Solano Electric Vehicle Transition Program

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Solano Transportation Authority

SolanoEV.org

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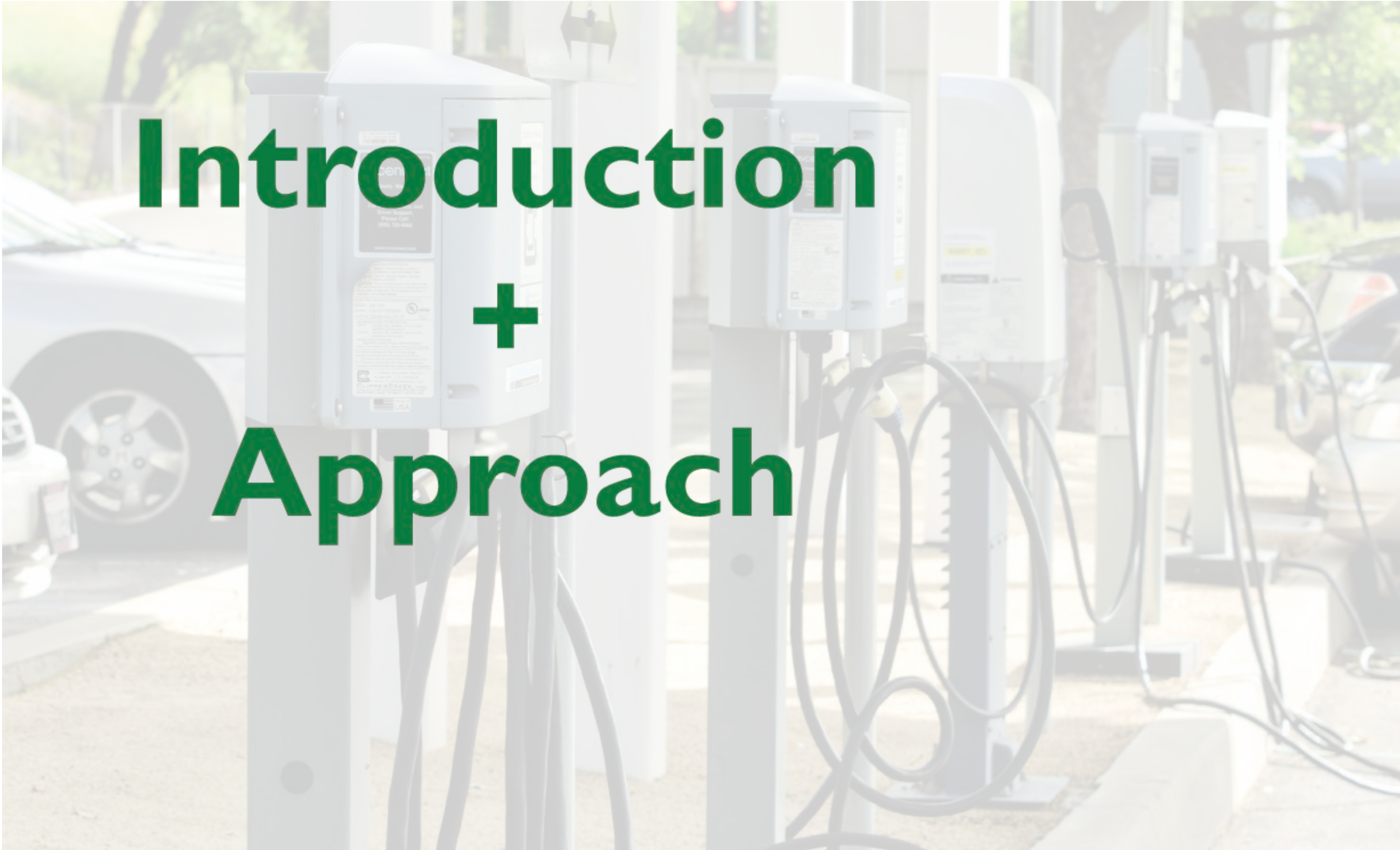
Acronyms and Abbreviations

Acronym / Abbreviation	Stands For
EVCS	Electric vehicle charging station
EVSE	Electric vehicle supply equipment
DCFC	Direct Current Fast Charging
STA	Solano Transportation Authority
EV	Electric vehicle

Introduction + Approach



1. Introduction and Approach

The Solano Transportation Authority (STA) was awarded a grant by the California Energy Commission to implement the *Solano Electric Vehicle Transition Program*. The objective of the project is to implement solutions to improve Solano County's readiness to deploy electric vehicles (EV). The project is designed to create a regional guidance tailored to Solano County, based on regional conditions, and implement a variety of steps to improve the county's EV readiness.

The market growth of EVs is a critical component of California's strategy to achieve a deep mitigation of the emission of greenhouse gas (GHG), and increase energy independence through the utilization of locally produced energy. The implementation of such strategy requires the participation of all levels of government to become "EV ready". This involves the adoption of a number of measures, from planning the charging infrastructure, to taking institutional steps, to supporting the access of information to the general public, etc. In the end, the market deployment of EV will be led by technology innovation, but new technologies cannot succeed on a large scale if not supported by a conducive techno-social-institutional framework. The Solano Electric Vehicle Transition Program is a critical component of this broader effort for Solano County, and it stands as an example of local and regional governments engaging the community and implementing readiness steps.

The program has the following high-level goals:

- Develop and implement a streamlined permitting and inspection process for charging infrastructure
- Develop a harmonized charging infrastructure installation process
- Develop a Solano-specific charging infrastructure siting plan
- Deploy trailblazer signs in the county
- Conduct electric vehicle awareness activities
- Provide training to local governments related to building codes
- Provide STA with the tools it needs to continue their work supporting electric mobility once the project is completed

1.1. High-level summary of tasks in the program

1.1.1. Streamline permitting and inspection for electric vehicle charging stations and improve installation practice

The goal of this task is to harmonize practices in the county related to the permitting and inspection of charging equipment installations. A common online resource will be prepared for cities in Solano County, including guidance documentation. Case studies of streamlined procedures will be investigated. A workshop or similar event on permitting for local permitting officials will be conducted.

A related goal of this task is to strengthen charging infrastructure deployment by engaging key stakeholders, such as utilities and cities.

1.1.2. Analyze potential locations for electric vehicle charging infrastructure

Based on critical factors, such as market assessments and vehicle utility, potential locations for charging infrastructure were identified. Tending to evolving trends on EV technology and policy, the project pivoted to include a local level plan for level 2 (lower power) infrastructure and a regional level plan for direct current fast charging (DCFC) infrastructure. In response to specific requests from STA, the analysis of these plans used more sophisticated methods than those employed in earlier similar projects.

1.1.3. Install trailblazer signage for plug-in vehicles

Best practices for the location and installation of street-level signage for plug-in electric vehicle drivers were identified. The location for a number of signs in targeted areas in Solano County was identified, with the installation of many of the recommended signs to be coordinated by STA. Documentation for signage deployment and guidance for subsequent installations was prepared.

1.1.4. Conduct electric vehicle awareness activities

To build awareness, action, and demand for EVs in Solano County, two (instead of the one originally planned) electric vehicle showcase were organized, hosted, and completed for audiences of at least 100 people with a ride-and-drive opportunity.

A website dedicated to EV for Solano County was tailor-designed and implemented, using techniques of experiential marketing.

1.1.5. Conduct training sessions for city governments

An event was conducted for interested city officials, to offer updates on the project, training on charging infrastructure installation, and information about opportunities for investments in the county on charging infrastructure.

1.2. Overall approach

Given the duration of the project, the dynamic nature of the technologies involved, and the multidisciplinary characteristic of the tasks at hand, STA's consultant, ICF, adopted an agile approach to project implementation. This approach supported relative independence across team members to implement their work, while maintaining continuous coordination by the project manager. The approach emphasized communication with STA with regular phone calls and periodic meetings. With a strong communication, ICF ensured that STA's preferences and feedback were adequately capture during the project.

In agile project management, it is common practice to develop *user stories*. User stories can be defined in the following way:

User stories are short, though clear, descriptions of a desired feature of the resulting product, told from the perspective of the person or group, typically a user of the product, who desires the capability. User stories are commonly constructed by completing three sentences, namely:

- As <a *type of user or owner*>
- I want <*some goal or feature*>
- So that <*the reason for the goal or feature*>

These three sentences are then integrated to complete the user story. One example could be: "As an electric vehicle owner, I want to have access to an online resource about the location of charging stations in Solano County, so that I can better plan my trips."

The resulting user stories are described below.

User Story 1:

As STA, I want to facilitate the development of a harmonized permitting process across local governments in Solano, so that users and installers face consistent requirements.

- The process will be collaborative and inclusive of local governments.
- The process will start with a discussion with planning directors at a July 21st regular meeting, to get buy-in and establish top-down support.
- Then permitting officials and inspectors will be presented with a best practice draft based on experiences from other jurisdictions, let them react to it, then adjust it to conform with general practices and preferences in cities in Solano.
- The process and best practices will be mindful of the societal benefits to Solano of vehicle electrification as well as of equity considerations.

User Story 2:

As STA, I want to have a website dedicated to electric vehicle infrastructure, so that local government offices and the general public can access resources on that topic that are succinct and easy to navigate.

- The website will be hosted by STA and will be nested in STA's main website.
- The website will be visually appealing, simple, and easy to navigate, with 3-4 max pages total.

User Story 3:

As a local government in Solano County, I want to find in the Solano EV website guidelines for the permitting and inspection of EV charging stations, so that all local governments in Solano have access to consistent guidelines.

- The resources will include a 1-2 page “best practice” guideline that will be based on consultations with stakeholders and/or other cities that have developed such guidelines.
- The best practice guideline will be adapted if and as needed to recognize local conditions in Solano.

User Story 4:

As STA, I want to document a number of case studies of EV charging station installations in Solano, so that they can serve as a means to identify challenges as well as best practices that can inform the process of streamlining charging station permitting, inspection, and installation.

- The case studies will cover a range of types of public-access installations, including workplace, multi-unit dwelling, and commercial.

User Story 5:

As a member of the public who is considering installing an EV charging station, I want to have access to a website with simple and actionable information about how to have a charging station installed, so that I am not deterred from getting an EV or installing a charging station because of lack of accessible information on this topic.

- The information provided to the public will include information about the pertinent public offices that can help with the installation.
- For public charging stations, the website will include guidelines for the design of the site, including signage.

User Story 6:

As STA, I want to integrate in the EV webpage a system for the online permitting of electric vehicle charging equipment installations, so that the process of obtaining a permit is more streamlined and less burdensome for local governments in Solano.

- The process will be developed in consultation with STA and stakeholders.

User Story 7:

As STA, a local government, a developer, and a property owner, I want to have an online data-based visualization (such as a heat map) that characterizes areas in the county according to their needs of charging station infrastructure, so that opportunities for charging infrastructure deployment can be identified and collaboratively pursued.

- This tool will be integrated with a separate analysis of charging infrastructure needs.

These user stories, developed with STA, served as a guidance for the work presented in the next sections.

Permitting + Inspection Streamlining

2. Permitting and Inspection Streamlining

A key step in the installation of EV charging equipment is obtaining city or county permits and passing inspection. Some Bay Area local governments have issued a large number of EV charging equipment permits in recent years while others have limited or no experience with these types of projects. Because the infrastructure has been expanding rapidly, there are many opportunities to streamline permitting and inspection procedures and harmonize processes between jurisdictions. For example, most EV charging takes place at home, so expediting permits for residential installations can speed the roll out of charging station, especially for single-family residences where installations are often straightforward.

Online information for EVSE installation permitting and inspection practices in the County was not easy to find. For example, a Google search of the terms "EV charging station permitting Solano County" A Google search of the terms "charging station permitting and inspection Solano County" gave the County of Solano's webpage related to permitting process first in the list and the County's webpage related to inspections second.

According to the County's webpage, building permits are required to erect, install, enlarge, alter, repair, remove, convert or replace any electrical system, the installation of which is regulated by the California Building Code or the California Electrical Code. The owner or an authorized agent, typically the electrician doing the installation, can request permits. The County has implemented a system that allows contractors to apply for permits online. Contractors need to register with the County by filling and mailing a form. Permits for EVSE installation are not available over the counter.

The County's website has a dedicated webpage to explicate the permit process. We found that the information in this page was not particularly user-friendly. The cognitive burden of this page could be reduced significantly with a different structure, simplification of the text and the use of graphical guides. To process a building permit the applicant needs to submit a competed permit application and a set of plans. The requirement of plans for EVSE installation permitting was identified by the state as generally unnecessary to ensure safe installations and factor of higher installation costs.

According to the fee schedule in the corresponding webpage, the City of Vallejo charges a fee for electrical inspections equivalent to 20% of the applicable building inspection fee. For example, for a residential building with valuation estimated at $300,000, the fee would be $494, while for a building valuated at $500,000; the fee would be $770.

The objective of this section is to identify gaps in the processes of EVSE installation permitting and inspection in Solano and to identify best practices that could be considered for adoption by local governments in Solano. To pursue these objectives, we use a multipronged approach which includes:

- Case studies of EVCS deployments in Solano,
- Identifying local jurisdictions at the vanguard in this area and study their practices

- Interviewing EVCS installers.

2.1. Definitions

The California Building Code differentiates between electric vehicle charging station (EVCS) and electric vehicle supply equipment (EVSE), and defines them as follows:

Electric vehicle charging station: One or more spaces intended for charging electric vehicles

Electric vehicle supply equipment: The conductors, including the ungrounded, grounded, and equipment grounding conductors and the electric vehicle connectors, attachment plugs and all other fittings, devices, power outlets, or apparatus installed specifically for the purpose of transferring energy between the premises wiring and the electric vehicle (Ch. 2 Sec. 202).

2.2. Current Processes

Different permitting and inspection offices have different requirements for EV charging station projects. Jurisdictions require some or all of the following:

- Permit application
- Plan for installation
- Electrical load calculation
- Permit and inspection fee
- Inspection

Requirements vary depending on each jurisdiction's process. Some permitting offices do not require site plans, especially for installations at single-family detached residences. Permitting commercial or public stations are often more complex than residential installations and may require significant back and forth between the installer and permitting staff. CALGreen, the green building code of the California Building Standards Code (Title 24, Part 11), requires new construction to be pre-wired for electric vehicle charging, which includes providing a service panel and conduit that can support the electrical load necessary for Level 2 charging.[1] Pre-wiring greatly simplifies installations, so additional streamlining may be possible for charger installations in new construction.

In addition to variations in the application materials required for different local governments, the permitting and inspection fees vary widely. Some jurisdictions may require fees less than $100 while

[1] More information available from the State Department of Housing and Community Development's 2014 Report to the Legislature: Status of the California Green Building Standards Code (Sept 2014), available for download at: http://www.hcd.ca.gov/codes/calgreen/docs/calgreen-report-to-legislature-2014.pdf

others in the Bay Area charge over $300. Even within a city or county, fees may vary if they do not charge a fixed fee for EV charger installations; some fees depend on the project size or value.

In a study conducted by Idaho National Laboratory, as part of the EV Project, researchers found that California cities had three of the four most expensive average permit fees – San Diego $207, San Francisco $161, and Los Angeles $93 – in the 13 markets across the country that were part of the project.[2]

In addition to the fees, permitting can incur indirect costs through contractor labor hours. Permitting that requires long office wait times or repeated visits can add significant costs to a project.

In some places, permit applications can be submitted online while some must be handled in-person in other jurisdictions. It should be noted that Assembly Bill (AB) 1236, passed in October 2015, requires jurisdictions to provide permit materials and allow submission of applications online:

> *The checklist and required permitting documentation shall be published on a publicly accessible Internet Web site, if the city, county, or city and county has an Internet Web site, and the city, county, or city and county shall allow for electronic submittal of a permit application and associated documentation, and shall authorize the electronic signature on all forms, applications, and other documentation in lieu of a wet signature by an applicant.*[3]

If an electrical panel needs to be upgraded or a new panel is being added, the installer also needs to work with the electrical service provider to meet all of the utility requirements, which may include submitting an application, communicating with a utility representative, and scheduling an inspection. These steps may add significant time to the project, depending on the complexity of the service change. PG&E provides a checklist of steps that should be taken when installing Level 2 charging equipment.[4]

To provide consistency between jurisdictions within the Bay Area, the EV Subcommittee of the ICC Tri-Chapter Uniform Code Committee (TUCC) proposed (and updated in 2014) guidelines for local governments on EV charging systems for single-family residences and for multi-family residences and commercial properties.[5] Cities and counties should consider adopting guidelines described below.

- Provide information about the EV charging system, including level of equipment (Level 1 or 2), equipment certification by nationally recognized testing laboratory, in compliance with UL 2202 (Standard for Electric Vehicle (EV) Charging System Equipment)

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[2] Full report "How do Residential Level 2 Charging Installation Costs Vary by Geographic Location?" (April 2015) available at: https://avt.inl.gov/sites/default/files/pdf/EVProj/HowDoResidentialChargingInstallationCostsVaryByGeographicLocations.pdf

[3] Text of chaptered Assembly Bill 1236 available at the California Legislative Information webpage: https://leginfo.legislature.ca.gov/faces/billVersionsCompareClient.xhtml?bill_id=201520160AB1236

[4] PG&E checklist for Level 2 charging equipment available online at: https://www.pge.com/en_US/residential/solar-and-vehicles/options/clean-vehicles/electric/charger-installation.page

[5] The guidelines can be downloaded from the East Bay Chapter of the International Code Council (ICC) at: http://www.eastbayicc.org/index.php/tucc

- Conduct load calculations to determine if existing electrical service panel is adequate or if an upgrade is required
- Upgrade panel and wiring in conformance with the California Electrical Code (Part 3 of the California Building Standards Code) [6]
- Determine if an additional electrical meter must be installed for an EV charging utility rate
- Identify charging equipment location and install according to manufacturer specifications
- Provide manufacturer installation guidelines to inspector on site

In addition to these guidelines for single-family residences, multi-family and commercial installations need to consider the following:

- At least one ADA accessible space must be provided, although it will not count towards minimum ADA counts since the non-disabled users can charge in those spots
- Property owners or Homeowners' Associations must approve of installations
- Lighting, shelter, and flood zones must be considered
- Approvals from the city or county engineering and fire departments may be required

2.2.1. Case Studies

Protocol for Electric Vehicle Charging Station Case Studies (outlined in Appendix A) identified a variety of property owners with plug-in electric vehicle (PEV) charging locations in Solano County through the U.S. Department of Energy's Alternative Fuels Data Center (AFDC) Station Locator and PlugShare. Stations contacted included a diversity of location types – public, workplace, multi-unit dwellings, and cities – each with its own distinct opportunities and challenges. ICF also reached out to a car manufacturer, to learn more about charging station installations at dealership locations in Solano County and nationwide. The locations contacted were:

- Public-access locations
    - Anheuser Busch Brewery
    - First Northern Bank
    - ARCO
    - Leisure Town Center
    - Stars Recreation Center
    - Nut Tree Village
- Workplace locations
    - Solano Community College

[6] Note that 2016 California Building Standards Code is effective January 1, 2017. The current codes are available to view on the California Building Standards Commission website at: http://www.bsc.ca.gov/Codes.aspx

    - Wiseman Company

- Multi-unit dwellings
    - River Oaks Apartments
    - Lennar Mare Island
    - Sterling Heights
- Cities
    - Benicia
    - Fairfield
    - Rio Vista
    - Vacaville
    - Vallejo
- Other

ICF reached out to each station owner or point of contact three times via email and phone and received responses from seven charging sites as well as corporate-level contacts at Nissan North America. Of the eight total responses, ICF was able to conduct an interview with Wiseman Company, a property owner with charging stations at Westside Professional (Fairfield), Green Valley Executive Center (Fairfield), and One Harbor Center (Suisun City).

In our communication with charging station hosts, we identified two barriers to gaining information about the permitting and inspection process: high turnover and third-party intermediaries.

High turnover

Of the seven sites that responded to ICF's outreach, four companies (Solano Community College, River Oaks Apartments, Lennar Mare Island, and Sterling Heights) had experienced staff turnover and the employees that managed the station installation process were no longer with the organization.

While this lack of institutional knowledge was not conducive to case studies about charging station installation, it indicates a regional opportunity to reexamine and rework the current permitting process; without preexisting practices of permitting and inspection, future site hosts may be more open to new processes.

Third-party intermediaries

Of the seven sites that responded to ICF's outreach, four of the organizations (ARCO, Stars Recreation Center, and Wiseman Company) did not have detailed information about the permitting and inspection process because an outside company handled all installations. The car manufacturer also acknowledged that their charging equipment provider handled permitting and inspection. Wiseman Company installed NRG charging stations and all installation, permitting, and inspection was completed by NRG or NRG subcontractors, ARCO charging stations were installed by ChargePoint, and Stars Recreation Center's stations were installed by Clipper Creek. Even though some of these large-scale companies subcontracted local contractors to install the charging stations, the purchase and installation process seemed streamlined to station owners and organizations expressed satisfaction with the full service aspect of station installation.

Case Study: The Wiseman Company

ICF was able to interview a representative of Wiseman Co, a business that installed charging stations at three of their properties since January 2016

The main motivations leading their investment decision were a) to add amenities for their tenants, and b) to promote a healthier environment. Wiseman consulted with their tenants and found interest in providing access to charging stations, which provided additional impetus to the investment. Wiseman, at the moment of our interview, had installed five charging stations, although they had created the infrastructure for seven additional installations.

The first step that Wiseman took was to research the market offerings, make phone calls to vendors, and ask all the questions. Conversations with prospective vendors are helpful in understanding well the array of financing options, including the availability of public funds (such as rebates) that may be available at any given time. They eventually worked with SemaConnect, who provided a turnkey solution to them. The turnkey offering including all the permitting and inspection, which required interfacing with the city. They were interested in their offering of Internet-able charging equipment that allows Wiseman to receive usage data. They did not see this investment as a profit opportunity; they were only interested in covering the electricity costs. In this respect, they decided to charge $1.5 per hour of usage. To arrive at this rate, Wiseman consulted with the electric utility company. Also of interest to Wiseman was the fact that the vendor handles all the billing and sends 90% of the revenue to them. The charging equipment is accessible to the public. Wiseman sees an opportunity for open access to help with exposure of the public to Wiseman properties.

For the future, Wiseman is interested in installing charging stations at other buildings. Their experience with the vendor was good. They feel that, having gone through the process once, successive installations will be much easier.

In view that site hosts were not able to provide sufficient information, work then shifted to reach out to EVSE installation companies. That work is the focus of the next section.

2.2.2. Interviews with charging station installers

ICF held phone conversations with representatives of eight companies with EVSE installation business lines, to learn about current practices and identify challenges. In this section, we identify key themes from these phone discussions. The individuals with whom we spoke have firsthand experience with the installation process, including applying for and obtaining permits and inspections. To improve the representativeness of the sample of interviewees, we reached out to businesses of different sizes, and included car companies. We do not include the name of individuals or companies, to respect their anonymity.

Most of the individuals with whom we spoke had experience with installations at single-family homes. Some of them had experience with installations at commercial or public-access sites.

Key themes and messages that came out of the interviews include the following:

- Inconsistent requirements between jurisdictions – Nearly all contractors expressed frustration with the difference of permitting and inspection requirements across jurisdictions. This lack of consistency is perceived as a challenge to the EVSE installation process and more broadly to the development of a network of charging stations in Solano. They all expressed that there is great need for harmonizing rules across jurisdictions.
- Local government staff experience – Multiple respondents found that many permitting and inspection staff did not have experience with EVSE installations, which resulted in some challenges and additional time to pass inspection. Also, some contractors noted that there is sometimes a lack of customer service emphasis in some permitting and inspection offices
- Inspections – The inspection process can be costly in terms of time and resources. Sometimes inspections must be scheduled days in advance, especially for bigger cities. And contractors are often wasting time waiting because inspections are not scheduled at specific times. Some jurisdictions require an electrician to be present for the inspection; multiple contractors mentioned that they always provide an electrician on hand whether or not it is required to avoid having to repeat an inspection.
- Plans and load calculations – Some jurisdictions require plans even though most contractors believe that they are not necessary for simple residential installations. One contractor requested that load calculators be simpler to use and to be implemented online.
- Permitting cost – Costs range widely between local governments, and sometimes depend on the value of the project, whereas other cities have a flat fixed fee for certain types of projects. While fees are sometimes small, cost of labor is often significant, which includes paperwork and administrative activities, travel time to permitting office, wait time at office, and communication and adjustments for application and plans. Even with some cities allowing online submission of materials, one contractor reported that they always submit all paperwork in person because repeated back and forth is often necessary, eventually requiring someone to go in-person to the

government office anyway. For some cities, the process may take multiple weeks because they outsource the permitting.

- Jurisdiction boundaries – It is sometimes unclear under which jurisdiction a project falls. Some contractors have assumed wrong jurisdictions for projects, especially for some that fall under unincorporated county areas. Multiple respondents mentioned still using paper maps to figure out boundaries.
- Utilities – Some mentioned that utilities can be a significant holdup in cases when panel upgrades are required; they are sometimes understaffed and many representatives are not familiar with EVSE installations and governing electrical codes

2.3. Best Practices

2.3.1. AB 1236 and Streamlining Requirements

Recognizing the important role of the permitting and inspection process in the expansion of the charging infrastructure in the state, California legislators passed a law in 2015 requiring local governments to streamline the permitting process. [7] AB 1236 required communities with populations greater than 200,000 to adopt ordinances that expedite the permitting process for EV charging stations by September 30, 2016. As the only jurisdiction in Solano County meeting this population minimum, the Board of Supervisors of the County of Solano adopted an ordinance on September 13, 2016, adding section 26 to Chapter 6.3 - Building Standards and Codes of the Solano County Code to provide an expedited permitting process for electric vehicle charging stations.[8] All other jurisdictions must adopt an ordinance by September 30, 2017.

The required ordinance must include a number of streamlining elements. Local governments must provide a permitting checklist; installation projects that meet all requirements on the checklist must be eligible for expedited review. Cities and counties can use the latest version of the "Plug-In Electric Vehicle Infrastructure Permitting Checklist" from the *Zero-Emission Vehicles in California: Community Readiness Guidebook* published by the Governor's Office of Planning and Research (OPR)[9]; they can also modify the standards based on "unique climactic, geological, seismological, or topographical conditions." In addition to developing streamlined procedures, permitting offices must provide the permitting materials on the government's website and must allow for electronic submittal of the application materials online.

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[7] Full text of chaptered Assembly Bill 1236 available at the California Legislative Information webpage: https://leginfo.legislature.ca.gov/faces/billVersionsCompareClient.xhtml?bill_id=201520160AB1236

[8] Full text of the adopted ordinance by the Board of Supervisors of the County of Solano is available at: http://www.codepublishing.com/CA/SolanoCounty/html/SolanoCounty0603.html#6.3-26

[9] Materials available from the Governor's Office of Planning and Research at: https://www.opr.ca.gov/s_zero-emissionvehicles.php

California Building Officials (CALBO) provides templates that jurisdictions can use as model language for ordinances and staff reports as part of an AB 1236 Toolkit.[10] CALBO provided templates for both an Administrative Ordinance, which would be part of an administrative chapter of a code, and a Technical Ordinance, which would be part of the technical chapters.[11] Current templates are for large jurisdictions that had to meet the September 2016 deadline, with templates planned for smaller jurisdictions to meet the September 2017 deadline and a suggested permitting checklist.

2.3.2. CalGreen

The California Building Codes (CalGreen) include provisions related to the accommodation of electric vehicles in parking infrastructure, both for residential and non-residential. Non-residential Site Development requirements of CalGreen already included minimum requirements on the number of parking spaces that should be designated for vehicles that fall in any of the following categories: low emission, fuel efficient, and carpool/vanpool (Section 5.106.5.2)—see Table 1. Electric vehicles are considered low-emission and fuel-efficient.

Table 1. Designated parking requirements for combinations of low-emission, fuel-efficient, and carpool/vanpool in non-residential site developments (Source: Table 5.106.5.2, California Building Codes)

TOTAL NUMBER OF PARKING SPACES	NUMBER OF REQUIRED SPACES
0-9	0
10-25	1
26-50	3
51-75	6
76-100	8
101-150	11
151-200	16
201 and over	At least 8 percent of total

In 2015, Sections 4.106.4 and 5.106.5.3 were added to include requirements for new residential and non-residential new construction related to electric vehicle charging stations, respectively (Table 2). The

[10] Toolkit available for download from California Building Officials website: http://www.calbo.org/

[11] CALBO points out that "an advantage of an Administrative only Ordinance is that you will not have to create new Chapters due to legislative changes."

Code sets requirements on the installation of raceway and on the capacity of service panel and subpanels. For new multifamily dwellings with 17 units, site development accessibility and dimensions requirements apply.

Table 2. Calculation of required number of parking spaces that meet requirements to support the installation of EV charging equipment

TOTAL NUMBER OF PARKING SPACES	NUMBER OF REQUIRED EV CHARGING SPACES
0-50	0
51-75	1
76-100	2
101-200	3
201 and over	3% [1]

[1] Calculation for spaces shall be rounded up to the nearest whole number

The California Manual on Uniform Traffic Control Devices (California MUTCD), published by the California Department of Transportation, includes specifications for signs and pavement markings for EVCS.

2.3.3. Examples from leading local governments

In this section, we look at permitting and inspection practices adopted by local governments outside of the County that are considered to be at the vanguard in this area.

Los Angeles, California

The City of Los Angeles Department of Building and Safety (LADBS) sets and administers the permitting and inspection process for electric vehicle charging stations within the City's jurisdiction.

The City allows for Express Permits to be issued online "where work does not require any type of plan review or approval," including for "electrical installation for electric vehicle charging in single family dwellings with up to 400 amps of service (including any needed charging equipment, service upgrade, receptacle and associated wiring)." Through this online system, customers can receive a permit immediately. One of our interviewees reported that permits can be obtained in about 10 minutes.

Customers can also obtain Express Permits over the counter from various LADBS offices throughout the city; in addition to single-family dwellings, customers can get these over-the-counter Express Permits for installations at commercial buildings, although still only up to 400 amps of service.

To expedite inspection, LADBS has assigned staff specifically for EVCS projects. Having a staff dedicated to charging stations reduces delays related to limited inspectors who may not be familiar with EV charging equipment installations.

Houston, Texas

The City of Houston is another example of a coordinated effort to streamline the EVSE installation permitting process. The City had an existing online permitting portal and process that was extended to include EVSE. To streamline the permitting and installation process, the City laid out six steps:

- Identification of equipment installers
- Assessment of host site by a licensed electrician to determine whether the electrical systems are adequate
- Permit request through online portal, which can be approved immediately for standard installations; Houston's Public Works and Engineering department established a 24-hour permitting process, although DC Fast Charging permits typically require a plan review
- Installation conducted by a licensed electrician
- Inspection is completed the next day for installations of Level 1 and Level 2 equipment
- Collaboration with local utilities to monitor the progress of EVSE deployments and evaluate their impact on the grid

State of Oregon

Oregon has established a "minor label" program for more straightforward projects that do not require significant oversight from the state. Licensed contractors can purchase ten permits for $140 for projects that meet the Minor Label program requirements, including EVSE installations that do not exceed 40 amps/240 volts.[12] Out these ten projects, agency staff inspects only one, thus greatly reducing the administrative and financial burdens for both contractors and staff.

Seattle, Washington

The City of Seattle's Department of Construction and Inspections website provides a number of tools to assist EVSE installers navigate the permitting and inspection process. The website provides specific "Tip" sheets to guide customers and answer questions regarding the "Installation of Vehicle (EV) Charger for Single Family and Multifamily Homes" (Tip 132) and "Installation of Electric "Installation of Electric Vehicle Charger for Commercial Properties" (Tip 133).[13]

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[12] Minor Label program described on website at: https://www.oregon.gov/bcd/minlab/Pages/info.aspx

[13] Tips available for download from the Seattle Department of Construction & Inspections Electrical Permit website under "Research" section: http://www.seattle.gov/dpd/permits/permittypes/electrical/

For projects not requiring a plan review, EVSE installers can apply for permits online or over the counter at the permitting office. Plans are not required for a typical Level 1 or 2 charging station at a residence; they are required for DC Fast Charging stations or any chargers requiring service of at least 400 amps. Permits not requiring plan reviews are issued the same day and are typically turned around within 20 minutes. Plans and specifications for review can be submitted electronically through a portal on the City's website or over the counter at the permitting office.

The City is also able to turn around inspections for standard installations relatively quickly. Inspections requested by 7 AM can typically be conducted the same day. Installers can schedule an inspection online or via a 24-hour telephone line. Customers can also contact installers; the City website contains a downloadable map showing each inspectors geographic area and their phone numbers.

2.4. Installation and Permitting Checklist Template

As discussed above, all jurisdictions are required to provide permitting checklists by the end of September 2017 as part of the streamlining requirements under AB 1236. In collaboration with STA, ICF implemented a process of consultation with local jurisdictions in Solano County to develop a set of practicable best practices for EVSE permitting and inspection.

In consultation with STA, ICF developed a plan involving the following sequence of steps:

- Understand how AB 1236 affects Solano
- Develops a draft template permitting and inspection process that incorporates findings from previous sections.
- ICF and STA implement consultative process involving local jurisdictions. Cities have established practices, constraints, and special needs/concerns that need to be acknowledged.
- Collect feedback from local jurisdictions and the County
- Refine the draft template as appropriate.

STA and ICF reached out to Solano jurisdictions and Solano County to offer support on their efforts toward meeting these requirements. The County, because of its population size, faced the earlier deadline of September 2016, and thus took the first steps to streamline EVSE installations.

Building upon the experience of the County of Solano, incorporating feedback from jurisdictions, and using other information, the checklist template below was developed to help jurisdictions in Solano to meet these requirements. This template can be adapted and used by any jurisdiction in the county. A downloadable copy of this template can be found at www.SolanoEV.org

Table 3: Solano EV Installation and Permitting Checklist

✓	ACTION	NOTES
	Pre-installation	
	Identify electric vehicle model and obtain charging equipment manufacturer specifications	
	Verify vehicle will fit completely on property while charging	
	Assess electrical system capacity and determine if upgrades (including new dedicated circuits) are needed	
	Contact electric utility to notify planned installation, consult on necessary upgrades, and discuss charging level, meter, and rate options	Visit PG&E EVSE installation website or call PG&E at 877-743-7782
	Permit Application	
	Submit site plan with property lines, garage or parking space dimensions, and clearances of proposed charging system location including location of additional meter, if applicable	
	Submit one-line diagram showing (1) location of new and existing meter/sub meter and charger controller; (2) wire sizing and routing	
	Provide manufacturer installation details and specifications for the electrical supply charging unit	
	Provide information from the manufacturer indicating whether or not ventilation is required, label plans accordingly and provide mechanical ventilation, if required	
	Complete the Electrical Load Calculation Worksheet and provide load calculation of electrical service; include the electrical load required to charge the vehicle at 125%	
	Note the voltage (120V or 240V) and ampacities of the vehicle charger	
	List or label all supply equipment	
	Pay permit fees	[List any standardized fees]
	Installation	
	Meet all code requirements (Article 625 Electric Vehicle Charging System)	Requirements include: Coupling means of electric vehicle supply equipment shall be stored or located at a height of not less than 18" and not more than 48" above the floor level. Electric vehicle supply equipment rated 125 volt, 15 or 20 amp may be cord and plug connected; all other EV supply equipment shall be permanently connected and fastened in place If both 120V and 240V circuits are desired to be monitored by the electric vehicle meter, a meter distribution will be required
	Inspection	
	Schedule inspection(s)	For standard residential installations, one inspection after installation is typically sufficient; more complex projects may require multiple inspections at points before wiring and final installation

2.4.1. Solano EVSE Permitting Roundtable

Figure 1: Presenting on the Solano EV Transition Program at the EVSE Roundtable Discussion

The Roundtable was a central part of this task and it was concerned with engaging local jurisdictions in Solano, to provide them with information and elicit inter-jurisdiction conversations related to the installation of EVSE. The planning the event was led by STA in collaboration with ICF staff. STA provided contacts and a location to hold the event. STA led the process of city engagement, and ICF provided support with drafting emails and materials. ICF led the development of content for the event. ICF worked closely with STA on the development of an agenda for the roundtable and on stakeholder engagement and invitations to the event. ICF was able to secure the participation of special guests, including Pacific Gas & Electric (PG&E), and the Sacramento Municipal Utility District (SMUD).

