California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Boulder Electric Vehicle Los Angeles Plant

Prepared for: California Energy Commission

Prepared by: Boulder Electric Vehicle

Gavin Newsom, Governor

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We would especially like to thank the fleet manager, as well as upper management of the United Parcel Service and Ameripride. Their initial orders for the DT-1000 series of vehicles will allow us to commercialize this plant immediately upon completion of this grant.

PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-09-605 to provide funding opportunities under the Clean Transportation Program for the development and expansion of manufacturing and assembly plants in California that produce electric vehicles, batteries, and component parts for alternative fuel vehicles. In response to PON-09-605, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards March 10, 2011 and the agreement was executed as ARV-10-039 on September 14, 2011.

ABSTRACT

This is the final report of Boulder Electric Vehicle's project to demonstrate a pilot production line for medium- and heavy-duty electric trucks and shuttles in Los Angeles, California. This project was funded with $3 million from Boulder Electric Vehicle and $3 million from the CEC. The task one scope of the project includes all administrative tasks necessary to complete a grant-funded project within the CEC guidelines. The scope of task two of the project was to develop the pilot production line with all needed tooling, engineering software, inventory control software, and production processes in order to produce three demonstration vehicles. The scope of task three was data collection and analysis both of the manufacturing methods as well as the vehicle performance and quality control.

Major findings of the report include a need for greater automation in order to reduce the costs of electric trucks and shuttles. The report results focus on the rapid ability for engineering to use three-dimensional models to expedite build books and repair manuals. Conclusions focus on the need for a greater number of parts to be produced by tier one suppliers instead of in-house. Market-based recommendations focus on the needs to maintain electric vehicle incentive programs as well as develop an economic incentive for major utility companies to expand the infrastructure for fleet-based electric trucks and shuttles.

Keywords: California Energy Commission, Boulder Electric Vehicle, manufacturing, green jobs, economic development, electric vehicles, electric trucks, Los Angeles electric vehicles, California electric vehicles, battery electric vehicles.

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TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

The goals of this project were to improve Boulder Electric Vehicle's manufacturing methods and processes and to demonstrate their effectiveness in a manufacturing line for Boulder Electric Vehicle's medium- and heavy-duty all-electric vehicles. Both goals were achieved by executing a detailed plan utilizing established automotive and manufacturing engineering principles for building assembly aids and by testing their implementation in an improved workflow with appropriate equipment. Boulder Electric Vehicle also incorporated a lighter frame design that allows improved safety and performance of the vehicles. Boulder Electric Vehicle's all-electric trucks and shuttles are purpose-built to be electric vehicles and have a significant emphasis on lightening the empty weight of the vehicles so that greater range is achieved from the same size battery packs.

The first goal of improving Boulder Electric Vehicle's manufacturing methods and processes was emphasized from top-level management on down. All aspects of design, purchasing, prototyping, and production fell under the mandate of "Improve reliability, reduce costs of the parts, reduce time to assemble and facilitate ease of repair." During this project our manufacturing methods and processes were improved from start to finish. This was achieved starting with the engineering foundation itself and incorporating a software suite that would not only allow us to design better parts but would also allow us to integrate revision-level control and export that information to our purchasing software. Additionally, the engineering software we sourced was coupled with a package that would allow Boulder Electric to integrate the electrical schematics and the wire routing into the same software suite. All of these features were then exportable to our build books onto the production line, not only in the form of drawings but in the form of three-dimensional models that would allow us to train up or down the assembly workers on the line depending on the market demand for the vehicles. This software suite allows our build books for the manufacturing process to specify the quantity and part numbers and even the tools used for each assembly step throughout the entire vehicle build.

The layout of the production floor was designed for maximum efficiency inside of the space available. The material storage and workflow was designed to decrease the number of times a part has to be handled before it actually goes onto a vehicle. This was largely achieved through our inventory control software and the implementation of that particular system. The asset management software or inventory control software was also instrumental in improving our manufacturing methods. This started with the ability to track discount pricing, generate custom incoming materials inspection reports, and track lead times for specific parts to better control future materials-based cash flow. Material moving tools and apparatus were installed, which reduces the amount of labor and increases the safety of the workers. This was exceptionally beneficial when it came to manufacturing the vacuum-bagged ultra-light-weight aluminum honeycomb chassis.

Another vast improvement over Boulder Electric Vehicle's previous manufacturing methods was achieved with battery pack cycling and quality control methods. Our background in battery pack testing as well as back feeding energy onto the grid resulted in a close to zero-sum energy usage for cycling battery packs before they go onto a vehicle. Our vehicle grid work inside our Los Angeles plant resulted in a final quality control check on the vehicles being available for all electrical systems without even needing to physically have the vehicles leave the building.

The second goal of the project, to demonstrate the improved manufacturing methods and processes, was accomplished through the building of the three demonstration vehicles. On each subassembly station, as well as each full assembly station, the build books were reviewed for accuracy as well as their ability for the assembly workers to comprehend the steps, processes, and quality control procedures. Each station had the build book instructions, part numbers, and part counts verified.

The resulting vehicles are largely viewed as the best electric trucks in the world. They actually perform their stated range of 100 miles, can reach speeds of 100 miles per hour (although most customers request they be limited to 65 miles per hour), and are the first electric trucks in the world to do vehicle-to-grid as part of the Ft. Carson Department of Defense micro grid program.

Our conclusions are both specific to the project—its execution and results—as well as broad-based in the marketplace and the perceived barriers, whether real or conceptual, to widespread adoption of electric medium-duty trucks and shuttles.

Our specific conclusions about the project are that it clearly achieved the goals of improving the manufacturing methods on several levels. Quality improved throughout the process. Energy used for cycling and battery packs was greatly reduced and almost reduced to zero net use. Purchasing, receiving, and materials inspections were enhanced with time/labor reduction for material handling. However, we understand that there is a world of difference between a $6 million manufacturing facility and a billion-dollar manufacturing facility such as Toyota or Tesla.

Further cost reduction in the base price of electric trucks and shuttles depends not only on additional automation, reduction in part count of design, and lowering costs of key components native to electric vehicles but on economies of scale. Economies of scale depend on serious number of real orders from economically sound customers sending clear signals to the marketplace about their long-term interest. At this point, those potential large fleet customers are encouraged by the existing incentives such as the Hybrid Voucher Incentive Program, but discouraged by the cost of additional fleet infrastructure. This leads us to our broad-based market conclusions.

Our broad-based market analysis summarizes that, on the whole, we no longer view other electric truck or shuttle companies as our competition. They generally do conversions rather than purpose-built vehicles and thus never perform as well as expected. We consider the status quo fossil fuels of compressed natural gas, liquefied petroleum, diesel, and gas as our competition.

CHAPTER 1:
Task 1 Administrative Tasks, Synopsis, and Execution

Attend Kick-off Meeting

A kick-off meeting was held at the CEC building in Sacramento on October 4, 2011. The meeting detailed expectations and timelines, provided evidence of match funds, and detailed billing and reporting procedures. Present from the CEC were Michael Poe, Kathy Jones, Larry Rillera, David Nichols, Jennifer Allen, and Debbie Jones. Present from Boulder Electric Vehicle (Boulder) were Carter Brown, Pete Averson, and David Graham. On the agenda were: invoicing, critical project reviews, monthly project reports, matching funds terms and conditions, permits, subcontracts, and technical tasks.

Critical Project Review Meetings

A Project Review meeting was held in Boulder's Los Angeles plant, at 9655 Irondale Avenue, on August 12, 2013. The primary focus of the meeting was to verify the work done to date and to outline closeout activities of the project. Workers pose in front of a billboard at the meeting in Figure 1.

Figure 1: Boulder's Los Angeles Plant

Grant manager Larry Rillera (left) and project manager Carter Brown (right).

Photo credit: P2Photography.net

Final Meeting

The final meeting was held in January 29, 2014. In attendance, from Boulder: Carter Brown, CEO. From the CEC: Larry Rillera, grant manager; Jim McKinney, program manager; Leslie Baroody, electric vehicle (EV) lead; Eric Van Winkle, Lindsee Tanimoto, Juan Garcia, and Brian Fauble. Topics covered: administration, technical tasks, presentation of the project, and closeout activities.

Monthly Progress Reports

Monthly progress reports were filed, most of which were on time. In the start of the project, there were a few hiccups having to do with billing that needed to be worked out before further reports and invoices could be filed. Toward the end of the project, some inconsistencies and inaccuracies in the working budget resulted in a few delays. In general, about 85 percent of the reports were filed within 10 days of the first of the month. Often, if a billing issue or working budget issue had to be resolved, then that would put a halt to billing and reports until that particular issue was resolved.

The monthly reports outlined what was expected to be accomplished, what actually was accomplished, and what the company's expectations for the following month were toward completion of the task list.

Final Report

The final report was submitted in January 2014. It contains all necessary documentation according the CEC templates as well as the contractual statement of work.

Identify and Obtain Match Funds

The entire financial size of the project was $6 million, of which $3 million were CEC funds and $3 million were matching funds provided by Boulder. Boulder identified match funds prior to the kick-off meeting and expended the match funds during the project.

Identify and Obtain Required Permits

The Los Angeles Mayor's Office of Economic Development helped greatly in determining that this was not a project under the California Environmental Quality Act. The landlord for our building and the electrical contractor worked closely with the Los Angeles Department of Water and Power (LADWP) and other city departments on getting the correct permits once a load assessment was performed for additional electric loads we would be installing. All permits required were obtained before any work was performed. Our CFO, Pete Averson, worked diligently and successfully to procure our California Vehicle Manufacturer's License.

Obtain and Execute Subcontracts

Subcontracts were obtained and executed with AK Electric for the electrical, compressed air lines, and safety shower buildouts in the facility. Throughout the project there were additional work orders for installing additional equipment and logistically improving the locations of certain equipment. Examples are obtaining a larger air compressor that had to be located in a different part of the building, as well as running CAT5 communication lines out onto the floor from the server room to service the receiving and computer numerically controlled machine computers. Subcontractors used were AK Electric, New Eagle Consulting, Western America Construction Corporation, and Automotive Testing and Development Services.

