CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Electric Vehicle Manufacturing Modernization Project

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Prepared by: Electric Vehicles International

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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.
- 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-09-605 to provide funding opportunities for medium-duty advanced vehicle technology. In response to PON-09-605, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards July 30, 2010 and the agreement was executed as ARV-10-011 on June 2, 2011.

ABSTRACT

Electric Vehicles International moved to California in 2009 to help transform the State's large and dirty fleet of medium-duty, diesel-fueled trucks into a clean, cost-effective model of sustainability. Electric Vehicles International invested over $10 million in private funding to develop a scalable powertrain solution for the medium-duty vehicle market that can run on electricity or electricity coupled with a range-extender for ultimate fleet flexibility. With the *Electric Vehicle Manufacturing Modernization Project*, Electric Vehicles International successfully developed a low-volume, pilot-scale assembly line that modernizes electric vehicle manufacturing, reduces manufacturing costs and accelerates deployment of clean, alternative energy vehicles.

Electric Vehicles International successfully demonstrated its capacity to manufacture medium-duty electric vehicles on its pilot-scale assembly line. The company built and deployed over 125 electric trucks in California, including 101 trucks to United Parcel Service, 15 trucks to Frito-Lay, and 8 additional trucks to a variety of customers.

The medium-duty electric vehicles deployed during the project are helping transform the state's large, dirty, diesel-powered medium-duty truck fleet into a clean, cost-effective model of sustainability, powered by state-of-the-art California technology. When compared to medium-duty diesel trucks, each electric truck reduces carbon dioxide emissions by 100 percent, eliminating 24 metric tonnes of carbon dioxide and 2,400 gallons of diesel fuel each year. The electric trucks also save an average of $7,500 in fuel costs and $10,000-$12,000 each year on engine maintenance.

Keywords: electric trucks, electric vehicle, battery-electric, medium-duty, range-extender, manufacture

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

EXECUTIVE SUMMARY

Electric Vehicle International's goal with the *Electric Vehicle Manufacturing Modernization Project* has been to reduce the cost of manufacturing electric vehicles because high cost continues to be the primary obstacle for transforming the medium-duty vehicle market to clean battery electric technology. Electric Vehicle International improved production and assembly efficiencies and reduced the costs associated with small-scale manufacturing, especially the inflated costs associated with purchasing major components, such as battery packs and motors, from third party vendors.

Electric Vehicle International successfully developed and tested its Pilot Manufacturing Line, which helped reduce the cost of each vehicle by around 20 percent. Increasing demand for Electric Vehicle International products has created up to 60 jobs in Stockton, California. and each pays a living-wage.

Electric Vehicle International teamed with Valence Technologies and other partners to leverage over $10 million in private funds and in-kind support to complement the $3.7 million CEC grant, resulting in total project costs of nearly $14 million. With these funds, Electric Vehicle International developed a semi-automated, electric vehicle manufacturing process for battery packs, battery boxes, electric motors and motor controllers, powertrains - including assembly of transmission and electric motor - and vehicle management units.

Over 100 Trucks Delivered

With the successful completion of the project, Electric Vehicle International delivered 101 medium-duty, electric drive walk-in vans to United Parcel Service, 15 medium-duty box trucks, three Pacific Gas and Electric range-extended utility trucks and seven Department of Defense range-extended units. The "100 Truck Deployment" with United Parcel Service was the largest single deployment of electric trucks and received significant media coverage, including a media event with Governor Edmund G. Brown Jr. at United Parcel Service's West Sacramento distribution center.[1]

In summary, Electric Vehicle International:

- Created and tested a new process for manufacturing electric-powered alternative vehicles;
- Designed, developed, and demonstrated an automated assembly line process that included on-site assembly of battery packs, battery boxes, motors, motor controllers, drivetrains, and vehicle management units;
- Engineered and developed a fully integrated power system that is compatible and flexible enough to fit all makes and models of medium-duty vehicles;
- Produced and deployed over 125 electric trucks;

[1] "UPS Rolls Out 100 Electric Vehicles in California." Sacramento Business Journal, February 5, 2013. https://www.bizjournals.com/sacramento/news/2013/02/05/ups-rolls-out-100-electric-vehicles-cali.html

- Teamed with major freight transport companies like United Parcel Service. United Parcel Service and Electric Vehicle International teamed for the "100 Truck Deployment," the largest single deployment of electric drive trucks to date;
- Built and field-tested 115 vehicles for United Parcel Service and Frito Lay that travelled over 2.3 million commercial miles and reduced greenhouse gas emissions by 2,300 tonnes. The Electric Vehicle International electric trucks reduced total greenhouse gas emissions 90 percent over their diesel-fueled equivalents and reduced diesel fuel use by 2,400 gallons per vehicle per year;
- Assisted the state in achieving its environmental goals and climate change policies, including the implementation of Assembly Bill 32 and the reduction of transportation greenhouse gas emissions; and
- Created green collar, living-wage jobs in Stockton, California, an economically distressed area and designated State Enterprise Zone.

