CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

California ZEV Fast-Charging Infrastructure Manufacturing Expansion Project

Prepared for: California Energy Commission

Prepared by: ChargePoint, Inc.

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PREFACE

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

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

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- 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 GFO-18-605 to fund projects that support the manufacture of zero-emission vehicle (ZEV) and ZEV infrastructure technologies. In response to GFO-18-605, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 11, 2019 and the agreement was executed as ARV-19-070 on August 14, 2019.

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ABSTRACT

During this project funded by the California Energy Commission, ChargePoint increased its California-based manufacturing capacity for its Express 250 product line – a direct current fast charger. ChargePoint also established manufacturing processes for its new direct current fast charger product, Express Plus. This project brought several economic benefits to the state, including California-based job growth, business for California-based vendors and sales tax revenue for California jurisdictions. ChargePoint's direct current fast charger's also brought environmental benefits to California and beyond, by displacing gasoline-based travel and reducing greenhouse gas, NOx and PM 2.5 emissions.

Keywords: Electric vehicle charging stations, direct current fast chargers, DCFC, transportation electrification, manufacturing, jobs, California, ChargePoint

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EXECUTIVE SUMMARY

Transportation accounts for more than 40 percent of California's greenhouse gas emissions – with conventional cars, trucks and buses responsible for most of these emissions. Conventional vehicles also emit nitrogen oxides, particulate matter and other pollutants that cause respiratory, cardiovascular and reproductive health problems. In light of the urgent need to slow the effects of climate change, improve public health, and mitigate the economic impacts associated with each of these problems, California has instituted a suite of ambitious goals and policies to transition to a clean transportation sector. This includes a target that all new car and passenger truck sales will be zero-emission vehicles by 2035 and 250,000 electric vehicle (EV) charging stations will be active by 2025. The transition to electric transportation is well underway, as evidenced by the growth in EV market share in the state from less than 7 percent in 2019 to more than 15 percent in 2021. Deployments of EV charging stations also have grown rapidly, and various government initiatives are accelerating these efforts.

In 2019, the California Energy Commission awarded funding to ChargePoint to scale up manufacturing of its direct current fast charger (DCFC) product lines, expand related supply chains and expand EV charging manufacturing-related job opportunities in California. ChargePoint applied this grant to improve various assembly and test processes for its Express 250 product line, enabling an increase in California-based manufacturing capacity to more than 60 dispensers per week per shift. ChargePoint also established processes for its new Express Plus product, adding to its California-based manufacturing capacity for DCFCs.

This project brought several economic benefits to the state. The number of California-based jobs supporting ChargePoint's DCFC manufacturing operations grew by 106 since 2019 when the project began. California-based sales and support jobs grew by 38 jobs. And because ChargePoint is headquartered in California, many other supporting job functions are based in the state as well. ChargePoint's DCFC manufacturing and testing teams source equipment and parts from more than 110 suppliers based in California. For prototyping new DCFC products, ChargePoint has spent nearly $90 million with California-based vendors over the last three years. Sales of ChargePoint's DCFC products generated more than $1.1 million in state and local sales tax for California jurisdictions.

ChargePoint's DCFCs also brought environmental benefits to California and beyond during this project. More than 2,300 ChargePoint DCFC dispensers were deployed globally; these fast chargers dispensed enough electricity to enable 107.8 million electric miles of travel, resulting in emissions reductions of 22,100 metric tons of greenhouse gases, 138,900 pounds of nitrogen oxides and 2,540 pounds of particulate matter 2.5. Within California, 535 DCFC dispensers were deployed, and 143 of these were in Disadvantaged Communities. The 143 DCFCs reduced NOx emissions by 9,400 pounds and PM 2.5 by 170 pounds in these areas disproportionately impacted by economic, health, and environmental burdens.

