



**CALIFORNIA
ENERGY COMMISSION**



California Energy Commission
Clean Transportation Program

FINAL PROJECT REPORT

California Zero-Emission Public Transit Bus Manufacturing Project Report

Prepared for: California Energy Commission

Prepared by: Proterra Inc.



PROTERRA

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PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-14-604 to fund the development of advanced vehicle technology manufacturing facilities in California that produce zero emission vehicles or components. In response to PON-14-604, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards on February 25, 2015 and the agreement was executed as ARV-14-044 on May 8, 2015.

ABSTRACT

In May 2015, the California Energy Commission executed a \$3 million grant to Proterra to fund the design, development, and construction of Proterra’s new state-of-the-art zero-emission, battery-electric transit bus manufacturing line in California. The proposed facility in the San Gabriel Valley was determined an optimal location to serve existing and future transit customers throughout California and the western half of the United States. In May 2017 the grant was amended to include the purchase of manufacturing equipment for the Proterra battery pack factory located in Burlingame. The bus manufacturing facility benefits economically distressed communities throughout the San Gabriel Valley—providing jobs in southern California’s emerging center of high-tech manufacturing. Proterra planned to manufacture zero-emission battery electric buses at the San Gabriel Valley facility, these buses will result in a reduction of carbon dioxide equivalent over the lifetime of the manufactured vehicles. Implementing the project will help lower the production costs and the upfront cost of zero-emission buses across the western half of the United States.

Keywords: Zero-emission, battery electric bus, total cost of ownership, manufacturing, policies, greenhouse gases, disadvantaged communities.

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EXECUTIVE SUMMARY

This project led to the design, development, and construction of a state-of-the-art manufacturing line for Proterra's zero-emission, public transit buses in the City of Industry in San Gabriel Valley, California. By creating increased manufacturing capacity of heavy-duty zero-emission vehicles, the project enabled Proterra to meet current and future demands, more efficiently for zero-emission bus deployments on the West Coast.

Proterra Inc, the leading U.S. manufacturer of the world's first all-electric, fast-charge commercial public transit buses, previously manufactured all its zero-emission vehicles in Greenville, South Carolina.

Because Federal and State funding opportunities are subsidizing and accelerating adoption, demographic mega-trends are supporting more urbanization, transit system growth and a nationwide commitment to sustainable solutions created a backlog at Proterra's East Coast facility, particularly with customers on the West Coast such as San Joaquin RTD and Foothill Transit.

Proterra has a real opportunity to reduce the significant costs of shipping, service and maintenance associated with servicing West Coast customers now with the construction of a new West Coast manufacturing facility.

By reducing these and other costs with a new facility, Proterra will continue to drive the cost down of its buses, which will only facilitate further adoption of electric vehicle zero-emission technology, as well as reduce GHG emissions, displace petroleum fuel demand and stimulate economic development.

The goals of this Project were to:

- Provide a zero-emission, battery, all-electric transit bus complete manufacturing line.
- Accelerate zero-emission bus adoption and improve economies of scale.
- Help reduce use and dependence on petroleum transportation fuels.
- Support the state in achieving its aggressive environmental goals.
- Provide electric miles for all, especially benefiting disadvantaged communities.
- Spur state and local investment and job opportunities.
- Reduce manufacturing, service, and maintenance costs.

CHAPTER 1:

Project Introduction

Proterra is a leading United States provider of zero-emission, all-electric transit solutions. Proterra designs and manufactures the world's most fuel-efficient battery electric bus and features on-route, fast-charge technology that offers functionally unlimited range, as well as an extended range version that enables transit agencies to travel as much as 230 miles on a single charge.

Figure 1 indicates Proterra customers spread out across North America from coast to coast.

Figure 1: Proterra Customer Locations Map



Source: Proterra Inc.