The agenda for the event was as follows:

EVSE Roundtable Discussion
Hosted by STA
Tuesday, November 14, 2017
STA Office, 1 Harbor Center, Suite 130 in Suisun City
1:00- 4:00 p.m.

I. **Welcome:** Bob Macaulay, STA
II. **Introductions**: All
III. **The Solano EV Transition Program**: Cory Peterson and Gustavo Collantes
IV. **AB 1236**: Bill Boyce, SMUD
V. **Proposed approach to streamline EV charging station permitting:** Gustavo Collantes
VI. **EVSE deployment opportunities in Solano**: Ben Villagra, PG&E
VII. **Cities' work to streamline EVSE permitting**: All
VIII. **Summary and next steps**: Cory Peterson

The slides used by STA and ICF in their initial presentation are included in an appendix (Appendix B. Slides for the EVSE Permitting Roundtable).

City participation was lower than what was expected. Representatives from four jurisdictions attended, in addition to the representation of STA. The conversations were, however, fluid. During the event, there was discussion on a range of issues related to EVSE deployment. Bill Boyce from Sacramento Municipal Utility District discussed potential funding options for EV deployment through the Volkswagen Settlement, PG&E's Charge Program, and incentives through the low carbon transportation fund. Volkswagen and PG&E are both looking for proposals to place EVSE chargers throughout their service areas. Ben Villagra from PG&E gave a presentation on their Charge program and informed the participants of options to fund EVSE deployment. Further, ICF and SMUD answered many questions related to broader aspects of EV technologies and markets.

2.5. Challenges and Recommendations

Based on the review of existing local permitting and inspection processes and interviews with site hosts and installers, we identified a number of key challenges that limit or slow the deployment of infrastructure.

2.5.1. Challenges

- Permitting and inspection fees are set by city councils, and thus establishing a harmonic flat fee across all jurisdictions would be challenging
- Cities are concerned with liabilities from their permitting/inspection processes, and this may hinder to some extent efforts to pooling resources
- Permitting and inspection guidelines need to account for any conditions that are specific to any given city; for example, in Benicia there are concerns about flooding in certain areas
- Commercial (i.e., non-residential) installations are very site- and project-specific, making some efforts to streamline such as providing permitting checklists and standardized fees more challenging
- Some installers and city, county, and utility representatives are not familiar with EVSE installations and may misapply codes and/or delay projects; also, some offices are understaffed, slowing the approval process

2.5.2. Recommendations

In collaboration with STA, ICF implemented a process of consultation with local jurisdictions in Solano County to develop a set of practicable best practices for EVSE permitting and inspection.

- Implement method for online submission, review, and modification of project drawings and plans; the City of Benicia works with a company that reviews the city's plans online using a software package called Bluebeam
- Adopt a "standard" checklist for all jurisdictions in Solano County while allowing modifications for city-specific considerations, such as Benicia's flooding concerns; consider working with TUCC to help refine and support a standard checklist in Solano

- Implement a program for simple residential installations with city staff conducting sample inspections to ensure compliance; for example, Oregon has administered its Minor Label program since 2010
- Create an online jurisdiction map that installers can easily reference, to identify the incumbent jurisdiction
- Train permitting and inspection staff to familiarize with EVSE installation
- For single-family residential installations, remove site plan requirements

To prepare for a future of increased EV adoption and mandated procedures, local governments may need to examine their current permitting and inspection practices and update their processes to improve convenience and support increased installations. However, they must balance efforts to simplify permitting and inspection while maintaining quality and safety standards. The following practices can help jurisdictions increase efficiency while meeting standards and state requirements:

- Prepare combined informational materials providing all guidance on the permitting and inspection processes specific for residential, multi-family dwelling, and non-residential charging equipment installations
- Prepare all guidance, including permitting and inspection checklist, and application materials for online submission to meet state law requirements
- Work with other local governments to make permitting and inspection procedures consistent between jurisdictions by using the TUCC proposed guidelines or other agreed-upon standards
- Consider streamlining permitting for installations in single-family residences by reducing application material requirements; for example, eliminate site plan requirements and require installer to provide manufacturer specifications and approved equipment testing certification at the time of inspection, limit to one inspection, and set a fixed fee
- Work with local utilities to create a notification protocol for new charging equipment through the permitting process
- Train permitting and inspection officials in EV charging equipment installation

Additionally, utilities can support permitting and inspections with the following:

- Assign utility representatives with relevant experience to review and approve EV charging installation projects
- Work with local government permitting offices to create a notification protocol for new charging equipment

While developing or adopting standardized permitting processes, local governments may also want to consider surveying charging station owners and installers to identify additional barriers and opportunities for improvement and to ensure that officials are designing processes that consider the needs of installers and consumers in addition to the needs and limitations of the government staff.

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Outreach Events + SolanoEV.org

3. Outreach Events & SolanoEV.org

As part of the effort to promote EVs to the general public and local governments, STA and ICF created an electric vehicle resource website, titled www.solanoev.org, and hosted two Ride and Drive Events at two employers in Solano County. Both were designed to promote the benefits of owning an EV. They provided the public with information such as permitting and installing a charging station, finding a public charging station, and the costs associated with owning an EV.

3.1. SolanoEV.org

The development of a dedicated EV website for STA was an important part of the project, as it was meant to be the main source of information on EV questions for cities and residents. For the design of the website, ICF took an innovative approach, using techniques of experiential marketing. STA expressed their interest in four main features for the website, namely:

- Visually appealing,
- Easy to navigate,
- Relatively minimalist, with emphasis on pages that are not cluttered with text
- Easy to integrate into STA's website.

The ICF team engaged in a site planning process that resulted in the core site structure shown in Figure 3.

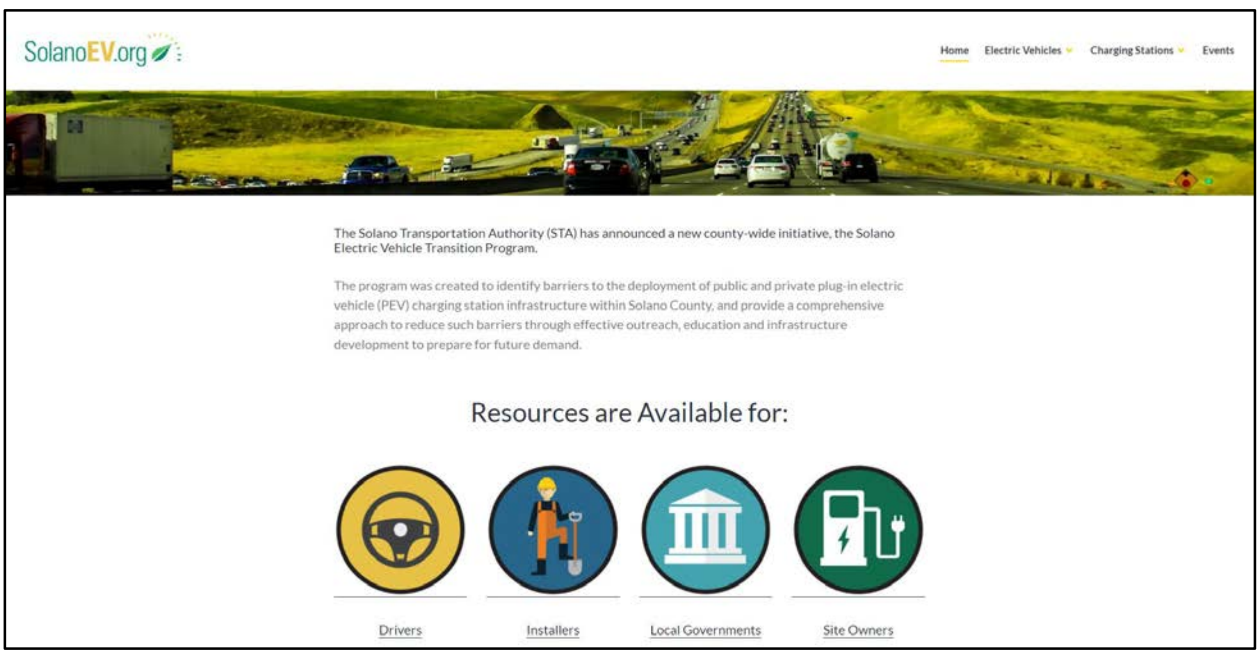


Figure 2: Screenshot of the SolanoEV.org home page

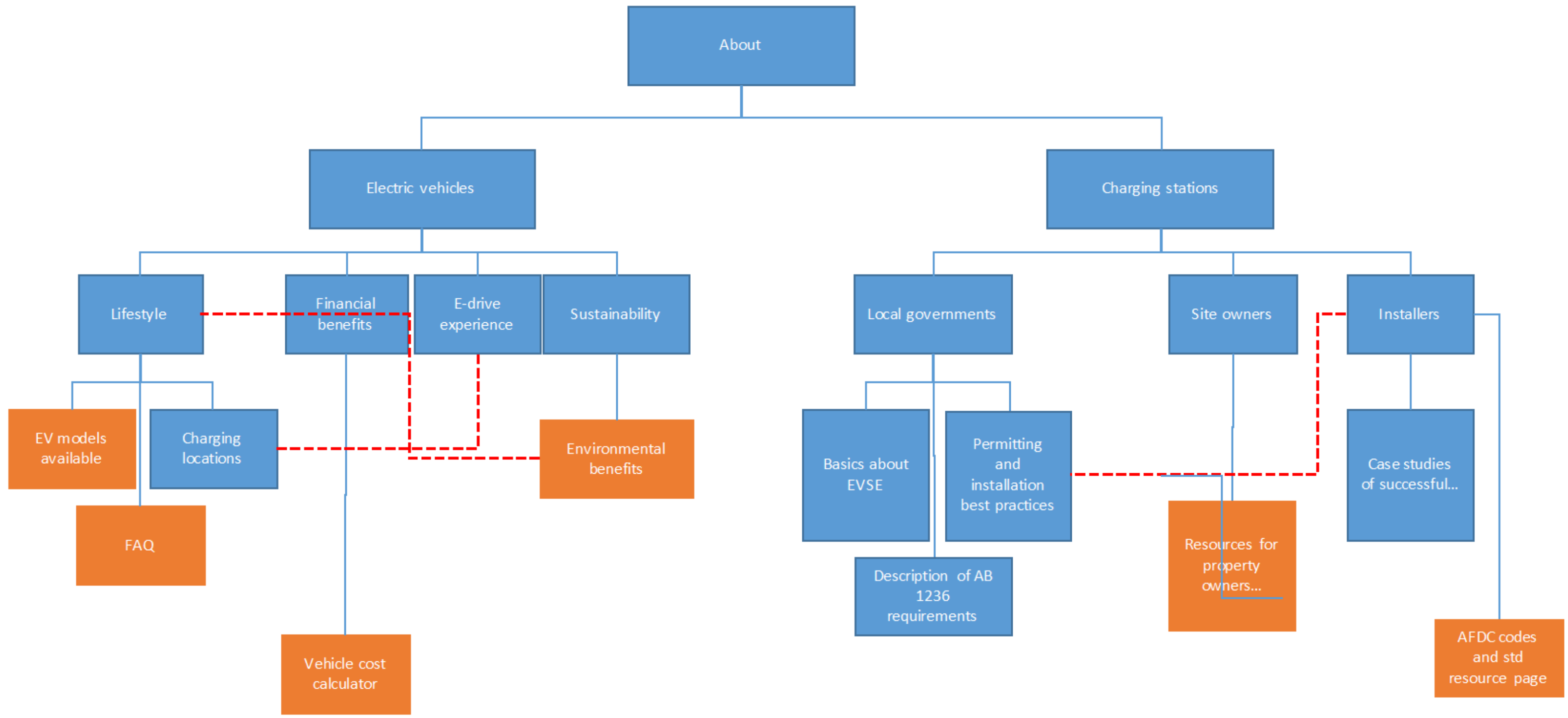


Figure 3. Core structure design for the STA EV website

The resulting website was posted at the URL www.SolanoEV.org , and it went public right before the ride and drives events that ICF help STA host. The website includes a host of information that can be seamlessly navigated on a variety of aspects of vehicle electrification, which will be of interest to the public as well as Solano cities. Information in the website includes a map of local charging stations, benefits of driving an EV, and information on permitting and installing an EVSE. Also available is information developed via the consumer survey (described below), such as the word cloud in Figure 4.

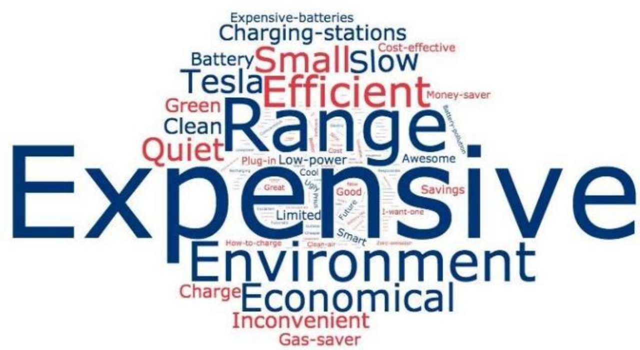


Figure 4. Word cloud showing the more frequent words that came to mind to survey respondents when they thought about EV

3.2. Earth Day Ride & Drive Events

While this task was toward the end in the list of tasks for the project, we include it here because if allows for a more natural thematic organization. Ride and drive events are considered an important tool to support EV market adoption, as they expose consumers to the technology and increase awareness. STA and ICF were able to organize two such events in different locations in Vacaville. These locations were chosen predominantly for two reasons: a) proximity of and ease of communication with local vehicle dealers, and b) STA's existing relationships with the employers where the events were hosted, who expressed interest in this partnership. Because of the date of these events, we named them the 2017 Earth Day SolanoEV.org Events.

2017 Earth Day Events for SolanoEV.org

The week of Earth Day 2017, Solano EV.org took part in two events in Solano County. As a part of both events, attendees were asked to fill out an "Electric Vehicle Experience Survey" to help STA assess their experience and impressions of electric vehicles prior to and following their interaction with the vehicles at these events. Survey respondents from each event were included in a drawing to win a Fitbit Alta.

Genentech Eco Fair

Wednesday, April 19 from 3:30 – 5:30 p.m.

Ride & Drive Event: Showcasing the Nissan LEAF

SolanoEV.org provided an opportunity for Genentech employees to get a firsthand experience with the Nissan LEAF to demonstrate the benefits, address potential concerns and ultimately increase the knowledge and familiarity with electric vehicles. We spoke with approximately 300 employees and 49 surveys were completed.

Kaiser Permanente Vacaville Earth Day Event

Friday, April 21 from 11 a.m. – 1:30 p.m.

Showcasing the Nissan LEAF & the Hyundai IONIQ hybrid

SolanoEV.org provided an opportunity for Kaiser employees and community members to get a firsthand experience with the Nissan LEAF and the Hyundai IONIQ hybrid to demonstrate the benefits, address potential concerns and ultimately increase the knowledge and familiarity with electric vehicles. We spoke with approximately 100 people and 25 surveys were completed.

Events like these help Solano EV Transition Program to forward local, regional, and state goals of improving the air quality, reducing greenhouse gas emissions, reducing dependence on petroleum, and raising awareness of emerging technologies in Solano County.

Figure 5: Photos from the SolanoEV.org Earth Day events

Events like these help Solano EV Transition Program to forward local, regional, and state goals of improving the air quality, reducing greenhouse gas emissions, reducing dependence on petroleum, and raising awareness of emerging technologies in Solano County. An important goal with organizing these events was to develop a template that would help STA organize similar events in the future. This was one example of the overarching goal of providing STA with tools to continue supporting EV growth after this project was completed. The template is included in an appendix at the end (Appendix C. Template for the Planning of EV Ride and Drive Events).

Solano Transportation Authority

SolanoEV.org

Electric Vehicle Fact Sheet

WHAT ARE ELECTRIC VEHICLES?

Electric Vehicles, a.k.a. EVs, are designed to use electricity as fuel. The electricity is stored onboard in advanced batteries that can be recharged from various sources, such as the grid and solar panels.

There are essentially two types of electric vehicles:

Plug-In Hybrid Electric Vehicles (PHEVs): They can use both electricity and gasoline as fuels. If the onboard battery is exhausted, they switch to a gasoline engine.

Battery Electric Vehicles (BEVs): They are powered exclusively with electricity. They typically can drive longer on electricity than PHEVs thanks to their large-capacity batteries.

HOW FAR CAN ELECTRIC VEHICLES GO?

It depends. There are models with rated ranges of about 100 miles, others with about 200 miles, and others with even longer range.

HOW CAN I HELP THE ENVIRONMENT?

EVs driving on electricity have no emissions, helping clean the air. EVs also help reduce emissions of greenhouse gases. In fact, when charged with renewable sources of electricity (like that from solar panels), EVs are all around zero-emission vehicles.

HOW DO I CHARGE AN ELECTRIC VEHICLE?

All EVs can be charged using regular 120 volt wall outlets, but standardized 220 volt charging equipment significantly accelerates the charge. Most people charge their EV at home at night, benefitting from dedicated lower electricity rates. Public charging stations can be found in many locations across the state, including workplaces, recreation destinations, and more.

During long trips, EVs can be charged at fast-charging stations. These high-power stations can supply 10 kilowatt-hours (about 35 miles worth of electricity) in just about 10 minutes. Fast charging stations can often be found along highway corridors.

In the near future, models with wireless charging capability will become available.

HOW MUCH CAN I SAVE?

If you purchase a BEV in California, you can claim **$2,500** in rebates and up to **$7,500** in federal tax credits.

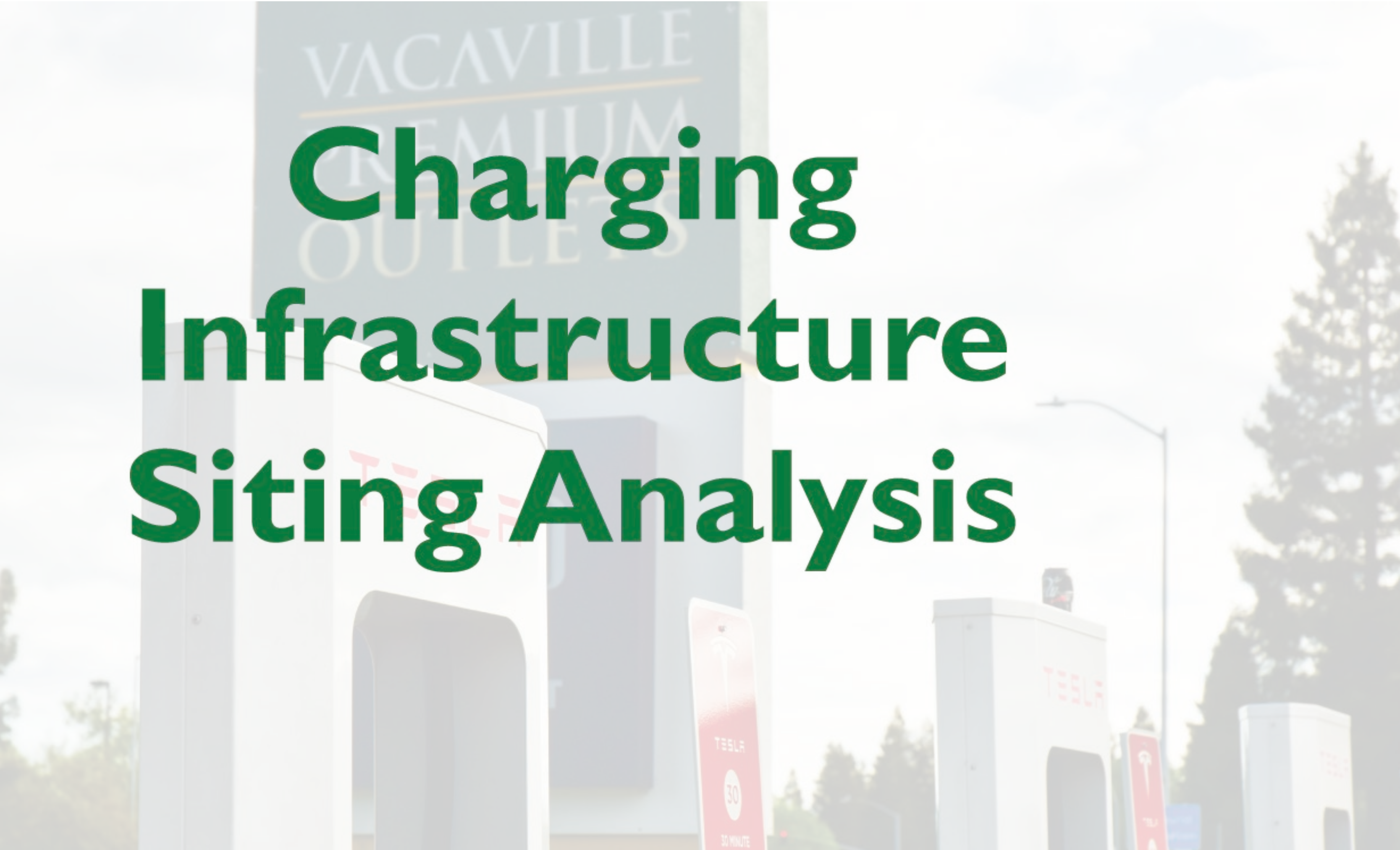
If gas costs $3 per gallon, it costs 9 cents per mile to drive an efficient 32 miles-per-gallon conventional car (just in fuel). In contrast, an EV that is charged during off-peak hours costs just 3-4 cents to drive per mile.

BEVs also require no oil changes or emissions testing and need less maintenance.

For more information, visit: SolanoEV.org
Contact us: (800) 535-6883

Figure 6. Data sheet distributed at the Earth Day SolanoEV.org ride and drive events

Charging Infrastructure Siting Analysis



4. Charging Infrastructure Siting Analysis

STA is interested in the development of a comprehensive framework for the siting of charging infrastructure in Solano. Earlier sections addressed some of the key institutional questions related to the actual installation. This section addresses questions related to the location of the stations, to create a charging environment that is supportive of current and prospective EV owners.

It has long been accepted that most of the EV charging occurs at residential sites. According to the U.S. Department of Energy, drivers of plug-in electric vehicles typically do 80% of their charging at home. However, this conclusion must be put in the right context. EV charging happens at the residence for consumers that have access to charging at home. Consider the following:

- Firstly, or many households, access to charging at home is hindered by institutional or economic reasons. This challenge is prevalent among residents of multi-unit dwellings as well as renters.

- Secondly, charging infrastructure at regional destinations is important to support return trips from distant locations.

- Thirdly, high-power charging infrastructure, technically known as direct-current fast charge, or DCFC, plays a critical role to support trips to regional destinations beyond the range of battery electric vehicles. DCFC enables BEV drivers to recharge in relatively short times thus significantly increase the utility of BEV to a broader market.

To start addressing these areas in Solano, ICF did an analysis of the DCFC infrastructure needs to support BEV travel at the regional level, as well as infrastructure needs to support EV regional commute travel.

For the analysis of infrastructure to support regional travel, we used a methodology that has been used in other regions, including the Pacific Northwest and the Midwest. The methodology involves the collection of Global Positioning Satellite (GPS) data while driving along regional corridors in Solano. These data gives information on topography and representative driving conditions. These data were then fed into a vehicle dynamics model that evaluates the consumption of energy that a typical EV would experience along these routes. With these results, ICF then evaluated prospective locations for the installation of DCFC infrastructure that would have a high impact on support regional longer-distance EV trips.

For the analysis of infrastructure to support commute travel, we designed a consumer choice study that comprises the following fundamental blocks:

- Design of a data collection instrument in the form of a survey to capture commuter stated preferences

- Administration of the survey to a sample of employers in Solano County

- Econometric analysis of the data using state-preference choice models

- Evaluating on a geographical level where infrastructure should be deployed, to support EV travel and adoption

We start with the analysis of the siting of charging infrastructure to support regional-level travel, and follow with the analysis of siting of local-level charging infrastructure to support commute travel to destinations in Solano.

4.1. Regional Corridor Network Analysis

While slower charge equipment is well suited to support electric vehicle travel in tours that include stops of some duration, it is not ideal to support seamless regional travel over distances longer than the electric range of the vehicles. To support regional travel, it is of interest to understand the needs for fast charging infrastructure. The type of equipment known as direct current fast charge (DC fast charge or DCFC) serves the purpose of charging the vehicle when charging time is a constraint. Typically rated at 50-60 kilowatts of power, DCFC equipment allows charging events using almost 10 times the power of the typical new generation electric vehicles.

The analysis of regional infrastructure needs to start with an assessment of the network of destinations at the regional level, with a particular interest in the connectivity of this network. In the case of EV charging infrastructure, the network connectivity is characterized by the energy required to connect any two nodes (destinations) in the network. This helps assess the ability of electric vehicles to navigate the network. When considering a trip using an electric vehicle, the following question must be answered; Can an electric vehicle travel between point A and point B at the regional scale, without recharging along the way? If the answer is no, then what are the recommended investments in infrastructure to support such trip? Clearly, a key part of these questions is how we define points A and B. In other words, what is the regional scope of interest? When points A and B are well defined and are the ends of a linear network, the problem simplifies itself greatly. This is not, however, our case. Our interest is to evaluate the regional network in Solano County, which in turn is embedded in a larger region.

Some studies have approached the energy analysis of a regional network via simulation; however, there is no substitute to the collection of real-world vehicle operation data along the routes of interest. We have thus used a global positioning system (GPS) device to collect data on a vehicle as we drove from point to point of the Solano regional network. The GPS records three-dimensional position and time at high frequency. These data enable us to construct profiles of speed and topography along any given route, which in turns enables us to construct profiles of acceleration. This information provides a real-world description of vehicle operation characteristic of the routes of interest. We use the term characteristic because clearly vehicle operation will depend on a variety of factors, such as time of the day, day of the week, weather conditions, and others. Within the scope of this study, we will consider the vehicle operation derived from the data that we collected as representative.

The vehicle operation thus determined is input to a model of vehicle dynamics that allows us to estimate the energy consumption along a given route of an electric vehicle defined with a set of attributes, including weight, coefficient of drag, rolling resistance, and others. We present these results below. For context of the estimate energy consumption along a given route, a typical battery on a 2015 Nissan Leaf holds approximately 24 kWh and has a range of about 84 miles. We first include the analyses of the individual corridor links. Each link connects one of the main urban areas in the County with each other and a few additional key destinations beyond the County's boundaries. The link analysis is followed by an integrated network analysis, which looks at the whole system of links (corridors) and nodes (origins and destinations), and evaluates the needs for DCFC infrastructure to support EV mobility over the regional network.

4.1.1. Link Analysis

In this section, we present our results of the GPS data collection and energy analysis for each of the regional links.

4.1.1.1. Davis – Dixon Link

Figure 7. DCFC station next to the Mondavi Center in the campus of the University of California, Davis

For data collection events starting in Davis, we typically take as the starting point the parking structure of at the Mondavi Center of the University of California, Davis. There are a number of level-2 charging stations at that location, in addition to a direct current fast charging station (picture).

The figures below show the profiles of driving speed and energy consumption along the route connecting Davis and Dixon, mainly along Interstate 80. We estimate energy consumption under two scenarios: one with no use of auxiliary loads (preeminently heating) and one in which auxiliary loads, including heating, are on all the time.

The second pair of charts show the same information but this time for the inverse route, from Dixon to Davis. The speed charts show different driving conditions on each direction, which adds to the representativeness of our data. The energy charts show that, with auxiliary loads on, the energy consumption is in the order of 2.8-3.0 miles per kilowatt-hour.

Figure 8. Satellite image showing the GPS data of the route between Dixon and Davis

Figure 9 shows the topographic profile of the route we measured from Davis to Dixon. As expected, for a relatively short route with such relatively flat topography and short distance, a representative electric vehicle would not need to recharge to cover a two-way trip. Figure 10 and Figure 12 show the duty cycle measured on each direction. The estimated vehicle energy consumptions along this route and under these duty cycles are shown in Figure 11 and Figure 13. The energy consumption charts in this and all subsequent links show two curves. The upper (blue) curves represent energy consumption when the vehicle auxiliary units are on. To produce conservative estimates, the auxiliary unit that we use in our modeling is the heating system, which is the most demanding on the battery. The lower (orange) curves represent the energy consumption with auxiliary units off. For example, Figure 11 shows that the energy connectivity of the link Davis-Dixon is 3.7 kilowatt-hours, with an average energy efficiency of about 0.4 kilowatt-hour per mile. Therefore, presumably, the charging stations at the Mondavi Center do not see much use from Dixon visitors.

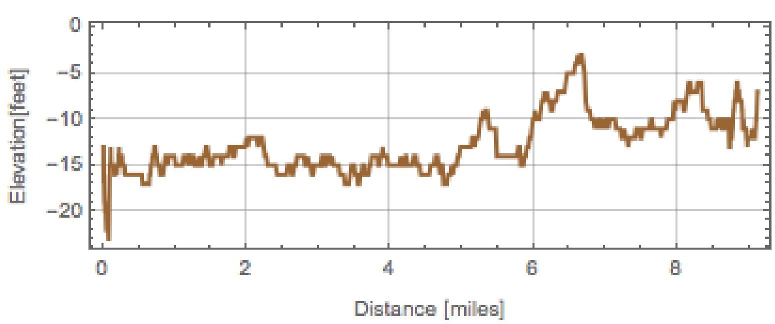


Figure 9. Topographic profile of the route between Davis and Dixon

The purpose of the duty cycle is to obtain a representation of driving conditions along a given route. This is a critical step in the modeling, as speed and acceleration have a direct impact on energy consumption. Therefore, using real world, representative duty cycles is essential to obtain estimates of energy consumption that are truly representative of the route under consideration. To collect speed and acceleration data, we used a GPS device onboard of a vehicle, which we tried to drive following prevalent conditions of speed and acceleration. The duty cycles included in this analysis typically show a segment at the beginning and a segment at the end with lower speeds. These segments represent urban driving conditions prior to entering and after exiting a highway. The rest of the duty cycle in general shows more uniform higher speeds, reflecting highway-driving conditions. Occasionally, also these highway segments may show areas of lower speed, which typically correspond to traffic slowdowns.

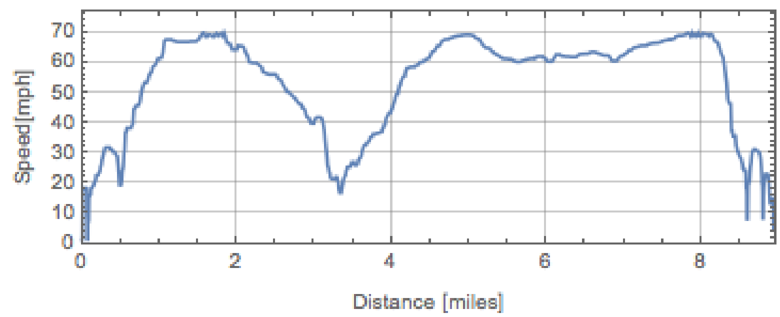


Figure 10. Representative duty cycle for a drive from Davis to Dixon

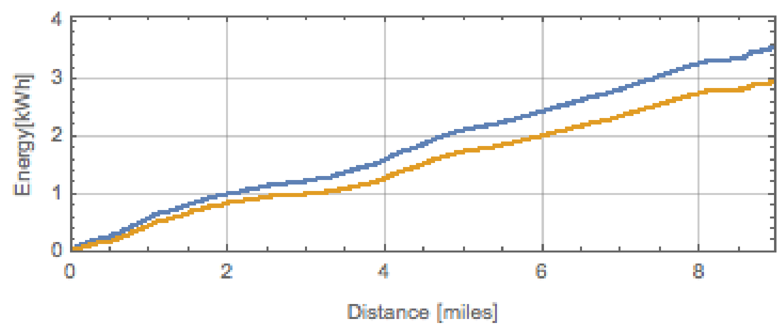


Figure 11. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Davis to Dixon

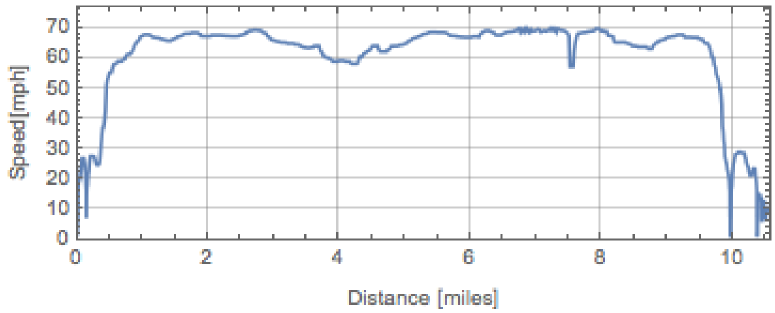


Figure 12. Representative duty cycle for a drive from Dixon to Davis

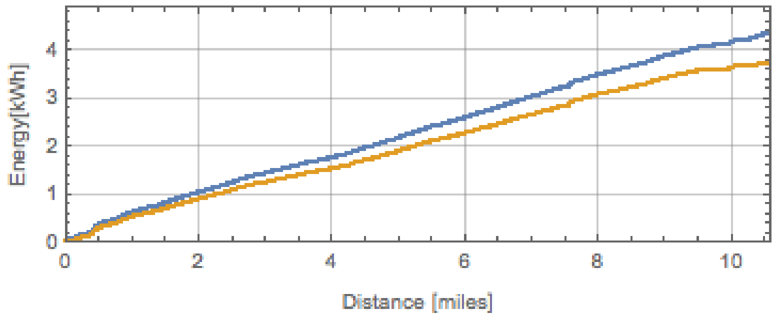


Figure 13. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Dixon to Davis

4.1.1.2. Dixon – Vacaville Link

The link connecting Dixon and Vacaville is approximately 10 miles long. Figure 15 shows a satellite image of the route on which we collected data (shown as the orange line). The topographic profile of the route between Dixon and Vacaville is shown in Figure 16. Unlike the earlier segments, we start to see more gradient in topographical elevation as we move toward Vacaville (shown in the elevation charts below). All else equal, routes with different overall grade (i.e. mostly uphill or mostly downhill) will show differences in the per-mile energy consumption. The inclines we see in this link are small however, so we expect no meaningful impact on energy consumption.

Figure 14. Charging stations near Vacaville's Historic Downtown

Vacaville has the denser network of charging stations from among the cities in Solano. Stations can be found closer to Dixon in the commercial areas around exit 55, and as far as the historic downtown.

