CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Walk-In Van Repower Demonstration

Prepared for: California Energy Commission

Prepared by: Motiv Power Systems, Inc.

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation 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.
- 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-13-602 to fund demonstration projects that convert used medium-duty gasoline and diesel vehicles to all-electric drive. In response to PON-13-602, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards October 17, 2013 and the agreement was executed as ARV-13-010 in April of 2014.

ABSTRACT

As the need for emission reductions grows, fleets have evaluated a variety of technologies at the early stages of feasibility. Zero-Emission Battery-Electric Trucks 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 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 saving opportunities.

Incumbent players 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 trucks into producing battery-electric trucks. Technology, such as the Motiv Power Systems electric Powertrain Control System, are needed for these traditional truck lines to easily integrate zero-emission battery electric powertrains.

This project allowed Motiv Power Systems to leverage its technology into repower applications and explore their economic viability. Over the course of this project Motiv Power Systems' technology matured and is now used in a variety of vehicle applications, both new and repower.

This project allowed the fleet partner, AmeriPride (now owned by Aramark) to gain confidence in zero-emission battery-electric trucks. AmeriPride's experience with Motiv Power Systems during the Repower project has increased their confidence in battery-electric vehicle adoption. As a result of this project, AmeriPride has received delivery of an additional 25 vehicles from Motiv Power Systems for continued use in fleets throughout California. As of today, AmeriPride has 31 Motiv Power Systems powered vehicles in service in their fleet and they intend to continue operating these vehicles indefinitely.

Keywords: electric, vehicle, truck, bus, heavy-duty, zero-emissions, manufacturing, controllers, zero-emission trucks, zero-emission buses, electric powertrain, battery-electric

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EXECUTIVE SUMMARY

In this grant, Motiv Power Systems sought to reduce the technological and market barriers that have limited the adoption of zero-emission battery-electric repowered vehicles. In this grant Motiv Power Systems repowered six delivery walk-in vans. These vehicles were identified as ideal for repowering because they have a long service life, high fleet uniformity and a duty cycle that was an excellent fit for a Motiv Power Systems electric Powertrain Control System. Motiv Power Systems received vehicles from the fleet partner AmeriPride and installed the original vehicle bodies on electric chassis with new electric powertrain technology. After the repowered vehicles were built, Motiv Power Systems tested them and returned them to the fleet which used them in normal operations.

The goals and objectives of this agreement have remained the guiding principles of this project and the project goals and objectives have all been accomplished. However, in the process of this project, Motiv Power Systems found that rather than technology limitations being the primary barrier for fleets, it has been a blend of economic, regulatory, infrastructure and technology limitations slowing the growth of zero-emission vehicles to get out of research labs and onto the streets.

Through the course of this project Motiv Power Systems has worked with the fleet, AmeriPride, to assure that the repowered demonstration vehicles perform as expected in the delivery fleet applications. Through careful monitoring of performance, maintenance requirements and cost of operation throughout the demonstration period, Motiv Power Systems has enabled the team to collect key insights to drive future decision making in approaching the challenge of electrification. AmeriPride's confidence in Motiv Power System's electric powertrain technology and realized economic benefits have resulted in the deployment of 25 additional Motiv powered vehicles.

The vehicles in this grant have traveled 23,420 miles in commercial operations that would have otherwise been traveled by fossil fuel burning traditional vehicles. During the data collection period eliminating fossil fuels resulted in approximately 141 kilograms of nitrous oxide, 13.7 metric tons of carbon dioxide, 6.61 kilograms of reactive organic gases, and 6.35 kilograms of particulates emissions savings. These reductions assist the Clean Transportation Program in meeting its goals as well as helping AmeriPride in meeting its corporate sustainability plan goals.

Final Report Intent

The goal of this Final Report is to assess the project's success in achieving its goals and objectives, advancing science and technology, and providing energy-related and other benefits to California. The objectives of the Final Report are to describe the project's purpose, approach, activities performed, results, and advancements clearly and completely in science and technology, to present a public assessment of the success of the project as measured by the degree to which goals and objectives were achieved, to make insightful observations based on results obtained, to draw conclusions, and to make recommendations for further projects.

CHAPTER 1:
Project Intent, Goals and Objectives

Introduction

In 2013 Motiv Power Systems (Motiv), an emerging electric powertrain technology provider, saw a unique opportunity to combine California's growing commitment to sustainability with fleet's desires to reduce fuel expenditures. Delivery vehicles presented a unique vertical to explore for electrification because they have a long service life, high fleet uniformity and a duty cycle that is an excellent fit for an all-electric powered chassis. Motiv acted as the catalyst by providing its electric Powertrain Control System and managing the upfit of standard original equipment manufacturer chassis to all-electric versions. Over the course of the project, Motiv received vehicles from the partnering fleet, repowered at a facility capable of high volume repowers, tested them and returned them to the fleet which then used them in normal operations.

This project intended to both provide a working repowered vehicle for use in revenue generating service as well provide a real-world example to understand the economics of retrofits, enabling a fleet to justify adding electric repowers and new electric vehicles into substantial portions of their fleets. Over the course of this project this goal has been realized. However, the success of repowered vehicles has been found to be less ideal than the equivalent new electric vehicles, and the added business and operational hurdles make it a pathway less ideal for scaling.

Over the course of this project Motiv has determined that the repowering of vehicles is a less optimal strategy to reduce emissions than to produce new vehicles. Within the repower space the key cost drivers remain the same as new vehicles with expensive batteries and components, however there are added labor and installation costs, unclear regulatory pathways for liability of the system, logistical costs to remove the vehicle from service prior to being able to place the replacement back into service (unlike a new vehicle being brought into service as the old one is retired), and increased vehicle shipping costs to bring the old vehicles to a facility capable of doing the work.

While the vehicles that were repowered were successful enough to prove the core technology in the powertrain, the barriers to repowers made the fleet select brand new all electric delivery trucks using the same technology when placing future orders.

Problem Statement

While battery-electric trucks have been an area of interest for local delivery applications, 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.

For repowers to be a viable solution, the application for the vehicle must fit an ideal profile to reduce risks. The ideal candidate vehicles for repowers are those medium-duty vehicles that have very long service life, high fleet uniformity, and require minimal original equipment manufacturer support. Repowered vehicles must have a long intended service life so that the vehicle has many years of operation post-repower in which the return on investment can make the investment economical. Fleet uniformity directly correlates to lower engineering costs for mass adoption of repowers. Finally, vehicles that require extensive certification or vehicles built by one single original equipment manufacturer are less ideal because that manufacturer would rather sell a new vehicle than see an old vehicle repowered. As such, walk-in vans have the highest market viability for repower of any medium-duty vehicles and were the focus of this project.