CHAPTER 2: Task 2 Report—Site Preparation, Production Line Assembly, and Performance

In starting off, we would like to point out that a fully automated vehicle assembly plant, of the type that the general public is used to seeing from GM or Toyota, usually has close to $1 billion invested before the plant produces its first vehicle. This specific pilot assembly line was funding by $6 million—$3 million from the CEC and $3 million from Boulder. Boulder has done great things with the funds available. We are eternally grateful for the funding from the CEC to get our Los Angeles plant up and running.

Boulder's original accepted application was for a $10 million loan, which was scaled down to a $3 million loan. This was originally supposed to be guaranteed by the California Capital Access Program, but when the interagency contracts and guarantees were unable to be fulfilled, the project became a $3 million grant. As a result, Boulder went through not one but two separate building searches a full year apart, the first in September 2010 and the second in October and November 2011. All of the resources and time expended on the first building search and permit work was never billed, as the contract had not yet been in effect. The second building search allowed Boulder to find a suitable location with all of the possible economic incentives available in relation to Federal, State, County, and City enterprise zones. A truck with the truck is seen outside of the location in Figure 2.

Figure 2: Boulder Flatbed Truck at Los Angeles Plant

The first Boulder flatbed truck, built in California, in front of the plant at 9655 Irondale Avenue in Los Angeles.

Photo credit: P2Photography.net

Abstract

Task 2 consisted of the site preparation, production line assembly, and performance. There are many subtasks inside this Task 2 report:

- Order and procure the equipment and materials for establishment of the pilot assembly line.
- Oversee all necessary interior retrofits.
- Manage the tooling installation, workflow logistics, software installation, and asset management systems.
- Install engineering systems management.
- Install tooling.
- Install asset management systems and software.
- Establish production line protocol.
- Produce three electric drive vehicles from the production line.

This report goes into the details and the challenges of tooling up an electric truck assembly line, specifically referencing the subtasks above. The fact that Boulder had already built one assembly line in Colorado greatly accelerated the progress on the pilot assembly line in Los Angeles, California. Much of the knowledge of systems integration was transferable and many processes were improved. In addition, Boulder was able to leverage previous vendor purchasing agreements to further reduce the costs of materials and tooling.

Necessary Equipment and Materials for Establishment of the Pilot Assembly Line

Many of the tools and most of the materials were already known quantities in our inventory management database from our previous operations in Colorado. We used this opportunity to improve and implement things that were deemed extremely desirable for assembly efficiency as well as greater end-product reliability. Almost all of the battery cell cycling and battery pack quality control test equipment was new to us in our California operations.

We managed to buy infrastructure equipment such as work tables, flame proof cabinets, welding equipment, wheel lifts, and other vehicle manufacturing-specific equipment out of auction from two failed alternative fuel vehicle companies, Aptera and Azure Dynamics. Most of this equipment we literally paid between 10 and 15 cents on the dollar, thus saving the project substantial funds that could be used elsewhere.

Our purchasing agent had the time and wherewithal to shop specific infrastructure as well. All of the pallet racking comes into the facility as “previously owned.” Often we would be able to get reduced pricing on either Computer numerically controlled machines or vacuum-forming machines due to the fact that we had either purchased product from the company previously or that we were buying multiple units. These machines are shown in Figures 3, 4, 5 and 6.

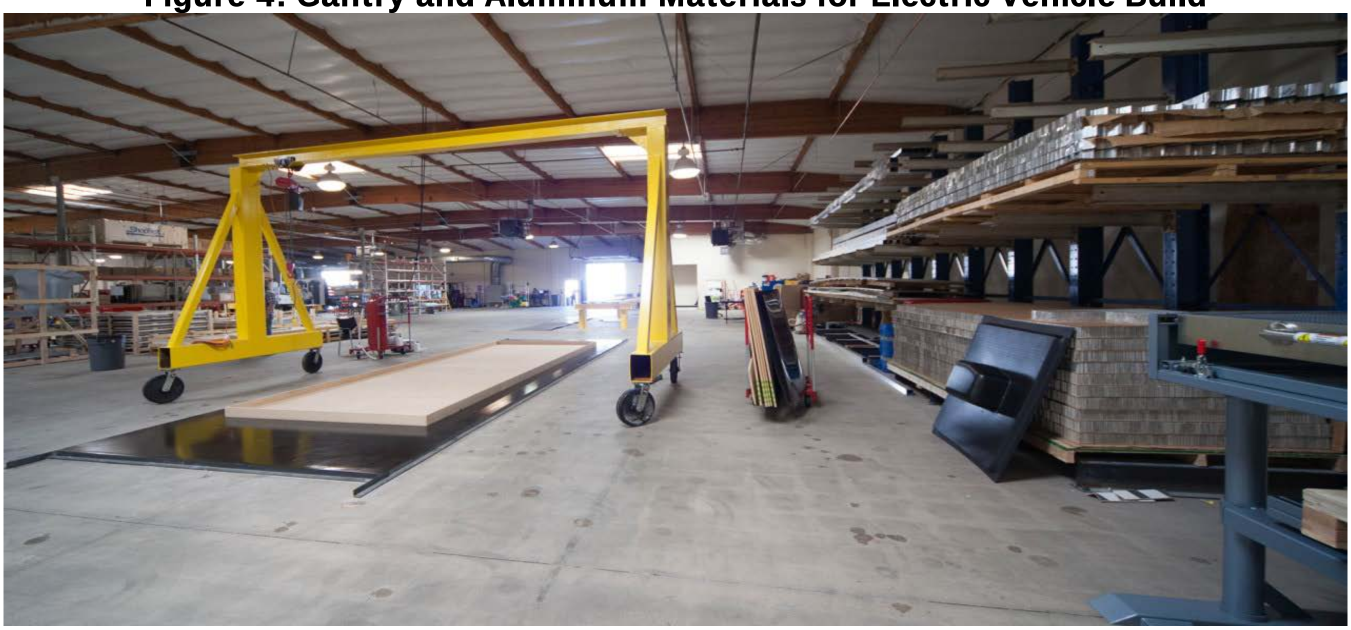
Figure 3: Pilot Assembly Line

As tooling and parts start to arrive. The first demonstration vehicle is visible at the far end of the line with vehicles two and three upside-down.

Photo credit: P2Photography.net

Software was often purchased or renewed in the same manner, waiting until the end of the year or the end of the quarter so that we could negotiate better deals. All purchases were tracked with purchase orders, and invoices and payment verification was provided to the CEC.

Figure 4: Gantry and Aluminum Materials for Electric Vehicle Build



The 20-foot-tall yellow gantry (left) and some of the aluminum honeycomb used in the ultra-light chassis for the electric trucks (right).

Photo credit: P2Photography.net

Many of our suppliers are based or have production in California.

Figure 5: Axles for the Demonstration Vehicles

Sourced from one of our numerous California-based suppliers, Dynatrac.

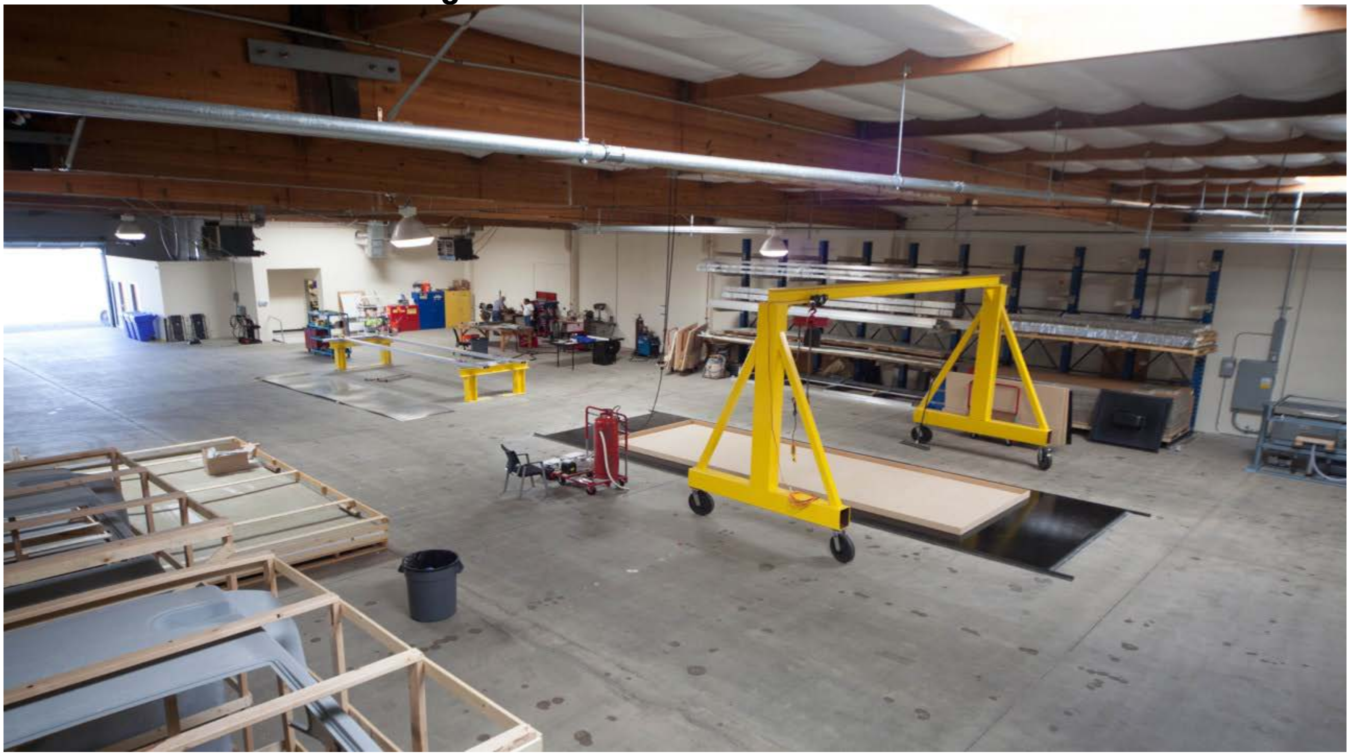
Photo credit: P2Photography.net

Oversee All Necessary Interior Retrofits

Retrofits to the building were made much easier due to the fact that the landlord has an excellent working relationship with a key contractor that was able to perform most of the interior work. The retrofits included specific electrical runs for tooling and battery cycling stations as well as EV chargers for completed vehicles. Additional retrofit included many additional compressed air lines and hoses so that they could supply compressed air to the tools on the production line. A safety shower was also installed, which the building was lacking. A few additional communication lines had to be installed so that the servers could communicate with the receiving station.

