CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Cal Poly Electric Vehicle Charging Infrastructure Initiative

Prepared for: California Energy Commission

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PREFACE

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

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

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

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-13-606 to provide funding opportunities under the Clean Transportation Program to fund electric vehicle charging infrastructure in four categories to support growth of electric vehicles as a conventional method of transportation and adoption of plug-in electric vehicles over a wide range of California's population and socioeconomic classes. In response to PON-13-606, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 4, 2014 and the agreement was executed as ARV-13-055 on July 8, 2014.

ABSTRACT

This report describes the results of the installation of 12 Level 2 electric vehicle charging ports with 12 dedicated parking spaces in two campus parking lots at California Polytechnic University State University in San Luis Obispo. The goal of the project was to bring electric vehicle charging infrastructure to the university to increase the use of electric vehicles and thus reduce emissions associated with transportation by increasing workplace and destination charging. Usage data were collected from the stations over a 13-month period ending April 30, 2016, to determine equivalent emission reductions as well as various vehicle and user statistics. Specific objectives to increase workplace charging to eight users and destination charging to 150 users were set.

The installation included 12 electric vehicle charging ports (six dual-charging stations) consisting of four Chargepoint CT4025 8-foot bollard dual charging stations and two CT4023 6-foot wall-mount dual charging stations. Greenhouse gas emission reductions were based on the number of electric vehicle miles traveled. The internal combustion engine miles displaced was determined by the measurement of energy delivered by the electric vehicle charging stations and the energy use per mile of an average electric vehicle. The estimated greenhouse gas emission reductions over the data collection period were more than 30,000 kilograms of carbon dioxide equivalent emissions and it is estimated that over the 15-year life of the project, the reductions will reach 500,000 kilograms of carbon dioxide equivalent through eventual displacement of 1.6 million internal combustion engine vehicle miles.

By the end of the 13-month data collection period, the number of workplace charging users on campus has risen to 31 users, and destination charging users have reached 163 users.

Keywords: electric vehicle, electric vehicle charging stations, greenhouse gas emissions

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EXECUTIVE SUMMARY

The broad goal of the California Polytechnic University Electric Vehicle Infrastructure Initiative is to expand electric vehicle charging infrastructure to reduce emissions associated with transportation by increasing workplace and destination charging. This infrastructure expansion is to be achieved through installation of 12 Level 2 charging stations at California Polytechnic University State University in San Luis Obispo. As the university did not have any publicly available charging infrastructure, staff, students, and visitors were unable to charge electric vehicles, and possible associated emission reductions that could be attributed to the university community were lost. It was desired to make charging infrastructure available to staff, students, and visitors for the cost of energy and fee collection to allow possible greenhouse gas (GHG) emission reductions. Two specific usage objectives for the stations were identified. The first was to have 150 users use the stations for destination charging in the first 18 months. The second objective was to increase the number of electric vehicle drivers on campus that would use the stations for workplace charging within the first year to eight vehicles. To further inform future electric vehicle infrastructure decisions, data gathering and analysis were performed to determine the usage characteristics of the charging stations.

The charging stations have been used by 194 users over the 13-month data collection period. Of these, 31 have been workplace charging users, and the remaining 163 have been classified as destination chargers. These numbers exceed the original project objectives and suggest an earlier-than-expected expansion of the existing 12 stations may be required to 18 or 24 stations within the next three to five years. Users were encouraged to limit charging sessions to four hours or less through a fee schedule that became much more expensive after the first four hours of low-fee charging. This schedule worked so well that more than 90 percent of users' sessions were under 4 hours long.

GHG emission reductions were based on the number of electric vehicle miles traveled. In the case of the installed electric vehicle charging stations, the internal combustion engine miles displaced were calculated by the energy used per mile of an average electric vehicle of 0.3 kilowatt-hours per mile. In the local area, emissions of 424 gram carbon dioxide-equivalent per kilowatt-hour for the average generation of electricity were used. Thus in our analysis the generic electric vehicle created emissions of 127.2 grams carbon dioxide-equivalent per mile. Using the U.S. Environmental Protection Agency estimate of 423 grams carbon dioxide-equivalent per mile, assuming 21 miles per gallon of gasoline consumed, the net GHG reductions associated with this project will be 295.8 grams carbon dioxide-equivalent per mile driven by the electric vehicles making use of the newly installed stations. Using this figure, the authors have achieved total GHG emission reductions of more than 30,000 kilograms (kg) carbon dioxide-equivalent through more than 100,000 displaced internal combustion engine miles in a 13-month period. The authors expect to achieve a total project lifetime emission reduction of more than 500,000 kg carbon dioxide-equivalent through eventual displacement of 1.6 million internal combustion engine vehicle miles.

CHAPTER 1:
Project Purpose

1.1 Introduction

California Polytechnic University (Cal Poly) is a nationally ranked, four-year, comprehensive public university located in San Luis Obispo, halfway between San Francisco and Los Angeles on California's Central Coast. It is a community offering students a hands-on educational experience that prepares them for today's scientific and technical world. In addition, Cal Poly is the second largest land-holding university in California, second only to University of California Berkeley, and one of the largest land-holding universities in the nation. Cal Poly uses all of its land holdings to support the education of its students. On average, Cal Poly is home to nearly 20,000 students and faculty. Sustainability has become a focus for the campus, and the desire to add electric vehicle (EV) charging infrastructure has grown from the goal of increasing the sustainability of campus transportation practices.

1.2 Goals and Objectives

The broad goal of this project is to expand EV charging infrastructure to reduce emissions associated with transportation by increasing workplace and destination charging. The university has installed 12 EV charging ports (six dual-charging stations) with 12 dedicated parking spaces in two campus parking lots. There are two reserved Americans with Disability Act compliant spaces, one in each lot. The university has installed four dual-charging stations with eight dedicated parking spaces in the H2 Bonderson parking lot with one reserved Americans with Disability Act-compliant space. We have installed two dual charging stations with four dedicated parking spaces in the Grand Avenue parking structure with one reserved Americans with Disability Act compliant space.

1.2.1 Goals of the Project

The goals of the proposed project include:

- Expanding EV charging infrastructure to increase use of EVs and therefore reduce emissions associated with transportation by increasing workplace charging, destination charging, and corridor charging.
- Successfully installing and integrating Level 2 charging into campus parking and commuter services.
- Supporting growth of EVs as a conventional method of transportation by demonstrating the high level of use of new EV charging infrastructure.
- Data gathering, including kilowatt-hours (kWh) used, number of vehicles charging, average charge duration, carbon dioxide equivalent (CO2e) emissions avoided.

1.2.2 Objectives of the Project

The objectives of this project are to:

- Install 12 Level II charging stations.

- Charge staff, students and public for the cost of energy and fee collection.
- Within one year of completion, increase the number of EVs driven regularly to campus to eight vehicles.
- Within the first 18 months after completion, have 150 vehicles use the Level 2 charging stations for destination charging.
- Collect usage statistics for each station.

