California Energy Commission
Alternative and Renewable Fuel and Vehicle Technology Program

FINAL PROJECT REPORT

Santa Clara Electric Vehicle Charging Center

Prepared for: California Energy Commission
Prepared by: The Electric Power Research Institute

California Energy Commission
Edmund G. Brown Jr., Governor

August 2018 | CEC-600-2018-006
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Contract Number: ARV-14-004

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ACKNOWLEDGEMENTS

EPRI would like to acknowledge the following organizations for their contributions to successful completion of the project:

Silicon Valley Power
ChargePoint, Incorporated
The City of Santa Clara
Joint Venture Silicon Valley
MJR Electric
Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). The statute authorizes the California Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state’s climate change policies. AB 8 (Perea, Chapter 401, Statutes of 2013) re-authorizes the ARFVTP through January 1, 2024, and specifies that the Energy Commission allocate up to $20 million per year in funding for hydrogen station development until at least 100 stations are operational.

The ARFVTP has an annual budget of approximately $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 non-road 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 ARFVTP, a project must be consistent with the Energy Commission’s ARFVTP Investment Plan, updated annually. The Energy Commission issued solicitation PON-13-606 to fund Electric Vehicle Charging Infrastructure in order 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 socio-economic classes. In response to solicitation PON-13-606, the recipient submitted an application which was proposed for funding in the Energy Commission’s Notice of Proposed Awards on July 3, 2014 and the agreement was executed as ARV-14-004 on July 9, 2014.
ABSTRACT

Based on a proposal submitted by a team consisting of the Electric Power Research Institute, Silicon Valley Power, Joint Venture Silicon Valley, ChargePoint, Inc. and MJR Electric, the Energy Commission approved and funded construction of an electric vehicle charging facility. The project completed the installation of plug-in electric vehicle (PEV) charging stations at a multi-level parking garage located in the City of Santa Clara. The Santa Clara Electric Vehicle Charging Center was completed in November of 2015 and provides visitors with easy and predictable access to PEV charging at a high-profile destination in the Bay Area. The site has 48 AC Level 2 electric vehicle charging ports located on the first two levels of a 6-level parking structure owned by the City of Santa Clara. Consumers are billed for the charging service at a rate of $0.25 per kWh. The 48 charge ports were installed as 24 dual port charging stations located on the first and second floors near the west corner of the garage structure. The garage is located on Tasman Drive between Lafayette Street and Great American Parkway.

Keywords: electric vehicle, charging station, Level 2

Please use the following citation for this report:

# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>1</td>
</tr>
<tr>
<td>Preface</td>
<td>2</td>
</tr>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>4</td>
</tr>
<tr>
<td>List of Figures</td>
<td>5</td>
</tr>
<tr>
<td>List of Tables</td>
<td>7</td>
</tr>
<tr>
<td>Executive Summary</td>
<td>8</td>
</tr>
<tr>
<td>Project Results</td>
<td>8</td>
</tr>
<tr>
<td>CHAPTER 1: Project Overview</td>
<td>10</td>
</tr>
<tr>
<td>Scope of Work Summary</td>
<td>10</td>
</tr>
<tr>
<td>Goals of the Agreement</td>
<td>10</td>
</tr>
<tr>
<td>Objectives of the Agreement</td>
<td>10</td>
</tr>
<tr>
<td>Project Task Summary</td>
<td>11</td>
</tr>
<tr>
<td>Site Description from Proposal</td>
<td>11</td>
</tr>
<tr>
<td>Project Timeline</td>
<td>14</td>
</tr>
<tr>
<td>CHAPTER 2: Installation</td>
<td>18</td>
</tr>
<tr>
<td>Selecting Charge Equipment Locations</td>
<td>18</td>
</tr>
<tr>
<td>Pre-construction Site Photos</td>
<td>21</td>
</tr>
<tr>
<td>Construction</td>
<td>24</td>
</tr>
<tr>
<td>Completed Installation</td>
<td>27</td>
</tr>
<tr>
<td>CHAPTER 3: Operation and Maintenance</td>
<td>34</td>
</tr>
<tr>
<td>System Operation</td>
<td>34</td>
</tr>
<tr>
<td>Maintenance</td>
<td>35</td>
</tr>
<tr>
<td>CHAPTER 4: Outreach Activities</td>
<td>36</td>
</tr>
<tr>
<td>CHAPTER 5: Data Collection and Analysis</td>
<td>38</td>
</tr>
<tr>
<td>Data Collection Test Plan</td>
<td>38</td>
</tr>
<tr>
<td>Charging Trends</td>
<td>38</td>
</tr>
<tr>
<td>Operations Data Environmental Impacts</td>
<td>41</td>
</tr>
<tr>
<td>Fuel Displacement</td>
<td>41</td>
</tr>
<tr>
<td>Air Quality Impacts</td>
<td>41</td>
</tr>
<tr>
<td>CHAPTER 6: Communications Protocols for EV Charging Management</td>
<td>44</td>
</tr>
<tr>
<td>Overview</td>
<td>44</td>
</tr>
<tr>
<td>The Goal of Standards</td>
<td>44</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1: Statement of Work Task List with Major Timeline Events ........................................ 14
Table 2: Green House Gas Calculation Summary .................................................................. 41
EXECUTIVE SUMMARY

The Electric Power Research Institute, Silicon Valley Power, Joint Venture Silicon Valley, ChargePoint, Inc., and MJR Electric were awarded Energy Commission funding under grant agreement ARV-14-004 to complete construction of and operate a plug-in electric vehicle (PEV) charging facility located at a multi-level parking garage in the City of Santa Clara. The facility, referred to as the Santa Clara Electric Vehicle Charging Center (EVCC), is located adjacent to 49ers Stadium at 2525 Tasman Drive and provides visitors with easy and predictable access to PEV charging at one of the highest-profile destination sites in the Bay Area. The site has 48 AC Level 2 electric vehicle charging ports, installed as 24 dual port charging stations, located on the first two levels of a 6-level parking structure owned by the City of Santa Clara. Consumers are billed for the charging service at a rate of $0.25 per kWh.

Project Results

The project was able to accomplish the following goals and associated objectives that were set forth in the initial project proposal:

- Completed the installation and commissioning of the EV chargers and demonstrated system operation for the three-year duration of the project.
- Engaged with stakeholders in proximity of the charging station facility to facilitate and enhance consumer awareness and utilization of the charging stations.
- Documented lessons learned and system utilization statistics in monthly reports and this final report to the Energy Commission.
- Demonstrated the use of electricity as a transportation fuel and documented the reduction of petroleum fuel use enabled by the charging system.