CHAPTER 1: Introduction

Transportation accounts for more than 40 percent of California's greenhouse gas emissions – with conventional cars, trucks and buses responsible for most of these emissions. Conventional vehicles also emit nitrogen oxides, particulate matter and other pollutants that cause respiratory, cardiovascular and reproductive health problems. In light of the urgent need to slow the effects of climate change, improve public health, and mitigate the economic impacts associated with each of these problems, California has instituted a suite of ambitious goals and policies to transition to a clean transportation sector. This includes a target that all new car and passenger truck sales will be zero-emission vehicles by 2035 and 250,000 electric vehicle (EV) charging stations will be active by 2025. The federal government has also set targets for half of new car sales to be zero-emission vehicles in 2030 and made a commitment to support the installation of 500,000 new public charging stations.

The transition to electric transportation is well underway, as evidenced by a rapid evolution of the EV market just within the last few years. EVs increased from less than 2 percent of the national car market share in September 2019 to more than 5 percent in September 2021. A significant portion of EV sales take place in California, where the EV market share increased from less than 7 percent to more than 15 percent over the same period. In total, more than 2.1 million EVs have been sold nationally, including more than 900,000 in California, since 2011.[1] Other recent market developments include several vehicle manufacturers' release or announcement of new EV models – including highly-anticipated body types such as the pickup truck – and/or plans to phase out internal combustion vehicles altogether. Furthermore, several entities that directly or indirectly control large fleets of vehicles – from companies with large delivery operations such as Amazon and PepsiCo to local transit agencies to transportation network companies such as Uber and Lyft – are taking significant strides toward electrification.

Equally important to the adoption of EVs is the deployment of EV charging stations. At the end of 2019, the Alternative Fuel Data Center reported nearly 62,000 EV charging ports in the U.S. and Canada. This grew to nearly 142,000 EV charging ports by January 2022. Of these, roughly 25,000 DCFCs and 117,000 are Level 2 chargers. Within California, there were nearly 7,000 DCFCs and 34,000 Level 2 ports in January 2022, for a total of more than 40,000.[2]

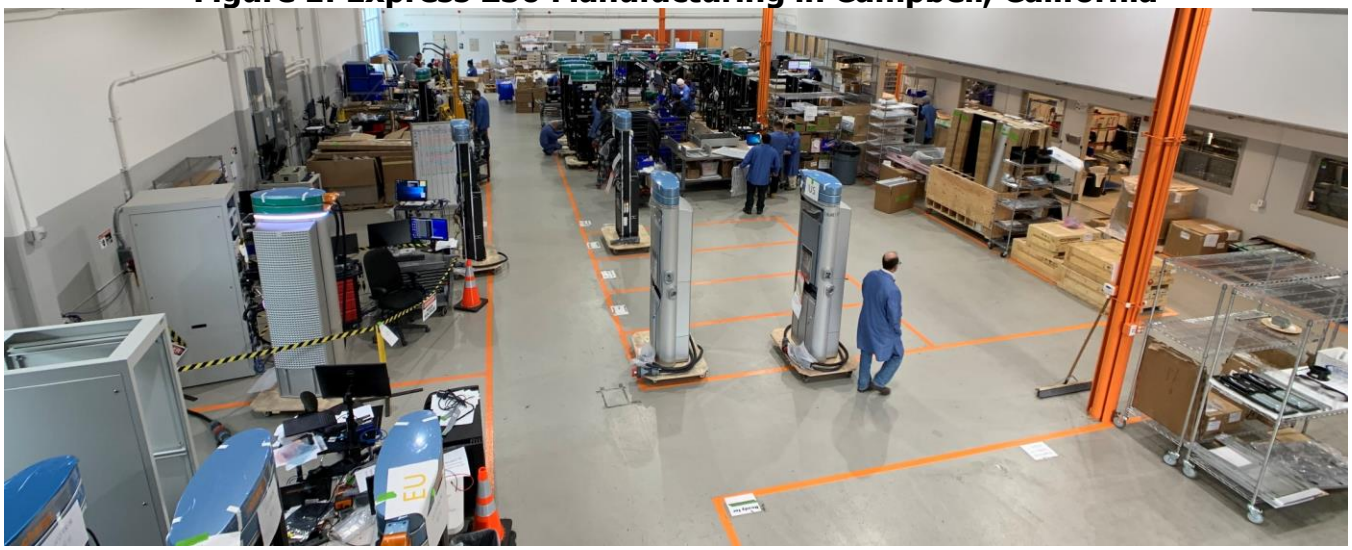
Federal, state, and local governments are accelerating transportation electrification efforts with a variety of financial incentives, mandates, and other policies to help the market meet the ambitious goals. One such effort to accelerate the deployment of DCFCs is the focus of this report. In 2019, the California Energy Commission awarded funding to ChargePoint to scale up manufacturing of its DCFC product lines (Figure 1), expand related supply chains and expand

