VTrans Electric Vehicle Fueling Infrastructure Plan

and Implementation Strategy

Final Report

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Prepared for:

VTrans Working to Get You There
Vermont Agency of Transportation

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Executive Summary

The Vermont Agency of Transportation (VTrans) is working to reduce greenhouse gas emissions from the transportation sector and increase the energy efficiency of Vermont's motor vehicle fleet. This is an important factor in realizing energy efficiency improvements and greenhouse gas reductions detailed in the Vermont Comprehensive Energy Plan (CEP) as well as climate action plans across all levels of government. Electric Vehicle (EV) technology supports these goals by providing low carbon, highly efficient and cost effective transportation.

The Need for Electric Vehicle Charging Equipment (EVCE)

As of April 2013, there were 238 plug-in passenger cars in the state, a small but fast growing fraction of the overall fleet. To support the further increase of EVs in Vermont, VTrans will use the information in this report to select and develop potential sites for EV Charging[1] Equipment (EVCE) located on VTrans owned properties. EV owners are generally expected to charge their vehicles at home overnight, but away-from-home charging will be needed to allow longer trips and increase the suitability of EVs for a variety of users. Availability of public charging is likely to affect consumers' willingness to purchase an EV, particularly for all electric vehicles which do not have gasoline operation capability. Vehicle price, vehicle range, and gasoline costs are also important considerations in EV purchase decision-making.

This report considers needs for public access to electric vehicle charging in Vermont in the coming decade (2013-2023) as well as business models, proposed EVCE locations on VTrans properties and the different types of EVCE available. Conceptual designs for three EVCE installations were developed to further speed VTrans' ability to install EVCE at the identified high priority locations in the next 6-12 months.

Public sector investments in EVCE are common since the current low penetration of EVs makes profitable provision of charging services difficult. As EV use grows the private sector is expected to develop additional charging networks and sites, but public investment is needed in the interim. Using US Energy Information Agency (EIA) projections of EV sales, we estimate that by 2023 approximately 5,600 EVs will be registered in Vermont, requiring 226 public charging stations. Current Vermont EV registrations exceed EIA projections, thus the number of EVCE required in the state in coming years may be even higher. Priority locations for public EVCEs include areas with concentrations of retail, recreation, and public administration services. These destinations commonly have parking durations long enough to allow time for appreciable charging.

The technology, data and costs provided in this report reflect the most current information available at the time of publication. However, in this dynamic and fast-changing market, technology improvements and cost reductions will continue to occur. Therefore the site recommendations provided do not

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[1] While we are using the common term "charging" equipment common industry terminology describes these as Electric Vehicle Supply Equipment (EVSE). We have opted to use the more generally used term charging equipment. The charger actually resides in the vehicle.

consider future cost reductions for charging equipment, especially for Level 3 DC Fast Charging that may make implementation more feasible in some locations. The cost of Level 3 DC Fast Charging, which can provide an 80% charge in 30 minutes or less, has decreased nearly 75% in the past 9 months.

EVCE Equipment

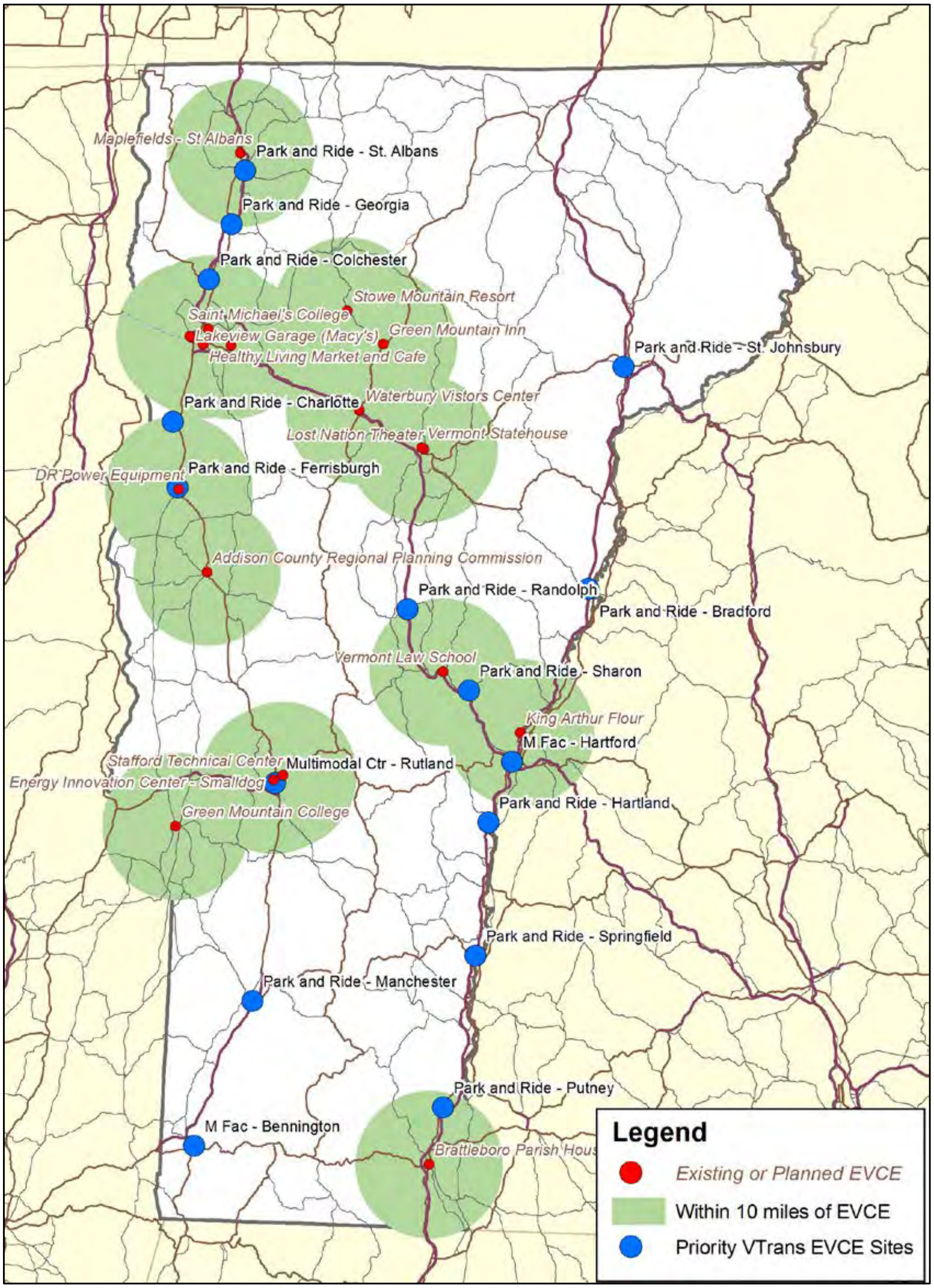
Equipment recommendations are detailed in Chapter 4 of this report. When investing in EV charging equipment, it is recommended that the equipment have remote monitoring capabilities and the potential to assess fees. This will increase flexibility to respond to EV ownership conditions as well as potential future policy changes, such as the need to institute fee collections for charging services as demand increases over time with greater EV market penetration. The ChargePoint equipment in use in several locations across the state has these capabilities. Several other manufacturers offer similar features in their equipment. The EVCE industry is evolving rapidly, with a number of different commercial operators developing fee-based subscription networks for EV owners as well as new technologies and decreased costs. In some locations with lower power level 1 charging, it may be more cost effective to install unmonitored charging equipment, such as standard outlets on light poles at park and ride locations.

EVCE Site Locations

VTrans properties were evaluated for their suitability for different types of charging equipment. Level 3 fast charging equipment, which generally requires three phase high voltage power connections to the electric grid, should be located convenient to high traffic routes. Candidate sites that are owned by VTrans include Interstate Rest Areas, Welcome Centers and VTrans Park and Ride lots. Level 2 charging, which is 208/240 volts (similar to an electric clothes dryer), are ideally located in areas with retail, services or public transit since it may take between 1-7 hours for a vehicle to charge depending on the size of the battery, the charging system capacity, the battery state of charge when charging begins and the desired state of charge at the end of the charge event. Parking areas in Vermont's downtowns and village centers would be excellent locations, but there are few opportunities to establish EVCE on VTrans-owned properties in these locations. Sites owned by other State agencies or municipalities could be well suited for public level 2 EVCE. Level 1 charging, which uses a 120 volt standard outlet, is appropriate where dwell times in excess of 5 hours are expected such as at Park and Ride lots or workplace parking.

VTrans properties were assessed for their suitability for Level 1 and 2 charging equipment installation. Level 1 sites are locations where vehicles typically remain parked for several hours or longer, and provide opportunities for EV users to leave their car while making a trip by carpooling, transit, or other modes. Level 2 sites have similar characteristics, but were also prioritized for locations that close gaps between existing EVCE sites and are accessible to areas with employment and services. Figure 2.3 shows the 25 existing and known planned public EVCE sites in Vermont, as well as the priority VTrans-owned locations for levels 1 and 2 charging equipment. Some of the VTrans Park and Ride lots shown in Figure ES.1.1 are currently at capacity, and may require expansion before installing EVCE. More information is provided in Section 3.3.

Figure ES.1.1: Priority VTrans-owned Sites for EVCE Installation



While these sites should be considered when opportunities arise to install EVCE, there are many additional sites that would also be reasonable locations, and are described later in this report.

There are many considerations in site design, which are described in detail in Chapter 6. These include providing accessible charging, addressing snow removal through design, and maximizing the number of spaces that can access each installation of EVCE to provide the greatest utilization.

Business and Management Models

There are a variety of possible business models available for establishing EVCE which are outlined in this report. A primary consideration is how VTrans chooses to manage an EVCE program. The following are several options for how VTrans may wish to structure future efforts:

1. **VTrans Staff Program Management**. VTrans staff person(s) designated to manage the EVCE program which would go through a typical RFP process for construction.
2. **Consultant Project Manager.** VTrans hires out most aspects of program management to an outside contractor who handles the procurement process, and designates VTrans staff to coordinate this effort.
3. **Contract with private entity to install and operate at little to no cost to the State.** Develop an agreement with an entity like eVgo or CarCharging Group to allow them to use VTrans property to install their own equipment and charge a fee to users. VTrans would receive at least enough payment in return to cover energy supply costs. This approach could require subsidies from the state to establish due to the comparatively light demand anticipated in rural locations at current levels of EV market penetration.

VTrans may wish to consider a combination of these management approaches, with internal VTrans staff program management and funding for short term high priority locations to be completed in 2013, and longer term implementation completed through public-private partnerships, potentially including solar photovoltaic installations as described in Section 6.3

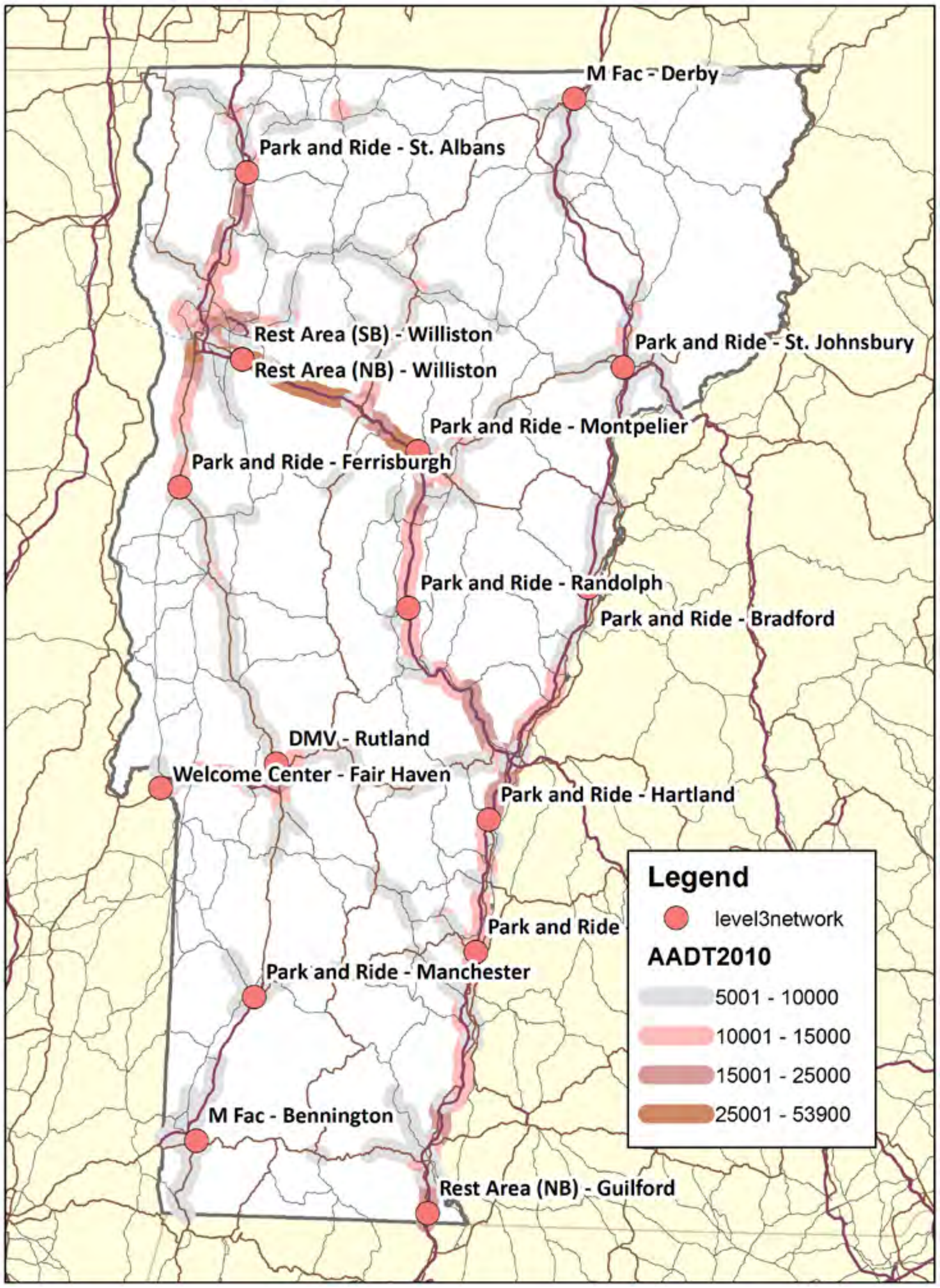
Implementation Plan

VTrans wishes to establish public EVCE on VTrans owned property in 2013. Installation priorities should be selected among the sites on the previous map. The Putney, Hartland, Bradford and Springfield Park and Ride Lots are scheduled for improvements in the next few years, which could include public Level 1 and 2 EVCE. Other sites are ready for installation of EVCE now, including the Rutland Multimodal Center (Level 1 only), and Randolph, Colchester, and Georgia Park and Ride Lots. More detailed investigation of these sites would allow the identification of the easiest and least costly installations, and identify any permitting requirements.

Among the most optimal locations for Level 2 charging, which requires several hours of dwell time, will be downtowns, village centers and growth centers, where retail and other services are available within walking distance, allowing a customer to charge their vehicle while shopping or doing business. Because VTrans generally does not own sites in these types of locations, the agency might consider providing incentives to private or municipal property owners to install EVCE, as these would be important elements in an EVCE plan for the state.

Level 3 charging should be established in a network along major routes, with EVCE spaced every 30 miles to provide flexibility for long distance travelers. Ideal locations will be highly visible and convenient to major routes, similar to gas stations and other roadside services. Because of ongoing price reductions in equipment, it is not recommended that Level 3 be installed in the next year, but VTrans should proceed with identifying a Level 3 network, and planning for installation as the equipment costs stabilize. Figure ES.1.2 shows a map of a possible Level 3 network on VTrans-owned sites.

Figure ES.1.2: Potential Level 3 EVCE Network



1 Introduction to Electric Vehicle Technology

The term Electric Vehicle (EV) used in this report describes a class of automobiles that use electric motors powered by energy drawn from the grid or off-grid electric source into a battery system for propulsion. These battery systems are available in a variety of storage capacities and are plugged in to a source of electrical power to recharge.

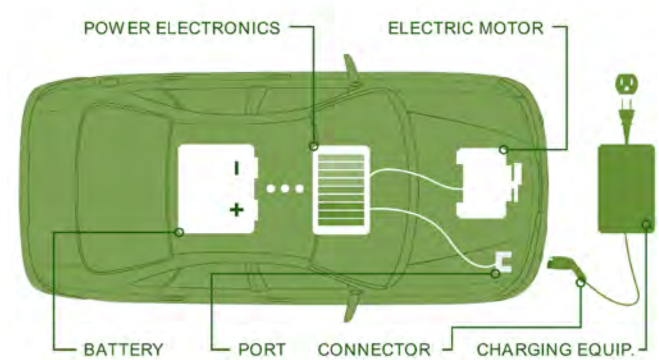
The terminology and acronyms associated with EV technology continue evolving, but many EV design concepts predate the internal combustion engine. In the early 1900's there were more EVs on our nation's roads than gasoline fueled vehicles. Several EV models are currently sold in Vermont and their presence is expected to significantly grow over the next 20 years. Advances in battery storage technology, vehicle weight reduction, the electrical grid and other factors will increase the attractiveness of EVs for consumers, businesses and government agencies.

There are two basic types of EVs:

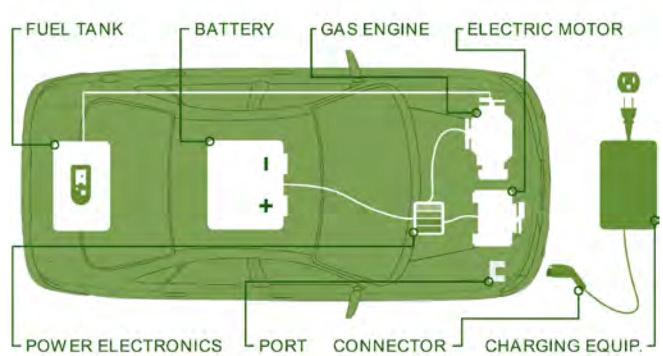
1. **All Electric Vehicles (AEVs)** are powered solely by energy stored in the vehicle's battery system. There is no backup power generation in the vehicle, so when the battery runs out of charge it requires recharging before operating again. The Mitsubishi i-MiEV, Nissan Leaf, Tesla Model S and Ford Focus Electric are examples of AEVs currently registered in Vermont.

2. **Plug-in Hybrid Electric Vehicles (PHEVs)** are capable of operating solely on electric energy for a certain distance after which an auxiliary internal combustion engine is engaged to offer additional range. PHEV's are often categorized according to their range in electric mode. The battery system of a PHEV-10, such as the Toyota Prius Plug-in, has approximately a ten mile electric range while a PHEV-40, like the Chevrolet Volt, has approximately a forty mile electric range. The Chevrolet Volt, Ford C-Max Energi and Toyota Prius Plug-in are examples of PHEVs currently registered in Vermont.