Two project goals were modified:

- The project attempted to document utilization of the system based on the impact of stakeholder engagement, but was unable to do so due to variability of system use and a steady growth over time in system utilization.
- The project initially planned to develop and evaluate peak power demand management across the charge station installation, an option not readily available at the time of the project proposal. This goal was not pursued for two key reasons:
  - Over the duration of the project system utilization did not reach a point where such management would be necessary.
  - This feature is now offered as a standard product offering from the system network provider, ChargePoint.
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CHAPTER 1: Project Overview

A proposal team consisting of the Electric Power Research Institute, Silicon Valley Power, Joint Venture Silicon Valley, ChargePoint, Inc. and MJR Electric was assembled for the program opportunity notice of PON-13-606 in 2013. The proposal team sought and was awarded Energy Commission grant funding to complete installation of plug-in electric vehicle (PEV) charging stations at a multi-level parking garage located in the City of Santa Clara under grant agreement ARV-14-004. As constructed, the Santa Clara Electric Vehicle Charging Center (EVCC), located at 2525 Tasman Drive in Santa Clara, provides visitors with easy and predictable access to PEV charging at one of the highest-profile destination sites in the Bay Area. Media exposure was used to actively promote and increase public awareness of electric vehicles and green transportation to a broad population. The EVCC serves as a showplace element in a 21st Century regional transit network, and as an example for creating similar destination-oriented PEV charging centers around the State and beyond.

Scope of Work Summary

Goals of the Agreement
The goals of the agreement were as follows:

- Complete installation of EV chargers.
- Operate and manage the charge station network using an Open Standard Protocol.
- Develop and evaluate peak power demand management across the charge station installation including power sharing between networked stations.
- Engage with stakeholders in proximity of the charging station facility to facilitate and enhance consumer awareness and utilization of the charging stations.
- Understand utilization of the system and the impact of stakeholder engagement.
- Reduce California’s use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.

Objectives of the Agreement
The objectives of the agreement were as follows:

- Commission and operate EV chargers.
- Demonstrate networked operation of the charging stations using the Open Charge Point Protocol and document short comings and challenges in doing so.
• Demonstrate the ability to manage peak power consumption of the charging station installation via the managing network and document how this could be used to lower cost of future installations.
• Document success and failures of outreach activities, document lessons learned and system utilization statistics in monthly reports and a final report to the Energy Commission.
• Attempt to correlate utilization data with stakeholder engagement activities.
• Through collection of utilization data, document reduction of petroleum fuel use.

Project Task Summary

Task 1 Administration
This task covers the project management and Energy Commission project requirements activities of the project, including this final report document.

Task 2 Install and Commission Charging Stations
This task covers physical installation of stations, establishing network connectivity to the stations and working within the community to promote usage of the facility. Chapter 2 of this report covers system installation activities of this task. Chapter 3 of this report includes a summary of community engagement activities and results as required under this task.

Task 3 Develop Site Power Management Capability
This task was designed to explore both site power management and the networking protocol used to operate the charging system. The task included activities to exercise system operation based on local site power consumption condition using the Open Charge Point Protocol for network communications. Results of this task are discussed in Chapters 5 and 6 of this report.

Task 4 Data Collection and Analysis
This task was designed to collect and analyze data from operation of the charging system to develop metrics for economic and environmental benefits of the installation. Chapter 4 of this report provides the results of this task.

Site Description from Proposal
The first two levels of a recently completed 6-level parking structure owned by the City of Santa Clara will be retrofitted with 48 Level 2 electric vehicle charging stations under this project. The plan is to install 48 charge ports as two sets of 12 dual cable charge stations on the first and second floors near the west corner of the garage structure. The garage is located at 2525 Tasman Drive, between Lafayette Street and Great American Parkway (see satellite image and map of the garage location in Figure 1). The parking structure houses 1,812 parking spaces. The proposed 48 charging spaces represent a little less than 3 percent of the available parking spaces.
To accommodate the added electrical load of the charging stations, a new electric service will be added also located near the west corner of the garage. The 48 charge stations account for nearly 300kW of new load at the facility. Dedicated conduit was pre-installed in the garage during construction in anticipation of future EV charging stations, and will be utilized as appropriate for these installations. The charge stations will be installed as pedestal mount units on the first floor and wall mount units on the second floor. The layout of the charge stations and a photo of the proposed charge station product, manufactured by ChargePoint are shown in Figure 2. The actual system layout was modified during installation with the as-built description of the system documented in Chapter 2 of this report.
The charge stations proposed for this solicitation have a flexible reservation feature that allows PEV drivers to reserve stations for their exclusive use before their time of arrival at the station. Once the station is reserved for use by a driver, then no other driver can use the station to charge their vehicle. The reservations capability is available to PEV drivers by logging onto the ChargePoint web portal, from the mobile applications available on iPhone and Android smartphones or on the station itself. Over the term of the project the team will explore clever ways to exploit this reservation feature.

Along with the grid-tied EV charging infrastructure, the parking structure holds a recently-completed 370 kW solar photo-voltaic (PV) system on the top level. Although the EVCC will not be directly powered by the PV system, locating the PEV charging stations in the same structure as the PV system provides an opportunity for all users of the garage to associate PEV charging with solar power. With the utilization plan that will be implemented as part of this project, the EVCC will be capable of serving 100-200+ charging sessions daily for PEVs.