[1] Alliance for Automotive Innovation (2021). Advanced Technology Vehicle Sales Dashboard. Data compiled by the Alliance for Automotive Innovation using information provided by HIS Markit (2011-2018, Nov 2019-2021) and Hedges & Bo. (Jan 2019-Oct 2019). Data last updated 12/15/2021. Retrieved January 19, 2022 from Automotive Innovation website, https://www.autosinnovate.org/initiatives/energy-and-environment/electric-drive.

[2] Alternative Fuel Data Center. Retrieved January 19, 2022 from Department of Energy website, https://afdc.energy.gov/stations/#/find/nearest?fuel=ELEC&ev_levels=dc_fast.

EV charging manufacturing-related job opportunities in California. ChargePoint applied this grant to its Express 250 product line, first launched in 2018, and established new manufacturing and testing processes for its recently launched Express Plus line. This report summarizes the improvements made to ChargePoint's manufacturing operations, the jobs and economic benefits associated with ChargePoint's manufacturing and DCFC sales, and the environmental benefits associated with the DCFCs deployed during the project.

Figure 1: Express 250 Manufacturing in Campbell, California



Credit: *ChargePoint, Inc.*

CHAPTER 2:
Product Overview

Express 250

The Express 250 delivers up to 62.5 kW to fast charge electric cars, buses, trucks and off-road equipment. At the heart of each Express 250 are two 31.25 kW Power Modules which convert alternating current to direct current (Figure 2). The Power Modules are housed inside a dispenser that includes two connector types (CHAdeMO and CCS Combo) and an LCD screen that enables drivers to easily interact with the station. The Express 250 also can be installed in a paired configuration, allowing two dispensers to share 125 kW of power.