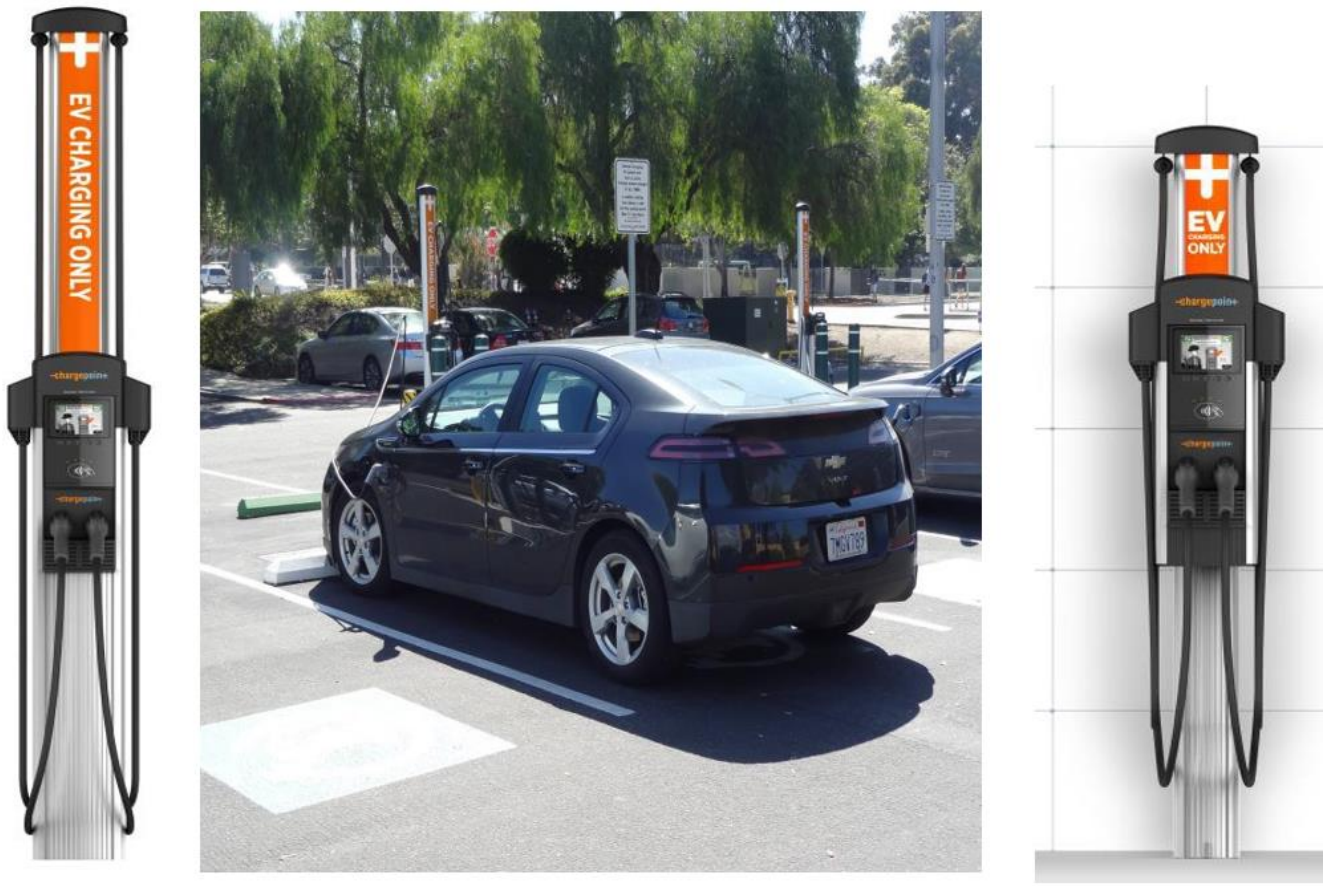
CHAPTER 2:
Project Approach

2.1: Task 1: Equipment Procurement

The equipment required was obtained through a competitive request for proposal process. Four bids were received and reviewed by the Evaluation Committee. The bidder selected to provide equipment was Chargepoint.

The authors have installed 12 EV charging ports (six dual-charging stations) consisting of four Chargepoint CT4025 8-foot Bollard, dual-charging stations and two CT4023 6-foot wall-mount, dual- charging stations. Each CT4025 charging station has two available charging ports with a 23-foot cord, with cord management. Each CT4023 charging station has two available charging ports with an 18-foot cord, with cord management. Each charging port at all stations is capable of providing 7.2 kilowatts at 240 volts and 30 amperes. All stations are available 24 hours a day. All stations accept credit card payments or can be operated with a Chargepoint card that users may obtain by creating a free account. The CT4025 and the CT4023 Charging Stations, and a Chevy Volt connected to one of the models, are shown in figure 1.

Figure 1: CT4025 Charging Station with Chevy Volt Connected to it and CT4023 Charging Station



Source: Cal Poly Corporation

Detailed layouts for each site are shown in figure 2 and figure 3, respectively. Both locations have been carefully selected to allow the greatest use of each charging station at the lowest cost and to have an expansion capacity of 100 percent. Each site has easy ingress and egress and is adequately lit for use 24 hours a day. Each site is near numerous attractions for EV owners while their vehicles charge. The sites are the most reasonable infrastructure cost sites as both had adequate electrical power capacity on existing building infrastructure such that only trenching, conduit, and cabling costs were required for installation, and additional power infrastructure to the facilities was avoided. Each site had a completed layout to ensure the quote provided for labor and materials through the university's facilities department could be as accurate as possible.

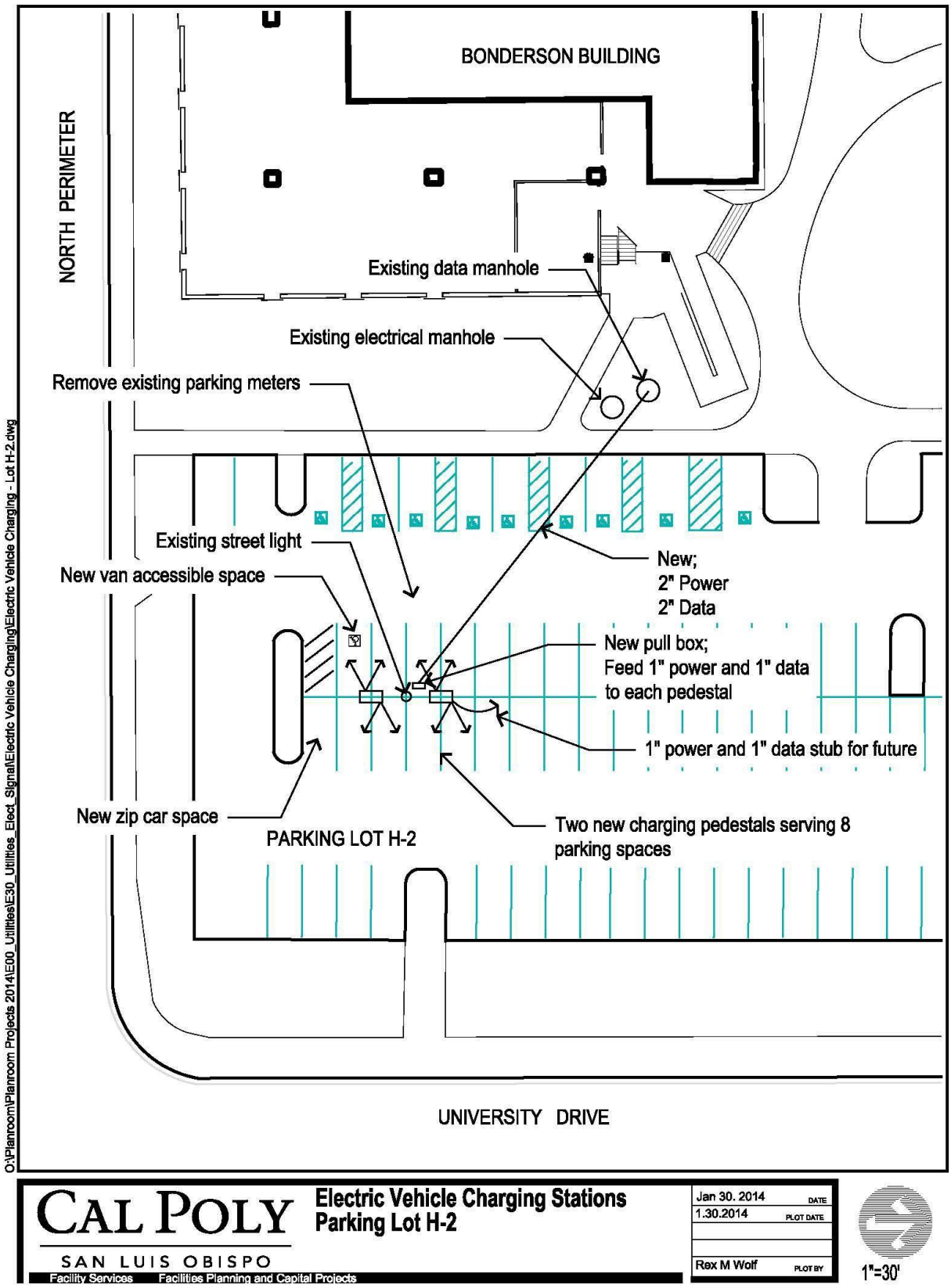
Energy costs will be passed on to EV owners at cost and the low average cost of electrical energy on campus will allow both on peak and off peak charging at reasonable rates, thus encouraging full utilization of the charging stations. To increase utilization and to allow all EVs access to charging stations, each charging session is encouraged to be less than four hours which will allow full charging of most vehicles on Level II charging stations.