The project team and structure as proposed to the Energy Commission is summarized in Figure 3.
Figure 3: Proposal Project Team Structure

Project Timeline

Table 1: Statement of Work Task List with Major Timeline Events

<table>
<thead>
<tr>
<th>Task Number</th>
<th>Task Name</th>
<th>Product(s)</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Kick-off Meeting</td>
<td>Schedule of Product; List of Match Funds; Kick-off Meeting Agenda</td>
<td>Aug 14, 2014</td>
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<tr>
<td>1.2</td>
<td>Critical Project Review Meetings</td>
<td>CPR Report</td>
<td>N/A</td>
</tr>
<tr>
<td>1.3</td>
<td>Final Meeting</td>
<td></td>
<td>TBD</td>
</tr>
<tr>
<td>1.4</td>
<td>Monthly Progress Reports</td>
<td>• Monthly Reports</td>
<td>First report Sep 4, 2014; final May 9, 2018</td>
</tr>
</tbody>
</table>
| 1.5         | Final Report                   | • Final Outline • Draft Report • Final Report                              | Mar 23, 2018  
|              |                                |                                                                           | Apr 4, 2018    
|              |                                |                                                                           | May 2018       |
| 1.6 | Identify and Obtain Match Funds | Match Fund Letter  
   Match Fund Commitments | Aug 30, 2014  
   Sep 15, 2014 |
| 1.7 | Identify and Obtain Required Permits | Permit Letter  
   MJR Electric Applies for Permit  
   Permit BLD2015-39370 Issued | Sep 15, 2014  
   Jul 31, 2015  
   Aug 27, 2015 |
| 1.8 | Obtain and Execute Subcontracts | Subcontract Letter  
   SVP notified EPRI that contract would require City Council Approval  
   SVP receives City Council Approval to proceed  
   SVP/EPRI contract signed  
   ChargePoint asks for mod to EPRI Terms and Conditions  
   ChargePoint contract executed  
   Network service contract executed | Jan 30, 2015  
   Dec 8, 2014  
   Feb 23, 2015  
   May 22, 2015  
   Jun 19, 2015  
   June 30, 2015  
   Nov 30, 2015 |
| 2 | INSTALL AND COMMISSION CHARGING STATIONS | Project Team meeting at SVP  
   Site Drawings  
   Meeting with ChargePoint to review site plans  
   Charge Station Hardware Ordered  
   MJR starts site construction  
   Electric Service Install - passed final inspection  
   Initial site power-up  
   Project team meeting at SVP  
   Charge station go live on ChargePoint network system  
   Community engagement meetings with JVSV  
   49ers Stadium hosts Super Bowl - system offline  
   JVSV Subtask Report  
   EPRI provides first system photo inventory to CEC  
   Press event held at the charging facility (SVP, JVSV, EPRI)  
   EPRI provides site photo inventory  
   EPRI, SVP, JVSV meet to discuss community outreach  
   EPRI provides site photo inventory | Oct 15, 2014  
   Jul 31, 2015  
   Oct 16, 2014  
   Jul 31, 2015  
   Sep 2015  
   Oct 22, 2015  
   Oct 30, 2015  
   Nov 4, 2015  
   Nov 12, 2015  
   Jan 15 and 29, 2016  
   Jan – Feb, 2016  
   Jan 31, 2016  
   Mar 11, 2016 |
| 3 | DEVELOP SITE POWER MANAGEMENT CAPABILITY (includes OCPP demo) | April 20, 2016  
May 9, 2017  
Jun 21, 2017  
Mar 22, 2018 |
|---|---|---|
| **Meeting w/ChargePoint to Review OCPP**  
**Meeting w/ChargePoint on OCPP**  
**ChargePoint Notification**  
**CEC and ChargePoint provided Evaluation Test Plan**  
**Revised OCCP plan included in Monthly Report**  
**EPRI and ChargePoint meet to discuss implementation**  
**ChargePoint receives permission to be on-site for OCPP testing**  
**First OCPP tests conducted**  
**EPRI, SVP and ChargePoint on-site for full OCCP demo**  
**Test Report** | Sep 19 and 23, 2014  
Nov 10, 2014  
Mar 6, 2018  
May 31, 2015  
Sep 13, 2017  
Oct 30 and Dec 20, 2017  
Feb 12, 2018  
Feb 22, 2018  
Mar 6, 2018  
See final report |
| 4 | DATA COLLECTION AND ANALYSIS | Jan 7, 2016  
August 2016  
May 2017  
Draft completed Mar 23, 2018 |
| **SVP grants EPRI data access rights to allow for reporting analysis**  
**System serves a record 158 charging sessions in a single month**  
**New record session count (234)**  
**Included in Final Report** |
CHAPTER 2: Installation

Construction of the Santa Clara Electric vehicle charging system started after the site construction permit was issued on August 27, 2015. Construction work was completed in late October 2015 and system commissioning was undertaken in November 2015.

Selecting Charge Equipment Locations

The proposal plan was to locate all charging equipment on a single floor of the parking garage. This was modified after review of the facility layout and meetings held between Silicon Valley power and other stakeholders associated with the garage. It was decided that having the charge ports distributed on two floors of the garage would be more optimal. Actual construction of the stations was carried out with this revised layout shown in Figures 4, 5 and 6.

Figure 4: Site Layout

Source: The Electric Power Research Institute
Figure 5: Level L Site Layout (Lower Floor)

Source: The Electric Power Research Institute
Figure 6: Level 1 Site Layout (First Floor)

Source: The Electric Power Research Institute
Pre-construction Site Photos

Figures 7 to 10 show the Tasman garage layout prior to installation of the charging facility. Figure 7 shows the Lower Level A area, where dual cable charge stations numbered 1 to 13 were installed. Note that columns along the interior wall would make installation of surface conduits difficult. During construction, surface conduits were run on the exterior wall of the garage to avoid having to install the complex u-shaped sections that would have been needed to navigate these columns.

Figure 7: Lower level A looking south (where stations 1 – 13 are now installed)

Photo Credit: The Electric Power Research Institute

The photo in Figure 8 shows the Level 1 A area where the dual cable charge stations numbered 14 to 24 were installed. Here again, note that the columns protrude inward from the garage wall.
The new electric service for the garage was located in the west corner of the facility, the area in the background of the photo in Figure 9. The screen fence seen just outside the garage in the background is a barrier for a set of tennis courts that are adjacent to the garage and just beyond the area where the new electric service installation was completed. The photo in Figure 10 was taken from the west corner of the garage and shows an existing electric service that was already onsite at the facility. Here again, the tennis courts can be seen in the background.
Figure 9: Level A looking to the west corner where the new electric service was installed

Photo Credit: The Electric Power Research Institute

Figure 10: Exterior area where electric service is to be installed

Photo Credit: The Electric Power Research Institute
**Construction**

System construction was completed in a period of approximately 8 weeks, with first power up of hardware being done in October 2015.

The photo in Figure 11 shows the area where the new electric service was installed to support the charging facility. The rows of vertical conduit runs are located under the main equipment island that is seen in the photo of Figure 15. The tennis court fence can be seen in the background of Figure 11. Again, this is at the northwest corner of the garage.