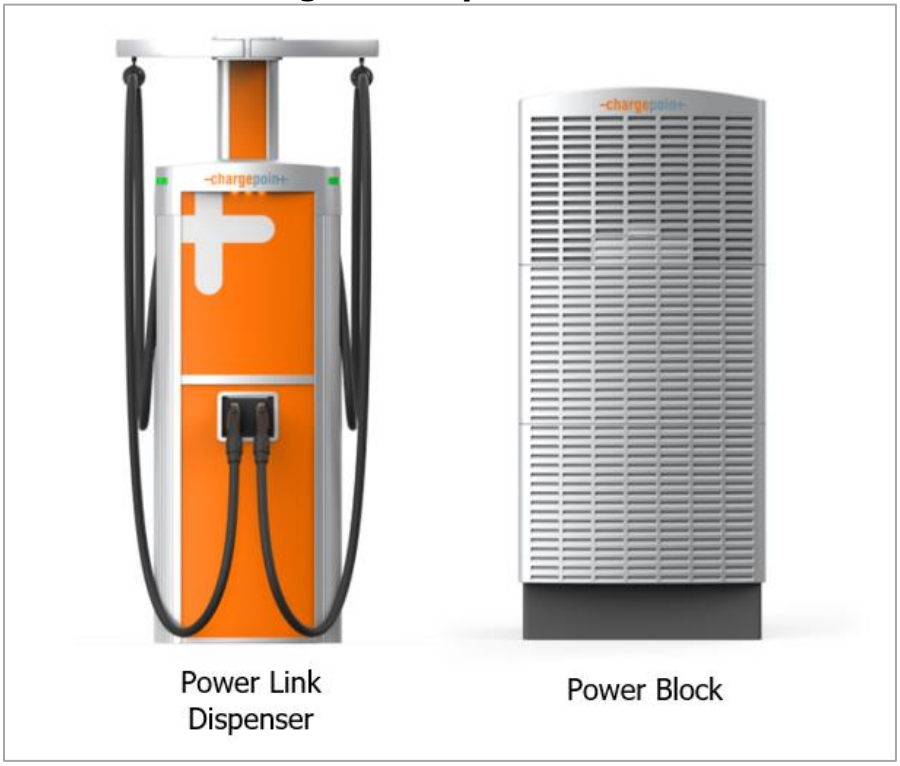
Figure 2: Express 250

Credit: *ChargePoint, Inc.*

Express Plus

The Express Plus is a modular and scalable DCFC platform that delivers even higher power than the Express 250. At the heart of each Express Plus is one or more Power Blocks, each containing up to five Power Modules (Figure 3); the new generation of Power Modules produce 40 kW each. The platform can be installed in various configurations, including two Power Link dispensers sharing one 200 kW Power Block or one Power Link drawing from two Power Blocks (offering up to 350 kW to a single vehicle). The modular nature of the system allows station owners to scale to serve more vehicles or provide higher power to each vehicle, depending on their needs. Like the Express 250, the Express Plus dispenser can include two connector types (CHAdeMO and CCS Combo) and an LCD screen that enables drivers to easily interact with the station. Not all use cases require both connector types and many fleet applications do not require the user interface offered by the LCD screen, so these items are optional.

Figure 3: Express Plus



Credit: *ChargePoint, Inc.*

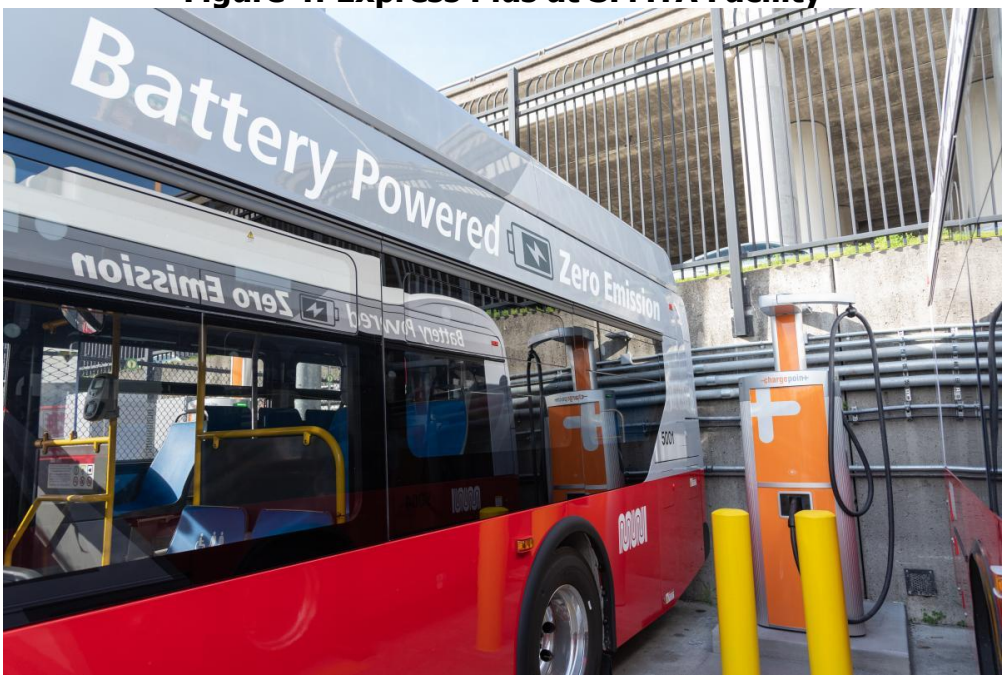
Both DCFC product lines (as well as ChargePoint's Level 2 charging products) operate on the ChargePoint network, which enables drivers to easily find and use stations, station owners to view station utilization data and manage pricing and power allocations, and ChargePoint to remotely monitor its stations to proactively identify and troubleshoot potential problems.