2.2: Task 2: Installation of EV Charging Stations

The locations of the two sites are shown in figure 4. The chosen sites meet the requirements for destination charging, corridor charging, and workplace charging. It is a destination for a host of tourist and community activities, including cultural activities, performances, sporting events, educational forums, short courses, academic and nonacademic instruction, and research. It serves the entire San Luis Obispo County area and draws vehicles from Santa Maria to Paso Robles and beyond daily. It also draws a large visitor/tourist population of vehicles year round, especially in the summer beach season and the fall winery season. The chosen site is on the heavily traveled U.S. Highway 101 corridor between Los Angeles and San Francisco. The stations are easily accessible from the highway and are 0.9 miles from the Grand Avenue exit off U.S. Highway 101 in San Luis Obispo. It is also an ideal location for workplace charging as the university is one of the major employers in the area and employees travel from several defined major urban areas, including Arroyo-Grande-Grover Beach, El Paso de Robles-Atascadero, San Luis Obispo, and Santa Maria, all within a 50-mile concentric ring of the chosen sites as shown in figure 5.

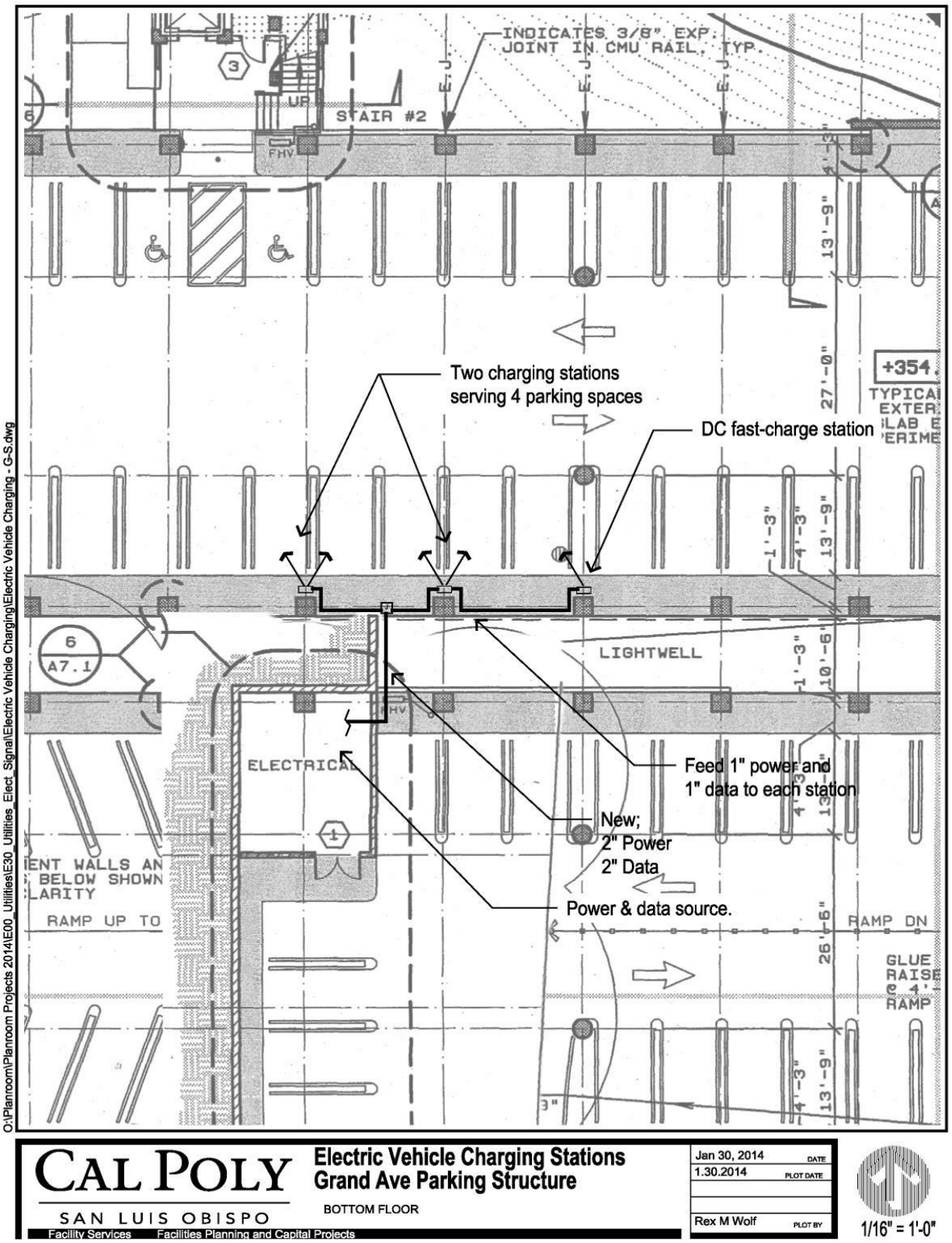
The effort to provide this forward-thinking opportunity on campus has been driven in part by the principal investigator, as well as the university police. The principal investigator is an EV driver and has gained experience and insight into EV charging over the last 48 months. The university police and university facilities have been receiving an increased number of inquiries about public EV charging station on campus.

