California Air Resources Board Zero- and Near Zero-Emission Freight Facilities Award – Zero Emission Beverage Handling and Distribution at Scale Project

December 2022

Submitted by:

Center for Transportation and the Environment

List of Acronyms

BEV – Battery Electric Vehicle
BYD – Build Your Dreams
CalEPA – California Environmental Protection Agency
CAN – Controller Area Network
CARB - California Air Resources Board
CTE - Center for Transportation and the Environment
DAC – Disadvantaged Community
ESG – Environmental, Social, and Corporate Governance
GVW – Gross Vehicle Weight
HVIP – Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
ICE – Internal Combustion Engine
KPI – Key Performance Indicators
LADWP – Los Angeles Department of Water and Power
NACFE – North American Council for Freight Efficiency
OEM – Original Equipment Manufacturer
RMI – Rocky Mountain Institute
SCE – Southern California Edison
SOC – State of Charge
ZANZEFF – Zero- and Near-Zero Emission Freight Facilities

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Executive Summary

The *Zero Emission Beverage Handling and Distribution at Scale* Project at the Anheuser-Busch Facilities was a four-year project beginning in March 2019 and completing in December 2022. This project is part of California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment – particularly in disadvantaged communities. This project deployed 21 Build Your Dreams (BYD) battery electric Class 8 Day Cab trucks and charging stations at three Anheuser-Busch facilities located in disadvantaged communities in the cities of Carson, Pomona, and Sylmar, California. At the Carson facility, solar generation was also installed and commissioned. Operating data for the trucks was collected for 15 months.

This project was successful in deploying trucks that met operational needs for the AB delivery routes, with an average uptime across the project timeline of 94.8%. These trucks met validation and performance requirements and entered into regular business operations. Throughout the project, numerous challenges allowed for learning opportunities. The telematics system posed a particular challenge in data tracking and reporting that required a custom solution from BYD. Charging cost management has been a project challenge as well, and the Center for Transportation and the Environment has made site-specific operational and charging recommendations for AB to minimize the cost-per-mile. CTE has found that the trucks have largely operated within DACs, therefore achieving the grant goal of emissions reduction in communities overburdened by pollution.

Dates: March 2019 – December 2022

Grantee: Center for Transportation and the Environment

Partners: Anheuser-Busch, BYD Motors LLC, ENGIE Services U.S., INC

Grant Amount:

CARB Contribution: $5,530,303
Matching Funds: $5,795,866
Project Total: $11,326,169

Vehicles/Equipment Funded:
21 Build Your Dreams Class 8 Trucks
21 BYD 40 kW chargers and associated infrastructure
958.5 kW rooftop solar array

Introduction

Project Team

The **Center for Transportation and the Environment (CTE)** is a nonprofit, 501(c)(3) organization that develops technologies and implements solutions to achieve energy and environmental sustainability. CTE is experienced in developing, implementing, and administering advanced transportation technology projects. CTE is the prime recipient of the grant funding and subcontracted with Anheuser-Busch as the fleet operator, BYD as the truck and charger manufacturer, and ENGIE as the infrastructure developer.

BYD is the original truck and charger manufacturer of the battery electric Class-8 Day Cab trucks and charging equipment for this project. In addition to providing equipment to service the needs of Anheuser-Busch, BYD also provided training for the operators and maintenance personnel alongside a full preventative maintenance program.

ENGIE Services U.S. was the infrastructure developer for this project. Engie managed the installation and commissioning of the 21 BYD chargers and a 958-kW solar array at Anheuser-Busch's Beach Cities distribution facility.

Anheuser-Busch is the end user for the project and worked with CTE to plan and manage the battery electric Class-8 Day Cab trucks and charging station deployment.

The Zero Emission Beverage Handling at Scale project is part of California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy, and improving public health and the environment particularly in disadvantaged communities.

Project Goals and Objectives

The purpose of this project was to accelerate the development and deployment of battery electric Class 8 delivery trucks to substantially reduce greenhouse gas and criteria pollutant emissions in freight facilities and to help provide economic, environmental, and public health benefits to disadvantaged communities.

The project was structured with five major tasks in an effort to meet the aforementioned goals.

1. Project management and administration
2. Development, build, and validation of 21 Battery Electric Class 8 trucks
3. Charging infrastructure and solar array design and construction
4. Completion of supporting activities necessary to prepare for the successful demonstration of the Battery Electric Class 8 trucks
5. Demonstrations and data collection

Project Background

The California Air Resources Board (CARB) is charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change. From requirements for clean cars and fuels to adopting innovative solutions to reduce greenhouse gas emissions, California has pioneered a range of effective approaches that have set the standard for air and climate programs for the nation and the world.

On March 31, 2018, CARB issued a Zero- and Near Zero-Emission Freight Facilities Project solicitation to provide funding for projects. In response to this solicitation, the Center for Transportation and the Environment (CTE) partnered with Anheuser-Busch, LLC, BYD Motors, Inc., and ENGIE Services U.S. Inc, collectively referred to as the "Project Team", to propose the Zero Emission Beverage Handling and Distribution at Scale Deployment project, which aimed to develop, validate, and deploy battery electric Class 8 delivery trucks at four Anheuser-Busch facilities located in disadvantaged communities in the cities of Carson, Riverside, Sylmar, and Pomona, and install 21 charging stations to support the vehicles, as well as install and commission solar generation at the Carson facility.

To realize these benefits and support their portfolio of battery technologies and applications, CARB awarded CTE's Zero Emission Beverage Handling and Distribution at Scale Deployment project under this agreement on October 8, 2018. CTE executed the contract with CARB on April 9, 2019.

Project Implementation

Overview

The project ultimately deployed 21 BYD Class 8 Day Cab (8TT) trucks and charging infrastructure in beverage handling and distribution services at three Anheuser-Busch (AB) distribution facilities in the Los Angeles region, and constructed solar energy generation at one of the locations to offset energy demand from the chargers. Based on input received from operators, for this project BYD made improvements to the range, acceleration, suspension, and ergonomics of the truck compared to previous generations to increase the range of applications that can be served by these battery electric trucks. This project demonstrates how to reach zero-emissions across the range of activities at AB distribution facilities with minimal modifications to fleet logistics.

With successful deployment of these Class 8 Day Cabs and rooftop solar, the team is developing the confidence and experience needed to expand this electrification initiative across an entire distribution fleet and is demonstrating the financial, operational, and environmental benefits of the technology. The project team consisted of BYD Motors LLC, the truck manufacturer; Anheuser-Busch, responsible for vehicle operation and maintenance; ENGIE Services U.S., Inc., the solar generation and charging infrastructure developer responsible for design and construction; and CTE, the overall project manager and technical consultant.

Change to Project: Riverside Relocation

The most significant change to this project after award was a result of Anheuser-Busch making a business decision to sell its Riverside facility. The project as proposed included four distribution centers, but after the Riverside facility was closed, Anheuser-Busch relocated the chargers and trucks assigned to that facility to its Pomona location.

Riverside Relocation

In July 2020, Anheuser-Busch made an internal business decision to close their distribution facility located in Riverside, California, and move its operations to the nearby Pomona facility, including the trucks and chargers that were planned for that site as part of the ZANZEFF project. While this relocation was certainly undertaken for legitimate business reasons internal to Anheuser-Busch, it also brought up many challenges for the completion of the project.

This resulted in a decrease in the number of deployment locations within the project from four to three, and there was a risk that some of the infrastructure would be moved from a Disadvantaged Community (DAC) to a non-DAC, as the Pomona site spans two census tracks, only one of which is designated a DAC. Anheuser-Busch agreed to cover all costs associated with the relocation and installed their chargers within the DAC portion of the Pomona site in order to preserve as much of the original intention of the grant as possible. CARB accepted this proposal and the changes to the project were reflected in a contract amendment.

The relocation imposed a schedule delay on the project, particularly due to electrical upgrades required at the Pomona site, which in turn delayed Anheuser-Busch's cost share incursion via truck operation. This postponement of cost share continued to affect the project budget thereafter.

Press/Outreach

There were multiple outreach events throughout this project.

Social Media and Initial Announcement

Anheuser-Busch completed a series of social media posts in an effort to publicize and communicate specifics for this project that are listed below.

- Initial Partnership announcement on Facebook, Instagram, Twitter, and LinkedIn
- CA Deployment Live Post on LinkedIn
- Latest Video Response on Twitter and LinkedIn.

The partnership is featured heavily on the sustainable logistics page of the Anheuser-Busch website and it was also mentioned in many different media interviews and speaking opportunities that Anheuser-Busch participated in throughout the years.

- https://www.anheuser-busch.com/community/initiative/logistics.html

Initial Deployment Press Release October 2, 2019

Anheuser-Busch, BYD, the Center for Transportation and the Environment (CTE), and ENGIE Services U.S. (ENGIE) announced that Anheuser-Busch will be deploying 21 BYD battery electric trucks in their California fleet as part of a state project to showcase economically and environmentally sustainable warehousing and distribution technology. This is a landmark achievement as the largest Class 8 electric truck deployment in North America.

'The Zero Emission Beverage Handling and Distribution at Scale' project will showcase BYD's second generation 8TT Class 8 electric trucks at four Anheuser-Busch distribution facilities across southern California: Sylmar, Riverside, Pomona, and Carson.

As part of the project, a southern California-based team from ENGIE will lead the design and installation of charging infrastructure at all four facilities. ENGIE will also be installing and commissioning a 958.5 kW solar array at the Carson site, which will generate zero-emissions power to offset the use of conventional energy in the charging process, further reducing emissions and resource consumption.

National American Beer Day 2020

The team conducted a social media event for National American Beer Day in 2020. Anheuser-Busch and BYD created a promotional video demonstrating the electric trucks on route. The video was shared by the project partners through their social media channels.

"Sustainable Supplier of the Year" Award

In 2020, Anheuser-Busch named BYD their sustainable supplier of the year at their Eclipse Sustainability Summit. BYD was commended for their innovative technology and collaborative partnership. Alongside the press release for this award, BYD includes the "Hard at Work" video, showcasing the trucks in action and closing with a image of the rooftop solar array.

Zero-Emission Beer Delivery for Super Bowl 2022

Figure 1: BYD Truck at loading dock. Source: Anheuser-Busch

In preparation for Super Bowl 2022 hosted in Los Angeles on February 13, 2022 Anheuser-Busch partnered with Nikola Corporation and BYD Motors to deliver Bud Light NEXT, a first-ever zero-carb beer with a zero-emission delivery footprint.

The transport of Bud Light NEXT from Anheuser-Busch's brewery in Van Nuys, CA to bars in the Los Angeles area was a partnership of innovative technologies and logistics. Nikola's Tre hydrogen fuel cell electric vehicle (FCEV) picked up a load of beer from Van Nuys and delivered it to the Anheuser-Busch AB One distribution facility in Carson, CA. From the AB One facility, a BYD battery-electric 8TT day cab tractor transported the beer to local bars and retailers in preparation for Super Bowl Sunday celebrations.

February 2022 also marked the expansion of Anheuser-Busch's partnerships with Nikola and BYD Motors as part of AB's Environmental, Social, and Corporate Governance (ESG) plan and 2025 Sustainability Goals, which includes a global net-zero ambition.

Anheuser-Busch and Nikola implemented a three-month pilot launch February - April, 2022 of two Nikola Tre alpha FCEVs running daily service in AB's Southern California network.

Anheuser-Busch is adding an additional 20 BYD battery-electric trucks into their California distribution facilities fleet in 2022. The fleet expansion was made possible by funding received from California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) and continued partnership with the California Air Resources Board (CARB) and CALSTART to deploy zero-emission vehicles.

Run on Less – Electric (RoL-E) Event

The North American Council for Freight Efficiency (NACFE) and Rocky Mountain Institute (RMI) hosted "Run on Less," a three-week, real-world truck technology demonstration in 2021. The event featured truck fleets hauling real freight on daily service routes.

Every two years, NACFE conducts an in-depth report on new technologies deployed. Focused on BEVs, the Run on Less event tracked 10 different vehicle fleets for a one-month period to monitor efficiency and gain insight on BEVs. Anheuser-Busch applied in April 2021 for RoL-E and was selected as a participant. Anheuser-Busch chose one BYD battery-electric truck from their Pomona site (truck 40368) as a representative truck to be tracked via Geotab to evaluate overall performance.

Anheuser-Busch and the California Air Resources Board (CARB) reviewed and confirmed all requirements were met for the press release prior to the start of the event. Filming sessions for RoL-E 2021 took place onsite at Anheuser-Busch's Pomona, CA facility on June 16 and 17, 2021. BYD staff, Anheuser-Busch staff, and the Pomona truck operator were interviewed for event video content and participant profiles.

Charge Ready Transport

Case Study: Anheuser-Busch

Southern California Edison (SCE) published a case study about the deployment of AB's electric trucks from their Southern California facilities. In particular, they highlighted the project's success due in part to early communication with the electric utility. SCE's Charge Ready Transport case study used this AB project as an example of a project that could benefit from their Charge Ready Transport program. Charge Ready Transport can support truck deployment on multiple components: coordination of the timing of the construction of charging infrastructure, coordination of the delivery of the electric vehicles, and education about incentives available through Southern California Edison. SCE champions this project as an example of successful local delivery with electric vehicles and how their Charge Ready Transport program is ready to work with other businesses on fleet electrification.

Project Administration

Planning

It is important to note that Anheuser-Busch's efforts to deploy battery electric Class 8 trucks in their fleet began long before the CARB ZANZEFF solicitation was released. Anheuser-Busch and BYD had been in discussions for many months prior to the solicitation, including conducting preliminary vehicle tests. This work was vital to developing a successful proposal, being able to start the project immediately upon award, and working toward execution of a clearly defined scope on a tight timeline. There were about 15 months from execution of CTE's contract with CARB to putting trucks in service. This timeline included testing a first article generation II truck, production, shipment, and delivery, as well as design, construction, and installation of the chargers, with the COVID-19 pandemic beginning just under a year after CTE's contract with CARB was executed.

One consequence of the extensive amount of upfront work that Anheuser-Busch and BYD had completed prior to contract execution was that none of that effort could be captured as cost-share. As a result, much of the cost share contributed to this project was sourced from Anheuser-Busch's operating costs. Unforeseen project delays, such as those related to TUV certification (see "Charging Infrastructure") reduced the operating time on the vehicles, resulting in a need to extend the project timeline to accumulate the committed cost share.

Funding

The team was awarded the full amount requested and successfully executed the overall project with the grant funds allocated, although the timeline for the project did need to be extended in order to enable the team to continue accruing cost share to meet the grant requirements.