Use Cases

DCFCs are typically used to serve EVs that need to charge quickly and get back on the road or to charge medium and heavy-duty vehicles. (The exact charging time will depend on the size of the vehicle's battery, the battery's state of charge, the power offered by the charging station, ambient temperatures, and other factors.) They may be installed as a service available to any EV driver or in a "behind-the-fence" fleet application with access limited to a specific set of EVs. Entities installing publicly accessible DCFCs include fueling and convenience stores offering a new kind of fuel to its customers, local governments seeking to advance environmental goals or attract visitors, retail properties or apartment buildings seeking to attract customers or tenants, and many others. Any organization with a vehicle fleet – who often choose to electrify their vehicles to reduce total cost of ownership – can be a good candidate to install privately accessible DCFCs. Both the Express 250 and Express Plus can be installed for public or fleet use cases.

The San Francisco Municipal Transportation Agency (SFMTA) is an example of an early user of the Express Plus system. SFMTA has set a goal of transitioning its entire bus fleet to electric by 2040 and has completed its first round of e-bus procurement by ordering 12 e-buses from four manufacturers. To charge its new e-bus fleet, the agency has installed nine Express Plus Power Link dispensers (Figure 4).

Figure 4: Express Plus at SFMTA Facility



Credit: San Francisco Municipal Transportation Agency

CHAPTER 3:
Manufacturing Processes

ChargePoint reviewed and enhanced various aspects of the manufacturing process, including assembly and testing. Assembly processes were improved through new equipment such as a coolant fill/purge station to consistently fill Power Modules with coolant prior to testing and then drain a precise amount before packaging and transport (Figure 5), automated torque drivers to bolt down critical connections, a thermal paste dispenser to control the volume and pattern of thermal paste inserted into Power Modules, and a coordinate measuring machine to help ensure that mechanical piece parts meet specifications prior to assembly. Several test procedures were improved to increase capacity, reduce field return rates, and/or help improve safety, as described below.

- **Functional tests** ensure components operate properly before they are shipped to customers. ChargePoint increased the capacity for Power Module, Power Block and Power Block Auxiliary Power Supply functional tests and enabled troubleshooting, software development feature updates and other required activities without disrupting production.
- **Burn-in tests** weed out infant mortality assembly issues with components such as Power Modules and Power Block Auxiliary Power Supply. ChargePoint made the Power Module burn-in system more modular, allowing Power Modules to be tested in smaller batches, thus improving manufacturing efficiency.
- **High Potential (HiPot) test** injects a large amount of voltage into Power Modules and Power Block Auxiliary Power Supply to ensure current does not flow from one point to another; this test is required to meet UL safety standards (Figure 6). ChargePoint installed new equipment to automate processes, reduce potential for human error, increase safety and improve yields.
- **High voltage test** is a diagnostic test to characterize faults triggered by higher power levels. ChargePoint implemented software to automate this test for Power Modules and record diagnostic data to identify deficiencies, thereby improving field return rates and yields. ChargePoint also increased the capacity of the high voltage test for the Express 250 dispenser.
- **Low voltage test** is applied to the printed circuit board assemblies in the dispensers prior to applying 480V that could damage the circuit boards. ChargePoint expanded capacity of the low voltage test system, doubling throughput when capacity is needed and improving yields.
- Other test procedures improved include the field-replaceable unit test, ChargePoint Network Kit subassembly test, printed circuit board assemblies level test and contactor box test. These improvements led to improved yields and improved field return rates.

Figure 5. Coolant Fill/Purge Station.

Source: ChargePoint, Inc.

Figure 6. HiPot Test System.