Figure 2: Site Plans for Bonderson H-2 Lot With Eight Reserved EV Spaces



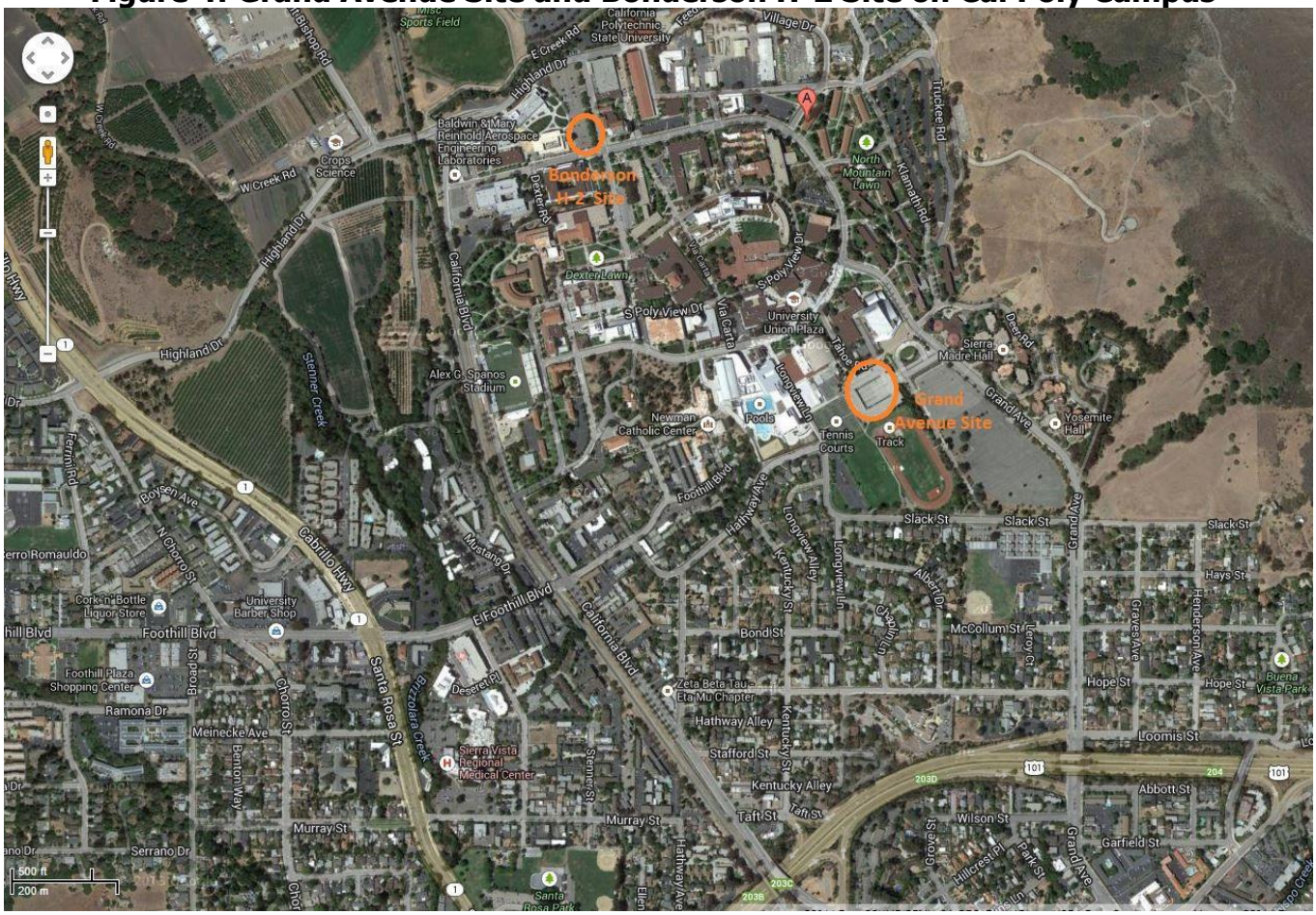
Source: Cal Poly Corporation

Figure 3: Site Plans for Grand Avenue Parking Structure With Four Reserved EV Spaces



Source: Cal Poly Corporation

Figure 4: Grand Avenue Site and Bonderson H-2 Site on Cal Poly Campus



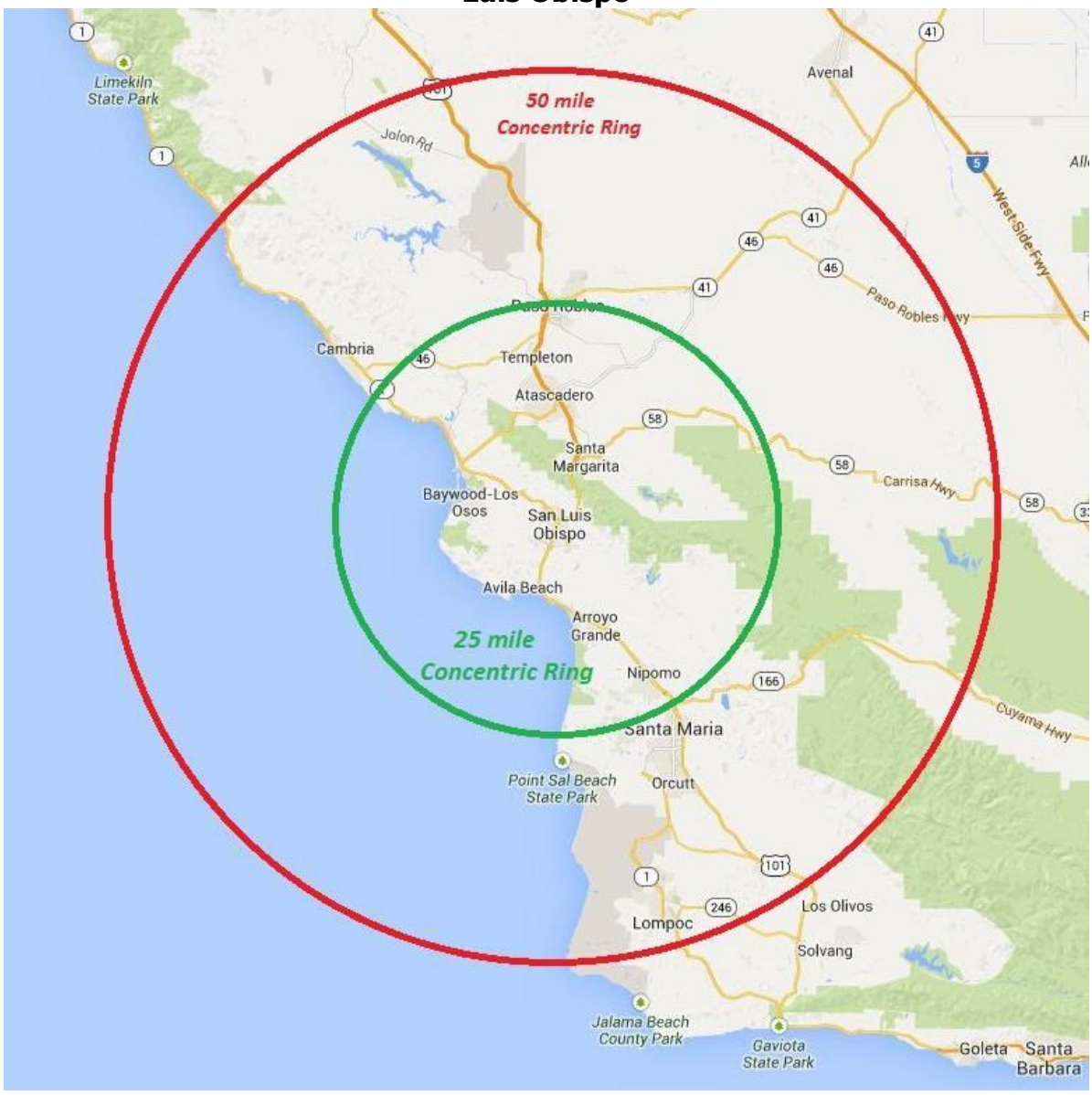
Source: Cal Poly Corporation

Two sites were selected to give the greatest variety of opportunities for the three types of charging options on campus. The Grand Avenue Parking Structure is the predominant parking location for the performing arts center, which is a major venue for concerts, plays, dance and theatre, comedy, and numerous other activities for the entire community. It is 0.9 miles from the Grand Avenue exit of US 101 in San Luis Obispo as shown in figure 4. Campus dining, the student union, student store, administration, and restaurants, coffee shops and pizza/fast food/cafeteria facilities are within 200 yards of the installed stations at the Grand Avenue Parking Structure. The site has full electrical service, is easy and well lit, has a safe public entrance and exit, and serves university student and staff parking. The site is a corridor and destination site, as well as a suitable workplace charging location.