Figure 1.1 Types of Plug-in EVs



All Electric Vehicle (AEV)



Plug-in Hybrid Electric Vehicle (PHEV)

Source: DriveElectricVT.com

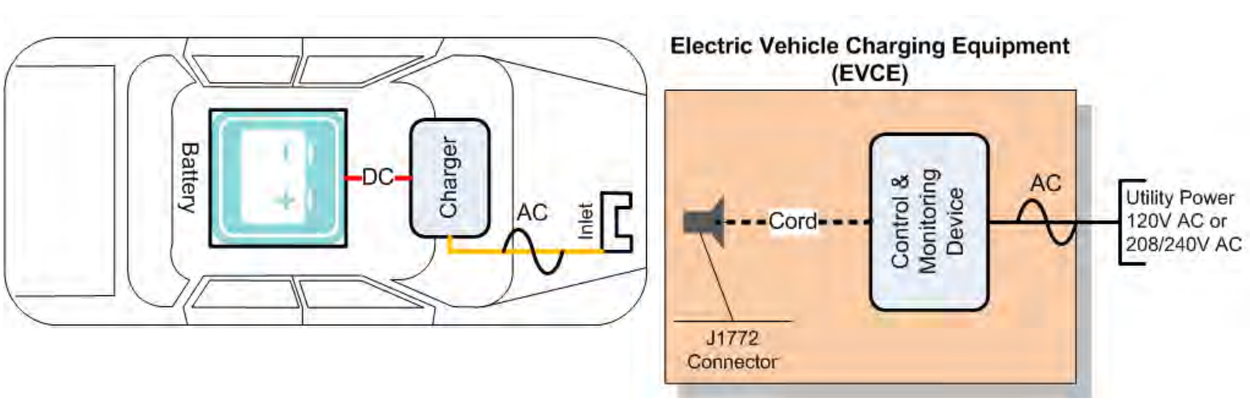
Traditional hybrid vehicles, such as the Toyota Prius, are not considered EVs since they are powered solely by internal combustion engines burning gasoline or other fuels albeit more efficiently than traditional technology in the same vehicle class and do not plug into electrical energy sources to charge battery systems.

One of the greatest barriers to EV adoption is the distance these vehicles are capable of traveling compared to internal combustion engine vehicles without stopping to recharge or, in the case of plug-in hybrid EVs, shifting to a gasoline engine back-up. Whereas a typical internal combustion engine vehicle is capable of traveling 300 miles or more on a single tank of gas, most EVs, other than the Tesla, are not equipped to travel more than 100 miles on a single charge. In Vermont, the average distance a vehicle travels in a day is around 33 miles[1], making the EVs on the market capable of meeting the mobility needs of the majority of Vermonters most days. Despite this ability to meet normal demands, the lower energy storage capacity of EV battery systems compared with internal combustion engine vehicles can still generate concerns of range inadequacy among current and prospective EV owners, particularly for AEVs. This is commonly referred to as "range anxiety".

Adoption of EVs in Vermont has the potential to dramatically reduce the environmental impacts and economic costs of transportation energy use. The transportation sector is the single largest source of greenhouse gas (GHG) emissions and energy consumption in Vermont[2], primarily due to reliance on Internal Combustion Engine (ICE) vehicles to meet the state's mobility needs. EVs use energy as much as three times more efficiently than traditional ICEs and can also be powered by renewable sources of electricity, including hydro, solar and wind power.

Recharging EVs is accomplished through Electric Vehicle Charging Equipment (EVCE), also referred to as Electric Vehicle Supply Equipment (EVSE). This is essentially a protective system which communicates with the vehicle and monitors electrical activity to ensure safe charging. Figure 1.2 is a diagram of the overall charging flow from the power grid, through the EVCE (shaded in orange) and into the vehicle through the industry standard J1772 port connector. With alternating current (AC) EVCE, charger electronics within the vehicle inverts the AC power into direct current (DC) for storage in the battery. Fast charging DC EVCE delivers high voltage (typically over 400 V) direct current straight to an electric vehicle's battery system. While the actual "charger" is contained in the vehicle, the appliance commonly referred to as a charging station or electric vehicle charging equipment (EVCE) is the conduit, control, and monitoring device which connect the vehicle to the electric grid.

Figure 1.2: Electric Vehicle AC Charging Equipment Diagram



There are three levels used to describe the charging power of EVCE:

- **Level 1** uses a 120V AC connection to a standard residential/commercial electrical outlet capable of supplying 15-20 amps of current, for a power draw usually around 1.4 kW when charging. EVs come equipped with Level 1 chargers from auto manufacturers, such as the one shown in Figure 1.3. AEVs with 60-80 miles of range will require 10-14 hours for a full charge using Level 1 EVCE. At Vermont's average residential electric rate of $0.16/kWh, one hour of Level 1 charging would cost about $0.25.

- **Level 2** requires a 208/240V AC connection to supply increased power to the vehicle, reducing the amount of time required to charge the EV battery. Although the J1772 connector specification can handle up to 80 amps of current providing 19.2 kW of power, most current EVs use only 3.3 to 6.6 kW. This is similar to the power draw of an electric clothes dryer appliance. AEVs with 60-80 miles of range will usually require 3-7 hours for a full charge using Level 2 EVCE, depending on the capacity of the EVCE and the vehicle's charging system. Vehicles with smaller batteries, such as a PHEV with 10 miles of range (e.g. Toyota Prius Plug-in) may require less than an hour to reach a full charge. Figure 1.3 includes one model of a Level 2 charger and a J1772 connector. At Vermont's average residential electric rate of $0.16/kWh, one hour of Level 2 charging would cost $0.50-$1.00.

- **Level 3**, also known as DC fast charging, delivers a high volume of DC into EV's battery system, enabling rapid charging. Typically, an 80% charge can be provided in 30 minutes or less for many All Electric Vehicles. Level 3 EVCE is deployed in various locations around the U.S. including an extensive network along the West Coast of the U.S. in Oregon and Washington State, allowing for long distance travel. Level 3 does not use the J1772 connector, instead relying on a CHAdeMO connector or the recently adopted SAE Combo plug, and not all EVs on the market can use Level 3 charging equipment. Figure 1.4 shows examples of the equipment and connectors. The dual standard for connectors may exist for many years, since Nissan and Mitsubishi plan to continue using the CHAdeMO while several American and European manufacturers are implementing the SAE. Many EVCE vendors and charging providers are hesitant to invest in Level 3 equipment due to this issue. Some EVCE manufacturers are developing equipment with both connector types. Tesla has developed their own proprietary DC fast charging system referred to as "Superchargers" which are not compatible with CHAdeMO or the SAE combo equipped vehicles. Recent testing of level 3 equipment by Hydro-Quebec's research group indicated there may be issues with fast charging at very low ambient temperatures. Manufacturers are expected to continue improving equipment capabilities across expected environmental conditions and pilot implementations can further ascertain the extent of any issues. Costs to provide fast charging are highly variable as many utilities charge "demand fees" based on peak electric use (kW) in addition to standard rates on kWh consumed. If the charging station use coincides with the peak usage for the property then demand fees can be assessed.

Figure 1.3: Level 1 and Level 2 EVCE Equipment and Connector

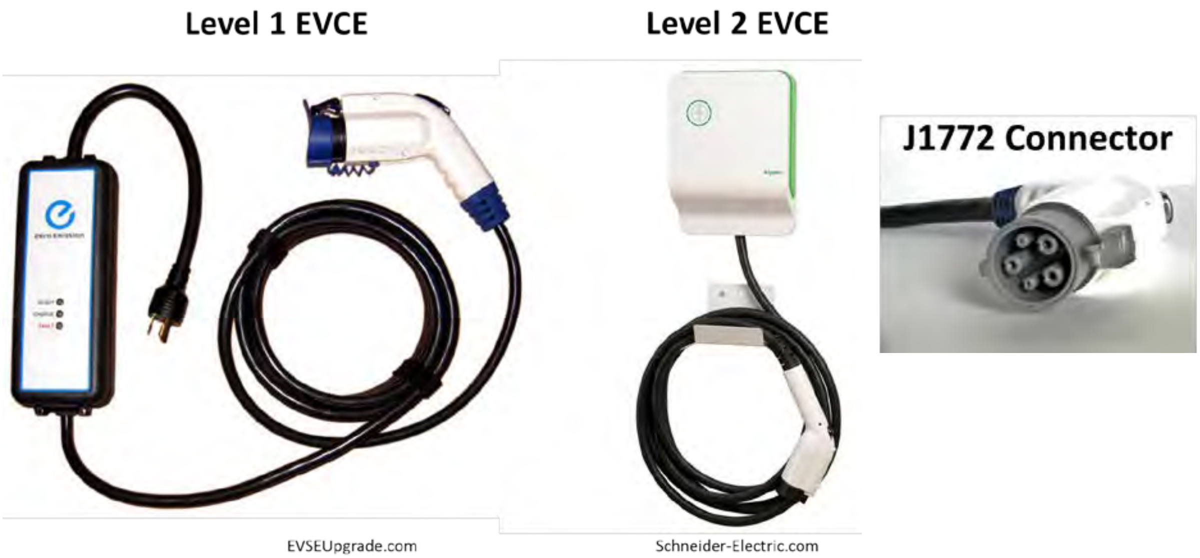


Figure 1.4: DC Fast Charging EVCE and Connectors

2 Vermont Existing and Future EVCE Demand Analysis

2.1 Vermont EV Ownership

As of April 2013, 238 EVs were registered in Vermont, spread across 92 communities. Clusters of EV ownership can be seen along the I-89 corridor from Swanton to Barre and along the New Hampshire border at the southeastern most tip of the state. At this early stage, it is unclear if EV fleet composition in Vermont will mirror national percentages of PHEVs and AEVs over time but the availability of charging infrastructure will likely be a factor in determining consumer willingness to purchase AEVs. EV fleet composition will in turn determine EVCE demand.

Table 2.1: Composition of EV fleet in the U.S. and Vermont, April 2013

EV model type	U.S.	Vermont
AEV	34%	30%
PHEV	66%	70%

The number of Vermont communities with registered EVs continues to grow. Burlington is home to the greatest number of EVs in the state with 14. There are currently 4 towns in Vermont with 10 EVs: South Burlington, Colchester, Rutland, and Montpelier (Figure 2.2). The growing concentration of EV ownership in central and northwestern Vermont indicates a need for regional coordination of EVCE deployment. Vermont EV registrations nearly tripled between July 2012 and April 2013 (Figure 2.1).

Figure 2.1: Vermont EV Registrations, July 2012 - April 2013

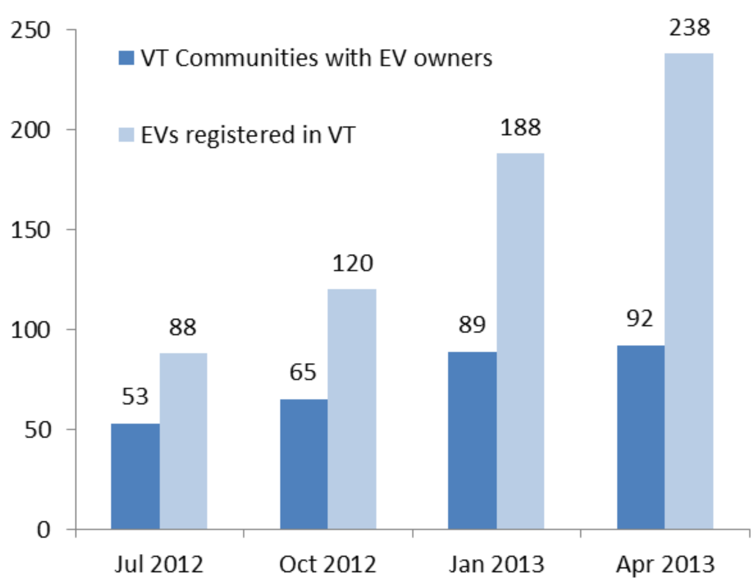
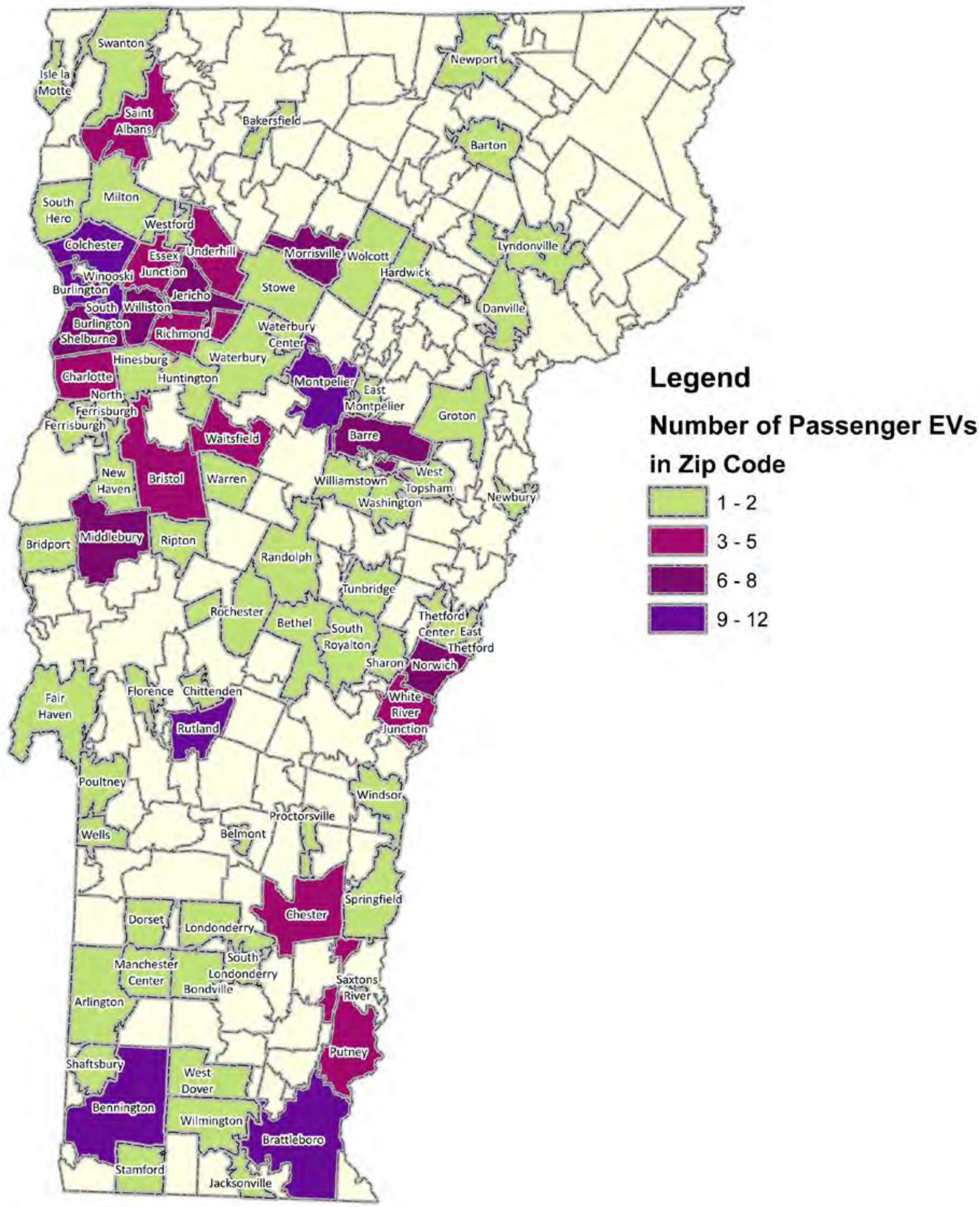


Figure 2.2: Vermont EV ownership by zip code, as of April 2013



Data Source:
Vermont Department of Motor Vehicles vehicle registration database as of April 2013. EVs distinguished by fuel type, model and/or VIN.

The breakdown of EV by model type is presented in Table 2.2. The majority of EVs in Vermont are PHEVs, and the most common model the Toyota Prius Plug-in, with an electric range of 10-12 miles.

Table 2.2: Vermont EV Fleet Characteristics, April 2013

Plug-In Vehicle Type and Electric Range	Number in Vermont[2]
PHEV - 10 mile	108
PHEV - 35 mile	56
AEV - 55 mile	1
AEV - 80-100 mile	32
AEV - 200+ mile	12

2.2 Current Vermont EVCE locations

2.2.1 Existing Public Vermont EVCE locations

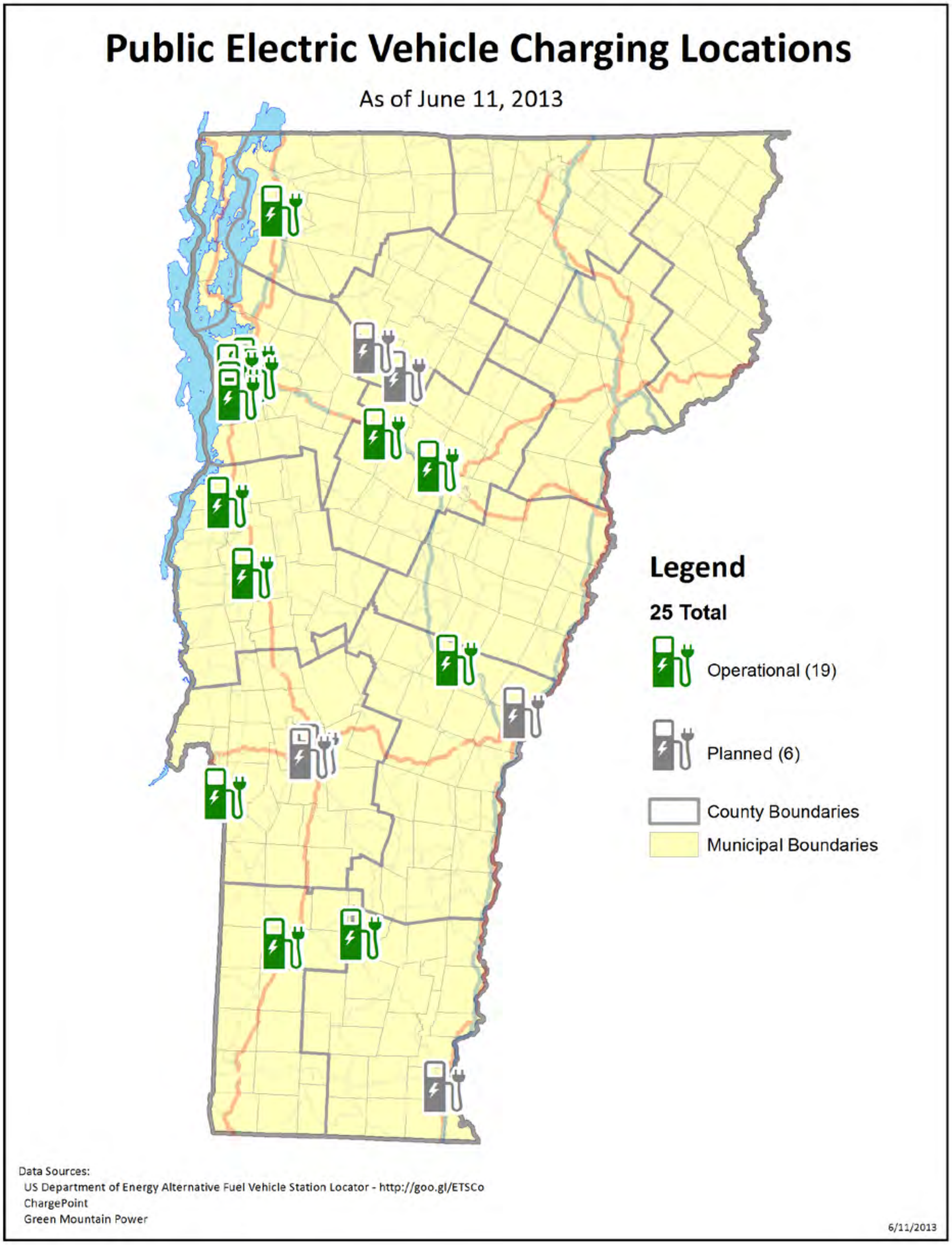
The locations in Vermont where publically accessible EVCE is available are shown in Table 2.3 and Figure 2.3. The great majority of charging is provided free of cost to users and charging activity data is not rigorously collected. Many of these locations are auto dealerships which are required by the auto manufacturers to have EVCE available prior to selling EVs. While several Vermont dealers offer their EVCE to the general public during their standard hours of operation, these are generally only used in critical situations and are noted in the table as restricted access since their availability to the public is limited. Several of the non-auto dealership existing locations were subsidized through a Green Mountain Power program which pairs EVCE with solar photovoltaic panels to offset EV electric use. A number of locations are still in planning with installation generally expected by August 2013.

