CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

Clean Transportation Program

**FINAL PROJECT REPORT**

# Class C Electric-Quest School Bus Demonstration

**Prepared for: California Energy Commission**

**Prepared by: Motiv Power Systems, Inc.**

**March 2023 | CEC-600-2023-024**

# California Energy Commission

Lilian Ardito
**Primary Author(s)**

Motiv Power Systems, Inc.
330 Hatch Drive
Foster City, CA 94404
Motiv Power Systems, Inc. (https://www.motivps.com/)

**Agreement Number: ARV-15-004**

Larry Rillera
**Commission Agreement Manager**

Charles Smith
**Office Manager**
**TRANSPORTATION INTEGRATION AND PRODUCTION OFFICE**

Hannon Rasool
**Deputy Director**
**FUELS AND TRANSPORTATION**

Drew Bohan
**Executive Director**

# ACKNOWLEDGMENTS

Motiv Power Systems, Inc. (Motiv) would like to acknowledge the following individuals for their support and contributions to this project:

- Larry Rillera, California Energy Commission
- Linda Silva, Motiv Power Systems
- Mark Brendal, Motiv Power Systems
- Henry Siller, Motiv Power Systems
- Jose Sanchez, Motiv Power Systems
- Gerry Glaser, Motiv Power Systems
- Brian Silva, Motiv Power Systems
- Caleb Lander, Motiv Power Systems
- Jack Miller, Motiv Power Systems
- Hamelmal Gobezie, Motiv Power Systems
- Shveta Mangal, Motiv Power Systems
- Urvashi Nagrani, Motiv Power Systems
- Pablo Gutierrez, Motiv Power Systems

# PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-14-605 to cost share the development of medium- and heavy-duty vehicle technology demonstrations. In response to PON-14-605, Motiv submitted an application that was proposed for funding in the CEC's Notice of Proposed Awards issued on October 17, 2013, and the agreement was executed as ARV-15-004 in August 2015.

# ABSTRACT

Fleets have evaluated a variety of technologies at the early stages of feasibility. Zero-emission battery-electric school buses have historically been plagued with higher costs, low reliability, low range, and low technology transferability between applications. These barriers have not been adequately addressed because the development of this technology is costly, risky, and vehicle volumes are too low to bring in enough capital despite opportunities for emission reductions, air quality improvements, community health benefits, and operational savings opportunities.

Incumbent vehicle manufacturers controlling the market with polluting technologies like gasoline and diesel engines are not incentivized to develop technologies that would displace their current business models. Both the right partnerships and technologies are needed to leverage capital intense production lines already in existence for traditional school buses into producing battery-electric school buses. Technology, such as the Motiv Electric Powered Intelligent Chassis are needed for these traditional school bus lines to easily integrate zero-emission battery-electric powertrains.

This project allowed Motiv Power Systems to leverage its technology on the Ford F-59 platform into school bus applications with the Starcraft Quest XL body and explore the return on investment for an electric school bus compared to a fossil fuel powered school bus.

This project allowed the sales partner, Creative Bus Sales to expand their electric vehicle offerings to include the Starcraft Quest school bus. This project resulted in the bus being used in service at Colton Unified School District. The demonstration of the bus has resulted in the delivery of 18 Starcraft Quest school buses across California and Illinois.

**Keywords**: electric, vehicle, school, bus, zero-emissions, manufacturing, controllers, zero-emission buses, zero-emission battery, electric powertrain, battery-electric, Clean Transportation Program, Motiv Power Systems, Kilowatt Hour, California Highway Patrol

Ardito, Lillian. 2023. *Class C Electric-Quest School Bus Demonstration*. California Energy Commission. Publication Number: CEC-600-2023-024.

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# EXECUTIVE SUMMARY

Motiv sought to increase the market adoption of zero emission battery-electric school buses. Motiv modified the Ford F-59 design to accommodate the Starcraft Quest XL body. Motiv sought to demonstrate the technical and economic benefits of the electric school bus application as opposed to comparable fossil fuel powered school buses by deploying the Starcraft Quest XL buses within disadvantaged communities in California.

The goals and objectives of this agreement have remained the guiding principles of this project, and the project goals and objectives have been addressed. Through monitoring of performance, maintenance requirements, and cost of operation throughout the limited demonstration period, Motiv has been able to talk about adopting electric school buses into school fleets. The project has resulted in the assembly of three of the five originally contracted Starcraft Quest XL school buses which went to Colton Unified School District, and follow-on orders for 18 additional Motiv-powered Starcraft Quest XL school buses from school districts across California as well as orders from Illinois.