The other selected site is used to serve the student and faculty parking adjacent to the Cal Poly Kennedy Library and the Bonderson center, as well as hosting parents and other visitors at all times. It presently hosts the Transportation Center that interfaces with the San Luis Obispo Transit Authority, where numerous transit buses daily connect with downtown San Luis Obispo, the Amtrak Station, and Morro Bay and the beach communities. The site also hosts a Zip Car facility on campus that provides car sharing with the community. The charging sites have close access to the engineering, architecture, agriculture, and business colleges, so it serves both local commuters and numerous visitors from the community, industry, and academia. The site is in a modern section of the campus with full access to sufficient electric

power and convenient entry and exit roadways. It is in a high-traffic area and is close to the police and parking administration buildings, ensuring security and service attention.

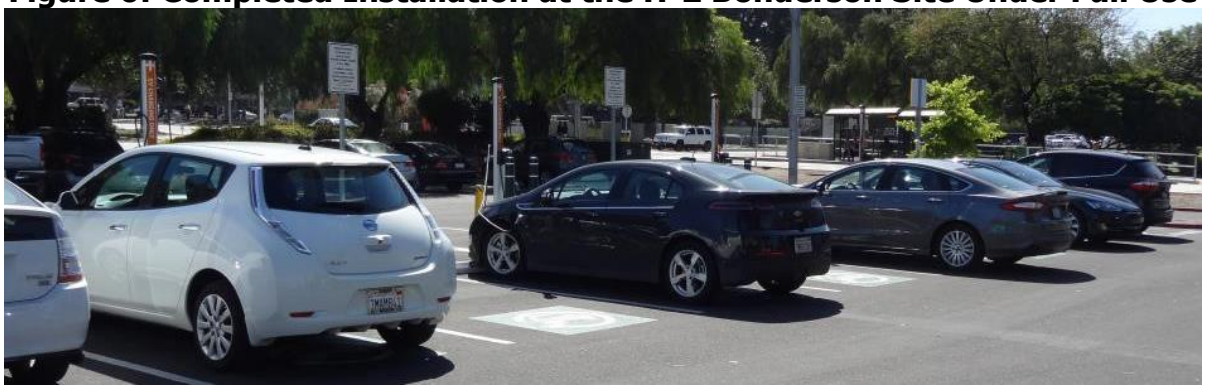
Figure 5: Major Urban Areas Located Within a 50-Mile Concentric of Cal Poly, San Luis Obispo



Source: Cal Poly Corporation

The Cal Poly workforce lives in several major urban areas within San Luis Obispo County. Four defined major urban areas are within a 50-mile concentric ring of the chosen sites. These include Arroyo Grande-Grover Beach (18 miles driving distance), El Paso de Robles-Atascadero (19 miles driving distance to Atascadero, 29 miles driving distance to Paso Robles), San Luis Obispo (1-7 miles driving distance), and Santa Maria (34 miles driving distance). All with the exception of Santa Maria are also within a 25-mile concentric ring as indicated on figure 5.

Figure 6: Completed Installation at the H-2 Bonderson Site Under Full Use



Source: Cal Poly Corporation

The installation of the EV charging station at these sites was performed by campus employees, who installed 12 EV charging ports (6 dual-charging stations) with 12 dedicated parking spaces in these two campus parking lots. Both sites have sufficient electrical capacity for expansion capability of at least 100 percent, and remaining capacity will be available in electrical and communication conduits to allow expansion cables to be run in the future. The campus installed four Chargepoint CT4025 8-foot bollard dual-charging stations with eight dedicated parking spaces in the H-2 Bonderson parking lot (with one reserved Americans with Disability Act-compliant space) and two CT4023 6-foot wall-mounted dual-charging stations with four dedicated parking spaces in the Grand Avenue Parking Structure (with one reserved Americans with Disability Act-compliant space). Figure 6 and 7 show completed installations at the H-2 Bonderson site under full use. Stations were commissioned on April 3, 2015, and an opening ceremony was held with university President Jeffrey D. Armstrong being the first to charge his EV at the H-2 Bonderson station as shown in figures 8 and 9.

Figure 7: H-2 Bonderson Site Under Full Use With a Variety of EV Models

Source: Cal Poly Corporation

Figure 8: Cal Poly President Armstrong at Charging Station Commissioning, April 3, 2015

Source: Cal Poly Corporation

Figure 9: Cal Poly President Armstrong's Opening Statement at Charging Station Commissioning

Source: Cal Poly Corporation

CHAPTER 3:
Project Results

3.1: Data Collection Plan

The Chargepoint system installed allows data collection of charging sessions such that data can be analyzed in a variety of ways. The focus has been on reducing carbon emissions, and maximizing eventual station usage, and promoting overall EV use. The analyzed metrics include:

- CO2e emissions avoided.
- Vehicle miles displace.
- Kilowatt-hours (kWh) used.
- Number of charging sessions
- Average charge duration
- Number of vehicles charging.

To obtain these metrics, investigators collected data from each session on the date and duration of each session, kWh used, and user identification. The data were analyzed to determine totals for the 13-month data collection period as well as monthly totals to determine usage progression. The data collection period for this report began April 1, 2015, and ended April 30, 2016.

GHG emission reductions are based on the number of EV miles traveled. In the case of the installed EV charging station, it was assumed that the internal combustion engine miles displaced can be calculated by the energy used per mile of an average EV of 0.3 kWh per mile. According to the Union of Concerned Scientists, the California-Mexico Power Area region emits about 424 grams CO2e per kWh for the average generation of electricity used. This amount does not take into account the time of usage and generation but will be accurate in this case since charging takes place at all times of days and is not generally shifted toward nighttime charging, when the electric generation mix is significantly different. Thus, for this analysis the generic EV will create emissions of 127.2 grams CO2e per mile (424 grams CO2e per kWh x 0.3 kWh per mile). Using the U.S. Environmental Protection Agency estimate of 423 grams CO2e per mile (assuming 21 miles per gallon of gasoline consumed), the net GHG emissions reductions associated with this project will be 295.8 grams CO2e per mile driven by the EVs making use of the newly installed stations.

The usage objectives for the stations was to have 150 motorists use the stations for destination charging in the first 18 months and to increase the number of employee EV drivers on campus to eight who use the stations for workplace charging within the first year.

3.1.1: CO2e Emissions Avoided

The overarching goal of this project was to reduce the CO2e emissions associated with transportation on campus and to promote the increased use of EVs. The monthly GHG savings in kg CO2e are shown in figure 10. As more vehicles began to use the charging stations more frequently, the equivalent emissions avoided increased. The emissions avoided in April 2016

were more than double that avoided in the first month after installation. Although there was a significant increase in use, and thus emissions avoided over the life of the project, the increases have slowed as many new potential EV owners who were waiting for appropriate infrastructure have since purchased vehicles.

The average monthly emissions avoided over the 13 months of data collection have been 2,312 kg CO2e. The average monthly emissions avoided over the last six months and three months have been 2,780 kg CO2e and 2,947 kg CO2e, respectively. Although much of this increased average can be attributed to more widespread use as more users have come to campus, some reduction in the project average is due to lower use during the summer months when students and staff do not use the charging stations as regularly. The total emissions avoided over the current span of the project have been more than 30,000 kg CO2e, as seen in the accumulated emissions avoided in figure 10. With an estimated lifetime of 15 years, the overall lifetime emissions avoided is expected to exceed more than 500,000 kg CO2e.