The project budget was made up of Energy Commission grant funding as well as Proterra match funding. The funding was divided up between the two facilities in the following manner:

- Grant Funding LA
 - Equipment \$900,000
 - Direct Labor & Fringe \$143,146
 - Materials & Miscellaneous \$54,055
- Grant Funding Burlingame
 - Equipment \$1,902,799
- **Total Grant Funding \$3,000,000**

- Match Funding LA
 - Materials & Miscellaneous \$3,445,398
 - Direct Labor & Fringe \$746,960
 - Travel \$47,000
- Match Funding Burlingame
 - Materials & Miscellaneous \$542,332
 - Equipment \$630,000
- Total Match Funding \$5,411,690
- **Total Match Commitment \$5,411,352**

- **Total Funding**
 - **Grant & Match \$8,411,352**

Proterra had long considered establishing manufacturing in California for many reasons including, supplying what is the biggest single state market for transit buses, favorable state policies, zero emission vehicle talent, and many early adopters.

Back in 2015, Proterra manufactured all its zero-emission buses in Greenville, South Carolina, where it had done so since 2010, despite having its first few customers based in California.

From 2010 to 2015 Proterra started to see significant demand which resulted in the South Carolina facility having a growing backlog, which included customers on the West Coast. This demand could be met in the near term by ramping up production shifts and manufacturing facilities on the East Coast, but the high shipping costs to deliver buses to the West Coast, which can cost thousands of dollars per bus, and the need for local service, repair, and maintenance personnel to serve San Joaquin RTD and Foothill Transit and additional West Coast customers all supported implementing a West Coast manufacturing facility as soon as possible. However, as a yet to be profitable start-up, the cost to establish a second manufacturing plant was prohibitive for Proterra.

Proterra determined that to become a viable nationwide manufacturer of zero-emission buses it had to establish manufacturing in California. The Energy Commission solicitation PON-14-044 was available at a moment of perfect timing that allowed Proterra to use the money to not only fund the start of the art manufacturing plant but to show existing and potential investors that the move to California made sense based on the policies and initiatives in place. Proterra had to show that manufacturing production capacity of heavy-duty zero-emission vehicles was not adequate to meet current and future demands for zero-emission bus and truck deployments on the West Coast and that expanded manufacturing capacity of zero-emission transit buses was especially needed in California to support the implementation of assembly bills, the Governor's zero emission vehicle Executive Order and action plan, as well as other state goals.

Additionally, there was an opportunity for these investments to spark job creation, accelerate economic and environmental benefits, provide lasting greenhouse gas emissions reductions, eliminate toxic emissions in communities throughout California and provide electric miles for all

especially benefiting California's disadvantaged communities.

Proterra buses charge using the J 1772 CCS standard, which allows medium and light duty vehicles to share the charging infrastructure. This technology choice supports the effort to build a nationwide network of workplace, community and highway chargers as well as providing municipalities to charge light and medium duty electric vehicles with the same electric vehicle service equipment being deployed for their transit fleets.

Proterra’s zero-emission, battery-electric technology is being deployed in revenue service throughout the nation. Transit agency early adopters such as Foothill Transit and Stockton RTD, have demonstrated the technology readiness of Proterra’s battery electric solutions on urban as well as mixed suburban routes – and now major metropolitan agencies such as SEPTA (Philadelphia), CTA (Chicago) and NYMTA (New York) are placing orders and putting zero-emission battery electric buses into service.

San Gabriel Valley is an optimal location to serve existing and future transit operators throughout California. The project benefits economically distressed communities throughout the San Gabriel Valley—providing good, living-wage jobs in southern California's emerging center of high-tech manufacturing.

Ultimately, the *California Zero-Emission Public Transit Bus Manufacturing Project* has helped further lower production costs, reduce the upfront cost of fast-charge zero-emission buses, provide a large physical presence in California to support branding and marketing and outreach to transit operators and provide a strong spark to accelerate widespread deployment and adoption.