The vehicles in this grant have traveled 35,873 miles in operations producing zero tailpipe emissions, that would have otherwise been burning fossil fuels. During the data collection period eliminating fossil fuels resulted in approximately 9400 grams of nitrogen oxides, 30 metric tons of carbon dioxide, 492 grams of Reactive Organic Gases, and 404 grams of particulate emissions savings.

# CHAPTER 1:
# Project Purpose, Goals, and Objectives

## Introduction

Motiv, located in Foster City California, is a sustainable technology company delivering proven software and chassis platforms for the electrification of medium-duty trucks and buses. Motiv electrifies medium-duty chassis produced by companies such as Ford Motor Company, and integrates them into the same dealer supply chain, allowing medium-duty electric vehicles to be completed by final-stage manufacturers and sold by dealerships alongside their internal combustion driven counterparts.

Starcraft is North America's largest shuttle bus company and America's fastest-growing school bus company and worked with Motiv to build the bus on the electrified F59 Chassis. As the builders of the Quest line of buses, they are experts in all details related to the vehicle body. Creative Green Alternative Systems (GAS)[1] is the nation's largest bus dealership and their numerous locations that can service customers across the state and nation. GAS is the exclusive dealership for the Starcraft Quest XL school bus (eQuest)[2] that was designed specifically with the California market in mind and was electrified to the eQuest during this project. Based in Chino, Green Alternative Systems is the largest fleet conversion company in North America. They operate cutting-edge facilities in multiple locations and have completed thousands of alternative fuel system installations for fleets across the country.

In 2015 Motiv, a sustainable technology company delivering proven software and chassis platforms for the electrification of medium-duty trucks and buses saw a unique opportunity to combine California's growing commitment to sustainability with the fleet's desires to reduce fuel expenditures and reduce harmful air pollution. School buses presented a unique opportunity to leverage existing vehicle production and sales models with new electric powertrain technology. During this project, the Starcraft Quest XL was electrified to the eQuest in partnership with GAS using the Motiv EPIC F-59[3] design.

The vehicles in this project utilize Clipper Creek CCS-100-3 charging stations equipped with Meltric connectors.

Projects funded under this CEC solicitation were done to help accelerate technology commercialization by placing zero-emission trucks and buses in field demonstration. Eligible projects included the infrastructure necessary to support project vehicles. Most of the available funding went towards projects that benefited disadvantaged communities.

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[1] The Green Alternative Systems, is available at (https://info.greenalternativesystems.com/).

[2] The Starcraft Quest XL School Bus, is available at (https://www.motivps.com/news/nine-california-school-districts-select-motiv-power-systems-equipped-all-electric-starcraft-equest-xl-school-buses/).

[3] The EPIC F-59 definition, is available at (https://www.motivps.com/products/epic-f59/).

The vehicles produced in this project have been successfully put in use at Colton Unified School District (USD)[4] showing the ease with which a vehicle made for fossil fuel power can be adapted for electric power utilizing the Motiv EPIC F-59 design and incorporated into fleet operations.

Electric vehicle technology has advanced greatly in recent years. However, this technology has been slow to be adopted by schools and fleets transporting students. Aging diesel buses release harmful emissions and particulate matter close to vulnerable students. The medium-duty electric vehicle space has been unable to provide reliable, safe, and cost-effective vehicles that fleet managers are willing to invest. While some pilot buses have begun to be deployed, there is still a lack of commercially available zero-emissions options that can meet the market need of better buses for students, communities, and fleets.

While battery-electric school buses have been an area of interest for school districts, that interest has been hampered by barriers such as financial and capital costs, emerging technologies lacking market verification, and young businesses being doubted by established fleets. These technological and market barriers have limited the adoption of these vehicles.

These barriers have not been addressed because development of this technology is costly and risky, and vehicle volumes are too low to bring in enough new capital. Incumbent players already control the market with more polluting technologies like gasoline and diesel engines, and they do not have enough incentives to develop new technologies rather than promote their existing portfolios.

## Project Purpose

The purpose of this project was to develop and demonstrate five all-electric school buses, seek California Highway Patrol certification to transport school children, and seek potential eligibility under California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, and to publish an economic analysis utilizing detailed demonstration data to determine the return on investment for fleets.