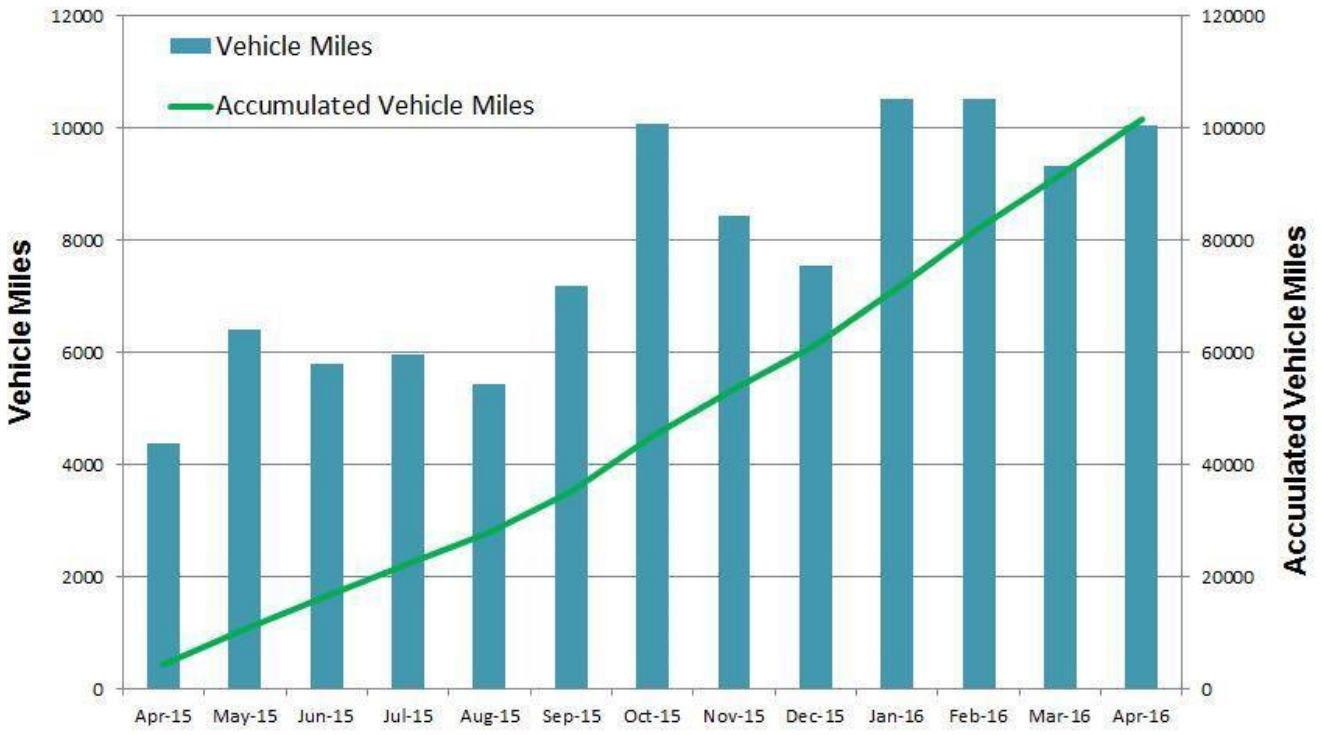
Figure 10: GHG Savings (CO2e) Achieved by EV Charging Infrastructure Initiative

Source: Cal Poly Corporation. Data from EV charging station data collection system.

3.1.2: Vehicle Miles Displaced

The internal combustion engine miles displaced by electric miles are calculated using the assumption of an average use of 0.3 kWh per mile. The monthly miles displaced and the accumulated displaced vehicle miles are shown in figure 11. Monthly values for displaced miles have approximately doubled from 5,000 miles at the beginning of the project to 10,000 miles over the last four months of data collection. Over the year of data collection, the total vehicle miles displaced have grown to nearly 100,000 miles.

Figure 11: Vehicle Miles Achieved by Cal Poly EV Charging Infrastructure Initiative

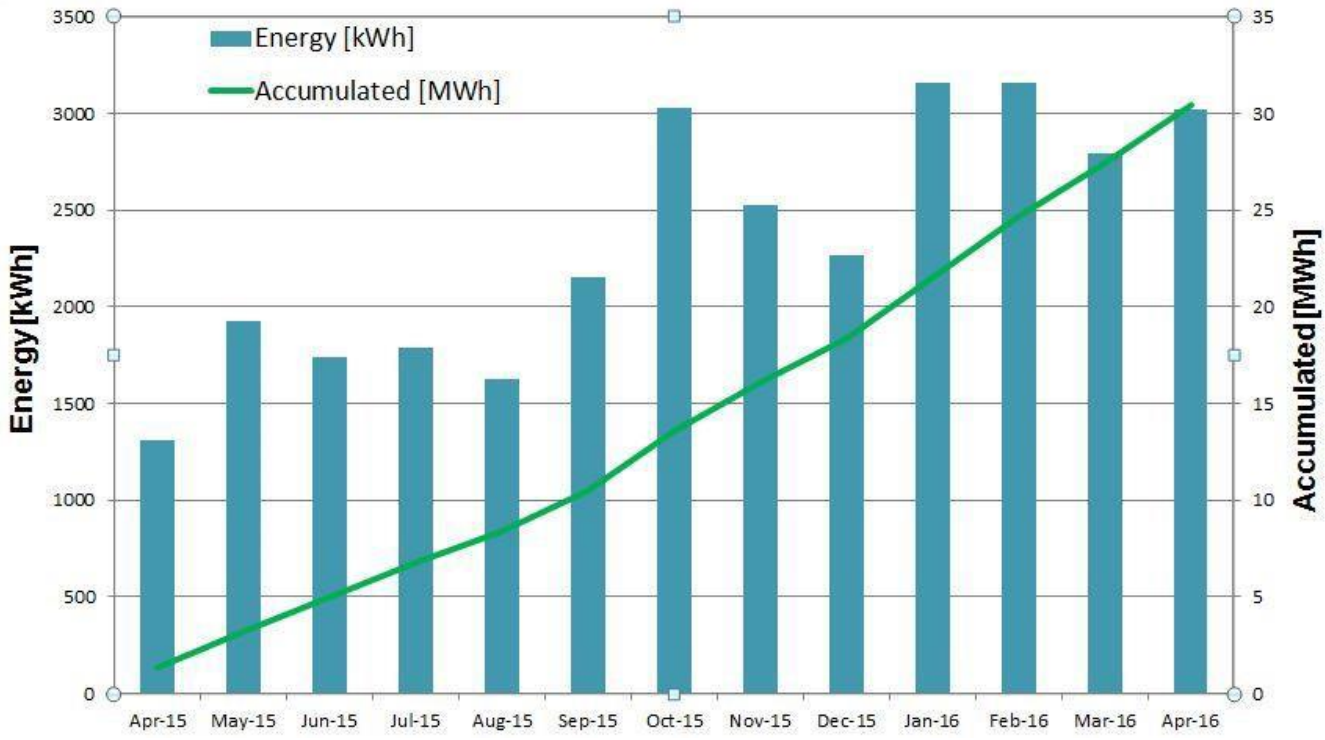


Source: Cal Poly Corporation. Data from EV charging station data collection system.

3.1.3: Kilowatt-Hours Used

The amount of energy delivered to EVs from the 12 EV charging stations is shown in figure 12. Both monthly energy (in kWh) and cumulative energy (in megawatt-hours) are shown and are proportional to the internal combustion engine vehicle miles displaced as shown in figure 11.