[2] Electric range of after-market conversions and homemade EVs is not known. Thus 29 vehicles are not classified in this list.

Table 2.3: Vermont Electric Vehicle Charging Locations, Existing and Known Planned, May 2013

	Station Name	City	Level 1	Level 2	Level 3	Restricted Access	Network
Existing							
1	Addison County Regional Planning Com	Middlebury	2	2			ChargePoint
2	Burlington International Airport	South Burlington	1	0			
3	Burlington Church & Main Street	Burlington	1	1			ChargePoint
4	Burlington Mitsubishi	South Burlington	0	2		Yes	
5	City Market - Onion River Co-op	Burlington	0	1		Yes	
6	DR Power Equipment *(fee)*	Vergennes	1	1			ChargePoint
7	Freedom Nissan	South Burlington	0	2		Yes	
8	Green Mountain College	Poultney	1	1			
9	Hand Chevrolet	Manchester	0	1		Yes	
10	Healthy Living Market and Café	South Burlington	1	1			ChargePoint
11	Lakeview Garage (Macy's)	Burlington	2	0			
12	Maplefields - St Albans *(fee)*	St Albans	0	2			ChargePoint
13	Montpelier City Hall	Montpelier	1	1			ChargePoint
14	Mountain Energy of Vermont *(fee)*	Londonderry	0	1		Yes	
15	Saint Michael's College	Colchester	1	1			ChargePoint
16	Shearer Chevrolet	South Burlington	0	1		Yes	
17	Vermont Law School	Royalton	2	2			
18	Vermont Statehouse	Montpelier	1	1			ChargePoint
19	Waterbury Visitors Center	Waterbury	1	1			ChargePoint
Planned							
20	*Brattleboro Parish House*	*Brattleboro*	*0*	*2*			
21	*King Arthur Flour*	*Norwich*	*1*	*2*			
22	*Small Dog Electronics*	*Rutland*	*1*	*2*			
23	*Stafford Technical Center*	*Rutland*	*1*	*1*			
24	*GMP Innovation Center*	*Rutland*	*1*	*1*	*1*		
25	*Green Mountain Inn*	*Stowe*	*1*	*1*			
26	*Stowe Mountain Resort*	*Stowe*	*1*	*1*			
27	*To Be Determined*	*Chittenden County*		*2*	*2*		

Figure 2.3: Vermont Public EVCE Locations, Existing and Known Planned, June 2013



2.2.2 Charging activity at Public EVCE Locations

Several EV charging equipment installations in Vermont are on the ChargePoint network which provides detailed use data, including Saint Michael's College (Colchester), Healthy Living Natural Market and Café (South Burlington), Governor Aiken Ave. and Montpelier City Hall (Montpelier), Church and Main Street (Burlington) and the Addison County RPC (Middlebury). Total monthly energy used from February 2012 to March 2013 at those stations in operation during this time is shown in Figure 2.4 through Figure 2.7. Energy use at the Montpelier charging station was highly variable over this period but was generally higher than the other locations, peaking at over 250 kWh in August 2012. Anecdotal evidence suggests non-EVs are sometimes parking in the EVCE location which prevents potential use at this location. Use at the other three locations examined was generally below 100 kWh each month. Healthy Living Natural Market and Café's EVCE energy use has increased steadily since summer 2012.

Figure 2.4: Montpelier City Hall EVCE Energy Use

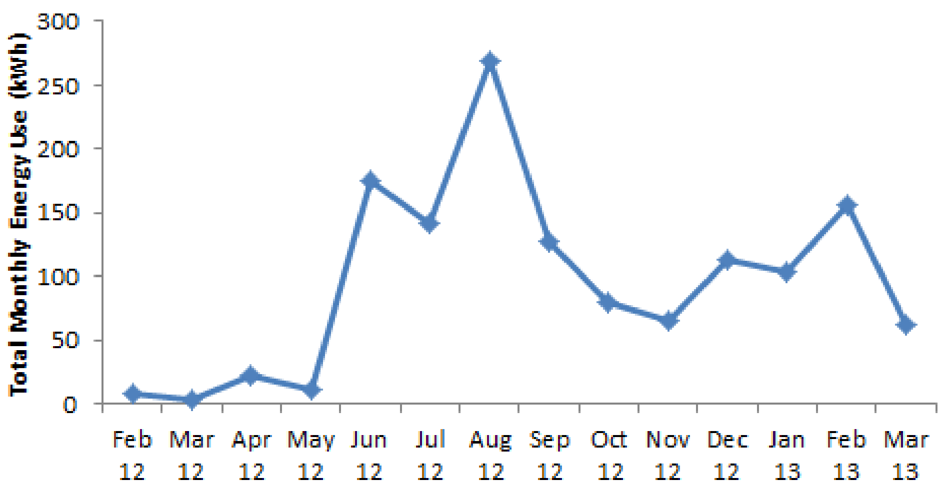


Figure 2.5: Healthy Living EVCE Energy Use

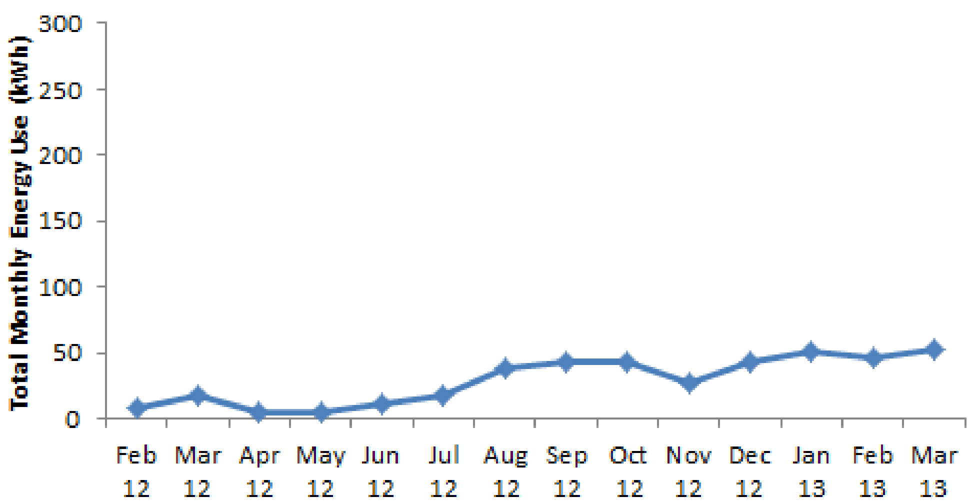


Figure 2.6: St Michael's College EVCE Energy Use

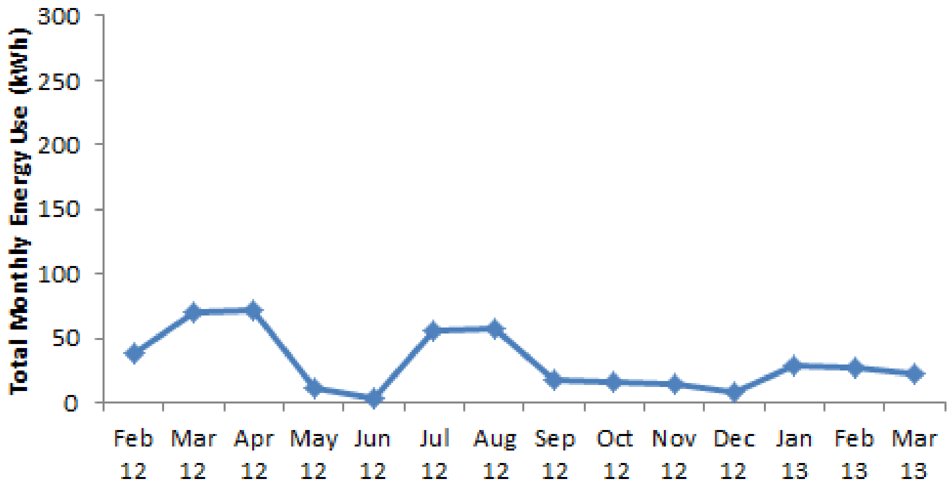
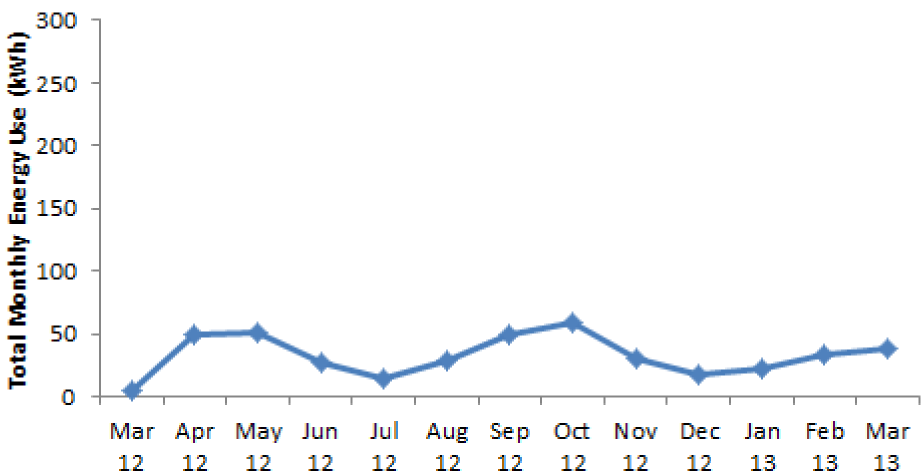


Figure 2.7: Addison County RPC EVCE Energy Use[3]



2.2.3 Distribution of charge timing

EVCEs at Montpelier City Hall and Healthy Living Natural Market and Café are equipped with software that records the details of each individual charge event. Use of EVCE in Montpelier appears to be heaviest on weekdays, peaking in the mid to late morning. Use was less variable at Healthy Living Natural Market and Café, although charging events occurred more frequently on weekdays, and a mid-day peak in charging is apparent. At both locations average charge time exhibited high levels of variability: in Montpelier average charge time was 2:06 (2 hours 6 minutes) ± standard deviation of 2:10, considerably longer than the mean charge time at Healthy Living: 51 minutes ± 55 minutes. At Healthy Living, EVCE use occurs during typical shopping hours and for a duration corresponding to the amount of time one would normally spend at a supermarket.

[3] Addison County Regional Planning Commission; stations funded by US Dept of Energy under grant DE-RW0000257 of the American Recovery and Reinvestment Act of 2009.

Figure 2.8: Daily distribution of charge events, February 2012- March 2013

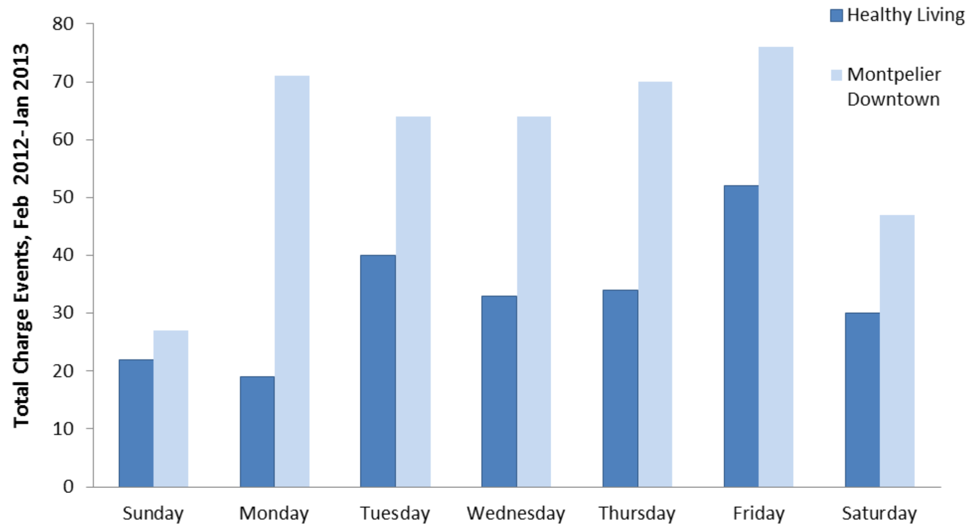
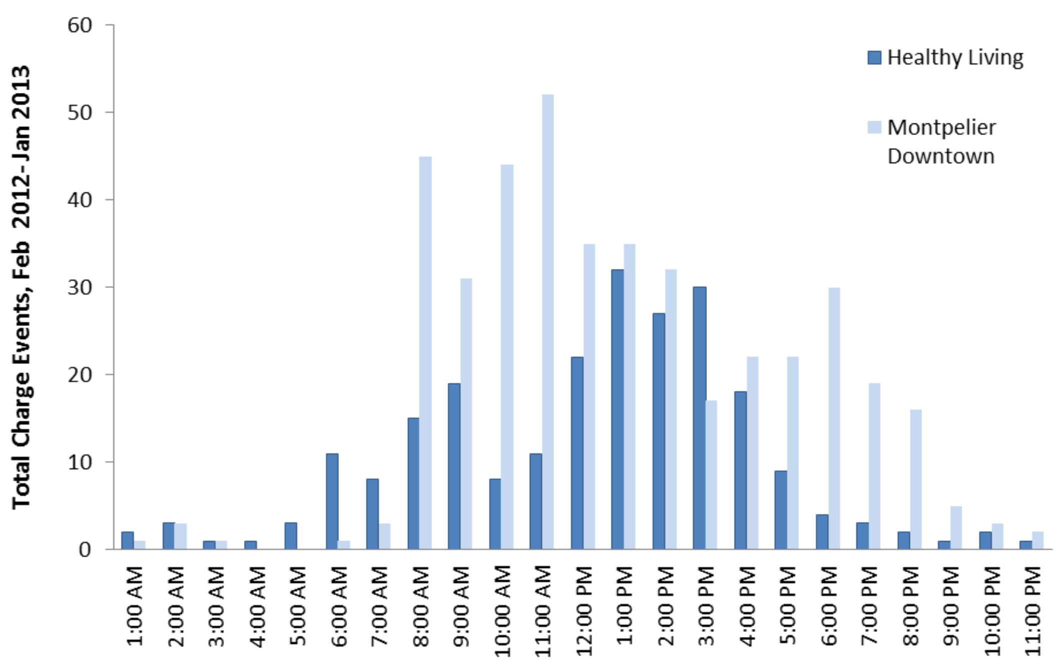


Figure 2.9: Charge event start time distribution at Healthy Living and Montpelier City Hall EVCE



Most AEVs and PHEV-40s currently on the market have sufficient range for typical vehicle tours including trips to and from work with normal stops made along the way[3]. A home tour refers to the entire sequence of trips a vehicle makes in between leaving and returning home. The National Household Transportation Survey (NHTS) reported over 80% of home tours in Vermont to be less than 40 miles[4].

Current and prospective EV owners tend to be more concerned about trip types that fall outside of normal day to day travel and in turn place value in having a network of EVCE available. Experience in regions where there has been greater deployments of EVCE has shown that widespread availability of charging opportunities tends to increase the distance EV drivers are willing to travel between charging but does not always increase use of public EVCE.[5]

Although charging may not be the primary reason for visiting a retail establishment, charging availability at retail establishments has been shown to increase the likelihood of repeat business from EV drivers by 300 percent compared to stores without charging[6]. EV owners also spend nearly twice as long in a store that has a charging station. As EVs become more prevalent, making EVCE available to customers may become a necessity for retailers in highly competitive markets.

2.3 Workplace Charging Availability

After home, the workplace is expected to be the second most common location for electric vehicle charging[7,8]. Although an increasing number of businesses in Vermont are providing EVCE for employees, it is still uncommon for workplaces to have EVCE available other than those providing charging for the public. According to the NHTS, the average commute distance in Vermont is approximately 13 miles and therefore most EV owners will be able to make the round trip journey to and from work in an AEV or PHEV-40 without charging during the day. However, having EVCE available at the workplace expands the utility of EVs, enabling a larger amount of after-work or work-related travel. This will provide a greater margin of range confidence for AEV drivers and reduce the use of backup gasoline engines in PHEVs.

Planning activities involved in the installation of EVCE at the workplace include the following:

- Negotiating sharing of equipment, installation, and energy costs between property owner, employer and employee users
- Establishing agreements for who is able to use it and when (use protocol and mitigating demand charges)
- Assigning responsibility for equipment ownership, repair and removal if necessary
- Evaluating fees for use (if provided free to employees, EVCE may be a taxable benefit)
- Assessing current and projected future demand for charging equipment[9]
- Identifying value added to the building including steps toward LEED green building certification for which installation of EVCE provides points

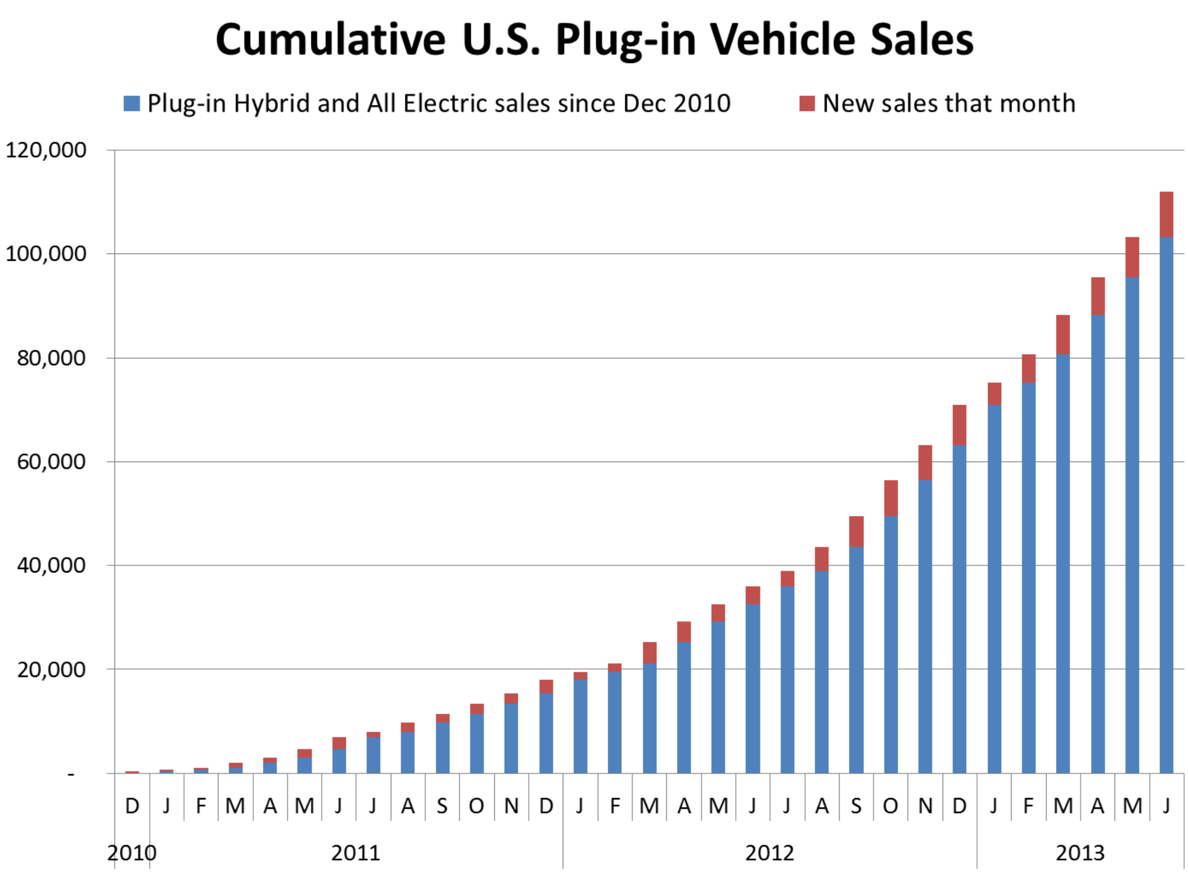
2.4 Future Electric Vehicle Charging Equipment Demand Forecast

Although the EV market continues to develop at a rapid pace, there are data available to allow forecasting of future sales and EVCE demand. In this report we use national projections of EV sales to predict the size of the future EV fleet in Vermont. These projections are examined within the context of Vermont travel behavior and observed travel behavior of EV owners nationwide to predict future demand for public EVCE.