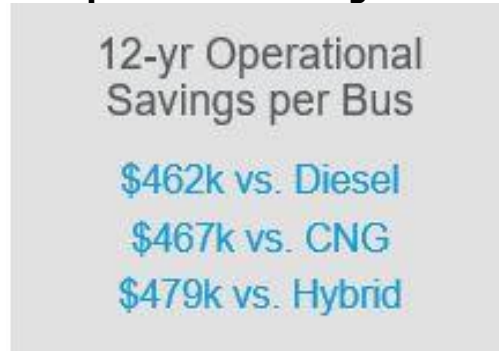
As recently as 2010 the Proterra zero-emission bus cost \$1.2 M dollars. Now the base model Proterra Catalyst E2 with 440 kilo watt hour of energy storage costs \$750,000. Proterra’s CATALYST™ bus achieves 22 + miles per gallon equivalent performance, 500 percent + better than diesel and compressed natural gas (CNG) buses, eliminating toxic diesel particulate matter and reducing carbon emissions by 70 percent or more compared to CNG or diesel buses. The improved mileage and higher reliability result in a total cost of ownership that is much lower than fossil fuel buses as indicated in table 1. On a per mile basis and/or a 12-year lifecycle basis, zero-emission buses are more cost effective than fossil fuel buses as indicated in table 2.

Table 1: Total Cost of Ownership

	Proterra EV	Diesel Bus	CNG Bus	Diesel Hybrid
Vehicle	\$749	\$493	\$531	\$712
Energy/Fuel	\$94	\$381	\$336	\$297
Maintenance	\$275	\$450	\$500	\$550
TCO	\$1,118	\$1,324	\$1,367	\$1,559
TCO \$'s/Mile	\$2.24	\$2.65	\$2.73	\$3.12

Source: Proterra Inc.

Table 2: Electric Bus Operational Savings Per Alternative Bus Type



Source: Proterra Inc.

To date, Proterra’s buses have logged 7+ million miles of service in cities across the United States.

With over 700 buses sold to over 90 customers across 41 states and 2 Canadian provinces, Proterra has become the zero-emission technology provider of choice for transit agencies nationwide.

CHAPTER 2: Project Deployment

Proterra, working with the Energy Commission, amended its original grant agreement to help establish a battery system manufacturing plant in their Burlingame headquarters. The amendment allowed Proterra to use the majority of the Energy Commission funds for advanced manufacturing equipment for battery pack production in Burlingame. The key elements of the amendment were:

- Cell Test & Cassette Load Machine – This machine has hoppers which individual cells are loaded into in bulk. Individual cells are then tested for functionality and then fed into a mechanized adhesive application that then pushes out cassettes made up of cells that are used to build modules.
- Laser Welder – This machine uses proprietary technology to bond the individual cells in multiple cassettes in the battery system modules. The technology ensures a lasting bond that will survive the rugged high mileage duty cycle of a transit bus.
- Conveyance System – This system is a series of conveyors that allow product to safely and efficiently travel from station to station along the battery system production line.

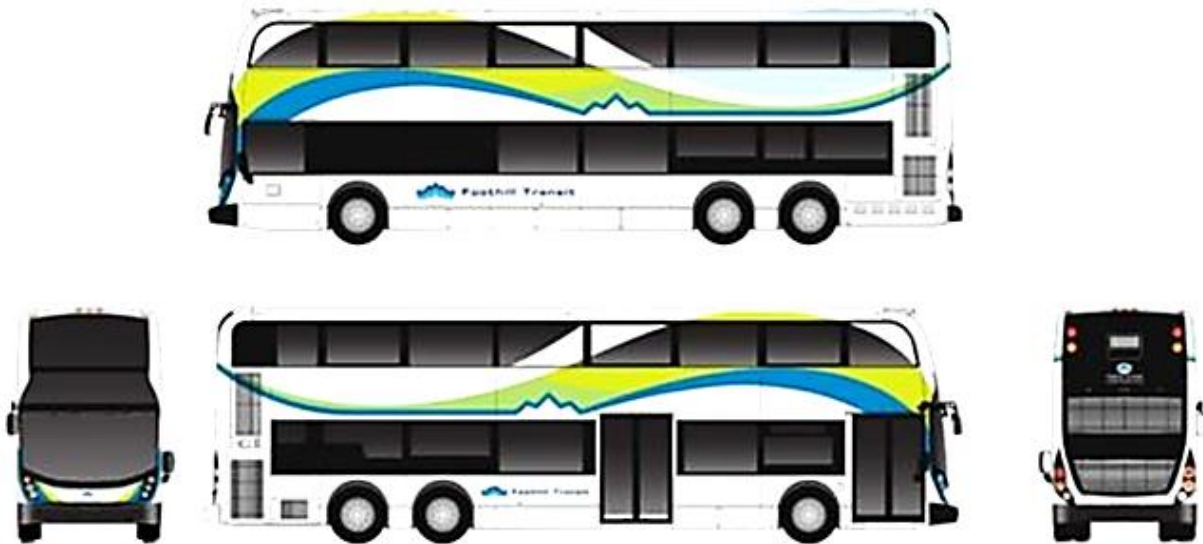
The build out of the battery manufacturing line has been an unqualified success. The production level in the factory produced 1 battery pack per day when first going live with commercial packs for customer buses. Utilizing and integrating all of the amendment equipment has allowed the battery production facility to reach a peak output of 4.5 packs per day.