Figure 12: Energy Delivered to EV Charging Station and to Vehicles

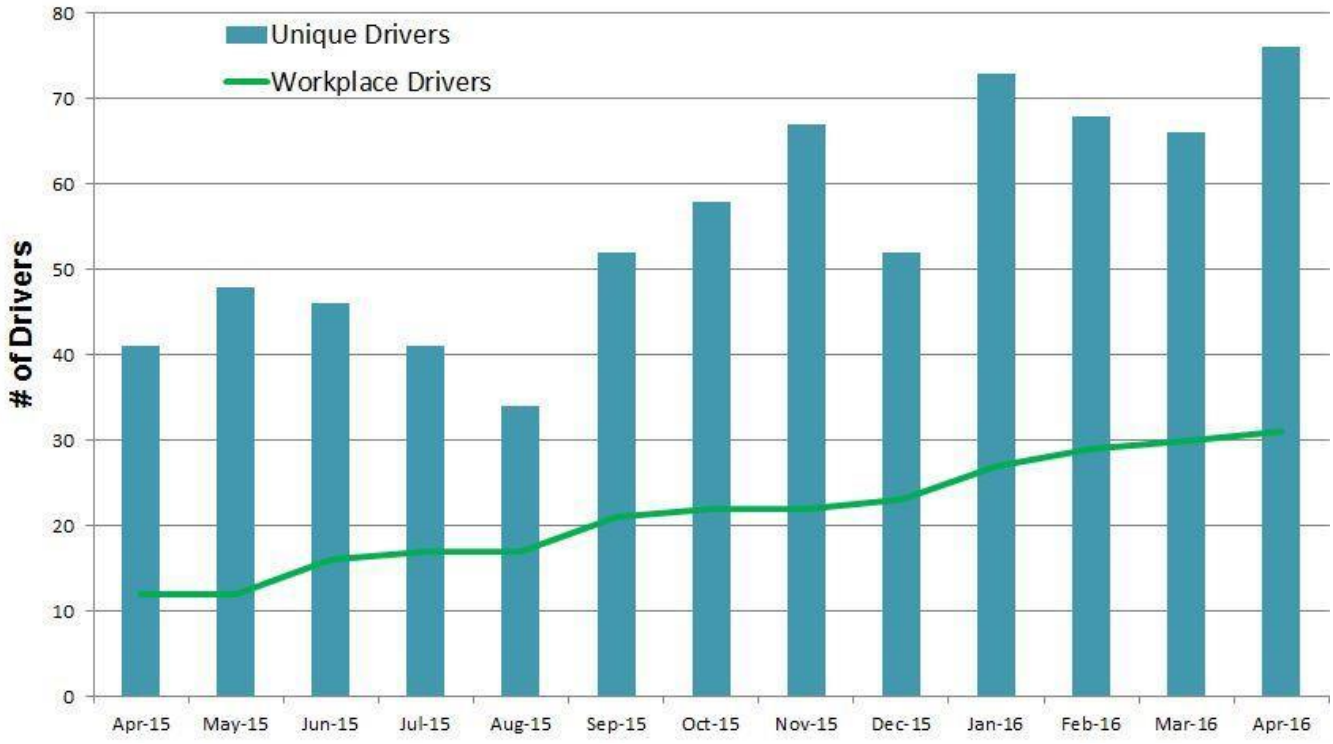


Source: Cal Poly Corporation. Data from EV charging station data collection system.

3.1.4: Number of Vehicles Charging

The number of unique vehicles using the EV charging station is shown in figure 13. Each vehicle can be identified as separate using an identification number that is recorded automatically when charging at a station. The number of unique drivers using the stations monthly has grown from nearly 40 per month in the first few months after installation to between 60 and 70 in the last six months. Also seen in figure 13 is the growing number of users who are using the stations for workplace charging. A workplace user was identified as a student or staff at the university that charges at least twice per week regularly. It can be seen that during the first month, the number of workplace charging users grew to 12 users, exceeding the project objective of reaching 8 within the first six months. By six months the number of workplace charging users grew to 21 and by the end of the first year reached 31 users. The total number of unique vehicles using the charging stations over the 13-month data collection period is 194 vehicles. The workplace charging users are repeated in the monthly unique driver totals as are many of the less frequent users who visit the university as destination chargers. Of the 194 unique vehicles, 161 of those were destination chargers, which exceeded the objective of having had 150 unique destination chargers over the first 18 months use the EV charging station.

Figure 13: EV Charging Station Used by Unique Drivers and Workplace Drivers

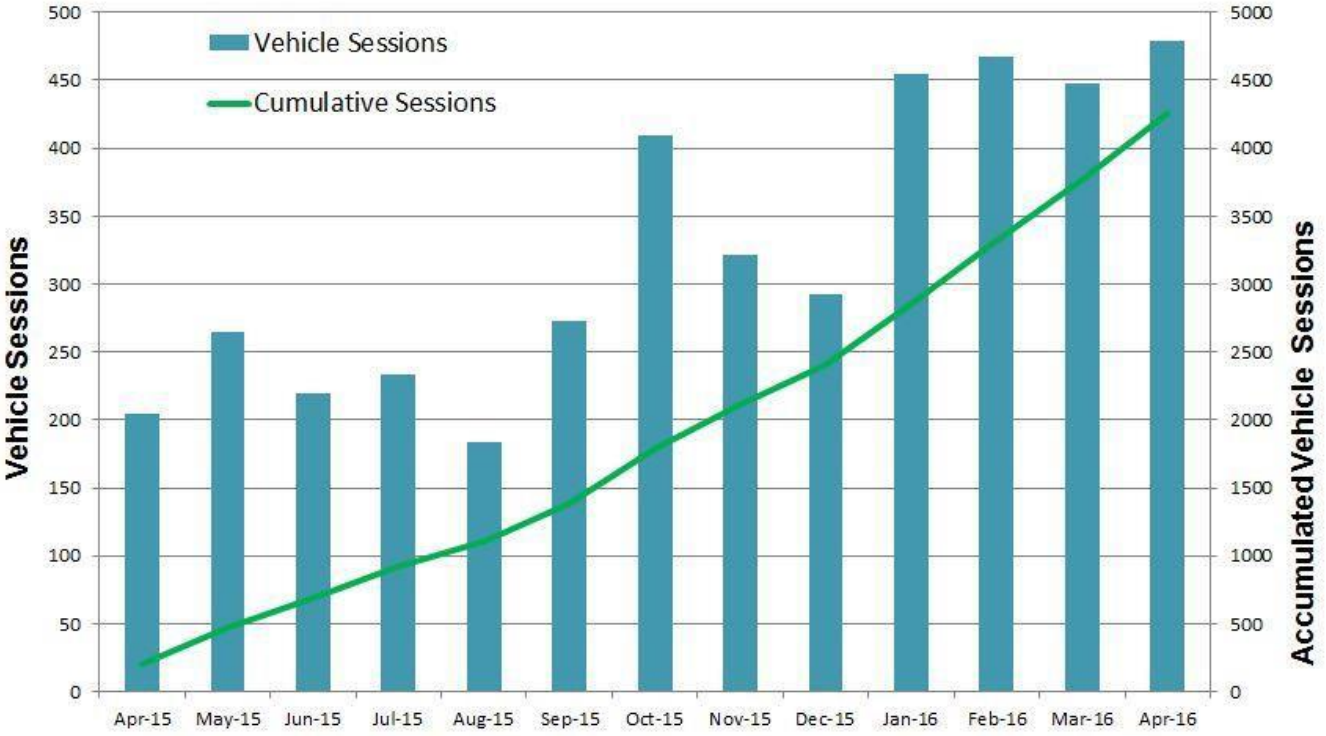


Source: Cal Poly Corporation. Data from EV charging station data collection system.