**Figure 11: Main Electric Service Installation - Conduits**

The conduit runs from the main electric service island, pictured in Figure 11 ran across a small alley located between the garage and the tennis court area. Figure 12 shows a
photo of the conduit runs where the interface with the exterior northwest wall of the garage. Note that the exterior wall of the garage had a surface that allowed for ready mounting of conduits using raised mounting hardware avoiding the need to route around support columns. Wall mounted junction boxes were used to manage the transition from vertical to horizontal conduit runs.

Figure 12: Conduits to Garage Structure on northwest wall

Photo Credit: The Electric Power Research Institute
Figure 13 shows the conduit runs that go from the west corner of the garage to the charge station locations. Running conduits on the exterior wall greatly simplified the installation. The trench and conduits seen in Figure 12 are located at the lower left of the photo in Figure 13. Both lower and upper level wall mounted junction boxes can be seen in this photo.

**Figure 13: Surface conduit runs on the west wall of the garage**
Figure 14 shows the trench that allowed running conduits from the main electric service to the exterior wall of the garage. The installation required digging up existing pavement in an alley that ran beside the exterior wall of the garage. Restoration required both filling of the trench and repaving a section of the alley.

**Figure 14: Conduit Runs Being Placed from Main Electric Service to Garage Structure**

Photo Credit: The Electric Power Research Institute
**Completed Installation**

The system was completed in late October 2015 with first system power-up occurring on October 30, 2015.

The completed electric service is shown in Figure 15. This is at the west corner of the garage between the exterior garage wall and a set of tennis courts located adjacent to the garage. A photo of the conduit runs that are located under the finished service can be seen in Figure 11. Note that completion of the service installation required addition of landscaping features to ensure a clean, aesthetic quality for the hardware.

**Figure 15: Completed New Electric Service – View to North**

![Completed New Electric Service - View to North](image)

Photo Credit: The Electric Power Research Institute

Figure 16 shows a second view of the new electric service, but viewed looking to the south and toward the garage exterior wall. Note the added concrete pads that support the electric service equipment to the left of an existing electric service transformer. Figure 17 shows a wider view of the same area pictured in Figure 16. Here the small alley that surrounds the garage can be seen.
Figure 16: Completed New Electric Service – View to South

Photo Credit: The Electric Power Research Institute

Figure 17: Wide View of Northwest Corner of Garage and New Electric Service

Photo Credit: The Electric Power Research Institute
Figures 18 and 19 show an exterior and interior view of the surface conduit runs used to carry power to the charging stations. Small conduit runs from the exterior set of conduits were run just under safety screens that enclosed the garage structure to each individual charging post. Each of the conduits as seen in Figure 18 carried two separate electric circuits to enable the dual cable station operation.

**Figure 18: Competed Surface Conduit Runs on West Wall of Garage**

![Figure 18](image1.png)

*Photo Credit: The Electric Power Research Institute*

**Figure 19: Detail of Conduit Connection to an EV Charger**

![Figure 19](image2.png)

*Photo Credit: The Electric Power Research Institute*
Figure 20 shows a detailed view of one of the short conduits runs from the exterior to the interior of the garage. The conduit is terminated to a strain relief fitting located on rear of the charge station post.

**Figure 20: Side View of a Newly Installed EV Charger**

The exterior conduit runs radiated from larger junction boxes mounted near the north west exterior corner of the garage, as seen in the photo of Figure 21. Figure 21 shows the upper level junction box.
The completed charge stations were installed centrally between parking spaces, as illustrated in Figure 22. This allowed the dual cable units to service the two adjacent parking spaces.
The design allowed for access to charge ports on any vehicle surface for a vehicle parked nose in, as illustrated in Figure 23.

**Figure 23: Verifying Cable Length is Adequate to Reach the Rear of a Parked Vehicle**
CHAPTER 3: Operation and Maintenance

The charging station installation was fully commissioned in November 2015. Commissioning consisted of ChargePoint completing association of the charging ports with the system account owned by Silicon Valley Power. Once associated, access to system activity was available through a web portal maintained by ChargePoint. Silicon Valley Power granted EPRI access rights to the system account to allow for project reporting.

System Operation

At completion of commissioning, the charging ports became operational for use by the public. Video screens located on each dual port charger provided instructions for user access to the system as shown in Figure 24.

Figure 24: Sequence of Images on Video Screen Provides User Access Explanation

Charging customers could follow these on-screen instructions to access charging, have access to a call in help line, and could select the HELP tab on the control screen to receive additional instructional support for station use.

System level operations, such as setting access control parameters and charge pricing were accomplished via the ChargePoint System Web Portal. The portal had a set of detailed help files that explained the system administrator available features and their use. Silicon Valley Power configured the system for open public access (that is no user restrictions or groupings) with a flat rate pricing for electricity use of $0.25 per kilowatt-hour. The ChargePoint system was capable of more complex pricing structures that could include flat rate fees, time based fees and fees that vary with length of connection time, but these were not used on the Santa Clara Charging Center system.

While the ChargePoint hardware installed for the project had the capability to allow users to make station reservations, this feature was not needed due the level of system utilization and to the large number of chart ports available at the site. Occupancy levels...
were not sufficient such that queuing has not occurred at the site where use of the reservation system would be of benefit.

**Maintenance**

The system was operated and maintained by Silicon Valley Power, the City of Santa Clara’s municipal electric utility.

System status was reported on the ChargePoint web portal. Stations in need of service or reporting operational issues were flagged by the system and shown graphically on a system map as seen in Figure 25. ChargePoint then would send the system administrator at Silicon Valley Power notification emails indicating that they had detected a station that was reporting an issue. As an example, note the “need service” chargers indicated with red flags in Figure 25 which indicated the stations needed attention.

As of this writing, no system repairs have been required at the site. The primary maintenance issue experienced by the system was the occasional tripping of circuit breakers that served the charging stations.

**Figure 25: Charge Station Status Map on ChargePoint System Web Portal**

Source: ChargePoint, Inc.
CHAPTER 4: Outreach Activities

Joint Venture Silicon Valley (JVSV) worked with EPRI and Silicon Valley Power to support community engagement. JVSV spearheaded a press event held on April 20, 2015 to promote existence of the facility to the public. JVSV has also made multiple presentations to area stakeholder groups promoting use of the facility. They have also worked with SVP to develop concept artwork and language that can be used by nearby business and venues to promote use of the facility. JVSV has worked to engage with stakeholders in proximity of the charging station facility to facilitate and enhance consumer awareness and utilization of the charging stations. The promotional flyer prepared my JVSV is included along with other JVSV produced materials in Appendix A.