One of the key difficulties that we ran into was that we had to perform a load assessment with the LADWP, in order that the new manufacturing tooling and up fits would not overload the building's existing electrical service. This meant that we had to have either the electrical plates or all of the tooling actually on site before the load assessment could be performed. This added considerable time to our performance of this subtask. This also created the occasional delay by not having electricity supplied to the tooling as soon as the tooling was installed. This often delayed the initial tooling tests. Because we installed the tooling sequentially in relation to the building processes, this did not significantly impact the project schedule.

Figure 6: Some Interior Retrofits



Safety shower (far left), welding electrical drops (behind gantry and welding jigs), and new electrical service for vacuum formers and robots (far right).

Photo credit: P2Photography.net

Manage the Tooling Installation, Workflow Logistics, Software Installation, and Asset Management Systems

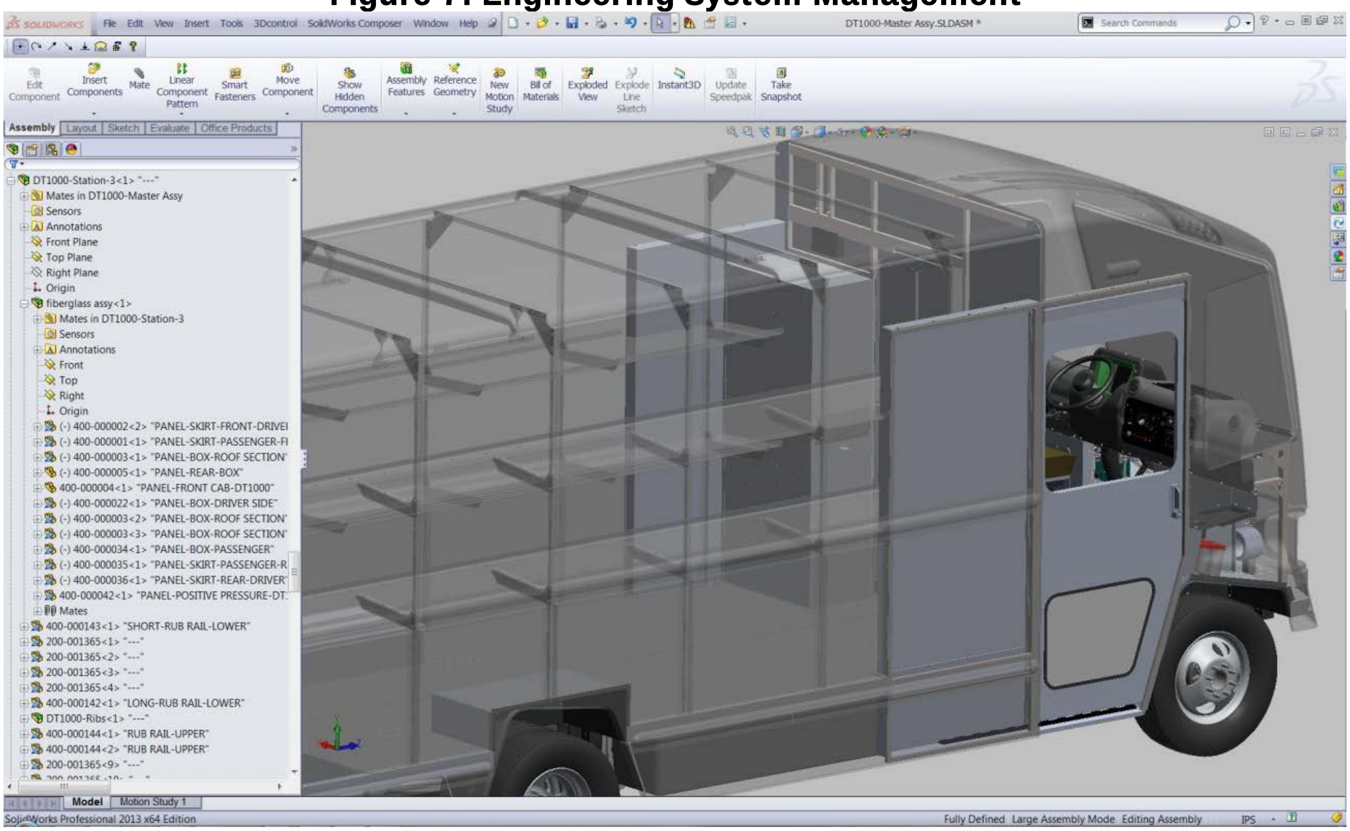
The installation timing of the tooling, the software installation, and the installation and implementation of the asset management systems were managed through a gant chart-based implementation. The software installation and IT systems were handled by our resident systems engineer with some contract work support. The engineering software was installed and additional modules of the three dimensional Computer Assisted Design (CAD) packages were installed and licensed as needed. Such additional packages allowed us to transfer engineering drawings and schematics directly to the production line, as well as into repair manuals, without costly additional personnel, to transfer files and documentation from one software suite to another. Throughout the process the software vendors gave great support in installation, implementation, and training.

Install Engineering Systems Management

All of our engineering models are in a 3D CAD program as demonstrated in Figure 7, which has an add-on package that allows both build books as well as repair manuals to be generated from the software and constantly updated without additional personnel necessary for document control or file transfer between software brands and types. The installation of this was somewhat complex in that the Los Angeles plant is Boulder’s second manufacturing plant, therefore the engineering software protocols needed to be designed with high-speed communications in mind as well as all of the ordinary functionality. The licensing of the software was also highly depended on which modules of the packages were needed by the most engineers at any one phase of the project. For instance, the way the engineering software exported files to the tooling software needed to be installed and implemented before the build books for the individual assembly stations. The module that controls the build books for the assembly stations needed to be installed and the work needed to be performed before the repair manuals were developed.

Before all of this, computers, servers, network switches and routers, defragmentation utilities, and standard office and communications software needed to be installed and tested for functionality. Because we leased a well-equipped 27,000 square foot building, much of the interior retrofit, which could have involved temperature-controlled server rooms and communications infrastructure add-ons, were not needed. This expedited the installation of systems and was one of the things that kept us on schedule when we fell behind temporarily in other areas.

Figure 7: Engineering System Management



Screenshot of parts and assembly management.

Source: Boulder Electric Vehicles

Install Tooling

The tooling installation involved four main areas: the chassis manufacturing area, the assembly line itself, the battery pack subassembly, and the vacuum forming/fabrication area. Figure 8 shows the three frames for the chassis of the trucks.

Figure 8: Three Frames

Prior to vacuum forming into three chassis for the demonstration vehicles.

Photo credit: P2Photography.net/Boulder

The chassis manufacturing area for our ultra-light aluminum honeycomb chassis takes up almost one third of the manufacturing floor space in the building. There is a cut/weld/fabrication area—most of the tooling for this area involved welding equipment and the safety requirements around that process. There were also several large prep tables and welding jigs for the interior components of the chassis that needed to be installed.

The chassis then moves onto the vacuum formation area where an ultra-smooth ultra-level platen had to be designed and build before the first deck could be made. Vacuum pumps and housing were also installed for this process. Additionally, flame and corrosive cabinets had to be specified for the containment of those kinds of materials. Lastly, the large computer numerically controlled machines had to be installed and tested. These are custom machines that are very particular about having continuous power without spikes during operation. Figure 9 shows the chassis after assembly.

Figure 9: Chassis on Demonstration Vehicle #1

Right before vacuum bagging top layer.

Photo credit: P2Photography.net

The assembly line needed to be measured, marked, and taped according to specific station requirements. Tool storage boxes, fastener carts, parts carts, and work tables were all installed for each station. Then the hand, air, and electrical tools had to be specified, purchased, and installed according to each station on the assembly line. For some stations, additional large tooling had to be specified, such as the vehicle lifts that allow the vehicle to be put into the air for the installation of the battery pack.

The battery pack assembly area had to have several different types of battery test equipment and battery cycling stations purchased and installed. We specified cycling stations for the individual cells so that faulty cells could be weeded out before the packs were built. We specified cycling stations to cycle the entire packs before they go onto a truck for greater quality control. We then specified vehicle-to-grid charging stations so that the packs could be cycled once they are actually on the trucks and working. This last serves as a final quality control mechanism before delivering a final vehicle. This allows us to test the full functionality of the vehicle without putting actual miles on the vehicle itself. All of this test equipment had to be installed and most of it needed additional electrical service, which triggered load assessments from the LADWP.