Source	Amount
CARB Contribution	$5,530,303
Matching Funds	$5,795,866
Project Total	$11,323,169

Table 1: Funding Sources

AB Site	Trucks	Chargers	Additional Infrastructure
Pomona	4 BYD Class 8 Day Cab (8TT) trucks	4 40kW BYD Chargers	N/A
Riverside	4 BYD Class 8 Day Cab (8TT) trucks	4 40kW BYD Chargers	N/A

Sylmar	5 BYD Class 8 Day Cab (8TT) trucks	5 40kW BYD Chargers	N/A
Carson	8 BYD Class 8 Day Cab (8TT) trucks	8 40kW BYD Chargers	958 kW Rooftop Solar

Table 2: Vehicles and Equipment Funded

Another important note is that the funding for this project created an early challenge with respect to the contracting structure for the project. The team was originally structured so that each partner would be a direct subcontractor to CTE so that all payments would flow from CARB through CTE to the partner directly and all cost share would be handled the same way. However, the project budget had some of the grant funds contributing to the cost of the trucks. If CTE were to receive those funds from CARB, CTE would effectively become the owner of the trucks until such time as the funds were transferred to BYD. CTE would have to take title of them and be legally responsible for the vehicles. It was not feasible for CTE to assume these obligations, so CTE structured the project such that BYD and AB executed a purchase order for the vehicles. AB purchased the trucks from BYD, then submitted an invoice to CTE and CARB for the cost of the vehicles and was reimbursed for the cost incurred. CTE also held separate contracts with both Anheuser-Busch and BYD to capture their obligations under the project and provide a mechanism for capturing cost share.

A key lesson learned was that the federal excise tax on Class 8 trucks is significant (12%). The tax is based on the cost of the vehicle. Since the cost of electric vehicles is often higher than the cost of diesel-powered vehicles, this creates an additional financial burden on the customer seeking to purchase electric vehicles.

Pre-Deployment

Truck Build and Testing

In mid-2019, BYD and Anheuser-Busch collaborated on the Gen II Truck Trials. The two companies had previously conducted a test of the first-generation truck, and Anheuser-Busch had requested specific changes to the truck to better meet Anheuser-Busch's operational needs, including modifications related to both electric vehicle specific performance, such as range and charging time, and those related to Anheuser-Busch's business operational requirements, such as the truck length and including a fifth wheel to allow connections with end loading trailers. These trials were meant to demonstrate that the 2019 Class 8 tandem-axle trailer met those requirements. A truck was deployed in regular delivery service from the Sylmar distribution facility between April 22nd and 25th in 2019, and from the Beach Cities facility between April 29 and May 2, 2019. A mobile charger powered by a diesel generator was used to charge the truck during the eight day demonstration.

Category: Expectation	Verification Method
1 - Suspension: **Air Based suspension system on front and rear suspension (minimum cab air ride suspension)**	AB Inspection
2 - Truck length: **No longer than 186 inch wheelbase**	AB Inspection
3 - Fifth Wheel: **Sliding fifth wheel attachment to allow connection with side loaders**	AB Inspection
4 - Torque: **1,770 lb* ft**	TBD—only needed if fails to meet performance expectation
5 - Horsepower: **Above 480 HP**	TBD—only needed if fails to meet performance expectation
6 - Downhill Performance: **Motor braking downhill, increased downhill resistance**	AB Test Routes-Subjective
7 - Acceleration: **can achieve 35mph under 1 min on 3% grade on full load**	AB Test Routes

8 - Acceleration: **90 Second 0-50 on 0% grade truck**	AB Test Routes
9 - Acceleration: **Ability to adjust gear ratios (Reverse gear ratios)**	AB Test Routes-Subjective
10 - Top speed: **65 MPH on flat grade at 80,000 GVW**	AB Test Routes
11 - Braking: **Air brake-based system compliant with DOT regulations**	AB Inspection or CHP inspection
12 - Visibility: **Heated Mirrors, minimum 8" longer then Gen 1**	AB Inspection
13 - Range: **Over 100 miles fully loaded in our operation (with 3% grade on 5 miles)**	AB Test Routes
14 - Range: **Battery time and distance notification capability**	AB Inspection
15 - Charging capability: **Full charge under 12 hours for AC / under 4.5 hours for DC**	AB Test Routes
16 - Safety: **Platform attachment to step up onto catwalk**	AB Inspection
17 - Comfortability: **Track seat capability so seat can be slid forward and back and adjusted upward and downward, air ride seat for driving comfort**	AB Inspection
18 - Comfortability: **Telescoping steering wheel, and ability to adjust steering wheel angle.**	AB Inspection
19 - Comfortability: **Additional handle for 3 points of contact when climbing up into cab.**	AB Inspection

20 - Comfortability: **Distance from the front of our seat to the steering column is 10.5”. The distance from the seat up to the steering wheel is 9.0”.**	AB Inspection
21 - Maintenance: **SLA of 95% up time during first 2 years of operation, replacing plan (short term rental) of asset if truck availability falls below**	BYD Service Agreement
22 - Maintenance: **Diagnostic packages on future models, for our own use**	TBD

Table 3: Gen II truck requirements

The trucks were sent out on several different routes, ranging from 18 to 105 miles, in a wide variety of environments within the greater Los Angeles area. Each route had a different driver and payload, and they served several different types of customers, giving a comprehensive picture of electric truck operations within Anheuser-Busch’s delivery operations.

In addition to usual operations, Anheuser-Busch and BYD conducted two truck performance tests. The charging test, conducted on April 19, 2019 was meant to evaluate the charging speed and efficiency of the chargers. This test took 10 hours and 10 minutes to charge 347.7 kWh, from 15% to 100%, for an average charging rate of 34.2 kW. In addition, the long-range test, conducted on April 30, 2019 was meant to test the range of the truck on Anheuser-Busch’s longest delivery routes. With an estimated 13,720 lb payload, the truck drove a 105-mile route from the Beach Cities facility to Malibu, consuming 65% of the battery and 265.85 kWh for a total energy efficiency of 2.5 kWh/mi.

Charging Infrastructure

The charging infrastructure was selected for this deployment prior to project award, so the team was able to begin design immediately after contract execution. This accelerated the timeline but also reduced the ability to optimize the charging infrastructure for this particular application at these particular facilities. While the power levels chosen were appropriate for the application, there was limited functionality in terms of automating charging times, which may have resulted in higher operating costs to Anheuser-Busch. This is described further in the Preliminary Financial Analyses section.

A key lesson learned from this project is to ensure required equipment certifications are addressed during the design and engineering phase of the project. This is especially important as new products are developed in the zero-emission transportation sector. At the start of this project, the BYD chargers that were planned to be implemented did not have a factory UL or TUV certification. As a result, the chargers needed to be field-certified so that the engineer of record would approve the installation and use of the chargers. The field certification process introduced additional risk into the project and it caused significant schedule delays, though some of the delays could be attributed to the travel restrictions implemented as a preventative measure during the COVID-19 pandemic.

Pre-Deployment Financial Analyses

CTE performed a charging requirements analysis to assess the cost sensitivity to time-of-use electricity pricing at Anheuser-Busch's four sites. Under a typical utility structure for a large-scale operation like an Anheuser-Busch distribution center, both the energy and demand costs can differ significantly depending on the time of day that charging occurs. By only charging during off-peak hours, all of the higher energy and demand costs associated with on-peak hours could theoretically be eliminated. For each of the four Anheuser-Busch sites with BYD electric trucks (the Riverside location was still intended to be used during this phase of the project), this analysis intended to assess the feasibility of charging exclusively during off-peak hours, evaluate the operational implications, and quantify the financial consequences of adopting such a strategy. This compared Anheuser-Busch's baseline operational approach to one where mileage was maximized and charging was optimized to minimize fuel cost per mile.

The CTE analysis varied based on the three different electricity providers for the four facilities. In the baseline scenario, the CTE analysis assumed that the trucks would be plugged in immediately upon returning from operation at 1:45 PM, and that they would have used 35% state of charge over the course of the day. The individual site analysis vary in charging strategy and assume a maximized mileage based on available charging time to evaluate a "best case" cost per mile.

Due to the fact that Anheuser-Busch's utility rates are proprietary, CTE determined a plausible rate structure at each of the four sites based on the assumption that the baseline facility loads are 200-500 kW. Carson and Pomona were assumed to be under the Southern California Edison (SCE) TOU-GS-3 rate structure. Sylmar was assumed to be under the Los Angeles Department of Water & Power LADWP A-3 rate structure. Riverside was assumed to be under the Riverside Large General and Industrial Service rate structure. CTE did not account for potential changes to the rate structures resulting from increased electricity loads from charging or, in the case of Carson, the addition of a solar array.

When assessing operational impacts, the CTE analysis assumed that the trucks at each site would run from 4:00 AM to 1:30 PM four days a week, loaded from 8:30 to 10:00 PM, and that charging would not be possible while loading.

When assessing cost per mile under the various charging scenarios, CTE assumed that Anheuser-Busch would run the maximum number of miles given the time available to charge, down to 30% state of charge SOC. This means that Anheuser-Busch was assumed to be able to run more miles than in the baseline cost per mile calculation, which assumes the trucks will only run down to 65% state of charge. Since both the fixed and demand costs are not dependent on truck mileage, increasing utilization will lead to a lower cost per mile for the trucks. Assumptions regarding charging power, battery capacity, energy efficiency, and related performance metrics were taken from the results of the Gen II truck trials.

- At Carson and Pomona, which are served by Southern California Edison, cost per mile could be reduced significantly by exclusively charging off-peak. At Carson, cost per mile could be reduced from $2.71 to $0.47, an 83% reduction. At Pomona, cost per mile could be reduced from $2.75 to $0.49, an 82% reduction.
- At Sylmar, which is covered by the Los Angeles Department of Water and Power, by exclusively charging off-peak and moving the loading time to on-peak hours, cost per mile could be reduced from $0.64 to $0.31, a 52% reduction.

- At Riverside, which is covered by the City of Riverside Public Utilities Department, by performing some charging on-peak and maximizing mileage, cost per mile could be reduced from $0.74 to $0.49, a 34% reduction.

Table 4: Summary of Cost Analysis

Site	Strategy	Annual Miles	Annual Cost	Cost per mile
Carson (SCE TOU-GS-3)	Charge at all times of day, use only 35% of battery capacity	93,448	$253,133.17	$2.71
	Charge off-peak, possibly move loading to on-peak, maximize mileage	217,293	$101,982.27	$0.47
Pomona (SCE TOU-GS-3)	Charge at all times of day, use only 35% of battery capacity	46,724	$128,492.53	$2.75
	Charge off-peak, possibly move loading to on-peak, maximize mileage	108,647	$52,964.28	$0.49
Sylmar (LADWP A-3)	Charge at all times of day, use only 35% of battery capacity	58,405	$37,556.53	$0.64
	Charge off-peak, move loading to on-peak, maximize mileage	119,673	$61,484.22	$0.31
Riverside (Riverside Large General and Industrial Service)	Charge at all times of day, use only 35% of battery capacity	46,724	$34,444.67	$0.74
	Charge on-peak sometimes and maximize mileage	95,739	$47,320.12	$0.49

Deployment and In-Service Vehicle Operation

Once the planning process was completed, the team prepared for delivery of the vehicles. The timeline between vehicle delivery and in-service vehicle operation was delayed for a few different reasons. In addition to TUV certification process delays described above, there were delays in truck registration due to the COVID-19 pandemic. There was a requirement that the registrations be done in person that stayed in place throughout the project, and it was difficult to schedule these in-person appointments during the early stages of the pandemic. Additionally, the DMV would not accept credit card payments, which caused some delay in registration, as multiple in-person appointments needed to be scheduled. This all meant that the trucks were be parked at Anheuser-Busch's facilities for some time after delivery before entering regular operation. The truck configuration is such that there are two main electrical systems on-board: a high-voltage system that includes the high-voltage batteries and drive system and a low-voltage system that operates many of the auxiliaries, similar to an internal combustion engine vehicle. Just as with a conventionally fueled vehicle, if the vehicle is not operated regularly, the low-voltage battery can be drained and need to be jump-started. BYD's truck has a switch to disconnect the low-voltage system, and it is important to do this if a truck is expected to be down for a period of time. There were times that the low-voltage system on the trucks was not disconnected and the low-voltage batteries were drained, ultimately leading to a need to replace the low-voltage batteries on the trucks.

However, once these issues were resolved, the trucks entered service gradually between August and October 2020. There were no challenges with vehicle range or performance on-route. Vehicle availability remained high throughout the deployment. Through the end of 2021, overall availability had averaged 94.8%, with similar values at the three deployment sites. This demonstrates that electric trucks have the potential to be highly reliable additions to commercial fleets. In addition, the overall fleet of BYD trucks had cumulatively traveled 189,586 miles up to that same point, a little over 9,000 miles per truck for the fourteen to seventeen months that they had been in operation up to that point. This is somewhat lower mileage than might be expected given this high rate of availability. This points to the relatively low rates of utilization that are discussed in the Truck Utilization section below. There is one fleet-wide maintenance issue that is being addressed at the time of this report. Anheuser-Busch identified cracking of the 5th wheel plate. Anheuser-Busch's observation of the issue is that a combination of the height the plate was mounted (~2" higher than standard) and the BYD truck sloping forward instead of being parallel to the group caused the cracking. Anheuser-Busch is replacing all plates on the trucks and adjusting the 5th wheel height to address the issue. Otherwise, the trucks have operated with no major maintenance issues.

Figure 2: Trucks parked awaiting inspection, December 2020

In-Service Validation Testing

During the early days of deployment, the team conducted validation testing. The goal of validation testing was to confirm that the vehicles were meeting Anheuser-Busch's operational needs once they entered service. All vehicles performed as expected. **Table 5** outlines the validation requirements of the project vehicles.

Table 5: Validation Testing Requirements

Requirement ID	Validation Test	Description
41	Downhill Performance	Motor braking is available on downhill segment
42	Acceleration 1	Truck is able to achieve 35mph in less than 1 min on a 3% grade with a normal load
43	Acceleration 2	Truck can accelerate from 0-50 mph in 90 seconds on a 0% grade
44	Acceleration 3	Ability to adjust the power and torque delivery for reverse operation
45	Top Speed	Truck can achieve 65 MPH on 0% grade at 80,000 GVW
46	Range 1	Truck can achieve 100 miles of range starting with 100% SOC, with normal load and normal operating condition
47	Charging Capability	Charge from 15% SOC to 100% SOC in under 12 hours using AC charger
48	Range 2	Truck can achieve 150 miles of range

CTE validated two of the performance requirements (Requirement IDs 46 and 47) vehicles while the vehicles were in revenue service. Geotab was the telematic data provider for CTE's analysis in this project.

Results

100-Mile Range Test

The 100-mile range test (ID 46) was completed in service on September 3, 2020 by vehicle 40363. It traveled 113 miles and carried 42,000 pounds. **Figure 3** shows where the vehicle made deliveries on this day relative to the greater Los Angeles area. At the end of the trip, it still had a SOC of 45.6%.