Figure 15. Satellite image showing the GPS data of the route between Dixon and Vacaville

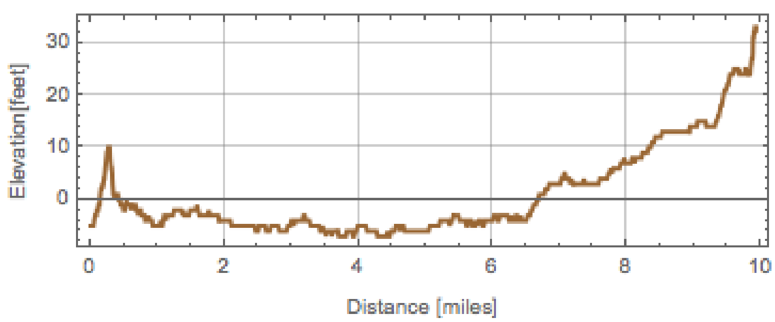


Figure 16. Topographic profile of the route between Dixon and Vacaville

The charts in Figure 17 and Figure 18 show results for travel West toward Vacaville, while the charts in Figure 19 and Figure 20 show results for travel East toward Dixon. Again, we obtain different speed profiles for the two trips. The energy connectivity of this link is about 3.9-4.2 kilowatt-hours assuming auxiliary loads operational, and average energy efficiency in the neighborhood of 0.4 kilowatt-hour per mile. This link by itself does not represent an energy challenge to electric vehicles.

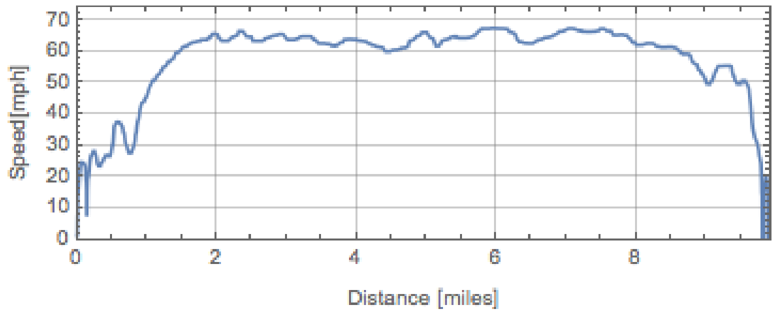


Figure 17. Representative duty cycle for a drive from Dixon to Vacaville

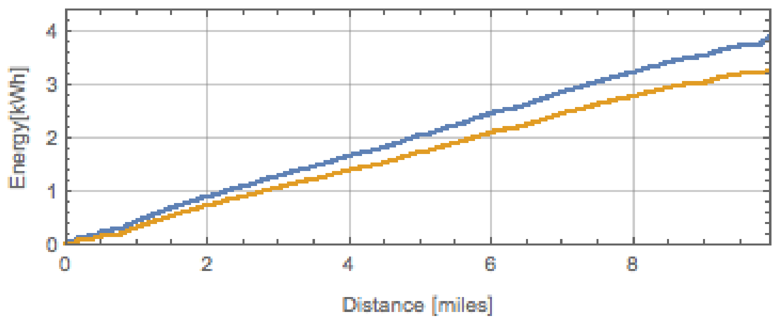


Figure 18. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Dixon to Vacaville

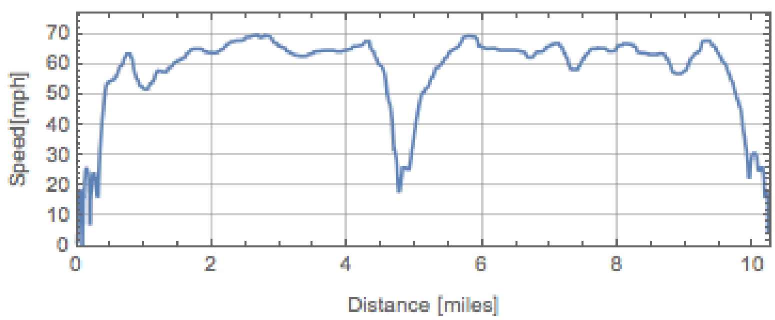


Figure 19. Representative duty cycle for a drive from Vacaville to Dixon

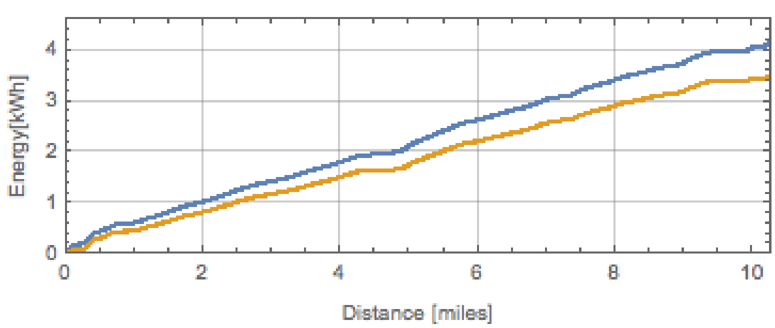


Figure 20. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Vacaville to Dixon

4.1.1.3. Vacaville – Fairfield-Suisun Link

The link connecting the cities of Vacaville and Fairfield-Suisun is approximately 13 miles long. We collected data along the route shown in Figure 22. It shows more topographical variation than earlier links (in the order of 80 feet), and while not too pronounced, they are sufficient for the energy chart below to show signs of regeneration (i.e. the battery recovers some energy from braking). Our end point in Fairfield-Suisun is the location of the charging stations at the offices of the Solano Transportation Authority (pictured). Figure 23 shows the topographic profile of the route we measured from Vacaville toward Fairfield-Suisun. The route has an overall positive gradient on the first third and an overall negative gradient on the second third. The duty cycle in Figure 24 shows that we collected data on highway conditions mixed with street conditions in Vacaville and over a relatively long stretch in Fairfield-Suisun.

Figure 21. Charging stations next to STA's offices

Figure 22. Satellite image showing the GPS data of the route between Vacaville and Suisun-Fairfield.

For the driving cycles shown in the charts, we estimate energy performances of about 0.4 miles per kilowatt-hour. As seen below, depending on the route selected, driving this link would require between 5.1 and 5.3 kilowatt-hours. Thus, this link by itself presents no challenge to electric vehicles.

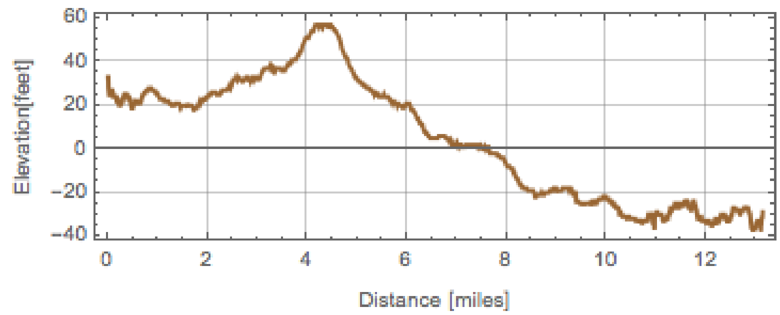


Figure 23. Topographic profile of the route between Vacaville and Suisun-Fairfield

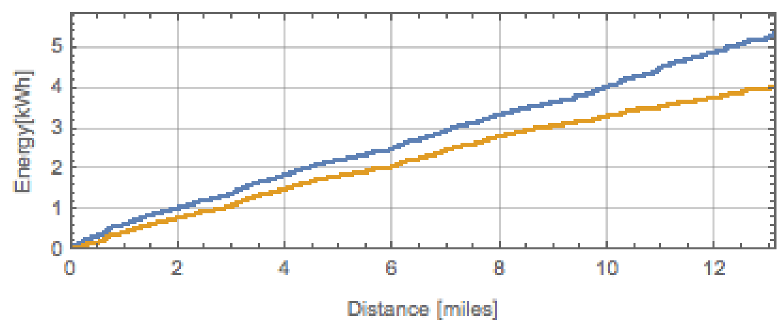


Figure 24. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Vacaville to Suisun-Fairfield

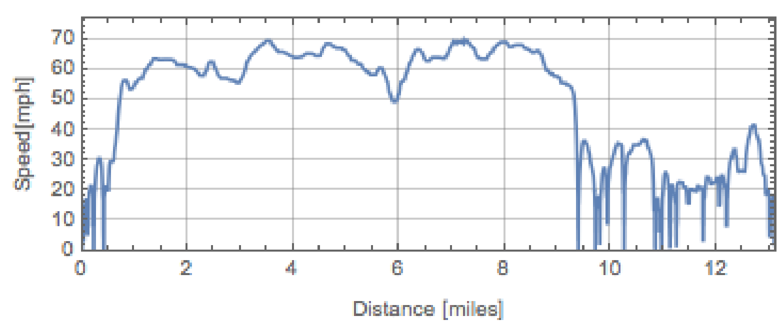


Figure 25. Representative duty cycle for a drive from Vacaville to Suisun-Fairfield

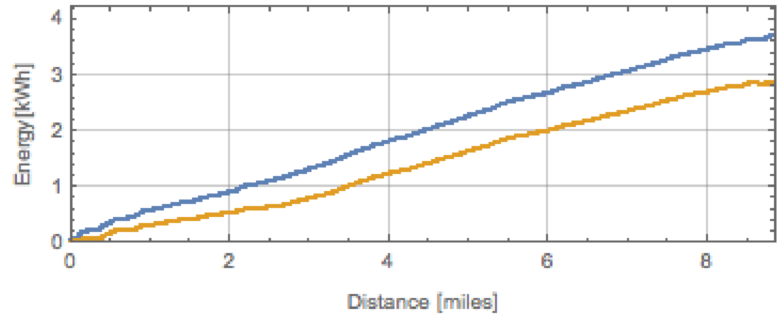


Figure 26. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Suisun-Fairfield to Vacaville

Figure 27. Representative duty cycle for a drive from Suisun-Fairfield to Vacaville

4.1.1.4. Fairfield-Suisun – Vallejo Link

Because the emphasis of the corridor analysis is on seamless EV travel and on DCFC, we started and ended data collection at positions relatively close to a freeway entrance or exit. For the case of Vallejo, having multiple exits along I-80, we ended and started data collection in the Southern section of the city, close to Cal Maritime, just before the Alfred Zampa Memorial Bridge (Figure 28). The route on which we collected data is shown in Figure 29.

We estimate the energy connectivity of this link at about 7 kilowatt-hours, which renders the energy performance at about 0.39 kilowatt-hours per mile. The elevations next to the Lynch Canyon Open Space impose additional load on the energy storage, and we did observe some opportunity for regenerative braking on the downhill sides, although these were not significant given the high prevailing speeds on those segments of the corridor.

Figure 28: Alfred Zampa Memorial Bridge

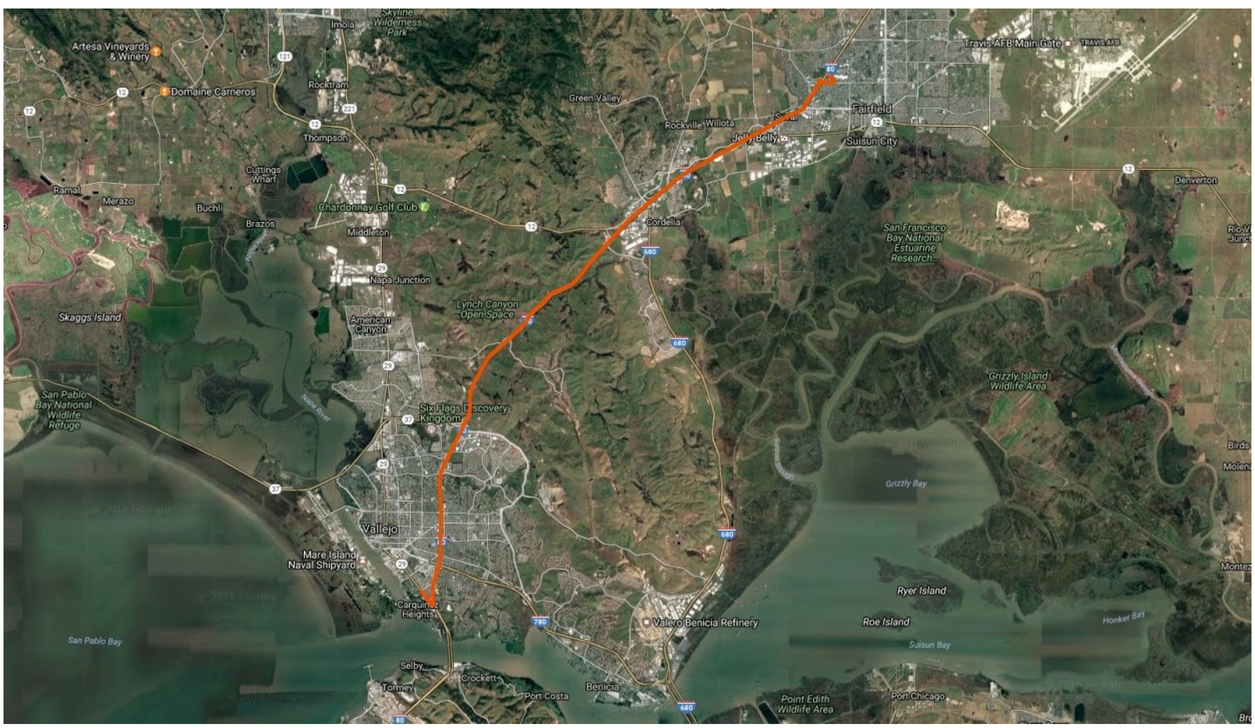


Figure 29. Satellite image showing the GPS data of the route between Fairfield-Suisun and Vallejo

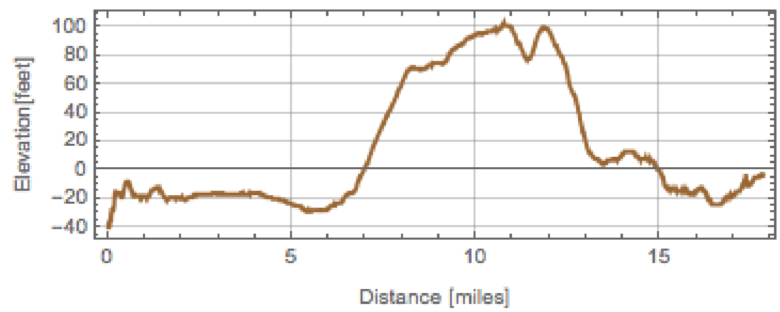


Figure 30. Topographic profile of the route between Fairfield-Suisun and Vallejo

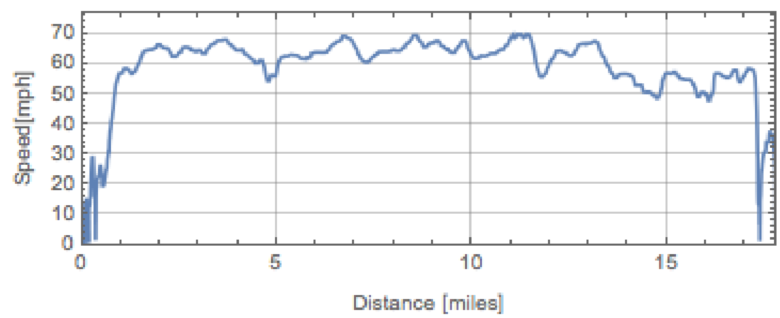


Figure 31. Representative duty cycle for a drive from Fairfield-Suisun to Vallejo

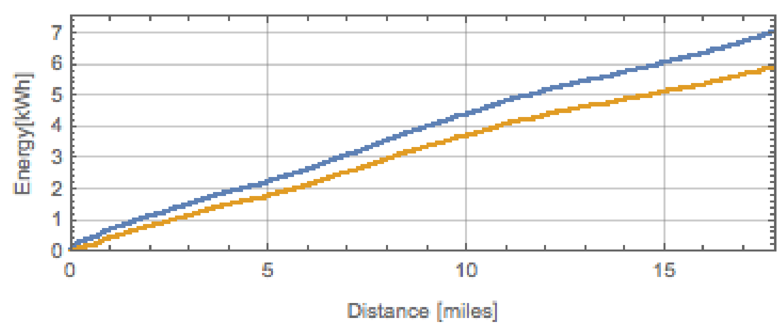


Figure 32. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Fairfield-Suisun to Vallejo

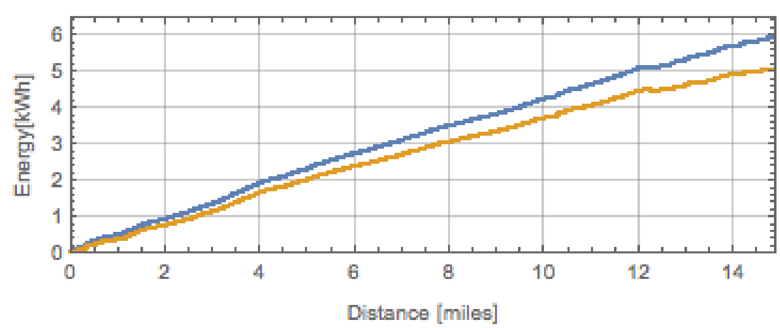


Figure 33. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Vallejo and Fairfield-Suisun

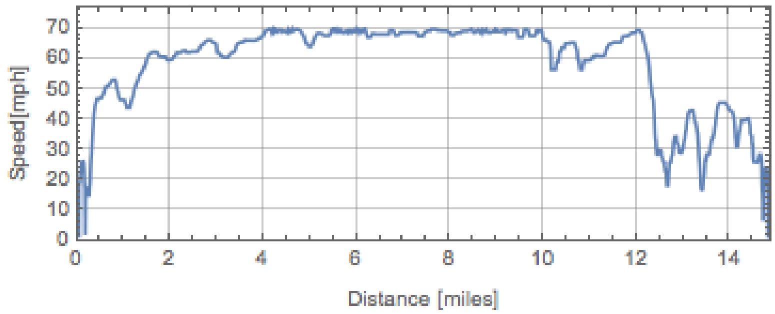


Figure 34. Representative duty cycle for a drive from Vallejo to Fairfield-Suisun

4.1.1.5. Vallejo – Benicia Link

Vallejo and Benicia are neighboring cities separated by only about seven miles. Both are gateway cities and are on routes entering and exiting the county. Interstate 80 crosses Vallejo and connects to the East Bay and San Francisco, 32 miles to the west. Benicia is located next to Interstate 680 and connects Solano with the East Bay and the city of San Jose, 63 miles to the south. Figure 35 shows the topographic profile along the route that we measured.

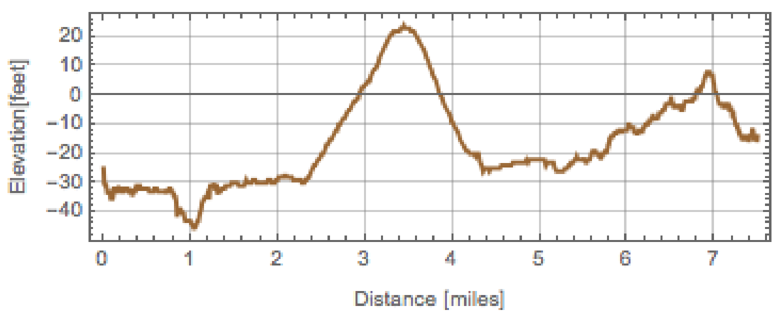


Figure 35. Topographic profile of the route between Vallejo and Benicia

Figure 36 shows the duty cycle (driving conditions) measured on this route. The duty cycle shows a number of areas with pronounced deceleration, and this gives opportunity to observe how these events result in regeneration (Figure 37). The directional energy connectivity of this link is estimated at about 3 kilowatt-hours, rendering the energy performance at about 0.4 kilowatt-hours per mile.

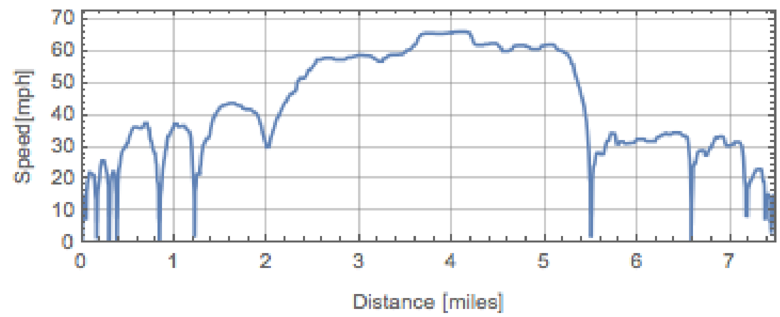


Figure 36. Representative duty cycle for a drive from Vallejo to Benicia

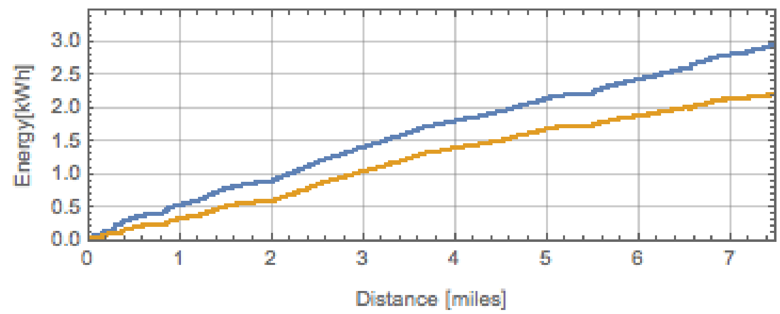


Figure 37. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Vallejo to Benicia

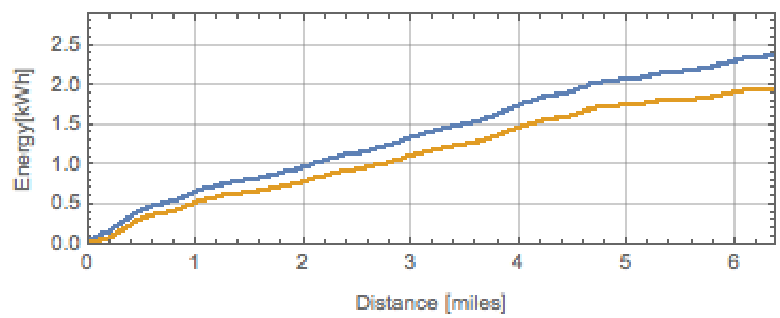


Figure 38. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Benicia to Vallejo

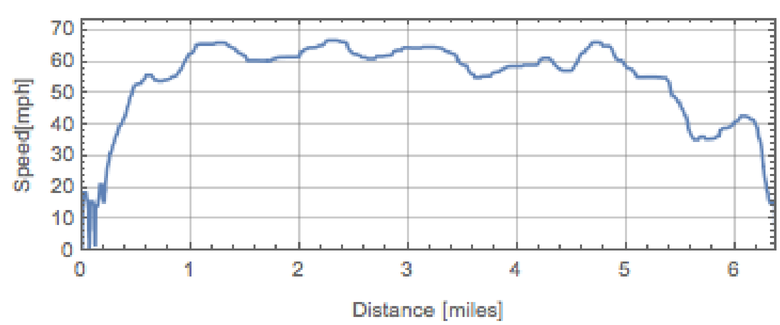


Figure 39. Representative duty cycle for a drive from Benicia to Vallejo

4.1.1.6. Benicia – Fairfield-Suisun Link

The link connecting Fairfield-Suisun and Benicia expands over about 20 miles on I-80, I-680, and I-780 (Figure 40). As discussed above, Benicia serves as a county gateway to localities in the southeastern Bay, including San Jose. In this sense, Benicia would be a natural place to install DCFC infrastructure that serves electric vehicles driving along the I-680 corridor into and out of the county. To this end, the charging site would be located at a safe site near an exit from the interstate and next to amenities.

The chart in Figure 41 shows the topographical elevation along the Fairfield-Benicia route. Figure 42 shows representative duty cycles and estimated vehicle energy consumptions on this link. Because of the influence of gravity, a vehicle consumes less energy traveling from Fairfield to Benicia than in the opposite direction. We estimate a difference in the neighborhood of one kilowatt-hour in the energy consumed in each direction. A number of factors affects these differences, but in this particular case, it is fair to conclude that topographical elevation plays a tangible role. For the more energy intensive direction, Benicia to Fairfield, we estimate the energy connectivity of this link at about 9 kilowatt-hours, averaging about 0.41 kilowatt-hours per mile. Thus, on an energy basis, this link presents by itself no challenge to EV travel.

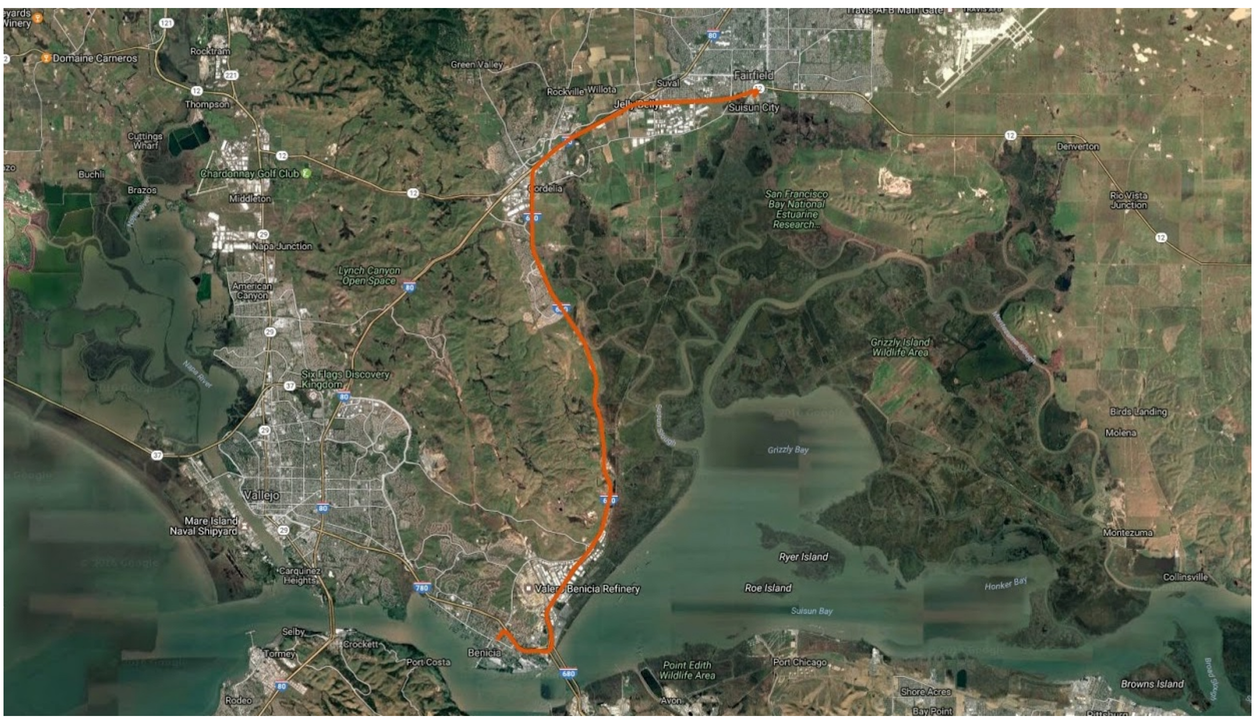


Figure 40. Satellite image showing the GPS data of the route between Benicia and Fairfield

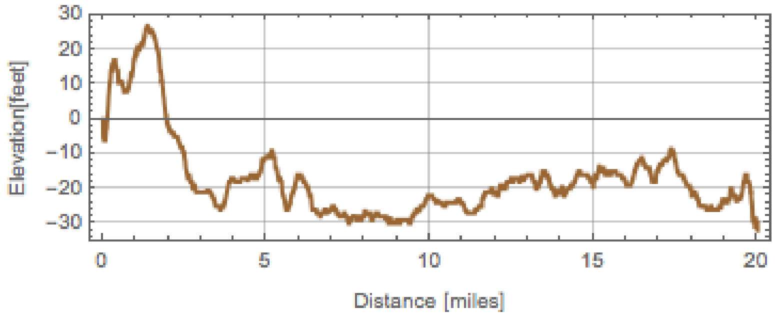


Figure 41. Topographic profile of the route between Benicia and Fairfield-Suisun

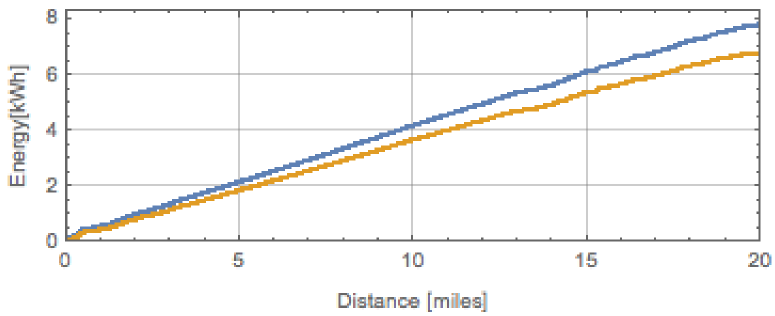


Figure 42. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Benicia to Fairfield-Suisun

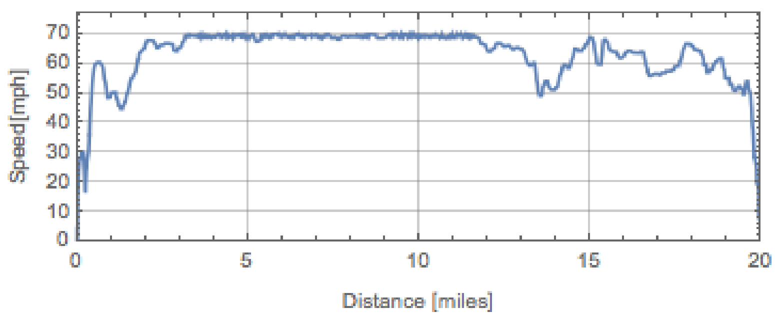


Figure 43. Representative duty cycle for a drive from Benicia to Fairfield-Suisun

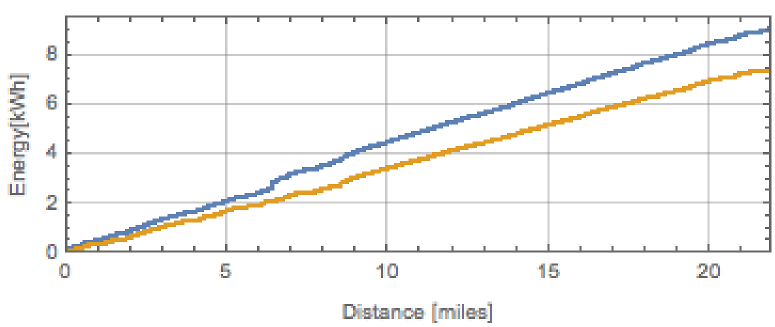


Figure 44. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Fairfield-Suisun to Benicia

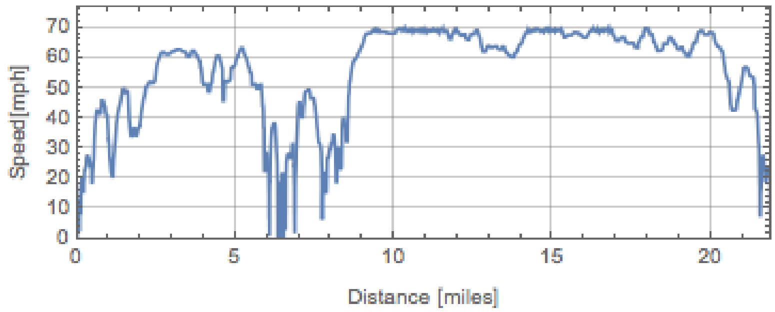


Figure 42. Representative duty cycle for a drive from Fairfield-Suisun to Benicia

There is a DCFC station at the Benicia City Hall (Figure 45), half a mile from I-780. This station is not very visible as it is located in the parking space behind the City Hall with no clear signage around. It is, however, an excellent location to support EV travel by government fleets or other potential longer-distance drivers coming to the City Hall. An alternative host site in the same area could be the Solano Square Shopping Center at the corner of East 2nd St. and Military East.

Figure 45. DCFC station in the parking lot of Benicia's City Hall

4.1.1.7. Rio Vista – Davis Link

The link connecting Rio Vista and Davis has a length of approximately 35 miles over a route including CA-12, CA-113, and Interstate 80. The route on which we collected GPS data is shown in Figure 46. Figure 47 shows the topographic profile of the route we measured, while Figure 49 and Figure 51 show the duty cycles in each direction. The energy charts in Figure 48 and Figure 50 illustratively show the steeper rates of energy consumption when the vehicle is cruising at higher speeds on I-80. We estimate the directional energy connectivity of this link on each direction at 12.3 and 14.2 kilowatt-hours, giving an average energy performance on this link of about 0.38 kilowatt-hours per mile.

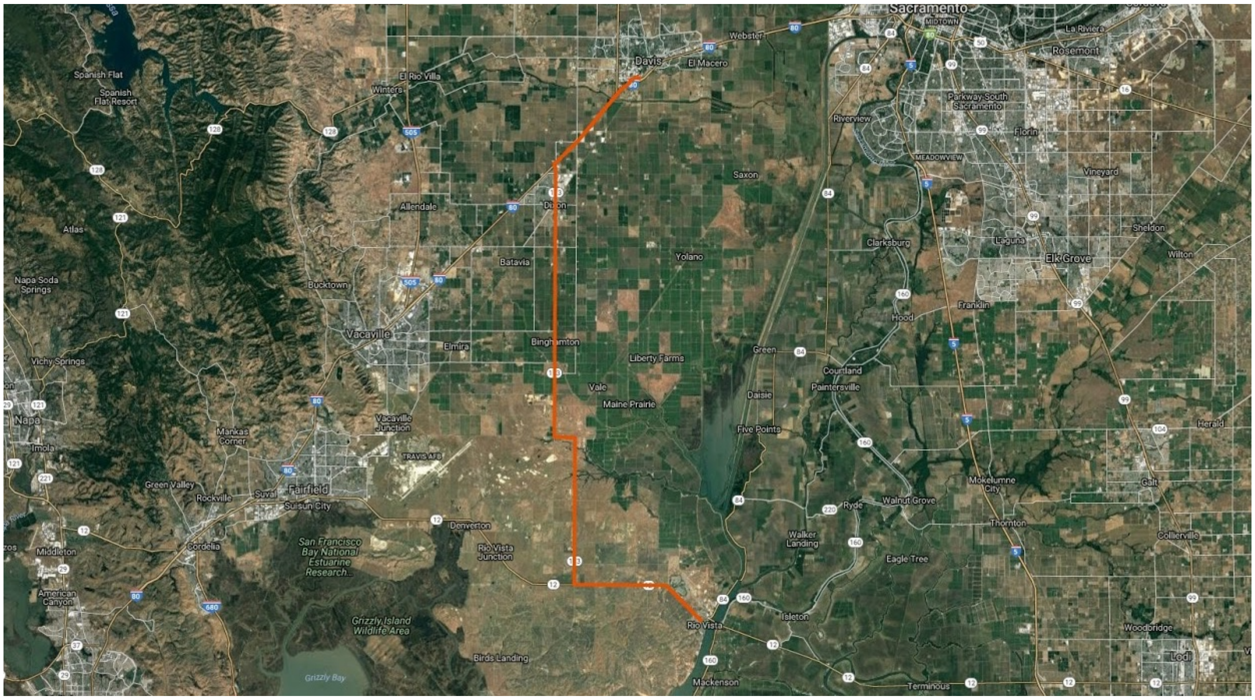


Figure 46. Satellite image showing the GPS data of the route between Rio Vista and Davis.