JVSV staff support consisted of coordinating and participating in meetings and communications with Silicon Valley Power, the City of Santa Clara staff, the Santa Clara Convention and Visitors Bureau staff, and the City of Santa Clara’s Marketing Committee. It also included development of concepts and tools for the promotion and increased visibility of the SCEVCC, such as graphics, tag lines, and blurbs for use by key stakeholders (see Appendix A). JVSV consulted with Silicon Valley Power and the City of Santa Clara staff about on-street signage and online tools for locating the Charging Center. They also conducted outreach to PlugShare, a crowd sourced charger mapping service, to improve their description of charging center’s features, and EVgo, to add this location to their website.

Joint Venture’s in-house graphic artist provided art and tag line development for consideration by Silicon Valley Power and the City of Santa Clara staff (see Appendix A).

Community outreach was useful in helping make nearby businesses aware of the charging facility’s existence and focused on getting those businesses to see the marketing value the system might have for their customer base. Given that not all businesses have an EV connection, it is likely that they would not have known about the facility without these outreach activities.

Where EV drivers were concerned, being sure that mapping services properly identified the system location and features was considered of greatest importance, though the site press event likely accelerated knowledge of the system’s existence in the EV driver community.
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CHAPTER 5:  
Data Collection and Analysis

Data Collection Test Plan

Data collection was provided as part of the ChargePoint network service. Summarized data on system usage and consumer charging demand was used in monthly reports from the time facility came online in November 2015 to the project close. The data was used to monitor system usage trends for both unique users, energy delivery and number of charging sessions occurring at the facility over time.

Charging Trends

Figure 26 shows the tally of unique drivers seen each month over the November 2015 to February 2018 timeframe. Year over year data indicated that 2015 and 2016 had a steady clientele of approximately 80 users, increasing to a nominal 90-100 users in 2017 with peaks of over 120 users. Data in 2018 showed more than 100 unique users for the first two months of the year. It should be noted that the 49ers Stadium facility hosted the 2016 Super Bowl and the charging facility was closed most of January and February of that year due to being part of a security area for the event.

![Figure 26: Number of Unique Drivers Using the Facility for Charging](image)

The gross site revenue (based on a $0.25 per kWh fee) is shown in Figure 27. A revenue level of > $400 per month was maintained for about the last year, with a record revenue of nearly $700 in January 2018.
Session counts have seen a gradual increase over the life of the project. Figure 28 shows a summary of the monthly session counts. While there were clear seasonal variations, comparing year over year counts for the same month showed a steady increase in facility use.

**Figure 28: Number of Charge Sessions by Month Over the Life of the Project**
The general usage trends were more difficult to see on a day to day basis. Figure 29 shows the daily session counts for the month of November 2017. Not that the number of ports at the site exceeded the number of daily sessions indicating that even on busy days, there were open ports.

**Figure 29: Daily Session Counts for the Month of November 2017**

Energy transfer at the facility has also seen consistent year over year growth throughout the project. January 2018 set a facility record for energy transfer, and as can be seen from the graph of Figure 30, January was generally a low usage month for the facility.

**Figure 30: Energy Transfer by Month Over the Life of the Project**
Operations Data Environmental Impacts

This section covers data analytics results as required under Task 4 of the EPRI contract. The following elements are covered in this section:

- fuel displaced by charging facility
- GHG air emissions impact of system

Fuel Displacement

Using the total energy consumed for the years of 2016 and 2017 (the only two full years of data) it was estimated that 1,115 gallons of gasoline (4220 L) were displaced in 2016 and 2,461 gallons of gasoline (9316 L) in 2017.

Air Quality Impacts

EPRI has calculated the following:

<table>
<thead>
<tr>
<th>Table 2: Green House Gas Calculation Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Energy (kWh)</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Driving Distance this Energy Would Provide (miles)</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Divide the total energy by energy per gallon of gasoline</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Gasoline Equivalent Gallons (geg)</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Calculate gasoline vehicle CO2 (multiply gal-equiv by CO2 kg/gallon-equivalent (10.9 for California) (kg)</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Calculate electricity CO2 (kg)</strong></td>
</tr>
<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
</tbody>
</table>

Source: The Electric Power Research Institute

Note that EPRI's calculations are based on California carbon intensity values for the California electric grid.

ChargePoint's web portal allows for calculation of GHG saving on a monthly basis as illustrated in Figure 31.
Figure 31: CO2 Savings Realized by the Facility, 2016 and 2017

Source: The Electric Power Research Institute
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CHAPTER 6: Communications Protocols for EV Charging Management

Overview
When a charge station is operated as part of a network, some form of communications is required from the EV charger to a back office or central system. This communication can make use of many different technologies, such as Wi-Fi, cellular networks and wired internet connections. Over the communications channel, the data flow must follow some predetermined protocol, or language, that both the EV charger and the central system “speak and understand”. The EV charger to central system protocol is the subject of this discussion.

The Energy Commission has required that charging stations deployed as part of this solicitation be capable of network control using an open protocol. A major challenge to this requirement is the lack of an industry accepted standard protocol within the electric vehicle supply equipment industry.

The Goal of Standards
It is worth taking a step back from a protocol discussion to look at the larger picture of what industry stakeholders hope to achieve through standardization in the EV infrastructure space. While all stakeholders are likely to agree that charging consumers will benefit from a widely available, reliable, easy to use and lowest cost deployment of EV infrastructure, what goals can and should be achieved through standards will have more nuanced answers. The adoption of a common network protocol is often associated with a broad list of goals, some of which are listed here:

- Any EV charger would work seamlessly on any network
- Any network would interact with and control any EV charger
- Ability to move a charger from one network provider to another network would be simple
- Changing network providers would be simple
- Consumers could use one form of credential at any charging station
- Site hosts could mix and match networks and hardware

One challenge is that the network protocol being discussed only covers one portion of a larger and somewhat complex ecosystem that represents a charging network from end-to-end. Many of the goals stated above, while being enabled by having a common protocol for networking, cannot be directly achieved with such a protocol. The following bulleted list highlights the multiple interfaces that may be associated with an EV charger, with the elements covered by this protocol discussion highlighted in light
blue. Note that while the protocol might carry data related to the other elements given in the list, it wouldn't be likely to cover standardization of the other elements:

- Consumer interaction with EV chargers
  - RFID card
  - Phone app
  - Web portal
  - Credit card
  - Cash collector
  - Other
- Site host interaction with EV chargers
  - Web portal
  - Phone app
  - Local interface
- Interconnects between multiple EV chargers at a site
  - Wired
  - Wireless
- Connection from EV charger to central system
- Network interaction with EV chargers
  - Firmware upgrades of communications client
  - EVSE firmware upgrades
  - Station set up and commissioning
- Interaction between various charging networks
- Web and smartphone based interactive EV charger maps

It is important to understand that a common network protocol represents only one of many steps needed to achieve the broader set of goals noted above. The next section will outline some of the challenges that touch on, but mostly lay outside the purview of a network protocol.