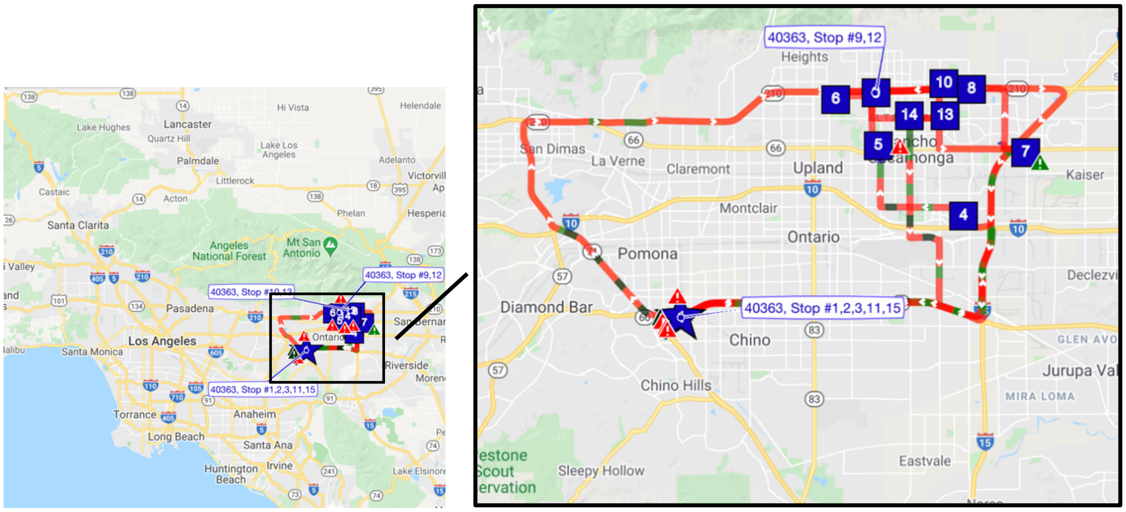


Figure 3: 100-Mile Range Validation Test Location and Route

Table 6 outlines the various requirements that were met by this day's revenue service for the purposes of CTE's validation testing.

Table 6: 100-Mile Validation Test Requirements and Results

Requirement	Validating Data	Additional Description
100-miles of range	113 miles traveled	n/a
100% SOC at start	SOC charged from 65% to 100% on September 2, 2020.	The vehicle was charged to 100% SOC the night before.
Normal load	42,278 pounds of load	The average load that this vehicle carried over the months of August and September was 25,900 pounds, which was exceeded by this test.
Normal operating conditions	Operation with typical drivers, routes, speeds, and weather conditions	The vehicle was placed into service throughout August and September without any mention of circumstances that would deem the operating conditions abnormal.

The 12 Hour Charge Test

On October 29, 2020, vehicle 40383 was charged from 6% SOC to 100% SOC using the AC charger. This charge lasted 10 hours and 45 minutes. The charge took place at 20499 S Reeves Ave, Carson, CA 90810.

A total of 428 kWh was discharged by the charger. Given that the nameplate capacity of the vehicle is 409 kWh, the charger output confirms that the vehicle was charged to completion, and that some energy was lost to heat and other charging equipment inefficiencies.

Table 7 outlines the various requirements that were met by this day's revenue service for the purposes of CTE's validation testing.

Table 7: 12 Hour Charge Test Requirements and Results

Requirement	Validating Data	Additional Description
15% - 100% SOC charge profile	6% - 100% SOC charge profile	This charge session met and exceeded the 15% - 100% SOC charge requirement range.
Less than 12-hour charge duration	10 hours and 45 minutes were used to complete this charge.	n/a
AC charger	The AC charger at Anheuser-Busch's vehicle depot was used.	n/a

Truck Utilization

In mid-2021, the project team became aware that the Anheuser-Busch trucks were not meeting their deployment goals. Based on Anheuser-Busch's cost share submissions to CARB, the trucks were not being utilized with the frequency that was expected, and on shorter routes than expected, despite a general lack of maintenance issues keeping the trucks out of service or significant range concerns. This posed a risk to the project, as Anheuser-Busch was required to incur sufficient cost share by the end of the grant period, and a significantly lower rate of utilization would delay that match.

It was difficult to diagnose the reasons for this underutilization, since deployment decisions were made by the site managers at the three distribution facilities, and therefore separated from the Anheuser-Busch team managing the grant. Initially, it was found that utilization had been low due to issues with the low-voltage batteries on the trailer lift gates. This was a maintenance issue extrinsic to the trucks themselves. BYD implemented a fix in which a new relay would be installed, allowing a higher voltage to flow from the truck to the trailer.

However, truck utilization remained low even after this fix was implemented in January 2021. Anheuser-Busch project manager Christopher Leonowicz traveled to California in August 2021 to work with the site managers to improve utilization, finding that dispatchers were running the trucks as much as possible, but were constrained by delivery volumes, equipment needs, and availability of trained drivers on a given day. In 2022, CTE performed analyses demonstrating that the trucks had the ability to run longer distances than they were currently. In addition to meeting its cost share obligations to CARB, CTE estimated that there would be financial benefits over diesel trucks, as well. Utilization has trended upwards somewhat in 2022 compared to 2021. However, operational constraints remain a barrier to full utilization. Site personnel have reported that the trucks are often unable to charge fully overnight, causing them to be held from longer routes the next morning. The AB team continues to work on solutions to improve truck utilization at Anheuser-Busch.

Deployment Data

CTE worked with Anheuser-Busch and ENGIE to track deployment data starting with the initial validation phase. Once the trucks had been deployed, CTE tracked data related to vehicle telematics via the Geotab data platform and charging and solar energy data via the UtilityVision data platform, while Anheuser-Busch tracked data related to vehicle operation, availability, and maintenance. These data were used in the benefits analysis portion of the project, which entailed the generation of key performance indicator (KPI) reports among others, and will be detailed in the next section.

Due to proprietary concerns at Anheuser-Busch, some information was unavailable for use in the benefits analysis. This included most information on their existing fleet of diesel trucks. For example, CTE will frequently use data from an existing baseline ICE fleet operated by the same entity to make comparisons and calculate environmental, financial, and operational benefits. Certain information about Anheuser-Busch's deployment sites was also unavailable, such as the particular SCE and LADWP utility rates on which they were described. For financial analyses, CTE therefore used publicly available information regarding rates that we deemed likely for Anheuser-Busch's distribution facilities. Finally, due to both proprietary concerns and the flat-fee nature of Anheuser-Busch's contract with Vehicare (Anheuser-Busch's maintenance contractor, who was responsible for installing and reinstalling the data hardware), detailed maintenance information was unavailable for the purpose of KPI reporting.

Moreover, certain operational data from Geotab was unavailable intermittently throughout the deployment due to hardware integrity issues as detailed below in "Challenges Associated with Telematics Tracking."

Nonetheless, enough reliable data was collected throughout the project that CTE was able to perform several analyses of Anheuser-Busch's operations, finances, and environmental benefits. These analyses are summarized and compiled below in the Benefits Analysis section.

Challenges associated with telematics tracking

One major challenge that arose following deployment of the trucks was the integration of data telematics hardware. The grant from CARB included considerable data reporting requirements, particularly with regard to battery electric propulsion technology. In addition, CTE's technical advisory scope included the performance of validation testing and other data-based analyses to ensure proper performance of the trucks. These requirements necessitated data telematics hardware that could monitor BEV-specific metrics such as electricity consumption. Specifically, Geotab was selected as the data telematics partner for this project. CTE and BYD had both worked with Geotab in the past on telematics tracking for BYD battery electric trucks, instilling confidence in the project team despite the relatively nascent state of the data logging technology.

However, difficulties arose when attempting to integrate the Geotab loggers *in addition to* the other data telematics devices already required on the trucks by Anheuser-Busch as standard operating procedure. These other telematics devices, known as Samsara and Omnitracs, were already being used on Anheuser-Busch's conventionally fueled trucks in order to serve other business purposes such as delivery routing. The installation of a third device on the trucks proved technically difficult, and led to interference between the signals on the three devices, undermining the completeness of all three sources. There were therefore intermittent periods in which the Geotab data necessary for grant obligated activities such as key performance indicator reporting contained many sizable gaps.

BYD addressed this issue by engineering a specialized harness that would accommodate all three telematics devices while minimizing signal interference. After this harness was installed on the 21 trucks, the data intermittency issues mostly but not completely resolved. CTE began providing daily, and later weekly, reports to BYD, Anheuser-Busch, and Vehicare detailing which trucks' Geotab loggers were and were not providing a signal, so that Vehicare could take corrective action on any that were not communicating. These changes led to significant improvements in the integrity of the truck data.

As of 2022, there are still intermittent issues with the reliability of the Geotab loggers. It is not entirely clear to what extent this is due to interference from the Omnitracs and Samsara loggers, versus other technical issues with the Geotab loggers.

The lessons learned from this issue are twofold. The first is that data telematics technology is in a nascent state, particularly for applications on battery electric trucks. The hardware that measures electricity input and output has not had time to mature on the market, and is naturally prone to errors that more established technologies are not. The second is that it is unwise to attempt to integrate too many telematics devices on a single vehicle. By attempting to collect data from three different loggers, the overall quality and reliability of the data on all three loggers deteriorated. It would likely have been preferable to forego collection of certain classes of data if it was known that the data that remained was accurate and complete. Communication amongst the local teams, maintenance, and OEM was the key to solving challenges that occurred.

Benefits Analysis

Following the deployment of the battery electric trucks in August 2020, CTE undertook the benefits methodology portion of the project. This entailed the collection, aggregation, manipulation, analysis, and visualization of various data related to the trucks' operations, costs, environmental benefits, and environmental justice impacts. In total, four key performance indicator (KPI) reports were generated, covering various periods between the beginning of deployment and the end of 2021. In addition, CTE performed several *ad hoc* analyses of particular areas of data inquiry, including electricity usage and operational efficiency.

Benefits Analysis Methodology

There were four main sources of data for the benefits analysis:

- **Geotab:** Data telematics hardware installed on the vehicles that reported operational data from the controller area network (CAN) bus, the onboard system that allows the vehicle's various components to communicate each other. This system reports data such as mileage, state of charge, energy usage, and maintenance faults, and accessed via an online interface.
- **Anheuser-Busch operational records:** Anheuser-Busch's internal processes include the generation of daily reports on truck routes, driver assignments, payloads, and availability, which were used to track operational data extrinsic to the trucks' CAN networks. This also became a secondary source of mileage data, due to reliability issues with the Geotab loggers.
- **UtilityVision:** Data telematics hardware installed at the charging and solar production sites that were built as part of the project, which reported on energy used for charging at the Beach Cities, Pomona, and Sylmar facilities, as well as solar production data at the Beach Cities facility.
- **National Oceanic and Atmospheric Administration (NOAA):** Data related to weather conditions at the three Anheuser-Busch facilities was accessed via NOAA's "Climate Data Online Search" interface.

In addition, certain one-time inputs were used throughout the benefits analysis phase which were accessed from disparate sources. For example, CTE used standard rate structures from both SCE and LADWP in our estimation of electricity costs. In addition, CTE used the definitions of disadvantaged communities (DACs) as defined by the California Environmental Protection Agency (CalEPA) as of 2020 via the Enviroscreen tool.

CTE used the following definitions for various KPIs:

- **Availability:** Equipment is defined as available when it is functional and ready for use on a given day, regardless of whether it is utilized. Expressed as a percentage of total truck-days or charger-days.
- **Average speed:** Average moving speed, calculated as the distance traveled over the number of operating hours.
- **Battery capacity:** Amount of usable energy able to be stored in the battery of a truck, expressed in kilowatt-hours (kWh). For most purposes, this was assumed to be 409 kWh, the nameplate capacity of the trucks according to BYD.

- In estimations of usable battery capacity, calculations were limited to instances where the change in state of charge was greater than 20%. In these instances, the following formula was used to estimate usable battery capacity: $\frac{Energy\ charged\ (kWh)}{\Delta\ State\ of\ Charge}$

- **Demand:** A feature of many electricity rate structures in which the customer is charged for the maximum amount of power, in kilowatts, demanded by the meter in a 15- or 30-minute period.
- **Disadvantaged community (DAC):** Census tract identified by State of California as particularly suffering from a combination of economic, health, and environmental burdens.
- **Distance traveled:** Change in odometer reading in a given period, in miles.
- **Energy used:** Amount of electricity consumed by trucks, or dispensed by chargers, in kilowatt-hours (kWh).
- **Fuel economy:** Efficiency of truck operations, expressed in terms of kilowatt-hours consumed per mile of service (kWh/mi).
  - Note that "greater" or "higher" fuel economy usually refers to a more efficient vehicle operation, which implies a *lower* kWh/mi value.
- **Miles between breakdowns:** A measure of truck reliability, defined as the average number of miles traveled between subsequent breakdowns.
  - If a truck experienced no breakdowns in a given period, this is equal to the number of miles traveled during that period.
- **Nameplate battery capacity:** Amount of usable energy able to be stored in the battery of a truck, in kilowatt-hours, according to the truck specifications. This was assumed to be 409 kWh based on BYD's specifications.
- **On-peak/Off-peak:** (See: Time of use.) Times of use, as defined by local utilities, wherein electricity usage during on-peak hours is more expensive than during off-peak hours.
- **Operating hours:** Time with ignition on, regardless of whether the truck was moving or deployed in delivery service.
- **Payload:** Approximate weight, in tons, of the product being delivered by a given Anheuser-Busch truck on a given day. AB tracks its delivery volume in units of case equivalents (CE), which are assumed to weigh 22 pounds.
  - The following formula was used: $\frac{Routed\ volume\ (CE) \times 22\ lbs}{2{,}000\ lbs}$
- **Range to 20%:** Distance possible for a truck to travel from 100% to 20% SOC, in miles.
  - The following formula was used: $\frac{Battery\ capacity\ (kWh) \times 0.8}{Fuel\ economy\ (kWh/mi)}$
  - Battery capacity was assumed to be 409 kWh for the purpose of range calculations.
  - This was calculated either per trip or averaged for longer periods of time, depending on the particular application.
- **State of Charge (SOC):** Percent of total battery capacity currently available.
  - This metric can also be conceptualized using the following formula: $\frac{Energy\ available\ (kWh)}{Battery\ capacity\ (kWh)}$
- **Temperature:** Daily high ambient temperature at the nearest weather station to the distribution facilities. The following weather stations were used for the purpose of our analysis:

- Chino Airport (Pomona facility)
- Torrance Airport (Beach Cities facility)
- Van Nuys Airport (Sylmar facility)

- **Time of use:** Feature of many electricity rates structures, in which prices for energy and/or demand vary by time of day, day of week, season, and holiday status. Usually expressed as "peak," "off-peak," etc. These times of use also depend on the local utility, with the Pomona and Carson sites being subject to Southern California Edison (SCE) rates and the Sylmar site being subject to Los Angeles Department of Water and Power (LADWP) rates.