## Goals and Objectives

The goals and objectives of the project were:

1. Develop and demonstrate five all-electric eQuest buses and deploy all buses in field service to selected school districts with charging infrastructure.
2. Collect 12 months of throughput, usage, and operations data for the project including:
    - Maximum capacity of the new fueling system.
    - Gallons of gasoline and/or diesel fuel displaced with associated mileage information.
    - Expected vehicle emissions reductions.
    - Duty cycle of the current fleet and the expected duty cycle of future vehicle acquisitions.
    - Specific jobs and economic development.

[4] The Unified School District, is available at (https://www.k12academics.com/school-types/school-district/unified-school-district).

3. Demonstrate the return on investment for an electric bus platform compared to gas/diesel equivalent.

The total project funding was $4,273,878. Of this total project amount, $2,760,391 was for CEC reimbursement and $1,513,488 was for match share. The total amount reimbursed for the project was $1,869,541 with an unspent balance of $718,175. The total match share invoiced to the project was $955,692 leaving a match balance of $557,796. The match funds budget came from Motiv's research and development budget and was used for labor, overhead, and some equipment costs. The reimbursable budget was used to purchase materials, pay for the labor to build and support the vehicles, and for some of the equipment costs.

# CHAPTER 2:
# Bus Builds and Demonstrations

The agreement required the build and demonstration of five electric school buses. As will be described later, only 3 buses were built during the project term.

Motiv worked with GAS, body builder Starcraft, and Transair for air conditioning to originally build five eQuest buses and deploy them in service in schools located in disadvantaged communities.

The project was broken down into 4 main tasks: administration, design and body integration, demonstration and field operation, and data collection and analysis. The bulk of the technical work was in performing environmental testing of components for California Highway Approval approval, conducting a packaging study to determine the optimal way to mount the kit for body integration, integrating accessory components, and testing.

The initial technical work was performed by Motiv to evaluate the body fit and determine if any mounting kit changes would be required to accommodate body installation. The first Ford F-59 chassis arrived and GAS began working to electrify the chassis using Motiv's design in July 2016. A trial body fit was done in October 2016 and some minor wire and hose routing adjustments were identified and an accessory inverter was relocated to facility installation.

While the initial chassis electrification and body fit was being conducted, at the direction of project partner Starcraft, Transair was selected as being the supplier for accessory air conditioning installation. Motiv began integrating the Transair system into the software configurations while the first chassis was being electrified by GAS. Figure 1 shows the lifted school bus body so modifications to wiring and mounting positions could be integrated on Model Vehicle Number 2011, the first bus build.

**Figure 1: Initial Body Fit of eQuest XL Model Vehicle Number 2011**


Source: Motiv

Figure 2 shows the first two finished school buses at a launch event on November 1, 2017, held by Colton Joint Unified School District.