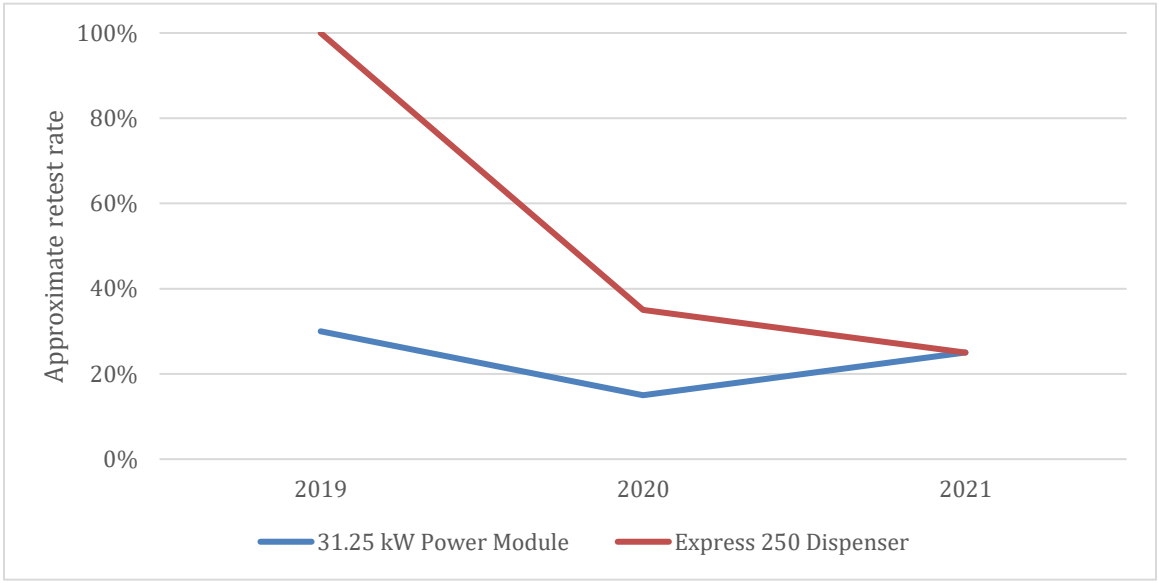
Source: ChargePoint, Inc.

CHAPTER 4:
Project Outcomes

Manufacturing Improvements

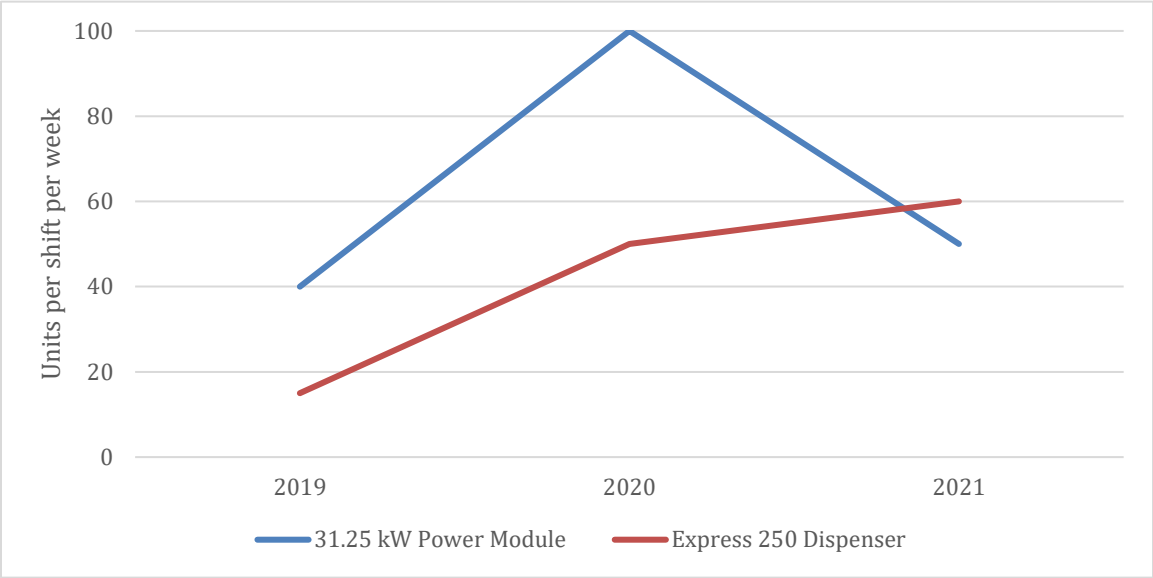
ChargePoint addressed two key manufacturing metrics for its Express 250 product line over the course of the project. For the Power Modules, the retest rate – i.e., the percentage of products that did not pass one of the tests described above, whether due to a bug in the product or a bug in the tester, and thus was retested – was reduced from approximately 30 percent in 2019 to approximately 25 percent in 2021 (Figure 7). California-based manufacturing capacity grew from 40 per week per shift to 50 per week per shift (Figure 8). For the Express 250 dispenser, ChargePoint also made improvements in the retest rate (from approximately 100 percent to 25 percent) and California-based manufacturing capacity (from 15 per week per shift to 60 per week per shift). The improvements in manufacturing capacity met the project's objective to achieve a capacity of at least 2,000 DCFCs per year. The increased capacity also will help meet an anticipated increase in demand for Buy-America-compliant EV charging products stimulated by the federal Infrastructure Investment and Jobs Act in the coming years.