**Limitations of a Common Protocol**

This section provides more insight into the ecosystem elements list provided in the previous section and adds a couple of topics that fall outside the ecosystem.

**Consumer Interaction with EV Chargers**

Many networked charging systems include functionality to authenticate users and to collect fees for charging. Both of these functions often involve some form of credential, such as an RFID card, or use of a smartphone app and user account to complete the transaction. The network protocol must be capable of carrying data for any inputs received at the EV charger, but in general, the protocol would not be involved in
standardizing those inputs, nor any outputs (e.g. messages displayed) required for consumer interaction.

**Site Host Interaction with EV Chargers**

Networks often provide the ability for site hosts to manage their stations through a web portal. There are no industry standards for features or implementation of these portals and the network protocol does not address this functionality.

**Interconnects Between Multiple EV Chargers at a Site**

In order to complete installations at the lowest cost, most charging network providers, including the ChargePoint system installed at the garage, aggregate communications from multiple charge stations via a single cellular data modem. Some vendors do this with an external communications enclosure, while others, such as ChargePoint, embed this gateway capability in the EV charger enclosures. OCPP does not address station nomenclature or structure for these types of aggregated systems and does not address the communications technology or protocol used to link stations. In some cases, the interconnect would simply be an extension of the internet data path from the central system to satellite EV chargers, while in other cases, these interconnects rely on a separate communications channel and protocol from the gateway to the satellite stations. Lack of standardization of these interconnects may limit the ability to “drop-in” replacement hardware that is not identical to, or at least from the same manufacturer as the installed hardware at a site.

**Network Interaction with EV Chargers**

While the protocol standard is expected to address the EV charger to central system connection, it may or may not address activities such as how stations are provisioned to run on a particular network or how firmware upgrades are handled. Even if the protocol addresses methodologies for remote firmware upgrades, it is unlikely to deal with software ownership rights and the logistics of having one party handle proprietary software of another party. This example comes into play when the company that developed the EV charger is not the same company as the network provider while remote firmware upgrades are generally handled via the network.

Station provisioning involves setting up the communications channel from onboard the EV charger to the central system – such as defining the network address that the central system is located at. This may involve a requirement to physically access a programming port on the EV charger, be done through a remote connection or through a hard coded factory setup that cannot be readily changed by the site host. Charging network protocol standards generally do not address this functionality.

**Interaction Between Various Charging Networks**

The EV charger to central system protocol does not address handling of network traffic between independent networked charging systems, nor does it cover the ability for consumers to “roam” across networks.
Web and Smartphone Based Interactive EV Charger Maps

Web and smartphone apps interact directly with the central system and therefore would not be covered by the EV charger to central system protocol.

Station Branding

A protocol standard would not address issues related to station branding and quality of service.

The Open Charge Point Protocol (OCPP)

At the time of the original solicitation for this work in the early 2014 timeframe, one potential candidate protocol was the Open Charge Point Protocol. OCPP was selected as the demonstration protocol for this work. This protocol was developed by an ad hoc group of stakeholders in Europe beginning in early 2011. In Q1 of 2014 the Open Charge Alliance was formed to support and refine the OCPP protocol. The Open Charge Alliance continues to refine the protocol with expected publication of a major revision, referred to as OCPP 2.0 expected in Q1 of 2018. OCA has developed and now sells interoperability test tools based on a “golden” central system implementation and a “golden” EV charger implementation of OCPP version 1.6. Similar tools are expected to be released for later versions of the protocol. For vendors, the long timeline and existence of multiple versions of OCPP presents a challenge in knowing what to support for their commercial products. As part of their OCPP validation efforts, ChargePoint purchased the OCPP version 1.6 Compliance Testing Tool from OCA. Their experience indicated that the tool as delivered was not bug free and remained under development. OCA indicated it would take several months to address any issues found in the testing tool. OCA continues to work on a defined certification process for OCPP 1.6, with this work expected to conclude in late 2018 or early 2019.

A second challenge for vendors in deploying OCPP systems is managing the ability to support capabilities that fall outside of the current message set within the OCPP protocol. Features, such as complex pricing information or graphic images for transfer to a station display are not implemented as part of the most widely used version, OCPP 1.5 nor in the most recent version, OCPP 1.6. For vendors to provide features that fall outside of the current capability of OCPP, the use of vendor specific messages in the protocol is required – referred to as “Data Transfer” messages within OCPP. While these messages use the structure of OCPP, their content is vendor specific – that is, not defined in the standard and typically is proprietary to the vendor - and therefore undermines the universality of the protocol. The net effect of such implementations is that these enhanced features would be network specific and only supported by a specific network vendor. For a site host, this means that in switching network providers, enhanced features, such as point of sale processing or special features the site host might desire could be lost in going to another network. Until such time as OCPP has matured as a protocol, that is, its specification defines a set of messages that
support the complete range charge station of functionalities; this situation is likely to persist.

**From Protocol to Function**

A protocol defines a language with a set of predefined terms and data structures. Ultimately, the individual commands of the protocol are used to achieve desired functionalities of the networked charging hardware. In general, there is not a one to one mapping of protocol messages to EV charger function. For example, enabling a session based on use of an RFID card might require use of three or four protocol messages, whereas, reading the state of an EV charger may only require a single protocol message. Different vendors may also use different structures to implement the same functionality. For example, where one vendor might use three protocol messages to process an RFID card interaction, while another vendor might use six protocol messages. This can be prevented to some extent, by including required message structures within the protocol standard for specific station functions.