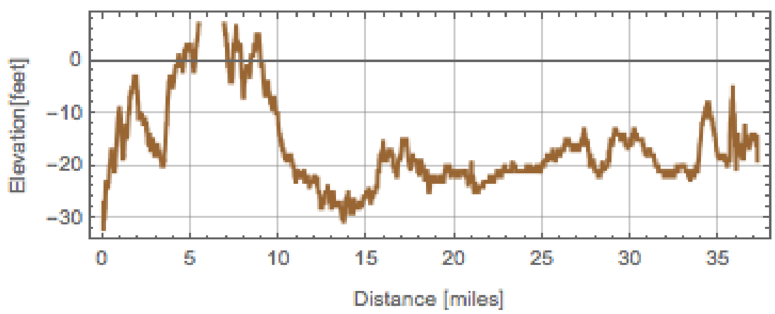


Figure 47. Topographic profile of the route between Rio Vista and Davis

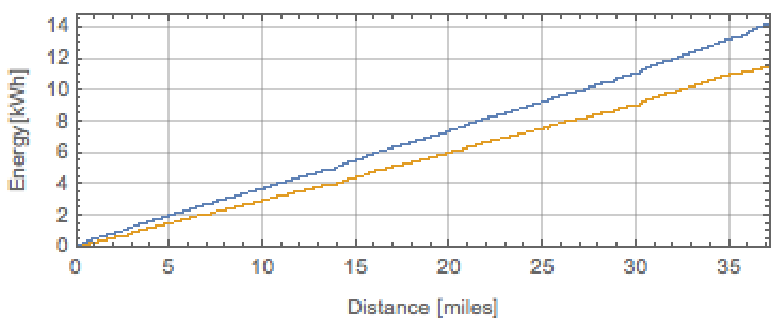


Figure 48. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Rio Vista to Davis

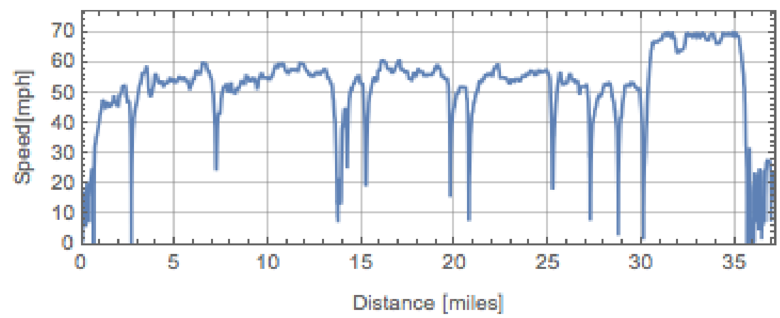


Figure 49. Representative duty cycle for a drive from Rio Vista to Davis

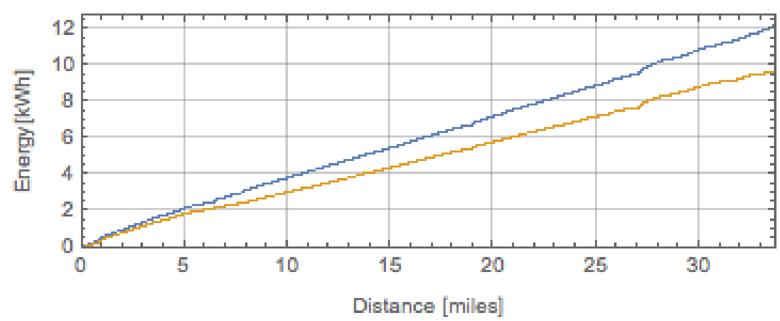


Figure 50. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Davis to Rio Vista

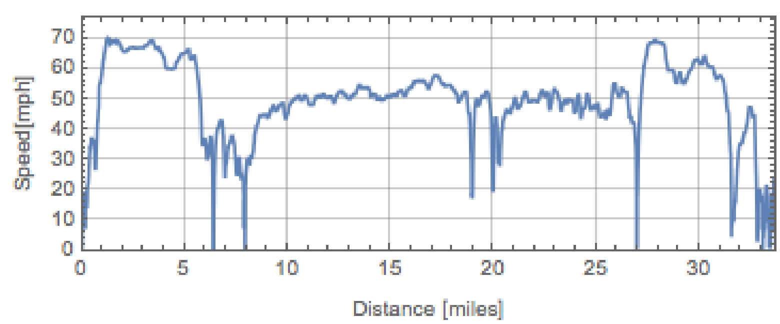


Figure 51. Representative duty cycle for a drive from Davis to Rio Vista

4.1.1.8. Fairfield-Suisun – Rio Vista Link

The link connecting Fairfield-Suisun with Rio Vista on the southern end of the county is about 20 miles long. The route on which we collected GPS data is shown in Figure 52. Most of the route is on CA-12, not an interstate which reflects lower cruise speeds shown in the duty cycle charts in Figure 55 and Figure 57. The directional energy connectivity of this link is estimated at 6.8 and 7.8 kilowatt-hours. The average energy performance we estimate is around 0.35 kilowatt-hours per mile, with auxiliary loads always on.

Figure 50. Chevy Volt parked on Main Street, Rio Vista

Figure 52. Satellite image showing the GPS data of the route between Rio Vista and Fairfield-Suisun

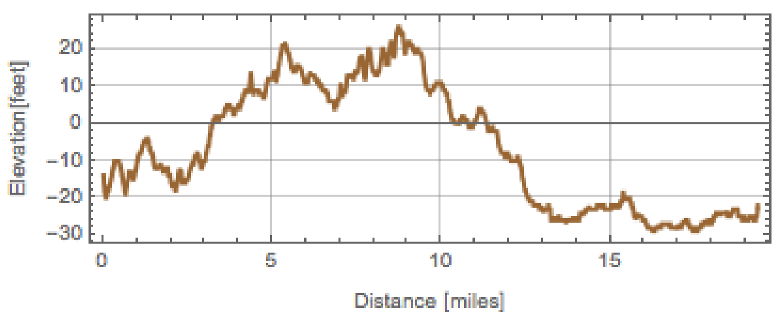


Figure 53. Topographic profile of the route between Rio Vista and Fairfield-Suisun

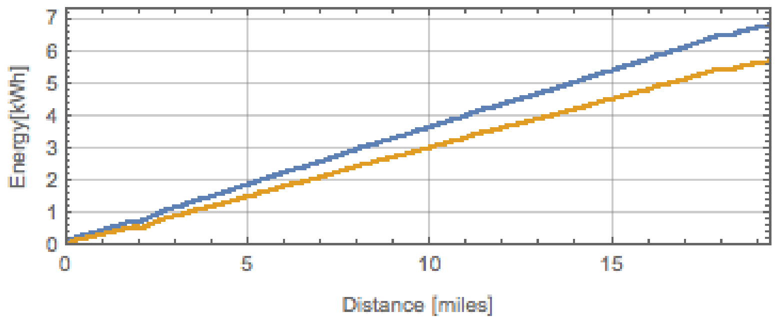


Figure 54. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Rio Vista to Fairfield-Suisun

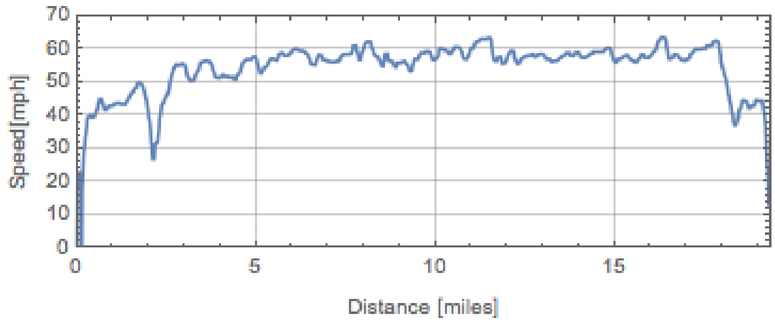


Figure 55. Representative duty cycle for a drive from Rio Vista to Fairfield-Suisun

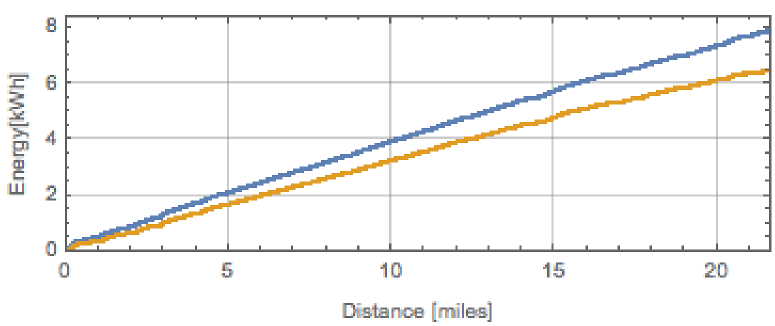


Figure 56. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Fairfield-Suisun to Rio Vista

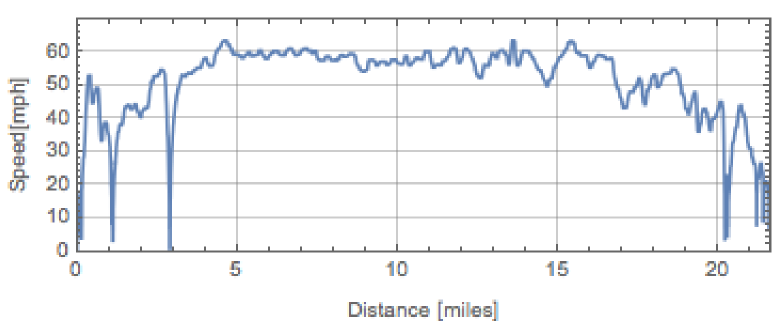


Figure 57. Representative duty cycle for a drive from Fairfield-Suisun to Rio Vista

4.1.1.9. Fairfield-Suisun – Napa Link

Napa is a popular regional recreational destination. We analyzed a segment between Suisun-Fairfield and Napa to assess the recharging needs of electric vehicles visiting from or via Solano. We collected GPS along a route of about 20 miles, shown in Figure 58. We collected these data on a weekend, which we expect to be reflective of the conditions seen on recreational trips along this corridor.

Figure 58. Satellite image showing the GPS data of the route between Fairfield and Napa

The topography chart in Figure 60 suggests that road grade made a meaningful impact on energy use along this corridor, although not as significant as along the Fairfield-Vallejo link. The duty cycle charts in Figure 62 and 64 show that highway driving conditions were mixed with slow-down and stop points at various road intersections. As shown in Figure 61 and Figure 63, assuming the auxiliary loads are on, the directional energy connectivity of the link between Napa and Fairfield is estimated at about 8 to 8.5 kilowatt-hour, with an average vehicle efficiency in the order of 0.4 kilowatt-hours per mile.

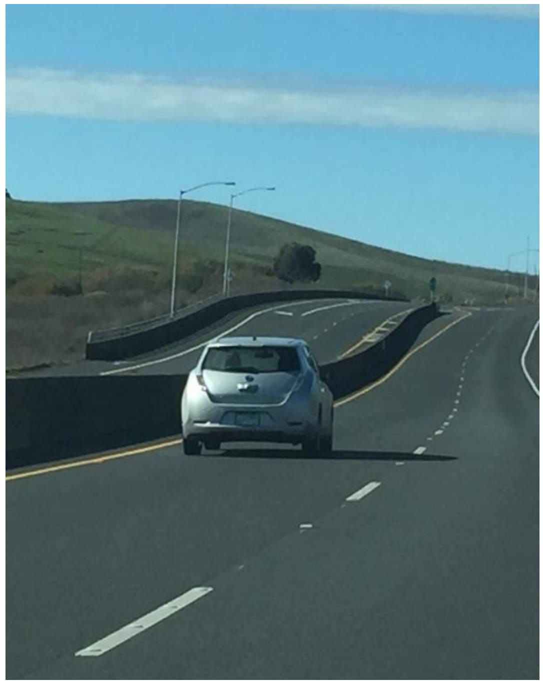


Figure 59: Nissan LEAF driving towards Napa

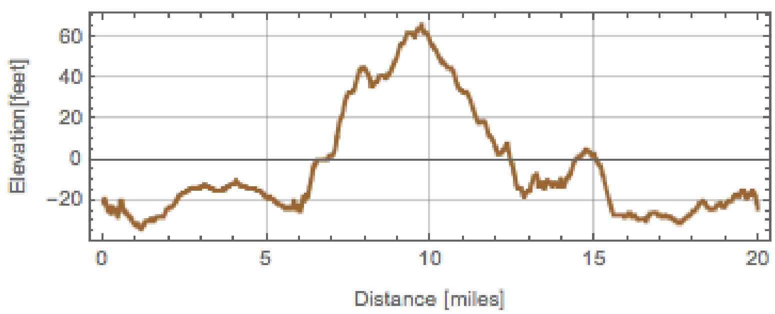


Figure 60. Topographic profile of the route between Fairfield-Suisun and Napa

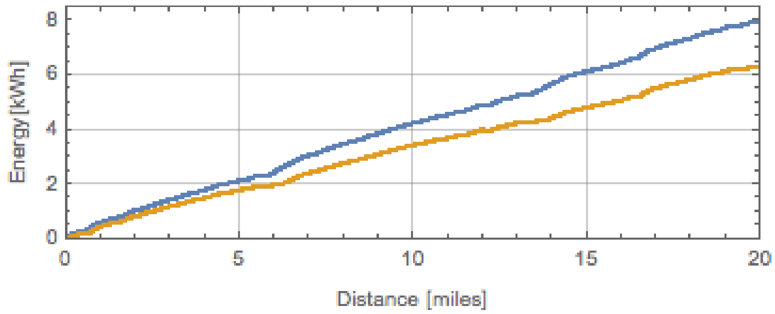


Figure 61. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Fairfield-Suisun to Napa

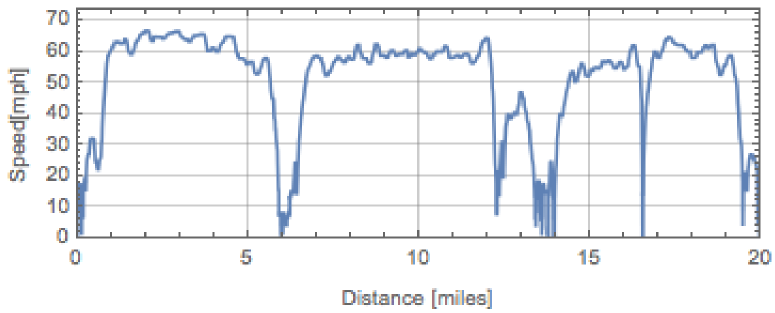


Figure 62. Representative duty cycle for a drive from Fairfield-Suisun to Napa

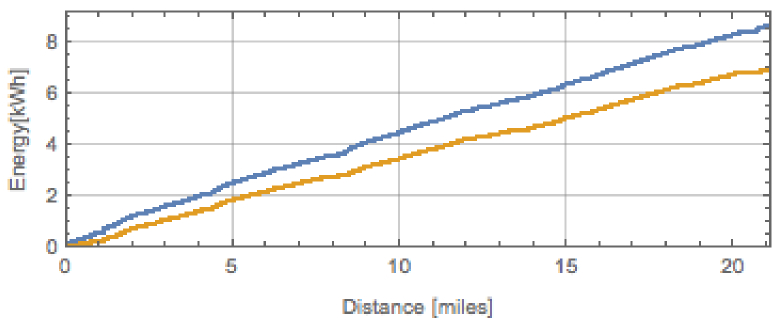


Figure 63. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Napa to Fairfield-Suisun

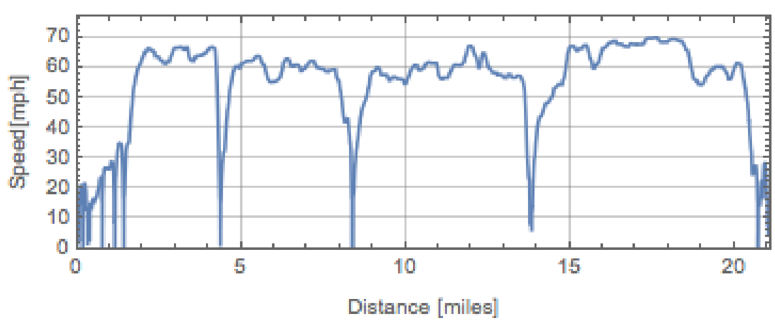


Figure 64. Representative duty cycle for a drive from Napa to Suisun-Fairfield

4.1.1.10. Vacaville – Winters Link

Figure 65 shows a satellite image of the GPS data that we collected on the link connecting Vacaville with Winters. We added this link to the analysis as an example of a trip connecting Solano with a travel attraction in Yolo County, and on route to other locations in Northern California. Most of the route lays on I-505. The energy connectivity of this link was estimated at about 5.3 kilowatt-hours.

Figure 65. Satellite image showing the GPS data of the route between Vacaville and Winters

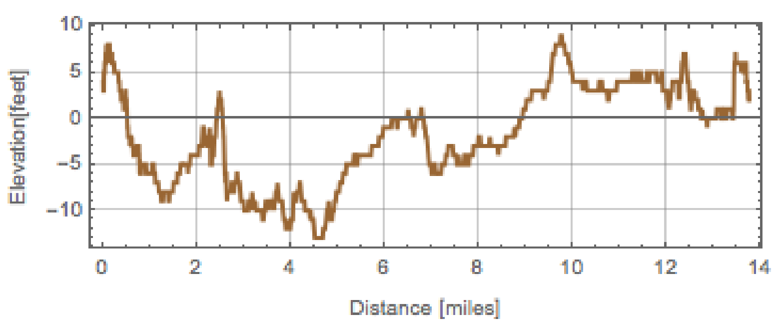


Figure 66. Topographic profile of the route between Vacaville and Winters

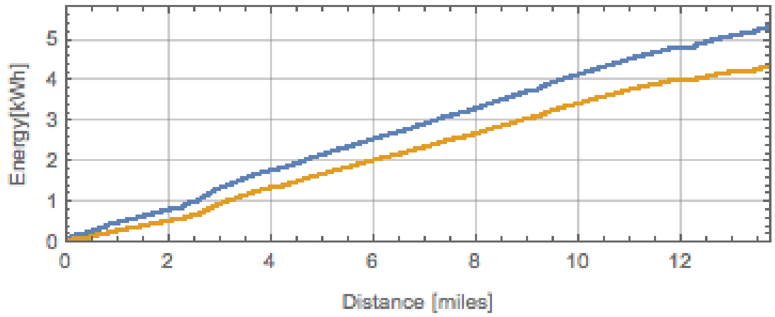


Figure 67. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Vacaville to Winters

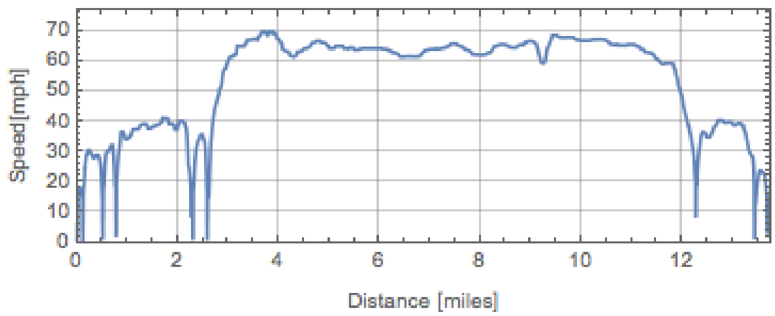


Figure 68. Representative duty cycle for a drive from Vacaville to Winters

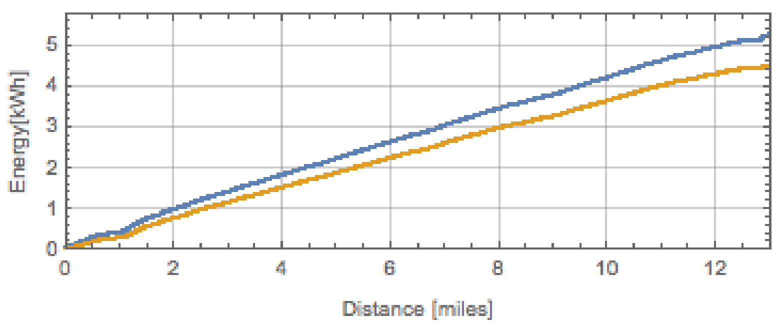


Figure 69. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Winters to Vacaville

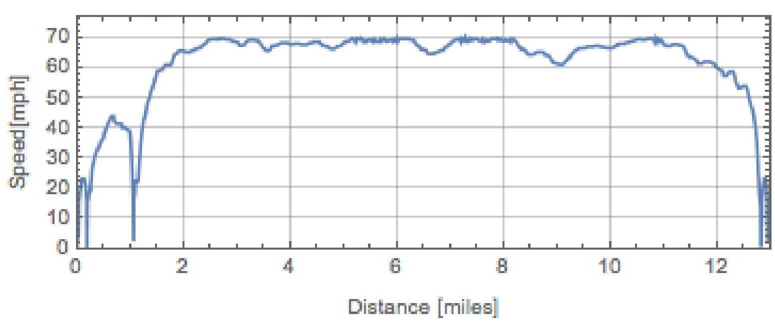


Figure 70. Representative duty cycle for a drive from Winters to Vacaville.

4.1.1.11. Fairfield – Lake Berryessa Link

Located in Northern Central California, Lake Berryessa is, like Napa a popular recreational destination. It is included in the analysis as another case of destinations outside of Solano. Figure 71 shows the stretch of approximately 15 miles along which GPS data collected, from Fairfield to the vicinity of the intersection between Wooden Valley Rd and CA-121.[14] While the topography is more challenging than in other links for energy efficiency, prevalent duty cycles are characterized by lower average speeds. The result is that the estimated energy connectivity for the uphill link is 6 kilowatt-hours, averaging 0.4 kilowatt-hour per mile.

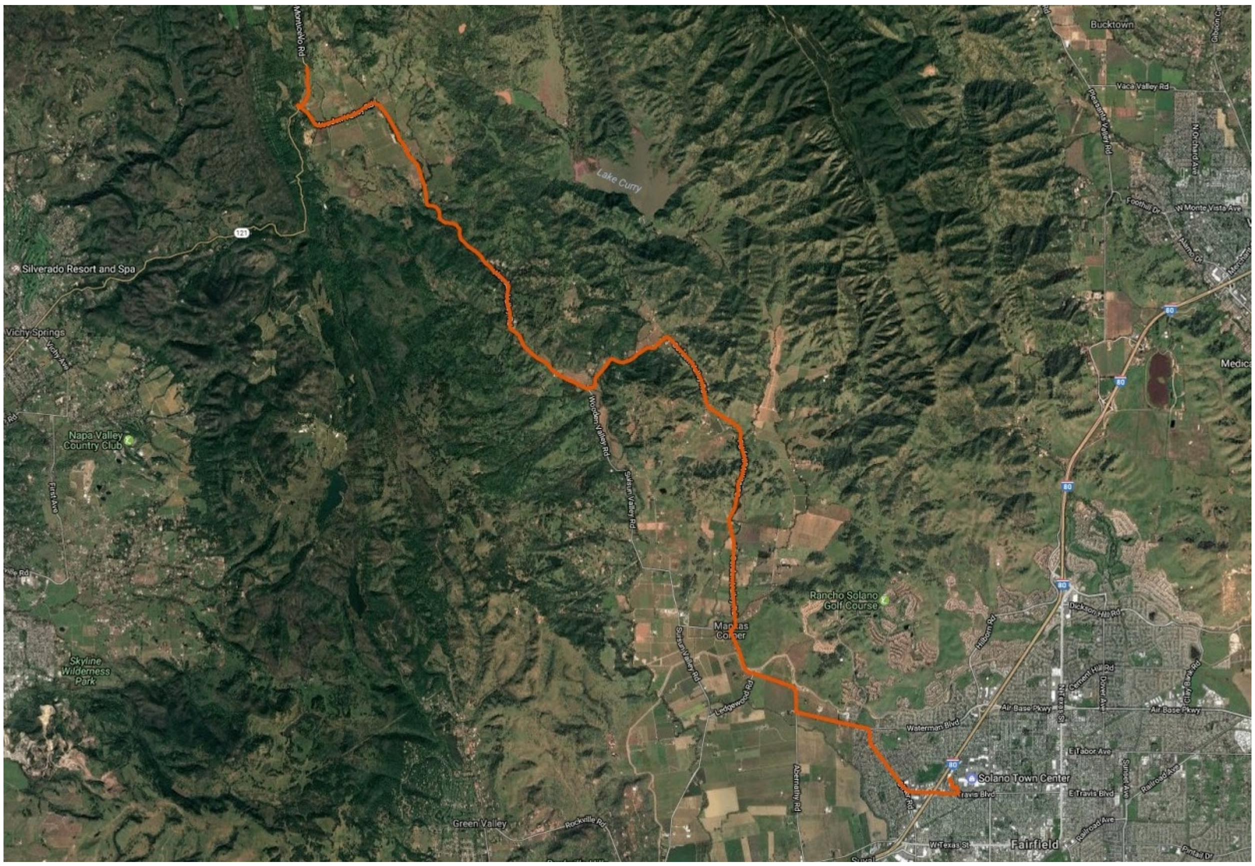


Figure 71. Satellite image showing the GPS data of the route from Fairfield-Suisun toward Lake Berryessa

[14] Lake Berryessa is located approximately 37 miles from Fairfield.

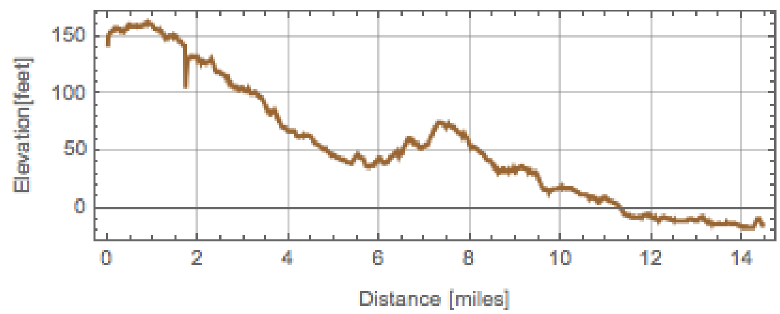


Figure 72. Topographic profile of the route from Fairfield-Suisun toward Lake Berryessa

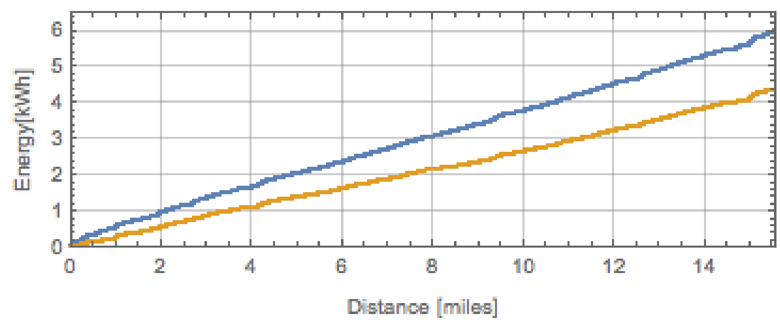


Figure 73. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Fairfield-Suisun toward Lake Berryessa

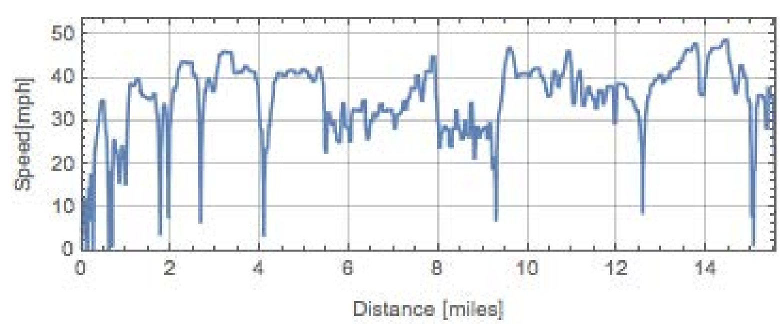


Figure 74. Representative duty cycle for a drive from Fairfield-Suisun toward Lake Berryessa

4.1.1.12. Davis – Sacramento Link

The link connecting Davis and the state's capital, Sacramento, lays entirely outside of Solano County. We include it in the modeling as another example of inter-county travel, to account for important destinations for Solano residents. Two possible highway routes can be used to travel between Davis and Sacramento: a) I-80 and b) H-113 connecting with I-5 in Woodland. For our analysis, we used the former.

Figure 75. Satellite image showing the GPS data of the route between Davis and Sacramento

The routes in each direction have slightly different lengths and driving cycles, but both gave energy connectivity of about 6.3 kilowatt-hours, giving average efficiencies in the order of 0.38 kilowatt-hour per mile. The relatively flat terrain between these nodes helps maintain steady driving conditions and avoids significant gravity losses. This may be a good moment to remember that highway speeds are demanding for vehicle energy efficiency, as kinetic energy is proportional to the square of speed. This means that cruising at 60 miles per hour uses *four* times more energy than driving at 30 miles per hour.

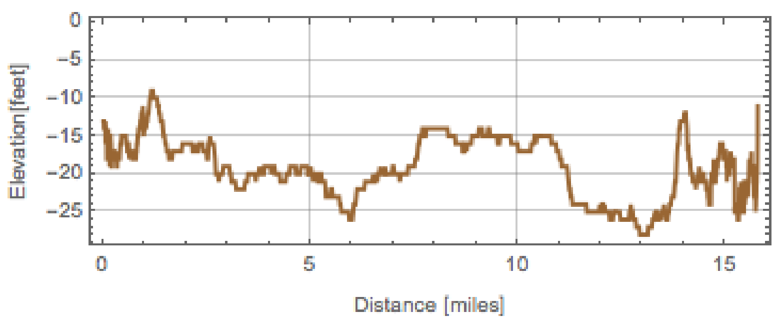


Figure 76. Topographic profile of the route between Davis and Sacramento

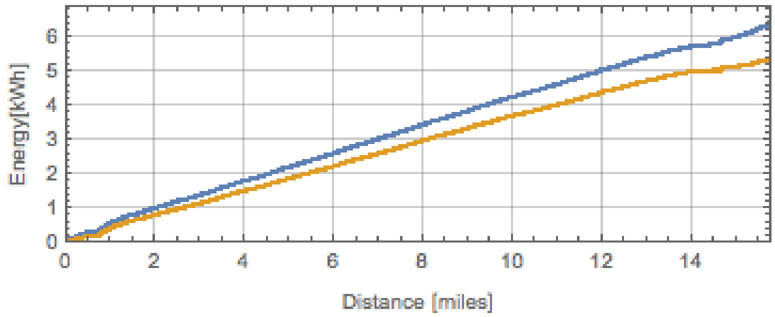


Figure 77. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Davis to Sacramento

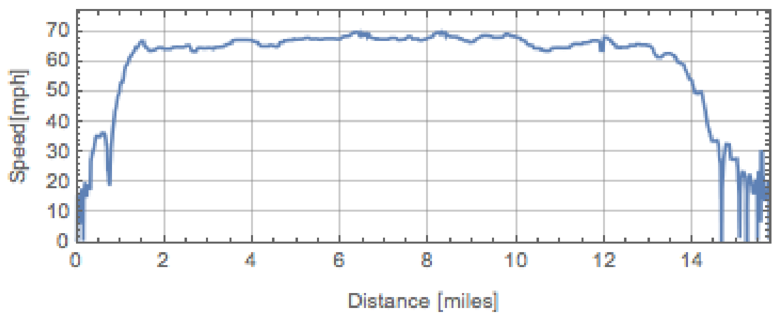


Figure 78. Representative duty cycle for a drive from Davis to Sacramento

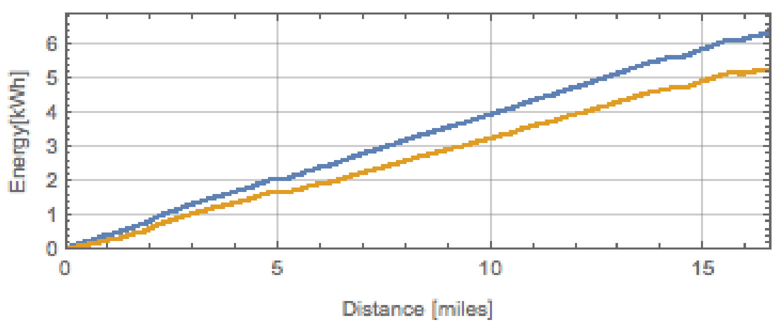


Figure 79. Estimated EV energy consumption with auxiliary loads on (upper curve) and off (lower curve) for the duty cycle from Sacramento to Davis

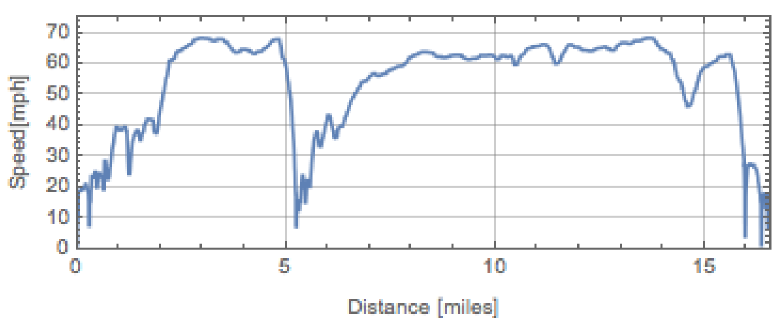


Figure 80. Representative duty cycle for a drive from Sacramento to Davis

4.1.2. Network Analysis

We collect the results for the individual links and assemble a regional network, in which the nodes are represented by the locations and the links by the corridor connecting each pair of locations. This network is represented as a graph in Figure 81. The graph is a visual representation of the network that was used for the mathematical analysis, so it should not be interpreted as a geographical network like what could be seen on a map. The lengths of the links are representative of the closeness between two given nodes (locations).

Figure 81. Graph representation of the regional network that was analyzed

The matrix in Table 4 shows the energy connectivity between each pair of locations in the network, as resulting from our modeling and described in the preceding section. The matrix is not symmetrical because, as described above, the energy connectivity of two locations can change depending on the direction of the trip between them. The matrix can be read in the following way: Each cell indicates the energy that a representative EV would consume when traveling between the location indicated in that row (leftmost column) and the location indicated in that column (uppermost row). For example, the matrix shows that the energy that an EV needs to travel from Vacaville and Vallejo, on a representative duty cycle, is estimated at 12.4 kilowatt-hours.

The network diameter is 28.2. The diameter of a network is defined as the maximum distance between any pair of nodes in the network, and in our particular case it indicates the maximum amount of energy needed for an EV to drive from any pair of locations in the network. From Table 4, it can be seen that the highest cell is the drive from Sacramento to Benicia, at 28.2 kilowatt-hours. If only routes entirely within Solano are considered, then the lowest energy connectivity is for Vallejo-Davis and Davis-Benicia. Finally, considering only locations within Solano, the lowest energy connectivity corresponds to the link between Dixon and Benicia.