**Figure 2: First Two eQuest School Buses**

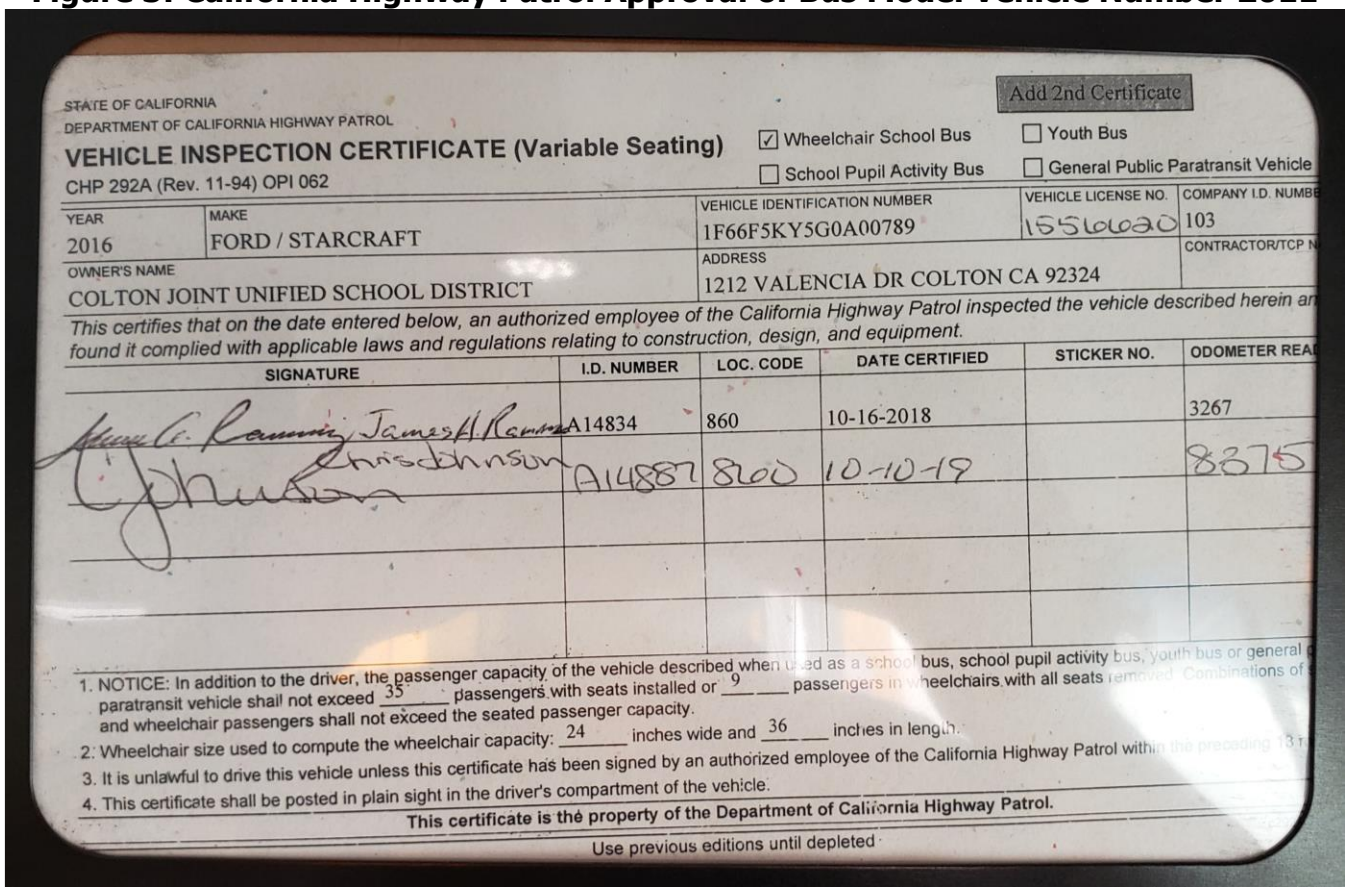

Source: Motiv

In January 2017 the first eQuest bus build was completed. The first bus was used at live demonstration events for Rialto Unified School District, Montebello Unified School District, and Bellflower Unified School District allowing fleet managers and staff to test drive the buses.

The second bus build with GAS began in March 2017. The second and third bus builds progressed faster than the first bus as GAS gained familiarity with the Motiv design and chassis assembly. Motiv made design adjustments based on lessons learned from the first bus that helped with body installation.

Motiv utilized the first bus for validation testing before the second and third buses were delivered to the Colton United School District. After validation was complete, the first two buses were delivered in August 2017. Work began on the third bus in October 2017 and was completed in December 2017. Figure 3 shows that the third bus validation was completed in February 2018 and delivered to the Colton USD in September 2018.

**Figure 3: California Highway Patrol Approval of Bus Model Vehicle Number 2011**



STATE OF CALIFORNIA
DEPARTMENT OF CALIFORNIA HIGHWAY PATROL

**VEHICLE INSPECTION CERTIFICATE (Variable Seating)**

CHP 292A (Rev. 11-94) OPI 062

Add 2nd Certificate

☑ Wheelchair School Bus ☐ Youth Bus
☐ School Pupil Activity Bus ☐ General Public Paratransit Vehicle

| YEAR | MAKE | VEHICLE IDENTIFICATION NUMBER | VEHICLE LICENSE NO. | COMPANY I.D. NUMBE |
|---|---|---|---|---|
| 2016 | FORD / STARCRAFT | 1F66F5KY5G0A00789 | 1556020 | 103 |

| OWNER'S NAME | ADDRESS | CONTRACTOR/TCP N |
|---|---|---|
| COLTON JOINT UNIFIED SCHOOL DISTRICT | 1212 VALENCIA DR COLTON CA 92324 | |