2.4.1 National EV Sales

Sales projections for the nation as a whole were reviewed and developed, working downward to estimate Vermont's share of national totals. We used historic hybrid electric vehicle sales in the state as the basis for our calculations. National sales of EVs have grown over the course of the first two years mass produced models were available in the U.S. National monthly EV sales since December 2010, the first month the Chevrolet Volt was placed on the market in the U.S., are shown in Figure 2.10.

Figure 2.10: National EV Monthly Sales December 2010 to June 2013[10]



Source: EDTA

Projections of electric vehicle sales vary widely. The U.S. Energy Information Administration predicts that just over 1.8 million EVs will be on the road by 2030 under the baseline scenario of moderate increases in oil price, economic growth, and technology development[11]. In contrast, the University of Michigan Transportation Research Institute has projected 3.5 million EVs on the road in the U.S. by 2020 and 15 million on the road by 2030, assuming continued subsidies by the federal government throughout this period.[12]

2.4.2 Vermont Sales Projections

Due to the large variation in projected national EV sales, it is challenging to develop reliable scenarios for Vermont. In Table 2.4 three projections are presented: one adapted from projections developed by the U.S. Energy Information Administration (2013-2023), another provided by the Center for Automotive

Research (2012-2015), and a final estimation from the Vermont Agency of Natural Resources' Air Pollution Control Program. The Center for Automotive Research provides sales projections for each state by estimating national projections of EV sales and then assigning each state a portion based on historic hybrid sales.[13] A similar methodology was used to adapt the EIA's national sales projections for Vermont: projected national EV sales were multiplied by 0.4%, Vermont's share of the national hybrid sales between 2007 and 2009. New EV registrations in Vermont in the fourth quarter of 2012 represented 0.31% of total U.S. sales. Because EV owners are assumed to follow the same demographic as hybrid owners, historic trends in hybrid ownership can be used as a proxy for future trends in EV ownership[14]. It should be noted that as of May 2013, EV ownership has surpassed EIA projections, nationally and in Vermont: the 100,000th EV was recently sold in the US, considerably more than the 12,000 projected by the EIA, and 238 EVs are currently registered in Vermont, more than four times the 50 projected by EIA estimates. Although they appear to be conservative, the EV projections provided by the EIA are the most comprehensive currently available and in wide use.

The Vermont Air Pollution Control projection is based on Vermont's Zero Emission Vehicle (ZEV) regulations. These require vehicle manufacturers to generate ZEV credits for each model year and may utilize a number of vehicle technology types and flexibility provisions to meet their ZEV obligations. Vermont's Air Pollution Control Division, which is responsible for VT's ZEV regulations, estimates that as a result of the ZEV regulations, somewhere between roughly 10,000 and 23,000 EVs will be registered in Vermont through 2023 depending on a number of factors such as which manufacturers are subject to the ZEV mandate, the compliance path taken by each manufacturer, and the annual sales growth rate. Note that this estimate does not take into account certain flexibility provisions in the regulation such as pooling across states participating in the ZEV program.[15]

Table 2.4: Projected National and Vermont EV Ownership 2012-2023

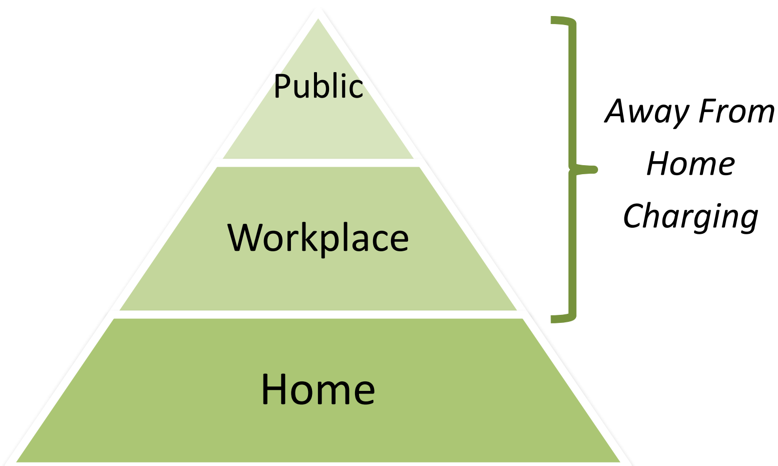
	EV ownership projections (total # EVs on the road)			
	National	**Vermont**		
Year	EIA	EIA-derived, VT	Center for Automotive Research	Vermont Air Pollution Control Division
2013	12,456 *(current registrations = 100,000)*	50 *(current registrations = 238)*	692	
2014	70,256	281	1,180	
2015	130,255	571	1,682	
2016	151,064	885		
2017	203,726	1,386		
2018	273,714	1,980		
2019	283,648	2,520		
2020	308,944	3,216		
2021	362,844	3,972		
2022	395,529	4,798		
2023	419,423	5,649		10,000 – 23,000

A longer term scenario of EV deployment in Vermont can be derived from the state's Comprehensive Energy Plan (CEP), which calls for 90% renewable energy use across all sectors by 2050. An interim objective of the CEP is to have 25% of vehicles registered in the state powered by renewable sources by 2030. Meeting these objectives through the use of EVs powered by renewable electricity would require approximately 143,000 electric vehicles on the road in 2030 and 515,000 by 2050. Achieving these goals through an electrified fleet would require rapid growth in EV registrations in the state.

2.5 Demand for home, workplace and public EVCE

Demand for EV charging at various locations is typically illustrated as a pyramid as shown in Figure 2.11. The majority of EV charging is expected to occur at home during the overnight hours, particularly as more utilities develop Time of Use (TOU) electric rates which provide lower electricity costs at night. Workplace locations are the second most common place for EV charging activity, as vehicles typically have longer dwell times and some drivers may significantly deplete their batteries during daily commutes. Public EV charging has the smallest demand of the three, as most EV drivers should be able to meet much of their daily travel needs by simply charging overnight at home. Although public charging needs are lower, it remains a critical component in the EV ecosystem as it will allow longer trips and reduce range anxiety concerns of potential buyers.

Figure 2.11: EV Charging Activity Patterns by Location Type



EV charging behavior data available through the EV Project, the U.S. Department of Energy and the Western Washington Clean Cities Coalition was examined for this study. The EV Project is a mass deployment of EVCE that has occurred since 2009 in select states across the U.S., supported by the U.S. Department of Energy and ECOtality, a private company specializing in EV charging equipment and services. Until very recently public EVCE installed for the EV Project have been available free of charge, but a new fee system was introduced in the fourth quarter of 2012. At this point it is not clear how payment requirements will affect charging patterns.

Table 2.5 provides the percentages of non-home charging for these three sources. Separate rates for PHEVs and AEVs are provided where available.

Table 2.5: National and Regional Analysis of EV Charging Behavior

Source	Percentage non-home Level 2 charging (PHEV)	Percentage non-home Level 2 charging (AEV)
Western Washington Clean Cities Coalition[16] (No distinction between PHEV and AEV)	22%	
EV Project[17]:		
• Chattanooga, TN:	16%	No data available
• Oregon	16%	16%
• Washington State	12.5%	14%
U.S. Department of Energy (No distinction between PHEV and AEV)[18]	33%	

Battery State of Charge (SOC) is the EV equivalent of the fullness of a gasoline tank in an internal combustion engine. Driving an internal combustion engine, everyone has a level below which they begin to experience anxiety about whether they have sufficient range in their tank to reach a refueling station. Data drawn from the EV project show that on average, drivers of the Chevrolet Volt PHEV-40 in Oregon traveled 25 miles between charge event and drivers of the Nissan Leaf AEV traveled 24 miles between charges[19]. This is an early indicator of the distance EVs drivers are comfortable driving.

2.5.1 Estimating Public EVCE Demand in Vermont

On average, Vermont drivers travel 33 miles per day according to data available through the 2009 National Household Transportation Survey. Therefore, even assuming that EV owners will begin their day with a full charge after plugging in overnight, most will reach a point during the day when they may wish to charge at a location away from home. Based on the data described above that showed on average, EV drivers are comfortable traveling 24-25 miles between charges, extending vehicle range by a little over 8 miles will likely be sufficient for Vermont EV owners. We estimate that acquiring this additional 8 miles of range will take approximately 1.5 hours per vehicle, assuming an average Level 2 charging rate of about 5 kW and factoring in coordination error of EVCE use when someone is parked in the EVCE spot, but not actually drawing power to charge. This approach is based on statewide averages; adequate spatial coverage of EVCE across the state is also an important consideration in this early phase of EV deployment to alleviate range anxiety and ensure the feasibility of long distance travel.

Daily Away from Home Charging Demand per Vehicle (hours) =

$$\text{Distance} \times \frac{}{\text{Vehicle efficiency}} \times \frac{}{\text{Vehicle charger power}} \times \text{coordination error factor}$$

$$\frac{8.12\ \text{miles}}{} \times \frac{\text{kWh}}{3\ \text{miles}} \times \frac{}{5\ \text{kW}} \times \frac{2.5\ \text{hours connected}}{1\ \text{hour of charging}} \approx 1.5\ \text{hours daily charger use per vehicle}$$

Based on the above analysis, EV owners will desire about 1.5 hours of Level 2 EV charging per day at away from home EVCE serving workplaces and general public use or about double this amount for level

1 charging. Over the course of an 8 hour workday (9 a.m. – 5 p.m.), each Level 2 charging equipment space can serve approximately 5 vehicles (8 hours / 1.5 hours per vehicle ≈5.8 vehicles per EVCE). **This results in an estimated demand of 0.17 away from home EVCE for every EV (1 / 5.8 vehicles per EVCE).**

The number of plugs needed at each charging station will vary with the amount of overall and EV traffic each location receives. New installations of EVCE are recommended to install at least two Level 2 ports to provide redundancy in case of equipment failure or use by other drivers.

Away from home EVCE includes both workplace and public charging locations. To estimate the need for public charging (non-workplace and non-home), we used Dun & Bradstreet employment data to identify non-home locations where public EVCE would be desired. These employment types are detailed in the location prioritization discussion that follows, but generally included retailers, entertainment and recreation, personal services, and public administration employers which have visitors over the course of the day. These destination types have an expected dwell time long enough to allow an appreciable amount of charging. Approximately 25% of all Vermont employees work at these establishments. This fraction allows for an estimate of how much non-home charging will be desired statewide since the number of employees is generally directly proportional to the number of vehicle trips made to a non-home location.

Vermont Public EVCE per EV =

$$\frac{0.17\ \text{away from home EVCE}}{\text{vehicle}} \times \frac{25.2\%\ \text{public charging employment fraction}}{} = \frac{0.04\ \text{public EVCE}}{\text{vehicle}}$$

Table 2.6 provides estimates of the number of EVCE needed under the two scenarios of EV ownership considered. These estimates vary widely, as would be expected due to the variation in EV projections. Estimates were not available for all years from all data sources. The most complete projections are available from the EIA. According to these estimates, the state will require 79 public charging stations by 2018 and 226 by 2023. These values are considerably lower than the number estimated using EV projections from the Center for Automotive Research. Using values from the Center for Automotive Research, we estimate 67 public EVCE will be needed by 2015. As noted earlier, the EIA projection of EV registrations in Vermont in 2013 is lower than the number of EVs in the state as of April 2013 (50 EVs vs. 238).

The 238 EVs registered in Vermont as of April 2013 are projected to require 10 public EVCE, considerably more than the 2 listed in Table 2.6, but slightly less than the 19 existing public EVCE sites, 6 of which have restricted hours of operation. As described above, this analysis addresses the number of public EVCE required based on statewide averages of vehicle performance and desired range extension. Although there appears to be an adequate number of EVCE at the present time, there are still large geographic gaps in EVCE coverage due to the rural nature of our state, most notably in northeastern Vermont. Additional EVCE would likely serve to reduce range anxiety concerns of potential EV owners and help advance the state's goals to reduce transportation energy use and pollution. In addition we expect the number of EVs registered in Vermont to increase in the future as discussed in section 2.4.2.

Table 2.6: Projected Public EVCE Demand in Vermont

	Estimated # Public EVCE needed in Vermont		
Year	EIA-derived	Center for Automotive Research	Vermont Air Pollution Control Program
2013	2	29	.
2014	11	47	.
2015	23	67	.
2016	35	.	.
2017	55	.	.
2018	79	.	.
2019	101	.	.
2020	129	.	.
2021	159	.	.
2022	192	.	.
2023	226	.	400 - 920

2.5.2 Charging Demand Analysis Conclusions

Research shows the bulk of EV charging occurs at home and this is expected to continue. However, many Vermont EV drivers will want to extend their range by charging away from home over the course of the day. An analysis of charging data from other states and Vermont travel patterns suggests an average EV operator in the state will want to plug-in during the day to get another 8 miles worth of travel energy stored. This will require 0.17 public EVCE per vehicle. Using EIA estimates of EV projections for 2023, this would require 226 public EVCE spread across the state, or using estimates from Vermont ANR there is demand for 400-920 public EVCE. Each location should have at least 2 charging connectors in case of equipment malfunction or use by other drivers.

3 VTrans EV Charging Location Prioritization

In order to facilitate the expansion of EV travel and use, VTrans is seeking to install charging stations on property owned by the agency. A review of potential sites has been conducted considering locations that will most likely have charging demand[20, 21,22]. The following sections outline the site characteristics that would be most suitable for public charging, and then applies these criteria to VTrans owned sites.

3.1 Site Selection Criteria

The ideal site for charging will depend first on the type of equipment provided. Table 3.1 compares the desirable characteristics for levels 1, 2 and 3 public (away from home) charging stations.

Table 3.1: Attributes for EVCE site locations

	Level 1	Level 2	Level 3
Typical Duration of Charge Event	6-10 hours	1-3 hours	15-30 minutes
Typical Users/Uses	▪ Employee parking during the work day ▪ Long term (8+ hours) parking at a commuter lot, charging while on a carpool, walking or transit trip	▪ Charging in a commercial area while shopping or doing business ▪ Shorter term (3-6 hours) parking at a commuter lot, charging while on a carpool, walking or transit trip	▪ Fast charging while on a long trip in order to reach a destination or extend the length of a trip.
Desirable Characteristics	▪ Security ▪ Transit Service ▪ Workplaces	▪ Transit service ▪ Pedestrian facilities ▪ Shopping, dining, banking etc. within walking distance.	▪ Amenities at the charging site (food, coffee, Wi-Fi)
Priority Locations	▪ Park and ride lots ▪ Long term parking ▪ Communities where EV ownership is more prevalent	▪ Municipal or private parking lots and park and rides in or adjacent to downtowns, village centers, growth centers or shopping centers.	▪ Adjacent to high volume roadways

3.2 Site Selection Criteria for Level 1, 2 and 3 charging

Optimal siting of public EVCE must account for projected demand as well as cost effective use of infrastructure. Ideally, public EVCE will be located close enough to one another such that adequate coverage of a region is achieved, while avoiding redundancy and under-utilization of stations[23]. Broadly, the criteria we propose for public siting of EVCE include:

- Availability of power
- Site with parking capacity, preferably paved to facilitate the demarcation of EV charging spaces

- Proximity to high traffic corridor
- Proximity to employment / destinations
- Potential to link with transit and other modes of transport such as biking, walking and car-pooling (e.g. Park and Rides)
- Locations that will fill the gaps in charging coverage (between 10 and 30 miles from the closest EVCE)
- Location along the Green Highway corridor, along I-89 and I-91 between the I-89 interchange and exit 13

Table 3.2 provides the charging rates and dwell times for each type of EVCE, as well as the typical installation costs.

Table 3.2: EVCE Type, Charge Rate, and Cost

EVCE Type	Charge Rate	Typical Dwell Time	Typical Cost Range
Level 1	~14 minutes/mile of driving	8+ hours	$230-1,350
Level 2	~3-6 minutes/mile of driving	2-4 hours	$7,000-21,000
Level 3	~24-48 seconds/mile of driving	15-30 minutes	$45,000-$85,000

The majority of public charging installed over the next several years is expected to be Levels 1 and 2. Level 3 charging is more expensive at present and not all vehicles are able to use the same equipment, as the technology is still emerging.

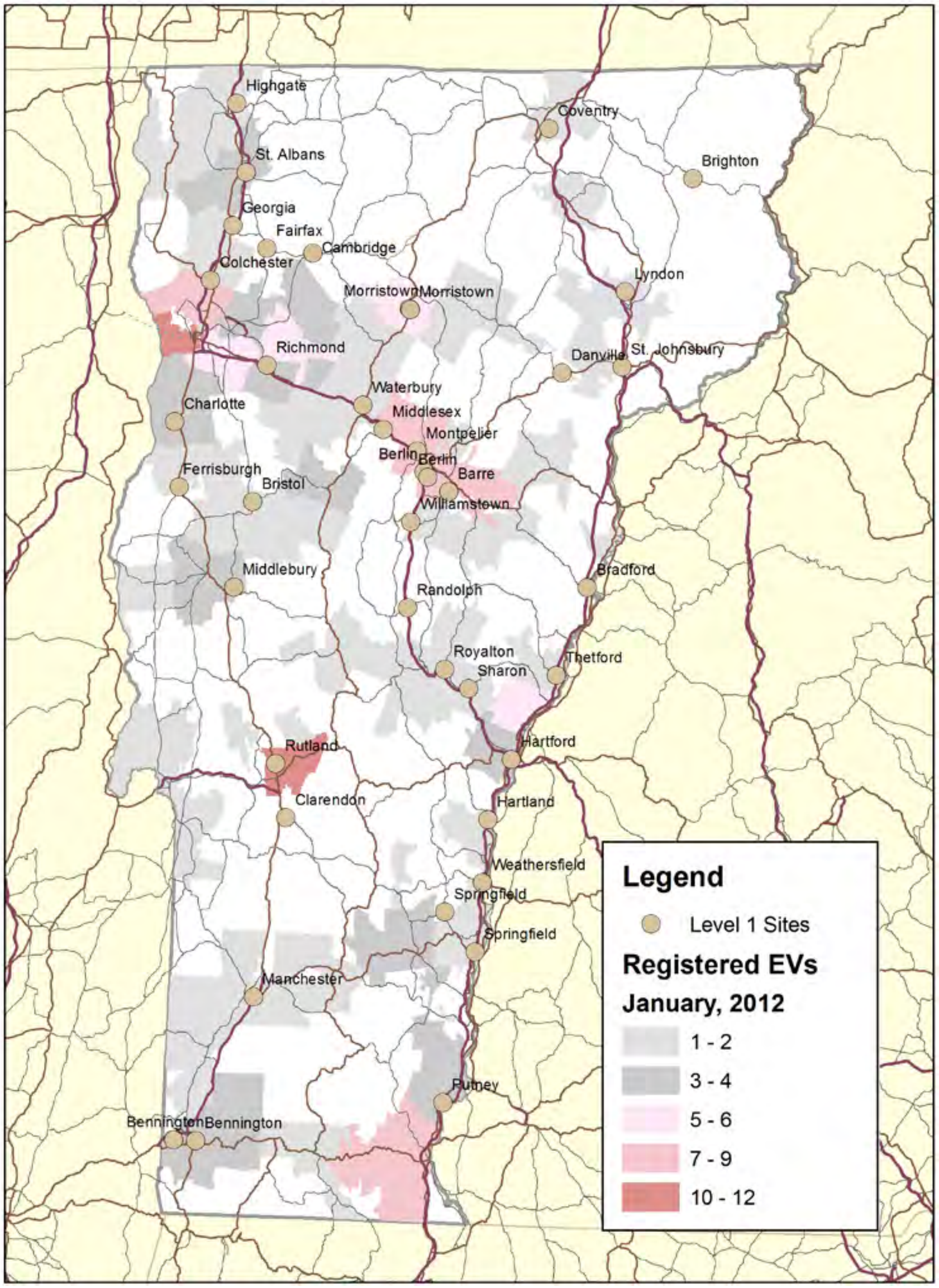
3.3 VTrans Property Site Ranking

In order to stimulate the use of electric vehicles, VTrans is considering the installation of EVCE on VTrans owned properties. A site selection process was conducted to determine the most feasible and optimal locations for Level 1, 2 and Level 3 charging stations. The "universe" of sites included VTrans owned park and ride lots, maintenance facilities, and state airports. Many of the Department of Motor Vehicles (DMV) offices have ideal locations for EVCE, but they are typically not owned by VTrans. By applying the criteria described in Table 3.1, priority locations for each type of charging facility are provided in the following sections. These rankings provide a general indication of the site's suitability for EVCE, and should not be interpreted as a precise ranking, as there are numerous site-specific factors to consider in selecting EVCE sites, such as the site's capacity to reserve several parking spaces for EVCE.