Table 4. Matrix of required energy (in kilowatt-hours) to complete a trip between each of the locations in the regional network

	Sacramento	Davis	Dixon	Vacaville	Fairfield	Vallejo	Benicia	Rio Vista	Winters	Lake Berryessa	Napa
Sacramento	0	6.3	10	13.9	19.2	26.3	28.2	18.6	19.2	25.2	27.2
Davis	6.3	0	3.7	7.6	12.9	20	21.9	12.3	12.9	18.9	20.9
Dixon	9.9	3.6	0	3.9	9.2	16.3	18.2	15.9	9.2	15.2	17.2
Vacaville	14.1	7.8	4.2	0	5.3	12.4	14.3	13.1	5.3	11.3	13.3
Fairfield	19.2	12.9	9.3	5.1	0	7.1	9	7.8	10.4	6	8
Vallejo	26.4	20.1	16.5	12.3	7.2	0	3	15	17.6	13.2	15.2
Benicia	27	20.7	17.1	12.9	7.8	2.4	0	15.6	18.2	13.8	15.8
Rio Vista	20.5	14.2	16.1	11.9	6.8	13.9	15.8	0	17.2	12.8	14.8
Winters	19.4	13.1	9.5	5.3	0	17.7	19.6	18.4	0	16.6	18.6
Lake Berryessa	24.1	17.8	14.2	10	4.9	12	13.9	12.7	15.3	0	12.9
Napa	27.8	21.5	17.9	13.7	8.6	15.7	17.6	16.4	19	14.6	0

Another important metric of the nodes forming a network is their *degree centrality*, which is defined as the number of links they have with other nodes.[15] In the network that we analyzed, the location with the highest degree centrality is Fairfield-Suisun, which is connected directly with other six locations (Vacaville, Rio Vista, Vallejo, Benicia, Napa, and Lake Berryessa). Another important metric is the *closeness centrality*, which measures the mean distance from any given node to the other nodes. In our case, this translates as the mean energy connectivity between a particular location and the rest of the locations in the network. Again, the location with the highest closeness centrality is Fairfield-Suisun. The final metric that we consider is *betweenness centrality*, which measures the extent to which a particular node is in the path connecting other nodes.[16] On all these metrics, Fairfield-Suisun stands as the most important node in the network, from a transportation energy standpoint.

On analyzing the regional corridor network to identify opportunities for DCFC deployment, it is important to realize that the boundaries of the network are somewhat arbitrary and that it is embedded in the context of a broader region, which could be defined as Northern California. This means that a DCFC deployment strategy has two facets: a) to serve Solano residents and Solano visitors and b) to serve a broader universe of trips that go through Solano but may not begin or end within the limits of the network considered herewith.

In many cases, regional trips can be served with Level 2 charging infrastructure at trip destinations. In Table 5 we include the approximate times (in minutes) that it would take EV drivers to charge at the end of each of the links in our network, to be able to complete the round trip. Clearly, these times will depend on technical factors such as the onboard charger and the size of the onboard energy storage. For the purpose of generating approximate values, we assumed an onboard charger of 6.6 kilowatt and an onboard energy storage of 20 kilowatt-hours. The cells with the text "DCFC" indicate links for which on-route charging would be needed.

Table 5 provides additional information to highlight Suisun-Fairfield as a hub for EV charging infrastructure. The deployment of DCFC infrastructure in this area would support EV travel simultaneously on the Vallejo-Davis-Sacramento and Benicia-Davis-Sacramento corridors. Table 5 also gives a taste of the role that Suisun-Fairfield can play as a regional charging hub supporting EV trips between end points *outside* of Solano. As shown, such could be the case for trips between Sacramento-Davis and Napa, or Sacramento-Davis and Lake Berryessa.

ICF also evaluated opportunities for County *gateway* infrastructure. While Benicia and Vallejo are on the edge of the network that was analyzed here, it is easy to imagine the role they could play as charging hubs supporting EV trips into or out of Solano connecting with localities in the East Bay. A similar reasoning can be applied to Rio Vista with respect to localities in the Central Valley.

[15] There are more technical ways to define centrality, for example distinguishing from in-degree and out-degree. The definition included in the report suffices for the purpose of describing our results.

[16] More specifically, betweenness centrality is a global centrality measure that is representative of the number of *shortest paths* that pass through a given node.

Table 5. Matrix of approximate charging times (in minutes) needed to complete two-way trips using Level 2 infrastructure, and links that need DCFC to be completed

	Sacramento	Davis	Dixon	Vacaville	Fairfield	Vallejo	Benicia	Rio Vista	Winters	Lake Berryessa	Napa
Sacramento	0	0	0	59	139	DCFC	DCFC	130	139	DCFC	DCFC
Davis	0	0	0	0	44	152	DCFC	35	44	135	DCFC
Dixon	0	0	0	0	0	95	124	89	0	79	109
Vacaville	62	0	0	0	0	36	65	47	0	20	50
Fairfield	139	44	0	0	0	0	0	0	6	0	0
Vallejo	DCFC	DCFC	98	35	0	0	0	76	115	48	79
Benicia	DCFC	DCFC	108	44	0	0	0	85	124	58	88
Rio Vista	DCFC	64	92	29	0	59	88	0	109	42	73
Winters	142	47	0	0	0	117	145	127	0	100	130
Lake Berryessa	DCFC	118	64	0	0	30	59	41	80	0	44
Napa	DCFC	DCFC	120	56	0	86	115	97	136	70	0

ICF visited these areas a number of times, to evaluate prospective locations for DCFC charging infrastructure. Emphasis was placed on locations that met the following criteria:

- Within half a mile of a highway exit;
- Abundant parking space;
- Within walking distance of amenities such as restaurants, coffee places, or other commercial areas;
- Nearby amenities were open to the public during extended hours;
- Have access to three-phase power; and
- Are visible to the general public.

With these criteria in mind, we identified the prospective DCFC host areas shown in the next four images. Figure 82 shows a satellite image of downtown Benicia, demarcating the area of the Solano Square Shopping Center, which is within easy access from I-780.

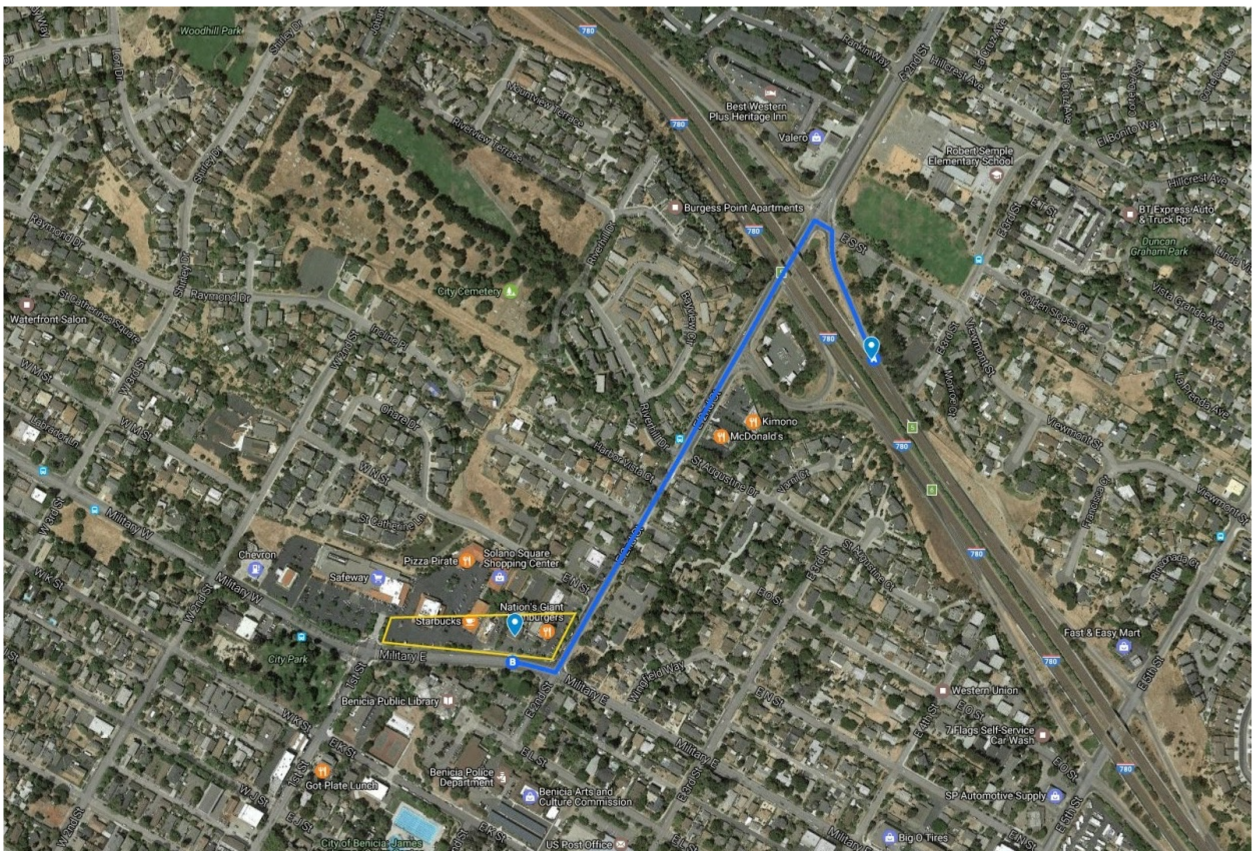


Figure 82. Suggested DCFC charging area in Benicia

Figure 83 is a satellite image showing three prospective areas with easy access from I-80 and off Travis Boulevard. The three areas are specifically:

- East of I-80, a parking area in front of two hotels and a restaurant, and further East a central section of the parking lot to the Solano Town Center shopping mall, and

- West of I-80, a parking lot in front of restaurants and a coffee place, and across the street from the Woodcreek Plaza Shopping Center.

Figure 83. Suggested DCFC charging areas in Fairfield

Figure 84 is a satellite image showing two prospective DCFC infrastructure host site in the Gateway Plaza, located in the northern edge of Vallejo. This large commercial area is adjacent to and immediately accessible from I-80. It counts with innumerable suitable destinations, and it includes some auto dealerships, which could open opportunities for partnerships on DCFC deployments. This area could be a gateway DCFC infrastructure hub, supporting EV trips to and from the San Francisco Bay and East Bay.

Figure 84: Suggested DCFC charging areas in Vallejo

The satellite image in Figure 85 shows two prospective DCFC deployment areas in Rio Vista. The area to the North encompasses a commercial segment of CA-12 right before (or right after) the Rio Vista Bridge over the Sacramento River on the edge of Solano County. There is no single obvious prospective host site in the area, although there are sites owned by auto dealers and by Pacific Gas & Electric, which could open opportunities for partnerships to install DCFC infrastructure. The area to the South is a short commercial corridor along Main Street, in downtown Rio Vista. There is no obvious single prospective host site in this area either, although the presence of the Rio Vista City Public Works offices suggests opportunities for partnerships with the City. This commercial street offers street diagonal parking, and the design of these spaces suggested to us opportunities to explore the possibility of an installation in the right of way, with significant public exposure.

One additional area near Rio Vista that we consider interesting is the wind farm in Montezuma Hills. We were not able to identify suitable sites that are ready to host EV drivers, but the direct integration of DCFC infrastructure with renewable energy could be the premise for a future site development.

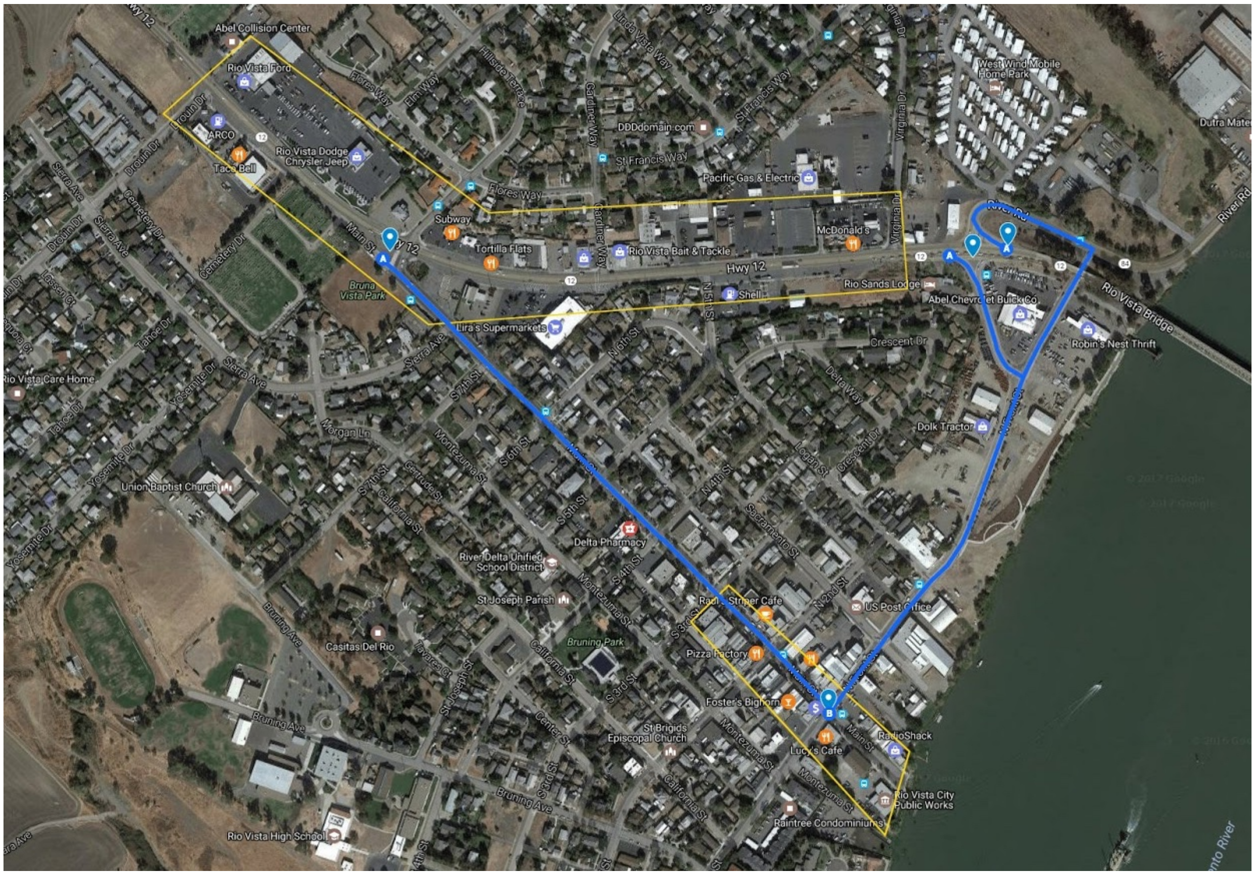


Figure 85. Suggested DCFC charging areas in Rio Vista

In summary, Solano County occupies a strategic position connecting a diversity of population centers with trip attractors. This opens opportunities for investments in DCFC infrastructure in gateway areas, as well as in the network hub of Suisun-Fairfield.

4.2. Local Charging Infrastructure to Support EV Commute Travel

The need for investments on charging infrastructure can be warranted on two main grounds, namely to support the displacement of fossil fuel consumption with increased use of plug-in vehicles on the road and/or to support further market uptake of plug-in vehicles. In other words, charging infrastructure can help materialize a latent demand for electric vehicles and electric miles. Therefore, an evaluation of charging infrastructure investments necessitates of an assessment of this demand.

In this section, we describe the entire process of analysis of prospective locations for investments in charging infrastructure that would effectively support commuters' EV travel and adoption. We start with the process of data collection, follow with a description of the experimental design, and complete with a description of the modeling and the results.

4.2.1. Data collection

We collected consumer data for the analysis via an online survey. STA has existing relationships with a large number of employers in the county, with whom they collaborate on transportation issues such as van-share programs. STA offered to leverage these relationships and ask these Solano-based employers to distribute the survey among their employees. In discussions with STA, ICF observed that the sample of employers was well distributed geographically across Solano, and that the potential population of recipients was extremely high. This gave the expectation of a large and representative sample of respondents to enable robust econometric analysis.

The central areas of inquiry that these data serve are the market demand for plug-in vehicles and the impact that workplace charging infrastructure could have in this demand. The latter should help inform county's strategies to support investments in charging infrastructure.

The survey included the following sections:

- Your Commute: Includes questions about the distance, level of satisfaction, and mode of the respondents' trip to work
- Did You Know? A section with information about electric vehicles for respondents who are not necessarily familiar with these vehicles
- Market Analysis Game: While we name it "game", this section is a stated choice experiment. We ask respondents to evaluate hypothetical sets of three vehicles, and to choose the vehicle that they would buy. This section provided the main data for the market analysis, and required careful experimental design. We describe the design of this set of questions in more detail below.
- Your Vehicle: Includes three questions about the vehicle that respondents drive
- About Electric Vehicles: Includes a few questions to test respondents' familiarity with electric vehicles
- EV Commuting: Only owners of electric vehicles are directed to this section, which Includes questions about their experience driving these vehicles
- About You: Includes questions commonly referred to as socio-demographics, such as type of residence, income, age, and others

Our strategy to maximize response rate was centered on creating a relatively pleasant interface, using easy-to-read question fonts, minimizing the use of formal and/or technical language, and the use of graphics to reduce the cognitive burden on respondents. Toward this end, we engaged a design team in ICF. Importantly, we made a concerted effort to minimize the number of questions.

The survey was administered via email to Solano employers in the list described above. ICF agreed for STA to communicate with employers and provided support in the writing of the email. Following standard practice, STA sent a reminder email to employers after two weeks of the first email, to encourage further responses. Eventually, 861 usable responses were obtained. ICF did not have the means to know how many individuals received an invitation to respond to the survey, and thus we were unable to estimate a response rate.

Survey Focus Group

To pretest the survey, ICF conducted a focus group. The group, composed of seven STA employees, took the survey and provided feedback on a range of questions related to survey readability, response burden, and possible gaps in the questions. The focus group also served us to identify other possible issues, including observing body language while taking the survey, collect overall perceptions of plug-in vehicles, and other intangibles.

It took participants between 10 and 19 minutes to complete the survey. This met our objective of average completion time under 20 minutes. We anticipated the stated preference section (called “game” in the survey) to be the most time consuming, and this was validated with the focus group. We observed some confused looks when participants were reading the explanation the game. During the discussion, participants revealed a range of reactions about the survey. Some felt that the description of the game was confusing, particularly the description of the plug-in vehicle alternatives. Others felt it was intuitive and fun. In general, participants like the use of images to help with the cognitive understanding of the game, but felt that the use of images could be increased. One participant felt it was “too hard” to choose anything other than the “current car” alternative, in part because the PEV alternatives were somewhat confusing, in part because the PEV range was not sufficient, and in part because the survey did not indicate if a charging station would be available at home. This participant indicated that a range under 100 miles would not be enough. Some of the alternatives however included battery electric vehicles with 200-miles range, and plug-in hybrid electric vehicles with total range higher than that. Other participants said that range was not an issue for them. This suggested the need to revise our explanation of the range in the choice alternatives.

Another participant discarded the “current car” alternative and only focused on the two “new” options. Participants thought that the question about what could be done to support adoption of PEV would be relevant for all survey takers to answer. This question was originally designed to be seen only by PEV users. The question of leasing vs. buying came up. Some participants felt confused by having only a leasing option. One participant asked “Who leases a car anyway?” In addition, participants provided feedback on a variety of ways to improve readability of the survey.

A copy of the survey that was administered is included in an appendix (), showing the survey questions as well as the design elements especially prepared by ICF for this survey, to help with respondent cognition and increase response rate.

4.2.2. Design of the Experiment

Above we briefly explained that the Market Analysis Game in the survey was the core that enabled the type of econometric analysis that was needed, and that it required careful experimental design. As explained above, ICF's choice of a more sophisticated approach to the analysis of infrastructure location responded to STA's interest.

The demand for electric vehicles received significant attention in the studies in the 1990's, around the time when the California Zero Emission Vehicle mandate was implemented. Prominent among these studies were Bunch, Bradley, Golob, Kitamura, and Occhiuzzo (1993)[17], Brownstone, Bunch, Golob, and Ren (1996)[18], and Brownstone, Bunch, and Train (2000)[19]. Those studies showed evidence of low market demand for electric vehicles. The technology 15-20 years ago was much less evolved than today, and vehicle price, range, and charging time were high in the list of deterrents for market adoption. Charging equipment was split between conductive charging (the technology used today) and inductive charging. In fact, during a field trip as part of this project, we encountered a legacy public-access inductive charging station in Vacaville! More recently, the subject was again investigated by Hidrue, Parsons, Kempton, and Gardner (2011)[20]

If no reference alternative is included (e.g. no-choice or status quo), we may be measuring relative preferences which may very distance from absolute preferences. In other words, the most preferred among the options that we offer may still be unappealing to respondents; but we would not have a means to capture this. We prefer to include a status quo choice alternative because we can obtain measurements of the vehicle currently owned by respondents. The no-choice option can be considered similar, however this can include two choice routes: keeping the same vehicle or choosing a vehicle that is neither the currently owned nor any of the options presented. It has been reported that offering the status quo alternative may lead to a so-called status quo bias, which is the observed tendency of respondents to pick this alternative with more frequency than is expected. In the other hand, it has also been reported that this perceived bias may actually be a valid representation of consumers' preferences (Adamowicz, Boxall, Williams, and Louviere, 1998).

The degrees of freedom for the experiment is $S \times (J - 1)$, where S is the number of choice situations and J represents the number of alternatives in each. The degrees of freedom has to be larger than the number of independent constraints in the model (i.e. the number of parameters). This presents us with the need to seek some balance. The more parameters we include would allow us to gain more information, but it

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[17] Bunch, D.S., Bradley, M., Golob, T.F., Kitamura, R., and Occhiuzzo, G.P. (1993) Demand for clean-fuel vehicles in California: a discrete-choice stated preference pilot project. *Transportation Research Part A* **27** (3): 237–253.

[18] Brownstone, D., Bunch, D.S., Golob, T.F., and Ren, W. (1996) A transaction choice model for forecasting demand for alternative fuel vehicles. *Research in Transportation Economics* **4**: 87–129.

[19] Brownstone, D., Bunch, D.S., and Train, K. (2000) Joint mixed logit models of stated and revealed preferences for alternative-fuel vehicles. *Transportation Research Part B* **34**: 315–338.

[20] Hidrue, M.K., Parsons, G.R. Kempton, W. and Gardner, M.P. (2011) Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics* **33**: 686-705.

would also increase the degrees of freedom needed for the estimation of the model, and in turn the higher the number of degrees of freedom, the larger the design.

One possibility is to take a main effects approach to the design. Main effects are the effects of each of the attributes, independent of the effects of other attributes. The main-effects utility for an alternative *i* is given by

$$V_i = \beta_{0i} + \beta_{1i} f(X_{1i}) + \beta_{2i} f(X_{2i}) + \cdots + \beta_{Ki} f(X_{Ki})$$

Where β_{ki} is the parameter associated with attribute X_k and alternative *i*. In other words, it represents the main effect of attribute X_k on the utility. β_{0i} is the alternative-specific constant (ASC), and represents the effect on utility of the unobserved attributes. When including interaction effects, the utility takes the following form:

$$\begin{aligned} V_i = \beta_{0i} + \beta_{1i} f(X_{1i}) + \beta_{2i} f(X_{2i}) + \cdots + \beta_{Ki} f(X_{Ki}) + \beta_{Li} f(X_{1i} X_{2i}) + \beta_{Mi} f(X_{1i} X_{3i}) + \cdots \\ + \beta_{Pi} f(X_{1i} X_{Ki}) + \beta_{Qi} f(X_{2i} X_{3i}) + \beta_{Ri} f(X_{2i} X_{4i}) + \cdots + \beta_{Ti} f(X_{2i} X_{Ki}) + \cdots \\ + \beta_{Zi} f(X_{1i} X_{2i} \ldots X_{Ki}) \end{aligned}$$

Here, β_{Li}, β_{Mi}, …, β_{Pi} are the parameters associated with the two-way interactions between attributes in alternative *i*. In other words, they represent the second-order interaction effects of the attribute on the utility. Similarly, higher order interactions can be defined.

Including only main effects would result in a smaller experiment design. However, the ensuing analysis would be meaningful only to the extent that the interaction effects are insignificant. In most situations, at least some of the interactions are in fact significant, and excluding them from the experiment design would render the ensuing results biased and inefficient. What is worse, there is no way to test for this effects if the interaction effects in question are not measured. A full factorial design would avoid any of these problems, but such designs are practicable only for small choice problems. A strategy must be adopted to reduce the number of treatment combinations while keeping the interaction effects of interest. To decide which interaction effects should be included, analysts typically rely on existing literature or their domain expertise. Evidence shows that most of the effect on the outcome (in our case, utility) comes from the main effects and the second-order interactions, while third- and higher-order interactions generally account for a few percentage points of the effect. Thus, it is good practice to consider the inclusion of interactions at least of second order.

We consider the case in which the utility of an electric vehicle is affected by four factors. These factors include the monthly lease (assuming the down payment is embedded in the monthly payment), the monthly savings in fuel, the vehicle platform, defined as two configurations of plug-in hybrid electric vehicles and two configurations of battery electric vehicles (defined by the estimated number of miles that the vehicle can run on electricity between charges), the cleanliness of the electricity that the owner could use to recharge the plug-in vehicle, and the presence of a charging station at the workplace. Assuming linear marginal utilities, we can write the main effects plus second-order interaction utility as follows:

$$V_{EV} = \beta_{0EV} + \beta_{1EV}\text{Lease} + \beta_{2EV}\text{Fuel} + \beta_{3EV}\text{eRange} + \beta_{4EV}\text{EVSE} + \beta_{5EV}(\text{Lease} \times \text{Fuel}) + \beta_{6EV}(\text{Lease} \times \text{eRange}) + \beta_{7EV}(\text{Lease} \times \text{EVSE}) + \beta_{8EV}(\text{Fuel} \times \text{eRange}) + \beta_{9EV}(\text{Fuel} \times \text{EVSE}) + \beta_{10EV}(\text{eRange} \times \text{EVSE})$$

We immediately argue that the effect of the lease payment on utility does not depend on the availability of a charging station at work, and that the effect of fuel costs on utility does not depend on the electric range. Also, the effect of fuel costs does not depend on the availability of charging infrastructure (although the fuel cost itself can depend on the pricing of the use of the charging infrastructure). Mathematically, this means that $\beta_{7EV} = \beta_{8EV} = \beta_{9EV} = 0$, which helps decrease the number of parameters to estimate. The interaction between lease payment and fuel costs is complex and depends on a variety of factors, for example the market segment under consideration (the willingness to pay for fuel savings varies across market segments), the cost of fuel, etc. In our case, we expect that price of electricity fuel to have a tangible effect on the utility of electric vehicles and consequently on the willingness to pay for electric vehicles. Mathematically, this means that $\beta_{5EV} \neq 0$. A similar argument applies to the interaction between lease payments and the electric range of the vehicle, and thus $\beta_{6EV} \neq 0$. Certainly, we expect the impact of the electric range on utility to vary with the availability of charging infrastructure at the workplace, meaning that $\beta_{10EV} \neq 0$.

In terms of stated choice experiment design, the prevalence in the literature is to use orthogonal designs, although alternatives exist. D-efficient designs are geared to minimize the covariance of the parameter estimates, S-efficient (or sample size-efficient) designs endeavor to minimize the size of the sample needed to obtain statistically significant parameter estimates, while orthogonal designs minimize (to zero) the correlations between attribute values. Researchers have argued that D-efficient and S-efficient designs perform better. However, to create such designs, the analyst necessitates to assume *prior* parameter estimates. Indeed, it has been shown that information on prior parameters and the use of D-efficient or S-efficient designs help increase the efficiency of the design relative to orthogonal designs. For the particular case in which prior estimates are assumed to be zero, the orthogonal design is the most efficient. This is common practice when information on prior parameters is not available. Recently the connection between the choice model and the design of the choice experiment has been better recognized. Traditional studies using orthogonal designs for the most part ignored this connection.[21] The efficiency of orthogonal designs increases with the sample size, and for sample sizes typically found in studies the orthogonal design performs well.

Important aspects of the experiment design are the choice of number of levels and ranges of the attributes. Studies show that designs with two levels and wide range (often referred to as *endpoint* designs) produce lower D-errors and require lower sample sizes. In particular, it appears that attribute range has a stronger impact on design efficiency, and thus we will strive to choose attribute level ranges as wide as possible within boundaries of realism. The limitation of two-level attribute definitions is of course that only linear relationships can be tested. In experiments with small numbers of attributes, the

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[2121] Rose, John M., Michiel C.J. Bliemer, David A. Hensher, and Andrew T. Collins (2008) Designing efficient stated choice experiments in the presence of reference alternatives. *Transportation Research Part B* **42**: 395-406.

use of two-level attributes may run the risk of resulting in dominant alternatives, or in other words, one of the alternatives will be chosen with much higher probability. Adding more levels reduces such risk.

4.2.3. Modeling and Results

A mixed multinomial logit model (or random parameters logit model) was used to estimate the probability of adoption plug-in vehicles among commuters to and within Sonoma County. The mixed multinomial logit (MMNL) model is adequate to account for the fact that some of the model parameters are not fixed but vary across individuals, following a given probability distribution. In the standard logit model, the utility of a given alternative *i* to individual *n* is expressed as:

$$U_{ni} = \beta x_{ni} + \varepsilon_{ni},$$

In the MMNL model, the expression for the utility transforms into

$$U_{ni} = \beta_n x_{ni} + \varepsilon_{ni},$$

where the error terms are still distributed as extreme value, but the coefficients β are now assumed random and varying across individuals (thus the subscript *n*). Because we are using a stated choice dataset, where each respondent is asked to choose a vehicle several times (i.e. once for each of eight scenarios), then we are actually using a *panel* data set.[22] We used a dataset with 861 responses, each of which was exposed to eight choice scenarios, rendering a dataset of 6,888 choice data points. We modeled respondents' choice from amongst three vehicles: two plug-in models and the vehicle they owned at the time of responding. The probability to choose a vehicle (*Choice*) was modeled as a function of the vehicle's monthly payment (*Payment*) and electric range (*eRange*), gasoline range (*gRange*), and operations savings relative to the current vehicle (*Savings*). From these variables, we considered *eRange*, *gRange*, and *Savings* as random variables. The results are shown in Table 6.

Table 6. Results of model of consumer vehicle choice

Choice	Coefficient	Std. Error	z	P>|z|	[95% Conf. Interval]	
Mean						
Payment	-.001595	.0003435	-4.64	0.000	-.0022683	-.0009217
gRange	.0006343	.0003274	1.94	0.053	-7.43e-06	.001276
eRange	-.0011224	.0006196	-1.81	0.070	-.0023368	.000092
Savings	-.0039419	.0019238	-2.05	0.040	-.0077125	-.0001714
Std Deviation						
gRange	.0039419	.0019238	-2.05	0.040	-.0077125	-.0001714
eRange	.0003806	.0008728	0.44	0.663	-.0013299	.0020912
Savings	.0365025	.0028521	12.80	0.000	.0309124	.0420925
						Number of observations = 15,302 Log likelihood = -4912.6648 Probability > chi-square = 0.0000

[22] This type of dataset is sometimes called "instantaneous panel", to reflect the fact that data points are collected at the same point in time, thus differentiating it from longitudinal panel data.

The results show, for each variable (except *Payment*) the mean and the standard deviation, consistent with the assumption that these are random variables. In practical terms, this means that the value of the coefficient for *gRange*, *eRange*, and *Savings* is not the same for all respondents, and each respondent will have her own coefficient indicating the degree to which that variable impacts her decision to choose a particular vehicle model. As expected, the coefficient of the mean of *Payment* is negative, indicating that the higher the monthly payment, the less likely people are to choose a vehicle model. The coefficient of the mean of *Savings* is negative, which we interpret as reflecting the average tendency of respondents to keep the type of vehicle they currently own (*Savings* is zero for the current vehicle and bigger than zero for the electric vehicle models). The size of the coefficient of the standard deviation of *Savings* however suggests that for many respondents the relative savings would help make them more inclined to buy an electric vehicle. The probabilities of respondents choosing an electric vehicle are visualized in Figure 86 through Figure 91.

We also modeled respondents' probability to choose a model as a function of the model's monthly payment (fixed) and electric range, gasoline range, operations savings, and the availability of charging stations at work (random). The assumption of randomness of some coefficients reflects our belief that there exists significant variability in the value of those coefficients across individuals. From this model, we obtained coefficients for the impact of the availability of charging infrastructure on EV adoption that vary across respondents.

We visualized the value of these coefficients on a geographical layer using a color scale, to show areas where charging infrastructure investments may have more impact on EV adoption. Figure 92 shows the overlay of these values on the county. The interpretation of these figures is straightforward: areas with red color indicate locations where investments in charging infrastructure may have higher impact on EV adoption among Solano commuters. Areas with purple color indicates locations that may have less of an impact on EV adoption among Solano commuters.

In the following visualizations, we zoom in on specific areas to add more locational detail. Figure 93 shows the distribution of coefficient values in Vacaville. Figure 94 shows the distribution of coefficient values in Fairfield, while Figure 95 and Figure 96 show in more detail this distribution for southern and northern sections of Fairfield, respectively. Figure 97 shows the distribution of coefficient values in the Cordelia area. Finally, Figure 98 and Figure 99 show the distributions of coefficient values in Vallejo and Benicia, respectively.