One of the best methods to verify that stations from different vendors will work with a given network (and multiple networks can support a given station) is for parties to conduct interoperability testing. Interoperability testing ensures that implementations have converged syntax and expected device behaviors. In general, interoperability testing is conducted by industry associations and remains one of the best methods to ensure a seamless end user experience. While OCA has conducted limited OCPP 2.0 interoperability testing in Europe at events held in late 2017 and early 2018, these events had limited vendor participation (two central system providers and three charge station providers) and limited scope (vetting about 50 percent of the OCPP 2.0 protocol). To date, neither OCPP 1.6 nor OCPP 2.0 has been vetted at an interoperability event with broad industry participation. This has left charge station providers and network providers to work independently when verifying station/network functionality, with their work not guaranteeing that interoperability would extend to other vendors.

Vendors can also develop unique functional behaviors by blending multiple standard protocol messages and/or data transfer messages. In a competitive market, these would be the distinguishing features offered by vendors and may be unique to one brand of product. Such features would not be readily transferable should a host chose to change brands of charging stations on a network or move existing charging stations to a new network, even though the stations make use of the same standard protocol. An example would be site host that currently has a network vendor that can transmit video to be displayed on an EV charger's local video screen. Should the site host move the hardware to another vendor’s network, that lacks the video support capability, this functionality would be lost.
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CHAPTER 7:
Field Evaluation of the Open Charge Point Protocol

ChargePoint has developed both an OCPP client for their EV charger and an OCPP based central system. For the field demonstration at the Santa Clara Charging Center, the limitations of OCPP (as detailed in Chapter 6, above) prevented ChargePoint from remotely replacing the existing firmware in a charging unit. For the demonstration, one of the dual port station at the SCCC was temporarily removed and replaced with another dual port station with the OCPP client.

ChargePoint's communications is encrypted, eliminating the ability to packet sniff traffic flows between the EV charger and the central system. In order to provide insight into the OCPP activity on the station, they used a local port on the EV charger to present the decoded data onboard the charger. This traffic was displayed on a laptop computer. Log files captured on the computer are presented in this section. Figures 32 – 35 show photos of the demonstration hardware.

Figure 32: Test Unit with Laptop to Read Out OCPP Traffic
Figure 33: Front Screen of OCPP Equipped EV Charger

Photo Credit: The Electric Power Research Institute

Figure 34: Chevy Spark EV Being Used to Test OCPP

Photo Credit: The Electric Power Research Institute
Demonstration Data Traffic

All of the data traffic from ChargePoint's back office to the charging stations is encrypted. In order to expose the station traffic for the demonstration, ChargePoint enabled the local charging station control board to provide a near real data stream of decoded communications traffic via a local hardware port. This data was displayed and captured on a laptop computer used during the demonstration.
Managing the initiation and close out of a charging session transaction can be accomplished with a very basic set of OCPP commands. At a high level, the following sequence of commands can be used to complete a session:

- RemoteStartTransaction
- Start Transaction
- Status Notification
- Meter Values  [Station -> Server]
  
  ..... (meter values are sent to the server at routine intervals during a session)
- RemoteStopTransaction

ChargePoint has verified that this message sequence complies with the OCA interoperability test tools mentioned in Chapter 6, above.
CHAPTER 8: Site Level Power Management

As part of the original project proposal, it was planned that the ability to manage the charge station peak power demand remotely via the charge station network be demonstrated. At the time of the proposal, energy management was not a generally available capability for charging networks. Site level power management was not carried out as part of the project for three primary reasons:

- ChargePoint now offers power management as part of their normal network offering.
- The intent was to perform the charge management while using the OCPP test protocol. Since the demonstration was carried out at a single station, due to the need to change the station firmware, there was no ability to manage power at more than one station.
- Given the large station count, power demand is still peaking at a small fraction of the system capacity (under 17 percent for the 30-day period from February 19, 2018 to March 21, 2018). Data is presented below.

As shown in Figure 36, data taken in the months of February and March 2018, indicated that peak power loads remain a small fraction of the system capacity. The 48 charge ports in this installation could account for up to 300kW of load. The graph below indicates that peak demand routinely reaches 20 to 25kW (< 8 percent of capacity) with a single peak at 50kW (about 17 percent of capacity). The peaks all occur in the daytime hours and generally peak around noon to 3 pm local time.

Figure 36: Peak Power Over a 30-day Time Window
Power management in general is used to limit demand charges associated with a commercial rate structure. Should that become of benefit for the system’s operation, Silicon Valley Power has the option to work with ChargePoint to enable the site power management capability as part of their network services contract.
Establishing contracts remains challenging, especially for projects that have multiple entities involved. At the outset of a project, it is difficult to know which contracts will be most challenging and which will lead to the longest delays. This can be mitigated in the project planning phase, to some extent, by sharing preliminary contract language, terms and conditions between the various entities.

Sources of project delay are difficult to predict. For this project, delays were related to two key elements: contracting and permitting. In order of their duration, delays were incurred in this project for:

- Contracting – The Energy Commission agreement with EPRI
- Contracting – The EPRI subcontract agreement with Silicon Valley Power
- Contracting – The Silicon Valley Power subcontract agreement with MJR Electric (installation contractor) – see note following about councils/boards
- Permitting – MJR permit to begin construction

An unanticipated delay encountered in the project related to contracting with a municipal utility, which required a city council approval vote for the project contract. Stakeholders should note that projects that involve city and/or county governments may encounter additional delays related to project approvals:

- Contract approvals may require a city council or board vote
- Prior to voting most councils/boards have a required public announcement and comment periods
- Timing of public meetings is generally set – missing a single meeting can add multiple weeks of delay to approvals
- Not always clear at the outset of a project what agencies might need to be engaged to gain needed project approvals

While the Santa Clara Charging Center has seen a steady growth in utilization over the three-year project term, the system still hasn't achieved what would be considered “full occupancy”, where all charge ports are occupied on a regular basis. Based on this experience, it is recommended that stakeholders developing large scale charging facilities consider taking a staged approach to installation of equipment. The potential benefits of staged approach include:

- Equipment costs are not incurred until needed (savings would need to be compared to savings that might result from quantity discount for equipment)
- Networking fees related to communications would be incurred only as needed
- Would lead to higher utilization of installed hardware and may mitigate perception that installed hardware is often “idle”
• Would require that electrical infrastructure be installed at construction (conduits, wiring, etc.); charging station hardware be added as needed
• Limits upfront investment should utilization fail to grow

This approach does present some challenges:
• May complicate utility revenue and cost of service calculations based on anticipated site energy use
• If site usage failed to grow, initial infrastructure installation would be “wasted”
  o This would require estimation of system occupancy prior to installation to set initial port count and continued monitoring of utilization statistics over time to know when to add additional charging ports

EV drivers often rely on crowd-sourced, web based mapping tools to look for charging stations that are available along their driving route. After new charging infrastructure is installed, it is recommended that stakeholders review the site description as presented on available third party mapping tools to ensure descriptions are accurate.

