Chittenden County RPC
Communities Planning Together

Electric Vehicle Charging Equipment Infrastructure Planning 2013-2023

Phase I Report

March 22, 2012

VERMONT ENERGY INVESTMENT CORPORATION

The preparation of this document has been financed by the U.S. Department of Transportation and matching funds provided by Chittenden County's 19 municipalities and the Vermont Agency of Transportation. The views and opinions expressed do not necessarily state or reflect those of the U.S. Department of Transportation.

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Executive Summary

As electric vehicle sales continue to grow in Vermont, it is imperative that we begin to plan for widespread use of these vehicles and understand potential need for public charging facilities. Availability of away-from-home charging is one of the primary factors thought to affect consumers' decisions regarding the purchase of an EV (along with vehicle price, vehicle range, and gasoline costs). In this report we consider needs for public vehicle charging in Chittenden County in the coming decade (2013-2023) as well as business models, optimal electric vehicle charging equipment (EVCE) location criteria in keeping with the ECOS planning goals and explore the different types of EVCE available.

Using US EIA projections of EV sales, we estimate that by 2023 approximately 5,800 EVs will be registered in Vermont, requiring 79 charging stations in Chittenden County. Cost estimates to install these charging stations varied from $553,000 to $1.66 million. We identify priority destination-types for public EVCE as those locations offering retail, recreation, and public administration services. These destinations commonly have dwell times long enough to allow an appreciable amount of charging (~ one hour). Future research may consider specific locations to serve as optimal sites for public EVCE in Chittenden County.

1. Background

The term Plug-in Electric Vehicle (EV) describes a class of automobiles that use electric motors powered by energy drawn from a battery system for propulsion. Several EV models are currently sold in Vermont and their presence is expected to significantly increase over the next 20 years.

Adoption of EVs in Vermont will dramatically reduce the environmental and economic costs of transportation energy use in the state. Transportation is the largest single source of greenhouse gas (GHG) emissions and energy consumption in Vermont, primarily because of the high reliance on Internal Combustion Engine (ICE) vehicles to meet the state's mobility needs, our relatively clean grid and low industrial base.[1] EVs can be as much as three times more efficient than traditional ICEs in using energy for propulsion and are capable of recapturing energy through regenerative braking. Furthermore, EVs can be powered by low carbon renewable energy resources.

EVs are separated into two types: Plug-in Hybrid Electric Vehicles (PHEVs) and All Electric Vehicles (AEVs). PHEVs are capable of operating solely on electric energy for a certain distance after which point an auxiliary internal combustion engine is engaged to offer additional range. PHEV's are grouped by their electric range. The battery system of a PHEV-10 has approximately a ten mile electric range and a PHEV-40 has approximately a forty mile electric range. AEVs are also sometimes grouped by their electric range into AEV-100 (electric range of approximately 100 miles) and AEV-200 (electric range of approximately 200 miles).

Electric Vehicle Charging Equipment (EVCE) is a device used to transfer electrical energy from an external source such as the power grid or a battery bank to an electric vehicle's energy storage system (Figure 1). AC EVCE delivers alternating current to an electric vehicle's onboard charger which then converts the energy to direct current for storage in a battery system. DC EVCE delivers power directly to an electric vehicle's battery system.