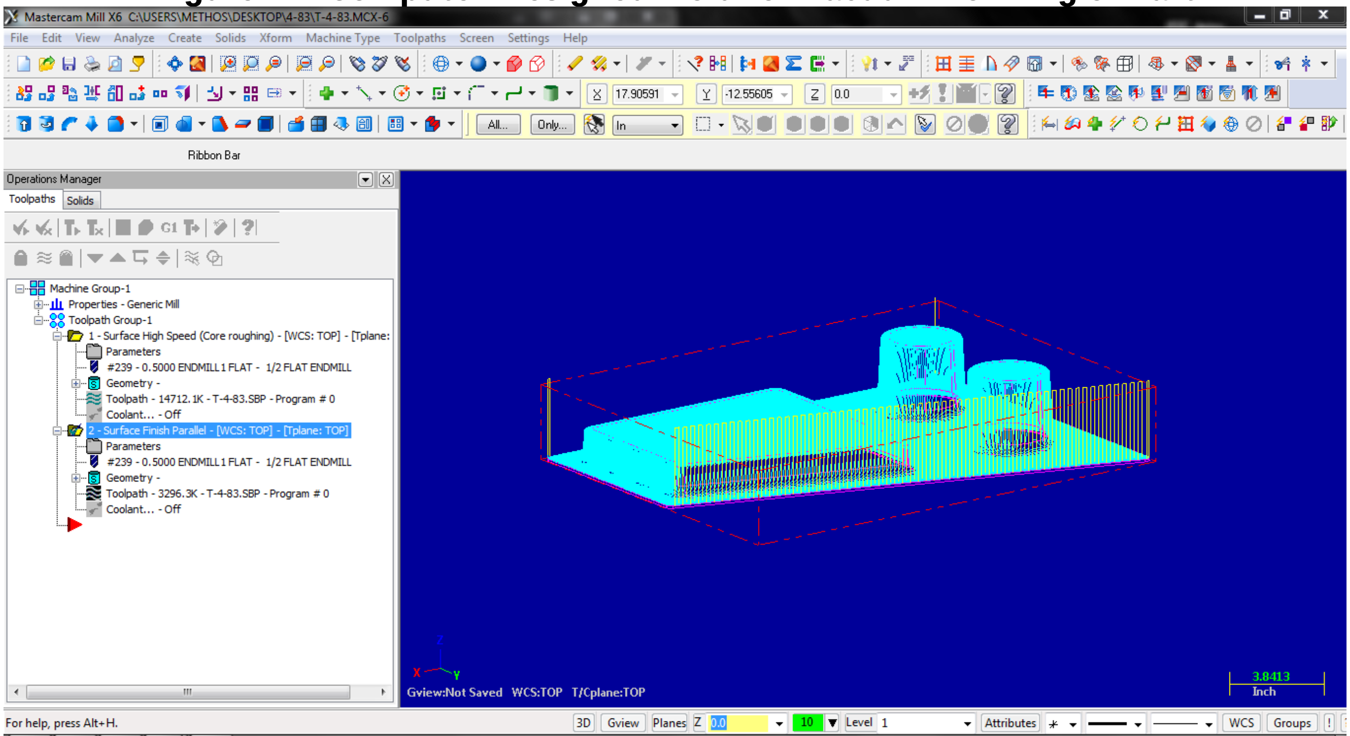
The following figure (10) is of an employee installing the wiring harness on the battery pack prior to final quality control pack cycling.

Figure 10: Battery Pack Subassembly

Photo credit: P2Photography.net

The vacuum-forming tooling allows us to make parts on-site for prototyping and limited production at a huge savings in tooling costs over what outside vendors might charge. Many things that are a custom fit for our electric trucks and shuttles—such as overhead storage bins, dashboards, cup holders, venting, and water trapping parts—have their plugs made on the computer numerically controlled machines and then the parts made on the vacuum-forming machines as shown in Figure 11. These machines also required additional electrical service as well as computers to run them.

Figure 11: Computer-Designed Mold for Vacuum-Forming of Part



Source: Boulder Electric Vehicle

Install Asset Management Systems and Software

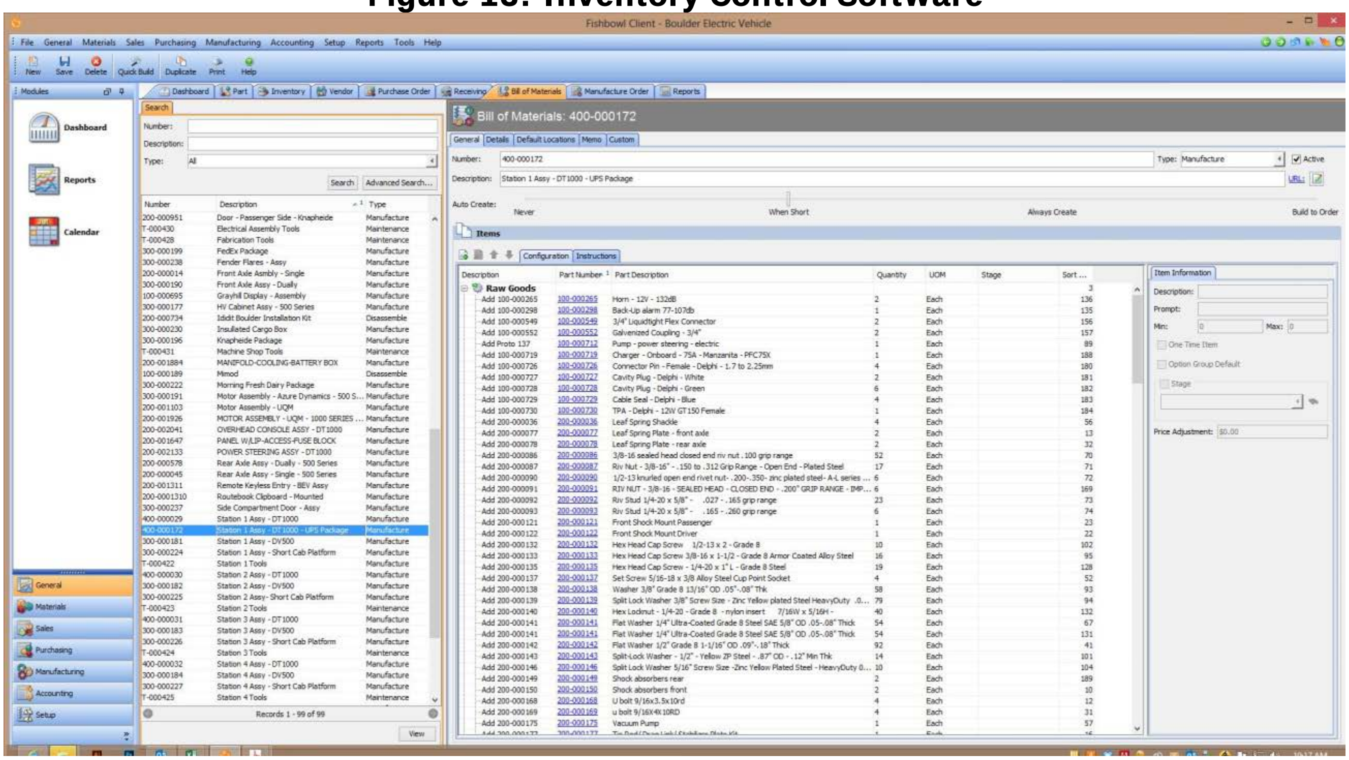
Our asset management system software is the same software used previously in our plant in Colorado. Licenses were purchased so that all engineers, purchasing, receiving, and accounting, as well as plant floor operations personnel, have access to the inventory and purchasing records. The particular software generates bar code inventory labels, location labels, work orders, purchase orders, and cross functions with scanners to reduce the manpower needed to properly keep track of inventory as it flows through the work process (Figure 12, 13, 14). The location tracking allows us to know where parts for the vehicles are stored so that when a build book specifies Qty 5 of part #200-000436, we know which Area, Column, and Level those parts are stocked on.

Figure 12: Inventory Racks

Labeled in orange tags and bar codes.

Photo credit: P2Photography.net

Figure 13: Inventory Control Software



Source: Boulder

Figure 14: Bar-coded Part Numbering and Identification System

Source: Boulder

Establish Production Line Protocol

The production line protocols fall into two main areas at this stage of development: build books and quality control procedures. It is too early to get into time/motion studies or assembly line balancing on the first three demo vehicles out of this plant.

The build books were designed to divide each station into the steps needed to fully assemble that station. The build books illustrate the part to be attached to the vehicle, call out the part number(s) and the attachment method, and specify the torque specs (if any) and the tooling needed. The build books went through initial creation and then the line verification, corrections, additions, and deletions, and then a repeat of the entire process for each of the three demo vehicles. This was a key area where the greatest amount of communication between the assembly workers and the engineers occurred.

At the end of each station there was a quality control document created so that everything for that station was checked before the vehicle moved on to the next assembly station.

For the deck assembly the same set of build book and quality control procedures were developed (Figure 16). Some of the quality control procedures would vary, such as measuring the amount of vacuum being held while the deck is bonding and curing. For the battery cell and battery pack quality control test procedures, the same was developed with a great emphasis being placed on delivering a perfectly balanced and rigorously tested pack to the assembly line before the packs are installed onto the trucks (Figure 17).

Incoming inspection and quality control procedures were developed with an emphasis on the battery pack. The following figure (15) depicts the initial data and the quality control comparison.