Figure ES-1: EVI's Electric Walk-In Delivery Van for United Parcel Service

Source: Electric Vehicle International

CHAPTER 1: Project Purpose and Approach

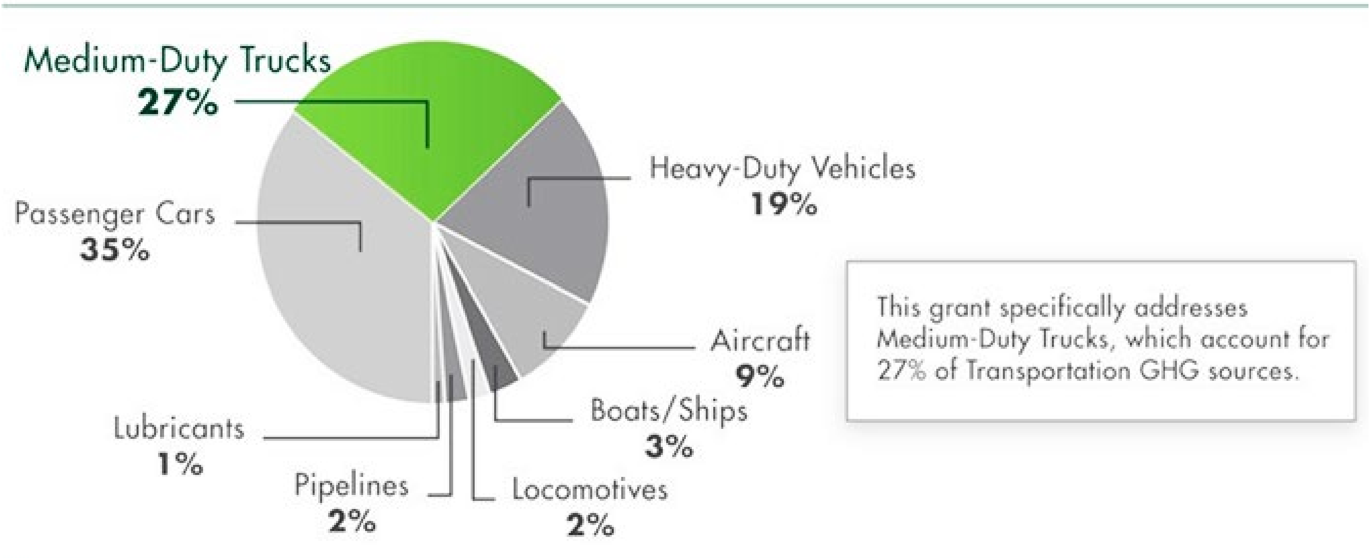
Introduction

The transportation sector is a major contributor to poor air quality in California, a significant portion of which is due to emissions from dirty, diesel-fueled medium-duty trucks. While progress is being made to produce environmentally friendly alternative energy vehicles to these markets, high costs are the primary barrier to the widespread adoption of clean technology in the freight and goods movement sectors. High costs for current market alternative energy vehicles are due to the small-scale, manual assembly methods and the high costs of purchasing and transporting vehicle components from other states. With financial support from the CEC grant, Electric Vehicle International's (EVI) mission has been to reduce the cost of clean energy vehicles and improve the efficiencies of the alternative energy vehicles manufacturing process.

Transportation Emissions

Transportation is the largest source of greenhouse gas (GHG) emissions in California. It is also the fastest-growing source of national GHG emissions, accounting for 47 percent of the net increase in total U.S. emissions since 1990. Medium-duty trucks are responsible for 27 percent of national transportation GHG sources. Figure 1 below shows the share of national transportation GHG emissions caused by medium-duty vehicles.

Figure 1: Transportation Greenhouse Gas Emission



Source: EVI

Purpose

The purpose of the project was to develop and pilot a complete alternative energy vehicles assembly method, including the in-house manufacture of major components. Additionally, EVI sought to:

- Transform California's current medium-duty diesel truck fleet by creating and testing a new process for manufacturing electric-powered alternatives that are competitively priced and can be sold without government purchase subsidies or rebates;
- Design, develop, and demonstrate a semi-automated assembly line process that includes the on-site manufacture of battery packs, battery boxes, motors, motor controllers, drivetrains, and vehicle management units;
- Engineer and develop a fully integrated power system that is flexible enough to fit all makes and models of medium-duty vehicles;
- Assist the state in achieving its progressive environmental goals and climate change policies, including the implementation of Assembly Bill 32;
- Develop an electric vehicle manufacturing processes that can reduce power system costs to end-users by 50 percent; and
- Create jobs in Stockton, California.

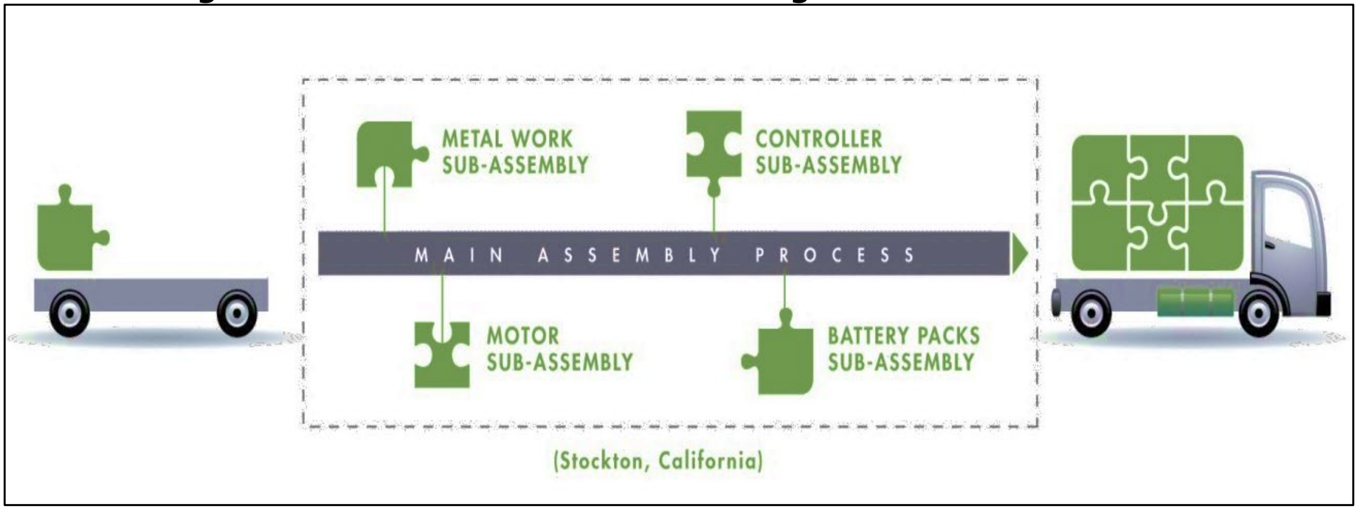
Project Approach

EVI revolutionized the manufacturing of medium-duty alternative energy vehicles by developing semi-automated manufacturing and assembly techniques at a pilot level. This included complete component manufacturing under one roof, which helped reduce costs. EVI plans to modernize the current method of manufacturing and assembling electric vehicles using Lean Manufacturing Principles. This method can be seen in Figure 2.

Lean Manufacturing Principles[2] include the concept of a primary manufacturing line that works both linearly and sequentially, pulling in parts as needed from integrated sub-assembly lines. The processes and sub-processes are carefully balanced to produce the needed number of parts to be ready "just in time" for the component to be used in the main assembly process. Quality control is built-in, as opposed to inspected, through smart automation and checking aids to ensure each sub-assembly step ends with verified dimensions and characteristics required for the next step.

[2] "Lean was originally created by Toyota to eliminate waste and inefficiency in its manufacturing operations. The process became so successful that it has been embraced in manufacturing sectors around the world. For an American company, being lean is critical for competing against lower-cost countries." American Society of Mechanical Engineers. "*5 Lean Principles Every Engineer Should Know*." March 9, 2016. https://www.asme.org/topics-resources/content/5-lean-principles-every-should-know

Figure 2: Electric Vehicle Manufacturing Modernization Method



Source: EVI

The successful execution of Lean Manufacturing Principles resulted in increased efficiency, reduced waste, and increased safety. Smart automation increases overall quality and repeatability, both extremely important to the vehicle manufacturing process. The goal was for each part to be identical to the others. Smart machines record data, which is analyzed over time to proactively watch for trends or drifts in performance. Statistical process controls objectively analyze processes, which increases quality and reduces waste.

Table 1 lists the specific advantages, along with the fewer associated drawbacks, of this approach.