Figure 7. Express 250 Retest Rates.



Source: ChargePoint, Inc.

Figure 8. Express 250 California-Based Manufacturing Capacity.



Source: ChargePoint, Inc.

The number of units produced and the location at which they are produced are influenced by manufacturing capacity, sales demand, and any limitations on component parts imposed by supply chain shortages, among other factors. Sales were temporarily impacted by the COVID-19 pandemic in 2020, while pandemic-related supply chain shortages were a significant issue in 2021 and beyond. In 2019, 3,298 Power Modules were produced, 2,478 of which were produced in California. In 2021, 14,611 Power Modules were produced, 191 of which were produced in California. Production of Express 250 dispensers rose slightly between 2019 and 2021 (1,183 units and 1,261 units, respectively), with a dip in 2020 primarily due to COVID-19 impacts. ChargePoint's 2019 production was enabled by a temporary approach of running two shifts, whereas production in later years was enabled by building out the capacity per shift. All Express 250 dispensers were produced in California.

ChargePoint also established its manufacturing processes for the new Express Plus product in 2021. While the testing process is still nascent, initial retest rates are approximately 85 percent for the 40 kW Power Module, approximately 100 percent for the Power Block and approximately 50 percent for the Power Link (Table 1). Retest rates for Power Block and Power Link represent high voltage tests only; the tester software for the Power Block is being fine-tuned and this retest rate is expected to come down to 15 percent or lower in early 2022. The manufacturing capacity of 42 Power Modules per week per shift, 10 Power Blocks per week per shift and 30 Power Links per week per shift add to the Express 250 capacity, which already exceeded the project's objective.

Table 1. California-Based Express Plus Manufacturing Capacity Metrics.

Component	Metric	2021
40 kW Power Module	Retest rate	~85%
	Manufacturing capacity	42/week/shift
Power Block	Retest rate	~100%
	Manufacturing capacity	10/week/shift
Power Link	Retest rate	~50%
	Manufacturing capacity	30/week/shift

Source: ChargePoint, Inc.

Express Plus production began in late 2021. COVID-related impairments (including shutdowns at supporting factories, logistics slowdowns, and travel restrictions) increased the time required to complete design iterations and delayed the start of production; 93 Power Modules, 35 Power Blocks and 90 Power Links were produced in 2021. Twenty-two of the Power Modules and all of the Power Blocks and Power Links were produced in California.

Adaptations for COVID-19 Impacts

As mentioned above, the COVID-19 pandemic had a significant impact on manufacturing operations and supply chain. At the beginning of the COVID-19 pandemic, ChargePoint scaled down manufacturing operations to meet shelter-in-place requirements. Over time, the company re-oriented the factory and production layout to ensure compliance with County guidelines for safe distancing and building capacity. In addition, on-site staff were tested weekly for COVID-19 and lab occupancy was closely tracked to mitigate risk of workplace exposure.

In anticipation of disruptions to supply chains, ChargePoint expanded its proactive measures in early 2020 and throughout 2021. Components expected to have increasing lead times, such as semiconductors, flame-retardant plastics, and charge cables, were ordered well in advance of typical release points. ChargePoint extended forecast horizons to suppliers to 36 months and established near-daily communication channels with a broader range of supply partners. Long-range clear-to-build surveillance, tight coordination with engineering to identify and qualify alternative material, and dedicated resources securing material through new channels combined to launch new production and expand output despite lead times stretching beyond two years.