Direct electricity cost data was unavailable for Anheuser-Busch, due to both privacy concerns and the fact that the chargers were not separately metered at any of the three deployment sites. In order to evaluate the financial impacts of the truck deployment, in the KPI reports CTE utilized a combination of charging data from UtilityVision, rate structure information from SCE and LADWP, and solar production data from UtilityVision in the case of the Beach Cities facility. However, this methodology was limited due to the lack of data on facility electricity usage. Specifically in the case of demand charges, the total amount of demand incurred by the chargers may be significantly less than would be implied by the raw charging data if the wider facility contains peaks of usage during other times throughout the month. For this reason, there is a chance that demand charges as estimated in the KPI reports were overstated.

In order to accommodate this constraint, in 2022 CTE secured data from SCE related to the 15-minute electricity usage data at the Beach Cities and Pomona sites. This allowed CTE to evaluate the electricity demand incurred by truck charging and its relationship to the overall site electricity usage, in turn developing a more accurate account of the impacts of charging on Anheuser-Busch's electricity costs. The results of this analysis are detailed in the next section: "Benefits Analysis Results Cost."

CTE evaluated the environmental justice impacts of truck operation using the geofencing functionality provided by Geotab. CTE uploaded keyhole markup language (.kml) files of the DACs, as defined by CalEPA, located within Anheuser-Busch's Los Angeles area service territory. The Geotab loggers were then able to determine, based on the trucks' GPS location, whether a given truck was at any moment operating within a DAC.

Finally, CTE evaluated the environmental benefits of the truck deployment using the AFLEET Tool from Argonne National Laboratory. Because actual diesel truck fuel usage was unavailable, CTE assumed that Anheuser-Busch's diesel truck operations average 6 miles per gallon. Greenhouse gas emissions from electricity generation were based on the California average of 276.23 grams of CO_2 per kWh in 2020, according to https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials.

Benefits Analysis Results

Operational:

To evaluate the operational benefits of the BYD trucks, CTE examined two aspects of truck operation: *range* and *availability*.

Range:

To calculate range, first CTE calculated energy efficiency in terms of kilowatt-hours, based on energy consumption and mileage data pulled from the Geotab telematics devices. Energy efficiency is combined with battery capacity to calculate range from 100% to 20% SOC, i.e., the distance the truck can expect to be able to drive before reaching 20% state of charge. Specifically, CTE examined trips on which the truck drove at least 30 miles and consumed 15 kWh of energy. Range to 20% was extrapolated from operating efficiencies collected per trip.

Overall, CTE found that the electric trucks exhibited a mean range of 131 miles with a standard deviation of 30 miles at Pomona, and 152 miles with a standard deviation of 30 miles at Sylmar. However, the anticipated range was not distributed evenly: the minimum observed ranges were typically not much lower than 100 miles, whereas the highest ranges approached 250 miles, as shown in **Figure 4** and **Figure 5**.

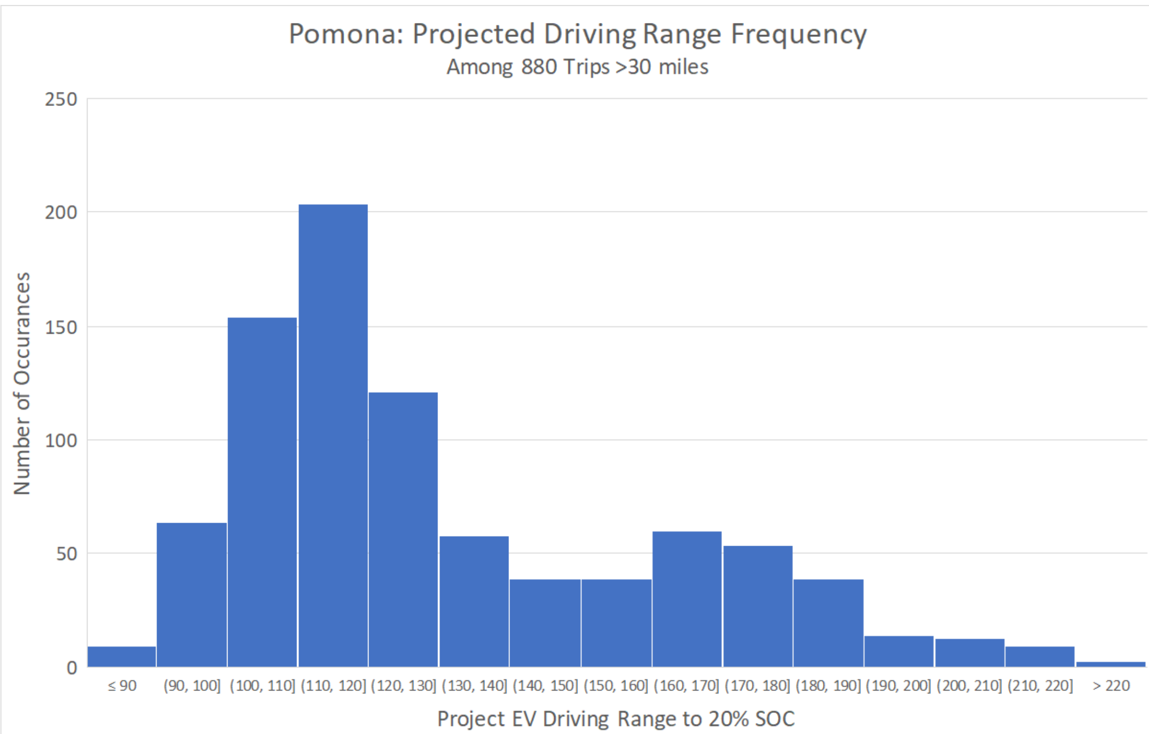


Figure 4: Projected Driving Range Frequency

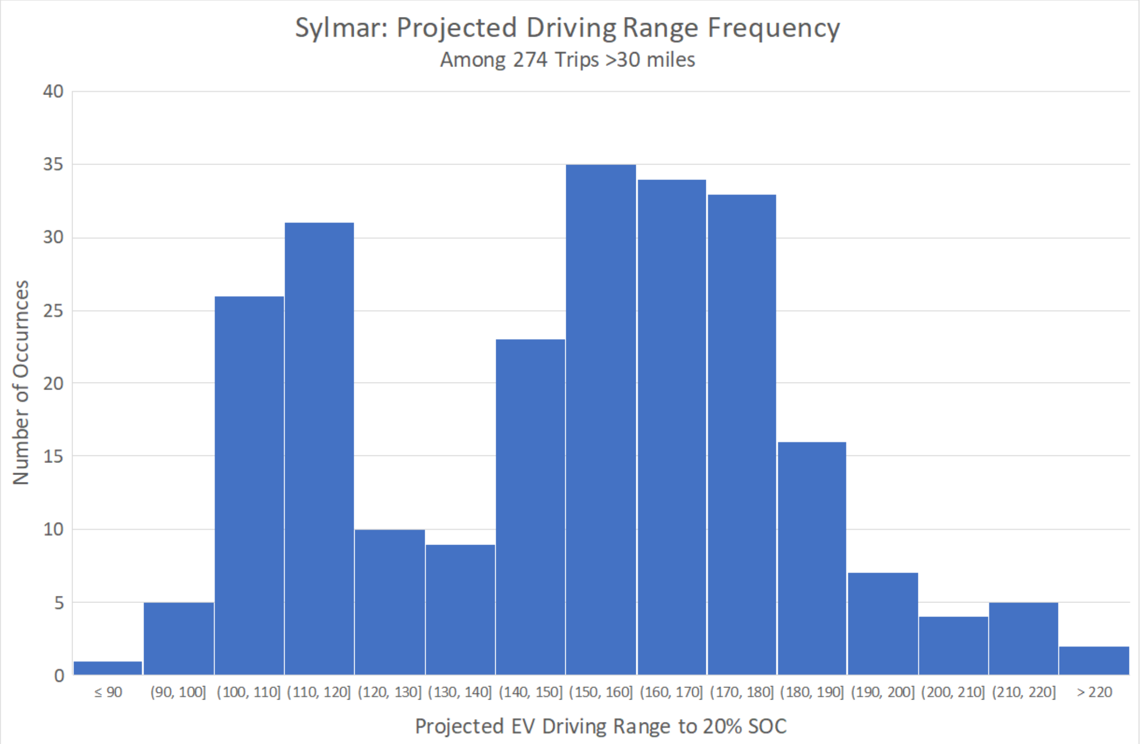


Figure 5: Projected Driving Range Frequency at Sylmar

For planning purposes, CTE examined the relationship of range with several independent variables: ambient temperature, routed weight, stops per route, and deployment location. No significant relationship was found between range and ambient temperature, routed weight, or stops per route, as seen in **Figure 6** through **Figure 8.**