Table 1: Advantages and Disadvantages of Lean Manufacturing

ADVANTAGES	DISADVANTAGES
REDUCED LOGISTICS COSTS	HIGHER UPFRONT INVESTMENT
REDUCED WASTE DUE TO A STREAMLINED PROCESS	MORE INTERNAL RESPONSIBILITY
MANUFACTURER/ASSEMBLER SELF-RELIANCE LEADING TO HIGHER ACCOUNTABILITY AND CONTROL	REQUIRES STEADY-STATE PRODUCTION WHICH REQUIRES STEADY-STATE ORDERS
QUICKER REACTION TIMES	
NO NEED TO RELY ON UNSTABLE EXCHANGE RATES AND SOURCE COUNTRY LOGISTICS	
REDUCED CUSTOMER LEAD TIMES	
SIGNIFICANT REDUCTIONS IN CUSTOMER COSTS	
CREATION OF HUNDREDS OF NEW LIVING-WAGE GREEN COLLAR JOBS IN CALIFORNIA	

Source: EVI

CHAPTER 2: Project Implementation

Project Implementation

EVI's project implementation plan was designed to maximize efficiency in manufacturing and deployment. As the project manager and operator for the *Electric Vehicle Manufacturing Modernization Project*, EVI successfully completed the responsibilities defined in the grant's Statement of Work, including:

- Overseeing the project;
- Researching and developing a fully automated power system manufacturing process;
- Testing the durability of pilot manufacturing lines, the integration of the power system into the vehicle, and the durability of the developed power system;
- Procuring and inspecting incoming materials;
- Ensuring quality management;
- Manufacturing power systems for demonstration purposes;
- Collecting data in the demonstration period; and
- Reporting progress to the CEC.

To ensure the effective implementation of the project responsibilities, EVI implemented its robust Product Lifecycle Management process. The process, based on best-practice automotive procedures, comprised six main steps, each with specific entrance and exit criteria to ensure that the product has successfully fulfilled each step.

Task 1: Administration

EVI completed all the administrative tasks as specified in the agreement, including kickoff meeting, critical project review meetings, onsite visits, monthly and quarterly progress reports and final report.

Task 2: Set Up Pilot-Level Metal Work Laboratory in EVI

The goal of this task was to reduce the cost and increase the quality of the metalwork components for EVI vehicles by designing and building a pilot laboratory within EVI. During the Project, EVI determined the requirements for metalwork components for the medium-duty trucks, which enabled EVI to design, develop, procure, install and ultimately operate the metalwork laboratory.

Upon completion of the metalwork laboratory, EVI conducted test production runs for the first three truck components. Following inspections and approvals by EVI's quality control group, the metalwork laboratory went to pilot production. At the peak of the pilot production runs, EVI's metalwork laboratory successfully provided metal components for 25 trucks per month with no issues. EVI believes the existing metalwork laboratory can expand capacity to produce as many as 75 trucks' worth of components and parts per month.

With this approach, EVI was able to:

1. Produce more than 85 percent of metal components in-house, rather than outsourcing;

2. Reduce dependency on outside metal workshops, which resulted in quicker production runs and lower costs. The in-house metalwork laboratory reduced the cost for metal components from $15,000 per vehicle down to $8,000; and
3. Create prototype designs in-house, which helped reduce the time needed for engineering work.

The metal workshop included a wide range of equipment, including a computer numeric control machine, manual lathes, welding equipment, band saw, punch, press, and a water jet.

Figure 3 illustrates some of the equipment acquired for under this Project.

Figure 3: Metal Workshop Equipment

Source: EVI

Task 3: Develop Glass Reinforced Plastic Molding Pilot Line in EVI

The goal of this task was to reduce unnecessary steel parts on the vehicle and replace them with lightweight glass reinforced plastic parts with superior durability. Reducing body and chassis weight was critical because most of the EVI electric delivery vans were "upfits" of existing diesel-powered trucks. Steel is heavy and corrodes over time, which decreases vehicle efficiency and increases maintenance costs, as steel parts must be painted for durability. EVI replaced steel battery boxes with aluminum castings and plastic injection molding, which shortened manufacturing time by eliminating the need for component painting and reducing the need for machine work.

EVI designed and developed the tooling equipment.

Upon successful development of the metalwork laboratory, EVI performed test production runs for the first three truck components. Components were inspected by a quality control team prior to beginning pilot production. At the peak of pilot production, EVI successfully provided 25 trucks' worth of battery assembly components a month. The Stockton facility EVI has potential to produce 500 trucks' worth of production a month.

Figure 4 shows pictures of the pieces made using the aluminum casting and plastic injection molding.

Figure 4: Battery Box Components

Source: EVI

Task 4: Set Up Pilot Stator and Electronics Lab at EVI

The goal of this task was to develop a pilot line to manufacture stators (electric motor casing) for the motors for EVI's and Light Engineering's new patented motor design. By assembling the stators in-house, it gave Light Engineering's flexibility in terms of design and lead-time.

Upon successful development of the metalwork laboratory, EVI conducted successful test production runs for the first three units. At the peak of pilot production, EVI successfully fabricated 160 units a month. Based on the current manufacturing layout, EVI has potential to produce up to 320 units each month.

The assembly line included a wide range of equipment, including winding tables, conveyor belts, overhead cranes, epoxy tanks, computer numeric control machines, tooling for tops and bases, sand blaster and a variety of ovens.

Figure 5 shows pictures from the stator production line.

Figure 5: Stator Production Line

Source: EVI

EVI developed an electronics lab for its engineering team for bench testing and product development. See Figure 6.

Figure 6: Electronics Lab

Source: EVI

Task 5: Pilot-Level Motor and Transmission Assembly at EVI

The goal for this task was to design, develop and implement the motor and transmission assembly line at EVI's Stockton facility. The motors were built by UQM in Denver and the transmissions by LENCO in San Diego. As part of the Electric Vehicle Manufacturing Modernization Project, EVI developed an assembly line capable of building up to 50 motor and transmission assemblies a month.

Figure 7 shows photos of the motor and transmission assembly line.