Goals and Objectives of the Agreement

Over the course of this grant, Motiv's operations goals and objectives for this project were:

1. Assure that the repowered demonstration vehicles perform as expected in the delivery fleet applications. Carefully monitor performance, maintenance requirements and cost of operation throughout the demonstration period.
2. Significantly reduce the emissions of nitrous oxide. hydrocarbons, carbon dioxide, and particulates by medium-duty commercial vehicles in the state of California.
    a. Assist the California Air Resources Board in meeting their goals for air quality and the use of electric repowers in the state of California.
    b. Assist the participating fleets in meeting their corporate sustainability plan goals.
    c. Provide other medium-duty commercial fleets with a model they can use to calculate potential emissions reductions by repowering their fleet with electricity.
3. Reduce the use of petroleum transportation fuels in California.
4. Analyze the collected data to:
    a. Confirm the expected reduction in net fuel consumption per vehicle, per year.
    b. Confirm the expected maintenance cost reduction per vehicle per year.
    c. Confirm the expected reduction in emissions of nitrous oxide, hydrocarbons, carbon dioxide, and particulates per vehicle, per year.
5. Validate that the vehicles meet the required durability, functionality, and cost of operation targets to provide an acceptable rate on investment.
    a. Refine the repower kit to minimize cost and installation time.
    b. Develop an economically viable five-year warranty for the conversion components.

CHAPTER 2:
Work Performed, Data and Results

This chapter reviews the activities performed as part of the project, presents data collected during the project and reports the results of the activities.

Work Performed

During the agreement, Motiv worked with fleet partner AmeriPride to repower six Walk-In-Vans for use in local deliveries based out of their Vernon, CA facility. The project was broken down into four main tasks: Administration, Repower, Field Operation, and Data Collection and Analysis. The project was signed into contract with the CEC in April of 2014.

The bulk of the technical work was in the Repower task in which Motiv identified a chassis ideal for this application, developed a repower kit, conducted a packaging study to determine the optimal way to mount the kit, chassis decontenting and reassembly with the electric system, and testing.

Instead of repowering the vehicle's original chassis, Motiv decided to use new Ford F59 chassis and reinstall the original body on the new chassis. This decision was primarily driven by Motiv's difficulty in obtaining technical information concerning the original chassis such as computer-aided design data, brakes, steering, ABS interface information, and instrument cluster information. Without the necessary technical information, Motiv could not ensure that the powertrain would operate as intended. The Ford F59 Chassis was selected to use in this project as they are a common base chassis for both Morgan Olson and Utilimaster, leading Walk-in-Van original equipment manufacturers. This also allowed the technical integration and processes developed in the design of Motiv's integration with Ford's E450 to be leveraged and reduce the technical learning curve. Selection of the Ford F59 chassis allowed for technology transfer to additional vehicle applications. The Ford F59 chassis as received is shown in Figure 1 below.

Figure 1: The Ford F59 Chassis as Received

Source: Motiv

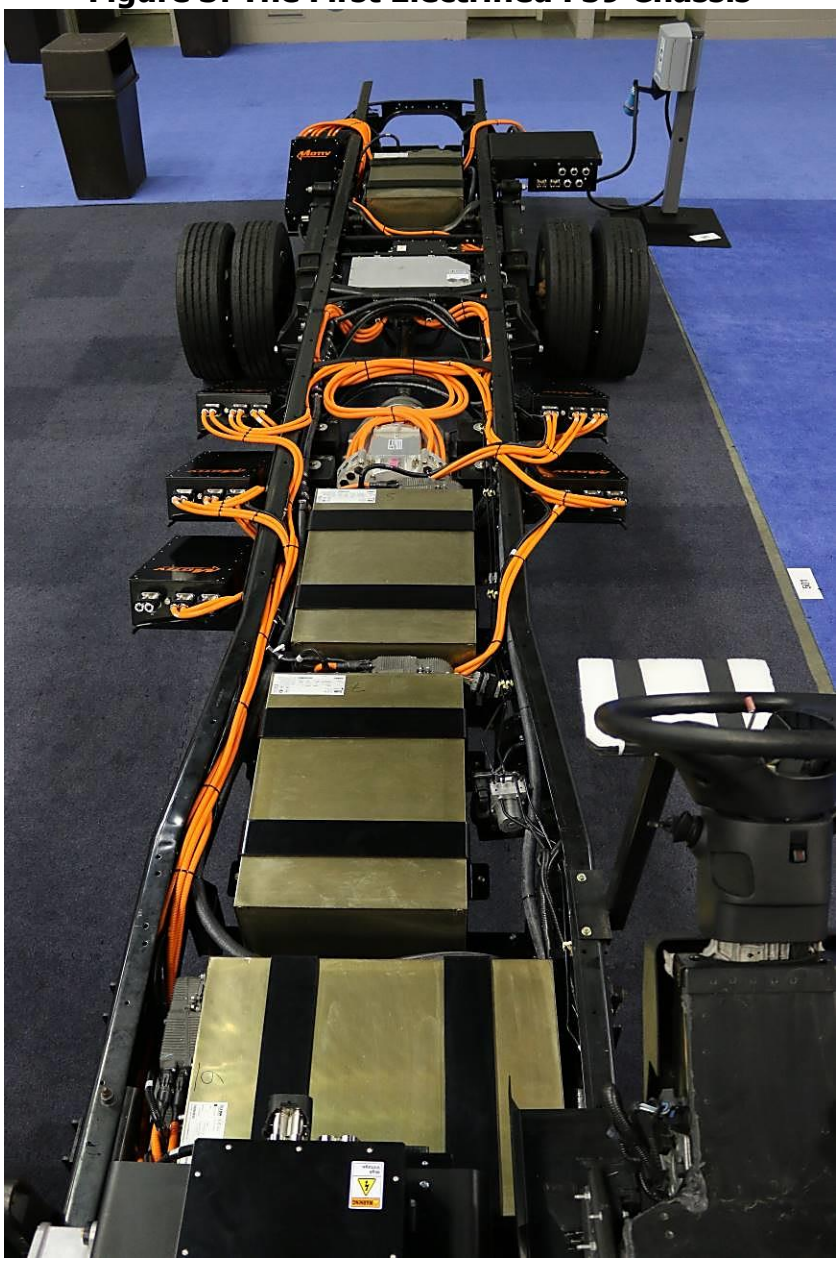
During the first several weeks of the project Motiv worked with key partners on the detailed project plan, including schedule and scope of work needed to finalize contracts and agreements.

