is consistent with the number of school days in the year. We see a peak in September and then a drop off in November and December when there we a smaller number of school days.
+ The summer usage did not drop off and it appears that the vehicles were used for summer school at almost the school year level

28

Project totals for all 3 schools

	TR	EG	Sac	Total
Total Miles	164,168	26,671	5,970	196,808
Dollar Savings	$81,953	$14,232	$2,040	$98,224
CO2 reduction v. Diesel (g)	31,512,000	11,324,000	3,513,000	46,349,000
CO2 reduction vs. LNG (g)	16,648,000	6,375,000	1,739,000	24,762,000
Formaldehyde avoided if LNG replaced (mg)	8,494,000	2,896,000	1,014,000	12,404,000

29

APPENDIX E

DAC Routes

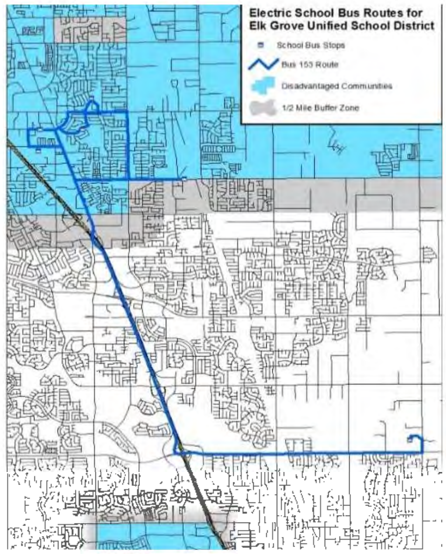


Figure 12: Route 153

For disadvantaged communities living within EGUSD zip codes, ten EVs serviced seven different routes, operating for the entirety of the necessary daily miles. Route 153, which travels from 8389 Gerber Road to Florin Mall, Orange Ave, to David Reese Elementary School, to Samuel Kennedy Elementary School, and back, requires 20.1 daily miles of driving. EVs stopped 12 times in or within a ½ mile of a disadvantaged community, which represented 92% of the route's 13 total stops. This route occurred until it was amended in 2019 due to issues with the EVs driving range, and traditional buses were brought on to service the route.

Elk Grove Unified School District. Disadvantaged community census tracts are highlighted in light blue.

Twin Rivers USD domiciled its 16 zero-emission EVs at 1400 Grand Ave, Sacramento, CA 95838, which is located within ½ mile of a disadvantaged community. Twin Rivers USD operated their 16 EVs on 16 different routes, operating many of the daily miles in ZIP codes containing disadvantaged community census tracts.

Figure 13: Route 101

Twin Rivers Unified School District. Disadvantaged community census tracts are highlighted in light blue.

Route 101, which travels from 1400 Grand Ave to Grand Ave & I-80, to Richards Blvd & 160 & Dos Rios, to Rio Tierra Junior High School at Northgate Blvd & San Juan Road, to Nova School near I-80 & Winters, and back, requires 50 daily miles of driving to be serviced. Route 101 operated 100% of its 50 daily miles in ZIP codes containing disadvantaged community census tracts, with 68% of the miles were located directly within DAC census tracts. All of Route 101's 31 traffic stops were serviced by EVs. This route occurred until it was amended in 2019.

APPENDIX F

Media Articles

PUBLISHED INFORMATIONAL ARTICLES

Bellwether - FROM YELLOW TO GREEN, Reducing School Transportation's Impact on the Environment

U.S. PIRG FALL 2019 - Electric Buses in America. Lessons from Cities Pioneering Clean Transportation

U.S. PIRG FALL 2018 - EV Buses Healthy KIDS, Paying for Electric Buses, Financing Tools for Cities and Agencies to Ditch Diesel

2020

New York Times January 22, 2020, Making Yellow School Buses a Little More Green, by Ellen Rosen

BusinessWire December 17, 2020, Largest Electric School Bus Fleet in California bolstered by 10 buses delivery from Lion Electric

2019

School Transportation News STN - April 1, 2019 - Electric School Buses are more affordable than you think

School Transportation News STN - April 17, 2019 - ACT EXPO Roundtable to Focus of School Bus replacements