Figure 7: Motor and Transmission Assembly Line

Source: EVI

Task 6: Set Up Pilot-Level Battery Pack Assembly Laboratory

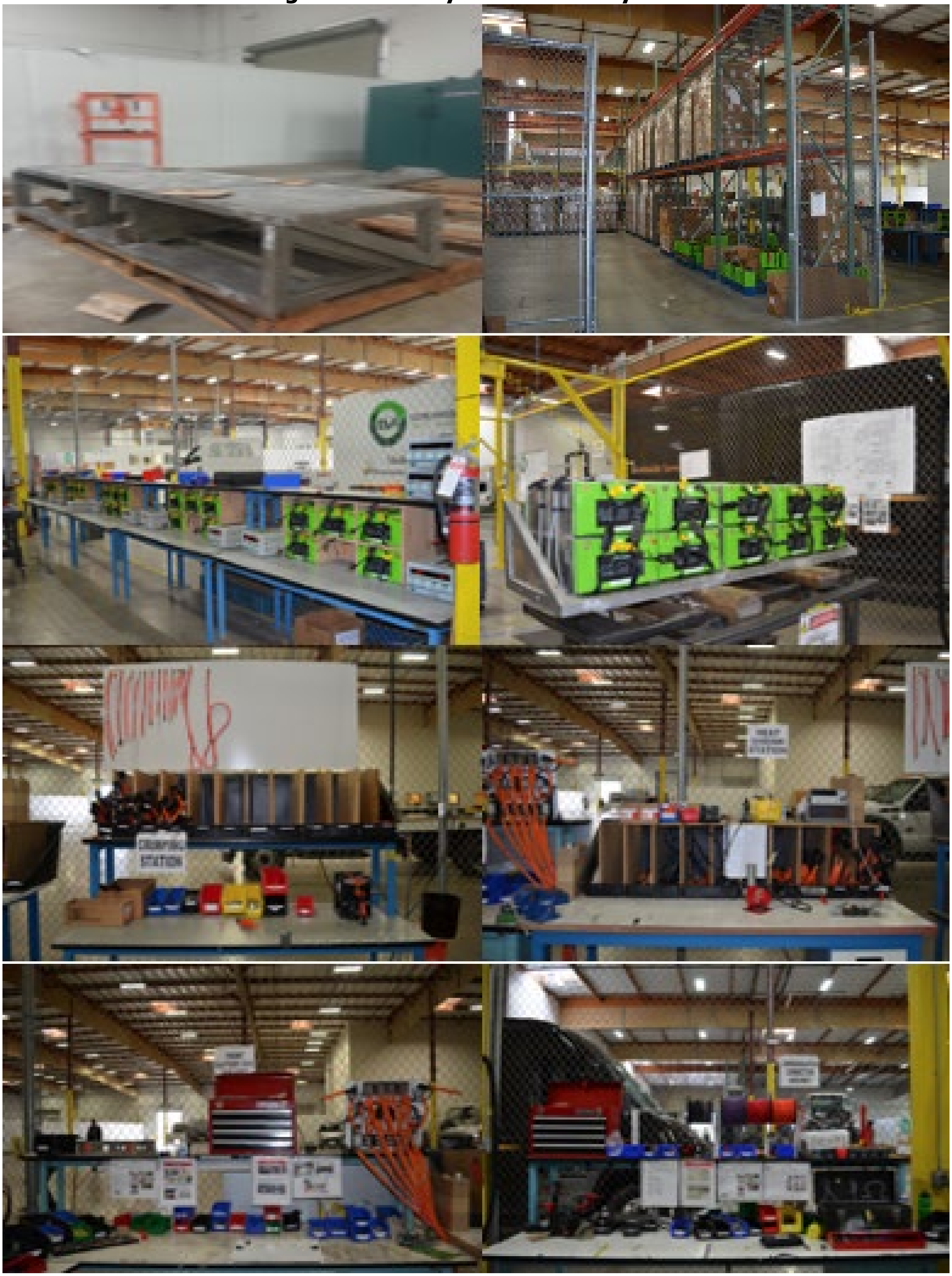
The goal of this task was to develop a pilot line to manufacture battery packs at the Stockton facility. By fabricating battery-packs in-house, EVI reduced vehicle costs, logistics costs, and product lead-time by eight weeks. The in-house capacity also allowed EVI to design custom battery packs tailored specifically for each brand of chassis and body.

Previously, EVI contracted with Valence to manufacture the vehicle batteries and then outsourced battery pack assembly to third party vendors. This was a cumbersome process. To minimize the delays, EVI designed, developed and implemented its battery pack assembly process. Battery pack assembly included:

1. Construction of a stockroom with the capacity to store up to 2,400 batteries point to support production schedules.
2. Capacity to charge individual batteries by constructing battery charging stations that could charge 36 batteries at a time.
3. Ability to read voltage, current, set parameters and label each individual battery using Valence software.
4. Capability to assemble castings, battery pods, and batteries to make a completed battery box (or pack) to supply the main production line. Final battery pack assembly phases included cable crimping stations, fuse plate build station, final connections to the batteries and installation of battery covers.

Figure 8 shows pictures of the battery sub-assembly line.

Figure 8: Battery Pack Assembly Line



Source: EVI

To help ensure product quality, EVI developed a battery test station to test the communication system and state of charge for the three sets of battery packs prior to installing them on each truck. By doing so, EVI was able to minimize the delay in its truck building process.

Figure 9 shows the test bench.

Figure 9: Battery Test Bench

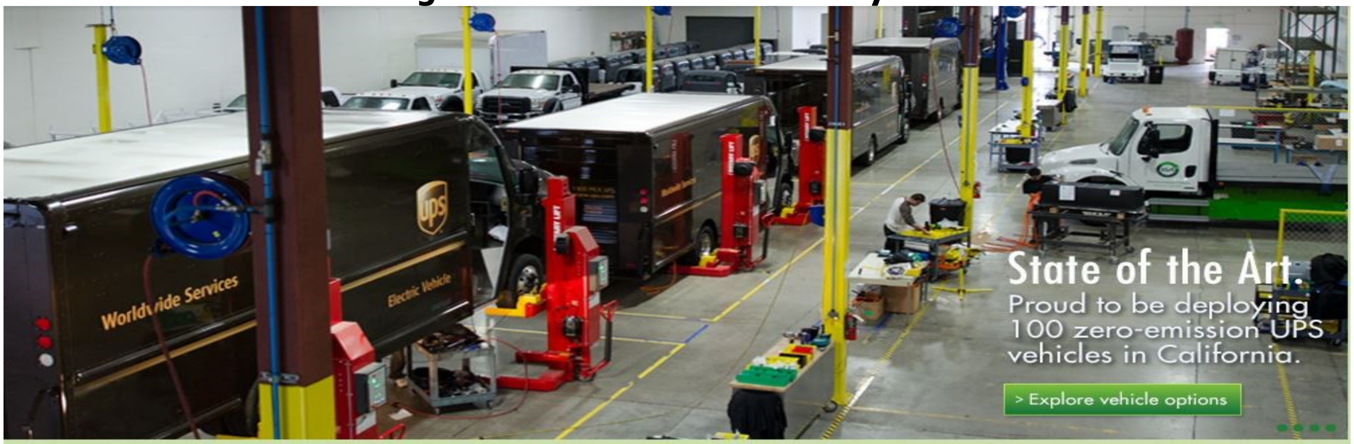
Source: EVI

Task 7: Set up Pilot-Level Vehicle Assembly Line at EVI

The goal of this task was to develop a pilot-level vehicle assembly line. All other subassembly pilot lines from Tasks 2 through 6 will feed into this main assembly line. The specific goal is to manufacture vehicles in a continuous linear fashion with all sub-assembly lines balanced to feed the main line "just-in-time," reducing the need for large parts and component inventories and increasing manufacturing efficiency.

Figure 10 shows the pilot-level assembly line with work in process.

Figure 10: Pilot-level Assembly Line



Source: EVI

The EVI assembly line integrates components from the six sub-assembly lines (Figure 11) listed below:

Sub-Assembly lines:

1. Battery pack assembly line.
2. Motor and transmission assembly line.
3. LV, HV wire harness assembly and testing station.
4. Fuse and relay assembly line.
5. LV, HV box assembly line.
6. Accessary pumps assembly line.