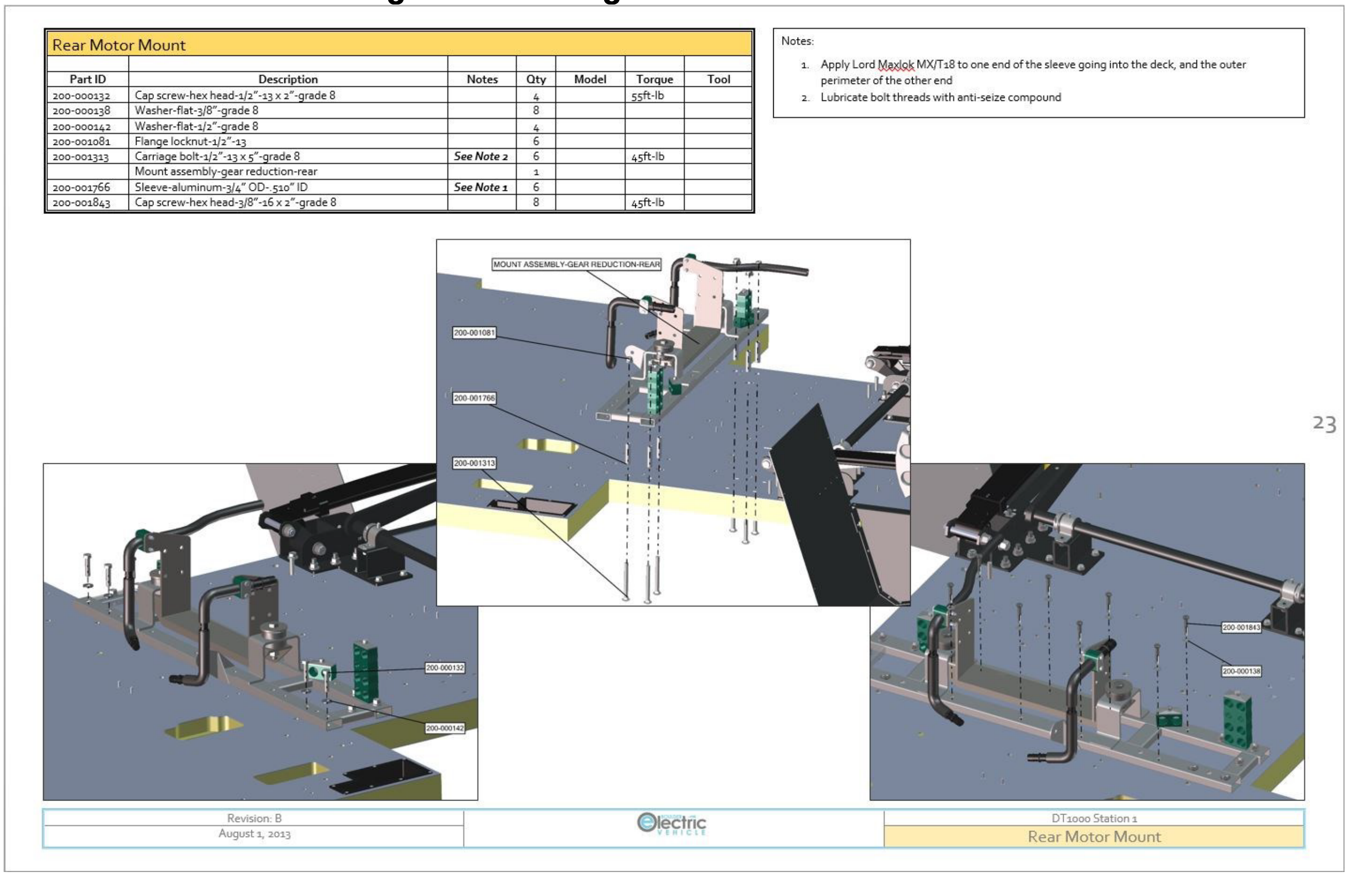
Figure 15: Battery Pack Quality Control Report

Battery Pack 11									
VM S#: 21590126		4/27/2012		Interconnects? | X		Cal:	5/25/2012		Tech: BB
Module	Serial #	Initial V	Final V	Delta V	Module	Serial #	Initial V	Final V	Delta V
1	24323	3.306	3.305	0.001	15	24083	3.307	3.297	0.010
	24324	3.306	3.305	0.001		24084	3.308	3.304	0.004
	24325	3.308	3.306	0.002		24085	3.307	3.304	0.003
	24326	3.308	3.307	0.001		24086	3.309	3.305	0.004
2	24327	3.308	3.307	0.001	16	24087	3.308	3.304	0.004
	24328	3.306	3.304	0.002		24088	3.309	3.303	0.006
	24329	3.308	3.306	0.002		24089	3.307	3.304	0.003
	24330	3.309	3.307	0.002		24090	3.307	3.305	0.002
3	24331	3.306	3.305	0.001	17	24091	3.307	3.304	0.003
	24332	3.309	3.308	0.001		24092	3.308	3.307	0.001
	24333	3.308	3.305	0.003		24093	3.308	3.305	0.003
	24334	3.307	3.307	0.000		24094	3.307	3.304	0.003
4	24335	3.304	3.302	0.002	18	24095	3.308	3.305	0.003
	24336	3.307	3.306	0.001		24096	3.307	3.305	0.002
	24337	3.307	3.304	0.003		24097	3.306	3.304	0.002
	24338	3.309	3.307	0.002		24098	3.308	3.305	0.003
5	24339	3.302	3.300	0.002	19	24099	3.309	3.307	0.002
	24340	3.306	3.305	0.001		24100	3.306	3.304	0.002
	24341	3.307	3.304	0.003		24101	3.307	3.304	0.003
	24342	3.305	3.302	0.003		24102	3.308	3.304	0.004
6	24343	3.306	3.304	0.002	20	24103	3.307	3.306	0.001
	24344	3.306	3.304	0.002		24104	3.306	3.304	0.002
	24345	3.306	3.304	0.002		24105	3.307	3.304	0.003
	24346	3.308	3.306	0.002		24106	3.307	3.304	0.003
7	24047	3.308	3.307	0.001	21	24203	3.307	3.305	0.002
	24048	3.309	3.307	0.002		24204	3.308	3.304	0.004
	24049	3.308	3.306	0.002		24205	3.307	3.305	0.002
	24050	3.305	3.304	0.001		24206	3.307	3.304	0.003
8	24051	3.305	3.304	0.001	22	24207	3.307	3.304	0.003
	24052	3.306	3.305	0.001		24208	3.307	3.305	0.002
	24053	3.306	3.305	0.001		24209	3.307	3.305	0.002
	24054	3.306	3.304	0.002		24210	3.308	3.305	0.003
9	24059	3.307	3.305	0.002	23	24211	3.308	3.304	0.004
	24060	3.308	3.306	0.002		24212	3.307	3.303	0.004
	24061	3.307	3.305	0.002		24213	3.308	3.304	0.004
	24062	3.308	3.306	0.002		24214	3.309	3.304	0.005
10	24063	3.308	3.305	0.003	24	24355	3.306	3.304	0.002
	24064	3.303	3.301	0.002		24356	3.309	3.303	0.006
	24065	3.306	3.304	0.002		24357	3.307	3.304	0.003
	24066	3.307	3.305	0.002		24358	3.307	3.304	0.003
11	24067	3.308	3.305	0.003	25	24119	3.306	3.305	0.001
	24068	3.306	3.302	0.004		24120	3.306	3.304	0.002
	24069	3.307	3.303	0.004		24121	3.306	3.304	0.002
	24070	3.306	3.302	0.004		24122	3.306	3.304	0.002
12	24071	3.306	3.303	0.003	26	24123	3.306	3.305	0.001
	24072	3.306	3.304	0.002		24124	3.306	3.305	0.001
	24073	3.307	3.305	0.002		24125	3.306	3.305	0.001
	24074	3.307	3.305	0.002		24126	3.306	3.304	0.002
13	24075	3.307	3.305	0.002	27	24127	3.307	3.305	0.002
	24076	3.308	3.306	0.002		24128	3.307	3.306	0.001
	24077	3.308	3.306	0.002		24129	3.307	3.304	0.003
	24078	3.307	3.306	0.001		24130	3.306	3.305	0.001
14	24079	3.307	3.306	0.001	28	24263	3.307	3.305	0.002
	24080	3.307	3.306	0.001		24264	3.306	3.304	0.002
	24081	3.308	3.306	0.002		24265	3.305	3.302	0.003
	24082	3.309	3.307	0.002		24266	3.306	3.305	0.001

Issued after battery cycling and before installation of the pack onto the vehicle.

Source: Boulder

Figure 16: A Page from Our Build Books



Rear Motor Mount						
Part ID	Description	Notes	Qty	Model	Torque	Tool
200-000132	Cap screw-hex head-1/2"-13 x 2"-grade 8		4		55ft-lb	
200-000138	Washer-flat-3/8"-grade 8		8			
200-000142	Washer-flat-1/2"-grade 8		4			
200-001081	Flange locknut-1/2"-13		6			
200-001313	Carriage bolt-1/2"-13 x 5"-grade 8	***See Note 2***	6		45ft-lb	
	Mount assembly-gear reduction-rear		1			
200-001766	Sleeve-aluminum-3/4" OD-.510" ID	***See Note 1***	6			
200-001843	Cap screw-hex head-3/8"-16 x 2"-grade 8		8		45ft-lb	

Notes:

1. Apply Lord Maxlok MX/T18 to one end of the sleeve going into the deck, and the outer perimeter of the other end
2. Lubricate bolt threads with anti-seize compound

23

Revision: B	Electric Vehicle	DT1000 Station 1
August 1, 2013		Rear Motor Mount

Illustrates part assembly and part names, numbers, and quantities for this step in the build process. This is for attachment of parts to the underside of the vehicle for Assembly Station #1.

Source: Boulder

Figure 17: Final Mechanical Pre-Drive Checklist

Final Mechanical Inspection

DV500 ✓ DV1000 ____ VIN # 1B9B V21 52CB94

Date: ____________ Tech BS JWC

Reason: New ✓ Service / Other____ Odometer____________

General Functionality

	Pass	Fail	Notes
Door Locks	✓		
Door /s operation	✓	✓	Rear door cable/Fixed JWC 10-23
Window Operation	✓		Pass. good, Dr side hits door pocket
Seat Adjustment Operation	✓		
Seat Belts	✓		
Washer Fluid	✓		
Brake Fluid	✓		
P.S. Fluid	✓		
Heater Fluid	✓		
Mirrors	✓		
Tire Pressure	✓		Set @ 80 psi

Appearance

	Pass	Fail	Notes
Appearance Front	✓		
Appearance Sides	✓		
Appearance Rear	✓		
Appearance Wheels	✓		
Appearance Underneath	✓		
Clean Cab	✓		
Clean	✓		

New Vehicle Checks

	Pass	Fail	Notes
Coolant level	✓		
Odometer Accuracy			Resets itself to Ø
Speedo Accuracy	✓		New program by Bala
Zerks Greased	✓		
Differential Oil (initial)	✓		
Coolant leaks	✓		
ABS Operation	✓		Turn off Regen Properly
Park Brake Adjustment	✓		
Backup Alarm	✓		
Users Guide	✓		
Keys Sets BEV Fob	✓		
Remotes (optional)	3		
Radio Manual	N/A		
Lug Nut Key	N/A		
Vin Plate	✓		
Wash-down Leak Check	✓		Bala x2
Differential Oil (replaced after 500 miles)	✓		As. 389.4 miles

Source: Boulder

Produce Three Electric Drive Vehicles from the Production Line

Three electric drive vehicles were produced from the pilot assembly line. Each was used to further refine the build books and quality control procedures. Each vehicle is currently going into use as a sales demonstration vehicle to further the emission reduction goals of AB 118 as well as to generate sales and help commercialize the project. Each vehicle has a data logging system and GPS tracking to provide potential customers with real-world data about how much electricity is used per mile and how much the diesel offset is when compared to a conventional truck of the same size. Figures 18 through 22 shows the first demonstration vehicle in various stages of the building process.