Figure 86. Distribution of probabilities of choosing an electric vehicle in Vacaville

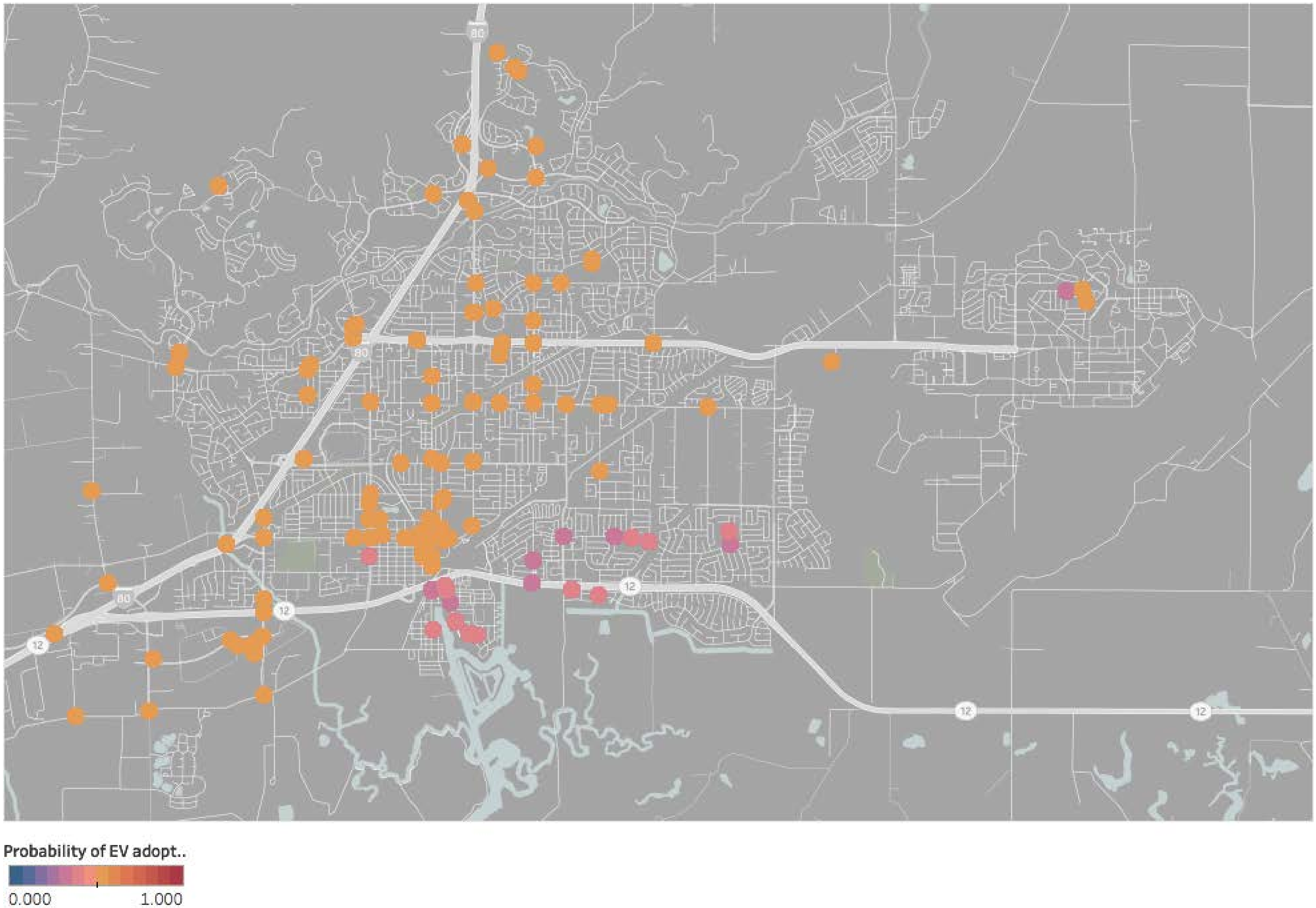

Figure 87. Distribution of probabilities of choosing an electric vehicle in Fairfield-Suisun City

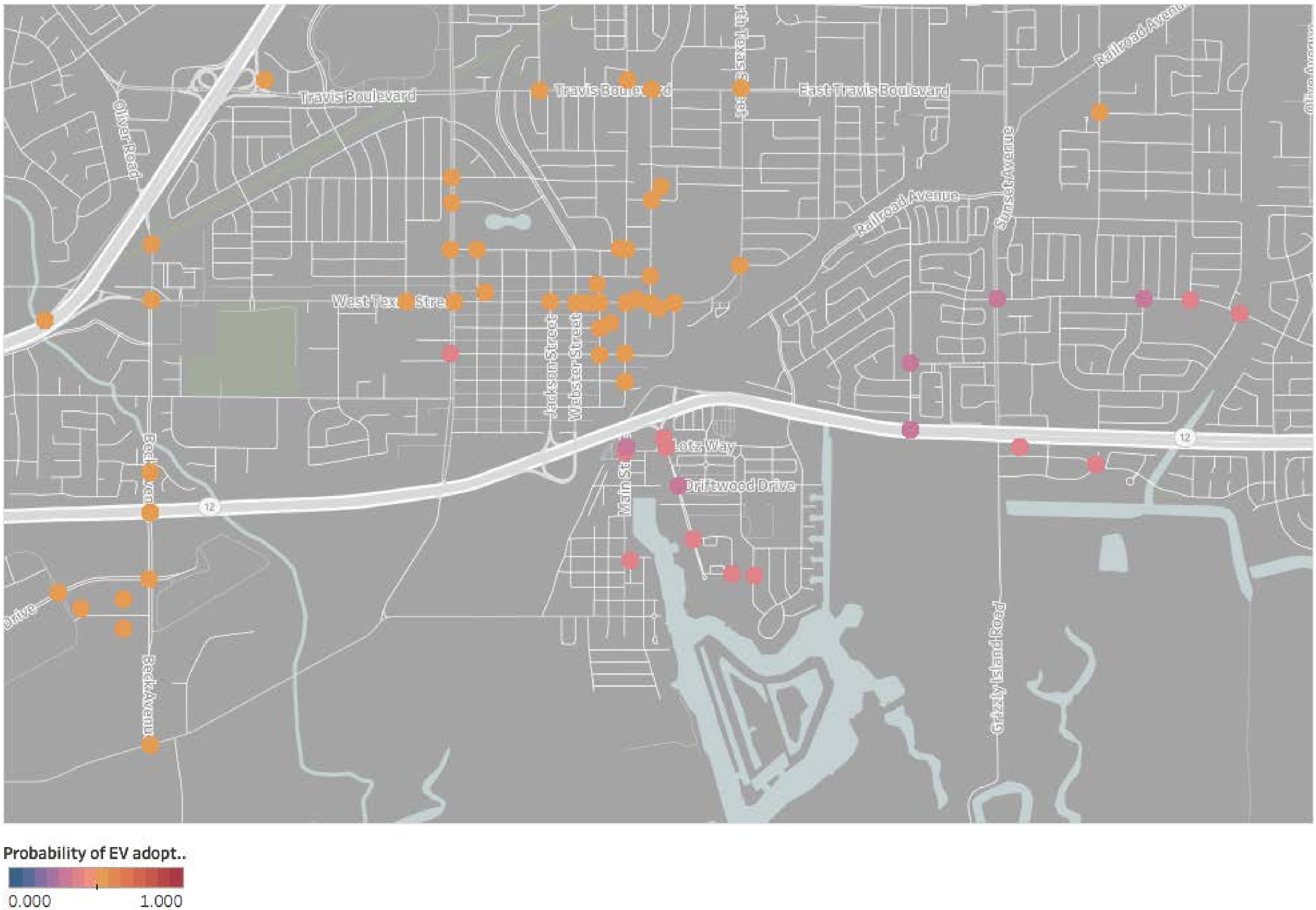

Figure 88. Distribution of probabilities of choosing an electric vehicle in the southern section of Fairfield.

Figure 89. Distribution of probabilities of choosing an electric vehicle in Cordelia.

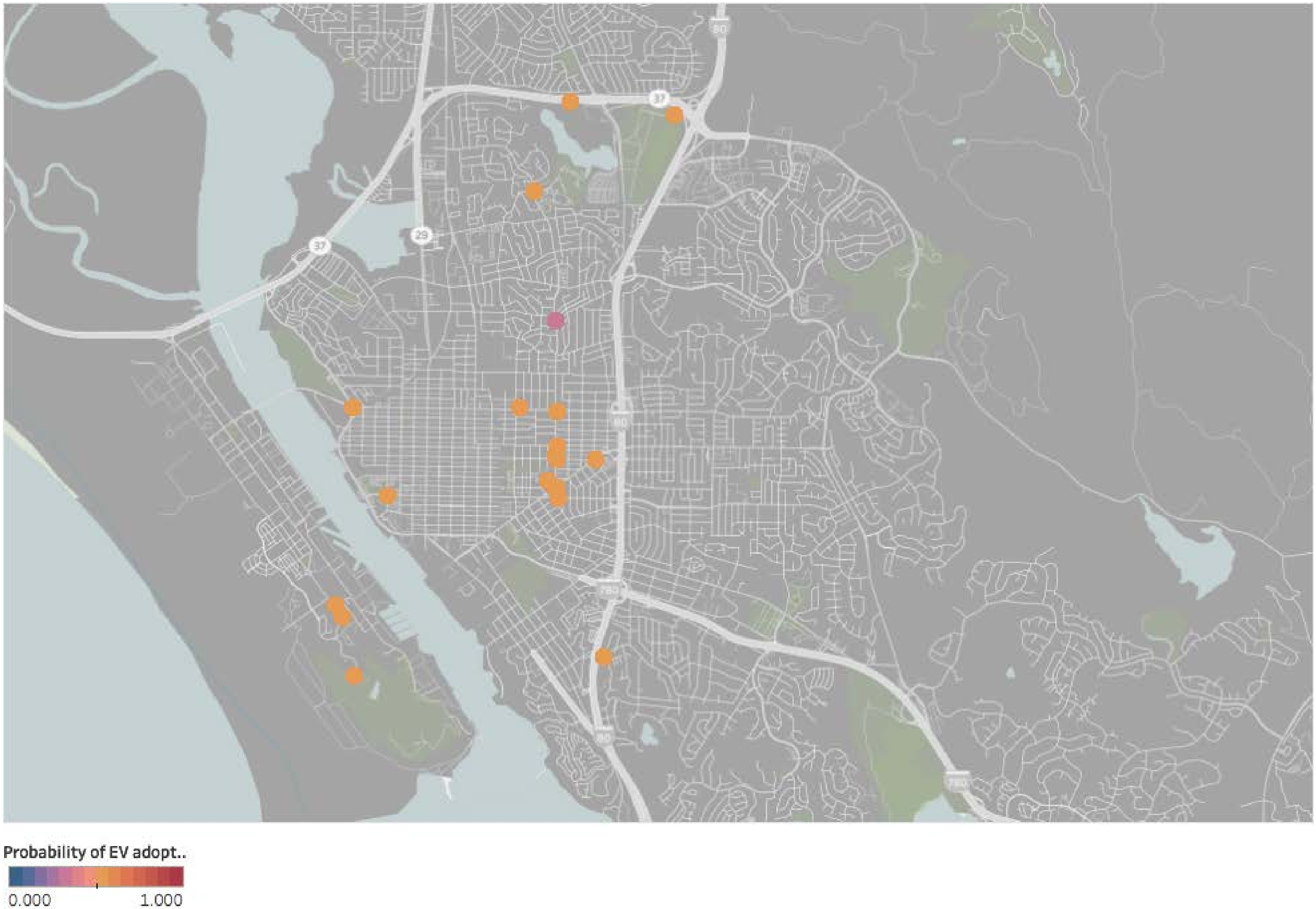

Figure 90. Distribution of probabilities of choosing an electric vehicle in Vallejo.

Figure 91. Distribution of probabilities of choosing an electric vehicle in Benicia.

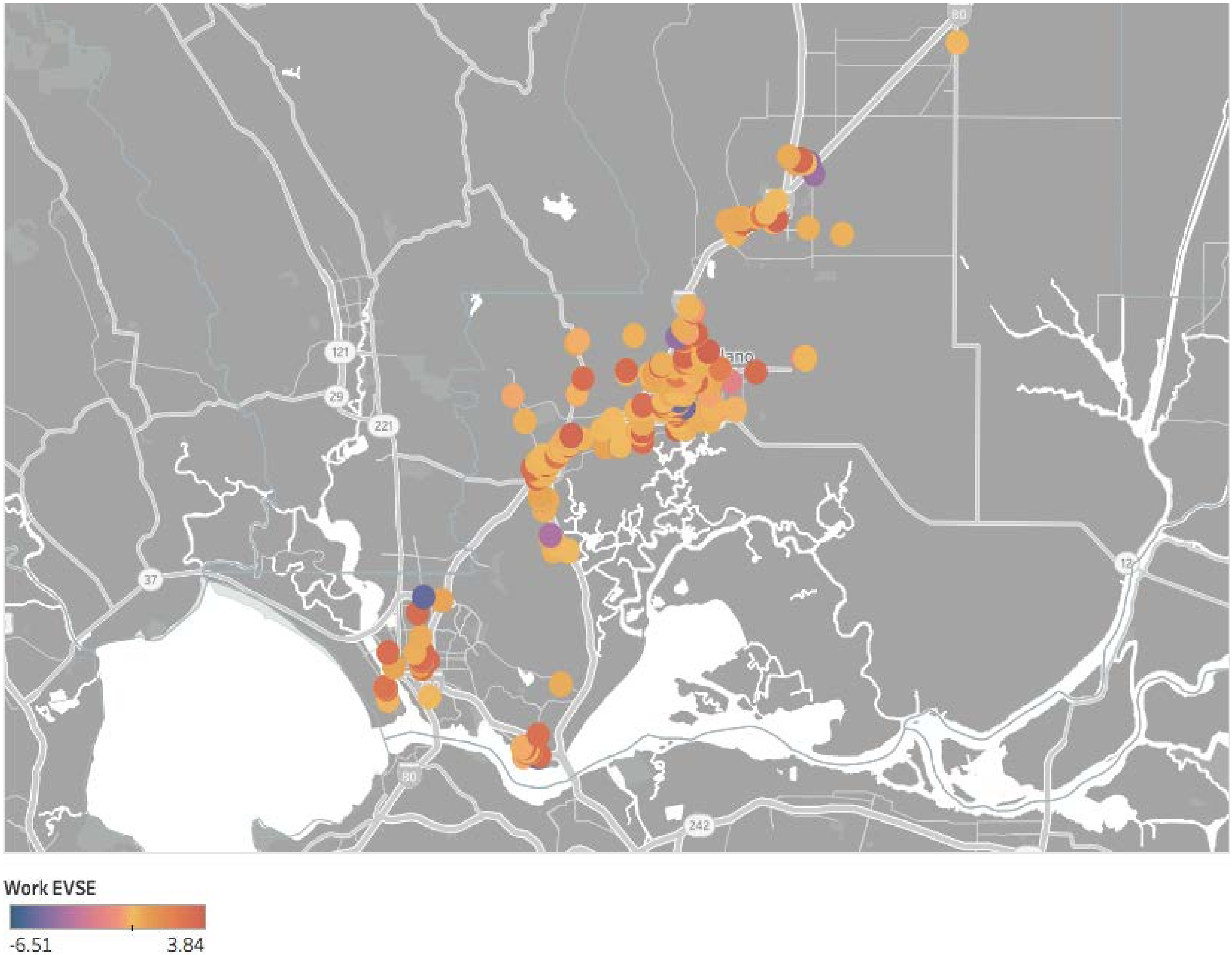

Figure 92. Estimated distribution of impact that EVSE installations may have on EV adoption by Solano commuters

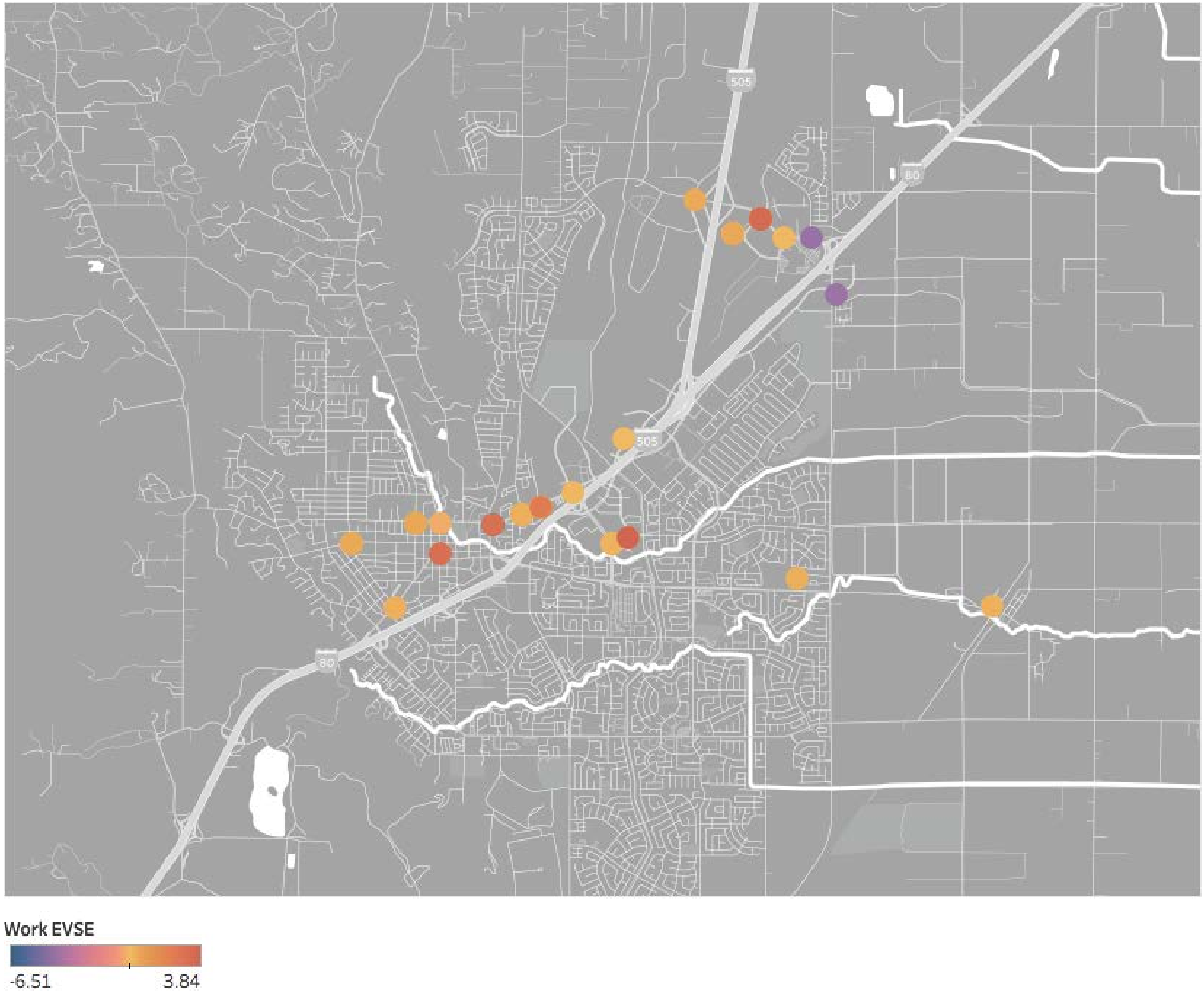

Figure 93. Estimated distribution of impact that EVSE installations in Vacaville may have on EV adoption by Solano commuters

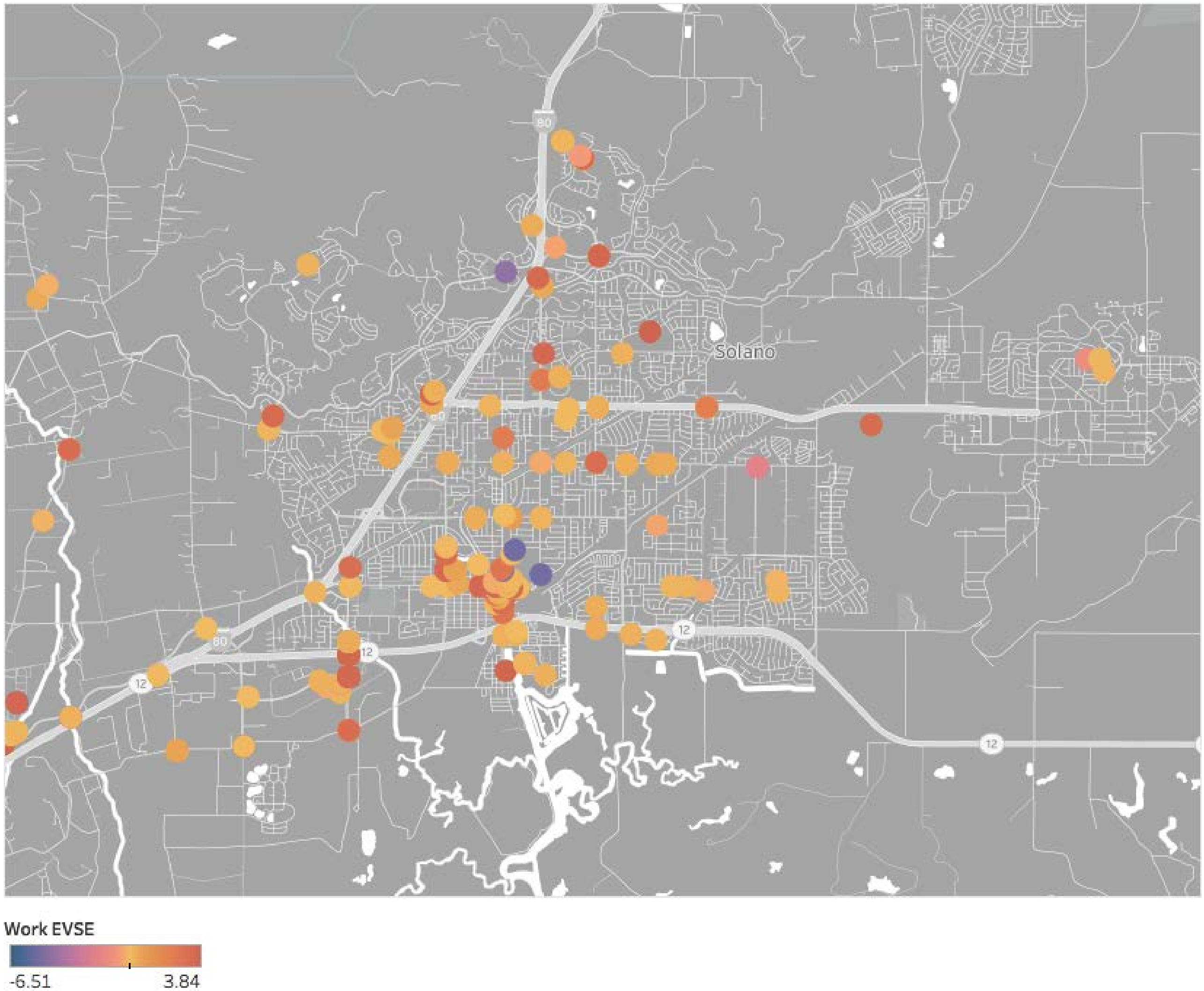

Figure 94. Estimated distribution of impact that EVSE installations in Fairfield may have on EV adoption by Solano commuters

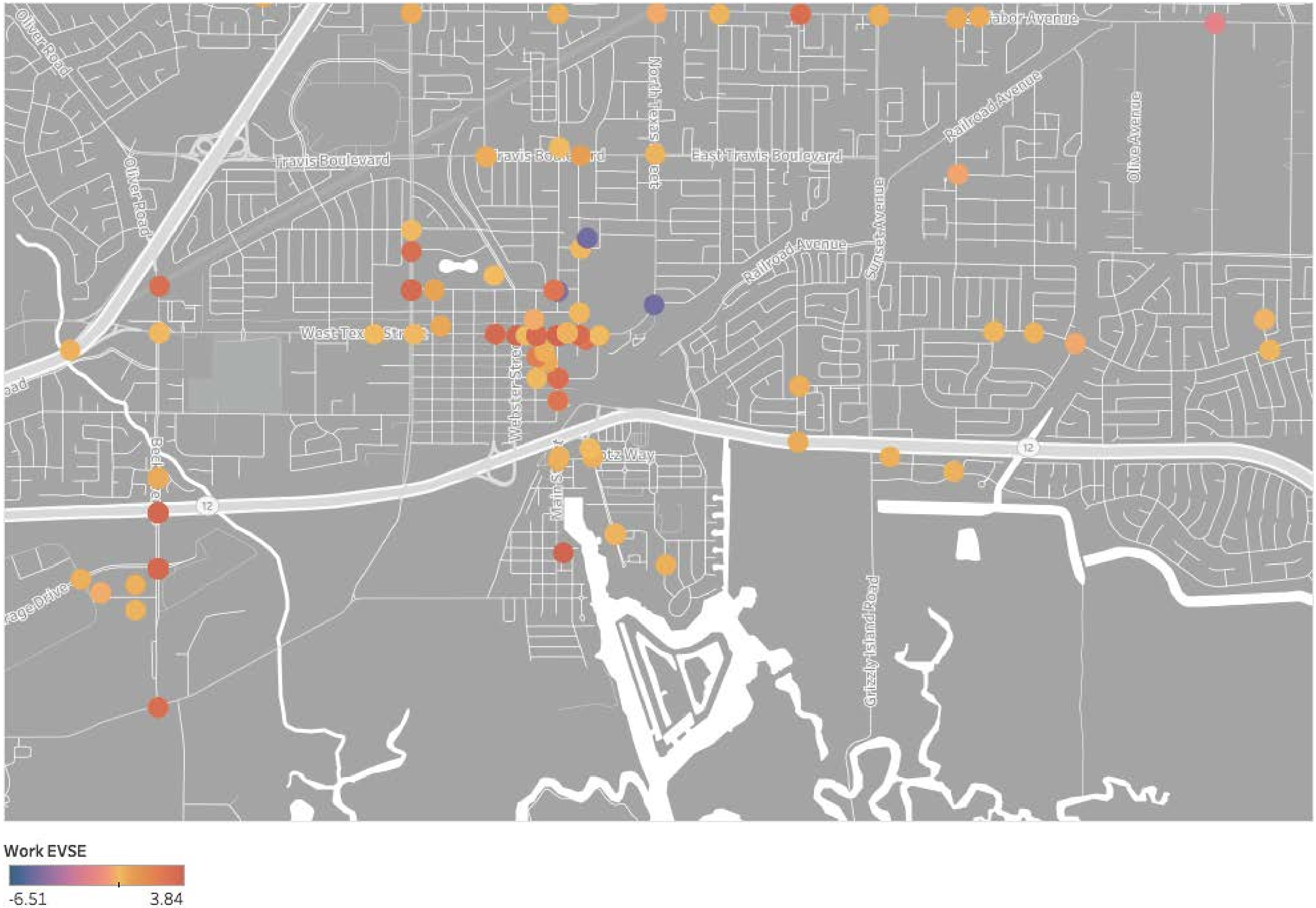

Figure 95. Estimated distribution of impact that EVSE installations in South Fairfield may have on EV adoption by Solano commuters

Figure 96. Estimated distribution of impact that EVSE installations in North Fairfield may have on EV adoption by Solano commuters

Figure 97. Estimated distribution of impact that EVSE installations in Cordelia may have on EV adoption by Solano commuters

Figure 98. Estimated distribution of impact that EVSE installations in Vallejo may have on EV adoption by Solano commuters

Figure 99. Estimated distribution of impact that EVSE installations in Benicia may have on EV adoption by Solano commuters

4.3. Trailblazing Signs for Electric Vehicle Charging Stations

Figure 100: Example EV Trailblazing Sign

One of the tasks of the Solano EV Transition Program was to site potential locations for trailblazing signs to point drivers towards existing EV charging stations. Many existing charging stations are difficult to locate and not near major thoroughfares. These signs seek to assist EV drivers in better locating available charging. For this task, STA worked with a consultant, Fehr & Peers, to develop the locations for the signs, as well as specifications for the signs themselves and mounting. Fehr & Peers also contacted each Solano County jurisdiction to compile information on required permits, and willingness to deploy these signs. The project included budget to purchase several of these signs and work with local agencies to install them on local streets.

Fehr & Peers developed 76 potential locations to deploy trailblazer signs in each of Solano County's seven cities, outlined in Appendix E. They also provided to STA a document that detailed all sign and mounting specifications required for installation. Figure 96 shows the proposed sign. Work on deployment of trailblazing signs continues. STA has been contacting local agencies to review the proposed sign locations and gauge interest in installing the signs. The plan is to have some trailblazing signs installed before the end of May 2018.

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Summary of Recommendations + Next Steps

5. Summary of Recommendations and Next Steps

The Solano EV Transition Program was a multi-faceted program that sought to bring together many Solano based stakeholders to improve the county's EV readiness. It did not come without challenges. At times, the stakeholders were a little difficult to engage as interest in electric vehicles in Solano County is still emerging. However, STA now has a plan (the results of this program) to carry out to ensure that the work to ready Solano County for widespread EV adoption continues. These are outlined in the potential next steps to follow the conclusion of the Solano EV Transition Program:

- **Seek funding for EV infrastructure**

  Now that this program has conducted a siting analysis for potential locations to deploy EV charging infrastructure, a natural next step is to seek funding for installation. To this end, STA is planning a first phase implementation of this EV Transition Plan to fund new charging stations at the Vallejo Ferry Building, and additional stations at the Amtrak station in Suisun City. Furthermore, STA will be utilizing the maps showing demand for EV charging to inform siting decisions in future phases of implementing EV charging infrastructure. STA has been monitoring funding opportunities from PG&E's Charge program, the Bay Area Air Quality Management District, the VW settlement and others. STA will continue to work with our member agencies to promote more EV charging infrastructure, as outlined in STA's Alternative Fuels and Infrastructure Plan[23].

- **Continue to work to streamline permitting and installation of EVSE**

  STA's Alternative Fuels and Infrastructure Plan also makes mention of increasing EV readiness through expedited permitting processes. This is something that the Solano EV Transition Program made strides in, by working with local stakeholders to develop recommendations to help streamline and expedite EVSE permitting. The permitting checklist template that resulted from this effort stands as an example of how Solano County's local governments can increase their EV readiness. In the future, STA will look to further engage local agencies and encourage adoption of the recommendations to streamline permitting and inspection processes.

- **Increase EV awareness through outreach**

  One of the ways STA can increase EV awareness and adoption is through public outreach. When conducting the SolanoEV.org Earth Day Events, ICF created a template for the Ride and Drive events that STA can potentially use to replicate these events in the future. Additionally, the charging infrastructure siting analysis may lead to additional outreach to potential site hosts for EVSE, especially in tandem with funding opportunities. As previously mentioned, STA will be looking to these maps to site potential locations for EV infrastructure in future implementation phases, and will conduct more site host outreach accordingly.

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[23] http://www.sta.ca.gov/docManager/1000004240/STA%20Final%20Alt%20Fuels%20Plan%2012-11-13.pdf

Appendices


CHARGING STATION
ELECTRIC CAR PARKING ONLY WHILE CHARGING
RESERVED PARKING
ELECTRIC VEHICLES ONLY


POWER
CHARGING
POWER FAULT
CHARGING FAULT
CHARGER
1
CLIPPERCREEK
ELECTRIC VEHICLE
CHARGE STATION
HIGH POWER
VOLT

6. Appendix A. Protocol for Electric Vehicle Charging Station Case Studies

Basic EVSE installation characteristics

- Equipment characteristics
  - Supplier
  - Model
  - Number of units
  - Number of level 2 connectors
  - Number of level 2 connectors
  - Number of DC Fast Charge connectors
  - Communication capable?
  - Are usage data collected?
- Who is the intended end user?
  - General public
  - General public with restrictions (e.g. members of a network)
  - Clients and customers
  - Employees
  - Fleet vehicles
  - Residential
  - Other
- Site characteristics
  - Number of assigned charging spaces
  - Number ADA compliant spaces
  - Host
- Governmental organization
  - Fleet
  - Workplace
- Private sector
  - Parking services facility
  - Offices/workplace
  - Commercial
  - Industrial
  - Fleet
  - Recreation
- Higher education
- Other (describe)
  - Site type (characterize the site in terms of public vs. private, parking lot vs. assigned, open vs. covered/in-building vs. public right of way, etc.)

Project motivations and structure

- Brief history (Main motivation, stakeholder involvement, etc.)
- Goals
- Were there regulatory/statutory requirements that influenced this installation, either positively or negatively?
- Project delivery method (DBB, DBOM, BOT, other)

Cost and Financing

- Source of capital for the equipment: Private, Public, PPP, other
- Source of capital for the installation: Private, Public, PPP, other
- Were there tax incentives available to offset these costs?
- Could you please characterize the following cost items?
- Total capital and installation labor costs ($)
- Permitting and inspection
- Utility hookup ($)
- Total operating cost ($/month). This may include average electricity costs ($/kWh, including any discounts or demand charges), insurance, network supplier fees, maintenance costs, lease or revenue loss, etc.)
  - Could you characterize the following operating cost and revenue items?
  - Operating revenue model: Complimentary service, sponsorship, pay-per-energy, pay-per-time, other
  - If the use of the charger is complimentary or subsidized, are there indirect benefits to your organization resulting from this service? (For example, customer/employee retention, increase in sales, public image, or other)

Design

- Stakeholders involved
  - Who participated in the physical design of the site?
  - Who was responsible for the electrical analysis?
  - Was the local electric utility involved?
  - What local government office needed to be involved (e.g. city, county)?
  - Who is the property owner, and if different, who is the business tenant?
- Was any guidance document used in the design of this site?
- Please describe process of selection of the charging site and any challenges identified during this process.
- Did the layout of the parking spaces have to be modified to accommodate the charging station/s?
- What solution did you adopt to meet ADA requirements?
- Please describe the on-site and off-site signage installed as part of this project
- Please describe the permitting and inspection process from application to completion.
  - Were there any challenges encountered during this process?
  - Who did the electrical analysis?
  - Was a site plan required?
  - Who applied for the permit?
  - What was involved in applying for a permit?
  - Was the inspector knowledgeable about EVCS?
  - How long did the entire process take?
  - Was the cost reasonable?
  - Were you overall satisfied with the experience?

Site development and installation

- Who did the installation?
- What type of construction work was done as part of the installation (surface trenching/repair, walls, etc.)?

- Did the electric service have to be upgraded? For example, was the panel amperage size increased, and/or was the local transformer upgraded?
- What challenge/s did you encounter during the site development and installation process?

Operation and Maintenance

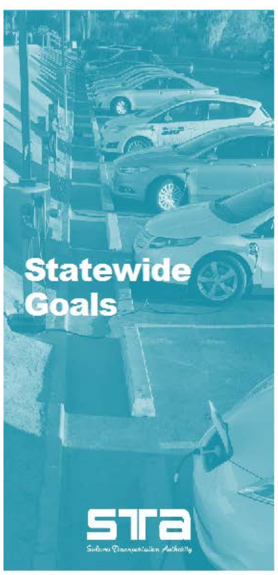
- Who is responsible for the operation of the equipment?
- How is liability for any issues related to the use of the equipment assigned?
- Please describe the maintenance program for this equipment. Have there been issues with the reliability of the equipment?

Utilization

- How would you characterize the use that the station/s receive? (How often? For how long? What time of day? By who?)
- Is usage data being collected? If so, can you share it with us?
- Have you received feedback from customers/employees/others about the charging stations?

7. Appendix B. Slides for the EVSE Permitting Roundtable

1



EV Infrastructure Plans for major metropolitan areas by 2015

Bay Area Plug-In Electric Vehicle Readiness Plan (2013)
Solano County Alt Fuels & Infrastructure Plan (2013)

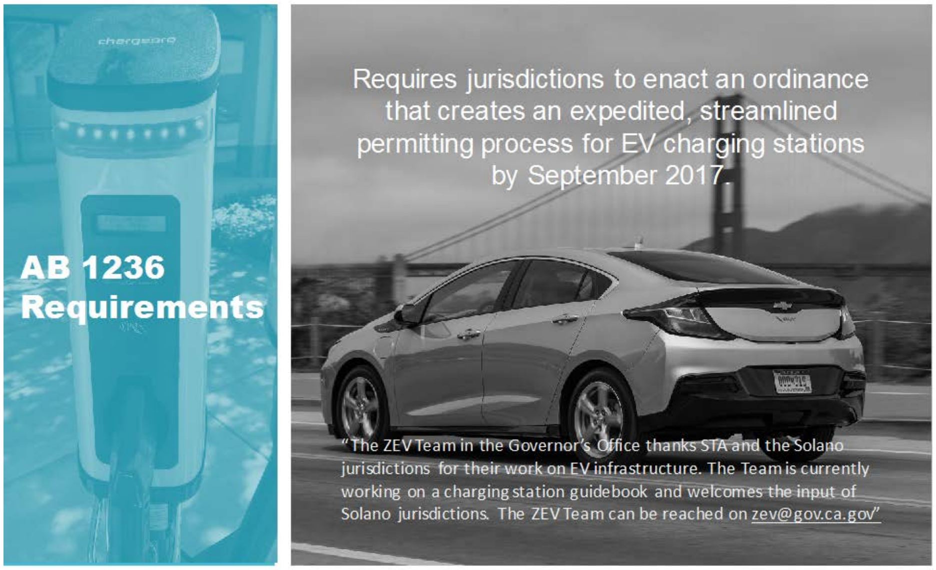
1 million EVs on the road by 2020

State programs to incentivize purchase and lease of EVs.
CA sells about half of the EVs in the country.