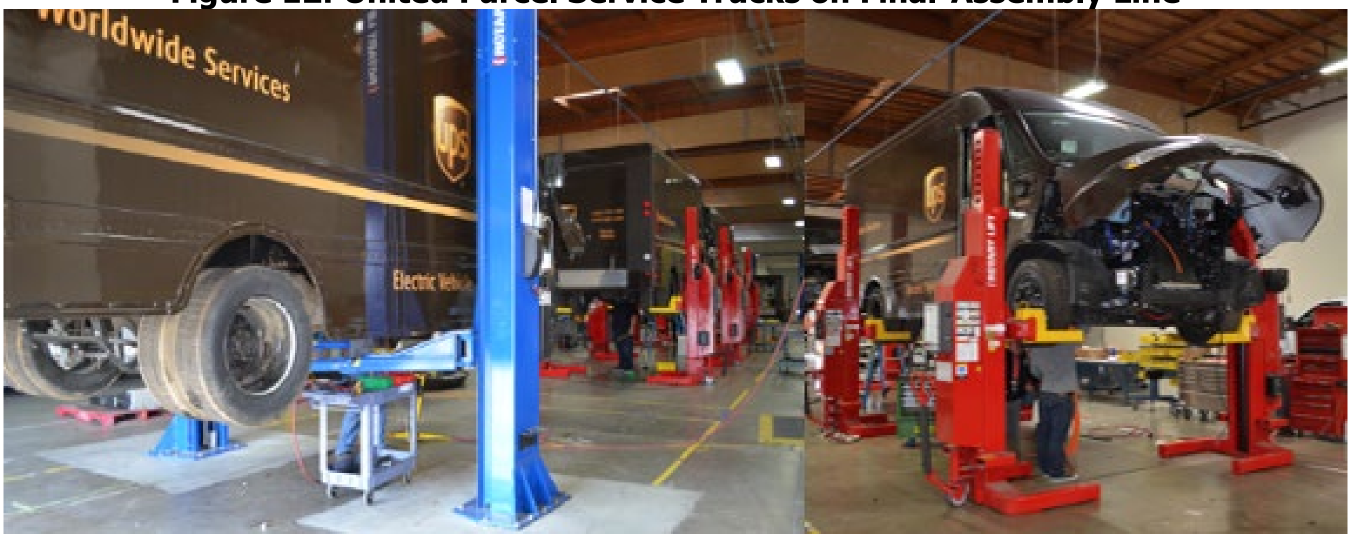
Figure 11: Sub-Assembly Assembly Lines

Source: EVI

EVI designed the main assembly line (Figure 12). Its primary design features include:

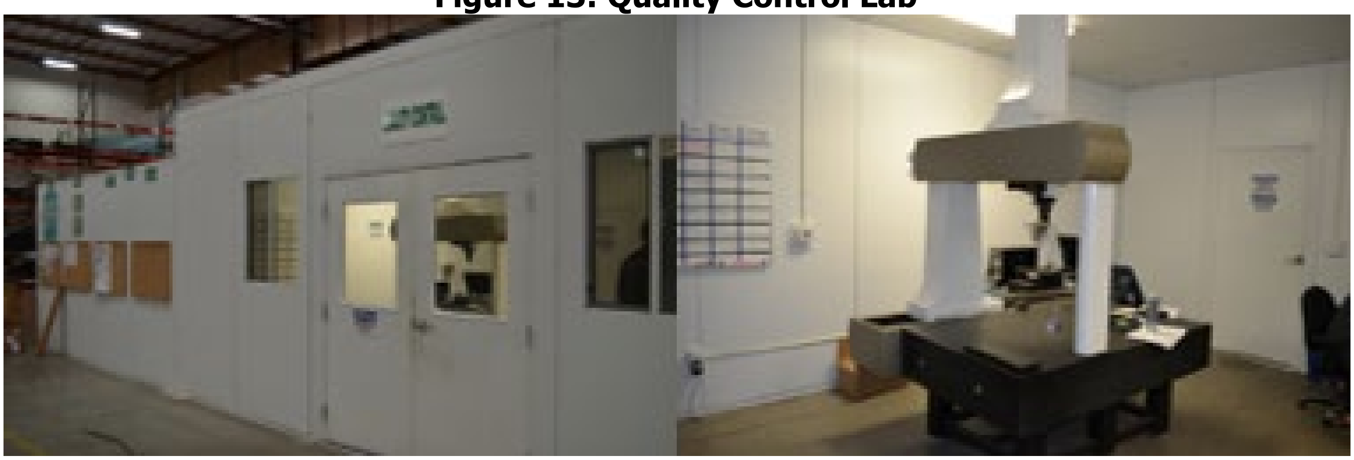
- Five stations capable of handling five trucks simultaneously at different levels of production.
- Quality control station seen in Figure 13.
- Dynamometer test station to run simulation testing on completed electric trucks.
- Six charging stations rated at 100 amperes.
- Quality Control lab with automated electronic quality tools.