3.3.1 Level 1 Charging Locations

Level 1 charging is ideal at destinations where vehicles will be parked for many hours, such as home and work. Away from home charging with level 1 equipment will require sites with relatively long dwell times. For this reason, commuter parking lots are the most suitable VTrans-owned sites. While no direct estimates of vehicle dwell time at Park and Ride Lots were available, previous research suggests that the vast majority of users of these lots are commuters, thus dwell time will likely be at least eight hours. Figure 3.1 shows potential locations for level 1 charging. Also shown is the level of EV ownership, which should be considered in the prioritization of equipment installation.

Figure 3.1: Map of Potential Level 1 charging equipment sites



Many of the sites shown in Figure 3.1 could readily provide Level 1 charging by making existing electrical outlets on street light posts available for EV users or with low cost installations of outlets on existing street lighting hardware when possible. Further investigation would be needed to determine which sites have outlets available for charging.

Sites for Level 1 charging were ranked based on the following criteria:

- Proximity to a heavily traveled route or interstate highway exit (0 to 5 points),
- Availability of public transit service (0 to 5 points)

- Lighting provided at the park and ride due to long dwell times (0 to 4 points).

Table 3.3 shows the rankings of the Level 1 site candidates, and includes selected maintenance facilities and state airports in areas where park-and-ride lots are not available. Sites within the Green Highway corridor are noted with an asterisk.

Table 3.3: Priority Level 1 Charging Locations

Facility Name	Level 1 Score	Other Considerations
Park and Ride – Colchester*	14	
Park and Ride – Georgia*	14	Lot is typically overcapacity
Park and Ride – Hartland	14	
Park and Ride – Randolph*	14	
Park and Ride – Springfield	12	
Park and Ride - St. Albans*	12	
Multimodal Center - Rutland	12	
Park and Ride - Ferrisburgh	12	
Park and Ride - Charlotte	9	
Park and Ride - St. Johnsbury	9	
Park and Ride – Sharon*	8	Lot is typically overcapacity
Park and Ride - Thetford	7	
Park and Ride - Putney	5	
Maintenance Facility – Hartford*	5	
Park and Ride - Bradford	4	
Park and Ride – Richmond*	4	Lot is typically overcapacity
Park and Ride – Berlin*	4	
Park and Ride – Montpelier*	4	
Airport – Highgate*	2	
Park and Ride – Waterbury*	2	Lot is typically overcapacity
Park and Ride – Williamstown*	2	Lot is typically overcapacity
Maintenance Facility - Bennington	2	
Airport - Lyndon	2	

All other candidate sites had a score of 0, or were in close proximity to a higher scoring site.

3.3.2 Level 2 Charging Locations

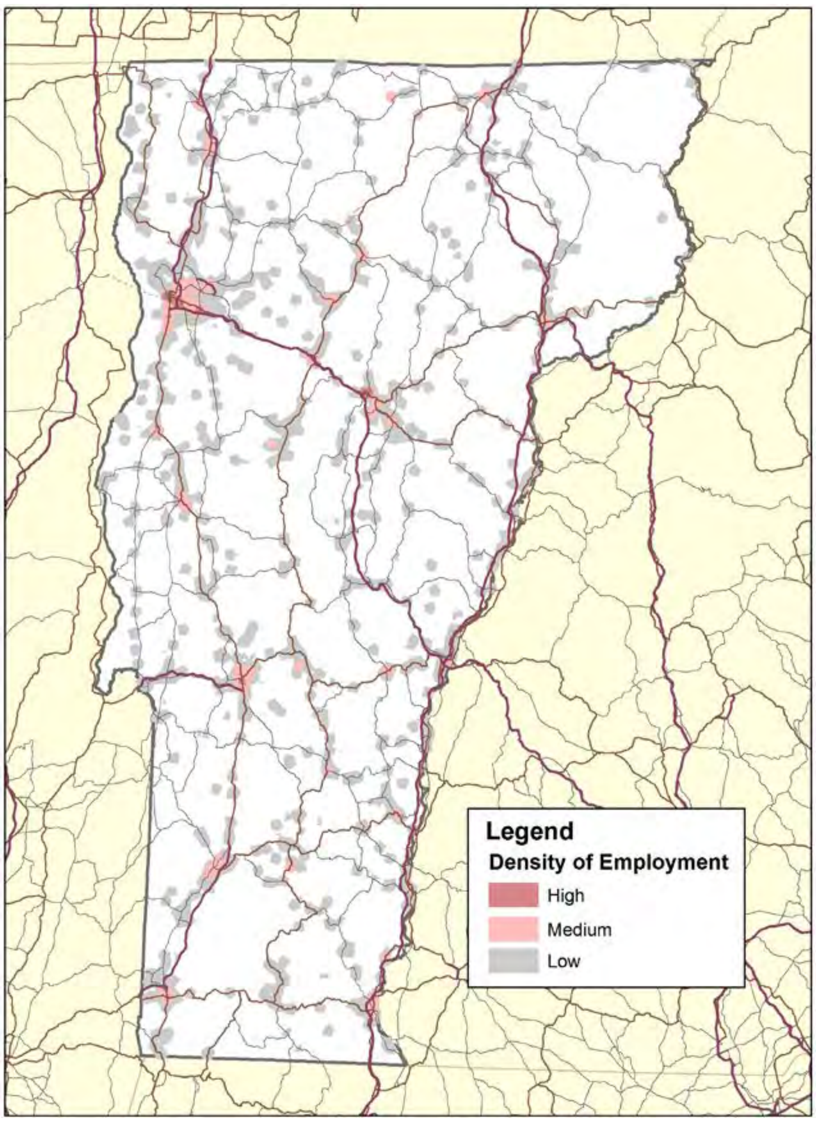
Level 2 public EV charging activities typically require dwelling at a charging station for several hours. Public EVCE will be used more frequently if there are retail and service establishments within walking distance, or public transit service that will allow charging patrons to use their time while their vehicle charges. Table 3.4 lists types of employment establishments that would strengthen the use and appeal of a public EVCE, which include Retail Trade, Arts, Entertainment and Recreation, Personal and Laundry Services, and Public Administration. This list uses the North American Industry Classification System (NAICS), a standardized system developed by the US Census Bureau for economic research.

Table 3.4: EVCE Priority Employment NAICS Codes

NAICS Code	Description
44-45	Retail Trade
71	Arts, Entertainment and Recreation – includes performing arts, sports, museums
72	Accommodation and Food Services – hotels and restaurants
812	Personal Services – hair salons, laundromats, etc
92	Public Administration – municipal offices, courts, etc.

Areas with high concentrations of the EVCE priority employment types are shown in Figure 3.2 and are typically located in downtowns and other areas which are regional shopping and service destinations. Level 2 EVCE installations by VTrans, municipalities, or private landowners in these medium and high density locations will benefit the local economy and EV drivers, particularly in walkable locations.

Figure 3.2: EVCE Priority Employment Concentrations



The need for public investment in EVCE will depend in part on the response from the private sector to EV market penetration. As EVs become more widespread, businesses may invest in charging equipment on their premises in an effort to attract and retain customers and employees. Working together with local businesses to overcome barriers and provide incentives to EVCE installation may be a cost effective means of leveraging public resources to meet the EV charging needs of Vermont residents and visitors in optimal locations. Private EVCE networks such as eVgo and CarCharging Group are also investing in fee-based charging systems which may provide additional opportunities for EVCE at minimal public expense.

VTrans owned airports, park and rides, and maintenance facilities (in locations without a nearby park and ride) were screened for suitability for providing Level 2 EVCE locations. Interstate rest areas were not considered for Level 2 stations, because they do not provide access to other destinations, making them inappropriate locations for a one hour or more dwell time. Figure 3.3 shows the locations of candidate Level 2 EVCE sites.

Figure 3.3: Map of Potential Level 2 Sites

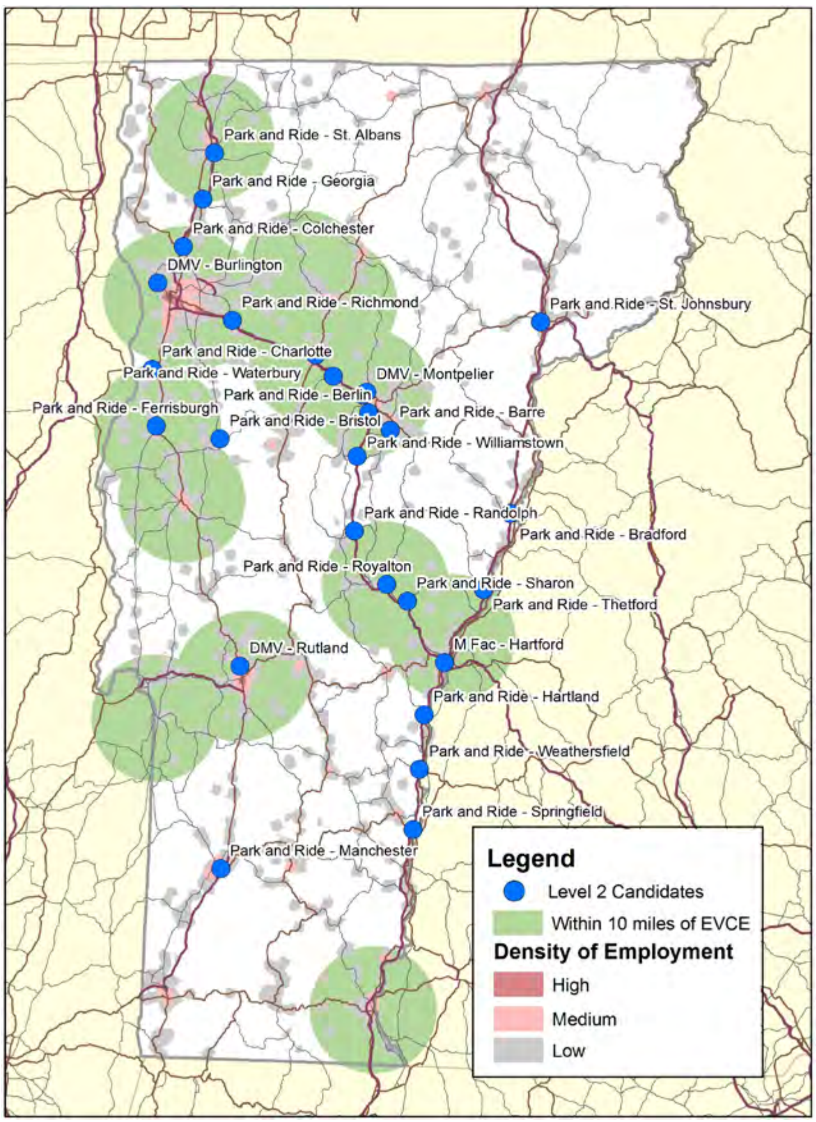


Table 3.5 provides the scores of VTrans owned sites for Level 2 charging equipment. The scoring criteria included the following:

- 10 points for proximity to an employment center (as shown in Figure 3.2),
- 10 points if services are available within walking distance
- 10 points for optimal location for filling in gaps in EVCE coverage (between 10 and 30 miles from an existing EVCE) and
- 5 points for public transit service.

Table 3.5: Level 2 Priority Sites

Facility Name	Level 2 Score	Other Considerations
Multimodal Center - Rutland	27	
Park and Ride - St. Johnsbury	22	Planned Park and Ride improvement
Park and Ride - St. Albans*	20	
Maintenance Facility - Hartford*	19	Future expansion might include park and ride
Park and Ride - Manchester	19	
Maintenance Facility - Bennington	19	
Park and Ride - Charlotte	17	Isolated location with low park and ride usage
Park and Ride – Georgia*	16	Lot is typically overcapacity
Park and Ride - Hartland	16	
Park and Ride – Randolph*	16	
Park and Ride – Colchester*	15	
Park and Ride - Bradford	15	
Park and Ride - Putney	14	
Park and Ride – Barre*	14	
Park and Ride - Springfield	13	
Park and Ride – Waterbury*	13	Lot is typically overcapacity
Park and Ride - Danville	12	
Park and Ride – Sharon*	12	Lot is typically overcapacity
Park and Ride - Fairfax	12	
Park and Ride - Cambridge	12	
Park and Ride – Richmond*	12	Lot is typically overcapacity
Park and Ride – Montpelier*	12	
Park and Ride - Thetford	11	
Park and Ride - Weathersfield	11	
Park and Ride – Williamstown*	10	Lot is typically overcapacity
Park and Ride - Bristol	10	
Park and Ride – Berlin*	10	
Airport – Highgate*	9	
Airport - Clarendon	9	

* Sites along the Green Highway corridor

Maintenance facilities in Hartford and Bennington have been included as there are no nearby park and ride lots. However, there are a number of issues that make VTrans maintenance facilities challenging locations for installing EVCE:

- Limited parking availability
- Limited signage and public awareness of these locations compared to park and rides
- Security gates that are often locked after business hours

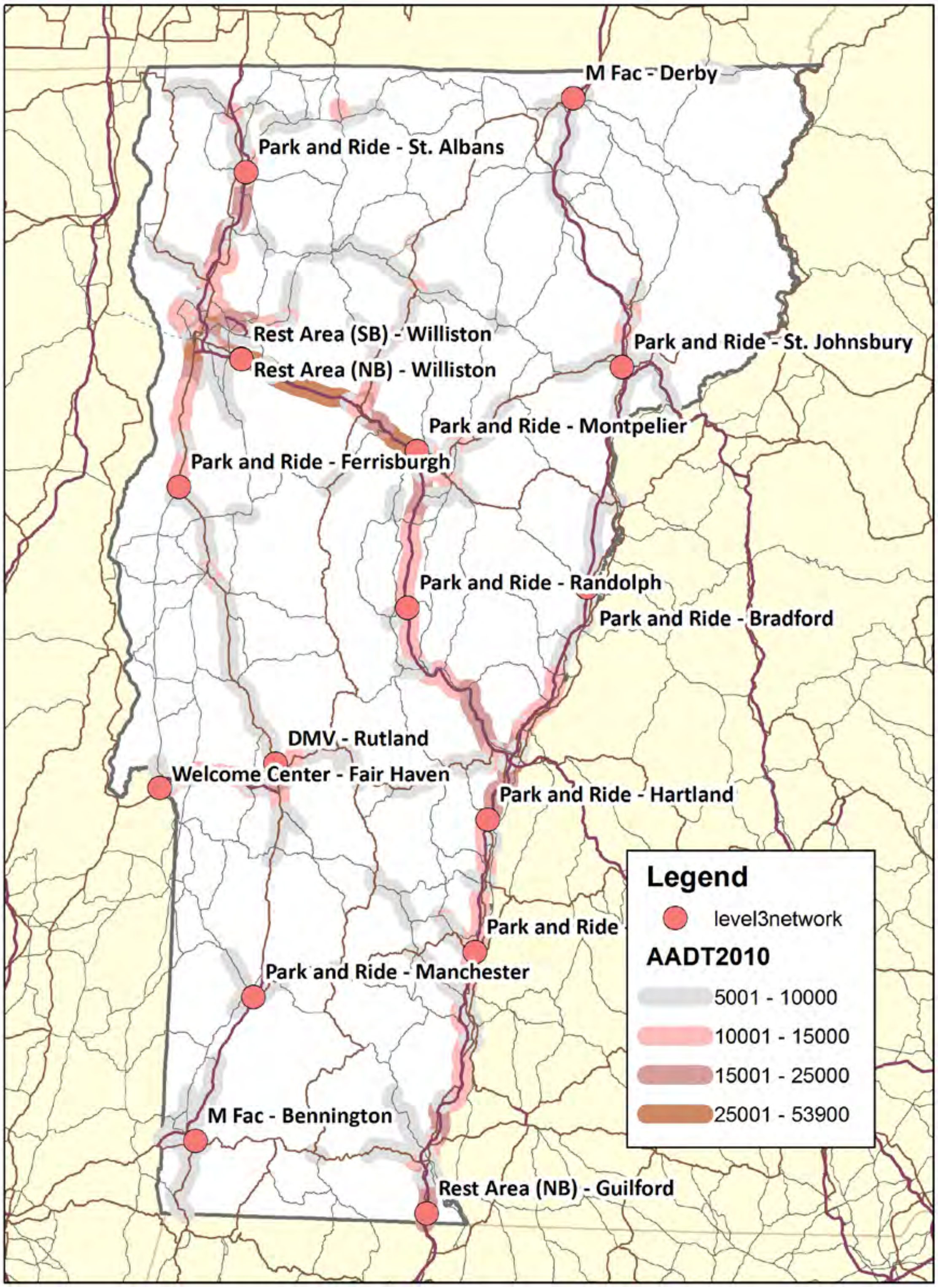
3.3.3 Level 3 Charging

At this time, installation of level 3 equipment is not recommended for VTrans properties due to the ongoing trend of price reduction and the limited number of vehicles that can take advantage of Level 3 charging at this time. As the technology matures, a network of level 3 charging sites should be located to provide travelers with rapid charging and allow them to continue on a long trip that exceeds the range of their EV. The ideal locations will be similar to roadside gas station for ICE vehicles, so proximity to a high traffic volume corridor is among the most important site characteristics. Green Mountain Power is planning to install two Level 3 chargers in the near future in the Burlington area and in Rutland. The need for additional Level 3 fast charging should be closely monitored as more EVs are introduced and sold with this capability.

Locations for Level 3 charging should emphasize service for longer distance travel, as the primary use will be to extend a longer trip. The ideal locations will be conveniently located along high volume routes, including the interstate system and other National Highway System corridors. Interstate rest areas could be well suited for Level 3 charging, as they offer some amenities to through travelers while they wait for their charge. However, there are currently restrictions on commercial activity at rest areas, so it may not be possible to charge a fee for this service. In addition, it will be more costly as facilities would need to be installed in both directions. Park and ride lots that are immediately adjacent to the interstate will be strong candidates.

To establish a Level 3 charging network, spacing between locations is a strong consideration. Figure 3.4 shows how the available VTrans sites could be designated as a Level 3 network that provides charging opportunities approximately every 30 miles. Although installation of Level 3 charging equipment is not recommended for the short term implementation, installation of Level 1 or 2 equipment at the Level 3 network sites should include preparing them for eventual installation of Level 3 charging equipment. Priority should be given to locations that are on the most heavily traveled highways, and are located 30 to 50 miles from the next closest Level 3 EVCE.