Figure 18: Station 1 Assembly Station with First Demonstration Vehicle Visible

Photo credit: P2Photography.net

Figure 19: Demonstration Truck Rotated

From station 1 onto its wheels for station 2 assembly.

Photo credit: P2Photography.net

Figure 20: Body Panels and Cab Joined at Station 3

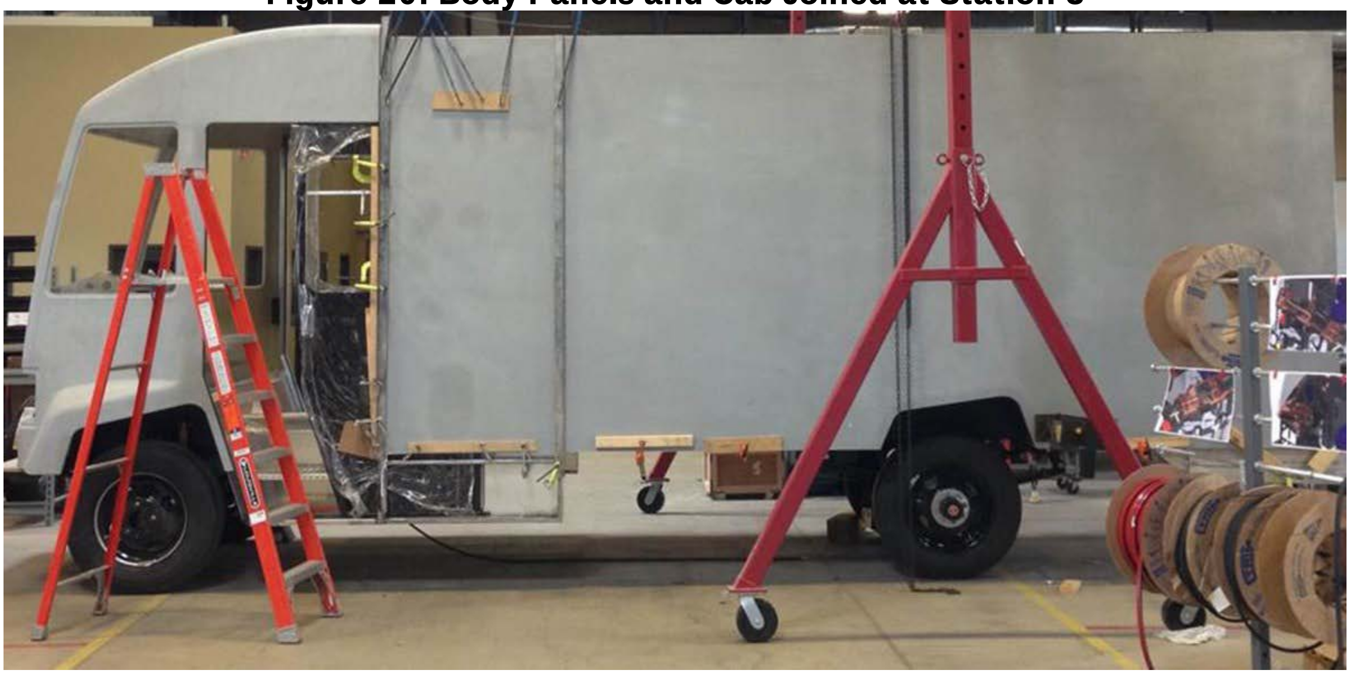


Photo credit: P2Photography.net

Figure 21: Trucks in Stations 1 through 4, Front View

Three demonstration vehicles in various stages of completion.

Photo credit: P2Photography.net

Figure 22: Trucks in Stations 1 through 4, Rear View

Photo credit: P2Photography.net

CHAPTER 3: Task 3 Report—Data Collection and Analysis

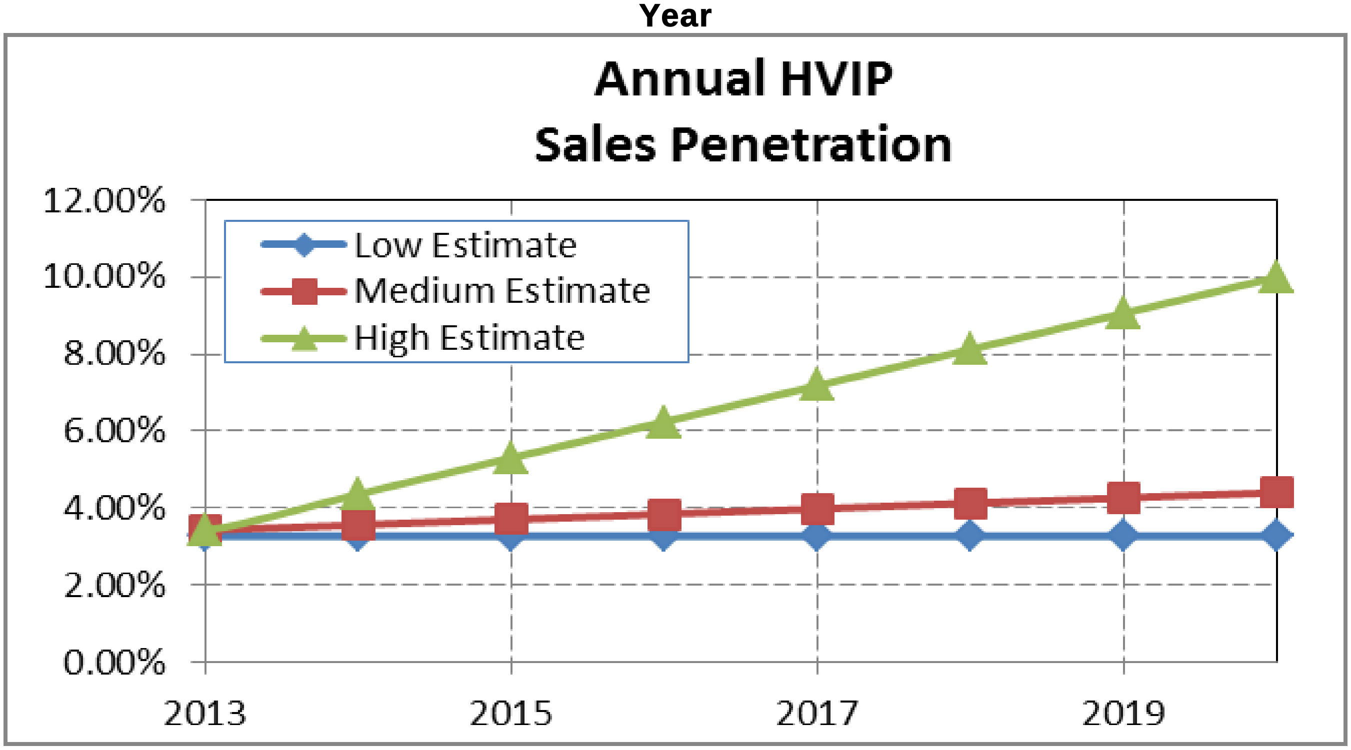
Summary of Task

Task 3 was to collect data and analyze how the project will help achieve goals and objectives that are in alignment with the AB 118 program. We have provided market penetration, sales projections, gasoline and diesel fuel displacement, and reduction of applicable air pollutants, estimated the project's carbon intensity values, analyzed the job creation, economic development, and increase in state revenue, and summarized the energy efficiency measures used in the project and manufacturing process. We have looked at how the project provides a measurable transition from petroleum-based vehicles to battery electric vehicles. We have demonstrated the cost effectiveness of all electric trucks built as a result of the project. We have suggested additional data that the CEC may request in future years.

Provide Market Penetration Scenarios

Market penetration Scenarios Low, Medium, and High for the horizon 2013—2020 in the State of California are shown in Figure 23. We use national medium- and heavy-duty sales numbers as a proxy for total California sales amounting to 10 percent of national sales. Because the annual sales trend behavior from 2007 averaged below zero, followed by extremely large growth from 2010—2012, we assume a cautiously optimistic forecasted growth rate in the total medium- and heavy-duty segment at 1 percent per year.