Jobs and Other Economic Benefits

The manufacturing operations supported by this grant have brought several economic benefits to California, including jobs, business for California-based companies in the supply chain, and tax revenue. In 2021, 203 California-based jobs supported ChargePoint's DCFC manufacturing operations – an increase of 106 jobs since 2019 when the project began. In addition, 51 California-based sales and support jobs were based in California in 2021, an increase of 38 jobs since 2019. And because ChargePoint is headquartered in California, many other supporting job functions are based in the state as well including product management, engineering, marketing, and public private partnership managers. These data demonstrate

accomplishment of another important project objective: job growth from expanded manufacturing operations.

ChargePoint's DCFC manufacturing and testing teams source equipment and parts from more than 110 suppliers based in California. For prototyping new DCFC products, ChargePoint has spent nearly $90 million with California-based vendors over the last three years. Finally, sales of ChargePoint's DCFC products generated more than $1.1 million in state and local sales tax for California jurisdictions over the course of the project.

Environmental Benefits

More than 2,300 ChargePoint DCFC dispensers were deployed and activated globally during the course of this project (Table 2). These fast chargers dispensed enough electricity to enable 107.8 million electric miles of travel. Compared to equivalent travel in gasoline-fueled vehicles, this resulted in a reduction of 22,100 metric tons of greenhouse gases, 138,900 pounds of nitrogen oxides and 2,540 pounds of particulate matter 2.5.

Within California, 535 ChargePoint DCFC dispensers were deployed during this project; 143 of these are in Disadvantaged Communities (DACs), which are census tracts that most suffer from a combination of economic, health, and environmental burdens. The 143 DCFC dispensers in DACs enabled 7.3 million electric miles and reduced NOx emissions by 9,400 pounds and PM 2.5 by 170 pounds during the project.

Table 2. Emission Reductions Attributed to ChargePoint DCFCs Deployed during Project[3]

Charging equipment	Number of dispensers	Energy dispensed (kWh)	Electric miles enabled	Greenhouse gas reductions (MT)	NOx reductions (lb)	PM 2.5 reductions (lb)
DCFC dispensers deployed globally during project	2,338	33.7 million	107.8 million	22,1000	138,900	2,540
DCFC dispensers deployed in California during project	535	11.6 million	37.1 million	6,900	47,800	870
DCFC dispensers deployed in California DACs during project	143	2.3 million	7.3 million	1,400	9,400	170

Source: ChargePoint, Inc.

[3] Data presented for Express 250s and Express Plus activated on the ChargePoint network between August 2019 and December 2021; energy and environmental metrics calculated based on charging sessions conducted by this set of DCFCs through December 2021. Due to the time it takes to permit, install and activate utility service for a DCFC site, some DCFCs activated during the project were manufactured and sold before the project; similarly, some DCFCs manufactured and sold before December 2021 were not activated on the ChargePoint network until after December 2021.

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.

DIRECT CURRENT (DC)—A charge of electricity that flows in one direction and is the type of power that comes from a battery.

DIRECT CURRENT FAST CHARGER (DCFC)—DCFCs enable rapid charging, typically through 208/480V AC three-phase electrical service. These units provide 60 to 80 miles of range per 20 minutes of charging.[4]

DISADVANTAGED COMMUNITY (DAC)—Established in California Senate Bill 535, disadvantaged communities are areas that most suffer from a combination of economic, health, and environmental burdens. This report identified DACs using CalEnviroScreen 3.0.

ELECTRIC VEHICLES (EV)—A broad category that includes all vehicles that are fully powered by Electricity or an Electric Motor.

KILOWATT-HOUR (kWh)—The most commonly-used unit of measure telling the amount of electricity consumed over time. It means one kilowatt of electricity supplied for one hour.

LB— pounds

METRIC TONS (MT)— A unit of mass equal to 1000 kilograms.

NOx—Oxides of nitrogen that are a chief component of air pollution that can be produced by the burning of fossil fuels. Also called nitrogen oxides.

PM2.5—Includes tiny particles with an aerodynamic diameter less than or equal to a nominal 2.5 microns. This fraction of particulate matter penetrates most deeply into the lungs.

[4] Alternative Fuels Data Center, https://afdc.energy.gov/fuels/electricity_infrastructure.html