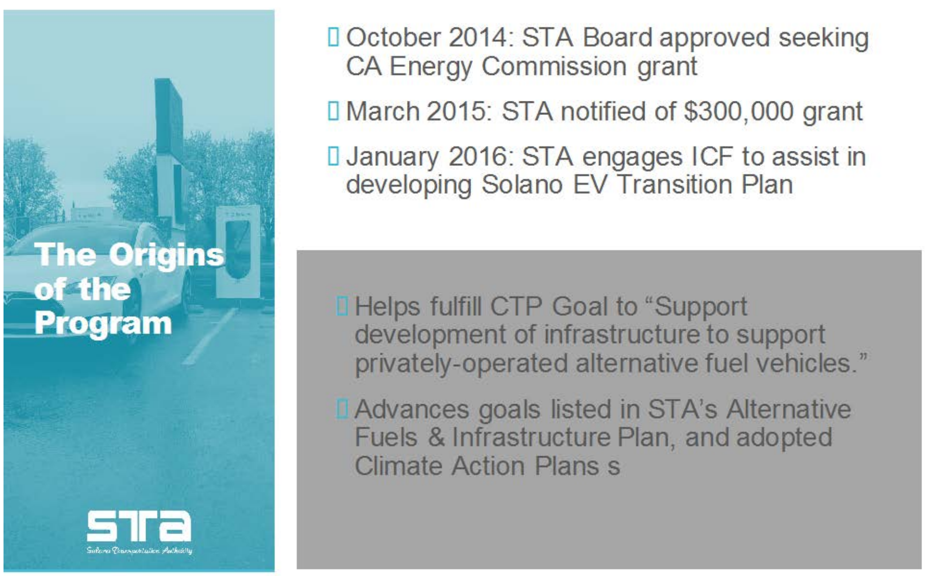
1.5 million EVs on CA roads with easy access to charging stations by 2025

Solano EV Transition Program to assist.

2


AB 1236 Requirements
Requires jurisdictions to enact an ordinance that creates an expedited, streamlined permitting process for EV charging stations by September 2017.
"The ZEV Team in the Governor's Office thanks STA and the Solano jurisdictions for their work on EV infrastructure. The Team is currently working on a charging station guidebook and welcomes the input of Solano jurisdictions. The ZEV Team can be reached on zev@gov.ca.gov"

3


The Origins of the Program
October 2014: STA Board approved seeking CA Energy Commission grant
March 2015: STA notified of $300,000 grant
January 2016: STA engages ICF to assist in developing Solano EV Transition Plan
Helps fulfill CTP Goal to "Support development of infrastructure to support privately-operated alternative fuel vehicles."
Advances goals listed in STA's Alternative Fuels & Infrastructure Plan, and adopted Climate Action Plans s
STA

4

1. **Permitting and Inspection Process**
2. **Installation Process**
3. Electric Vehicle Charging Station Siting
4. Wayfinding Signage
5. EV Awareness and Education
6. **Local Government Code Adoption and Engagement**

5

- Goal is to assist in streamlining permitting processes among Solano County jurisdictions
- Developed a suggested Permitting Checklist
- Host a EVSE Permitting Roundtable Discussion to coordinate efforts
- Case studies of successful EVSE installation available on SolanoEV.org

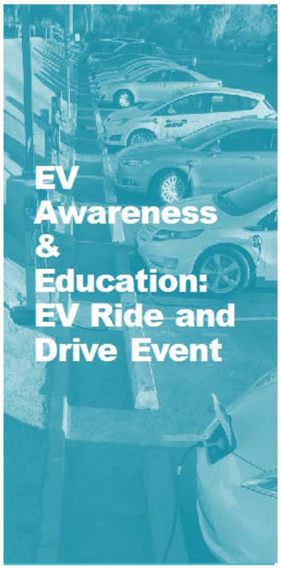
6

- Solano EV Transition Plan will identify areas of high demand for EV Charging Stations.
- Commuter Survey conducted in two rounds: Spring 2017 and Fall 2017. ___ responded to survey on commute habits and opinions of EV's.
- Survey and vehicle registration data will result in heat map of potential EVSE locations.
- Could be used for outreach to potential site hosts in the future as funding for EVSE becomes available.

7

- Solano EV will identify locations for potential signage to EV Charging Stations.
- Many areas lack good signage, and finding EV stations can be difficult.
- Up to 30 locations to be identified.
- Outreach to cities about potential installation, pending future funding opportunities.

8



EV Awareness & Education: EV Ride and Drive Event

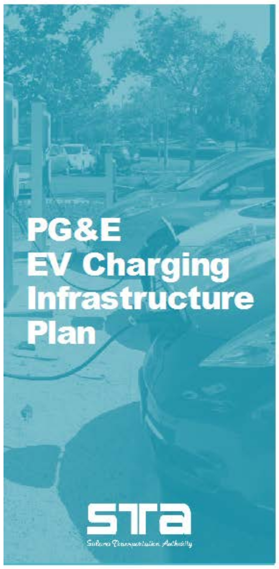
- April 2017 EV Ride and Drive Events
  - Locations: Kaiser Hospital and Genentech, Vacaville
  - Audience: Employees of Kaiser, Genentech, State Fund Insurance, Solano College, and the Public
  - Partners: City of Vacaville, dealerships, EV charging equipment providers
- Gave the general public a chance to try out EV's
- Educate on the benefits of owning an EV
- Events were successful: STA and ICF spoke with hundreds of people about the benefits of owning an EV

9

Next Steps

- STA will continue to work with Solano County's cities and the County to advance EV infrastructure in our county.
- Currently pursuing funding from the BAAQMD for EV Charging Stations in Suisun City, Fairfield, and Vallejo.
- Staff will continue to stay updated on and pursue funding opportunities for EV infrastructure.

10



- Initially proposed adding 25,000 charging units to the statewide network (cost of $654M)
- CA Public Utilities Commission requested multiple amendments to Plan
- Plan approved to add 7,500 charging units (cost of $130M)
  - 15% in low-income areas
  - PG&E to own up to 35% of units
- The EV Transition Program will identify areas of high demand

11

- VW settlement will fund a $2.7B trust called Electrify America
- CA will receive $800M administered by CA Air Resources Board (CARB)
- Primary focus:
  - Installing fast-charge infrastructure
  - Education and outreach
  - “Green City” initiative: Sacramento
- Could bring potential future funding to Solano County

12

- Find more info about the Solano EV Transition Program at SolanoEV.org.
- Intended to be a resource for EV Drivers, Potential EV Owners, Local Governments, and more.
- Let's take a tour now!

SolanoEV.org

13

8. Appendix C. Template for the Planning of EV Ride and Drive Events

Electric Vehicle Ride & Drive Events
Steps to Creating a Successful Event

Getting more Electric Vehicles (EVs) on the road is key to successful mainstream adoption of advanced clean vehicles that support of California's clean air, climate change, energy and economic goals. Consumer access and real-world experience behind the wheel of an EV helps stimulate new prospective buyers and increase EV use.

Ride & Drive events are great ways to introduce consumers to EVs. They can help create awareness of EVs and provide a hands-on driver experience. The goal for an event of this nature is to provide an opportunity for individuals to get a firsthand experience with a variety of EVs to demonstrate the benefits, address potential concerns and perceived barriers and ultimately increase the knowledge and familiarity with these vehicles.

The Ride & Drive event would include:

- Variety of EVs on display
- Opportunity to drive a EV
- Information on EVs and Charging Stations
- Experience at a Charging Station
- Experts to talk with

The steps below will provide a guide of best practices when planning a Ride & Drive Event. Situations may arise where you will need to be flexible and be able to adapt your event to fit with the location host needs and/or dealer involvement.

<u>Selecting a Location for your Event</u>

Identify Charging Infrastructure

When looking for a location, it is important to find a site where charging infrastructure is available at the site or reasonably nearby. You will want the charging experience to be a part of the event.

Identify Large Employers or Locations Holding Existing Events as Potential Sites

- Selecting a location with a built in audience is beneficial to the event and will ensure a larger turnout. If possible select a large employer or company that is already holding a compatible event. Earth Day events are a perfect fit for Ride & Drive events and companies are likely to welcome your involvement.
- When initially reaching out to a company, it is helpful to have a direct contact from someone within your organization to a high level manager to enable you to reach the correct contact with initial support from a superior. If not, then contact the event manager by sending an introductory email (see attached) and then follow-up with a phone call several days later.
- Some sites may have reservations about the liability of holding a Ride & Drive event at their facility. Even though the Ride & Drive Events are usually covered under the dealers' umbrella policy for test drives, some sites may still have concerns. I have included a sample liability waiver that may help ease concerns and provide an additional layer of protection. You should check with your legal department about liability issues and the waiver. If the waiver does not satisfy their concerns you may want to look at other site options or just have the EVs available for viewing instead of driving. Attendees can sit in an EV at a parking spot with a charging station and have a stationary experience behind the wheel with the engine on to demonstrate how quiet it is.

Preferred Sites

A preferred site is at a location where:

- Traffic can be controlled or where traffic is low
- Parking arrangements include parking spaces located in a highly visible area where foot traffic can be controlled
- If possible, park at the charging stations available onsite (you will need to work with the facility to close off selected parking spots the evening before or early the morning of your event before other vehicles use these parking spots).

Work with Location Hosts (Facility Managers or Event Coordinators)

Work with a facility manager or event coordinator at your selected site to determine the best setup for your event.

- Ensure you have access to a facility contact on the day of your event to assist you in making any last minute changes.
- Ask the facility manager or event coordinator about the flow of vehicular traffic and foot traffic.

- Work with the appropriate facility contact to determine the best flow of the event. Will there be directional signs or staff persons the day of the event to direct the flow of traffic?
- Will areas need to be blocked off?
- Does someone need to move barriers to allow vehicles to enter and depart?

Select EV Dealers

Contact your Local Dealers
Once you have selected a location for your event, you will want to select the closest EV dealers to that location to invite.

- Having a large event? It is better to have a large number of dealers on site to maximize the number of rides you can offer.
- Having a small event? You may want to stick to a small number of dealers who will have the opportunity to offer rides to a reasonable number of participants.
- Remember, you don't want a dealer to show up to an event with 10 people and 4 other dealers offering a ride in the same type of vehicle. Make it worth their time.

Encourage Dealer Participation

- Tell them about your target audience
- Tell them how many people you are planning for
- Offer them recognition as a participating dealer. Recognition can be as simple as their name and logo on your event website and a link to their website
- Remember, car dealers are in the business of selling cars, so you want to make the event worth their time. Time is money. Pitch an opportunity where they can market themselves while helping you promote EVs.

Confirm Dealer Contacts
Determine your contact person for coordination of the event and also request contact information for the salesperson who will actually attend the event. Many dealers have a point person for EVs and may already conduct Ride & Drive events on their own.

- The dealer representatives are the "experts" that participants will get direct information about the cars and EVs in general. You want to make sure that knowledgeable sales staff will be on hand during the event.

Additional Considerations for Dealer Involvement

- Ask participating dealers about liability coverage for test drives.
- Do participants need to sign a waiver of liability form prior to test driving a vehicle? Usually dealers only need to see a photo identification of a driver prior to participating in a Ride & Drive event but, check with each dealer to be aware of individual liability policies.
- Ask dealers about their vehicle charging needs. They need enough charge to get to the event, test drive the vehicle with participants, and get back to their dealership.

Select a Route

Some dealers may already have a route that they would recommend for the site, if not then the following are suggestions for selecting a route.

Route Design

- Try to design a route with all right turns or as many as possible.
- Circular routes are preferred.
- Use an EV to test the route.
- Ask dealers to drive the route prior to the event to insure that they know the route and can instruct participants on where to drive, and to insure that the route is appropriate for their standards.

Route Length

- Routes should be anywhere from 3/4- to- 1 mile.
- Select a route where the driver can experience a quarter mile stretch where the driver can go from 35-45 mph.

Once your route is selected, type it up in large, bold font and make copies to be placed on vehicle dashboards. Be sure to make an additional copy of the route for the registration table.

Market your Event

- Market your event through your website and social media.
- Encourage the host facility to include your Ride & Drive event info in all their communications.
- If a public event, distribute a press release.

Day of Event Details

- Have cones on hand. They will be helpful in saving spaces and directing the flow of foot traffic and vehicular traffic.
- Resources onsite should include: copies of the route, EV Fact Sheet, Charging Stations info & locations, Vehicle collateral from dealers (ask for SWAG)
- Some dealers may handle their own registration of participants, but if you are responsible you will need a sign-in sheet (verify info needs with dealers), liability waiver, wristband or marker following registration to show dealers who is eligible to participate.
- To encourage people to come up to your table you should offer some promotional item or giveaway. You can also hold a raffle for those that participate with a prize (like a Fit Bit or other compatible and desirable item) and then promote with a large poster board at your table.
- Bring your camera and take pictures to post on your website and social media.

9. Appendix D. Consumer Survey

Solano Transportation Authority

Solano Commute Options

YOUR TRIP TO WORK (A.K.A. YOUR COMMUTE)

* 1. Typically, how many days in a WEEKdo you make the trip to work and how many do you work remotely?

	Never / Rarely	1 day	2 days	3 days	4 days	5 days	6 days
Commute to work	○	○	○	○	○	○	○
Work remotely	○	○	○	○	○	○	○

1

Solano Commute Options

ABOUT THE VEHICLE THAT YOU USE REGULARLY

* 10. What is the TYPE and MODEL YEAR of the vehicle that you drive regularly?

	Type	Model year
Characteristics		

* 11. If you were to replace your vehicle with a similar newer one TODAY, how much would you expect the monthly payment to be, approximately?

* 12. How many miles per gallon (MPG) do you typically get from your vehicle?

10 MPG or less — 50 MPG or more

13. Do you go on long distance trips (over 100 miles) with this vehicle?

Never ◯ Seldom ◯ Sometimes ◯ Frequently

4

Solano Transportation Authority

Solano Commute Options

ABOUT YOUR PLUG-IN ELECTRIC VEHICLE

16. Which plug-in electric vehicle model do you drive?

If more than one, please pick the one that you drive more regularly

- Audi A3 e-Tron
- Cadillac ELR
- BMW 330e
- BMW 740e
- BMW i3 BEV
- BMW i3 REX
- BMW X5 xDrive
- Chevy Bolt
- Chevy Spark
- Chevy Volt
- Fiat 500e
- Ford C-Max Energi
- Ford Focus Electric
- Ford Fusion Energi
- Hyundai Ioniq
- Hyundai Sonata PHEV
- Mercedes-Benz C350e
- Mercedes-Benz S550e
- Mitsubishi iMiEV
- Nissan LEAF
- Smart Fortwo
- Tesla Model S
- Tesla Model X
- Toyota Plug-in
- Volkswagen e-Golf
- Volvo XC90
- Other

6

Solano Commute Options

YOUR MOBILITY WITHOUT A VEHICLE

23. How often do you use these options to meet your NON-COMMUTE transportation needs?

	Never/Rarely	Seldom	Sometimes	Often
Bicycle	○	○	○	○
Uber, Lyft, or similar	○	○	○	○
Zipcar or similar	○	○	○	○
Public transportation	○	○	○	○

Solano Transportation Authority

Solano Commute Options

ABOUT ELECTRIC VEHICLES

24. Who in your social network drives an electric vehicle?

- [ ] A family member
- [ ] A friend
- [ ] A neighbor
- [ ] A workmate
- [ ] Other
- [ ] No one

25. What words come to mind when you think about electric vehicles?

* 26. Do you think electric vehicles are good for the environment?

No	Not sure	Yes
○	○	○

27. Did you know that the state of California offers rebates to buyers of electric vehicles?

No	Yes
○	○

9

Solano Commute Options

ELECTRIC VEHICLES 101

You can skip this page if you are familiar with electric vehicles.

Electric vehicles are vehicles that use electricity as fuel. They have on-board batteries that are recharged with **charging stations**, which are installed at residences and commercial buildings, and can also be found in many public places.

Running on electricity, electric vehicles don't pollute the air.

There are two types of electric vehicles:

- A **BEV**, or battery electric vehicle, or all-electric vehicle, runs only on electricity from a large battery or series of batteries. The batteries can be recharged at any opportunity site (e.g. home, work) with slower charging stations. For longer trips, charging can be done faster with fast charging stations.

- A **PHEV**, or plug-in hybrid electric vehicle, runs on electricity from a (smaller) battery, and when the battery is exhausted, an efficient gasoline engine kicks in (thus the "hybrid" in their name). For longer trips, they generally rely on their gasoline engine to supplement the electric range.

When charged using **renewable energy** (for example, solar), electric vehicles can have **zero emissions** ***both*** from the vehicle and from the production of the electricity it uses.

Solano Commute Options

MARKET ANALYSIS GAME

In the next page, we will ask you to imagine that you are out shopping for a new car.

We will present you with 8 different scenarios, each with 3 car models. The 3 are comparable in terms of quality and safety.

For each of the scenarios, tell us which vehicle model you would choose.

30. Please pick a number (this is just to randomly assign you a version of the game)

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5

Solano Transportation Authority

Solano Commute Options

MARKET ANALYSIS GAME V.1

The infographic below is for your reference: It explains the meaning of the icons used to describe the plug-in vehicles in the choice scenarios. Once you review it, you are ready to start making your choices.

ICON GUIDE:

80 mi. Electric Range 300 mi. Gas Range	The lightning and droplet ratings tell you how far each model can go on electricity and gasoline, respectively. For BEVs, the gasoline range is zero, because they do not have a gas engine. *In this example, the model can go 80 miles on electricity (with no emissions), and then can switch to gasoline for an additional 300 miles.*
Monthly Payment: $250 /mo	The **Monthly Payment** icon shows the payment amount for each model. Assume a zero down payment.
Savings: 60%	The **Savings** icon tells you how much each model could save you in annual fuel expenses, compared to Model C.
Workplace Charging: OFFICE Yes / OFFICE No	The **Workplace Charging** icon tells you whether or not a free electric vehicle charging station will be available for you at work for each model.
Source of Electricity: Renewable / Grid Average	The **Source of Electricity** icons tell you how clean the electricity is that would be used to charge your plug-in electric vehicle. The **Renewable** icon indicates that the energy would be derived from solar panels and wind turbines, with zero emissions. The **Grid Average** icon indicates that the energy would be derived from average electricity across the grid: 47% Renewable Energy and 53% Fossil Fuel Energy with emissions.

13

Solano Commute Options

LAST PAGE: ABOUT YOUR CONTEXT

The questions in this last page help us understand your personal context, and are very important to do a fair analysis of the information that you and many other Solano commuters are sharing with us.

71. Which of the following most closely describes your residence?

Multi-unit dwelling	Single family home	Other
○	○	○

72. Do you have access to off-street parking where you live?

No	Yes
○	○

Solano Commute Options

THANK YOU!

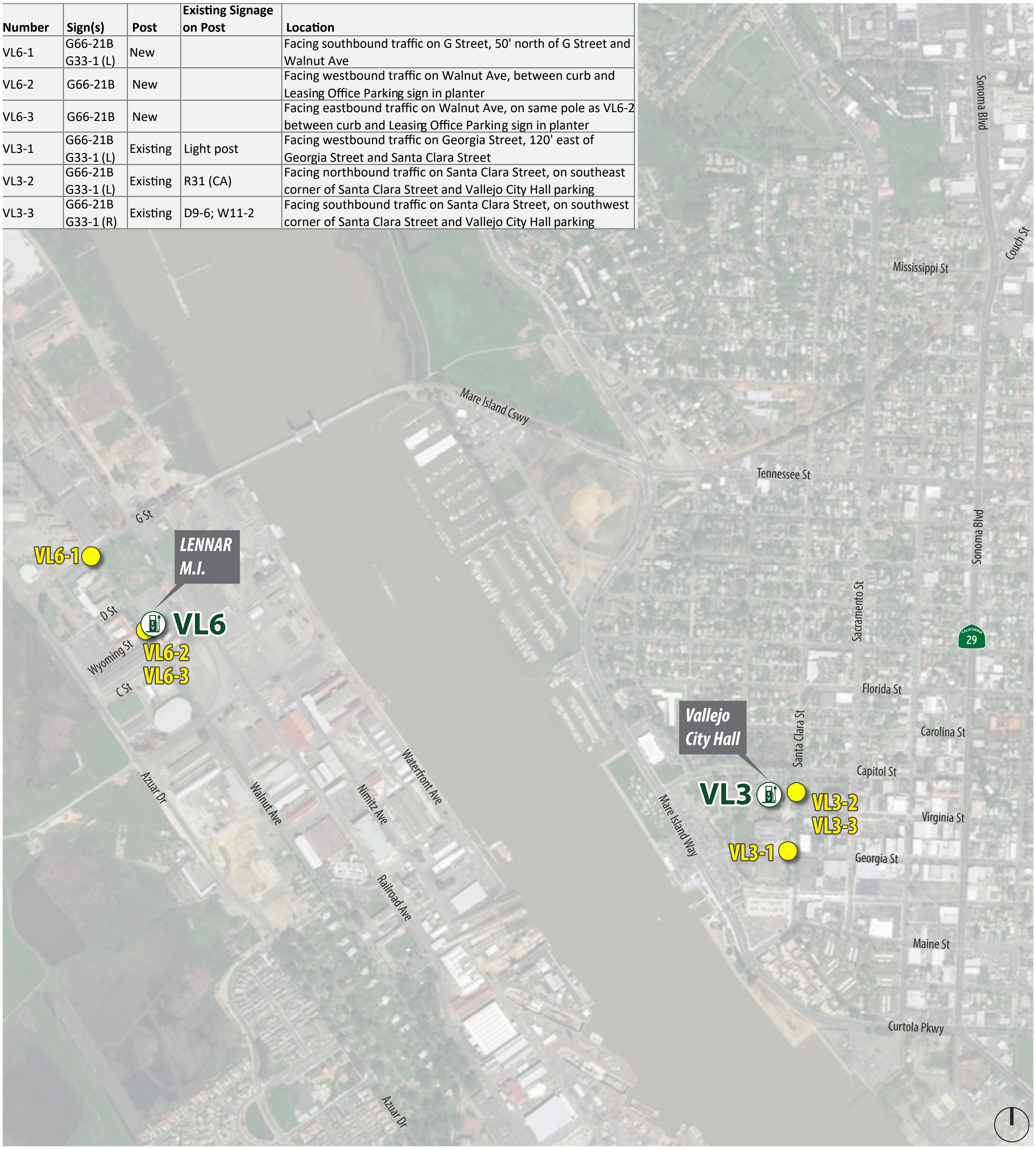
The team at the Solano Transportation Authority appreciates your partnership on helping us understand your transportation experience and needs.

10. Appendix E. Proposed Locations for EV Trailblazing Signs

Number	Sign(s)	Post	Existing Signage on Post	Location
B3-1	G66-21B	Existing	R3-8; R7-1	Facing southbound traffic on 2nd St, 215' north of 2nd Street and Military East
B3-2	G66-21B G33-1 (R)	New		Facing westbound traffic on K Street, 30' from City Hall parking driveway in planter
B3-3	G66-21B G33-1 (L)	New		Facing eastbound traffic on K Street, 30' from City Hall parking driveway
B4-1	G66-21B G33-1 (R)	New		Facing westbound traffic on K Street, 30' from Community Center parking driveway in planter
B4-2	G66-21B G33-1 (L)	New		Facing eastbound traffic on L Street, 30' from Community Center parking driveway in planter
B6-1	G66-21B	Existing	Vista Point	Facing westbound traffic at the northeast corner of Park Road and Industrial Way

Figure B-1

Number	Sign(s)	Post	Existing Signage on Post	Location
VL6-1	G66-21B G33-1 (L)	New		Facing southbound traffic on G Street, 50' north of G Street and Walnut Ave
VL6-2	G66-21B	New		Facing westbound traffic on Walnut Ave, between curb and Leasing Office Parking sign in planter
VL6-3	G66-21B	New		Facing eastbound traffic on Walnut Ave, on same pole as VL6-2 between curb and Leasing Office Parking sign in planter
VL3-1	G66-21B G33-1 (L)	Existing	Light post	Facing westbound traffic on Georgia Street, 120' east of Georgia Street and Santa Clara Street
VL3-2	G66-21B G33-1 (L)	Existing	R31 (CA)	Facing northbound traffic on Santa Clara Street, on southeast corner of Santa Clara Street and Vallejo City Hall parking
VL3-3	G66-21B G33-1 (R)	Existing	D9-6; W11-2	Facing southbound traffic on Santa Clara Street, on southwest corner of Santa Clara Street and Vallejo City Hall parking



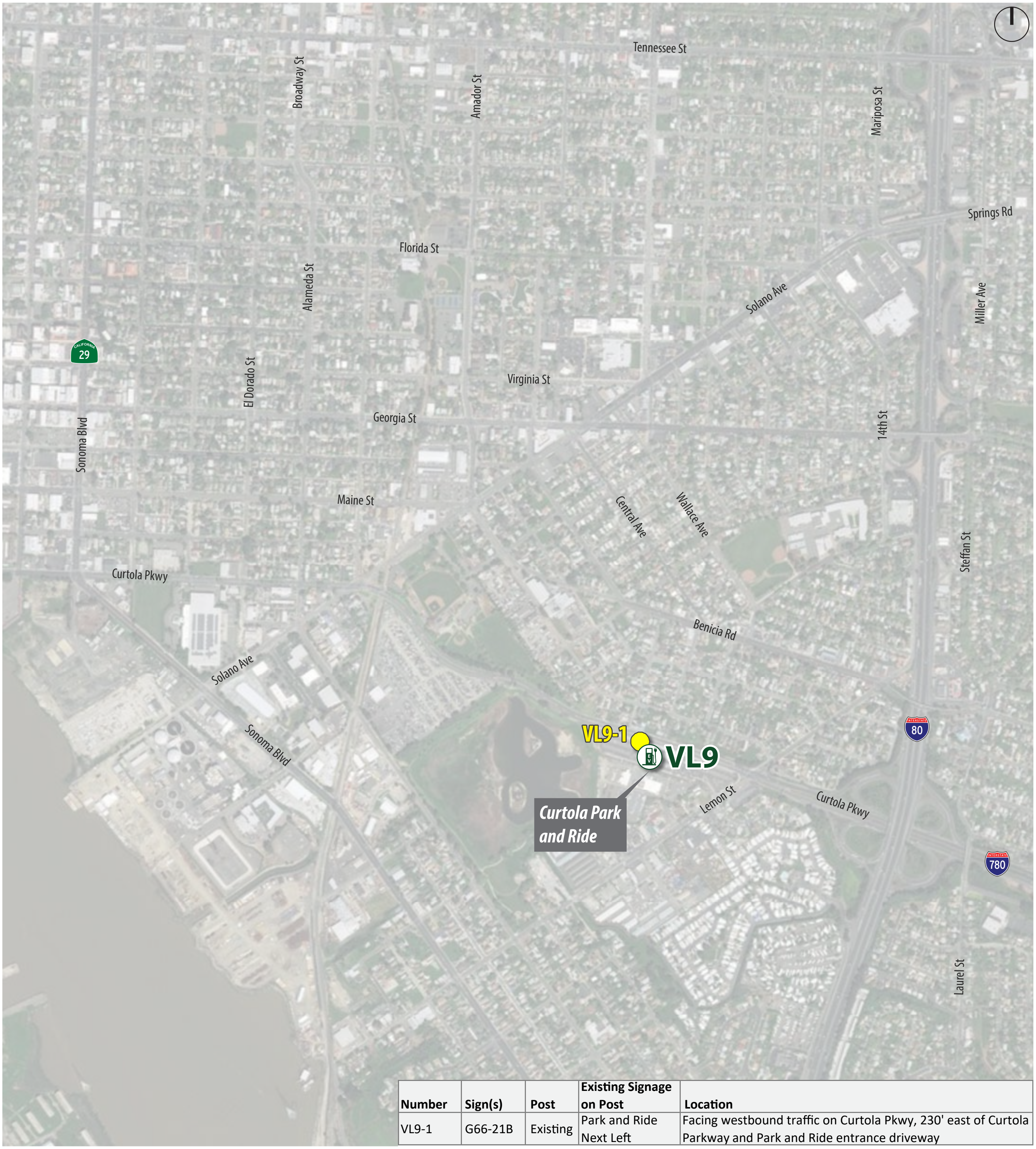
LEGEND

EV Charging Station　EV Wayfinding Sign

Figure VAL-1

Vallejo Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vallejo1



Number	Sign(s)	Post	Existing Signage on Post	Location
VL9-1	G66-21B	Existing	Park and Ride Next Left	Facing westbound traffic on Curtola Pkwy, 230' east of Curtola Parkway and Park and Ride entrance driveway

LEGEND

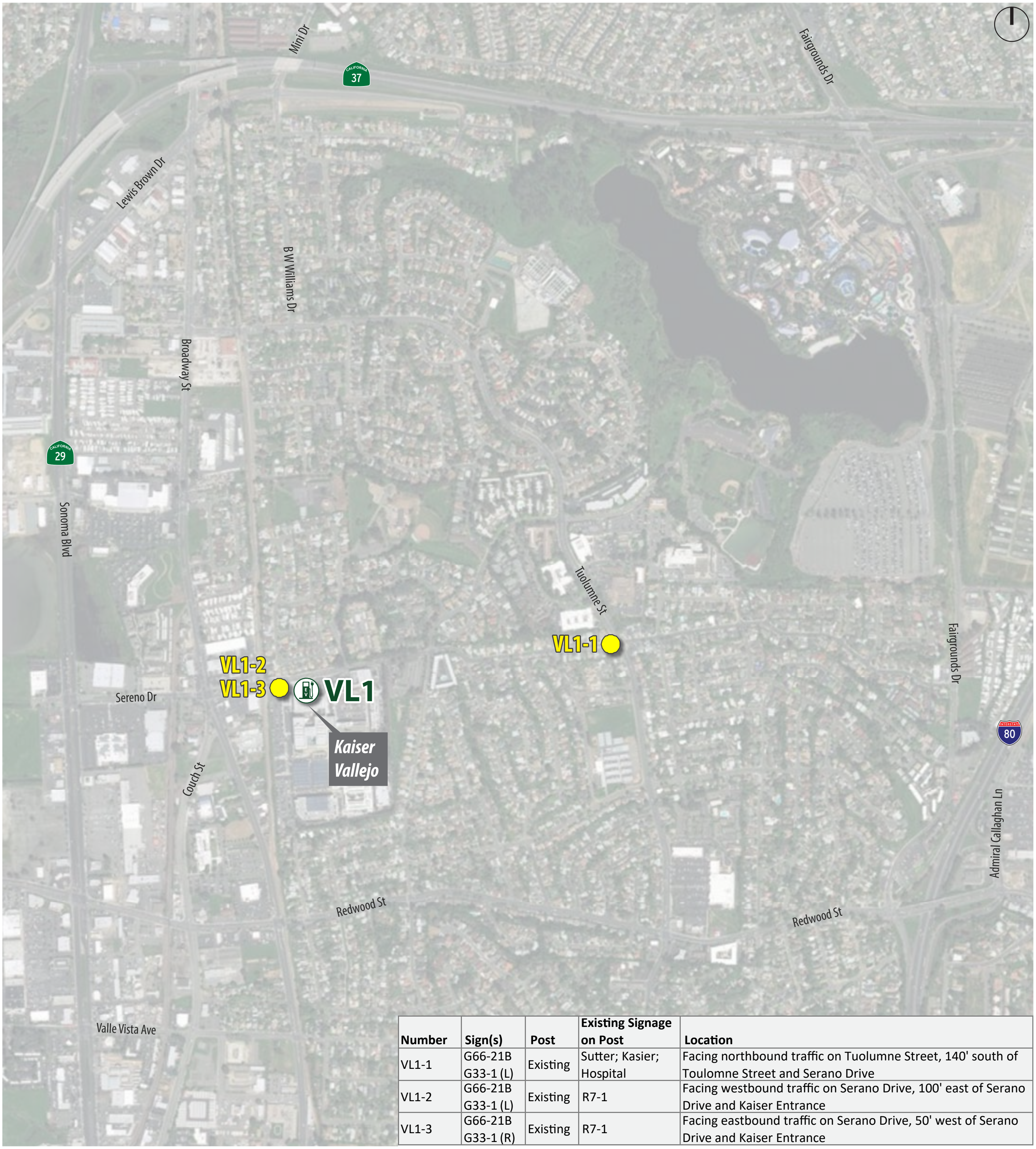
EV Charging Station

EV Wayfinding Sign

Figure VAL-2

Vallejo Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vallejo2



Number	Sign(s)	Post	Existing Signage on Post	Location
VL1-1	G66-21B G33-1 (L)	Existing	Sutter; Kasier; Hospital	Facing northbound traffic on Tuolumne Street, 140' south of Toulomne Street and Serano Drive
VL1-2	G66-21B G33-1 (L)	Existing	R7-1	Facing westbound traffic on Serano Drive, 100' east of Serano Drive and Kaiser Entrance
VL1-3	G66-21B G33-1 (R)	Existing	R7-1	Facing eastbound traffic on Serano Drive, 50' west of Serano Drive and Kaiser Entrance