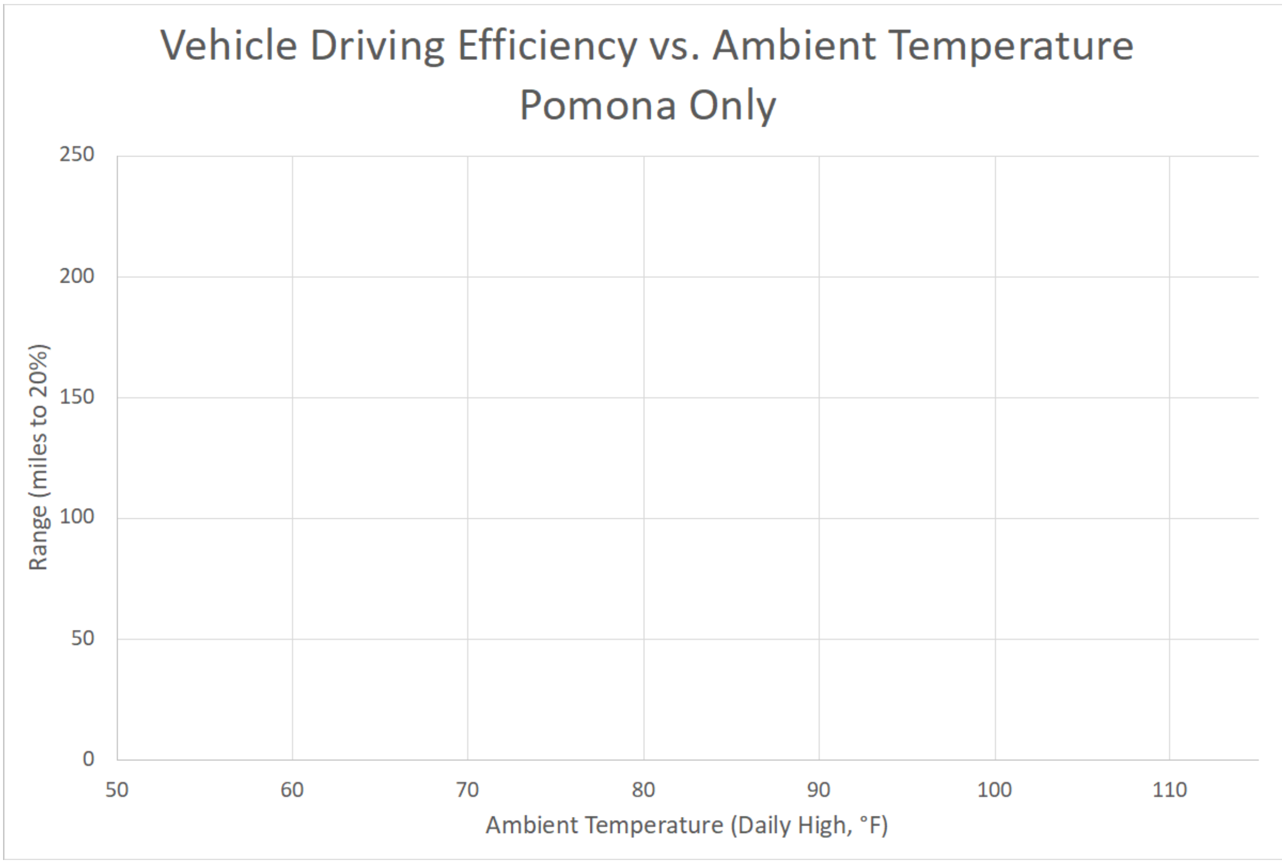


Figure 6: Ambient temperature vs. range to 20% at the Pomona site

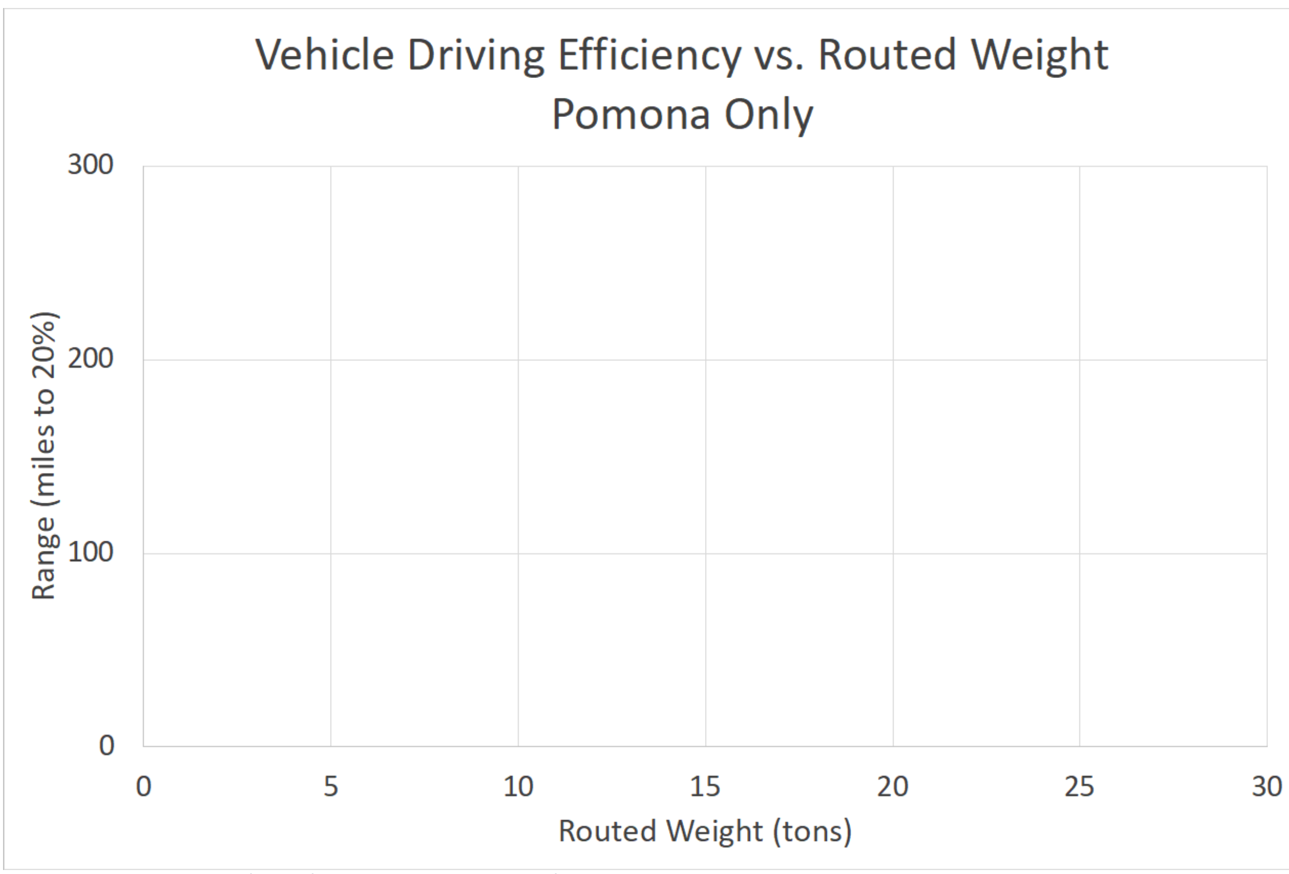


Figure 7: Routed weight vs. range to 20% at the Pomona site

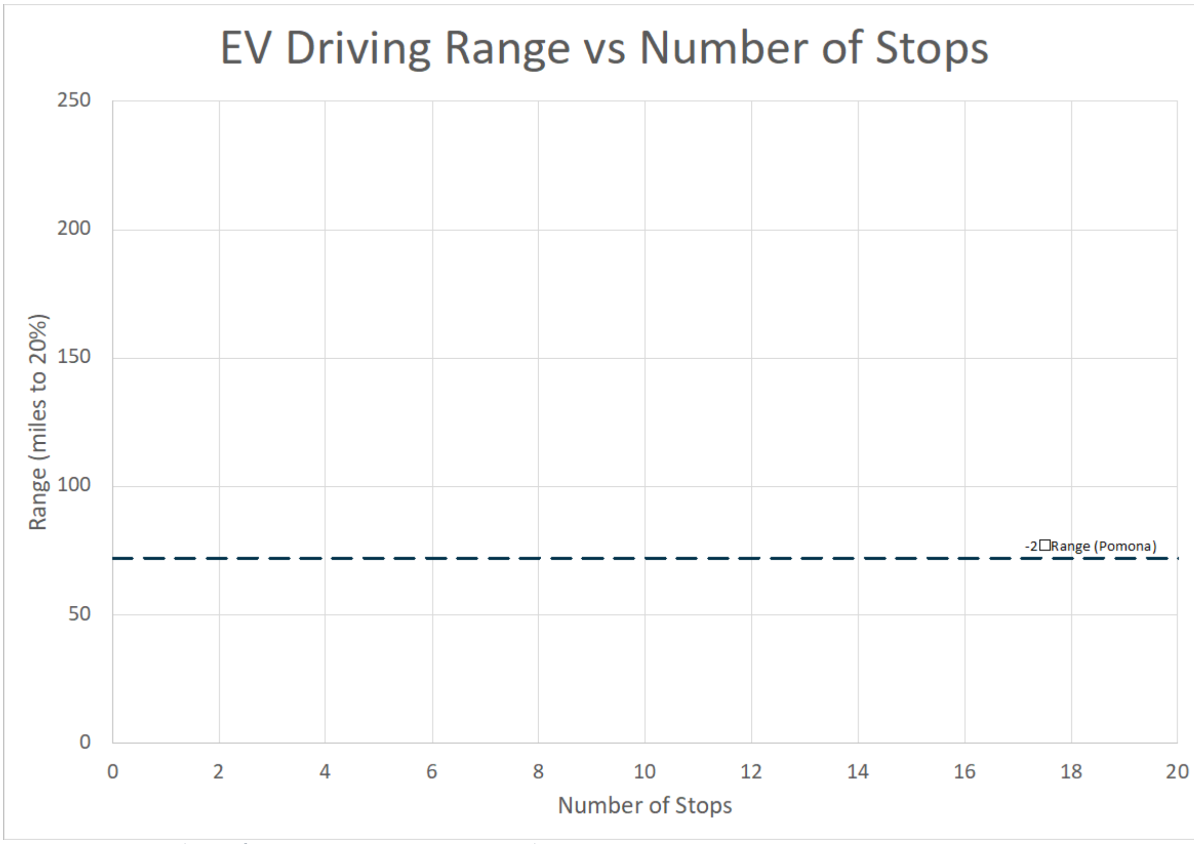


Figure 8: Number of stops vs. range to 20% at the Pomona site

However, CTE did find that the deployment location was a distinct indicator of range. **Figure 9** shows the percentage of trips on which a given range was projected at the three deployment sites. For example, at Sylmar, approximately 70% of trips were estimated to have been able to travel at least 140 miles, regardless of how long the trip actually was.

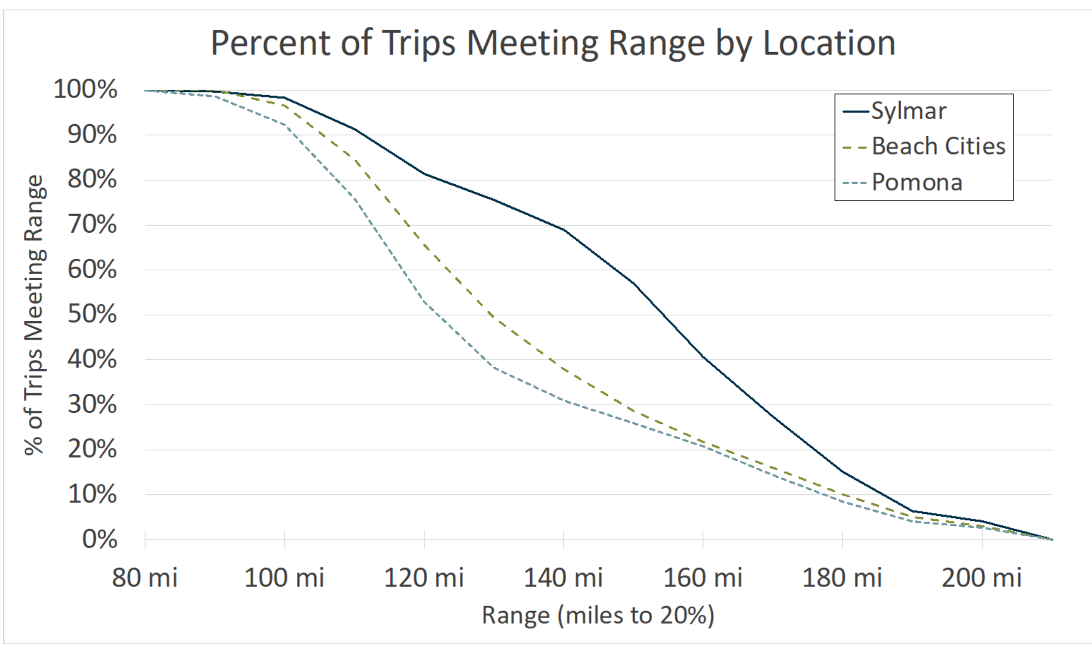


Figure 9: Percent of trips with a given projected range at Sylmar, Beach Cities, and Pomona deployment sites

Figure 9 shows that significantly higher ranges were projected at Sylmar than at the other two sites, with Beach Cities exhibiting a somewhat higher projected range than Pomona. This trend is further illustrated **Figure 10.**

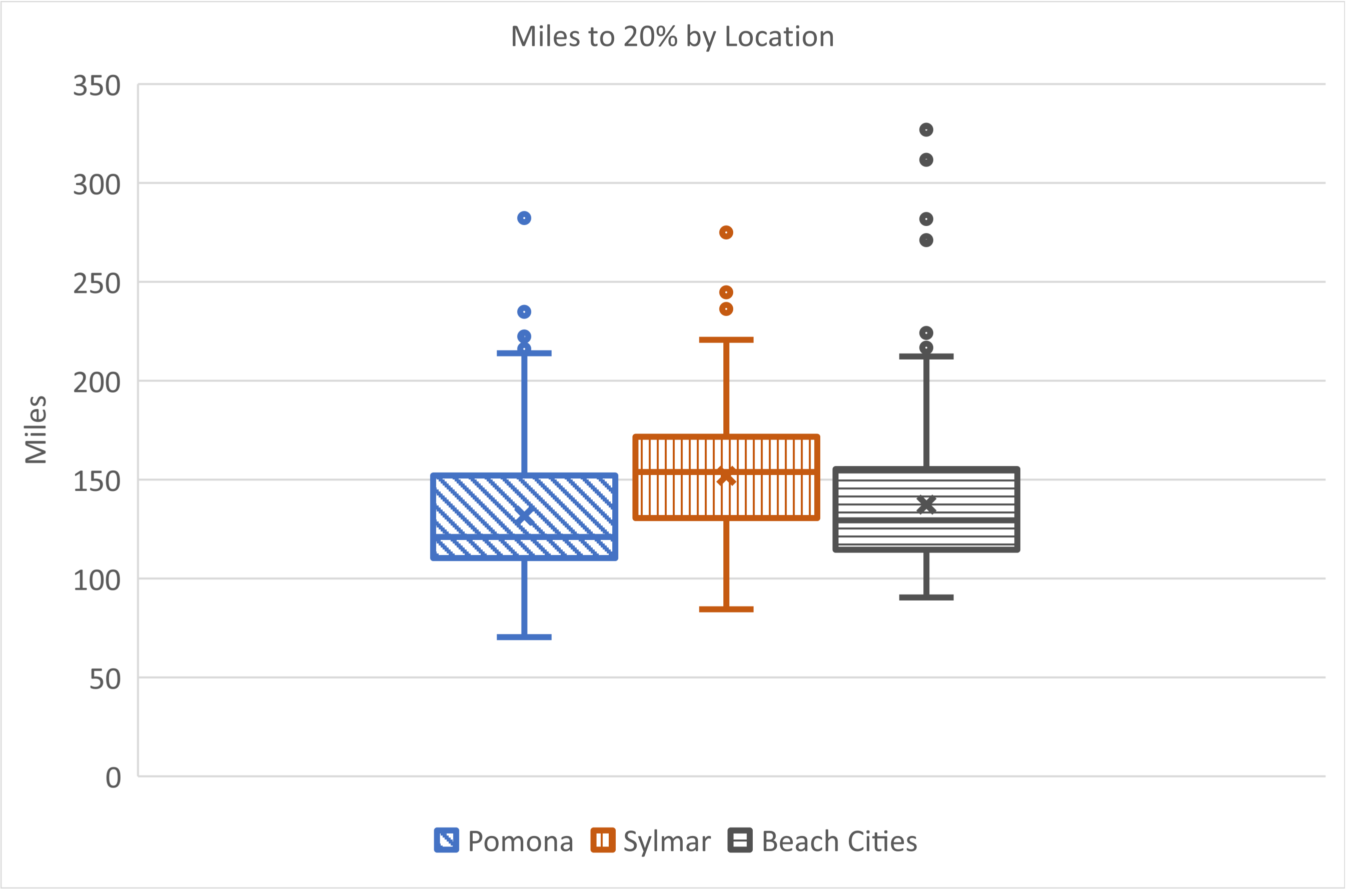


Figure 10: Box and whisker plot of mileage to 20% at the Pomona, Sylmar, and Beach Cities sites

This confirms that ranges at Sylmar were higher than the other two sites, but with some caveats. While Pomona and Beach Cities exhibited similar trends in **Figure 9,** here it is clear that there is quite a bit more variability in daily range at Pomona, and Beach Cities has the lowest variability of the three sites. There are no outliers on the low end at any site, but all three sites have outliers on the high end, particularly Beach Cities, with several trips exceeding 250 miles of anticipated range.

Further analysis is needed to explain the differences at these sites. The specifications of the trucks at each site are identical, and comparable driver training was completed at all sites. CTE did not find a relationship between range and average speed, as Beach Cities had the lowest average operating speeds and Pomona had the highest; however, this could imply that higher speeds lead to greater variability in range. Additional data would be required to determine whether certain properties of the sites' service territories are responsible for the differences in range, such as topography, traffic conditions, or idling time. In addition, the differences could be attributable to variations in standard operating procedures within the three sites. The major takeaway from this analysis is that truck operations are site-specific: dispatchers at each site should make decisions on truck routing that are particular to their operating environments.

Availability:

Anheuser-Busch provided detailed availability data throughout the period of data collection. This is a measure of how likely it was that the BYD trucks were available for operation on a given day. CTE lacks baseline data regarding Anheuser-Busch's conventionally-fueled trucks against which to compare the electric truck availability data, but nonetheless, the results are striking. Through the end of 2021, the BYD trucks exhibited an average availability of 94.8%.