By June of 2014 the project had begun execution on key tasks including signing subcontracts with the battery supplier and upfitter. Based on these early discussions the fleet AmeriPride was selected due to alignment with the vehicle application of Walk-in-Vans. At this time the number of vehicles were changed from the initial plan of seven vehicles for UPS to six for AmeriPride based on the fleet's need at the site selected. By August of 2014, the vehicles had been selected and key components for the chassis were being ordered. Over the next few months, the design of the system, selection for key components, designing of the upfit package including mounting brackets and placement was done. The Ford F59 non-electric and electric chassis prior to installation in March 2015 are shown in Figure 2 and 3. In April of 2015 the first unit was shipped to Morgan Olson for the body placement.

Figure 2: The Ford F59 Chassis After Upfit

Source: Motiv

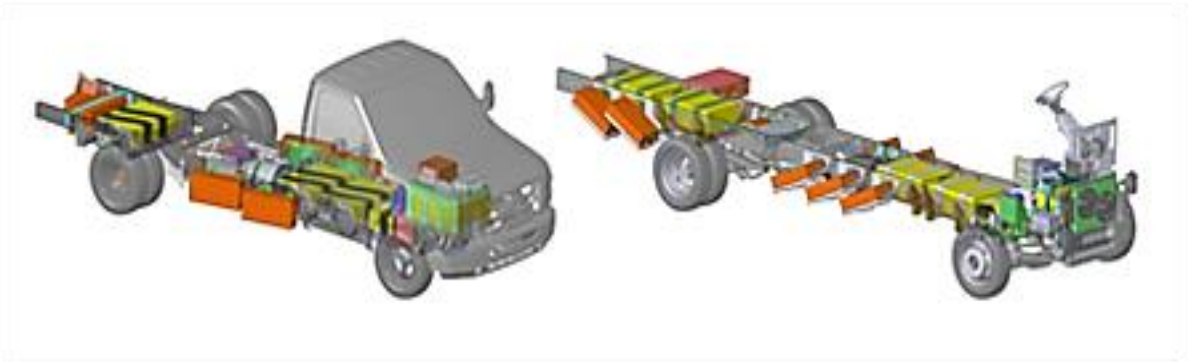
Figure 3: The First Electrified F59 Chassis



Source: Motiv

The first electrified chassis, while mildly delayed due to a few parts in the procurement process, was able to have enough key components installed that the body could be installed with minor reworks planned after the body installation. Comparison between the Ford E450 Motiv upfit package and the Ford F59 Motiv upfit package used in Walk-in-Vans is shown in Figure 4. Components like the vehicle motor which were larger than the E450 application, had to be procured, and supplier delays were unavoidable due to the design work being a prerequisite for selection of all parts. The first vehicle was also being used to test the design prior to building the remaining units to avoid costly reworks, however this meant initial delays also pushed back the work on the second through sixth trucks. At the time the delay was thought to be negligible based on the project having some built-in buffer, however this reduced the ability to respond to later delays while meeting the original schedule.

Figure 4: E450 and F59 Motiv Upfit Package Comparison



Source: Motiv

In July of 2015 the first vehicle was inspected by AmeriPride's staff at Motiv's headquarters. The AmeriPride fleet representatives show in Figure 5 in Foster City to inspect and give feedback on the first vehicle. This feedback was used to modify and enhance the fleet experience by modifying the software configurations. Their staff also reviewed the Vehicle Performance Testing plan to ensure a vehicle that passed Motiv's test plan would be able to meet their operational needs. This vehicle remained at Motiv until delivery to the fleet in early November.

Figure 5: The First Electrified Walk-In-Van

Source: Motiv

Around October an unexpected barrier to deployment was discovered when the California Department of Motor Vehicles didn't know how to register the vehicle. For technical reasons to ensure the durability of the product, a new chassis was used with the old body. However, this approach meant the new chassis had a new VIN, and an old body. The Department of Motor Vehicles lacked a process for how to account for a new VIN on the chassis with a repowered body. The fleet was able to secure a temporary registration, however, the time to get permanent registration was greater than if they had purchased a new vehicle, and thus required additional business support for the project. Figure 6 shows first repower unit in Foster City where initial validation was completed.

Figure 6: First Repower Unit - MVN2001

Source: Motiv

At this time scheduling also began to remove the remaining five vehicles from service to remove the bodies to be installed on the new electric chassis. From November through January 2016 AmeriPride put the vehicle into service to test the technology prior to a public announcement around the project. In February of 2016 they held a public event and invited stakeholders to see the vehicle as well as announce an increased investment in the project based on the initial success of the first unit. The coordination of pulling vehicles out of service for the build process was found to be arduous so in addition to the six vehicles from this grant, they ordered the same F59 electric upfit package for use in four new vehicles at Vernon with funding assistance from California Air Resources Board's Hybrid and Zero-Emission Truck and

Bus Voucher Incentive Project (HVIP) at the Vernon facility. This number of vehicles represents 20 percent of the Vernon fleet.

"We are extremely excited to pilot the new electric delivery trucks at our facility," said Annette Casemero, General Manager of the Vernon branch "Our first truck has been running daily routes since it was delivered in November and has been running great, with zero service incidents or calls needed. Adding electric vehicles to our fleet complements our expanding alternative fuel program and we look forward to adding additional electric vehicles to our fleet in the coming year."

This order revealed both a confidence in the technology being used in the vehicles, as well as a logistical barrier to using repowered vehicles within a commercial fleet. This was a barrier initially not identified at the time of the project proposal. Additionally, the initial success with the upfit package well positioned Motiv to begin the next phase of the project building the remaining repower units. AmeriPride offers a tour of the Vernon facility and how energy efficiency fits in and the CEC's staff joins Motiv and AmeriPride's senior leadership at the launch event. Photos of this event are shown in Figure 7.

Figure 7: AmeriPride Launch Event

Source: Motiv

Delays in removing the vehicles from service in addition to delays from the body builder on mounting the units on the electrified chassis had pushed the project behind schedule. Since

the initial launch the 6 repowers have been placed in service and are expected to remain in service alongside 25 additional Motiv powered vehicles that AmeriPride purchased as a result of their confidence in the technology from the repower project.