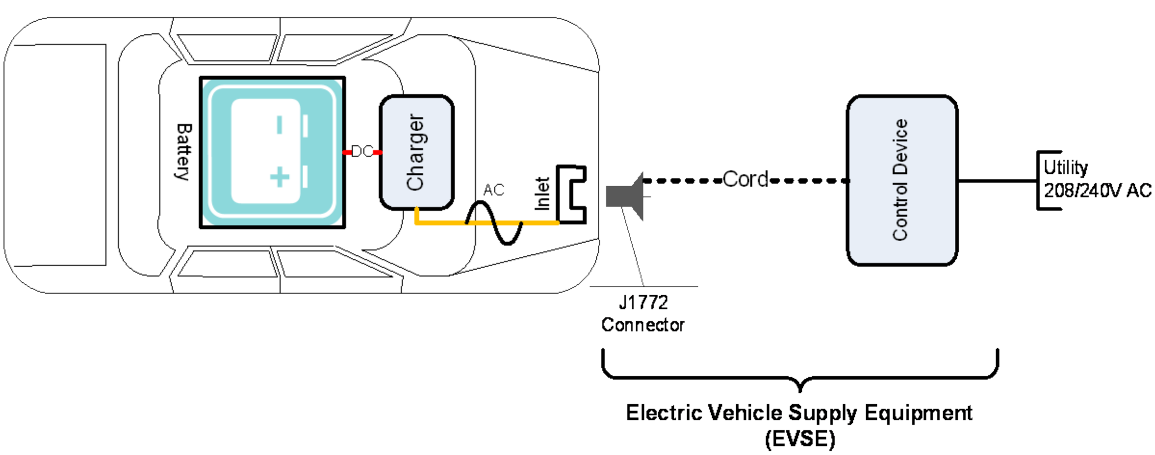

Figure 1. Electric Vehicle Charging Equipment

There are two types of EVCE presently in use in Vermont: Level 1 and Level 2. Level 1 uses a 120V AC connection to a standard residential/commercial electrical outlet capable of supplying 15-20 amps of current. Level 2 requires a 208/240V AC connection to supply increased power to the vehicle charging system, reducing the amount of time required to charge the EV battery. EVs come equipped with Level 1 chargers but acquiring a Level 2 home charger typically means an additional investment for EV owners.

Level 3 DC EVCE, also known as a Level 3 fast charger, deliver a high volume of DC current directly to EV's battery system and enables rapid charging of electric vehicle battery systems. Level 3 is seen as a means for increasing the practicality of long distance AEV travel. Level 3 has been deployed in various locations around the U.S. including along the West Coast of the U.S. from Southern California to Washington state.

2. Chittenden County Existing and Future EVCE Demand Analysis

2.1 Vermont EV ownership Geography

As of January 2013, 188 EVs were registered in Vermont, spread across 89 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 an influential factor in determining consumer willingness to purchase AEVs. EV fleet composition will in turn determine EVCE demand.

Table 1. Composition of EV fleet by model type in the U.S., Vermont, and Chittenden County, as of January 2013