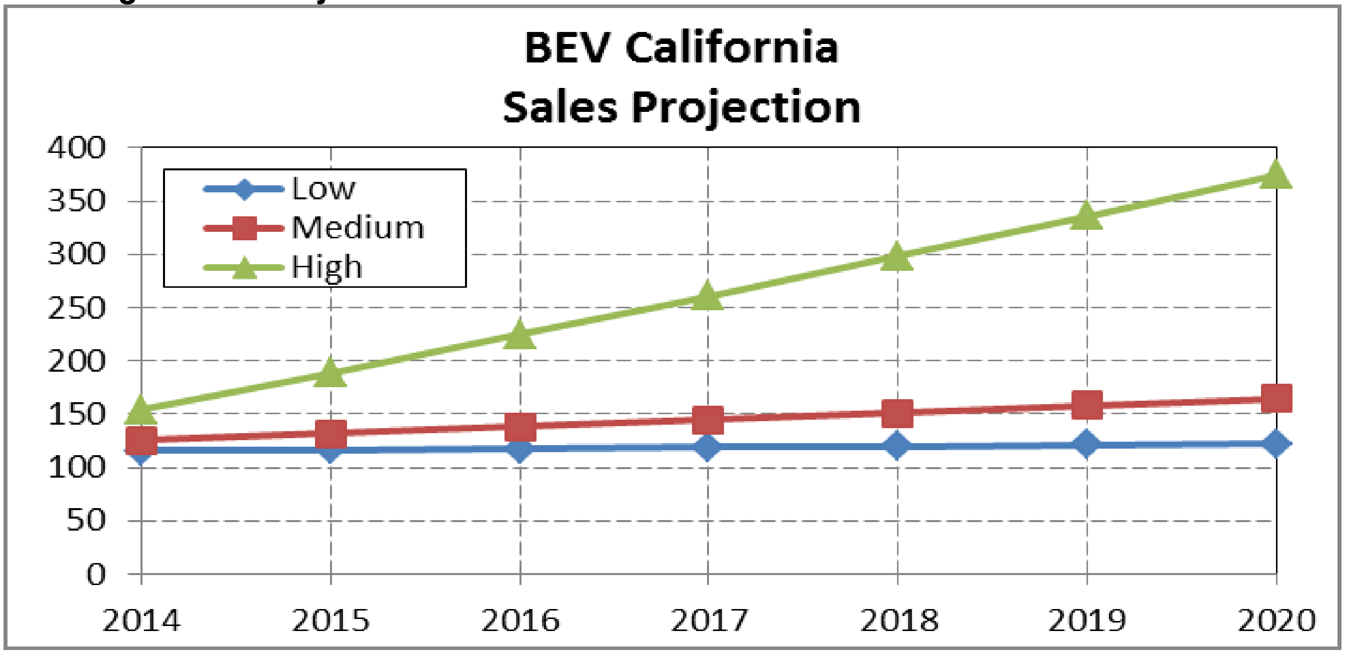
Figure 23: Projected Increase in Hybrid and Electric Vehicle Sales Penetration by Year



Source: Boulder

Given these scenarios, we assume an annual growth rate in sales of zero for the low estimate, 0.14 percent for the medium estimate, and 0.94 for the high estimate. EVs are beginning to capture a larger portion of the market, and we assume Boulder captures 10 percent of the total Hybrid Voucher Incentive Program market. Given these inputs, the annual estimated sales numbers for California are shown in Figure 24.

Figure 24: Projected Unit Sales of Boulder All Electric Trucks in California



Source: Boulder

Using the Market Penetration Scenarios

All of the market penetration scenarios in this report are static tables. Thus we have tried to include a low-, mid-, and upper-level in all graphs to demonstrate to the reader the possibilities for electric trucks to assist in petroleum savings and pollution reduction between now and the year 2020.

Estimate Annual Gasoline/Diesel Fuel Displacement

Fuel displacement statistics are generated from real-world fleet operating data collected by Boulder. The typical on-route distance for Boulder's market segment hovers around 70—100 miles per day and conventional diesel fuel economy is estimated to be eight miles per gallon (MPG). We assume that fleets choose to replace non-hybridized trucks with EVs before replacing existing hybrid units. Calculations for estimated diesel fuel displacement are shown in Figure 25.

Figure 25: Cumulative Diesel Fuel Displacement

	A	C	D	E	F	G	H
1	Year	2013	2014	2015	2016	2017	**5 Year Total**
2	Vehicles Produced	3	50	150	500	1000	
3	Total Fuel Savings (Gal)	**187,500.00**	**3,125,000.00**	**9,375,000.00**	**31,250,000.00**	**62,500,000.00**	**106,437,500.00**

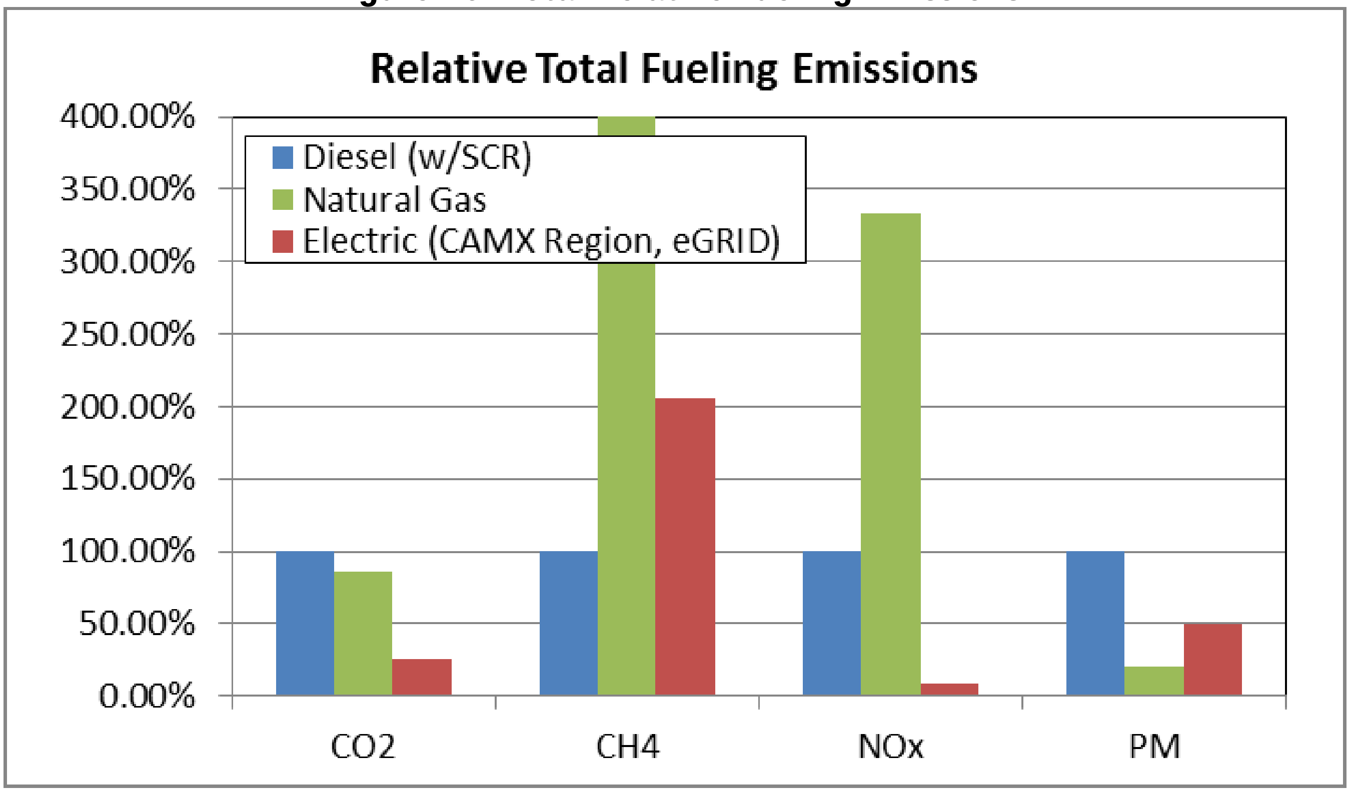
In gallons, of all vehicles produced by full-scale commercialization of the project, based on 20-year life of the vehicle.

Source: Boulder

Explain How the Project Will Reduce Applicable Air Pollutants

Mobile-source emissions for Boulder trucks are zero because there is no tailpipe. Stationary-source emissions from the grid fuel source, like natural gas-fired power plants, are still less than their mobile counterpart due to the efficiency of the electric drivetrain of the vehicle. An additional health benefit of EVs is that emission sources tend to be sites away from dense population centers, mitigating air quality issues where most people live. eGRID2012 data was used to estimate carbon dioxide (CO2), methane (CH4), nitrogen oxide (NOx), and particulate matter (PM) emissions per mile, assuming an EV efficiency of 0.8 kilowatt hours (kWh) per mile. A comparison of the total vehicle emissions for diesel truck versus the Boulder truck is shown in Figure 26.

Figure 26: Total Relative Fueling Emissions



Source: Boulder

An Estimate of the Project's Carbon Intensity Values

Over 70 percent of the mass of the vehicle is metal (primarily aluminum) or batteries, which can be recycled at the end-of-life. Lifetime CO2 fueling emissions are less than one third their conventional or natural gas counterparts. Additionally, power grid NOx and CH4 emissions are significantly less for EVs than natural gas vehicles, while diesels actually beat EVs in terms of lifecycle fuel CH4.

Job Creation, Economic Development, and Increased State Revenues

The potential economic impact from Boulder operations in Los Angeles, California, forecasted for 2014—2018 (five years) totals over $250 million. This number is based upon our actual fixed costs plus our estimated variable costs based on forecasted units of production (Figure 27), plus estimated 9 percent sales tax on sold trucks—all multiplied by a 1.5 economic impact factor. Total five year costs: payroll $18,145,000; rent, utilities, insurance, etc. $2,261,000; materials purchased to assemble our trucks from California-based suppliers $127,500,000; sales tax collected and paid to California $22,950,000; all multiplied by a 1.5 economic multiplier.

The number of employees in the below table are factory workers only and do not include sales, marketing, or general and administrative staff. The table also does not include any of the employees covered by the grant. Additional hires and subsequent growth are highly market-dependent and may not be achieved or may in fact be exceeded depending on actual sales numbers.