Community engagement appeared to be positive and useful in raising awareness of the facility, but it was difficult to gain a quantitative measure of impact given that the system has seen a steady growth in utilization and has a widely varying occupancy from month to month. Some factors that complicate a quantitative evaluation of community engagement:
• Growth trend may have been natural result of “word of mouth” information exchange between electric vehicle owners or may have been increased by the community engagement
• Not clear how one could establish a baseline expected growth rate for a system to see if it was enhanced by external activities
• The population of electric vehicles has seen a steady increase – utilization data would need to be normalized to this growth, but it may be difficult to enumerate the population of vehicles that “might” make use of a given site.
APPENDIX A:
Joint Venture Silicon Valley Materials

This appendix contains samples of JVSV’s community outreach work and materials in Figure A1 through A8.

Figure A1 – April 20, 2016 First Press Event Flyer

Santa Clara Electric Vehicle Charging Center
Grand Opening Showcase

Wednesday, April 20
10:30AM – 1:00PM
Program: 10:30 – 11:00am | RV Showcase/Open House 11:00am – 1:00pm

Tasman Parking Garage
2525 Tasman Drive - Directly across from Levi's Stadium Main Entrance

Please join Santa Clara Mayor Lisa Gillmor and leaders from the local electric vehicle community to officially open the Santa Clara Electric Vehicle Charging Center.

The new Center features 44 EV charging stations, including 9 Level 2 and 3 DC Fast Chargers, energy load management, battery storage and solar PV. Built to serve a growing volume of “destination” traffic to the convention center, stadium and surrounding vicinity, the Center is one of the largest and most advanced charging facilities of its kind.

Representatives from local electric vehicle, charging and integration companies will also be on-hand. Come learn more about electric vehicles, charging systems, and how local charging facilities can serve you!

THANK YOU TO OUR SUPPORTERS!
Bay Area Air Quality Management District
California Energy Commission
Green Sports Alliance
San Francisco 49ers

Santa Clara Stadium Authority
Santa Clara Chamber of Commerce
Santa Clara County Board of Supervisors
Silicon Valley Leadership Group
Santa Clara Convention Center is Green

We are proud to participate in the Green initiative to put our stamp on the environment. Santa Clara Convention Center has been recognized as one of the most environmentally friendly buildings in the nation. The City of Santa Clara is also making strides and being recognized for their efforts in going Green.

How the Convention Center and the City are making an impact:

- There are six Electronic Vehicle (EV) Charging Stations at the Convention Center, and 49 in the nearby City of Santa Clara Tasman Parking Garage.

Electric vehicles are welcome at your conference, trade show, or meeting coming up at the Santa Clara Convention Center! The Tasman Garage is home to 48 Level 2 Charging Stations and one Level 3 Station. Parking is free and convenient, and our charging center is just one more reason to make the Santa Clara your meeting destination.
Parking areas available for guests:

- Handicapped Parking is available directly in front of the Convention Center.
- 1,500 on-site parking spaces in a 3-story parking garage on the Santa Clara Convention Center campus shared with the Hyatt Regency and TechMart.
- Additional overflow parking may be available in surrounding lots based on availability.
- There are six Electronic Vehicle (EV) Charging Stations at the Convention Center, and 49 in the nearby City of Santa Clara Tasman Parking Garage.
- Electric vehicles are welcome at your conference, trade show, or meeting coming up at the Santa Clara Convention Center! The Tasman Garage is home to 48 Level 2 Charging Stations and one Level 3 Station. Parking is free and convenient, and our charging center is just one more reason to make the Santa Clara your meeting destination.
Figure A4 – JVSV Generated Logo – Example 1

Figure A5 - JVSV Generated Logo – Example 2
Figure A6 - JVSV Generated Logo – Example 3

Santa Clara Electric Vehicle Charging Center

Figure A7 - JVSV Generated Site Name Font Samples

Santa Clara Electric Vehicle Charging Center

Santa Clara Electric Vehicle Charging Center

Santa Clara Electric Vehicle Charging Center

EVCC   EVCC
Figure A8 - JVSV Language Developed to Support Local Stakeholder Promotion of Facility

Charge up with us!

1. You already know that Santa Clara is your #1 destination for entertainment and events – did you know it’s also the best electric vehicle destination as well? With 49 charging stations in its Tasman Drive parking structure, adjacent to the Santa Clara Convention Center and across the street from Levi’s Stadium, you can recharge your EV while visiting Great America and the Santa Clara Golf & Tennis Club, or staying at the Hyatt or Hilton. Visit Santa Clara in your EV with confidence!
   a. Shorter Alternate: Bring your Electric Vehicle and get charged up. With 49 charging stations in the nearby Tasman Drive parking structure, both you and your EV can recharge for what’s next!

2. Got a conference, trade show, or meeting coming up at the Santa Clara Convention Center? Make sure your participants know: their electric vehicles can come along for the ride! Just steps away from the Convention Center is the Tasman Garage, home to 48 Level 2 Charging Stations and 1 Level 3 Station. Parking is free and convenient for your guests. Our charging center – just one more reason to make the City of Santa Clara your meeting destination.
   a. Shorter alternate: Electric vehicles are welcome at your conference, trade show, or meeting coming up at the Santa Clara Convention Center! The Tasman Garage is home to 48 Level 2 Charging Stations and 1 Level 3 Station. Parking is free and convenient, and our charging center is just one more reason to make the Santa Clara your meeting destination.

3. Yes, you can drive your EV to work – and charging is close at hand. The City of Santa Clara’s Tasman Drive garage has 49 convenient charging stations available for your use. Parking in the structure is free, and the 48 ChargePoint Level 2 stations are located on Levels L & 1, with one Level 3 EVgo station on Level L, right next to the lower-level entrance. Charge up while you work, and leave your range anxiety behind!