3.1.5: Number of Charging Sessions

As the number of users increased, as would be expected, so did the number of charging sessions. After the EV charging station opening ceremony, there was an average of nearly 200 charging sessions per month. In the last four months, there has been an average of more than 400 charging sessions per month. In total, there have been just more than 4,250 charging sessions across the EV charging station that are part of the Cal Poly EV Charging Infrastructure Initiative. The number of monthly sessions and the accumulated sessions are shown in figure 14.

Figure 14: Number of Monthly Vehicle Sessions and Accumulated Vehicle Sessions

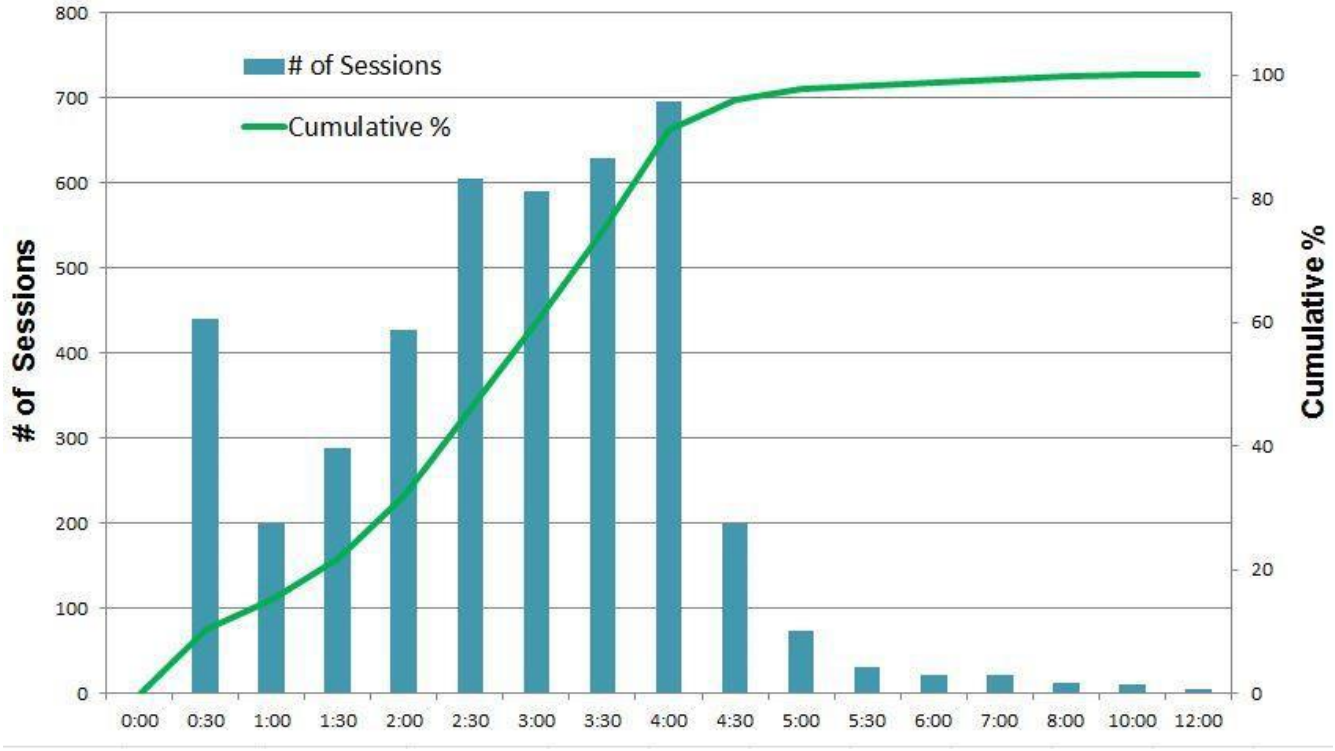


Source: Cal Poly Corporation. Data from EV charging station data collection system.

3.1.6: Average Charge Duration

As the number of users increased, it became more important to ensure that only those using the EV charging station were occupying dedicated spaces to allow all users fair and efficient access. To encourage vehicle movement after a reasonable charging period (chosen as four hours), the rates increased from $0.11 per kWh to $0.10 per minute. This much higher rate encouraged users to leave the charging station before the higher rates started after four hours of charging. As shown in figure 15, only 8 percent of users remained longer than four hours, and only 1 percent remained longer than 5.5 hours. The majority, two-thirds of users, had charging sessions between two and four hours. The rate structure implemented was effective at maintaining efficient use of all charging stations throughout the day, although at times it was inconvenient for workplace charging and users staying on campus for longer periods. For public charging to become more widespread, infrastructure needs to be deployed and used efficiently to reduce the overall equipment costs and resulting user fees. The distributions of charging times did not change over time with increasing number of users.

Figure 15: Session Length Histogram With Cumulative Frequency



Source: Cal Poly Corporation. Data from EV charging station data collection system.

CHAPTER 4: Conclusion

The Cal Poly EV Charging Infrastructure Initiative has met all the original goals and objectives, including the installation of 12 EV charging ports (six dual-charging stations) each capable of providing 7.2 kilowatts at 240 volts and 30 amperes. All stations are available 24 hours a day, seven days a week. The use of EVs on campus for both workplace charging and destination charging has substantially increased since the installation of the EV charging station. There were two usage objectives for the stations. The first was to have 150 users use the stations for destination charging in the first 18 months. The second objective was to increase the number of EV drivers on campus that would make use of the stations for workplace charging within the first year to eight. The number of workplace charging users on campus has already grown to 31 users in one year, in addition to more than 150 destination charging users.

As the stations become more heavily used, it is anticipated that additional stations will need to be provided to meet the increasing demand. The amount of cabling required for a doubling of stations was put in place during the original installation to reduce future costs of adding additional capacity. It is expected that additional stations will be required depending on demand in the next three to five years.

The goal of this project was to reduce the CO2e emissions associated with transportation on the campus. To date the university has achieved total GHG emission reductions of more than 30,000 kg CO2e. The authors expect to achieve a total project lifetime emission reduction of more than 500,000 kg CO2e through eventual displacement of 1.6 million internal combustion engine vehicle miles.

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 California 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

Funding for the Commission's activities comes from the Energy Resources Program Account, Federal Petroleum Violation Escrow Account and other sources.

CARBON DIOXIDE EQUIVALENT (CO2e) – A metric used to compare emissions of various greenhouse gases. It is the mass of carbon dioxide that would produce the same estimated radiative forcing as a given mass of another greenhouse gas. Carbon dioxide equivalents are computed by multiplying the mass of the gas emitted by its global warming potential.[1]

CALIFORNIA POLYTECHNIC STATE UNIVERSITY SAN LOUIS OBISPO (Cal Poly) - Cal Poly is a nationally ranked, four-year, comprehensive public university located in San Luis Obispo, halfway between San Francisco and Los Angeles on California's Central Coast.[2]

GREENHOUSE GASES (GHG) – Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), halogenated fluorocarbons (HCFCs), ozone (O3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

KILOGRAM (kg) – The base unit of mass in the International System of Units that is equal to the mass of a prototype agreed upon by international convention and that is nearly equal to the mass of 1,000 cubic centimeters of water at the temperature of its maximum density.

KILOWATT-HOUR (kWh) – The most commonly used unit of measure telling the amount of electricity consumed over time, means one kilowatt of electricity supplied for one hour. In 1989, a typical California household consumed 534 kWh in an average month.

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1 California Air Resource Board (https://ww2.arb.ca.gov/ghg-inventory-glossary)

2 Cal Poly (https://www.calpoly.edu/about/)