That cooperation has been a success. Proterra now builds battery systems for use in its Southern California and South Carolina bus manufacturing plants in Burlingame. In addition, the battery system manufacturing plant now builds battery packs for other heavy-duty applications including eCoach high floor buses, school buses and the first battery electric double decker bus. Furthermore, the now proven battery systems being built in Burlingame are being contemplated for use in multiple other HD applications.

The other key amendment in the project was allowing Proterra to use Energy Commission funding to purchase a mold for the manufacturing of the Proterra composite bus body. The mold was important as it allowed the bus body supplier to increase production to match the bus production growth in the LA County factory.

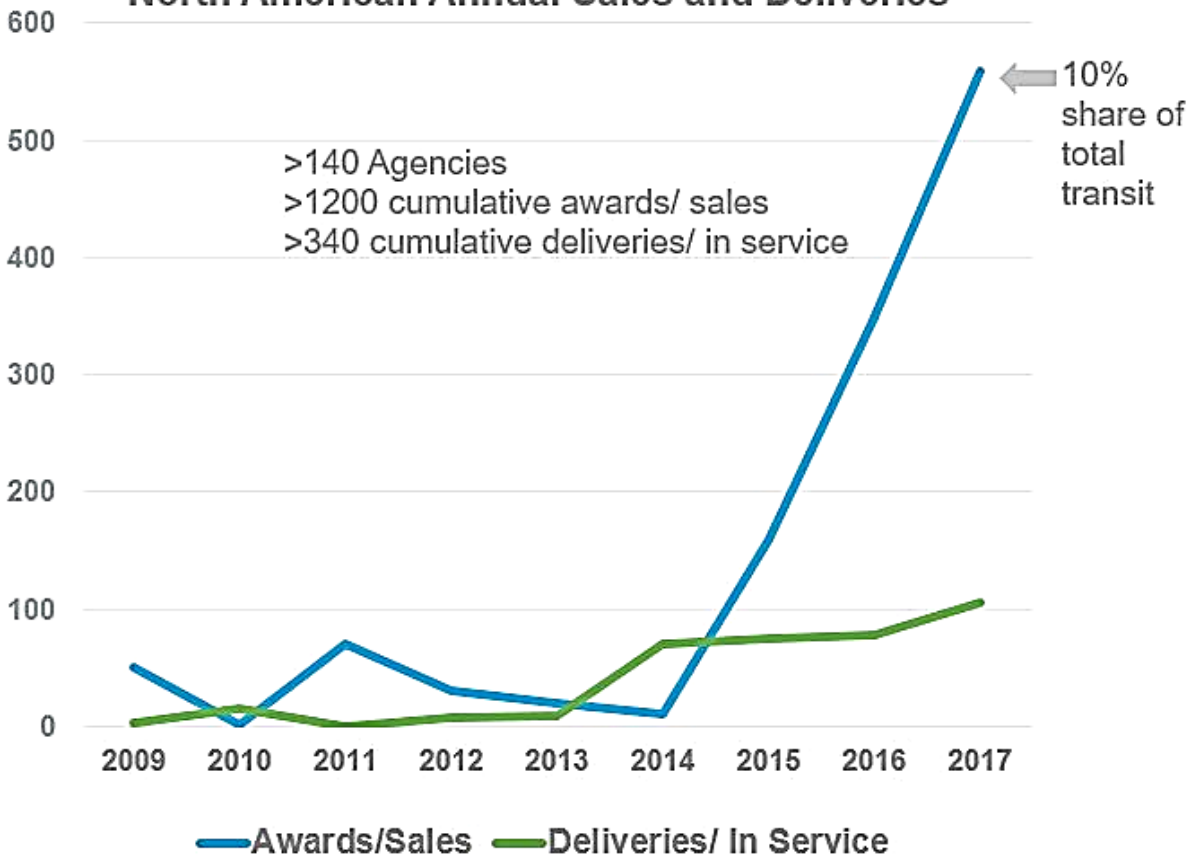
Figure 2 is an illustration of the double decker bus profile views and figure 3 indicates the 2009 to 2017 zero emission bus market annual sales and delivery growth in North America.