Figure 12: United Parcel Service Trucks on Final-Assembly Line



Source: EVI

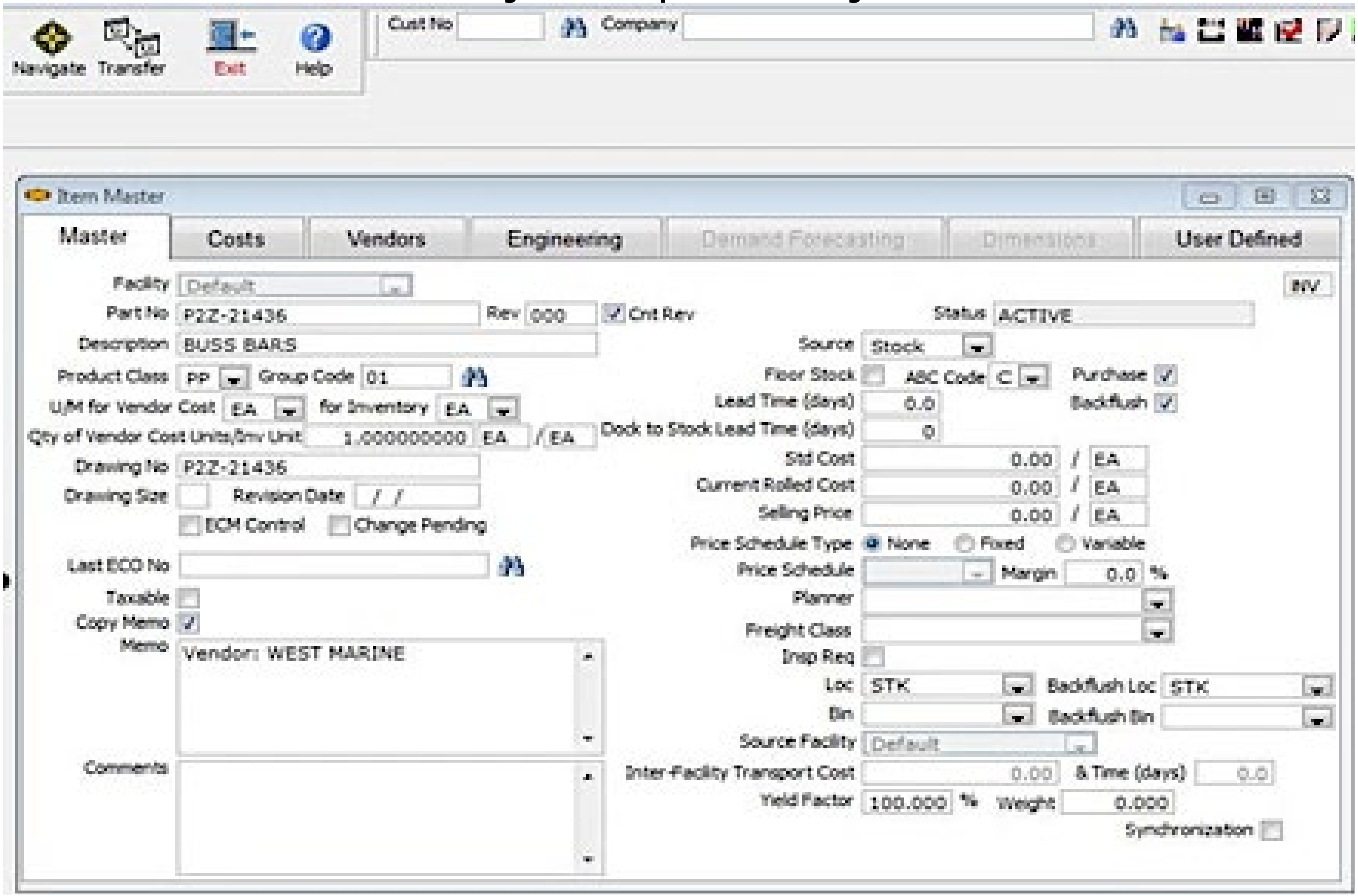
Figure 13: Quality Control Lab



Source: EVI

EVI also implemented a database system (Figure 14) that allowed EVI to maintain Quotes, Supply Chain, Human Resources, Accounting, Production, and Shipping and Receiving.

Figure 14: Sample Database Page



Source: EVI

CHAPTER 3: Project Results

EVI successfully designed, developed and implemented a pilot-level production line for medium-duty electric-drive trucks. Construction and sales of these trucks are helping to reduce greenhouse gas emissions and criteria pollutants from the freight and goods movement sectors. The *Electric Vehicle Manufacturing Modernization Project* helped advanced state-of-the-art technology to transform California's large and dirty diesel truck fleet into a clean, cost-effective model of sustainability. With this project, EVI is building the zero emissions vehicles needed to achieve the Governor's climate policies and goals, which include reaching 1.5 million ZEVs by 2025, reducing petroleum consumption by 50 percent by 2030, and meeting the AB 32 GHG reduction goals.

EVI's medium-duty electric vehicle (EV) trucks can run up to 90 miles per charge, depending on driver habits. Top speed is 70 miles per hour. Range can be extended by adding more batteries to the truck.

Over 100 Trucks Delivered

With the successful implementation of the project, EVI delivered 101 medium-duty, electric drive walk-in vans to United Parcel Service (UPS), 15 medium-duty box trucks, three Pacific Gas and Electric range-extended utility trucks and 7 Department of Defense range-extended units. The "100 Truck Deployment" with UPS received significant media coverage, including a media event with Governor Edmund G. Brown Jr. at UPS' West Sacramento distribution center.[1]

Figures 15, 16 and 17 show the delivered vehicles for UPS, Frito Lay and PG&E.

Figure 15: UPS Walk-In Van

Source: EVI

Figure 16: Frito-Lay Box Truck

Photo Credit: EVI

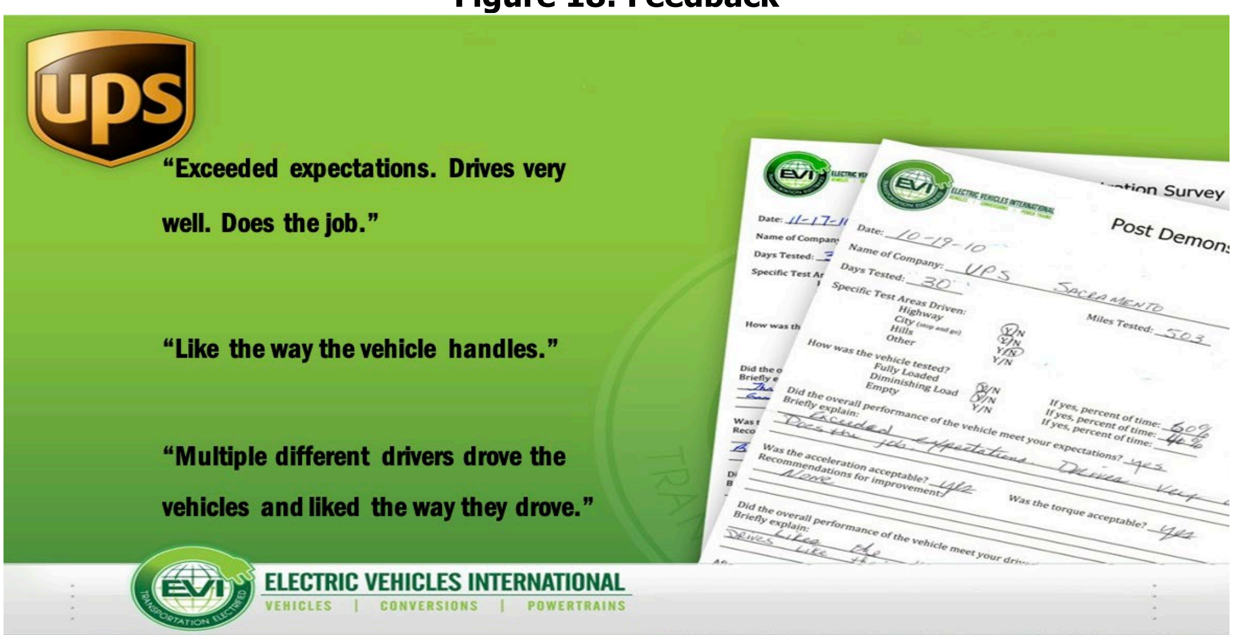
Figure 17: PG&E Utility Work Truck

Source: EVI

Customer Satisfaction

Drivers and companies were generally satisfied with the electric drive trucks. End-user feedback has been quite positive, as shown in Figure 18.