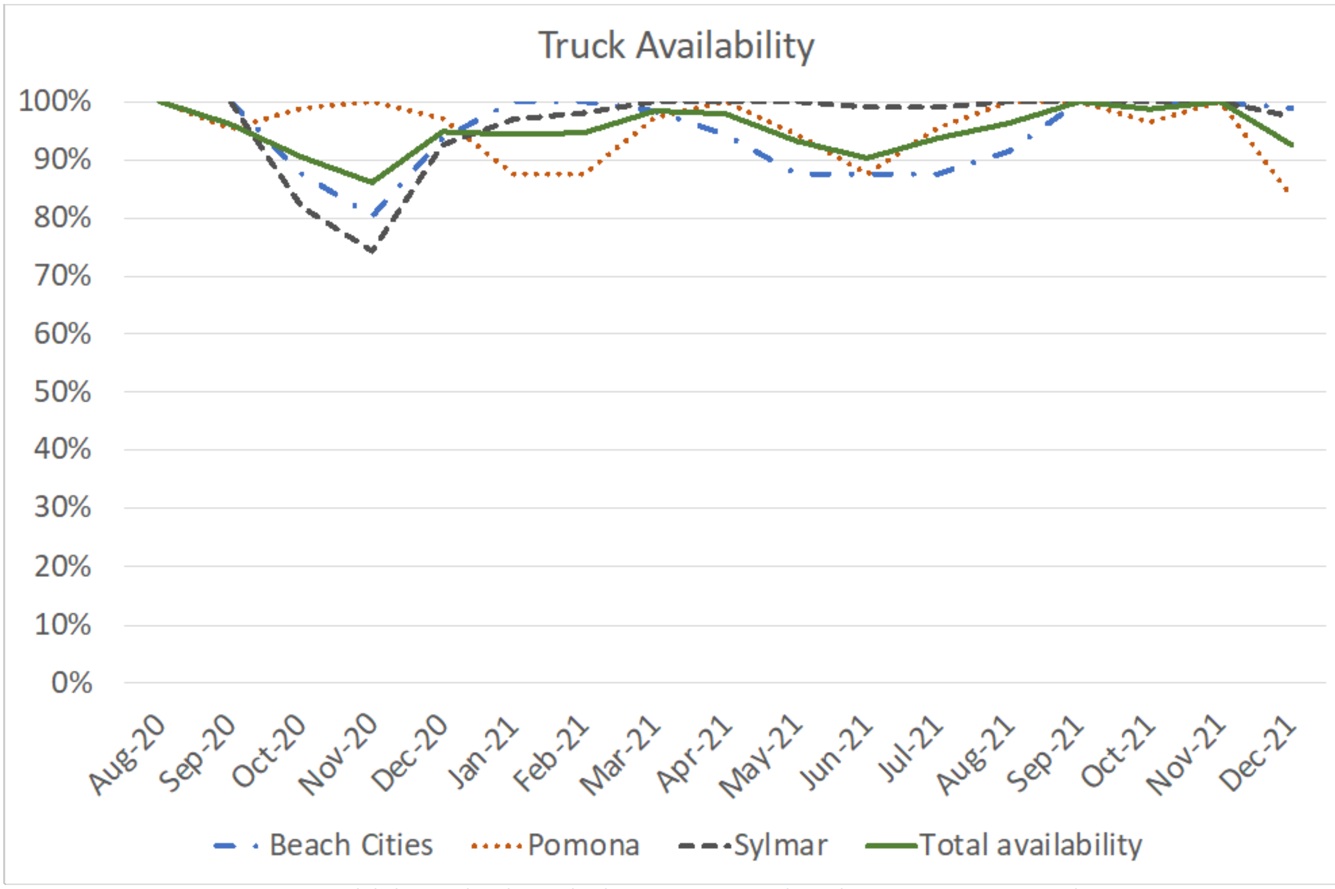


Figure 11: Availability at the three deployment sites and total, August 2020-December 2021

While there were a few hiccups early in the deployment, particularly at the Beach Cities and Sylmar deployment sites, availability remained strikingly high throughout 2021. Overall availability never dropped below 90%, and only at one site during one month did availability ever drop below 80%. This points to a low burden of maintenance issues that would keep trucks out of service. However, more detail is needed on the trucks' maintenance and deployment histories in order to make any conclusions about the general causes of truck unavailability.

Cost:

Shortly after the trucks were deployed, CTE performed a preliminary analysis of electricity cost impacts of charging at the Pomona facility in September 2020. Specifically, CTE examined the usage of electricity by time of use, calculated the corresponding demand, and compared the overall estimated electricity cost between the actual rate schedule and a theoretical EV specific rate.

Figure 12 shows the charger usage by hour throughout the month of September 2020:

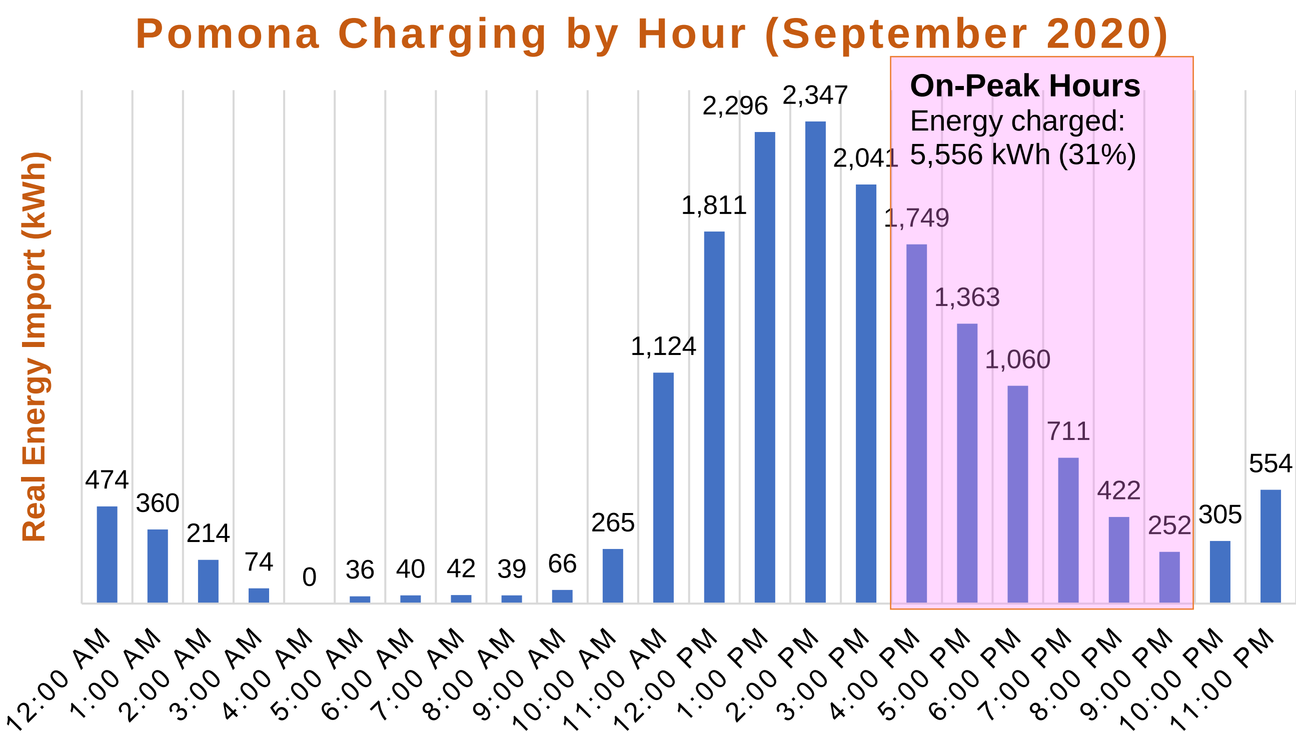


Figure *12*: Total amount charged per hour at Pomona site per hour throughout September 2020.

Figure 12 shows that, while the peak of charging occurred around 1:00-3:00 PM, outside of on-peak hours, almost a third of charging during this month occurred during the on-peak hours of 4:00-9:00 PM. In addition, little charging occurred past 8:00 and virtually none occurred early in the morning, which suggests that there were underutilized off-peak hours during which truck charging could have occurred. Granted, many later morning hours are times when many trucks are typically driving their delivery routes, but this analysis indicates that there were ways that Anheuser-Busch could optimize their operations to avoid charging during on-peak periods.

Next, CTE looked at calculated demand during September 2020. This is equivalent to the maximum power, in kW, that was demanded of the grid during any 15-minute period over the course of the month. **Figure 13** specifically looks at the calculated demand of every 15-minute increment throughout the day of September 29, 2020. One important limitation to this analysis is that it does not account for the demand of the facility as a whole: it is likely that the peaks for which Anheuser-Busch was actually charged were not entirely attributable to truck charging.

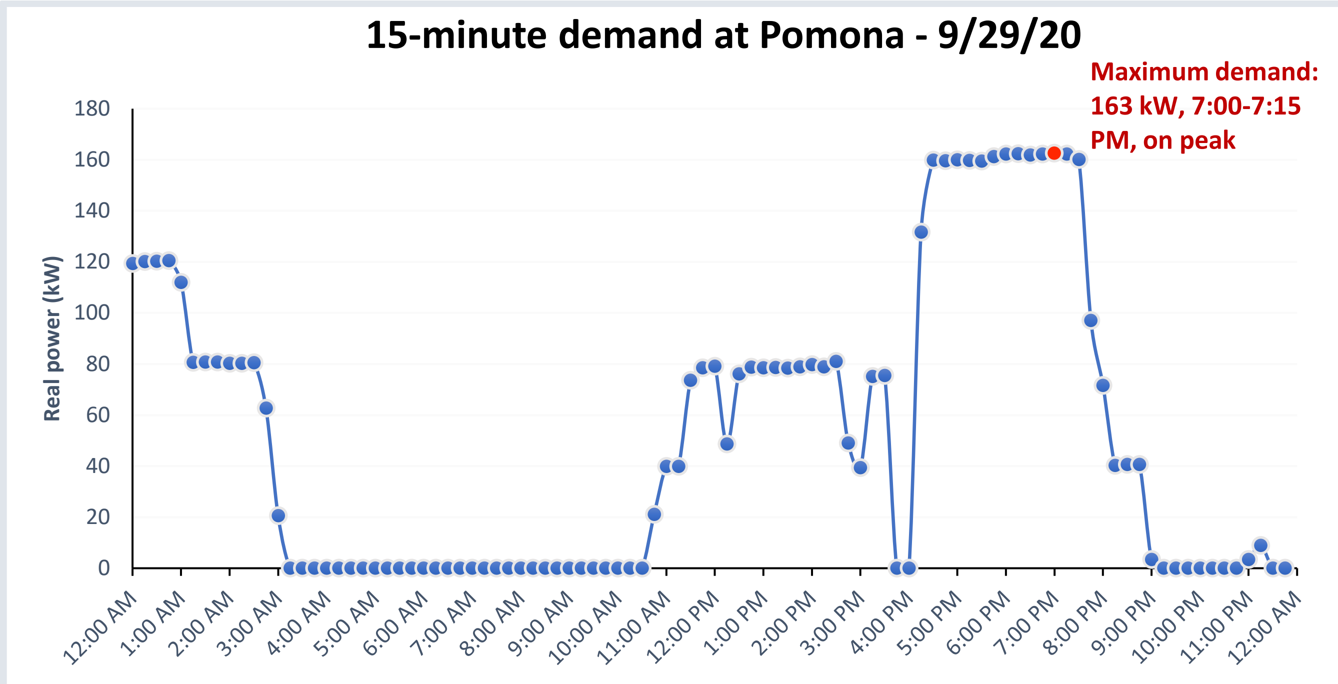


Figure 13: 15-minute demand (kW) at Pomona on September 29, 2020

Figure 13 shows not only that demand was highest during an on-peak period, but the highest demand for this day almost exactly corresponds to the on-peak period: that is, 4:00 to 9:00 PM. This implies that the most trucks were being charged at once during on-peak periods. This can have profound effects on an electricity bill, even if it only occurs one day per month.

Finally, we compared the electricity costs in September 2020 under an assumed actual rate structure (SCE rate D-CPP) to the theoretical electricity costs under an EV-specific rate (SCE rate EV-8). This does not account for the potential costs of upgrading electrical services and performing other work so that the charger bank could exist on its own utility meter, nor does it account for the wider facility electricity costs in the case of the regular rate.

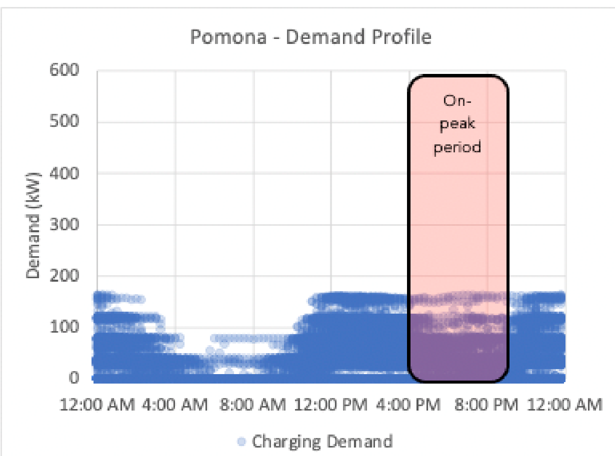
Upgrade costs notwithstanding, CTE estimated that electricity costs would have been up to 49% lower under an EV rate. The primary driver of this difference is in the lack of demand cost, which makes up the vast majority of the total cost in the case of the regular rate. While the EV rate does contain higher per-kWh energy costs both on- and off-peak, this is not nearly enough to offset the savings from the lack of demand charges. Overall, CTE estimated that Anheuser-Busch could have saved $4,477 that month at Pomona by utilizing an EV rate.

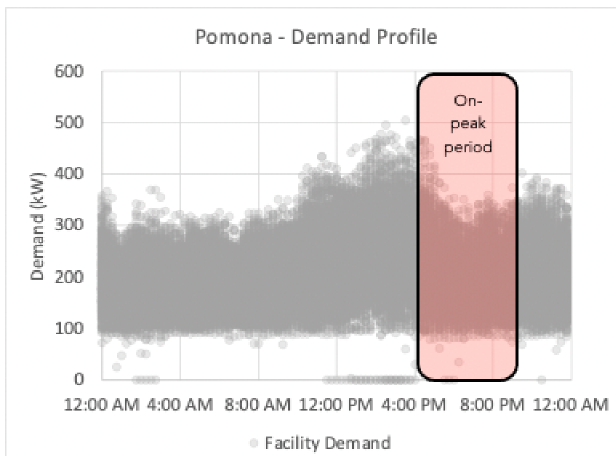
In spring 2022, CTE received 15-minute facility usage information from both SCE sites (Pomona and Beach Cities). When combined with UtilityVision electricity usage data, this allowed for a more comprehensive analysis of the ways that truck charging interfaced with the overall facility demand, as well as a more precise estimate of Anheuser-Busch's electricity costs associated with truck operation. To estimate energy costs, CTE analyzed the times that truck charging typically took place at each facility, the demand and energy loads associated with charging, the demand loads of the facilities themselves, the off-peak and on-peak utility rates for the facilities and the timing of those rates, and the electricity expenses incurred from charging.