Figure 2: Proterra/Alexander Dennis Double Decker Bus



Source: Proterra Inc.

**Figure 3: Zero -Emission Bus Market Growth
Battery Electric Buses:
North American Annual Sales and Deliveries**



Source: Center for Transportation and the Environment.

CHAPTER 3:

Data Collection & Analysis

The data contained in table 3 represents information aggregated from the buses manufactured during the grant period. Data was collected utilizing on board cloud based proprietary Proterra software known as Apex. In addition Proterra used U.S. Energy Information Agency, and customer reporting to calculate the values in the chart.

Customer reporting from their existing diesel fleet gave us an average MPG of 3.9. The Apex onboard data collection supplied the number of miles driven by each bus for the grant period. These two values allowed us to calculate the gallons of diesel eliminated during the grant period. Finally, the U.S. Energy Information Agency gives us a value of 22.4 pounds of GHG's generated per gallon of diesel fuel burned. This value allows us to calculate the total GHG's eliminated by the fleet of zero-emission buses built and deployed during the grant period.

Table 3: Production & Green House Gas Elimination Tracker

Customer	Buses Built - 12/7/18	Miles Driven	Diesel Displaced (gal)	GHG Avoided (lbs)
LA Pilot	1	5079	1302	29172
Foothill	17	32799	8410	188384
Reno	17	117857	30220	676928
Kitsap	1	6418	1646	36870
VTA	5	22086	5663	126853
Tri-Delta	2	11645	2986	66886
Everett	4	2309	592	13262
Fresno	5	N/A	N/A	N/A
Visalia	3	4903	1257	28161
RIPTA	3	N/A	N/A	N/A
Humboldt	1	N/A	N/A	N/A
Bryce	1	N/A	N/A	N/A
Yosemite	2	N/A	N/A	N/A
Modesto	5	N/A	N/A	N/A
NYPA	8	N/A	N/A	N/A
SJ Airport	4	N/A	N/A	N/A
SamTrans	2	N/A	N/A	N/A
Totals	81	203096	52076	1138355

Source: Proterra Inc.

CHAPTER 4:

Observations and Challenges

Due to a change in corporate long-term planning Proterra shifted its strategy for energy storage to significantly increase the capability of our upcoming Extended Range product. The original plan was to produce battery packs that were comprised of modules (which were produced by a third party in Michigan).

Upon testing and review by the first wave of battery team employees it was determined that the third party modules had neither the energy density nor the reliability needed for the transit sector and other vehicles in the heavy duty sector. The implication of this change is that Proterra is now designing, testing, and manufacturing our battery packs from the ground up – with all effort based out of our new Burlingame facility.

The newly formed battery team grew rapidly to allow this project to undergo several development and test cycles in 2016. Proterra went through 4 design cycles to progress from proof of concept to production.