Data Collected

The following parameters for both EV and internal combustion engine (ICE) vehicles formed the basis for data collection and analysis (Table 1).

Table 1: Collected Data

Per Route	Definition	EV Source	Internal Combustion Engine Source
Vehicle Mileage - Start	Odometer value at start of day	ViriCiti	
Vehicle Mileage - End	Odometer value at end of day and plugged in for charging.	ViriCiti	
Total Route Mileage	Difference between above Odometer readings	Calculated	
Time- Start	Time of day vehicle leaves the depot (GPS Location)	ViriCiti	
Time - End	Time of day vehicle returns to depot (GPS Location)	ViriCiti	
Total Route Time	Difference between above times	Calculated	
Vehicle Stops	Number of times motor rotation is zero for more than 5 seconds	ViriCiti	
Brake Applications	Number of times the brake switch opens in the period between Time-Start and Time-End	ViriCiti	
Ignition On/Off Cycles	Number of time ignition is switched On + 1 between Time-Start and Time-End	ViriCiti	
Battery State of Charge - Start of Route	Battery SOC (percent) recorded prior to leaving the depot (GPS Location)	ViriCiti	N/A
Battery State of Charge - End of Route	Battery SOC (percent) recorded after arrival back at the depot (GPS Location), but before charging	ViriCiti	N/A
kWhrs Used		Calculated	N/A

Per Route	Definition	EV Source	Internal Combustion Engine Source
Gasoline Fuel Gage Reading - Start of Route	Fuel Gage Reading at start of day	N/A	Driver
Gasoline Fuel Gage Reading - End of Route	Fuel Gage Reading at end of day	N/A	Driver
Gasoline Used	Amount of Fuel added to vehicle during the day + any Fuel added to the vehicle at end of day.	N/A	Driver
Distance Traveled - Highway	Driving at speeds over 50 MPH	ViriCiti	
Route Time - City Driving	Aggregate Time Driving Between 10 MPH and 50 MPH	ViriCiti	
Route Time - Low Speed Driving	Aggregate Time Driving below 10 MPH	ViriCiti	
Route Time - Vehicle Stopped, foot on Brake	Aggregate Time spent in this operating condition	ViriCiti	
Route Time - Vehicle Stopped, in Park, Ignition Off	Aggregate Time spent in this operating condition	ViriCiti	
Total Route Time	Calculated - Sum of above times	Motiv	
Time Spent at Speeds 0 - 10 MPH	Aggregate Time spent within this speed range	ViriCiti	
Time Spent at Speeds 11 - 20 MPH	Aggregate Time spent within this speed range	ViriCiti	
Time Spent at Speeds 21 - 30 MPH	Aggregate Time spent within this speed range	ViriCiti	
Time Spent at Speeds 31 - 40 MPH	Aggregate Time spent within this speed range	ViriCiti	

Per Route	Definition	EV Source	Internal Combustion Engine Source
Time Spent at Speeds 41 - 50 MPH	Aggregate Time spent within this speed range	ViriCiti	
Time Spent at Speeds 51 - 60 MPH	Aggregate Time spent within this speed range	ViriCiti	
Time Spent at Speeds 61 - 70 MPH	Aggregate Time spent within this speed range	ViriCiti	

Source: Motiv

Regulatory Challenges

The assumption in this project was all applicable state and federal regulations were already being satisfied and thus a repower project would not have additional regulatory hurdles to clear prior to deployment. Within the original grant application federal and state regulations were identified as well as the compliance pathway.

However, the optimal repower approach that engineering used instead of repowering an old chassis and body, was to couple a new chassis with the electric powertrain. While this increased the system reliability it also introduced regulatory hurdles. The challenges in vehicle registration as well as who is the legal final stage vehicle manufacturer for a new chassis VIN with an old body is a challenge which would need to be addressed. The added regulatory and compliance risk makes it unattractive for an upfitter, and the fleet who knows the vehicle best is not the one doing certification or regulatory compliance for the build process. Without a clear process or waiver for this, scaling a repower model would be very difficult.

Results

While hampered by cellular connectivity limitations, the data collected shows a transition from fossil fuel powered vehicles to zero-emission vehicles provides real environmental and financial savings for their fleets. The data shown below in Table 2 presents an average day of work for a repower vehicle

Table 2: Indicative Day of Data Collection for a Repower

Per Route	Definition	EV Results	ICE Results
Vehicle Mileage - Start	Odometer value at start of day	9,442	

Per Route	Definition	EV Results	ICE Results
Vehicle Mileage - End	Odometer value at end of day and plugged in for charging.	9,491	
Total Route Mileage	Difference between above Odometer readings	49	
Time- Start	Time of day vehicle leaves the depot (GPS Location)	6:15 AM	
Time - End	Time of day vehicle returns to depot (GPS Location)	2:46 PM	
Total Route Time	Difference between above times	8 hrs, 31 mins	
Vehicle Stops	Number of times motor rotation is zero for more than 5 seconds	16	
Brake Applications	Number of times the brake switch opens in the period between Time-Start and Time-End	16	
Ignition On/Off Cycles	Number of time ignition is switched on + 1 between Time-Start and Time-End	12	
Battery State of Charge - Start of Route	Battery SOC (%) recorded prior to leaving the depot (GPS Location)	100%	N/A
Battery State of Charge - End of Route	Battery SOC (%) recorded after arrival back at the depot (GPS Location), but before charging	15%	N/A
kWhrs Used		71 kWh	N/A
Gasoline Fuel Gage Reading - Start of Route	Fuel Gage Reading at start of day	N/A	
Gasoline Fuel Gage Reading - End of Route	Fuel Gage Reading at end of day	N/A	
Gasoline Used	Amount of Fuel added to vehicle during the day + any Fuel added to the vehicle at end of day.	N/A	
Route Time - Highway Driving	Aggregate Time Driving above 50 MPH	6 mins	