*This certifies that on the date entered below, an authorized employee of the California Highway Patrol inspected the vehicle described herein an found it complied with applicable laws and regulations relating to construction, design, and equipment.*

| SIGNATURE | I.D. NUMBER | LOC. CODE | DATE CERTIFIED | STICKER NO. | ODOMETER REA |
|---|---|---|---|---|---|
| James A. Ramm | A14834 | 860 | 10-16-2018 | | 3267 |
| Chris Johnson | A14887 | 860 | 10-10-19 | | 8375 |
| | | | | | |
| | | | | | |
| | | | | | |

1. NOTICE: In addition to the driver, the passenger capacity of the vehicle described when used as a school bus, school pupil activity bus, youth bus or general p paratransit vehicle shall not exceed 35 passengers with seats installed or 9 passengers in wheelchairs with all seats removed. Combinations of and wheelchair passengers shall not exceed the seated passenger capacity.
2. Wheelchair size used to compute the wheelchair capacity: 24 inches wide and 36 inches in length.
3. It is unlawful to drive this vehicle unless this certificate has been signed by an authorized employee of the California Highway Patrol with the preceding 13 t
4. This certificate shall be posted in plain sight in the driver's compartment of the vehicle.

**This certificate is the property of the Department of California Highway Patrol.**

Use previous editions until depleted

Source: Motiv

# CHAPTER 3:
# Data Collection and Analysis

Motiv's partners for this project were GAS and Starcraft. GAS was involved with electrifying the chassis and installing the bodies on three of the five total buses that were delivered.

One of the primary goals of this project was to create an electric school bus. This project allowed Starcraft to take their existing Quest bus body and develop a process to install it on a Motiv EPIC F-59 chassis, creating the eQuest bus. GAS was the dealer for Starcraft school buses. Until this demonstration project, GAS and Starcraft were unable to offer fully electric school buses to their customers. This demonstration project allowed these project partners to potentially expand their product portfolio.

During the 12-month data collection period for this project, Motiv collected data related to bus performance and cost of ownership. There were many difficulties during the data collection period related to poor cellular connectivity for the cellular devices installed in the buses, and difficulties maintaining a connection to the WIFI device at the Colton USD site. Motiv addressed these issues by investigating new cellular providers and troubleshooting the wireless connection to Colton USD. These project connection problems resulted in data loss when the system reported back to Motiv servers. Additionally, the total bus mileage was stored on the bus odometer independently of cellular connectivity.

Every day after completing their bus route runs, the buses would be connected to their electric chargers. Each bus had its own dedicated Clipper Creek CS-100-3 charging station, three electric chargers total. The bus drivers would park the buses at their central fleet location and connect to their respective chargers at the end of their daily routes. Each bus would charge automatically while connected to the charging station. The buses would remain connected to the charging station throughout the night until the bus drivers disconnected the chargers before beginning their routes the following day or when the bus drivers used the bus. Motiv did not collect charging events/data for the demonstration of the buses.

While hampered by cellular connectivity limitations that impacted daily data collection, the total mileage driven by these buses is provided in Table 1. The total mileage driven shows an estimate of 16,396 miles for the 3 buses that were in demonstration service.

Table 1 shows an estimated comparison of the maintenance costs between a diesel school bus and the eQuest buses. The table also shows an estimated average decrease in annual non-warranty covered maintenance costs of $3,661 per bus. This estimate was developed by comparing the standard maintenance cost of diesel buses provided by Colton USD, $0.67 per mile, to the actual maintenance cost incurred by the Colton USD, which was $0 as was to be expected for a new bus. There was a very large warranty-covered cost incurred during this project due to the replacement of high-cost components that failed during the demonstration. The buses built and demonstrated were new to Motiv. When a component failure occurred Motiv investigated the root cause of the problem and implemented fleet-wide corrective measures when necessary.

**Table 1: Estimated Maintenance Cost Comparison for the Demonstration Period**

| Bus Code | Model Vehicle Number 2011 | Model Vehicle Number 2012 | Model Vehicle Number 2013 | Total |
|---|---|---|---|---|
| Mileage | 3,382 | 5,423 | 7,591 | 16,396 |
| Diesel Vehicle | $2,266 | $3,633 | $5,086 | $10,985 |
| Electric Vehicle Warranty Covered | $11,554 | $8,498 | $499,258 | $519,310 |
| Maintenance Savings | $2,266 | $3,633 | $5,086 | $10,985 |