Figure 18: Feedback



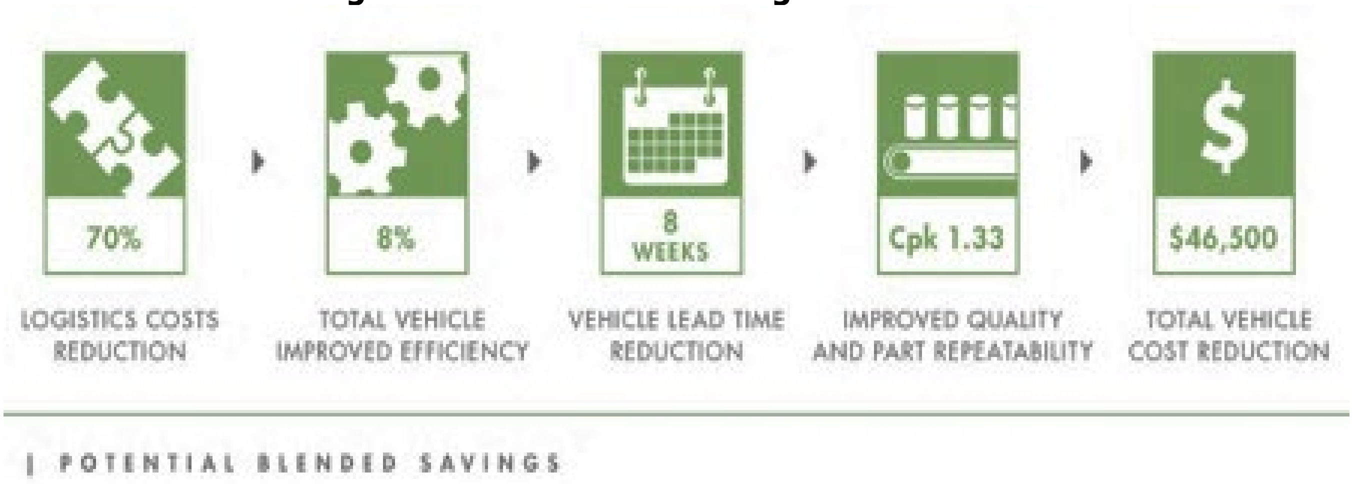
Source: EVI

Reduced Purchase Costs

EVI understands that reducing the purchase price of electric-drive trucks is critical to increasing EV sales. Government incentives have provided for the temporary acceptance of alternative energy vehicles by key customer groups, but may not lead to a sustainable, long-term market penetration among these groups. Modernizing the manufacturing process to allow more vehicles to be produced for less cost is the only way to ensure permanent price reductions for manufacturers and vehicle owners.

With help of the *Electric Vehicle Manufacturing Modernization Project*, EVI developed a method in which key components are produced and assembled entirely in-house. By bringing these processes in-house, EVI has significantly reduced production costs. Figure 19 shows EVI's cost reductions.

Figure 19: EVI Manufacturing Reduces Costs



Source: EVI

Reduced Operating Costs

The price of oil is a factor in the commercial demand for alternative energy vehicles because fuel costs are one of the highest cost factors in total vehicle operating costs. EVI believes that the 2008 price increases can lead to lasting changes in the market, leaving consumers more open to a less volatile and predictable fueling option. By converting to fully electric vehicles, consumers can eliminate dependence on oil, including vulnerability to fluctuations in oil prices, thus creating more accurate cost predictions. Deploying one electric medium-duty vehicle can save an end-user approximately $7,500 to $22,500 per year on fuel (assuming $3 per gallon of fuel).

EVI's electric vehicles also provide significant reductions in maintenance costs. A key component of maintenance cost is the labor necessary to ensure that vehicles are operating properly, which averages over $1,500 per vehicle per year. The electric drivetrain components of EVI's vehicles will require far less servicing than combustion engine components. EVI estimates that end-users can save approximately $10,000 to $12,000 per year on engine maintenance.

Environmental Benefits

EVI's electric drive trucks create environmental benefits. Switching from diesel to electric fuel reduces carbon dioxide (CO_2) emissions by approximately 90 percent. To compare:

- One gallon of diesel emits 20-30 pounds of CO_2. A typical medium-duty diesel vehicle averages 6 miles per gallon.
- One kilowatt of electricity emits 0.5 pounds of CO_2. Electric vehicles travel approximately one mile per kilowatt of electricity expended. This number is based on California Public Utility Commission (CPUC) estimates (See Figure 20). EVI believes that this number is lower in Northern California due to the higher percentage blend of solar, wind, and hydro- electric power sources.

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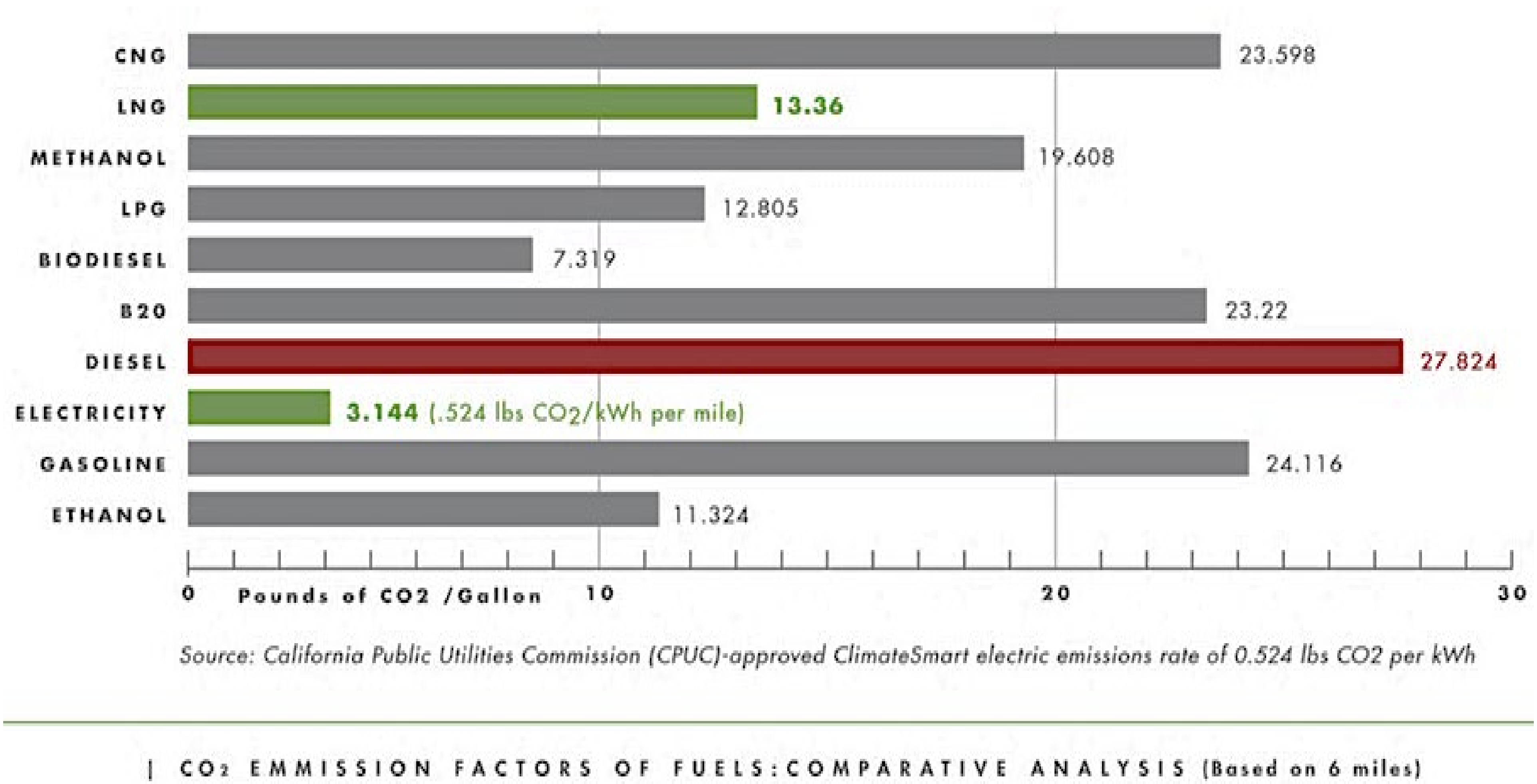
Figure 20: CPUC Emission Factors for Vehicular Fuels



Source: CPUC

In addition to significantly reducing GHG emissions, EVI's electric vehicles also reduce mobile source criteria pollutants that harm public health. Zero tailpipe emissions means that EVI's electric trucks emit no harmful pollutants in congested urban areas, which will reduce exposure to criteria pollutants like particle matter 10, particle matter 2.5, and ultrafine particulates. Exposure to particulates has been linked to cancer, heart disease, and asthma.