Figure 3.4: Potential Level 3 EVCE Network

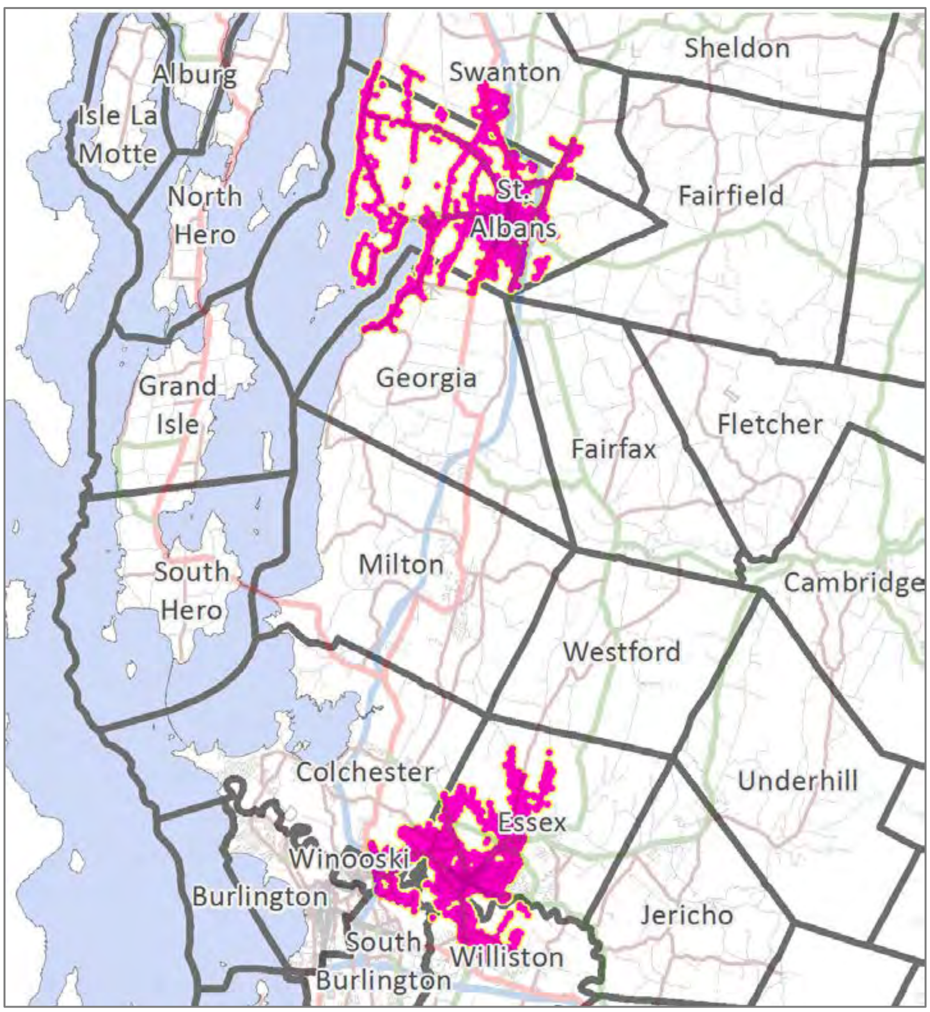


3.4 Other EVCE Siting Considerations: Grid Infrastructure and Geotargeted Areas

The electric grid infrastructure in the vicinity of planned EVCE needs to have adequate capacity to serve the additional demand created by EV charging activity. Some areas of Vermont have peak summer power use which may exceed existing capacity in the next 3-10 years. The Vermont System Planning Committee and Public Service Board have identified two “Geotargeted” areas which are the focus of efficiency and other demand reduction programs to offset the need for expensive grid upgrades. The current geotargeted areas are highlighted in pink in Figure 3.5, and include:

1. Susie Wilson substation areas in Essex, Essex Junction, Colchester, and Winooski; and
2. St. Albans area

Figure 3.5: Vermont Systems Planning Committee Geotargeted Areas, 2012



Siting of high power Level 3 EVCE in these areas may need additional equipment to decrease peak power needed from the grid, such as the use of battery storage devices which can charge slowly from the grid during non-peak use periods and then consume this power when the charger is used.

VTrans should consider the potential impacts to grid infrastructure for any charging stations planned for geotargeted areas. Utilities can assist with identifying any specific upgrades which may be needed, particularly for level 3 installations.

4 EV Charging Equipment Recommendations

There are currently over 50 vendors of EVCE selling hundreds of models of equipment[24]. As the EVCE industry matures a small number of industry leaders are expected claim the major share of this market. This variety provides prospective purchasers of EVCE with a number of options to meet their particular requirements. ChargePoint and GE equipment is used in the majority of the current public EVCE installations in Vermont, but other major vendors for consideration include Aerovironment, Eaton, Leviton, Schneider Electric, Siemens, ECOtality and ClipperCreek.

Hydro Quebec (HQ) has used Aerovironment equipment configured with custom payment systems to establish an EVCE network across the province. They have recently gone through a procurement process to re-establish a vendor of choice for EVCE and selected AddÉnergie, a Quebec company which manufactures their EVCE in the province.

Many regions across the United States received ARRA funding to provide EVCE through ECOtality's Blink Network. These installations provide data for the EV Project reporting used in this study to examine charging patterns in other regions. ChargePoint also installed a large number of EVCE through ARRA funded efforts.

As noted in the review of existing charging activity above, the ChargePoint units are equipped with monitoring and communications systems which provide detailed information on charging activity. It is highly recommended that VTrans invest in equipment with similar capabilities for this initial investment in EVCE to allow detailed monitoring of usage patterns for consideration in future studies of EVCE in Vermont.

Based on conversations with current Vermont EVCE owners, units currently in service have required very little maintenance. The Madison, Wisconsin area is similar to Vermont in terms of population and climate. The Madison electric utility, Madison Gas and Electric, constructed a 26 unit EVCE network using ChargePoint equipment over the past few years. The network has been relatively problem free, although some units required electronics upgrades which were covered under warranty. Since many EVCE units are fairly new to the market, VTrans should require manufacturer warranties on any purchased equipment for a minimum of 1 year, with longer coverage desired.

The most common issue for EVCEs nationwide is damage to the cords and/or J1772 connectors. Most manufacturers have modular equipment designs which allow for swapping out damaged parts, although UL requirements sometimes dictate replacing entire sealed modules rather than individual components to maintain certification after repairs, particularly for EVCE in outdoor environments.

VTrans requirements for equipment that is plugged into the grid like an EVCE, such as traffic signal control cabinets, pedestrian push buttons, etc., were investigated to determine general standards that might apply to EV charging equipment. The following factors are recommended requirements for an EVCE vendor or contractor to submit a valid proposal in response to future procurement efforts.

Table 4.1: EVCE Equipment Specification Recommendations

1. Americans with Disabilities Act (ADA) accessible buttons and components
2. Warranty - Minimum 1 Year, longer desired
3. Modular Field serviceable parts, particularly for cord and J1772 connector a. Minimum cord length of 20 feet b. Cord management system to keep cord off the ground and comply with National Electric Code (NEC) article 625 as it applies to cord management systems
4. Network monitoring capability for status and fault reporting a. Current status of charging station equipment (in-use, malfunction, etc) b. Reporting on power consumption and usage patterns
5. Fee collection system using credit cards and/or RFID cards from widespread charging network(s) with customer service phone assistance available 24 hours a day, 7 days a week.
6. Ability to operate in extreme temperature conditions (-20 to +100 degrees F)
7. Underwriters Laboratories (UL) Listed for outdoor use
8. NEMA Type 3R or 4 certification for outdoor electrical enclosures

Several vendors offer equipment which complies with the above list of specifications. Large scale implementation of EV charging equipment should go through a competitive procurement process. The ChargePoint units in widespread operation across the state have been relatively problem-free and should be considered as one option in future procurement. Table 4.2 includes a listing of most of the major manufacturers of EV charging equipment.

The ChargePoint network has implemented an interoperability agreement with ECOtality/Blink. ChargePoint has also licensed their software systems to other equipment manufacturers such as Schneider and Eaton.

The following section includes more detailed information on installation and operational costs for EVCE units.

Table 4.2: EV Charging Equipment Manufacturers and Capabilities[25]

	Charge type			Communications & Billing Options			Mounting Options			
Manufacturer	Level 1 (120V)	Level 2 (208/240V)	Level 3 (DC Fast Charging)	Network Communications Available	Billing / Payment Interfaces	Billing / Payment Networks	Floor / Ground	Bollard	Wall	Overhead
ABB			●	●	●	●	●			
AddÉnergie		●		●	●	●	●	●	●	
Aerovironment, Inc	●	●	●	●	●	●	●		●	
Andromeda Power			●	●	●	●	●			
Bosch		●					●			
ClipperCreek, Inc	●	●		●	●	●	●		●	
Control Module Industries (EVSE LLC)	●	●		●	●	●	●		●	●
ChargePoint	●	●		●	●	●	●	●	●	
DBT USA		●		●	●	●	●	●	●	
Eaton	●	●	●	●	●	●	●		●	
ECOtality		●	●	●	●	●	●	●	●	
EVoCharge	●	●		●	●	●	●		●	●
Fuji Electric			●	●	●	●	●			
General Electric		●		●	●	●	●		●	
Kanematsu			●	●	●	●	●			
Leviton		●		●	●	●	●		●	
Nissan			●	●	●	●	●			
OpConnect	●	●		●	●	●	●		●	
Pep Stations		●		●	●	●	●		●	
Schneider Electric		●	●	●	●	●	●		●	
SemaConnect		●		●	●	●	●	●	●	
Shorepower	●	●		●	●	●	●		●	
Siemens	●	●		●	●	●	●	●	●	
Signet Systems		●	●	●	●	●	●			

5 EVCE Installation and Operational Costs

5.1 EVCE Installation Costs

Costs of EVCE installation vary widely depending on site characteristics and the quantity and type of EVCE being installed. Like any product, price is also influenced by the degree of competition amongst EVCE vendors and the ability of vendors to achieve economies of scale in service delivery. Equipment prices and installation costs are decreasing as EVCE became more prevalent, with particularly rapid cost reductions for Level 3 charging equipment[26].

Table 5.1 provides estimates of per unit costs for charging equipment likely to be seen in Vermont over the next 5 years. The different components of commercial EVCE costs include the equipment price from the vendor and installation which can include the following items:

- Power connection to the electric grid, including any electric circuit components and conduit runs necessary to reach the equipment;
- Mounting (wall mount generally less expensive than post mounted which require concrete pedestal);
- Protective devices, such as bollards or wheel stops
- Wayfinding signage, parking lot lines and stripes
- Lighting
- Internet connection if cellular data service not available
- Permitting

Table 5.1. Projected EVCE Infrastructure Costs

	Level 1 AC – 1.4 kW	Level 2 AC – 3.3-6.6 kW	Level 3 DC – 25-50 kW
Equipment Price	$30-900[27]: Prices vary with system capability to monitor and charge for use.	$3,500 - 9,000	$15,000 – 60,000[28]
Installation	$200-450	$3,500-12,000	$20,000 - 25,000
TOTAL	$230-1,350	$7,000-21,000	$35,000 – 85,000

Installation cost estimates were obtained directly from experienced installers. Green Power Technologies is one of the most prolific installers of EVCE in the nation having completed more than 1,500 installations to date. They provided a range of installation costs depending on site specific factors. Peck Electric is a local Vermont contractor that has completed 6 EVCE installations.

Table 5.2. Level 2 EVCE Installation Cost Experience

Vendor	Cost per port of Level 2 EVCE Installation
Green Power Technologies	$7,000-$21,000
Peck Electric	$16,000

Additional installation cost estimates were developed considering typical conditions at park and ride lots, and using VTrans cost pay items. The results ranged from $8,000 for a Level 1 installation (includes costs for trenching and conduit) to $38,000 for Level 3 installation.

5.1.1 Reducing Installation Costs

Providing electrical service to parking spaces for EVCE can account for as much as 40% of installation costs. [29] Installing EVCE simultaneously with parking lot resurfacing or new construction can reduce the costs of delivering electrical service to EVCE. Installing multiple EVCE simultaneously can also substantially reduce per unit cost of EVCE by nearly a third[30]. Businesses installing EVCE are currently eligible to claim a federal alternative fuel infrastructure tax credit for 30% of the cost of the system up to $30,000. Public sector and non-profit entities may be able to receive this benefit passed down through a lease or sales agreement with a third party vendor.

5.2 Operating Costs

EVCE operational costs include energy costs for power supplied to EVs, costs for ongoing remote monitoring services as well as maintenance costs for the equipment. VTrans facilities are spread across the state in several different utility territories, including service provided by Green Mountain Power (GMP) and Vermont Electric Coop (VEC). Electricity service costs are paid through VTrans maintenance district billing systems. Table 5.3 includes a summary of electricity costs at several VTrans facilities based on data obtained from District staff as well as an estimate of the energy costs associated with one hour of Level 1 and Level 2 EV charging and 30 minutes of Level 3 DC Fast Charging. Rates 2 and 3 in the table below assess demand charges to the customer based on peak usage periods during the month. If EV charging occurs at the same period as other peak use equipment, such as lighting, motors, heaters, etc., then the demand peaks may coincide and increase the monthly fees significantly, particularly for DC fast charging equipment which has very high loads. Some EVCE manufacturers are developing equipment which will allow utility customers to limit or stop EV charging activity during times of peak use to avoid or reduce these charges.

Table 5.3: VTrans Energy Rates and Costs for EV Charging

		Charging Power (kW) [a]				
		1.5	3.3	6.6	25	50
Electric Rate	Energy Rate[b] ($ / kWh)	Level 1 Cost for 1 Hour	Level 2 Cost for 1 Hour		DC Fast Charge Cost for 30 Minutes	
1. GMP Rate 2 (no demand charge)	$0.18128	$0.27	$0.60	$1.20	$2.27	$4.53
2. GMP Rate 2D (with demand charge, see Table 5.4 for additional cost details)	$0.15144	$0.23	$0.50	$1.00	$1.89	$3.79
3. VEC Small Commercial Rate	$0.15389	$0.23	$0.51	$1.02	$3.85	$7.69

[a] – EVs have an average efficiency of approximately 3.5 miles/kWh; 1 hour of charging at 6.6 kW would provide enough energy for about 23.1 miles of travel
[b] - Energy Rate includes utility rate plus $0.00867 energy efficiency charge

Table 5.4 includes an estimate of the monthly peak use (aka demand charges) at various charging levels. Table 5.5 includes a total operational cost estimate with electric use and peak demand charges for a 100 kWh / month charging station, an approximate average of existing charging stations in Vermont with usage data available.

Table 5.4: Potential Monthly Demand Charge Costs for EV Charging

	Level 1 120V	Level 2 208/240V		Level 3 DC Fast Charge	
Charging Power (kW)	**1.5**	**3.3**	**6.6**	**25**	**50**
GMP Rate 2D ($13.99527 / kW demand charge)	$20.99	$46.18	$92.37	$349.88	$699.76

Table 5.5: Potential Monthly Total Operational Costs for EV Charging (based on 100 kWh use)

	Power Use (kWh)	Potential Demand Charges (kW)	Total Monthly Cost Estimate
1. GMP Rate 2 (no demand charge)	$18.13	n/a	$18.13
2. GMP Rate 2D (with demand charge)	$15.14	$45-700	$60-715.00
3. VEC Small Commercial Rate	$15.39	n/a	$15.39

In the absence of smart charging equipment to manage peaks, VTrans may wish to consider requesting utility rates which do not assess a demand charge when possible, particularly for DC fast charging equipment. Some states are pursuing special utility rates which would apply to EV charging, and not include demand charges. This may be an area of further research beyond this study.

Table 5.6 provides estimated operational costs of EVCE, including energy, usage monitoring, point of sale services, insurance and maintenance costs. Snow removal costs will vary widely depending on the design and need for hand clearing or other special practices. Insurance costs to extend coverage to EVCE will also depend on the owner's policy and coverage.

Table 5.6. Annual EVCE Operational Costs

Cost Category	Level 1 AC – 1.4 kW	Level 2 AC – 3.3-6.6 kW	Level 3 DC – 25-50 kW
Energy	$200/year to $800/year: Energy costs will vary depending on time of use and total use.	$200/year - $2,500/year: Energy costs will vary depending on time of use and total use.	Unknown (Demand charges could reach $12,000/year for a 50 kW Level 3 Fast Charger)
Usage monitoring and point of sale systems (optional)	$400: One time cost for a monitoring and payment system device.	$400/year: Fees for access to software and network systems	Unknown
EVCE Unit Maintenance	$400/year	$400/year	Unknown
Snow Removal	Unknown	Unknown	Unknown
Insurance	Unknown	Unknown	Unknown
Total	***$600+***	***$1,200+***	***n/a***

5.3 US DOT Funding Requirements

The most recent federal transportation bill, MAP-21, includes a provision making EVCE an eligible federal transportation fund expenditure. FHWA has stipulated these funds are only available to charging stations located within publicly owned properties. It should be noted that fees for charging services are not allowed within interstate highway rights-of-way in keeping with long-standing prohibitions on commercial activities in these zones.

6 Potential EVCE Business Models

There are a wide variety of potential EVCE business models, which are summarized in Table 6.1. The best business model for VTrans to consider will in large part depend on how an EVCE program is staffed within the agency. Many of the models that allow for more revenue generation also have a larger administrative burden, which is a primary consideration.

Table 6.1: Potential EVCE Business Models

EVCE Business Model	Description
Subscription and fee for use	EVCE owner charges for use of individual stations or access to a network of stations for a specified period of time.
Advertising based revenue generation	EVCE is designed to allow its owner to lease space for advertising signage on it; can be implemented in conjunction with other models
EVCE Paired with Renewable Energy Generation	Solar Photovoltaic installations can offset energy costs of EVCE through utility net metering arrangements as described in section 6.3.

EVCE Business Model	Description
Philanthropic and Corporate Social Responsibility	Company or private individual installs charging equipment for public use or compensates the system owner for operations, energy or maintenance costs so that charging can be used freely by the public.
Tax based and code based	State or municipal government finances EVCE for public use through tax revenues or allocated federal funds or sets in place building codes that require new developments to include a prescribed percentage of EV ready parking spaces.
Renewable fuel credits	The US EPA's Renewable Fuel Standards establish criteria for the generation and sale of Renewable Identification Numbers (RINs). These help importers and refiners of fossil fuels to meet Federally-mandated Renewable Volume Obligations (RVO's), such as the addition of ethanol to gasoline. The conversion of biogas to electricity to be used in transportation, as through an EVCE system, could generate RINs. As a tradable commodity the value of RINs varies. It is expected that biogas generated electricity, like the Coventry landfill or CowPower programs will be classified as the highest form of RIN and could generate up to \$0.54 per 22.6 kWh or ~\$0.50 for 3 hours of use at a Level 2 charger.
Public land or asset swap	EVCE installation is included in negotiations involving a private sector entity seeking access to publicly owned land and or assets of commercial value; effective when the commercial activity involves bringing electrical service to the location, the private sector entity is offered public recognition for its contribution, maintenance/operation/ energy costs are shared by users or the municipality.
Leveraging EVCE improvements for non-federal transportation matching funds	Section 1111(c) of the U.S. Transportation Equity Act for the 21st century enables a State to apply resources allocated by operators of toll facilities or private corporations that improve the surface transportation system towards the non-federal match requirements for federal transportation funding. For instance if Lake Champlain Transportation Company installed a charging station the value of this capital improvement could count as match. In addition if a private entity were to include a charging station and perhaps accompanying photovoltaic panels as part of a power purchase agreement erected such that they provide a protective canopy as part of a construction or re-construction project in a park and ride, rest area or welcome center, the value of that investment could count as non-federal match toward the project cost.