Source: Motiv

Table 2 shows an estimated comparison of the fuel costs between a diesel school bus and the eQuest which indicates that there is an average decrease in annual fuel costs by $1,250 per bus. This estimate was developed by comparing the estimated number of gallons of diesel fuel consumed to travel the equivalent number of miles as the buses in this demonstration to the reported kilowatt hour (kWh) used by the buses. The typical diesel school bus has a fuel efficiency of 8.5 miles per gallon, at an average fuel price of $3.51 per gallon the total fuel cost to travel the same 16,396 miles recorded during the data collection period is estimated to be $6,772. The eQuest buses in this demonstration consumed a total of 19,288 kWh of energy. At the average electricity rate in California in 2018 of $0.16 per kWh, the total energy cost during the data collection period would be $2,843 based on this state-wide average.

**Table 2: Estimated Summary of Fuel Savings for the Demonstration Period**

| Bus Code | Model Vehicle Number 2011 | Model Vehicle Number 2012 | Model Vehicle Number 2013 | Total |
|---|---|---|---|---|
| Mileage | 3,382 | 5,423 | 7,591 | 16,396 |
| Gallons of Fuel Saved | 398 | 638 | 893 | 1,929 |
| Fuel Cost | $1,432 | $2,288 | $3,330 | $7,049 |
| Energy Used (kWh) | 3,979 | 6,380 | 8,931 | 19,288 |
| Electricity Costs | $660 | $702 | $1,481 | $2,843 |
| Savings | $773 | $1,130 | $1,849 | $3,752 |

Source: Motiv

Tables 3, 4, and 5 show the estimated fuel savings for each of the three buses built and demonstrated for the 12-month data collection period. For bus number Model Vehicle Number 2011, four months of data were not collected.

**Table 3: Estimated Fuel Savings of Bus Model Vehicle Number 2011 for the Data Collection Period**

| | March – April | May – June | July – August | September – October | November – December | January – February | Total |
|---|---|---|---|---|---|---|---|
| Mileage | - | - | 271 | 965 | 884 | 1,262 | 3,382 |
| Gallons of Fuel Saved | - | - | 32 | 114 | 104 | 148 | 398 |
| Fuel Cost | - | - | $112 | $437 | $381 | $502 | $1,432 |
| Energy Used (kWh) | - | - | 319 | 1,135 | 1,040 | 1,485 | 3,979 |
| Electricity Costs | - | - | $53 | $188 | $173 | $246 | $660 |
| Savings | - | - | $59 | $249 | $209 | $256 | $773 |

Source: Motiv

**Table 4: Estimated Fuel Savings of Bus Model Vehicle Number 2012 for the Data Collection Period**

| | March – April | May – June | July – August | September – October | November – December | January – February | Total |
|---|---|---|---|---|---|---|---|
| Mileage | 621 | 300 | 744 | 1,391 | 548 | 1,819 | 5,423 |
| Gallons of Fuel Saved | 73 | 35 | 88 | 164 | 64 | 214 | 638 |
| Fuel Cost | $248 | $132 | $310 | $629 | $240 | $727 | $2,288 |
| Energy Used (kWh) | 731 | 353 | 875 | 1,636 | 645 | 2,140 | 6,380 |
| Electricity Costs | $121 | $58 | $145 | $271 | $107 | $355 | $702 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Savings | $127 | $74 | $165 | $258 | $133 | $373 | $1,130 |

Source: Motiv

**Table 5: Estimated Fuel Savings of Bus Model Vehicle Number 2013 for the Data Collection Period**

| | March – April | May – June | July – August | September – October | November – December | January – February | Total |
|---|---|---|---|---|---|---|---|
| Mileage | 1,824 | 419 | 574 | 2,784 | 1,237 | 753 | 7,591 |
| Gallons of Fuel Saved | 215 | 49 | 68 | 328 | 146 | 89 | 893 |
| Fuel Cost | $786 | $192 | $238 | $1,262 | $551 | $300 | $3,330 |
| Energy Used (kWh) | 2,146 | 493 | 675 | 3,275 | 1,455 | 886 | 8,931 |
| Electricity Costs | $356 | $82 | $112 | $543 | $241 | $147 | $1,481 |
| Savings | $430 | $110 | $126 | $718 | $311 | $154 | $1,849 |

Source: Motiv

With respect to Table 6, the eQuest bus does not produce tail pipe emissions since it is an electric vehicle. The estimated emissions savings were calculated by multiplying the standard emissions per mile of a diesel school bus by the total miles driven by Colton USD during the data collection period.