Table 2 shows CO2 emissions reductions for the UPS and Frito-Lay electric trucks.

Table 2: CO2 Emissions Reductions for UPS and Frito-Lay

Company	Displaced Fuel Type	Electric Miles Driven	Average MPGe	Avoided Tonnes CO2
UPS	Diesel	2,039,665	10	2,050
Frito-Lay	Diesel	275,515	10	280
Totals		2,315,180		2,330

Source: EVI

CHAPTER 4: Advancements in Science and Project Success

Advancements in Science

With successful completion of the *Electric Vehicle Manufacturing Modernization Project,* EVI has designed, constructed and operated a pilot-level production line that can produce 25 medium-duty trucks a month. Over 125 electric drive trucks were built during this project. Technology advancements helped to improve quality, reduce lead times, increase efficiency, reduce weight, increase safety and reliability, and reduce costs. These advancements include:

- Tailoring battery assembly to match vehicle and duty-cycle requirements to help improve efficiency, reduce weight, and increase the charge and discharge rate of the battery units. EVI's customized battery assembly test station drastically reduced production time of the trucks.
- Development of EVI's own vehicle management system software. This has drastically increased EVI's ability to monitor how the trucks can perform by monitoring data logging, fault code system, charging system, vehicle communication system and drive performance.
- Customized dynamometer test programming that helped EVI to validate multiple powertrains in a temperature-controlled environment. This has also provided flexibility to simulate various road conditions and monitor each vehicle's components, such as grade performance, transmission temperature, motor temperature, and battery temperature.
- The design, development and use of a customized LV/HV harness station, which helped to reduce lead times. EVI also developed its own state-of-the-art wire harness test station that helped to cut down the production time of the trucks.
- Development of a strategy to test each and every truck before delivery to the end-user.

In conjunction with the *Electric Vehicle Manufacturing Modernization Project*, EVI also designed and developed range-extended electric vehicles for use in utilities.

Project Success - Goals and Objectives

EVI successfully designed and developed a state-of-the-art, pilot-level production line to build medium-duty electric trucks. EVI now sells medium-duty electric vehicles and range-extended electric vehicles that are helping to reduce GHG and criteria emissions from California's fossil-fueled freight and goods movement fleets.

EVI met its key goals for the Project, including:

- Develop, implement and prove the pilot-level production line before investing in a completely automated production facility;
- Creation of up to 80 jobs as per the end-user demand in California. With potential to expand;
- Reduce costs by manufacturing and assembling all key components in-house;
- Reducing service time with help of customized test procedures and equipment;

- Transforming California’s current dirty diesel-fueled medium-duty fleet by offering clean, cost-effective alternative trucks;
- Achieving significant reductions in greenhouse gas and criteria pollutant emissions;
- Assisting the state in achieving its progressive environmental goals, including the AB 32 milestone for 2020; and
- Creating green jobs in an economically distressed area of California.

Environmental Benefits

EVI’s zero-emission electric trucks helped to:

- Reduce CO2 emissions 90 percent per vehicle.
- Eliminate 72,000 pounds of CO2 each year per vehicle deployed.
- Save 2,400 gallons of fuel each year per vehicle.
- Reduce fuel consumption for fleet operators and medium-duty pickup truck owners by 2,400 gallons for each vehicle, averaging $7,500 in fuel savings every year.
- Save $10,000-$15,000 every year on gasoline engine maintenance per vehicle.
- Lower net cost to purchase and operate medium-duty pickup trucks.
- Reduce return on investment to less than five years with incentives, creating an attractive and immediately viable market.
- Reduce gasoline-related pollution and health effects, including particulates pollution, air toxics, and criteria air pollutants, which minimizes exposure and associated health effects, including cancer, asthma, and heart disease.
- Increase awareness and adoption of commercially viability electric truck solutions through the deployment of 125 medium-duty vehicles to the end-user.
- Generating green jobs in Stockton, California.

CHAPTER 5: Observations and Conclusions

Observations and Conclusions

EVI successfully designed, developed, and operated a state-of-the-art, pilot-level production line for medium-duty truck applications. EVI now deploys an array of attractive, medium-duty electric vehicles.

Funding for the project helped to advance technology for medium-duty electric vehicles. Even with the experience of deploying 125 zero emission vehicles to date, EVI believes more development work is needed to fully automate the production and assembly lines.

Key conclusions and recommendations include:

- High Costs

  Even with successful implementation of the pilot production line, initial costs for EV’s are still high when compared to the regular diesel vehicles available in the U.S.
- Government Incentives

  The current incentive structure from the State is highly commendable, but the lack of interest from private fleets is dampening progress. Unless new mandates are imposed on private fleets to spur commercial sales, it will be hard to continue progress in a positive direction.
- Infrastructure Cost

  The high cost for charging infrastructure is hindering customers’ ability to add EV’s into their fleets. For example, charging infrastructure costs for just five units can be as high as $250,000. This is in addition to the high vehicle price.
- High Sales Tax

  The initial purchase price for an electric truck is already high compared to conventional vehicles. This raises sales taxes because the tax is calculated on the manufacturers’ suggested retail price. Even though incentives help reduce the high purchase price for EVs, customers must pay higher sales tax based on the full manufacturers’ suggested retail price. Sales taxes are averaging about 17,500 per vehicle. Lowering EV sales taxes will resolve this issue.
- Lack of Compensation

  With the experience of deploying over 115 zero emission medium-duty trucks, EVI has faced several challenges in working with the fleet drivers and maintenance teams. As electric drive is a new technology, EVI trains all team members involved in daily usage of the electric trucks at the customer’s site. EVI has learned that some drivers and mechanics believe that they are not being compensated enough to learn and use the new technology.

Irrespective of the above-mentioned conclusions, EVI is developing second-generation vehicles with lower purchase prices and increased reliability and range. EVI anticipates increased market demand and vehicle sales based on the discussions with state and private fleet operators.

GLOSSARY

CARBON DIOXIDE (CO_2)—A colorless, odorless, nonpoisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO_2 is the greenhouse gas whose concentration is being most affected directly by human activities. CO_2 also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent).

ELECTRIC VEHICLE (EV)—A broad category that includes all vehicles that are fully powered by electricity or an electric motor.

ELECTRIC VEHICLES INTERNATIONAL (EVI)—Manufacturer of alternative energy vehicles specializing in battery electric vehicles and range extended electric vehicles for multiple applications covering a diverse range of transportation options.[3]

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_x), halogenated fluorocarbons (HCFCs), ozone (O_3), per fluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

UNITED PARCEL SERVICE (UPS)—An American multinational shipping and receiving and supply chain management ompany founded in 1907

[3] Electric Vehicles International LinkedIn https://www.linkedin.com/company/evi/?originalSubdomain=in