Per Route	Definition	EV Results	ICE Results
Route Time - City Driving	Aggregate Time Driving Between 10 MPH and 50 MPH	36 mins	
Route Time - Low Speed Driving	Aggregate Time Driving below 10 MPH	36 mins	
Route Time - Vehicle Stopped, foot on Brake	Aggregate Time spent in this operating condition	3 hrs, 11 mins	
Route Time - Vehicle Stopped, in Park, Ignition Off	Aggregate Time spent in this operating condition	4 hrs, 3 mins	
Total Route Time	Calculated - Sum of above times	8 hrs, 31 mins	
Time Spent at Speeds 0 - 10 MPH	Aggregate Time spent within this speed range	36 mins	
Time Spent at Speeds 11 - 20 MPH	Aggregate Time spent within this speed range	9 mins	
Time Spent at Speeds 21 - 30 MPH	Aggregate Time spent within this speed range	10 mins	
Time Spent at Speeds 31 - 40 MPH	Aggregate Time spent within this speed range	12 mins	
Time Spent at Speeds 41 - 50 MPH	Aggregate Time spent within this speed range	6 mins	
Time Spent at Speeds 51 - 60 MPH	Aggregate Time spent within this speed range	6 mins	
Time Spent at Speeds 61 - 70 MPH	Aggregate Time spent within this speed range	0 mins	

CHAPTER 3:
Assessment of Project Success

Here, we discuss the advancement in science from this project and present an assessment of the success of the project as measured by the degree to which the goals and objectives were achieved.

Advancements in Technology

When Motiv began this project the Motiv electric Powertrain Control System was a product with a limited application to one chassis type: the Ford E450. Over the course of this project in addition to developing the packaging for the Ford F59 application, the hardware generation has gone from a Gen 2 to a Gen 4.5. The more robust design is better weatherized and suited for manufacturing. Supplier components have also been improved because of this project.

This project has acted as a catalyst not just for Motiv development of the F59 EPIC chassis and AmeriPride's adoption of electric vehicles into their fleet, it has also aided suppliers in improving their products and bringing technology out of the labs and into the real world. The direct current to direct current converter was not initially a commercially available product. Motiv worked with the supplier to improve upon the product for reliability and it has since become commercially available. The high voltage batteries used in this application have received significant reliability improvements from the manufacturer including better weatherization as a result of learnings from the repower vehicles.

The process of designing for another vehicle application also led to software architecture improvements with improved performance and reliability. With 78-88 percent uptime, the repowers perform on par with aging fleets in the field. The positive feedback from the fleet partner as well as cobranded partnerships with both Ford, and AmeriPride and additional fleet orders as a result indicate a high degree of commercial validation and interest.

Project Goal Accomplishment

Goal 1: Assure that the repowered demonstration vehicles perform as expected in the delivery fleet applications. Carefully monitor performance, maintenance requirements and cost of operation throughout the demonstration period.

This goal has been met. The repower vehicles entered service between December 2016 and March 2018. Deployments of the six vehicles show high levels of fleet satisfaction. The fleet partner AmeriPride intends on keeping the vehicles in service for the foreseeable future and has become a return customer for Motiv powered vehicles. The vehicles service dates are provided in Table 3 below. Motiv's support team monitors all service and maintenance requirements, and per the data detailed above, the vehicles have had a 78-88 percent uptime.

Table 3: Vehicle in Service Date

VEHICLE	IN SERVICE DATE
MVN2001	2/8/2017
MVN2002	12/6/2016
MVN2003	12/18/2016
MVN2004	11/6/2017
MVN2005	3/16/2018
MVN2006	3/2/2018

Source: Motiv

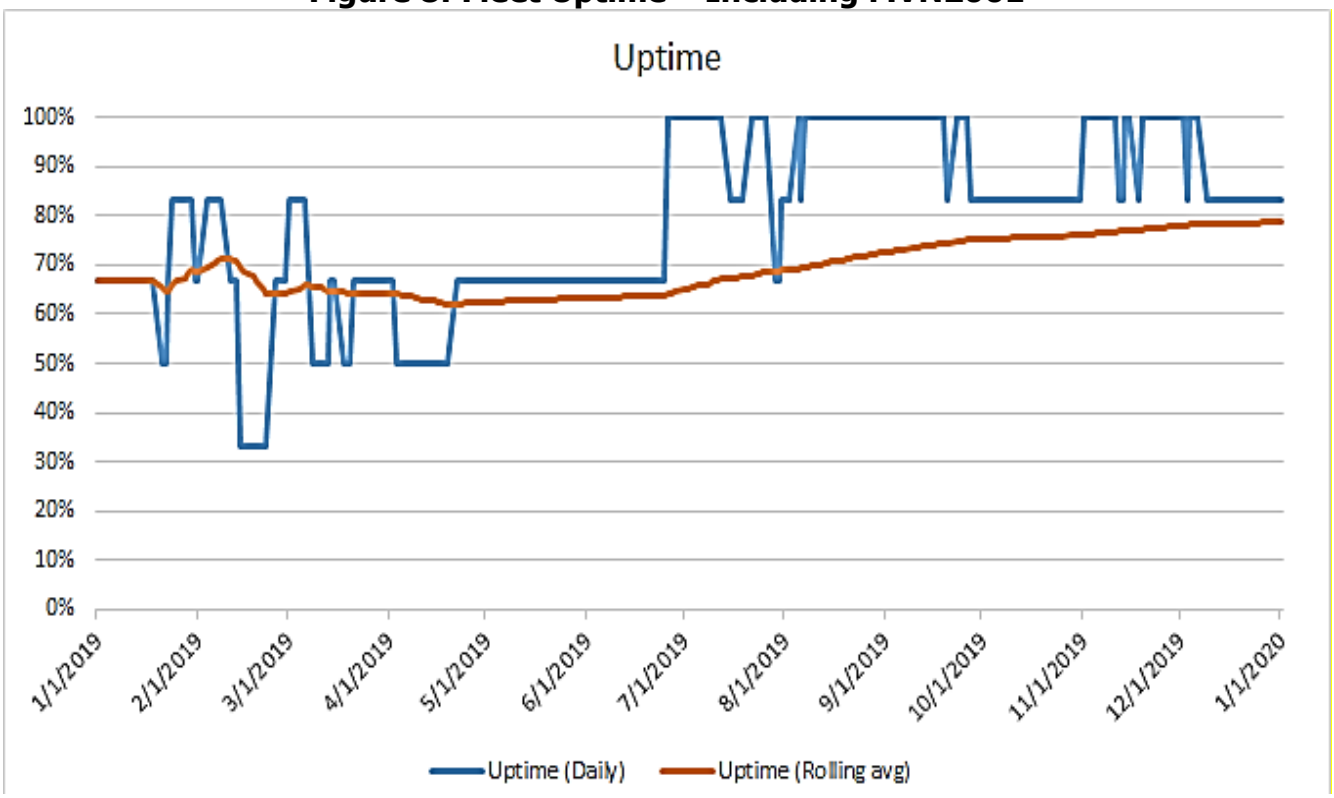
The operational performance of the repower vehicles were comparable to their ICE counterparts. The power steering force is designed to be equivalent to an ICE vehicle by matching the pressure and flow rate to the power steering pump. The vehicles have been shown to operate well on a gradeability of 20 percent. The added weight due to batteries and other electric Powertrain Control System components lowers the center of gravity to improve the handling over their ICE counterparts. Acceleration was not as fast as the ICE counterparts since the peak power to the motor was limited in order to increase range.