School Transportation News STN - May 1, 2019 - How Transportation Directors Find Needed Dollars Through Technology

KCRA 3 - May 28, 2019 - School District Rolls our Electric School Buses

SAC BEE - May 29, 2019, Take a Ride on Twin Rivers Unified School District's new Electric Buses

CBS 13 - May 29, 2019 - Twin Rivers Selected to get all Electric Buses

ABC 10 - May 29, 2019 - Twin Rivers Unified School District rolls out 5 new Electric Buses

SAC BEE - May 30, 2019 - Twin Rivers rolls out Electric Buses

School Transportation News STN - May 31, 2019 - District add to the Largest Electric School Bus Fleet, Taylor Hannon

School Transportation News STN - October 14, 2019 - Paper Shares Successes, Lessons Learned from Early Electric School Bus Adopters

School Transportation News STN - December 16, 2019, Lion Delivers 1st Electric School Buses from Calf. Energy Commission School Bus Program

Next-Ge Transportation NGTNews December 18, 2019 School District Puts Lion Electric Buses into Service

KCRA3 December 18, 2019 - California invests millions in electric school buses

2018

New York Times - November 2018: The Wheels On The Buses Go Round And Round with ZERO Emissions, By Brad Plumer

CBS 13 Sacramento - November 2018, Electric School Bus Fleet Leaving Green Footprint On Twin Rivers School District By Cambi Brown

School Transportation News - September 2018: Rising SuperStars in School Transportation, by Claudia Newton

School Transportation News - May 2018 - Webinar Answers Common Questions on Electric School Buses, by Claudia Newton

School Transportation News - May 2018 - Electric School Buses Take to the Road: Real World Results: By Nicole Schlosser

MNN, Mother Nature Network - June 2018: Making the case for electric school buses, by Matt Hickman

School Transportation News - September 2018: NTSB National Safety Transportation Board, Recommends Pedestrian Safety Systems, by Art Gissendaner

Cool Solutions Pod Cast - September 2018: Clean rides for kids, by Wendy Ring

NDTV India - May 2018: Freewheeling Electric Buses, by Mahindra Treo

Government Technology - December 2018: Electric buses are not only clean but less costly to run, by Skip Descant

School Transportation News - December 12, 2018: No Engine, No problem, by Taylor Hannon

Good Day Sacramento TV News - December 2018 - Electric School Buses

2017 AND 2018

School Transportation News STN - May 12, 2017: Largest U.S. Electric School Bus Pilot Comes to California: By Ryan Gray

Capital Public Radio – July 11, 2017: Ditching Diesel: Sacramento Schools Test drive electric buses. By Ali Budner

Chicago News Journal – Jan 13, 2018: The all-new zero emission Blue Bird all American school bus heads to northern California as A-Z Bus Sales wraps up their Ride and Drive event: Written by Allen Stafford A-Z Bus Sales

San Francisco Gate, - Jan 16, 2018: Goodbye, diesel: California school buses drive toward electric age: By David R. Baker

School Transportation News STN – Jan 31, 2018: California School Districts take advantage of Alt-Fuel funding. Written by Ryan Gray

School Transportation News STN - April 17, 2018 ACT Expo roundtable to focus on school bus replacements Written by Claudia Newton

School Bus Fleet Digital Magazine, Digital Issue – May 15, 2018: Electric School Buses take to the Road: Real-World Results. Written by Nicole Schlosser, Managing Editor

School Transportation News STN - June 1, 2018 Transportation's future is paperless, electronic and automated Published in Partner Updates by Tyler Technologies

6.0 WORKS CITED

Gray, R. (2019, October 14). *Paper Shares Successes, Lessons Learned from Early Electric School Bus Adopters*. Retrieved from School Transportation News: https://stnonline.com/special-reports/paper-shares-successes-lessons-learned-from-early-electric-school-bus-adopters/

James Horrox, M. C. (2019). *Electric Buses in America.* U.S. Pirg Education Fund, Environment America Reserch and Policy Center, Frontier Group.

Lion Electric Bus Company. (2019, May 1). *School Buses Going 100% Electric? Just Common Sense.* Retrieved from School Transportation News.