**Table 6: Total Estimated Emissions Savings for the Data Collection Period**

| | Model Vehicle Number 2011 | Model Vehicle Number 2012 | Model Vehicle Number 2013 | Total |
|---|---|---|---|---|
| Mileage | 3,384 | 5,424 | 7,588 | 16,396 |
| Net Carbon Dioxide Emissions (MT) | 6.24 | 9.98 | 13.70 | 30 |
| Nitrogen Oxide (g) | 1,940.16 | 3,109.76 | 4,350.45 | 9,400 |
| Reactive Organic Gases (g) | 101.52 | 162.72 | 227.64 | 492 |
| Particulate (g) | 83.47 | 133.79 | 187.17 | 404 |

Source: Motiv

# CHAPTER 4:
# Findings and Recommendations

## Findings

When Motiv began this project the Motiv EPIC F-59 design was being used on Ford F-59 chassis for walk-in delivery van applications. The conventionally fueled Starcraft Quest XL bus line was a successful product before the start of this project, but no electric bus equivalents were being offered by Starcraft. Over the course of the build and demonstration project, Motiv made design changes to accommodate the integration of the Quest XL body onto the Motiv EPIC F-59 chassis. Transair successfully integrated auxiliary cooling equipment on the Motiv chassis.

Over the course of this project, multiple design changes were implemented to increase the reliability of the eQuest bus. Water ingress issues were discovered on the Battery Management Interface or the high voltage batteries. As a result, Motiv designed and implemented wheel well liners to prevent water ingress and worked with the battery supplier to improve their product reliability.

Motiv worked with a battery supplier to improve upon the product for reliability which has since become commercially available. The high voltage batteries used in this application have received significant reliability improvements from the manufacturer including better weatherization.

This project resulted in the creation of the eQuest school bus line which GAS has been able to market as a commercial product offering. Along with three of the five buses delivered that were to be delivered as part of this agreement, the eQuest bus line has enjoyed success with 18 eQuest buses in use within school districts in California.

One new full-time position was added in Motiv's customer support department as a direct result of this project. Post project, two additional positions were added to support follow-on orders of the eQuest bus as a result of the project. Motiv hired one additional Field Support Technician to support the three eQuest buses with Colton USD. Motiv anticipates that additional support positions may be generated with future sales eQuest buses. These jobs represent well paid positions and tax revenues in the regions that they support.

It should be noted that there was one key problem during field demonstration of bus Model Vehicle Number 2011, the first bus built and demonstrated. On February 1, 2018, bus Model Vehicle Number 2011 was involved in a single bus accident where a California Highway Patrol (CHP)[5]. Traffic Collision Report Local Report Number 9860-2018-00459 was completed. The bus was sustained damage which resulted in a significant and deleterious impact on time spent in active service routes transporting school students. The accident occurred when the bus accelerated, turned off the road in an industrial section and into a grass/dirt field, collided with a concrete block wall, then proceeded to travel across a street to another grass/dirt field before colliding with a chain link fence causing moderate damage to the fence. The CHP report

[5] The California Highway Patrol, is available at (https://www.chp.ca.gov/).

noted a dent to the front bumper, the engine cover was broken, the windshield was cracked, and the rearview mirrors were broken. The report noted that the CHP was unable to determine the mechanical cause of the accident given the condition of the bus. The CHP did not provide statements with respect to any fault attributed to the bus components. The CHP noted reports of injuries as a result of the accident. Additionally, Motiv provided an analysis of the mechanics of the accident.

The bus accident caused Model Vehicle Number 2011 to remain out of demonstration service and off-route until August 2019, approximately 15 months after the end of the term of the agreement. After the CHP investigation was complete, the bus arrived at GAS on August 2, 2018, for body repairs and was shipped back to Colton USD on July 30, 2019. Motiv found that the accident caused no damage to the chassis components. There were no problems with the CHP recertification based on report findings provided by the CHP post-agreement.

The electric school bus market has grown to include multiple competitors and body types. Most new entrants to the market have brought products designed from the ground up while established market manufacturers have worked to incorporate electric vehicle technology into established product offerings.

The following goals are provided to help frame some of the project results:

- Goal 1: Develop and demonstrate an electric version of the eQuest bus platform and deploy to a school district with proper charging infrastructure.

  Three of the five school buses were built and demonstrated by Colton USD. As a result of this project, the eQuest has become a successful product for Motiv, Starcraft, and GAS. The school buses were demonstrated in disadvantaged communities.