The repower vehicles showed comparable performance to their ICE counterparts in all performance criteria except for peak power and range, and drivers showed a preference for the repower vehicles over diesel. The vehicles were able to operate on the same routes as their ICE counterparts would have operated on. The repower were unable to reach a range of 100 miles, as a result shorter routes were selected for the vehicles. Motiv has learned from these experiences and pursued opportunities to improve future vehicle range through an improved battery architecture with the next Motiv F59 design having a range of 105 miles.

The very first repower vehicle (MVN2001) experienced significant downtime as compared to the other vehicles in the repower project. While issues with MVN2001 during the data collection period has had an impact on the fleet uptime calculations shown in Figure 8, the vehicle is currently back in service and performing well. The fleet uptime during the data collection period, not including MVN2001, are shown in Figure 9.

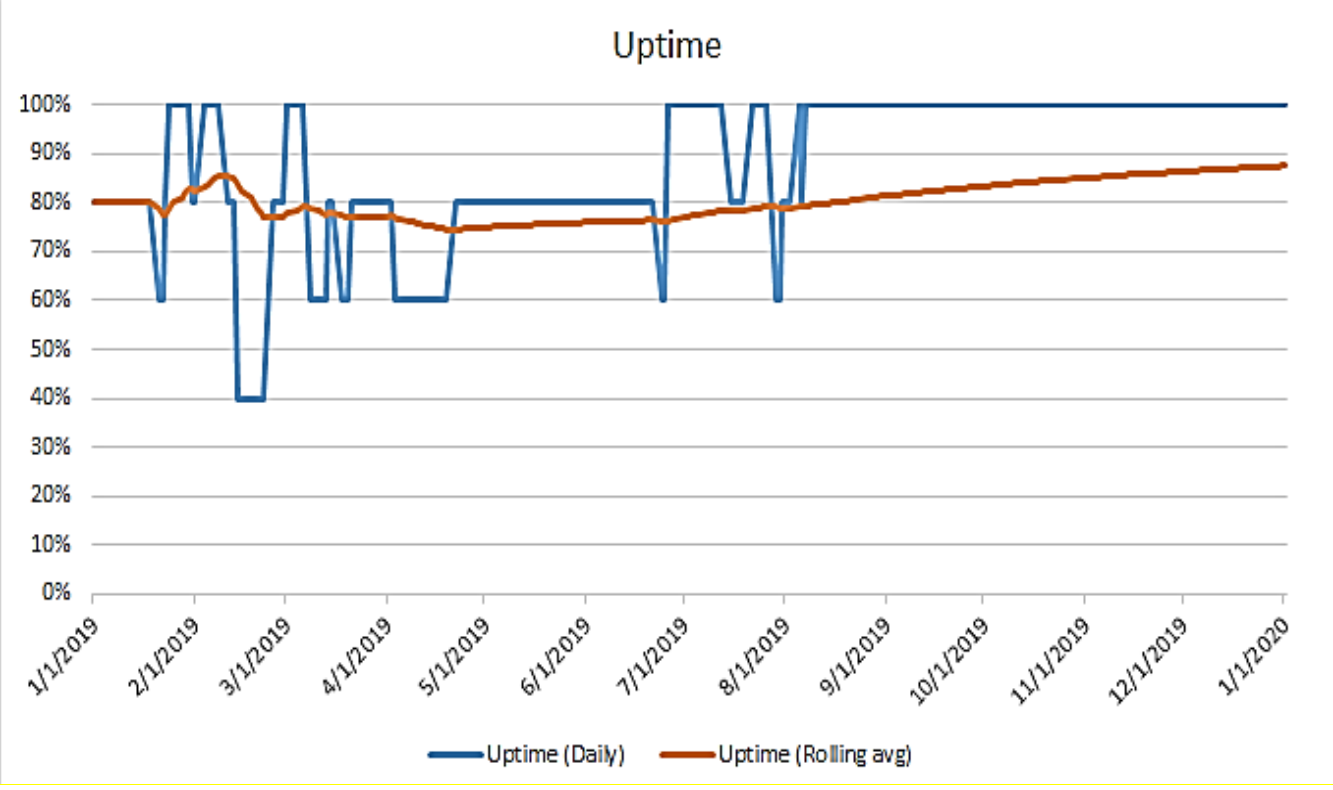
Additionally, vehicles experiencing non-powertrain related maintenance needs are considered as being in service since non-powertrain related maintenance is not part of Motiv's purview. MVN2006 was included in the Q5 logs because it was out of service for a non-powertrain related issue. In this instance, MVN2006 had an operational powertrain during the quarter but spent much of the time in a body shop for non-powertrain related maintenance.

Figure 8: Fleet Uptime – Including MVN2001



Source: Motiv

Figure 9: Fleet Uptime – Not Including MVN2001



Source: Motiv

Goal 2: Significantly reduce the emissions of nitrous oxide, hydrocarbons, carbon dioxide, and particulates by medium-duty commercial vehicles in the state of California.

Since the project began, the F59 Upfit design has been integrated into Walk-In-Vans, Type C School Buses, and specialty vehicles. The vehicles using this technology are HVIP eligible and available for fleets to purchase today, enabling the reduction of diesel usage. This enables Motiv's product to be used in a key program that is a part of the State of California's strategy to reduce emissions.

In Governor Brown's Executive Order B-48-18 he points out that, "the transportation sector still emits 50 percent of California's total greenhouse gas emissions and 80 percent of the smog-forming oxides of nitrogen". By further developing commercially viable solutions for fleets, Motiv is meeting its goal to reduce emissions associated with transportation.

Assist the participating fleet in meeting its corporate sustainability plan goals.