Table 8: Comparison of Electricity costs in September 2020 under regular and EV rates

	Regular Rate (D-CPP)	EV Rate (EV-8)
On-Peak energy used (kWh)	5,557	5,557
On Peak monthly energy cost ($)	$693	$2,895
Mid-Peak energy used (kWh)	N/A	N/A
Off Peak energy used (kWh)	12,090	12,090
Off- Peak energy cost ($)	$1,073	$1,668
Demand (kW)	163	N/A
On-Peak demand cost ($)	$7,058	N/A
Monthly meter cost ($/meter)	$349	$133
Total cost	**$9,173**	**$4,696**
Cost per mile	**$1.49**	**$0.76**

At the Pomona facility, charging loads were highest between 11:30 AM and 5:00 PM and between 10:00 PM and 12:30 AM. Facility load was highest between 2:00 PM and 5:00 PM





Figures 14 and 15: Demand incurred at Pomona site Oct 21-Nov 22 from charging (14) and from the wider facility excluding charging (15)

CTE looked at the energy demanded from charging separately from the energy demanded from the rest of the facility. CTE found that while the typical high charging loads were during the early afternoon and nighttime, significantly high charging loads were also prone to occur during the on-peak hours of 4:00 to 9:00 PM. This exacerbated the existing facility's electricity usage, which also saw high peaks during those hours even when excluding charging, particularly between 4:00 and 5:00 PM. This led to unnecessarily high electricity costs, as demonstrated in **Table 9,** which uses June 2022 as an emblematic month to demonstrate the electricity costs at Pomona that can be attributed to truck charging.
CTE estimated the electricity cost attributable to charging at $4,245, or $0.96 per mile driven. Most (72%) of this cost came from incremental demand load expenses that charging created. Of these expenses, 70%, or $2,174, were due to additional load incurred during On-Peak

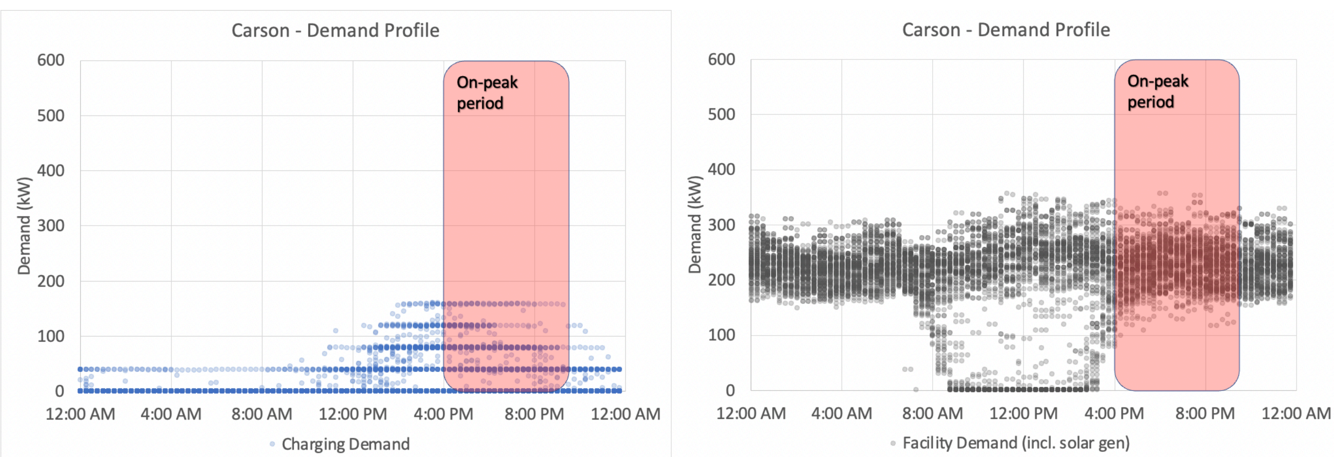
hours. This suggests that significant savings could be realized if charging were limited during on-peak periods. Savings could also be realized if charging occurred during times when facility loads are lower than their peak. This cost per mile lines up with expected cost per mile shown in **Table 4** above. Because of demand charges, the cost per mile exceeded the preliminary estimate of $0.49 for strategic charging, but fell well below the "charge anytime" estimate of $2.75 per mile, as most charging was done off-peak.

Table 9: Estimated electricity costs at Pomona, June 2021

	Time of Use	Amount Used	Rate	Total Cost	Cost per Mile
Energy	Off-Peak	9,761 kWh	$.098/kWh	$955	$0.22
Energy	On-Peak	2,061 kWh	$.134/kWh	$275	$0.06
Demand	Overall	49 kW*	$18.47/kW	$905	$0.20
Demand	On-Peak	63 kW*	$34.50/kW	$2,174	$0.49
Total				***$4,245***	***$0.96***

**This is the incremental demand from charging. It is found by determining the maximum demand when including and excluding charging, and finding the difference between the two.*

At the Beach Cities facility, charging loads were highest between 2 PM and 8 PM. Facility load was fairly consistent, with slight peaks between 10 AM and 4 PM. Unlike Pomona, Beach Cities contains solar production capacity, which was greatest between 9 AM and 3 PM and was often able to offset facility power usage. However, because this benefit was not present every day, and the vast majority did not occur during on-peak hours, this could not offset the on-peak demand charges.



Figures 16 and 17: Demand incurred at Beach Cities (Carson) site Oct 21-Nov 22 from charging (16) and from the wider facility, excluding charging and subtracting energy from solar production (17)

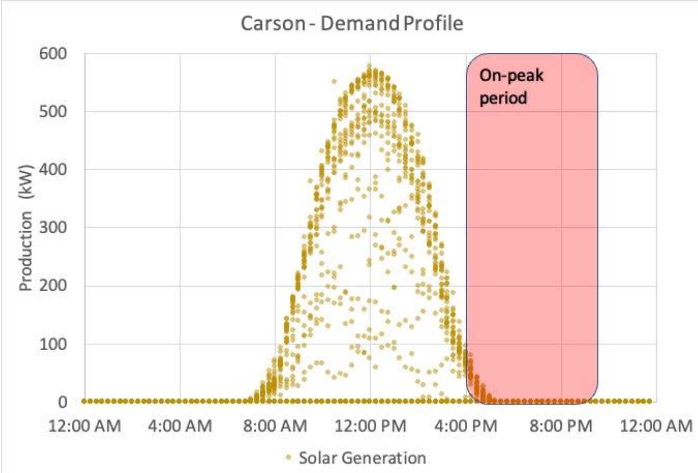


Figure 18: Solar production at Beach Cities (Carson) site Oct 21-Nov 22

CTE looked at January 2021 as a representative month to estimate the electricity costs at Beach Cities that were attributable to truck charging. The results can be found in **Table 10.**

Table 10: Estimated electricity costs at Beach Cities, June 2021

	Time of Use	Amount Used	Rate	Total Cost	Cost per Mile
Energy	Off-Peak	2,323 kWh	$.09/kWh	$209	$0.11
Energy	On-Peak	1,764 kWh	$.124/kWh	$220	$0.11
Demand	Overall	102 kW*	$18.47/kW	$1,935	$0.99
Demand	On-Peak	102 kW*	$34.50/kW	$3,841	$1.96
Total				**$6,205**	**$3.17**

**This is the incremental demand from charging. It is found by determining the maximum demand when including and excluding charging, and finding the difference between the two. In this case, the maximum overall demand from charging was during an on-peak period.*

In January 2021, charging cost $6,205, or $3.17 per mile driven. The vast majority (93%) of this expense came from incremental demand load charges, including 66% ($3,841) from on-peak demand alone. This suggests that a significant portion of Anheuser-Busch's electricity bill could be reduced if charging was limited to off-peak periods. This cost per mile exceeds the expected cost per mile shown in **Table 4** above. In the "charge anytime" scenario, the cost per mile was estimated at $2.71; demand charges made up a larger portion of cost per mile than expected.

CTE concluded that as Anheuser-Busch considers future pilots and deployments of battery electric delivery trucks, they should note the demand load profiles of the facilities where the vehicles will be charged. Anheuser-Busch should set charging schedules to align with periods where the loads that charging incurs will not create incremental demand loads. This strategy is known as "demand stacking."

CTE's analysis yields the following guidance: Charge the vehicles between 9pm and 10am, especially avoiding On-Peak rate hours. Doing so will keep charging from incurring higher load expenses, because charging loads will be "hidden" beneath the peak loads which the facilities create during the day. Where solar power is available, charge the vehicles during periods of high production, particularly on sunny days. Explore charge management system implementation which can automate the above recommendations. Applying this guidance could reduce vehicle charging costs by 50% or more.

A key lesson learned by Anheuser-Busch is to consider charge management options as early as possible when deploying new technology. Fueling and the charge management aspect was a priority during this project. The focus on charge management ensured Anheuser-Busch continued to watch their planning needs, sizing charging, and managing charging as they work to install more chargers and expand deployments for additional zero emission vehicles.

Environmental Justice

As part of the grant requirements, the trucks performed significant operations within disadvantaged communities (DACs) as defined by the California Environmental Protection Agency (CalEPA). These communities are targeted for investment as part of California's Cap-and-Trade Program, based on geographic, socioeconomic, public health, and environmental hazard criteria, in order to alleviate environmental burdens on the state's most vulnerable communities. DAC operations were tracked using Geotab, which contains a geofencing function that uses GPS data to identify periods during which the trucks were located within DACs.

As noted above, all three of Anheuser-Busch's deployment sites were located within DACs. In the case of Pomona, the site spans two census tracts, one of which was designated a DAC, the other of which was not; the chargers and truck parking were located in the DAC portion of the site. The trucks therefore operated within DACs, by definition, during every day of operation.

From the start of deployment to the end of 2021, CTE estimates that 42% of truck mileage occurred within DACs, with Beach Cities slightly exceeding and Pomona slightly falling short of 50% of mileage. Sylmar had the lowest proportion of DAC mileage of the three sites, at only about 25%. A summary of the breakdown of DAC mileage by site can be found in **Figure 19**.

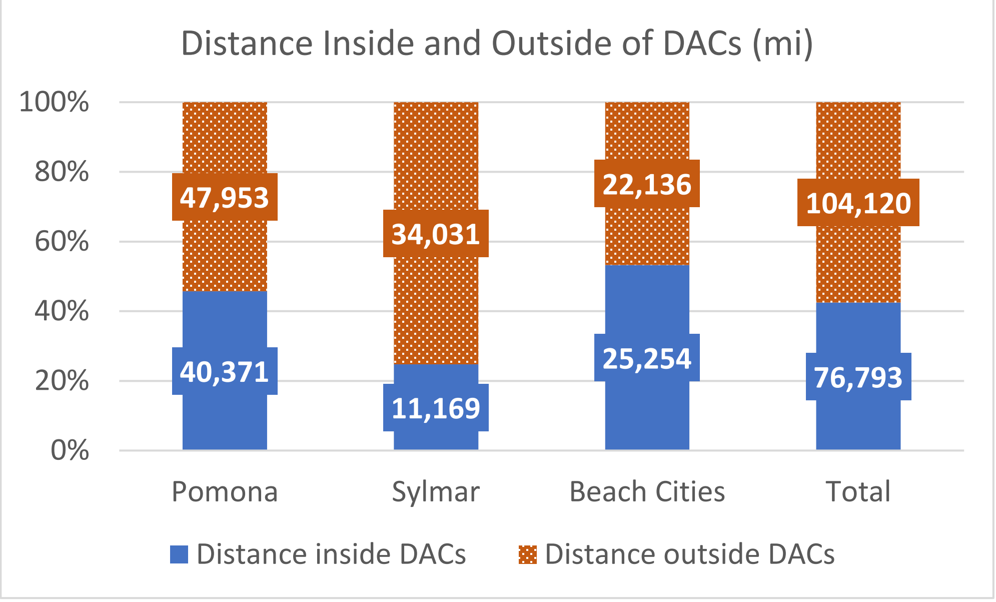


Figure 19: Total distance inside and outside of DACs, August 2020-December 2021

A slightly different picture emerges when examining DAC operations by *time* within DACs. Every site performed a greater percent of its operations within DACs in terms of hours as opposed to miles. Overall, the breakdown is almost exactly 50-50: the trucks only ran about

0.2% fewer hours within DACs than outside of them. At the Beach Cities site, almost 2/3 of hours of operation occurred within DACs. A breakdown of driving hours inside and outside of DACs by site can be found in **Figure 20.** This includes both driving time and idling time.

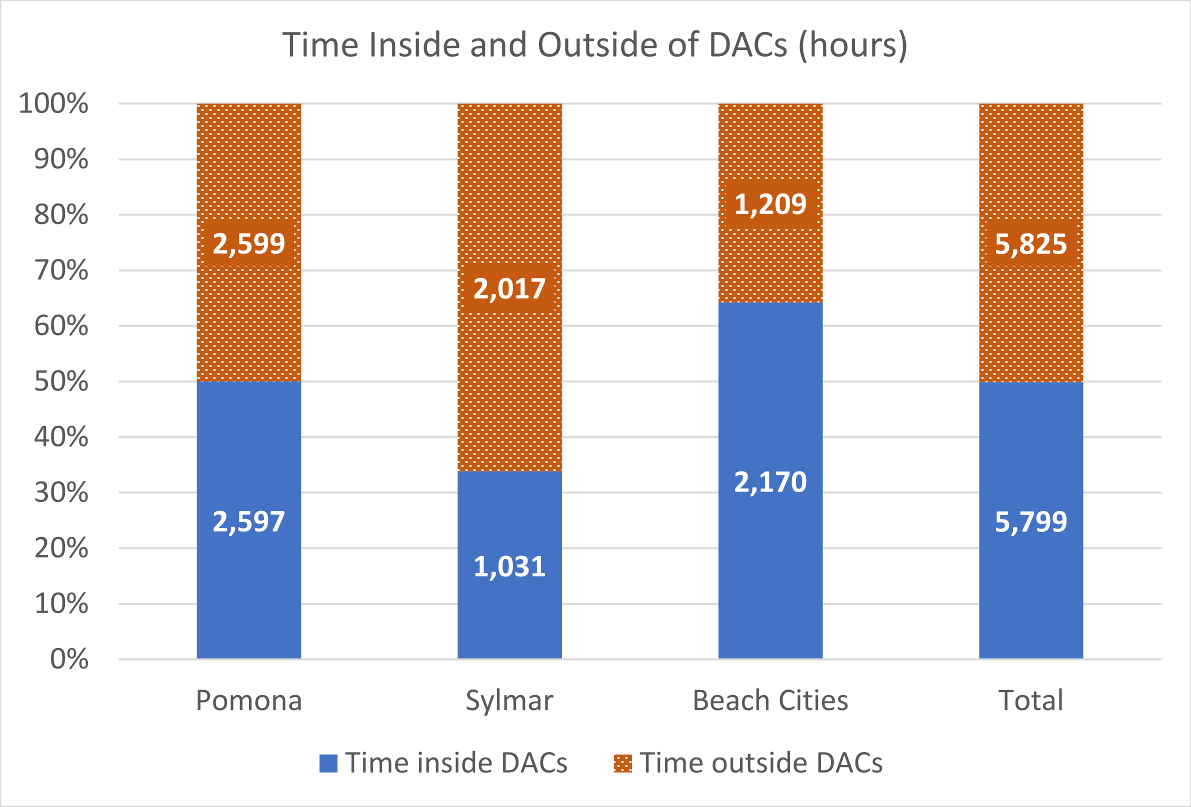


Figure 20: Total hours operating inside and outside of DACs, August 2020-December 2021

This has positive implications for the environmental impacts of the trucks. Because the trucks operated more hours within DACs relative to distance, this implies that their average speed was lower in these areas, suggesting that delivery stops and idling were more likely to occur inside of DACs. Many harmful pollutants tend to be emitted into a given area when idling or driving at low speeds whereas at high speeds, these pollutants may be emitted at a higher rate, but the truck spends a far shorter amount of time within each community and therefore has a lesser environmental impact on each DAC. Therefore, DACs preferentially benefitted from the operation of electric trucks relative to non-DAC areas.