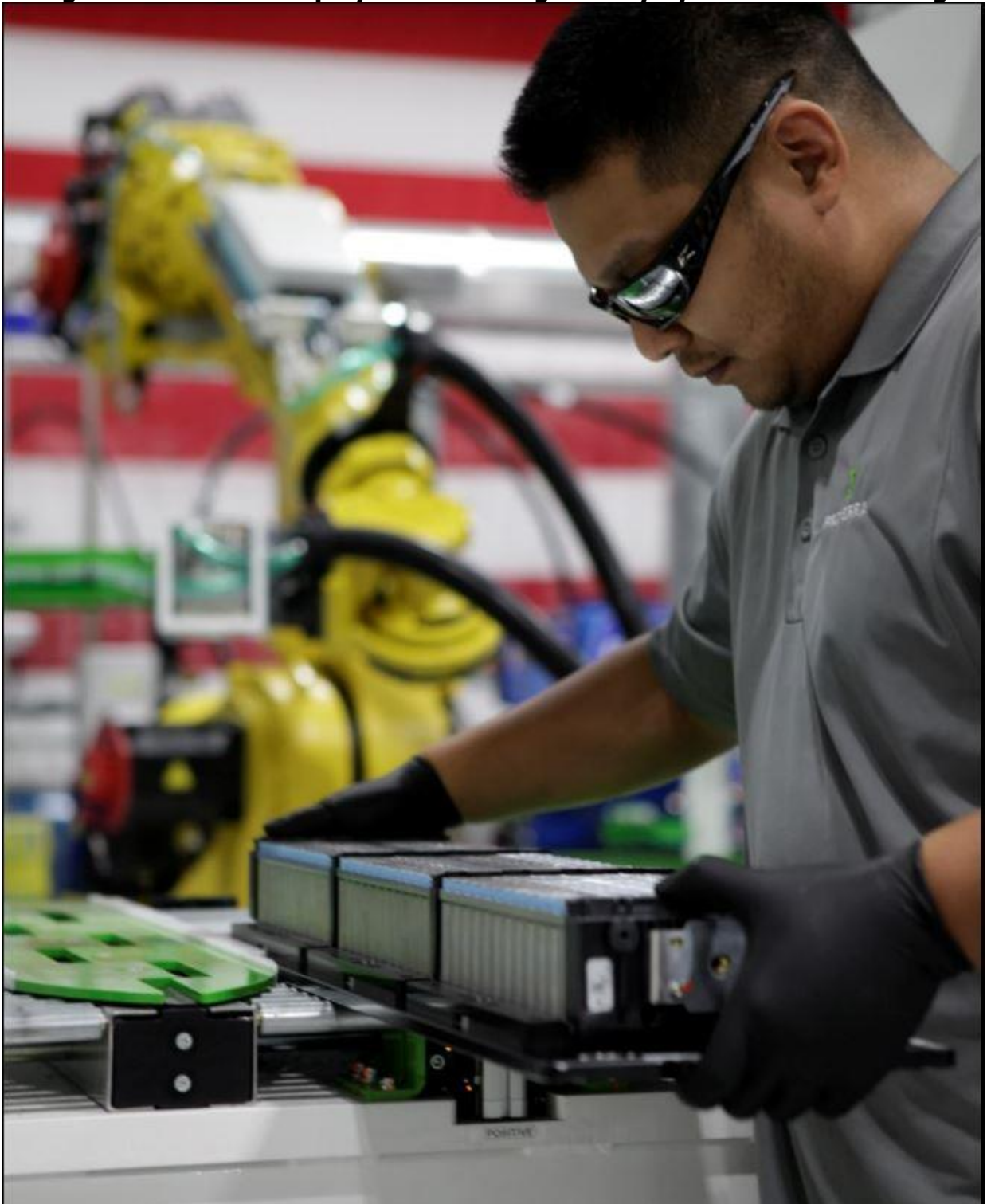
The battery production line went live April 2017, and the first packs were installed in customer buses in May of 2017. Proterra is now producing the battery modules in the Burlingame facility and fully completed battery packs will be delivered directly to City of Industry facility where they will be installed into bus 'gliders' near their final stage of assembly.

Components such as a state-of-the-art laser welder will enable rapid and reliable connection of battery cells in our module configuration. Finally, we are upgrading the facility to enable production of this new battery to meet customer demand, beyond projected 2019 volumes, with multiple shifts.

Establishing two manufacturing facilities has resulted in Proterra dramatically exceeding its objectives in the job creation area. Proterra had an objective of creating 70 direct new jobs in its LA County facility by project end. In fact, Proterra has created 98 direct jobs in LA County and 29 direct jobs in Burlingame, where battery systems are manufactured (Figure 4).