6.1 Subscription and fee for use

A variety of models exist for generating revenue through billing users of EVCE. Of the models in practice currently, the most common are a membership based model and a pay per use model. Vermont and many other states do not allow unregulated utilities to sell electricity by the kWh, so unless there are changes to state statute, billing would be done based on time spent at an EVCE or through unlimited access for a fixed monthly fee. Examples of membership and pay for use business models include the eVgo Network operated by the private electric vehicle charging service company eVgo and the Plug-in EVerywhere program managed by Texas utility Austin Energy. eVgo offers subscription plans of $29.99 to $69.99 per month for a Level 2 charging installation. The operator avoids the upfront costs of the installation as well as the operation and maintenance costs and eVgo earns a return through the charging fees[31]. Austin Energy's Plug in EVerywhere program allows utility customers the ability to purchase a membership to a network of publicly accessible EVCE for a fee of $5 per month or to use EVCE in their public charging network without subscription for $2 per charge event. Austin Energy also works with private companies to install EVCE, offering to assume the cost of operation, management and energy costs for companies that install Plug-in EVerywhere EVCE on their premises.

6.2 Advertising based revenue generation

Vermont's sign law restricts off-premise advertising signs in the highway right of way which limits the potential for sales of advertising space on EVCE wraps to serve as a means of generating revenue through EVCE. [32] However, advertising signage on EVCE that is located out of view of the highway targeted at customers, employees and visitors of a host establishment may be a viable means of generating revenue through EVCE depending on local sign ordinances. Price Chopper has pioneered this model in New York state with what it refers to as "alternative fuel pads", charging stations equipped with a canopy and space for advertisers to promote products within the store or of presumed interest to the supermarket's clientele.[33] The model could function through direct ownership—as in the case of Price Chopper—or third party ownership. In a third-party ownership model, a vendor would install and operate the EVCE on the premises of the host[34].

6.3 Offsetting Energy Costs through Solar Photovoltaic Installations

Daytime charging of EVCE has the potential of increasing demand during hours of peak energy usage, causing strain on the power grid and, in turn, additional costs to utilities which may be passed down to rate payers. As PEVs become more prevalent, utilities will likely continue developing variable time of use rates, using price signals to encourage charging during off-peak evening hours.

One means to ensure that installation of public EVCE does not result in costly impacts to the power grid is to pair EVCE with solar photovoltaic panels (PV). PV generates electricity during the day while the sun is shining which tends to be the same period of time that energy demand on the power grid reaches its peak and the cost of energy is at its highest. This feature of PV makes it a particularly valuable resource when connected with the power grid, a value which will be amplified in the years to come if EV charging during daytime increases.

Vermont law allows owners of grid connected photovoltaic systems to generate credit from the production of electricity that can be applied to a utility account. Because of the unique value of PV in mitigating peak demand energy costs, utilities are required by Vermont state law to offer customers a credit for power generated by grid-connected systems covering at the customers current rate plus an additional "solar adder" credit calculated as $0.20 minus the utility's highest residential rate.[35] Currently law stipulates that this premium applies for the first 10 years of operation after which point credit will be valued at the utility's highest residential rate.

The premium paid for PV generated energy accelerates the return on investment and implies the possibility that the value of PV could grow in the future if costs of peak energy demand increase. As widespread daytime use of EVCE may be a cause for increases in peak demand costs, pairing EVCE installations with PV is an ideal means of hedging against any rise in energy costs that may occur in the future.

To further enhance incentives for investing in PV, under current state and federal tax incentives, private companies with sufficient tax appetite can achieve upwards of a 10% return on investment over the course of a PV system's life in the form of deductions from their utility bills. For non-profits and public sector entities that are not able to capitalize on tax benefits, a number of companies in Vermont offer power purchase agreements that enable hosts of solar arrays to receive compensation for use of roof space or open land by private investors in solar. In such arrangements, the host receives compensation for use of their space—either in the form of offsets to their energy costs, a lease payment or both—and the peace of mind that a substantial portion of the energy they use is offset by clean renewable energy with no upfront costs.

VTrans is eligible to participate in a contract managed by VT Buildings and General Services (BGS) to provide solar power through a master agreement with AllEarth renewables. Details regarding this program are still in review, but it should be considered for new EV charging on VTrans properties. The state contract covers power purchase agreements (PPAs) for systems capable of generating 150 kW of power, orders of magnitude over what is expected to be consumed by a VTrans park and ride or maintenance facility with EV charging available. VTrans could set up an agreement for one large PV installation to cover several properties served by the same utility, or may consider smaller sized systems.

This equipment could be located on private land or within VTrans properties, such as highway right of way or at facilities under consideration for EV charging in this report. FHWA has approved the use of highway right of way for renewable energy generation recommends a comprehensive statewide or regional evaluation of properties and development of location selection criteria.[4]

For example, a single AllEarth series 20 solar tracker (their smallest product) generates about 7,500 kWh/year. A small VTrans maintenance facility might require approximately 300 kWh/month based on a review of several VTrans utility bills. EV charging energy use could add another 100 kWh/month based on current public EV charging station usage in Vermont. This location would then have a total energy demand of 400 kWh/month or 4,800 kWh/year. This is well below the 7,500 kWh generation of the

[4] FHWA, Accommodating Renewable Energy Technologies and Alternative Fuel Facilities, Jan 2012 http://www.fhwa.dot.gov/real_estate/publications/alternative_uses_of_highway_right-of-way/altusesreport.pdf

tracker, so VTrans should consider pairing at least two locations together to create a total demand of 9,600 kWh per year to get the full benefit of the PV investment.

A sample analysis of potential savings from a PPA for a 2-facility net metered system consuming 9,600 kWh annually in Green Mountain Power's former CVPS service area found 11% annual savings on electric power costs in the first year ($244). These savings would cover 118 kWh of use per month, enough to cover more than half of the estimated 200 kWh/month of EV charging at two locations. The annual savings would rise to 23% ($640 in 2022 nominal dollars) at the end of a ten year period as electric rates are anticipated to continue rising around 3% per year while the PPA would be fixed at $1,500/yr. The net present value of all the annual savings over the 2013-2022 period totals $3,700. Additional future savings after 2022 may be possible, but potential changes in net metering policies are difficult to predict beyond the 10 year horizon currently included in Vermont's net metering statute.

In addition to savings on electric utility expenses, VTrans may be able to arrange for AllEarth renewables to pass through the federal alternative fuel infrastructure tax credit for EV fueling equipment as part of this arrangement to provide further savings on a package of EV charging equipment installations with Solar PV systems.

VTrans is strongly encouraged to take advantage of the AllEarth PPA program or a similar offering to provide long-term savings and stability in electric utility expenses as well as ensure the investments in EV charging infrastructure strongly support the goals of the Comprehensive Energy Plan and greenhouse gas reduction goals. These programs do not require up front capital investments, only monthly lease payments, so lack of funding should not be an obstacle to the widespread use of this business model.

6.4 Renewable fuel credits

The U.S. Environmental Protection Agency (EPA) requires a certain quantity of transportation fuel consumed each year in the US to be derived from biological compounds. Specific annual quotas are described in the revised Renewable Fuel Standard (RFS2) instituted in May 2009. In 2009 the quota was 9 billion gallons and this will increase each year, reaching 36 billion gallons in 2022. In order to achieve the volumetric requirements laid out in RFS2, importers and producers of fossil fuels used for transportation purposes are required to purchase a prescribed quantity of renewable fuel attributes from biofuel producers. These attributes are tracked through Renewable Identification Numbers (RINs) which are sold in a free market exchange. RFS2 divides biofuel types into separate categories and each is assigned its different target volume. The category requiring the largest volume is termed Advanced Biofuels. Farm methane, landfill biogas and biomass fall into this category.

When used to charge EVs, electricity generated by RFS2 qualifying biofuel generated electricity can be assigned RINs which in turn can be sold in US RIN exchange markets. One RIN is generated for every 22.6 kWh of power and is worth approximately $0.54, although as a tradable commodity this value fluctuates. Under full utilization, an EVCE would generate approximately $250 annually if served entirely by electricity generated from biomass at the $0.54 per RIN rate.

Additional research is needed to explore the possibility of generating Renewable Identification Numbers (RINs) and enabling EVCE to operate as gateways for grid-interactive vehicles. Both of these schemes would provide revenue to owners of EVCE and electric vehicle thus creating viable business models with positive returns on investment.

6.5 Public land or asset swap

When a business makes use of public land for commercial activity--such as sidewalk space for outdoor seating for a restaurant or a piece of municipal park land for a telecommunications box--this is referred to as an encumbrance. Typically a business is required to file for a permit or license for an encumbrance and pay a fee based on the degree and duration of imposition that their business activity will have on public space. In cases where businesses require usage of publicly owned land or resources for business operations, there is an opportunity to negotiate the provision of EVCE in lieu of—or for reduced--encumbrance or licensing fees.

One example of this type of negotiated agreement was reached in British Columbia, Canada between the city of Vancouver and TELUS, a major telecommunications provider in the region. TELUS was given permission to site a set of ground level cell towers at a reduced cost lease in a busy area of downtown in return for co-locating EVCE with these installations.

7 EVCE Typical Design Site Plans and Wayfinding Recommendations

Numerous publications of EVCE design guidelines were reviewed for applicability to Vermont installations. EVCE installations have several requirements:

- Power availability (240V for Level 2, 3 phase 480V for Level 3)
- Level parking surface, preferably paved so EVCE spaces can be marked
- Lighting to provide security
- Accessibility per ADA requirements
- Bollards or wheel stops to protect EVCE equipment from vehicles
- Signs and pavement markings to designate sites and restrict their use

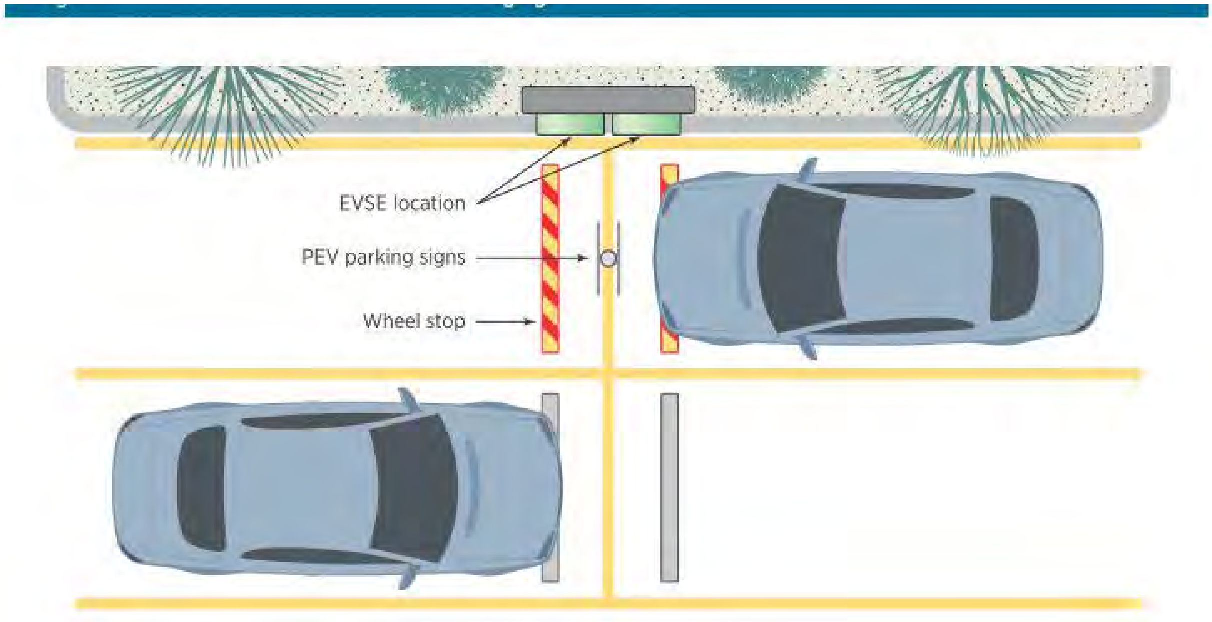
There are several options to provide accessibility of EVCE, which are discussed further in Section 7.2.3. There are also options for addressing snow removal, discussed in Section 7.2.4. Figure 7.1 shows several examples of the range of EVCE installations.

Figure 7.1: Photos of Typical EVCE Stations

7.1 Typical Site Plans

There are many possible arrangements and designs for EVCE installations, depending on the parking area layout, availability of power, and other site considerations. Figure 7.2 shows a typical EVCE layout for perpendicular, head-in parking. Most EVCE plans utilize wheel stops to prevent vehicle contact with the EVCE, but these can be problematic with snow removal. Bollards can also provide the same protection for EVCE, and are recommended.

Figure 7.2: EVCE Typical Layout



7.2 Concept Plans for VTrans parking lots

The following are guides that provide additional details in the layout of EVCE, and were utilized in the development of the design concepts that follow.

- Sustainable Transportation Strategies, 2012. *Site Design for Electric Vehicle Charging Stations.* NYSERDA/ Virginia Clean Cities/Clean Fuels Ohio.
- Advanced Energy, 2011. Community Planning Guide for Plug-in Electric Vehicles. North Carolina Advanced Energy Corporation.
- Advanced Energy, 2011. Charging Station Installation Handbook for Electric Contractors and Inspectors. North Carolina Advanced Energy Corporation.
- City of Houston, 2010. *Recommended Electric Vehicle Charging Infrastructure Deployment Guidelines for the Greater Houston Area*. Ecotality/HARC.
- US Department of Energy. 2012. Plug-in Electric Vehicle Handbook for Public Charging Station Hosts. Clean Cities.

Figures 7.3 through 7.5 show possible layouts of EVCE on VTrans park and ride lots in Randolph, Ferrisburgh and Montpelier. The Montpelier example shows both Level 2 and 3 charging stations. Among the key features are power availability and service, protection of the EVCE through bollards, signage to identify site and restrict parking to EV users, and marking of additional spaces within reach of EVCE with blue lines. Additional features include photovoltaic installations and canopies to protect EVCE from snow. The layout should intersperse EVCE with parking spaces in order to maximize the number of vehicles within reach of an EVCE, as over the course of a day, several different vehicles may want to access the EVCE.

Figure 7.3: Illustrative concept for EVCE at the Randolph Park and Ride

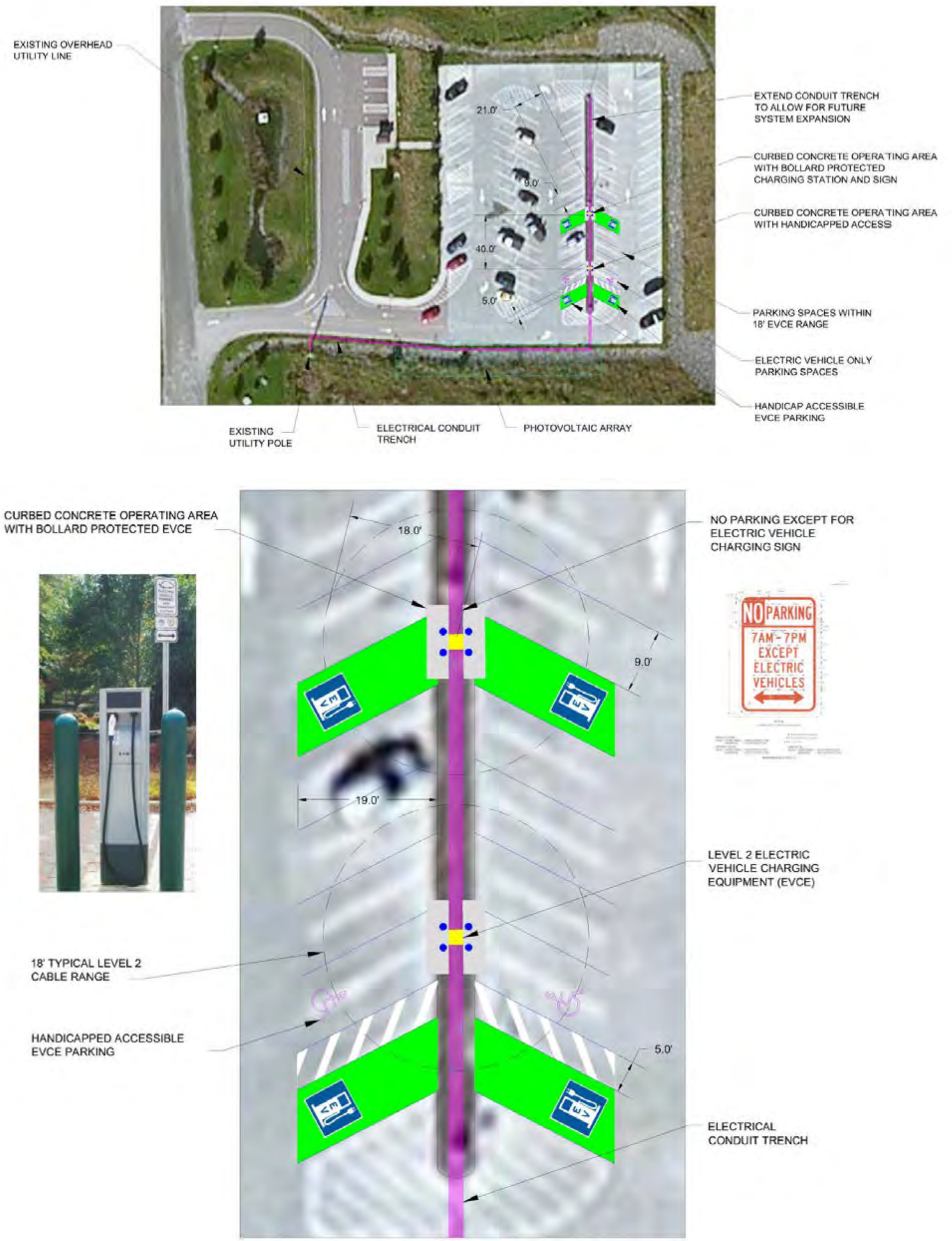
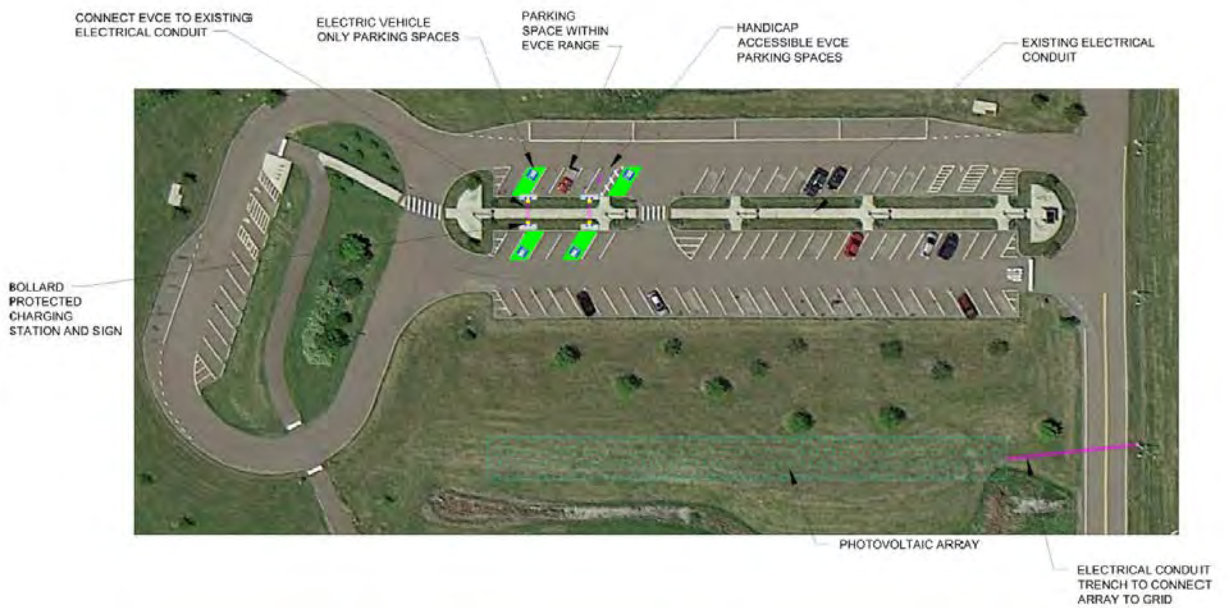