Environmental

CTE evaluated the environmental benefits of the trucks based on their odometer mileages through the end of 2021, which totaled 219,489 miles between all trucks. This includes all mileage, including not only delivery service operations but also testing, validation, and any vehicle operation that occurs within the deployment site.

CTE estimates that Anheuser-Busch avoided consuming 36,582 gallons of diesel fuel by operating electric trucks. This is estimated to have saved about 501.8 tons of greenhouse gases from being emitted at the tailpipe. However, there are additional greenhouse gas emissions associated with electricity generation, estimated at 199.9 tons based on the California grid. Of these additional emissions, Anheuser-Busch was able to avoid 17.9 tons of greenhouse gas via onsite solar generation at Beach Cities. Overall, CTE estimates that

Anheuser-Busch enjoyed a well-to-wheel net greenhouse gas savings of 319.8 tons. This is the equivalent of 62.5 cars taken off the road for one year, 343 acres of US forests growing for one year, or 4,797 tree seedlings grown for ten years.

In addition to greenhouse gas benefits, Anheuser-Busch avoided a great deal of criteria pollutants that impact air quality close to the area of observation. These pollutants have the most immediate environmental justice implications, since they largely affect the air surrounding the trucks and have direct impacts on human health. CTE's estimates for criteria pollutant emissions reductions from electric truck operation can be found in **Table 11.**

Criteria Pollutant	Avoidance (pounds)
Carbon Monoxide (CO)	420.0
Nitrous Oxides (NOx)	437.0
Particulate Matter <10 micrometers (PM10)	48.4
Particulate Matter <2.5 micrometers (PM2.5)	7.7
Volatile Organic Compounds (VOC)	36.8
Sulfur Oxides (SOx)	5.7

Table 11: Criteria Pollutant Avoidance

Conclusion

Overall, this project achieved significant success in deploying 21 Class 8 battery electric trucks and associated charging infrastructure across multiple locations within DACs in southern California. The trucks proved to be reliable, achieving over 94% uptime through the end of 2021, which included fifteen months of operating data.

While this project has been successful, there have been many lessons learned through this project that the team would like to share with the industry to inform future deployments of battery electric trucks.

Lessons Learned

The project team identified a number of opportunities for learnings that were expressed throughout the report.

Understanding the project funding structure and required outcomes for the funding agency is critical to the success of these kinds of deployments. This came up at multiple times throughout the project, from ensuring the project was set up properly so that liability was assigned properly during vehicle title transfer through ensuring the data collection platforms were reporting correctly to capture operating time cost share. Any time a project issue arose, it was critical to keep CARB informed and coordinate solutions with them to ensure the project goals were obtained.

Another key area with lessons learned was from the data reporting for this project. CTE uncovered many insights regarding Anheuser-Busch's operation and opportunities for financial savings through its data reporting efforts. However, this was a challenge due to the requirement to integrate multiple data loggers on the trucks. It is important to address these integrations during the design of new vehicles to ensure that all systems function together properly. Another key consideration for electric vehicle deployments is the feedback mechanism between data reporting insights and implementing those into the operations team. Multiple departments within a large company, such as Anheuser-Busch, need to be coordinated and having a zero-emission vehicle champion is critical for bringing an organization together to effectively deploy electric vehicles and maximize the benefits of the technology.

Working with utilities is also important for deploying electric vehicles. Not only does early planning help with ensuring that infrastructure is deployed prior to vehicle delivery, but it can inform operational strategies and set expectations for the cost of electricity to fuel the vehicles. Outside of utility communication, confirming required certifications ahead of time will speed up the infrastructure process, and avoid the delays this project saw due to field commissioning of BYD chargers.

There was also some learning associated with the new trucks themselves. Between delivery and full deployment, the trucks experienced some extended periods of downtime awaiting administrative steps. These windows of downtime drained the low-voltage batteries, and required the batteries be jumped or replaced before the vehicles could be operated. The trucks are equipped with an off switch to these low-voltage batteries, which, once utilized, allowed this problem to be avoided in the future.

Anheuser-Busch received feedback from the project team members as well as their front-line employees that was used to help leaders make decisions for future deployments for zero emission vehicles. Driver comfort and safety has been a significant point of focus during the project and Anheuser-Busch will use the feedback and findings to address issues for future technologies deployed. Driver feedback was generally positive on topics related to the electric propulsion system, but mentioned areas for improvement in cab access (particularly in narrow docks) and blind spots.

Additionally, Anheuser-Busch learned that measures can be taken to maintain the reliability of their zero emission trucks even during periods of no electricity when they partner with the local electricity provided. Because of the planning and partnership they forged with the utility provider, Anheuser-Busch was able to operate their trucks for several weeks during a power outage using a backup diesel generator at the Beach Cities distribution facility in 2021.

These lessons learned inform CTE's recommendations for optimizing the performance of this fleet and planning future deployments.

Recommendations

Electricity usage – time of use and charging strategy

CTE recommends performing as little charging as possible during peak hours. Anheuser-Busch's distribution facilities are served by electric utilities that strongly incentivize electricity usage outside of peak periods. This is especially true at Pomona and Beach Cities, both of which are served by Southern California Edison (SCE), with peak periods between 4 and 9 PM. In evaluating Anheuser-Busch's charging behavior, CTE found that Anheuser-Busch may have been incurring thousands of dollars per month in avoidable charges by charging their trucks during this period.

There are no obvious operational reasons to perform truck charging between 4 and 9 PM. With one charger per truck and unrestrictive parking layouts, there is no need to queue truck charging in a way that poses operational constraints. In almost all cases, trucks can fully charge between 9 PM and the next morning's pullout. Even when the truck's SOC does not reach 100%, it will almost always reach a sufficient SOC to meet the next day's service requirements. Moreover, many trucks pull in well before 4:00 PM, giving them time for additional charging in the late morning and afternoon without incurring unnecessary on-peak charges. CTE therefore recommends Anheuser-Busch implement a policy to unplug their trucks during peak hours. This can be accomplished manually or via a charge management system. CTE estimates that this could result in charging cost savings of 50% or more at the sites served by SCE.

In addition, CTE recommends evaluating facility electricity loads to identify opportunities to "stack" or "hide" demand charges. This means charging vehicles during the times of day when the wider facility experiences the lowest electricity demand, such that the overall maximum demand for the month does not increase (or increases minimally) due to vehicle charging loads. The specific electricity loads of each facility may not enable this if electricity demand is relatively static over the course of the day. This strategy is also highly dependent on facility electrical design, including how circuits are metered, and should be considered at the earliest stages of site design and construction. This strategy is somewhat more advanced and may pose operational challenges, but has the potential for immense cost savings. Identifying opportunities for demand charge hiding will require collaboration with the local utility, and may be facilitated by charge management software.

Technology need – BEV truck data telematics

CTE recommends fleet operators use as few discrete data telematics platforms on one vehicle as possible, making exceptions to their standard operating procedures if necessary. The operator may prioritize different products based on the desirability of their functions. However, for early adopters of battery electric vehicles, CTE recommends including telematics loggers with the ability to measure energy consumption at all points in the system or process. This data is vital for optimizing operations, alleviating range anxiety, and understanding the financial and environmental impacts of the vehicle deployment.

In addition, CARB or other government agencies may take steps to bolster the electric vehicle telematics industry, so that the telematics technology matures at a faster rate, increasing the reliability and interoperability of the hardware. CTE recommends projects with a strong data reporting component be preferentially funded. Good data allows early adopters of EVs to learn lessons that can then inform future EV deployments.

Finally, manufacturers of electric vehicles may continue to develop solutions for integrating multiple loggers, in the same manner as the data logger harness engineered by BYD. CTE recommends that electric vehicle OEMs develop strong partnerships with data telematics OEMs so that their technologies can be integrated more seamlessly, allowing for more accurate, reliable, and meaningful data.

Commercial Contributions

With the successful deployment of the 21 8TT Class 8 electric trucks, Anheuser-Busch considers this project a proof of concept. The project has provided valuable information to consider as Anheuser-Busch moves forward with future plans to also procure and deploy additional zero emission trucks for their fleets. The lessons learned allows Anheuser-Busch to proceed with future opportunities equipped with understanding gaps versus current state of the market. This project serves as a demonstration of Anheuser-Busch's commitment to a sustainable fleet for their front-line operators.

Anheuser-Busch plans to keep all trucks in service for 10 years. The plan is to explore possibilities for moving the electric trucks to other facilities in Los Angeles, with no firm plans developed at the time of this report. Based on the knowledge gained from this deployment, Anheuser-Busch is planning to upgrade the existing chargers from the current AC chargers to DC chargers for faster charging and charge management capabilities. At the time of this report, Anheuser-Busch was in the process of reviewing all of their sites' electrical capacity to determine how many additional electric vehicles they can bring into each site's operations.

After the deployment of the electric trucks, a select number of drivers were interviewed and asked to complete a survey to provide feedback on driver preferences for the electric trucks. The project team asked drivers at all three deployment sites to complete an informal questionnaire about their experience with the BYD trucks. These responses gauge the general reactions of the drivers and are not presented as official survey findings. Drivers were asked to rank the trucks on a 1 to 5 scale, where 1 was a "poor" rank, 3 was an "average" rank, and 5 was an "excellent" rank. The survey had 18 total responses across the three facilities. As shown in **Figure 21**, the highest ranked feature of the trucks was the quiet operation, with 94% of drivers ranking above average. Next in preference was acceleration (67% ranked above average) and handling (55% ranked above average). Braking, training received, and driver comfort were the lowest ranked features, with 33%, 33%, and 28% respectively ranked above average. Overall, the majority of drivers found the vehicles better than diesel, reliable, and safe.

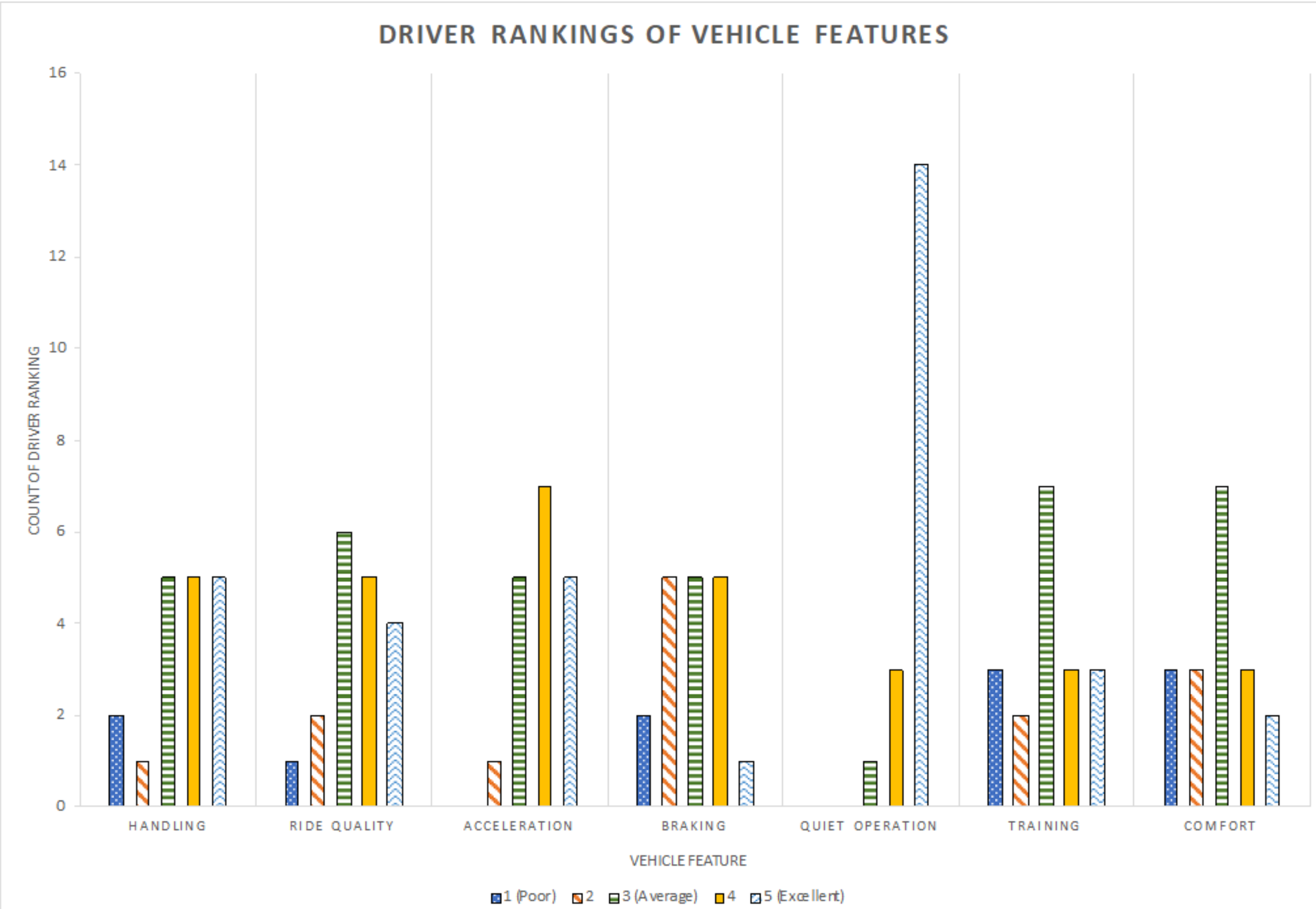


Figure 21: Driver Rankings of Vehicle Features

The survey concluded with an open answer question on what the drivers liked and disliked about the vehicles. The most commonly reported preferences were not having to pump diesel, the quiet ride, the smoothness of the truck operation, and the acceleration. Listed on the dislikes were the sensitivity of the braking, especially when backing up and at slow speeds; the fifth wheel placement angling the trailer in a way that made the load unstable; the difficulty of getting in and out of the cab, especially in narrow docks or as a larger person; and the blind spots. Notably, the features drivers liked best are related to the vehicle being an EV, and the features drivers liked least could be true of any new model truck. These drawbacks can all be overcome with incremental improvements to the truck design and additional training. Drivers saw the many benefits provided by EVs and were generally excited about the new technology.

In conclusion, these trucks were found to meet operational needs for Anheuser-Busch and have had no significant barriers to adoption. The core technology has been proven to work, and the minor drawbacks to the vehicles can be improved in future models and additional training. There is still a need for advancements with supporting technologies for EVs, including charge management, data analytics, and ancillary system design, but as it stands today, the technology works in local delivery applications.