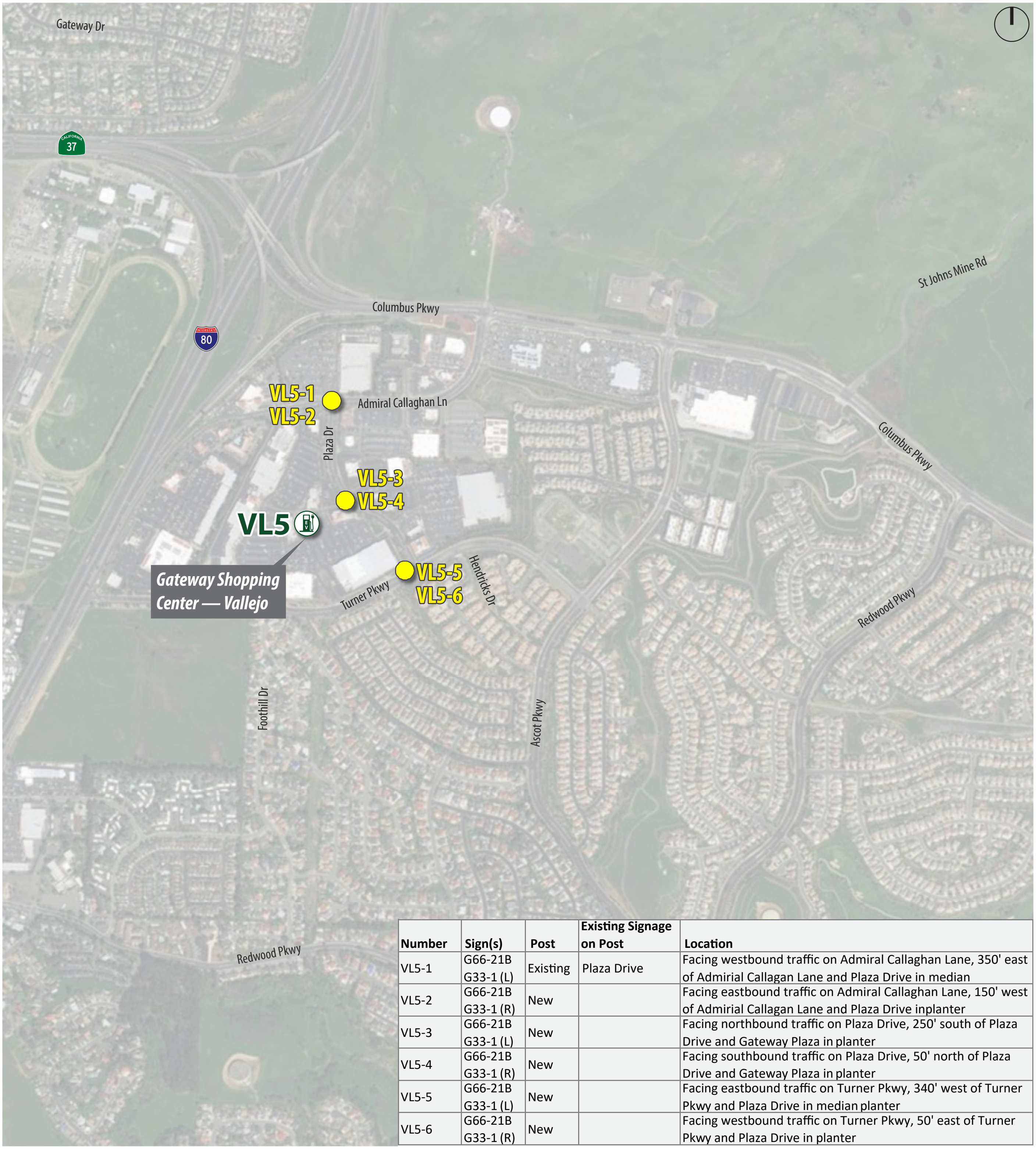
LEGEND

EV Charging Station   EV Wayfinding Sign

Figure VAL-3

Vallejo Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vallejo3



Number	Sign(s)	Post	Existing Signage on Post	Location
VL5-1	G66-21B G33-1 (L)	Existing	Plaza Drive	Facing westbound traffic on Admiral Callaghan Lane, 350' east of Admirial Callagan Lane and Plaza Drive in median
VL5-2	G66-21B G33-1 (R)	New		Facing eastbound traffic on Admiral Callaghan Lane, 150' west of Admirial Callagan Lane and Plaza Drive inplanter
VL5-3	G66-21B G33-1 (L)	New		Facing northbound traffic on Plaza Drive, 250' south of Plaza Drive and Gateway Plaza in planter
VL5-4	G66-21B G33-1 (R)	New		Facing southbound traffic on Plaza Drive, 50' north of Plaza Drive and Gateway Plaza in planter
VL5-5	G66-21B G33-1 (L)	New		Facing eastbound traffic on Turner Pkwy, 340' west of Turner Pkwy and Plaza Drive in median planter
VL5-6	G66-21B G33-1 (R)	New		Facing westbound traffic on Turner Pkwy, 50' east of Turner Pkwy and Plaza Drive in planter

LEGEND

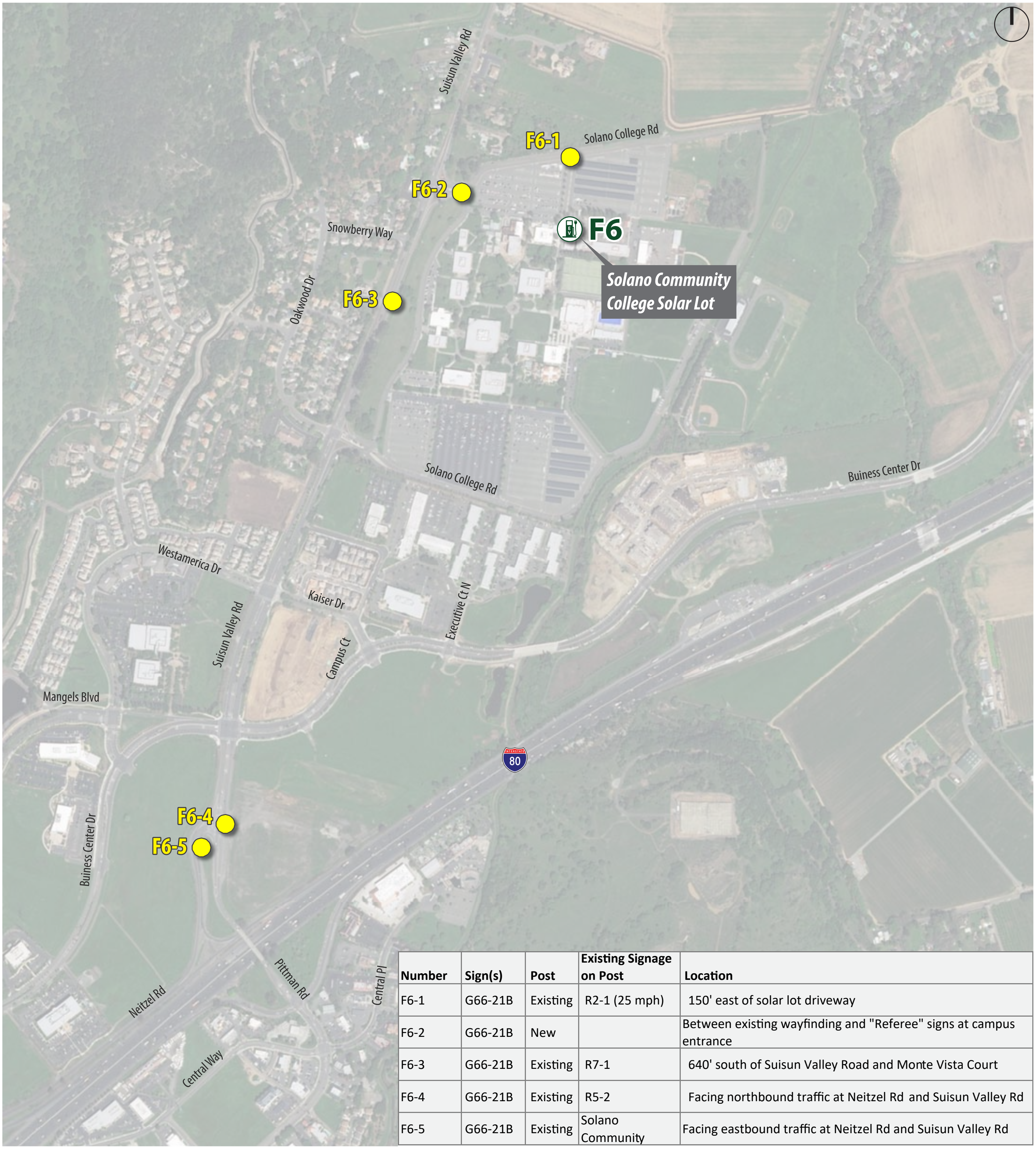
EV Charging Station

EV Wayfinding Sign

Figure VAL-4

Vallejo Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vallejo4



Number	Sign(s)	Post	Existing Signage on Post	Location
F6-1	G66-21B	Existing	R2-1 (25 mph)	150' east of solar lot driveway
F6-2	G66-21B	New		Between existing wayfinding and "Referee" signs at campus entrance
F6-3	G66-21B	Existing	R7-1	640' south of Suisun Valley Road and Monte Vista Court
F6-4	G66-21B	Existing	R5-2	Facing northbound traffic at Neitzel Rd and Suisun Valley Rd
F6-5	G66-21B	Existing	Solano Community	Facing eastbound traffic at Neitzel Rd and Suisun Valley Rd

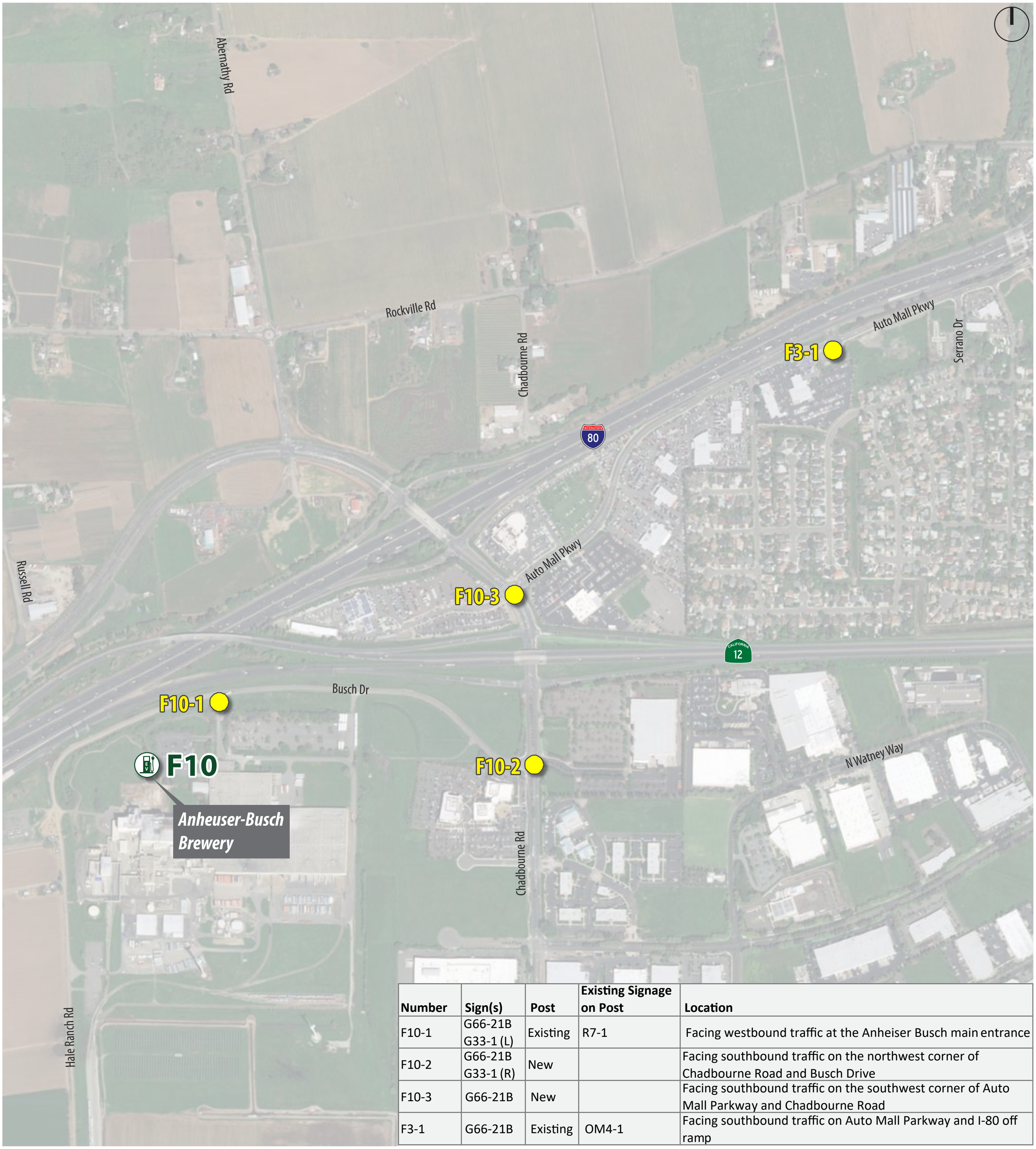
LEGEND

EV Charging Station   EV Wayfinding Sign

Figure F-1

Fairfield Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Fairfield1

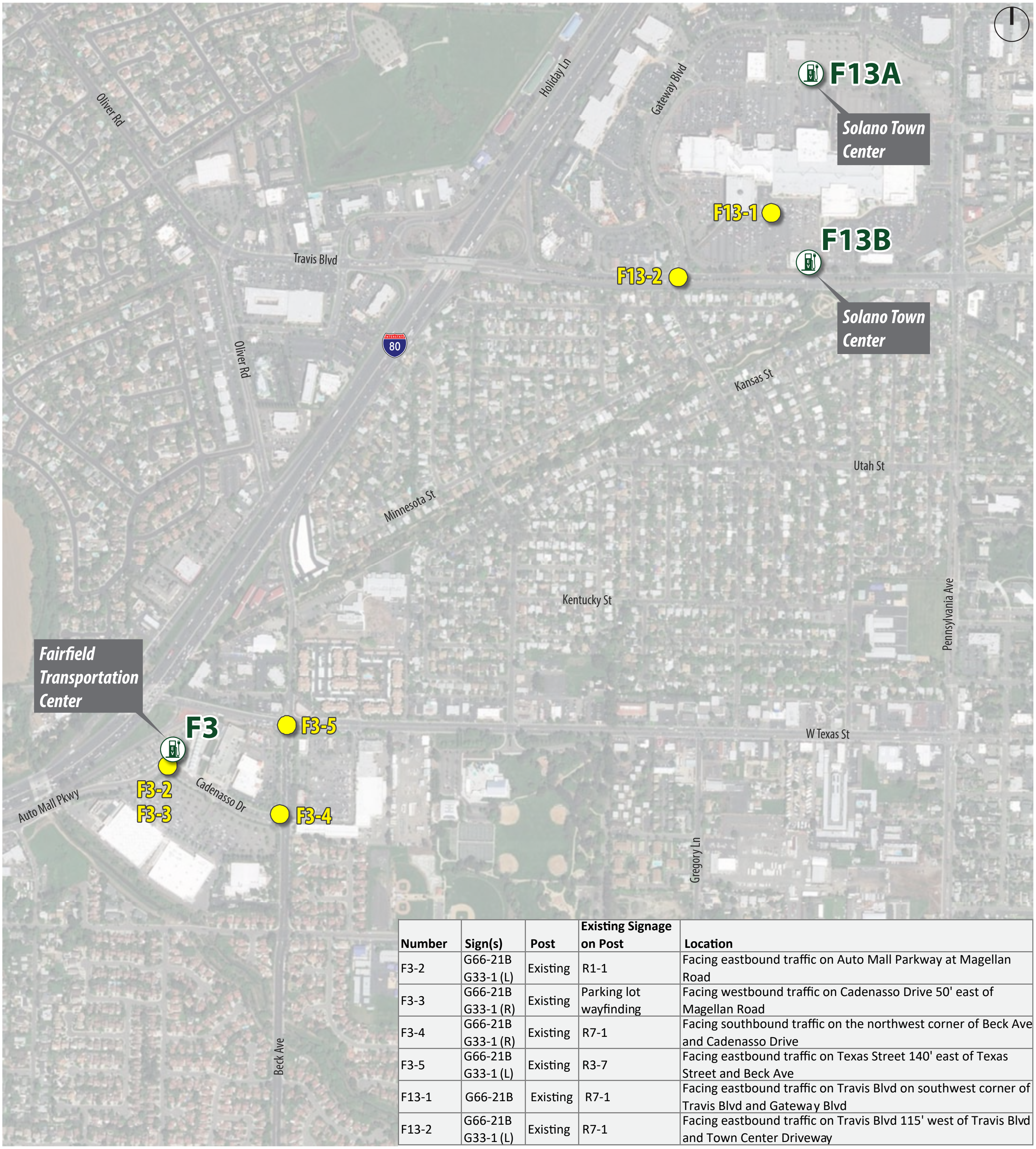


Number	Sign(s)	Post	Existing Signage on Post	Location
F10-1	G66-21B G33-1 (L)	Existing	R7-1	Facing westbound traffic at the Anheiser Busch main entrance
F10-2	G66-21B G33-1 (R)	New		Facing southbound traffic on the northwest corner of Chadbourne Road and Busch Drive
F10-3	G66-21B	New		Facing southbound traffic on the southwest corner of Auto Mall Parkway and Chadbourne Road
F3-1	G66-21B	Existing	OM4-1	Facing southbound traffic on Auto Mall Parkway and I-80 off ramp

Figure F-2

Fairfield Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Fairfield2



Number	Sign(s)	Post	Existing Signage on Post	Location
F3-2	G66-21B G33-1 (L)	Existing	R1-1	Facing eastbound traffic on Auto Mall Parkway at Magellan Road
F3-3	G66-21B G33-1 (R)	Existing	Parking lot wayfinding	Facing westbound traffic on Cadenasso Drive 50' east of Magellan Road
F3-4	G66-21B G33-1 (R)	Existing	R7-1	Facing southbound traffic on the northwest corner of Beck Ave and Cadenasso Drive
F3-5	G66-21B G33-1 (L)	Existing	R3-7	Facing eastbound traffic on Texas Street 140' east of Texas Street and Beck Ave
F13-1	G66-21B	Existing	R7-1	Facing eastbound traffic on Travis Blvd on southwest corner of Travis Blvd and Gateway Blvd
F13-2	G66-21B G33-1 (L)	Existing	R7-1	Facing eastbound traffic on Travis Blvd 115' west of Travis Blvd and Town Center Driveway

LEGEND

EV Charging Station

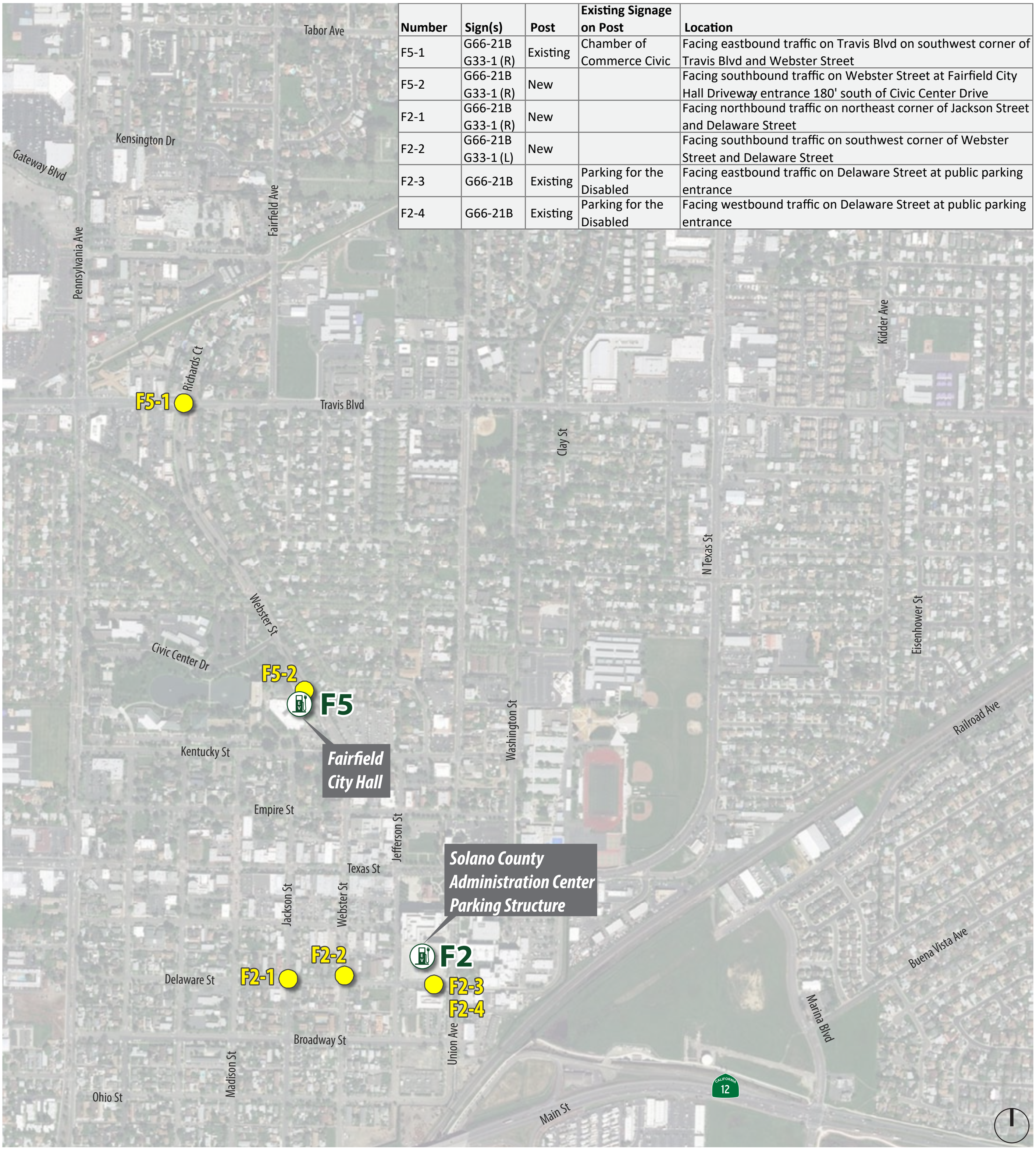
EV Wayfinding Sign

Figure F-3

Fairfield Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Fairfield3

Number	Sign(s)	Post	Existing Signage on Post	Location
F5-1	G66-21B G33-1 (R)	Existing	Chamber of Commerce Civic	Facing eastbound traffic on Travis Blvd on southwest corner of Travis Blvd and Webster Street
F5-2	G66-21B G33-1 (R)	New		Facing southbound traffic on Webster Street at Fairfield City Hall Driveway entrance 180' south of Civic Center Drive
F2-1	G66-21B G33-1 (R)	New		Facing northbound traffic on northeast corner of Jackson Street and Delaware Street
F2-2	G66-21B G33-1 (L)	New		Facing southbound traffic on southwest corner of Webster Street and Delaware Street
F2-3	G66-21B	Existing	Parking for the Disabled	Facing eastbound traffic on Delaware Street at public parking entrance
F2-4	G66-21B	Existing	Parking for the Disabled	Facing westbound traffic on Delaware Street at public parking entrance



LEGEND

EV Charging Station

EV Wayfinding Sign

Figure F-4

Fairfield Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Fairfield4

Number	Sign(s)	Post	Existing Signage on Post	Location
F14-1	G66-21B G33-1 (L)	Existing	R2-1 (40 mph)	Facing northbound traffic on Texas Street 320' south of Walmart driveway
F14-2	G66-21B	Existing	N. Texas	Facing eastbound traffic on Air Base Pkwy 280' from off ramp
F14-3	G66-21B G33-1 (L)	Existing	North Texas St Buiness District	Facing eastbound traffic on Air Base Pkway off ramp 100' from Texas Street
F14-4	G66-21B	Existing	R3-18	Facing northbound traffic on Texas Street in median at Texas Street and Air Base Pkwy ramps

LEGEND

EV Charging Station

EV Wayfinding Sign

Figure F-5

Fairfield Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Fairfield5

Number	Sign(s)	Post	Existing Signage on Post	Location
S1-1	G66-21B G33-1 (R)	Existing	R7-1	Facing westbound traffic on Lotz Way at Park & Ride lot driveway
S1-2	G66-21B G33-1 (L)	New		Facing eastbound traffic on Lotz Way at Park & Ride lot driveway in planter
S1-3	G66-21B	Existing	Traffic signal	Facing southbound traffic on Main Street at northwest corner of Lotz Way and Main Street
S2-1	G66-21B G33-1 (L)	Existing	lightpost	Facing eastbound traffic on Driftwood Drive on northeast corner of Driftwood drive and One Harbor Way parking
S2-2	G66-21B G33-1 (L)	Existing	Light Industrial Services	Facing southbound traffic on Main Street at southwest corner of Main Street and Driftwood Drive
S3-1	G66-21B	Existing	R7-1	Facing southbound traffic on Civic Center Blvd at Suisun City Civic center main entrance
S3-2	G66-21B	Existing	R7-1	Facing southbound traffic on Civic Center Blvd on southwest corner of Civic Center Blvd and Driftwood Drive

LEGEND

EV Charging Station

EV Wayfinding Sign

Figure SC-1

Suisun City Electric Vehicle Charging Stations and Wayfinding

Number	Sign(s)	Post	Existing Signage on Post	Location
V2-1	G66-21B G33-1 (L)	Existing	Light pole	Facing northbound traffic on Merchant Street, 75' south of Merchant Street and Walnut Ave
V2-2	G66-21B	Existing	Vacaville Municipal; R4-7	In existing median of Vacaville Municipal parking lot driveway and Walnut Ave

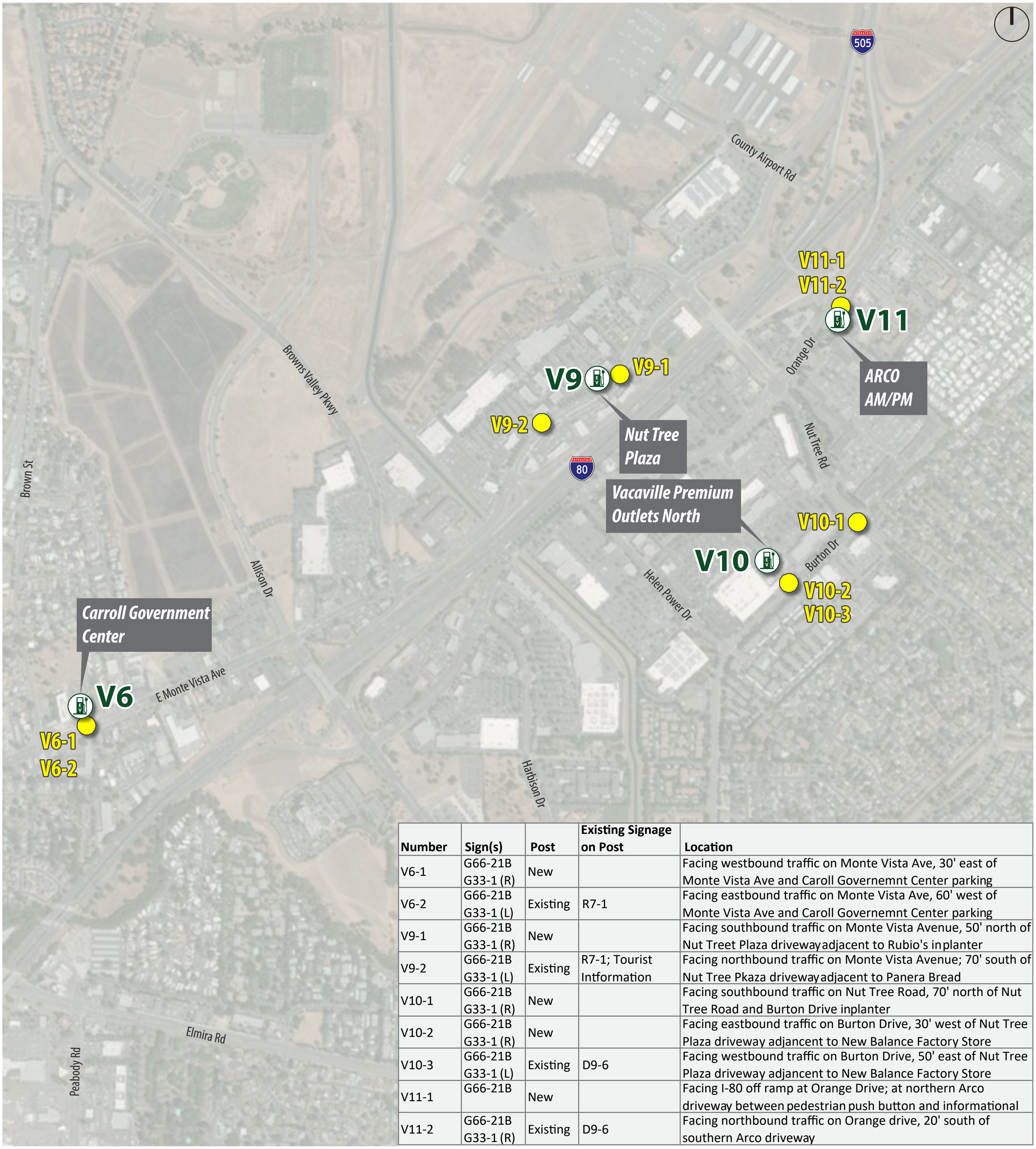
LEGEND

EV Charging Station EV Wayfinding Sign

Figure VAC-1

Vacaville Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vacaville1



Number	Sign(s)	Post	Existing Signage on Post	Location
V6-1	G66-21B G33-1 (R)	New		Facing westbound traffic on Monte Vista Ave, 30' east of Monte Vista Ave and Caroll Governemnt Center parking
V6-2	G66-21B G33-1 (L)	Existing	R7-1	Facing eastbound traffic on Monte Vista Ave, 60' west of Monte Vista Ave and Caroll Governemnt Center parking
V9-1	G66-21B G33-1 (R)	New		Facing southbound traffic on Monte Vista Avenue, 50' north of Nut Treet Plaza driveway adjacent to Rubio's inplanter
V9-2	G66-21B G33-1 (L)	Existing	R7-1; Tourist Intformation	Facing northbound traffic on Monte Vista Avenue; 70' south of Nut Tree Pkaza driveway adjacent to Panera Bread
V10-1	G66-21B G33-1 (R)	New		Facing southbound traffic on Nut Tree Road, 70' north of Nut Tree Road and Burton Drive inplanter
V10-2	G66-21B G33-1 (R)	New		Facing eastbound traffic on Burton Drive, 30' west of Nut Tree Plaza driveway adjancent to New Balance Factory Store
V10-3	G66-21B G33-1 (L)	Existing	D9-6	Facing westbound traffic on Burton Drive, 50' east of Nut Tree Plaza driveway adjancent to New Balance Factory Store
V11-1	G66-21B	New		Facing I-80 off ramp at Orange Drive; at northern Arco driveway between pedestrian push button and informational
V11-2	G66-21B G33-1 (R)	Existing	D9-6	Facing northbound traffic on Orange drive, 20' south of southern Arco driveway

LEGEND

EV Charging Station

EV Wayfinding Sign

Figure VAC-2

Vacaville Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vacaville1

Number	Sign(s)	Post	Existing Signage on Post	Location
V16-1	G66-21B G33-1 (L)	Existing	Solano Community	Facing westbound traffic on Leisure Town Road, 120' east of Leisure Town Toad and Quality Drive
V16-2	G66-21B	New		On Quality Drive at driveway entrance closest to Leisure Town Road in planter
V17-1	G66-21B G33-1 (L)	Existing	D9-6	Facing southbound traffic on Leisure Town Road, at south side of Leisure Town Place Driveway, 290' north of Leisure Town

LEGEND

EV Charging Station   EV Wayfinding Sign

Figure VAC-3

Vacaville Electric Vehicle Charging Stations and Wayfinding

WC17-3442_Vacaville3

Number	Sign(s)	Post	Existing Signage on Post	Location
D2-1	G66-21B G33-1 (L)	Existing	Frontage Rd Dorset Dr	Facing southbound traffic on Lincoln Hwy, 140' north of Lincoln Hwy and Dorset Drive
D2-2	G66-21B G33-1 (L)	Existing	R3-8	Facing eastbound traffic on Dorset Drive 105' west of Dorset Drive and Walmart Supercenter driveway

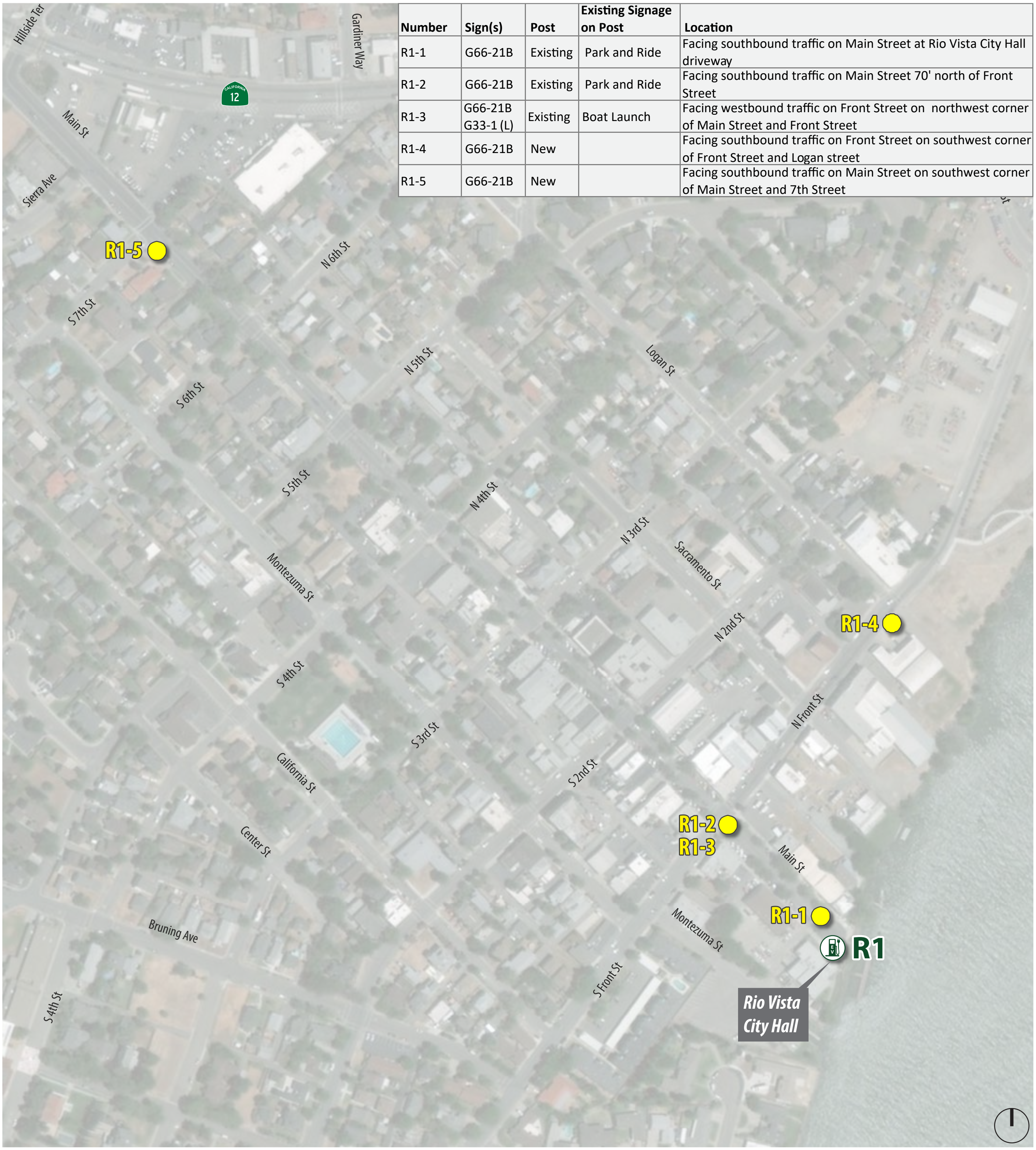
LEGEND

EV Charging Station   EV Wayfinding Sign

Figure D-1

Dixon Electric Vehicle Charging Stations and Wayfinding

Number	Sign(s)	Post	Existing Signage on Post	Location
R1-1	G66-21B	Existing	Park and Ride	Facing southbound traffic on Main Street at Rio Vista City Hall driveway
R1-2	G66-21B	Existing	Park and Ride	Facing southbound traffic on Main Street 70' north of Front Street
R1-3	G66-21B G33-1 (L)	Existing	Boat Launch	Facing westbound traffic on Front Street on northwest corner of Main Street and Front Street
R1-4	G66-21B	New		Facing southbound traffic on Front Street on southwest corner of Front Street and Logan street
R1-5	G66-21B	New		Facing southbound traffic on Main Street on southwest corner of Main Street and 7th Street



LEGEND

EV Charging Station

EV Wayfinding Sign

Figure RV-1

Rio Vista Electric Vehicle Charging Stations and Wayfinding

WC17-3442_RioVista

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ELECTRIC VEHICLE PARKING
ONLY WHILE CHARGING
ELECTRIC VEHICLE PARKING
ONLY WHILE CHARGING
ELECTRIC VEHICLE PARKING
ONLY WHILE CHARGING
SQUARE D


1 HOUR CHARGING
UNLESS OTHERWISE POSTED
ELECTRIC VEHICLE PARKING ONLY
FAST


evconnect


Solano EV Transition Program