Figure 27: Economic Impact Numbers

	A–E	F	G	H	I	J	K	L
1	**Five Year 2013 -2017 California Economic Impact - Boulder Electric Vehicle, Inc**							
2		2013	2014	2015	2016	2017		
3	Number of trucks sold:	0	50	150	500	1000		
4								
5	Number of factory employees	2	20	40	80	120		
6	Average pay: $50,000							
7	Yearly Expenses:							
8	California Payroll:							
9	Factory	$ 100,000	$ 1,000,000	$ 2,000,000	$ 4,000,000	$ 6,000,000		$ 13,100,000
10	Sales	$ 100,000	$ 125,000	$ 250,000	$ 400,000	$ 1,000,000		$ 1,875,000
11	Executive Payroll (Pres,CEO,CFO)	$ 75,000	$ 175,000	$ 300,000	$ 750,000	$ 1,250,000		$ 2,550,000
12	Administrative Payroll	$ 40,000	$ 55,000	$ 100,000	$ 175,000	$ 250,000		$ 620,000
13								**$ 18,145,000**
14	LA Rent	$ 216,000	$ 225,000	$ 250,000	$ 300,000	$ 350,000		$ 1,341,000
15	Utilities	$ 50,000	$ 60,000	$ 75,000	$ 85,000	$ 100,000		$ 370,000
16	Insurance	$ 50,000	$ 75,000	$ 100,000	$ 150,000	$ 175,000		$ 550,000
17	Materials for **each** truck produced							**$ 2,261,000**
18	purchased from California suppliers:	$ -	$ 3,750,000	$ 11,250,000	$ 37,500,000	$ 75,000,000		$ 127,500,000
19	9% California Sales Tax on Trucks Sold	$ -	$ 675,000	$ 2,025,000	$ 6,750,000	$ 13,500,000		$ 22,950,000
20	Yearly Totals	$ 631,000	$ 6,140,000	$ 16,350,000	$ 50,110,000	$ 97,625,000		$ 170,856,000
21	Conservative Economic Multiplier Effect 1.5							
22	**Yearly California Economic Impact**	**$ 946,500**	**$ 9,210,000**	**$ 24,525,000**	**$ 75,165,000**	**$ 146,437,500**		**$ 256,284,000**
23								
24	**Five Year 2013 -2017 California Economic Impact - Boulder Electric Vehicle, Inc**					**$ 256,284,000**		

Generated from projected sales and commercialization of the project.

Source: Boulder

The figure (28) below shows our staff, including marketing, sales, and production at Boulder's Los Angeles plant in August 2013.

Figure 28: Boulder Employees

Outside the plant during the critical project review meeting in August 2013. Approximately half of these staff members were hired without the financial support of this grant.

Photo credit: P2Photography.net

Energy Efficiency Measures Used in the Project and Manufacturing Process

The two key energy efficiency measures used in the project had to do with chassis production and battery pack cycling. Boulder uses a production process in the chassis that allows for a significant reduction in energy use over conventional steel frame rail construction.

The battery packs also must be charged and discharged 10 times each for quality control before the packs go onto a truck. Since there is 80 kWh of energy in the truck's battery pack, 800 kWh of energy is used per truck before each truck even drives a single mile. However, Boulder has employed our proprietary battery cycling technology to decrease this by 90 percent. Figure 29 illustrates the kWh savings as the project goes into commercialization. Our battery pack efficiency measures result in a five-year savings of 1,226,160 kWh.

Figure 29: Estimated Annual kWh Savings

2013	2014	2015	2016	2017	5 Year Total
3	50	150	500	1000	
2,160.00	**36,000.00**	**108,000.00**	**360,000.00**	**720,000.00**	**1,226,160.00**

Source: Boulder

How the Project Provides a Measurable Transition from Petroleum to Viable Alternative Fuels

Of all the vehicles that are realistically able to be replaced by EVs at this date, medium-duty trucks and shuttles are the types of vehicles with the worst fuel economy. A Toyota Prius that gets 50 MPG will use 500 gallons of gasoline for a 25,000-mile driving year, whereas a medium-duty delivery truck that gets eight MPG will use 3,125 gallons of fuel over the same distance.

The following figure (30) shows the petroleum saved by the projected sales numbers of commercialization of the project. This is based on replacing medium-duty delivery vehicles that get an average of eight MPG and drive 100 miles per day, five days per week, 50 weeks per year, for a total annual mileage of 25,000. This is based on a useful service life of 20 years.

Figure 30: Petroleum Reduction Numbers

	A	C	D	E	F	G	H
1	Year	2013	2014	2015	2016	2017	**5 Year Total**
2	Vehicles Produced	3	50	150	500	1000	
3	Total Fuel Savings (Gal)	**187,500.00**	**3,125,000.00**	**9,375,000.00**	**31,250,000.00**	**62,500,000.00**	**106,437,500.00**

Source: Boulder

How the Project Demonstrated the Cost Effectiveness of the Proposed Technology

Boulder trucks offset an estimated 3,125 gallons of fuel annually, reducing the cost of fueling to the operator, while diversifying the fuel mix, which comes from the electric power grid. A quantification of health benefits of improved air quality is beyond the scope of this analysis. However, qualitatively, healthcare needs would likely be reduced as more in-town mobile emission sources are taken off the road in favor of EV trucks.

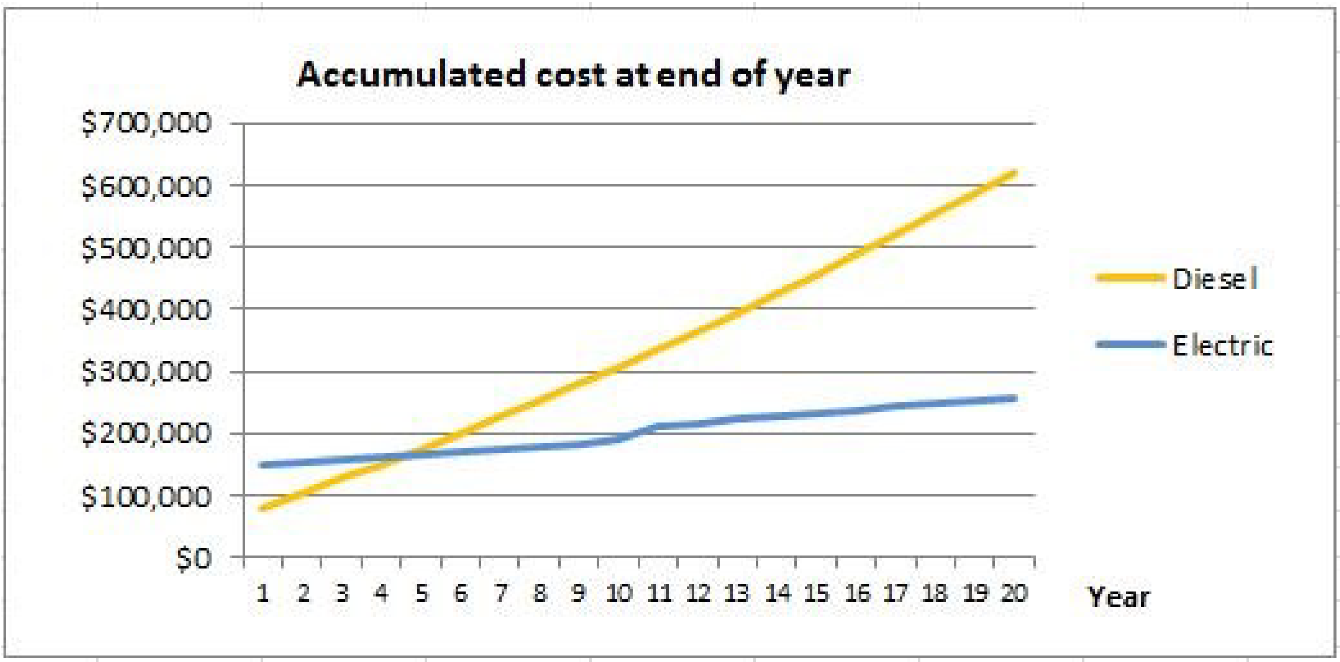
The following table shows the base assumptions for generating Figures 31 and 32. Note that these assumptions include no tax credits or rebates, thus proving the case for electric trucks without incentives attached.

Figure 31: Base Customer Costs and Fuel Price Assumptions

Customers data:			**Note:** Only values in grey boxes with **thick** border should be changed.		
State (pick from list for CO_2 calculations):	California				
Annual milage:	25,000	miles			
Fuel economy diesel vehicle:	8.0	MPG			
Purchase cost for diesel vehicle:	59,000	$			
Cost for diesel:	4.00	$/gallon	Expected annual increase:	5.00	%
Cost of electricity:	0.14	$/kWh	Expected annual increase:	5.00	%
Purchase cost for electric vehicle	145,000	$			
Federal tax credit for electric truck:	0	$	Type in as positive numbers.		
State tax credit for electric truck:	0	$	All credits will be accounted for on the		
Other grant or credit for electric:		$	first year.		

Source: Boulder

Figure 32: Accumulated Lifecycle Costs of Medium-Duty Diesel and Boulder Electric Trucks



Source: Boulder

Potential Energy Savings that Exceed Title 24 Standards

Boulder believes the battery cycling technology and energy efficiency measures used in Section 3.8, constitute a potential energy savings above and beyond what Title 24 calls for. Please see Figure 33 for the details of this energy savings.

Figure 33: Lifetime Fuel and Financial Savings of Electric vs. Diesel Medium-Duty Delivery Trucks

Estimation based on the customers data - summary:				
The total cost over 20 years is			$619,750	for a diesel truck
			$259,075	for an electric truck
		Difference:	$360,675	
Average annual cost over 20 years			$30,988	for a diesel truck
			$12,954	for an electric truck
		Difference	$18,034	per year
Annual fuel/electricty cost:			$18,438	for a diesel truck
			$2,581	for an electric truck
		Difference:	$15,856	
Over 20 years you will have saved			62,500	gallons of diesel fuel
			1,235,000	lbs of CO_2 emissions

Source: Boulder

Provide Additional Data that may be Requested by the CEC

Additional data that may be requested over the coming years are actual employee and production numbers at the end of each calendar year, disposition of equipment location and use, as well as any monies received from the sale of equipment if and when that happens.

GLOSSARY

COMPUTER-ASSISTED DESIGN (CAD) – The use of computers to aid in the creation, modification, analysis, or optimization of a design.

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.

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

LOS ANGELES DEPARTMENT OF WATER AND POWER (LADWP) – An electric municipal utility serving the greater Los Angeles, California, region.