EV model type	U.S.	Vermont	Chittenden County
PHEV	66%	72%	70%
AEV	34%	28%	30%

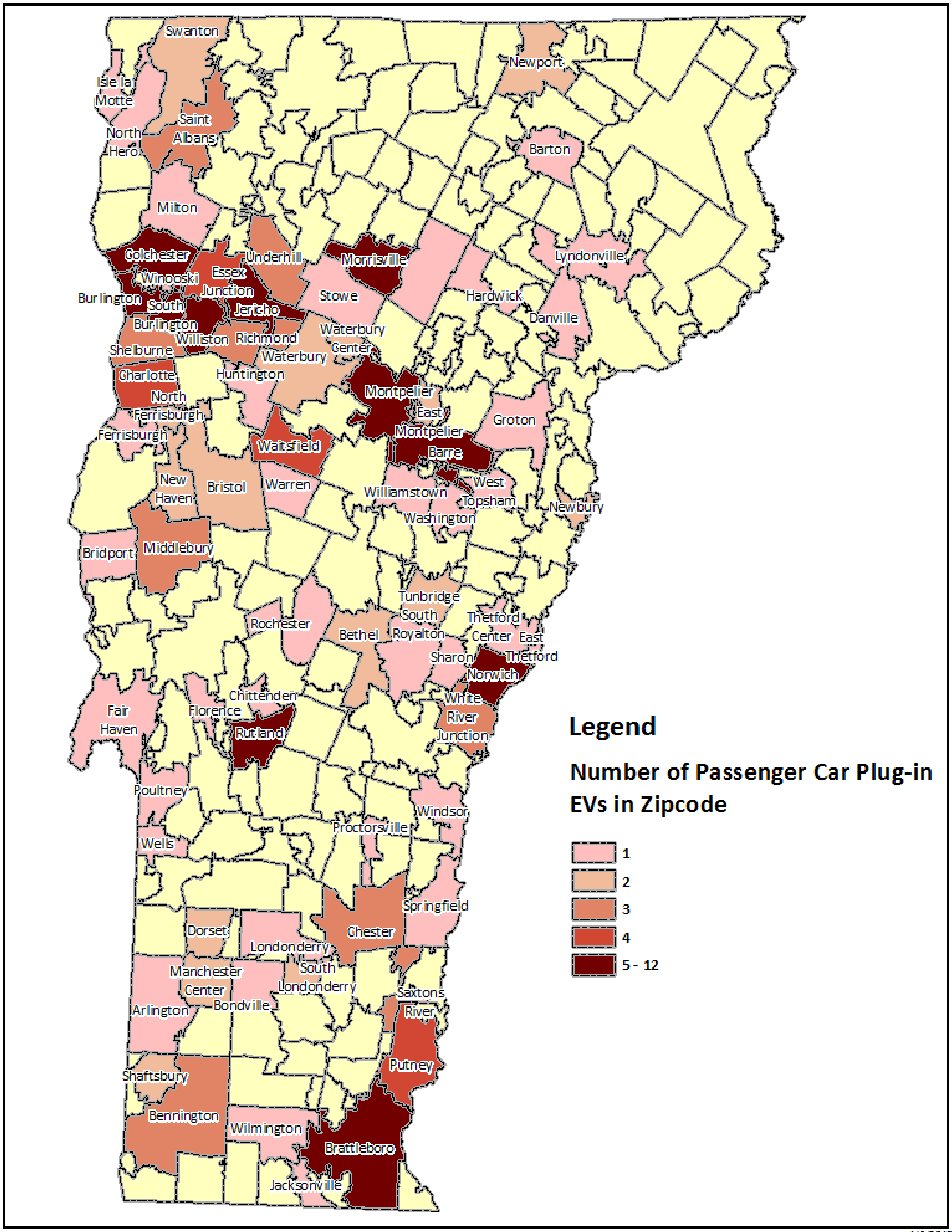

Figure 2. Vermont EV Ownership by Zip Code, January 2013

Vermont EV registrations have grown steadily between July 2012 and January 2013 (Figure 3).

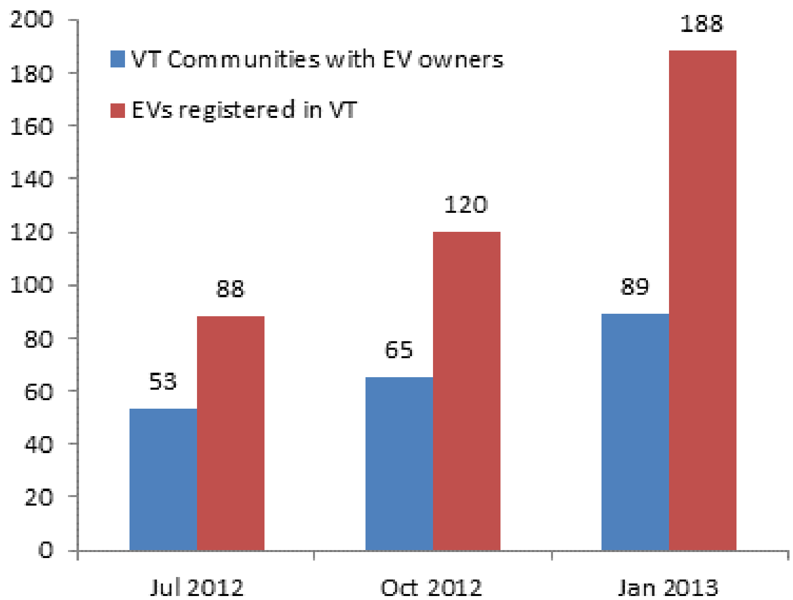

Figure 3. Vermont EV Registrations, July 2012 - January 2013

2.2 Chittenden County EV Ownership Geography

Chittenden County is currently host to approximately 30% of the EVs registered in Vermont and approximately 40% of total registered vehicles in the state[2]. Figure 4 below shows the geographic dispersion of EVs across Chittenden County.