AmeriPride strives to have environmentally friendly operations, however prior to purchasing Motiv's Electric Walk-In-Van, was unable to get zero-emission solutions despite past efforts. On page 11 of AmeriPride's 2017 Corporate Responsibility Report they specifically mention the incorporation of 10 all-electric delivery trucks with 20 more to be incorporated in 2017. All 30 of these vehicles use the technology matured during this project.

Provide other medium-duty commercial fleets with a model they can use to calculate potential emissions reductions by repowering their fleet with electricity.

Motiv has developed a tool to calculate approximate emission reductions based on the baseline of fuel usage in different applications and carbon intensity values used by California Air Resources Board.

Goal 3: Reduce the use of petroleum transportation fuels in California.

The vehicles in this project have cumulatively traveled 23,420 miles during the data collection period, which, at a rate of six miles per gallon, has reduced the amount of fuel AmeriPride has used by 3,903.33 gallons. This is $13,700.69 in fuel savings at a rate of $3.51 per gallon.

Goal 4: Analyze the collected data in order to:

1. Confirm the expected reduction in net fuel consumption per vehicle, per year.
2. Confirm the expected maintenance cost reduction per vehicle per year.
3. Confirm the expected reduction in emissions of nitrous oxide, hydrocarbons, carbon dioxide, and particulates per vehicle, per year.

This goal has been met. Due to downtime for MVN 2001 during the data collection period, per vehicle calculations are done with the five vehicles instead of six. The expected reduction in net fuel consumption per vehicle per year amounts to approximately 780.66 gallons. This fuel savings is equal to $2,740.12 in fuel savings per vehicle per year at a rate of $3.51 per gallon. The average maintenance cost for the vehicles was $315, the calculated maintenance cost for their diesel equivalents is $946, resulting in an expected maintenance cost reduction of

approximately $631 per vehicle per year. This represents a 66.7 percent decrease in maintenance costs. The total expected monetary savings are $3,370.12 per vehicle per year.

As shown in the quarterly reports, switching from a fossil fuel powered vehicle to a zero-emission vehicle produces significant emissions reductions when compared to replacing all of the vehicles with 2010-compliant new vehicles. Nitrous oxide emissions reductions are estimated to be 2650 grams per vehicle per year. Carbon dioxide emissions reductions are estimated to be 12.9 metric tons per vehicle per year. Particulate emissions reductions are estimated to be 146 grams per vehicle per year. Reactive Organic Gases emissions reductions are estimated to be 215 grams per vehicle per year.

When compared to keeping the old vehicles on the road, during the data collection period this project saved 312 pounds nitrous oxide, 60570 pounds of carbon dioxide, 14.0 pounds of particulates, and 14.6 pounds of Reactive Organic Gases based off the EMFAC2017 calculations.

On an ongoing basis, each repowered vehicle deployed in this project are expected to save 45.3 pounds nitrous oxide, 8800 pounds of carbon dioxide, 2.03 pounds of particulates, and 2.12 pounds of reactive organic gases based off the EMFAC2017 calculations, assuming no increase in annual mileage. This is less than what was anticipated in the grant application primarily because the annual mileage of the repowered vehicles was 3400 in the last year instead of the 25,000 miles per year we assumed in the grant application.

Aramark has demonstrated that they will continue to run these vehicles beyond the data collection period. We expect that they will be used for 10 years at least. Over that period, we would expect to see a total emissions savings of 2,540 pounds of nitrous oxide, 493,000 pounds of carbon dioxide, 114 pounds of particulates and 119 pounds reactive organic gases based on EMFAC2017 calculations compared to keeping the diesel vehicle running for 10 more years, assuming no worsening of the diesel vehicles' emissions controls and assuming 3400 miles per year per vehicle, which 10 years of five vehicles and six years for the sixth vehicle.

Note that all above emissions reductions are at the tailpipe and do not account for any emissions created in the generation of the electricity used to power the vehicles.

Goal 5: Validate that the vehicles meet the required durability, functionality, and cost-of-operation targets to provide an acceptable rate on investment.

This goal has been met. AmeriPride has found the vehicles able to meet their field needs and cost targets using the current pricing and incentives available. However, the repower solution was logistically more expensive than a new vehicle due to increased oversight needs, shipping costs, body upfitter delays, and lost service days. Based upon the technology reliability coupled with market barriers, Motiv recommends fleets replace vehicles on a rolling basis with new electric vehicles rather than doing repowers when possible.

Refine the repower kit to minimize cost and installation time.

This goal has been met. At the start of this project, it took 542 hours to upfit a Ford F59 chassis with a Motiv electric powertrain. Motiv improved the upfit time simplifying the design for manufacturability, creating templates for use during chassis upfit, and standardizing and

refining the build instructions. After refinements made to the repower kit during this project and improvements to the manufacturing processes, it takes 250 hours to upfit a Ford F59 chassis with a Motiv electric powertrain.

Develop an economically viable five-year warranty for the conversion components.

Motiv has applied a three-year warranty to the conversion components for this project. Based on the learnings from this project and others, Motiv now offers a standard five-year warranty for the powertrain components. However, it is difficult to apply this warranty to repowers because the base vehicle may be out of warranty. Based upon the project's learnings repowers may be a less scalable method of vehicle electrification unless done with an original equipment manufacturer partner who can warranty the entire repowered vehicle thereby reducing the end user burden.

CHAPTER 4:
Conclusions and Recommendations

Summary of Results

The goals of furthering the development of the technology, establishing fleet comfort with said technology, and introducing the technology into commercial deployment were all accomplished.

Through the repower project, Motiv developed the necessary packaging to install an electric powertrain F59 chassis. The technology has matured from a Gen 2 architecture to a Gen 4.5 architecture and manufacturing techniques were refined. The fleet partner, AmeriPride gained confidence in the technology and Motiv, resulting in additional vehicle orders and a long lifetime for the repower vehicles in AmeriPride's fleet.

Conclusions and Recommendations

Based upon this project success and learnings Motiv believes this program from the CEC should be amended and continue to receive funding to ensure the next generation of technology providers have the resources needed to demonstrate the feasibility of manufacturing and fielding their clean technologies in California. While the timelines were off track due to the integration with partners, the end results helped mature the field of vehicle electrification and those solutions are now commercially available, enabling California Air Resources Board programs such as Truck and Bus Pilots and HVIP to include a more robust solution set.