It should also be noted that due to the increased demand for buses and the resultant need for increased production in the City of Industry factory, not only will there be more job creation in LA but there will be additional job creation in Burlingame. The battery production area will be establishing a second shift to be able to double the previously documented output from 4.5 packs per day to 9 packs per day. The second shift will cause the factory to be operating 20 hours a day doubling the usage and productivity of the equipment purchased under the Energy Commission grant.

Figure 4: Proterra Employee Performing Battery System Manufacturing



Source: Proterra Inc.

CHAPTER 5: Lessons Learned

Despite experience operating a factory in South Carolina, establishing a factory in California from scratch and outfitting it to manufacture a zero-emission bus is more time consuming than anyone in Proterra could have envisioned.

The objective to design, develop, and construct a state-of-the-art manufacturing line in California to be operational by fourth quarter of 2015 was completely unrealistic. The reason it was unrealistic was that after signing the agreement with the Energy Commission and signing the lease in May 2015, the basics like cleaning the building and improvements that would allow buses to even enter the facility were not permitted and completed until September 2015. To then have an operational manufacturing line ready was not possible. Many key components had order and delivery timelines that exceeded 6 months.

Finalizing the factory for manufacturing was not the only challenge. There was also the time-consuming search for a manufacturing leader and then all the employees necessary. It took over 6 months to find an experienced leader for the manufacturing plant. Proterra learned that in California every aspect of establishing and scaling manufacturing from scratch takes longer than anticipated.

The Proterra objective set for bus sales and production, has been exceeded on the sales side. The objective was to manufacture and sell 424 buses. Proterra has been able to sell over 500 buses during the term of the agreement however the manufacturing has fallen short with the factory producing 60 buses to date.

Early in the project it became clear to Proterra the objective for buses was entirely too aggressive for many reasons. The first challenge that fed into the objective was that the production numbers were based on a fully operational manufacturing line in place by December 2015. Once that did not happen the production numbers were going to be less than the planned objective before manufacturing even commenced.

The next challenge that contributed to the production shortfall was that despite the South Carolina manufacturing plant having been up and running for over 5 years it had never produced as many buses as the objective goal for the LA County facility in 3 years. In fact, the objective goal in year 3 exceeded production for any previous 3 years combined in South Carolina. Proterra had no manufacturing experience or supply chain experience at the levels anticipated in the objective. While objectives and goals are important, it is more important to set realistic objectives. Despite exceeding the employment objectives, the production objectives fell far short which is a clear indication of how aggressive the production goals were.

CHAPTER 6:

Conclusions

Amending the agreement to facilitate battery system manufacturing has been a success and the entire project to fund the design, development, and construction of Proterra's new state-of-the-art zero-emission, battery-electric transit bus manufacturing line in California has been a success too.

The Proterra bus manufacturing facility began operations and increased production is planned and on schedule to occur year over year and the battery system manufacturing facility is supplying two factories and other heavy duty manufacturers through technology transfer deals. As currently configured the factory has in a given quarter been able to build at a rate that would be 100 buses per year. The actual production varies by quarter due to customer configuration changes that must be accounted for when producing only a few buses for multiple customers on the production lines.

The factory could add a second shift, add a second line and a second shift to that line that would translate into over 400 buses per year. That number could rise as high as 450+ buses in a year depending on the number of customer buses in a build. The more orders of like buses the greater the ability of the factory to produce. While the production numbers are not as high as projected in the agreement the job creation has exceeded the project goals.

By developing world class battery systems Proterra has been able to exceed the sales objectives which ultimately make the entire project a success. The backlog guarantees the factory will not only continue to manufacture buses but that it will continue to increase production and create more and more jobs in California.

GLOSSARY

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

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

COMPRESSED NATURAL GAS (CNG)—Natural gas that has been compressed under high pressure, typically between 2,000 and 3,600 pounds per square inch, held in a container. The gas expands when released for use as a fuel.

GREENHOUSE GAS (GHG)—Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (NO_x), halogenated fluorocarbons (HCFCs), ozone (O₃), per fluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).