- Goal 2: Collect 12 months of throughput, usage, and operations data for the project.

  This goal has been met. While there were difficulties from data losses on the electric charging parameters due to a variety of telemetry issues, Motiv was able to collect data related to all the key performance metrics for the vehicles including the following:

  - Utilization of Meltric charging connectors. The charging stations installed for these three buses were Clipper Creek CS-100 three phase stations with a charging capacity of 20 percent to 70 percent in 2-3 hours and 100 percent in 8 hours.
  - The buses traveled 16,396 miles with an estimated fuel savings of approximately 1,929 gallons of diesel.
  - Switching from a fossil fuel powered bus to a zero-emission vehicle produces significant tailpipe emissions reductions Nitrous oxide emissions reductions are estimated to be averaging 3133.46 grams per bus per year. Carbon dioxide emissions reductions are estimated to be averaging 6.45 metric tons per bus per year. Particulate emissions reductions are estimated to be averaging 134.81 grams per bus per year. Reactive Organic Gases emissions reductions are estimated to be averaging 164 grams per bus per year. The baseline for the estimated air emissions reductions is the gasoline powered Quest XL bus.
  - The buses developed and field demonstrated in this project were able to perform on the same routes as their fossil fuel powered alternatives. The demonstrated

eQuest buses have a limited range of 70 miles and increases in the range may accrue due to improvements in battery technology.

- Additional heating and cooling requirements may be needed to address a wider variety of use cases which may decrease bus range. Additional factors that may impact range must be considered when determining a bus' duty cycle.
- One new position was added at Motiv as a direct result of this project. An electrician was contracted to install the electric charging stations.

- Goal 3: Demonstrate the return on investment for the eQuest bus platform compared to diesel equivalent.

  The eQuest has been shown to have a favorable return on investment when compared to diesel equivalents. The deployed buses are estimated to have a decrease in maintenance costs compared to the diesel equivalents. Over one year of data collection, the eQuest is estimated to save an average of almost $5,000 per vehicle.

## Recommendations

Based upon project lessons learned, Motiv believes CEC should continue to receive funding to ensure the next generation of technology providers have the resources needed to commercialize their zero-emission school bus technologies in California. This project helped mature the field of school bus electrification and those solutions are now commercially available, enabling CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project to include electric school bus options.

California has ambitious goals to promote zero-emission transportation and improve air quality. These goals will require policy solutions to encourage technical and business advancements. It is important to note that the electric school bus market is still in its infancy. There are a variety of areas the state can support which would enable technology providers to reduce the time between proof-of-concept to market viability and market integration of vehicles into school fleets.

Motiv was selected for this project as a leading engineering and manufacturing company, and throughout the project has matured as a company with better accounting and business processes. However, the tools for better accounting, auditability of file formats, and preferred administrative methodologies differ between government grants and standard business practices on small teams where accounting is often a single person rather than a team with a set process. CEC staff could help advise small businesses on best practices for scaling projects as these programs often have very specific timelines, expectations, and methodologies. We believe the CEC assisting small businesses in this way would improve the maturity of the businesses, the accountability of the funding pools, and enable winners of contracts to grow in a responsible and stable way, improving the likelihood of market integration of the technologies they develop.

# GLOSSARY

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

KILOWATT-HOUR (kWh)—The most commonly used unit of measure telling the amount of electricity consumed over time, means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumed 534 kWh in an average month.

CREATIVE BUS SALES'S GREEN ALTERNATIVE SYSTEMS (GAS)—the largest fleet conversion company in North America, to add Motiv to its portfolio of available alternative fuel systems for fleets across the country.

HYBRID AND ZERO-EMISSION TRUCK AND BUS VOUCHER INCENTIVE PROJECT (HVIP)—A project launched in 2009 by the ARB in partnership with CALSTART to accelerate the purchase of cleaner, more efficient trucks and buses in California.

UNIFIED SCHOOL DISTRICT (USD)—A unified school district or unit school district is a school district which includes both primary school (kindergarten through middle school or junior high) and high school (grades 9–12) under the same district control.

CALIFORNIA HIGHWAY PATROL (CHP)—a state law enforcement agency of the U.S. state of California.

MOTIV POWER SYSTEMS, INC. (MOTIV)— a sustainable technology company delivering proven electric truck and bus chassis and related charging infrastructure.