Figure 7.4: Illustrative concept for Level 2 EVCE at the Ferrisburgh Park and Ride



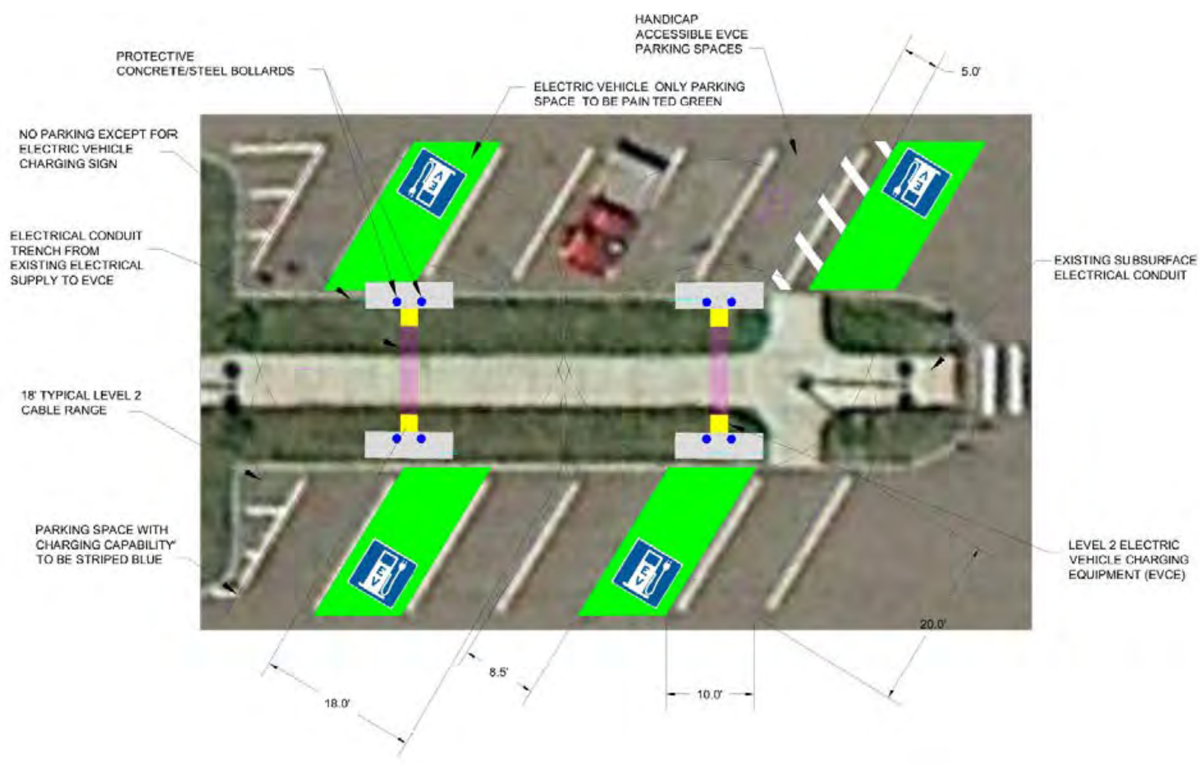
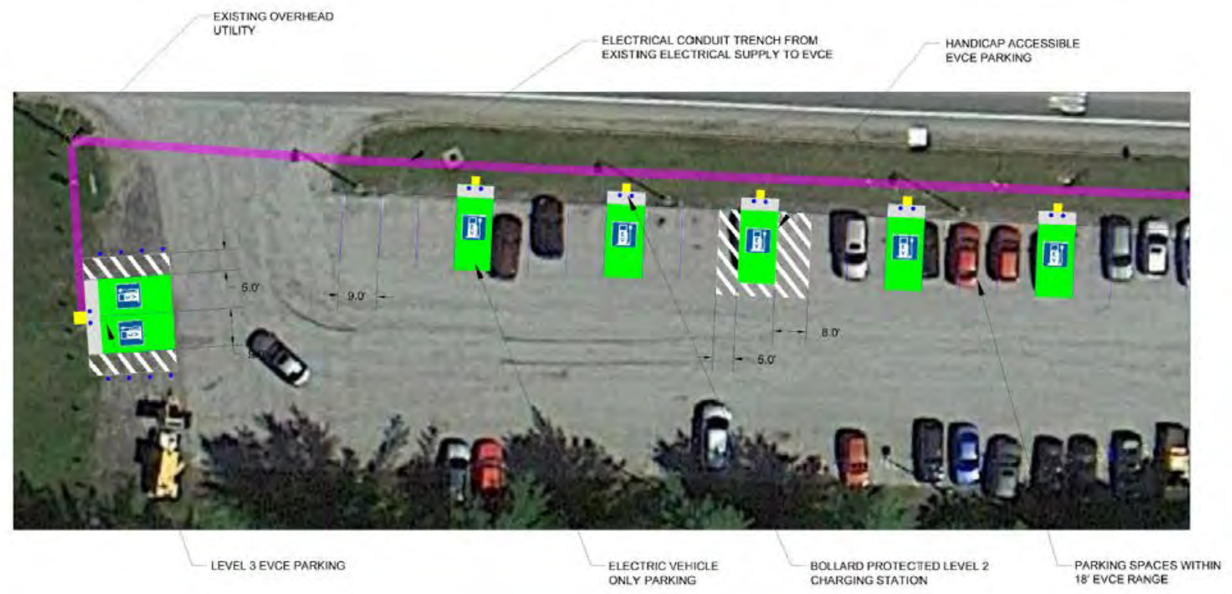


Figure 7.5: Illustrative concept for Level 2 and Level 3 EVCE at the Montpelier Park and Ride



7.2.1 Parallel Parking Spaces

Many of the locations suitable for Level 2 EVCE, discussed previously in Section 3.1, have state highway right-of-ways that could potentially be suitable for EVCE. While some jurisdictions in other parts of the US have provided curbside EVCE in parallel parking spaces, these are not recommended for early installations in Vermont for the following reasons:

- Only one vehicle may access a parallel space at a time. If a parked EV has finished charging, no other users can access the EVCE.
- The EVCE would be exposed to snow and salt from plowing, which could damage the equipment and shorten its life.
- EVCE may provide a hazard for pedestrians, such as tripping over the cords.

7.2.2 Parking Garages

Parking garages provide an additional option for EVCE, which can provide a convenient place for charging, as dwell times in garages are typically two hours or longer. There are ample design guidelines available for their layout. Garage installation is relatively easier due to the protected environment and availability of power. Because garages often have a fee for use, or are restricted in access, garages may not be ideal places to provide public away-from-home charging. Figure 7.6 shows a typical installation plan for a parking garage EVCE.

Figure 7.6: Parking Garage Installation

7.2.3 ADA Requirements

While the design of EVCE is an emerging and evolving topic, there are guidelines specifically for accessible EVCE[36]. Generally, parking accessibility standards require one accessible space for every 25 spaces, so there should be at least one accessible EVCE parking space for every 25 EVCE stations. At this time, we do not anticipate any locations having close to 25 EVCE in one location, so one accessible EVCE space should be provided in each location. The design concept of accessible charging spaces is shown in Figure 7.7.

Figure 7.7: Accessible EVCE Design

Source: Sustainable Transportation Strategies, 2012.

7.2.4 Snow removal considerations

In order to provide accessible operation of EVCE, a 3’ by 3’ (minimum) handicapped accessible operating area must be kept clear of vehicles and snow between the nose of the vehicle and the EVCE. Strategic placement of bollards, curbing, or wheel stops may be required to protect EVCE from vehicular impacts, while still providing accessibility and reasonably convenient snow removal. Several options below are presented for consideration to ease the snow removal, while maintaining accessible EVCE operations. While each of the following options could increase installation costs by several thousand dollars, there could be substantial savings in operations costs making any of these options a good investment.

Canopies. Covering the operating area with a roof structure or canopy would keep the operating area clear of snow, and reduce weather-related pavement damage. Canopies also offer large visible areas on which to raise awareness of the EVCE, and also incorporate solar arrays. There are turn-key solar canopies with built in level – 2 charging units that are currently being installed in other states.

Heated pavement. Providing sub-surface heating is another option to keep the EVCE operation areas free from snow and ice, as power will be available, easing installation. There are two types of heated pavement: hydronic and electric radiant. Electric radiant employs low-voltage mats installed under the pavement which are heated using electricity. Hydronic systems employ small tubing running underneath the pavement; in which heated water mixed with anti-freeze is circulated (the ambient soil temperature below the frost line is above 50 degrees). Installation and operational cost of these systems will need to be weighed against the savings in maintenance.

Retractable cable. Another newly available option is a retractable cable that provides access to the EVCE cable with minimal snow removal. Many EVCE designs require users to manually wind and replace the cable after use. This may become difficult in cold weather when the cable becomes stiff, and may result in the cable being placed on the ground in or around the operating area. This exposes the cable to potential damage from vehicles and snow plows, and makes use difficult, particularly for less mobile users. Figure 7.8 shows retractable cable units that are mounted on concrete pedestals and require no additional protection from snow and ice. Retractable cables are also more easily accessible for wheelchair users. However, this equipment is new and experience is limited, and the reliability of the retractable cable should be evaluated before this equipment is selected for use on VTrans properties.

Figure 7.8: Retractable Cable for EVCE

7.3 EVCE Signage

While many EV users will find charging locations through their smart phones or onboard navigation systems, there is still a need for clear roadside signage for EVCE[37]. Many users may be visitors to Vermont who are unfamiliar with the area, and signage will help alleviate anxiety about finding a charging location. In addition, while many patrons may be able to find EVCE with their smart phones, cellular service is not uniform across the state, and gaps remain. Signage required for EV users include General Service signs (at interstate exits), "trailblazing" signs to lead the driver from an interstate or major highway to the EVCE, and regulatory signage and pavement marking that will indicate that the parking is restricted to EVs while charging.

With so few EVCE statewide, signage is an important component of the EV Fuel infrastructure, and clear guidance is needed about how and where signs directing patrons to EVCE should be installed. This guidance will likely need to be revisited annually in the next five years, particularly if there is a proliferation of public EVCE locations, which could alter the need or conditions for signage. As always, policies and guidance for signage needs to strike a balance between the needs of those who may rely on the signs (anxious EV drivers who may not be familiar with the specific EVCE locations), and the reality of finding appropriate places to install signs and funds to maintain them.

7.3.1 General Service Signs

The Manual on Uniform Traffic Control Devices (MUTCD) has adopted a standard sign symbol for EV charging stations, shown in Figure 7.9, and VTrans will need to update signage policy to guide in its appropriate use. Currently Vermont's policy for interstate service signs does not recognize EVCEs, and will need to be updated. This will require a definition of what qualifies as a charging station. Recommended characteristics of a qualifying EVCE include the following:

- Level 2 or 3 charging is provided.
- Site is open to the public 24 hours a day/7 days a week, and never locked or gated.
- EVCE is visible from the street, or on-site wayfinding signs are provided to direct the user to the EVCE.

If signs are desired for locations that only provide Level 1 charging, such as park and ride lots with electric outlets available for EV charging, it would be possible to add a plaque to the sign set denoting "Level 1" so that drivers are aware of the limitations. Recommended language to amend the VTrans General Service Sign Guidelines is attached to this report.

Figure 7.9: MUTCD Approved EVCE Symbol

7.3.2 Trailblazing Signs

Experience in Washington and Oregon indicates that, while most EV users will have access to smart phones or onboard navigation, having trailblazing signs, to direct EV users from a major highway to the site, are important to alleviate anxiety of EV users. As EVCE's eventually proliferate, these may not be required, but should be provided in this early period of technology adoption. Signs must be provided to direct users to the actual charging station, if the EVCE is not visible from the entrance to the facility.

VTrans has established interim guidance on signing of EVCE that includes trailblazing signs, but additional clarification is needed. The following is recommended for consideration:

- Trailblazing signs from interstate exits should direct EVs to the nearest EVCE that is within 5 miles of the exit. If there are more than one EVCE within 3 miles of an interchange, then an informational sign can be provided at the closest EVCE that directs EVs to other nearby sites if the EVCE are in use and not available.
- VTrans can install and maintain trailblazing signs on Vermont State Routes. In some cases, EVCE are located off of the state highway system. If trailblazing signs are needed on non-state routes, VTrans can install signs if the municipality grants permission. Ideally, the municipality will also accept responsibility for maintaining the signs as part of their system.
- In locations where there is such a high degree of sign clutter that EVCE signs will be very difficult to install due to sign clutter and conflicts, other options can be explored such as the community providing EVCE location information at a visitor information center, town bulletin board, or other local information source.

Another type of location that trailblazing signs may be appropriate to provide directions to EVCE that are along major non-interstate highways. For EVCE that are on or near Vermont's Primary Highway Network, directional signs to the EVCE should be provided if they are within 3 miles of the major state highway. The same considerations as noted above for trailblazing signs should apply.

7.3.3 Regulatory Signs

The final type of signage that is required is a regulatory sign to restrict use of the parking spaces to charging EVs only. Recent guidance from the FHWA provides recommendations for signage in order to encourage uniformity and clarity in parking restrictions. In order to provide for enforcement Examples are shown in Figure 7.10.

Figure 7.10: EVCE Parking Restriction Sign Examples

VTrans has authority to restrict parking on state facilities in 23 VSA 13 § 1106, so no additional municipal action would be required to establish parking restrictions. If EVCE is provided on municipal or private property, than the municipality's traffic ordinance may be expanded to allow enforcement of the above restrictions.

Providing proper and clear signage for EVCE will require VTrans to commit staff resources. In the coming years, there will likely be many new sites getting installed, and others may be discontinued or relocated as more optimal locations are found. Unless signs are maintained and accurate, they are not useful, so maintenance and management will be required. As discussed below in section 8.1, VTrans should establish a program and staff appropriately, and maintenance of the signage for EVCE should be among the responsibilities of an EV Program.

8 Implementation

This report provides VTrans with criteria to select optimal locations for EVCE on properties within their jurisdiction and control. The locations and business models listed provide a roadmap for the agency to direct their resources to support the implementation of the state's Comprehensive Energy Plan and the agency's greenhouse gas reduction goals. The following specific steps are recommended for the development of EVCE.

8.1 Establish EV Program Office

VTrans has several options available for supporting and administrating the build-out of the EVCE facilities recommended in this report. VTrans could use a combination of the following management approaches as the Agency's strategy evolves over time with staff experience and increased demand for public charging.

1. **VTrans Staff Program Management**: VTrans staff person(s) designated to manage the EVCE program which would go through a typical RFP process for construction.
2. **Consultant Project Manager**: VTrans hires out most aspects of program management to an outside contractor who handles the procurement process.
3. **Contract with private entity to install and operate at little to no cost to the State**: VTrans could enter into an agreement with entity like eVgo or CarCharging Group to allow them to use VTrans property to install their own equipment and charge a fee to users. VTrans could receive payment in return that should cover energy supply costs. While this approach has worked in more populated states with higher concentrations of electric vehicles, it is not clear how well this approach would work in Vermont, and VTrans would have little influence on how quickly these are constructed.

8.2 Evaluate Non-VTrans Sites

There are some VTrans-owned properties that could be developed into viable EVCE stations, with Park and Ride lots being generally the most promising locations. Priority VTrans owned properties are provided for installation of Levels 1 and 2. In addition, while level 3 installations are not prudent in the near term due to the high cost and potential for price reductions, a potential future network of fast charging stations is proposed. Ideal locations for Level 2 charging would include parking areas in village centers, shopping districts, or other places where services are concentrated, and VTrans owns few properties in these locations. Therefore, it is also recommended that VTrans conduct an analysis of optimal charging locations, particularly for Level 2 charging equipment, to prioritize and encourage charging stations in the most appropriate locations. This would require working with local municipalities, regional planners and others to develop project designs to establish a network of EVCE in the state. VTrans can also provide incentives to non-VTrans property owners to install EVCE, by developing a standard incentive offer to private property owners to target specific areas of the state, such as downtowns and growth centers, where there may be many opportunities for EV charging activities which also support other state policy goals.

8.3 Early Implementation Recommendations

Several options are available for VTrans to spur the development of EVCE.

8.3.1 Establish Level 1 Charging at VTrans Park and Ride Lots

Some of VTrans park and ride lots have electric outlets available on lamp posts. These could be marked for use by EV owners with an information sign plaque, possible simply attached to the light posts that offer outlets.

8.3.2 Initiate EVCE Demonstration Project

As funding for EVCE becomes available, a small number of sites, possibly those shown in Table 8.1, could have EVCE installed following a site-specific investigation of feasibility, design constraints and permitting requirements. It is recommended that this project select several different options for equipment and installation practices, so that valuable experience in installation, operations, and maintenance can be evaluated. This could include installing retractable cables, solar array canopies, or heated concrete to reduce snow removal needs. Table 8.1 shows potential demonstration projects and estimated costs using estimates derived from VTrans experience. The Rutland and St. Albans sites propose only Level 1 charging, as there are planned Level 2 facilities in those communities.

Table 8.1: Early Implementation VTrans Sites for EVCE

Candidate Sites:	Units (Level 1 / 2)	Cost
Rutland Multimodal Transportation Center	4/0	$40,000
St Albans Park and Ride	4/0	$40,000
Georgia Park and Ride	2/0	$20,000
Randolph Park and Ride	4/2	$92,000
St Johnsbury Park and Ride	4/2	$92,000
Colchester Park and Ride	4/2	$92,000
TOTAL		$376,000

These sites were selected as they show high potential for EVCE through the GIS analysis, and have capacity to allow several parking spaces to be reserved for EVCE use.

8.3.3 Implementation via VTrans Park and Ride Program

The VTrans Park and Ride program provides several possibilities for implementation of EVCE. There are a number of existing park and ride lots with electric outlets on light poles, which could be made available for level 1 charging, as long as there are no hazards posed (i.e. tripping over cords. Signs could be placed on or adjacent to the light poles indicating that charging is permitted.

There will also be opportunities in the next two to three years to incorporate Level 2 EVCE into several park and ride improvement projects, including the following priority locations:

- Putney
- Hartland
- Springfield
- Bradford

Including EVCE in these projects would likely increase the cost of the park and ride improvements by up to $60,000, depending on the number and type of units. There would be savings in reduced contractor mobilization costs, and by concurrently installing with lighting and other improvements.

8.4 Level 3 Implementation

Early implementation of Level 3 equipment is not recommended at this time due to a lack of convergence on the connector technology, as well as the current trend of price reductions. However, establishing a Level 3 charging network will be very important to provide longer distance travelers with EVCE. Once the network is identified, any installations or construction projects in those locations should result in these sites becoming “level 3 ready.” There is significant potential for private sector involvement in developing level 3 fast charging installations as they could fit well with a traditional gasoline and convenience store business model. There are also many possibilities for providing EV charging at non-VTrans properties which were outside the scope of this investigation.

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