However, Motiv recommends that repower projects are not pursued at this time. Repowers proved to be challenging because of the additional complexity versus a new vehicle (ie. Registration, compliance, warranty, body reinstallation), and those barriers must be overcome for repowers to be as viable as a new vehicle solution. Logistical barriers in removing vehicles from service for repower conversion proved to be a central consideration when purchasing new vehicles in follow-on orders rather than continuing to repower the existing fleet.

The State of California has ambitious goals to promote clean transportation, however attaining these goals will require policy solutions to encourage technical and business advancements. It is important to note the electric medium duty vehicle market and its needs are still in its infancy. To grow to its full potential 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 fleets. Motiv's suggestions on how to best do this as well as analysis detailing how we arrived at this suggestion are discussed below.

Accessory System Integration Funding

One of the key tasks in the project was selecting a new higher power electric motor for the F59 Upfit Package. The options in the market were somewhat limited given this is an emerging market, but successful integration of software and electrical components with mechanical parts is essential for customer success. Choices made outside of the key electrical pieces such as

designing a more robust brake system were important for the fleet, but not often funded in most grant pools.

While our system could easily power the vehicles, the heating and cooling needs and some of the auxiliary systems for work trucks require components that are not yet ruggedized and/or have few suppliers. The lack of options on high powered components has been a barrier to providing the same quality level fleets expect and is a barrier to growing the portfolio of zero-emissions vehicle offerings. The powertrain performance only accounts for the driving needs of fleets, and with the diversity of truck and bus applications, funding to provide incentive to develop more robust accessories would reduce that barrier. This is a key ingredient to market viability of the technology beyond the delivery segment.

Systems like air conditioning and hydraulic motors for accessory functions require substantial engineering integration efforts, and such components and the function of integrating them into existing vehicle platforms are both areas which lack funding opportunities. Additional funding to integrate and test accessories which impact the performance of work vehicles will be needed to bring zero-emission offerings into many duty cycles. Until the accessory system components are scaled, ruggedized, and tested in the field, powertrain solutions will be limited to applications such as delivery where the vehicle's driving performance is the key use to productive commercial applications.

Streamlining Compliance Mechanisms

Certification of Zero-Emissions vehicles is an evolving process. In the initial grant application Motiv identified the Federal Motor Vehicle Safety Standards that would be impacted by a Zero-Emission Powertrain. While the lack of emissions means no such certification was needed to sell a vehicle in California, to be eligible for programs such as the California HVIP, vehicles made between 2014 and 2017 had received a letter from California Air Resources Board indicating the vehicle itself is zero-emission. Within this last calendar year, the process has continued to evolve, and California Air Resources Board's new certification process for Zero Emission Vehicles being different than the process for an aftermarket part means the choice between being a repower or new vehicle is both a legal and technical one.

Under the United States Environmental Protection Agency's Phase 1 rules from 2014 to 2017 Electric Vehicles were specifically exempted from testing. For the model of a powertrain builder using a certified chassis configuration and removing the emissions system to install a powertrain, such as what Motiv does when using a Ford chassis is exempted under the United States Environmental Protection Agency's Mobile Source Enforcement Memorandum No. 1A from June of 1974. However, the process is evolving, and it takes significant resources to monitor the changing policy landscape, and many technology focused companies do not have the depth of policy experience necessary to fully engage in this process. Given the CEC is funding and working with these companies on emerging technologies, if there was a way for a CEC project manager on CEC-funded projects to certify or be a conduit of information regarding zero-emission technologies developed within grant programs, it would allow grant recipients to spend more resources on the technology development, design, manufacturing, and deployment and fewer resources on trying to summarize new research in evolving forms that may become outdated. Over the course of this project from application to present there

have been four different pathways to ensuring compliance, on a system that was fundamentally unaltered.

Furthermore, because California Air Resources Board's process can take many weeks and sometimes months, and a CEC-facilitated pathway would allow emerging technologies to receive certification as they are being tested and proved with the CEC, and without the state requiring separate agencies to use resources to evaluate the same technology portfolio twice. The regulatory staff of California Air Resources Board's Emissions Compliance, Automotive Regulations and Science division has less direct experience with new technologies and CEC's staff, and this staff knowledge could be a vital resource in improving the process development to match build processes and technology readiness.

Increase Funding for Testing

While there is a substantial pool of funds California has invested in clean technologies, there is a gap between the steps of the pipeline which include research and development level research, initial deployments, and large pilots. There is little funding for design iterations. In the process of building these repowered vehicles, design reviews of the manufacturing process showed there were opportunities to revisit initial component design to make better components. Design improvements can lead to greater efficiencies, cost reductions in the end product, and better serve both customer fleets and the communities in which they operate; however, the cost of design improvements can be high.

Small companies often cannot afford immediate design improvements, and so they delay such improvements. The result is that more early-design-stage products get on the road, which ultimately become a liability. Past electric truck companies which are no longer actively operating were significantly impacted by this problem. Projects which would support California's emission reduction goals are sometimes abandoned for lack of funding for design improvements rather than technical feasibility. Given the state's long-term interest in high quality zero-emission offerings which can beat diesel products in both price and performance without incentives, additional funding for design improvements and their testing would help ensure technology progresses to a place where it's truly viable. Furthermore, federal funding for labs which do such testing is limited, making California's programs even more essential.

Based on its learning, Motiv believes that robust testing of new products is key to electric vehicle adoption and would encourage the Commission to fund such efforts. In turn, better-developed and better-tested products would help early fleet adopters seeking alternative fuels find better, more reliable and robust solutions. Better products make the difference between a one-time demonstration customer and a recurring customer who scales up their clean air efforts.

Scaling Businesses and Process with Funding

Motiv was selected for this project as a young company, and over the term of the project has matured into a more stable manufacturing company with better 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 with the agency 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.

These policy recommendations would all build stronger products with a pipeline to communities that need clean technologies the most. Motiv urges the state to consider a balanced approach that accounts for new technologies, emerging markets, the evolution of compliance standards, and the economic factors around the development industry, as all must be considered in bringing zero-emission vehicles out of the lab and onto the streets.

GLOSSARY

CALIFORNIA AIR RESOURCES BOARD (ARB) -- The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

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.

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.

INTERNAL COMBUSTION ENGINE (ICE)—The ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work.

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

MOTIV POWERS SYSTEMS (MOTIV)—[1]Motiv specializes in medium-duty commercial all-electric trucks and buses — plus the charging infrastructure and expertise required for deploying commercial fleets.

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1 What We Do - Motiv Power Systems (motivps.com) https://www.motivps.com/what-we-do/