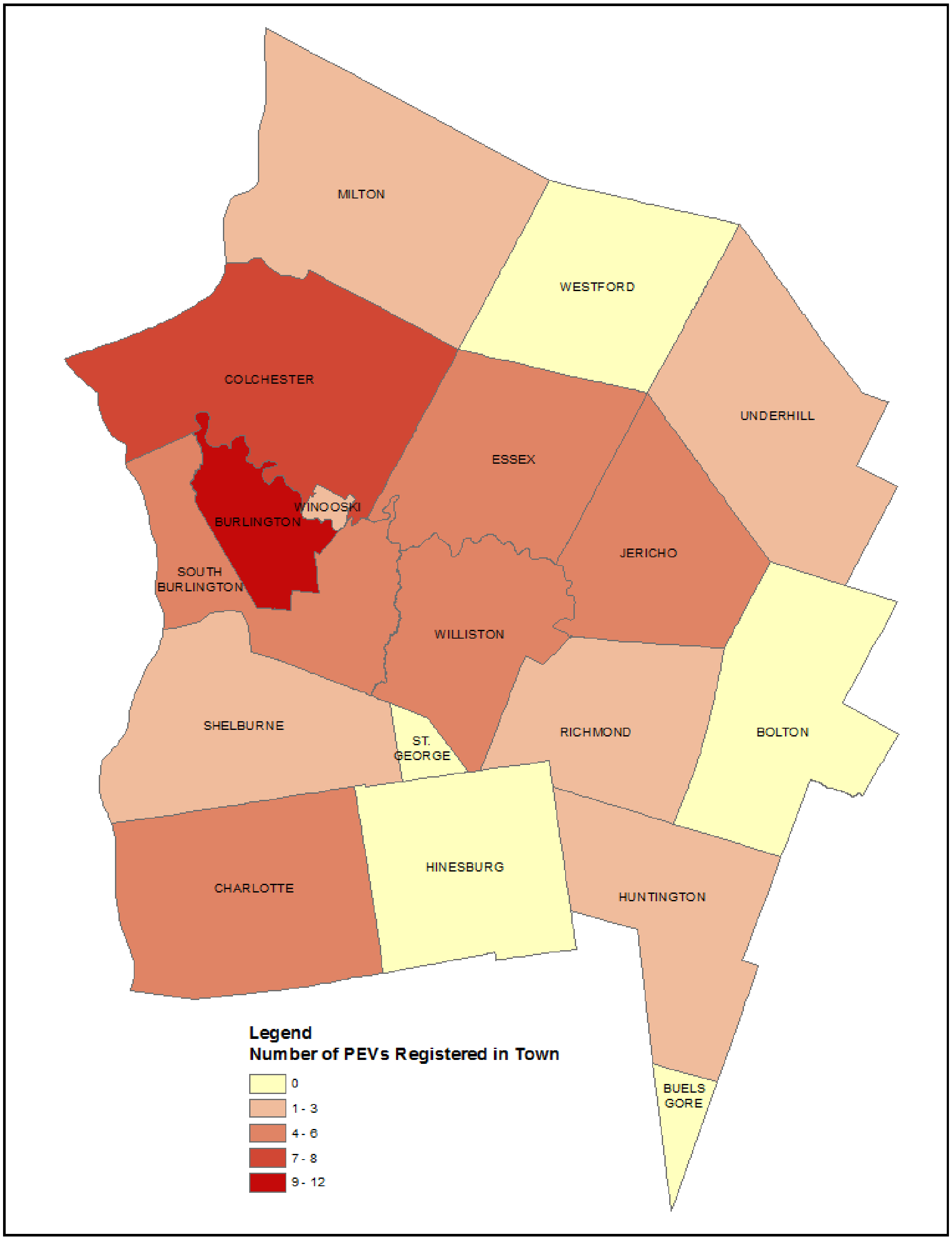

Figure 4. Chittenden County EV Ownership by Town, January 2013

The breakdown of EV by model type in Chittenden County is presented in Table 2.

Table 2. Chittenden County EV Fleet Characteristics, January 2013

Plug-In Vehicle Type	Number EVs in Chittenden County *(% total EVs in Chittenden County)*	Number EVs in Vermont *(% total EVs in VT)*
PHEV – 10 mile electric range	28 *(50)*	114 *(60)*
PHEV – 40 mile electric range	11 *(20)*	21 *(12)*
AEV – 100 mile electric range	13 *(24)*	45 *(24)*
AEV – 200 mile electric range	4 *(8)*	8 *(4)*
Total	56	188

The towns in Chittenden County with the greatest number of EVs are Burlington with 12 EVs and Colchester with 8 EVs. Green Mountain Power is headquartered in Colchester and its plug-in fleet currently accounts for more than half the EVs in the town.

The growing concentration of EV ownership in central and northwestern Vermont indicates a need for regional coordination of EVCE deployment. In addition to EV travel originating in neighboring counties, dialog has begun between policy makers in Vermont and Quebec to develop a corridor of EVCE stretching from Montreal southward, passing through Chittenden County along I-89. If developed, Chittenden County could see use of EVCE by visitors from Canada as well.

2.3 Current EV Charging Activity at Public EVCE locations

2.3.1 Existing Public EVCE locations in Chittenden County

The nine locations in Chittenden County where publically accessible EVCE is available are shown in Table 3 and Figure 5. Aside from normal parking fees, all charging is provided free of cost to users and charging activity data at the majority of EVCE is not rigorously collected.

Table 3. Current Chittenden County EVCE

Station Name	Street Address	City	Access Days/Time	Number and type of EVCE Available
Saint Michael's College	30 College Pkwy	Colchester	24 hours daily	1 Level 1, 1 Level 2
Healthy Living Natural Market and Café	222 Dorset St	South Burlington	24 hours daily	1 Level 1, 1 Level 2
Burlington International Airport	1200 Airport Dr	South Burlington	24 hours daily (pay lot)	1 Level 1, 1 Level 2
Burlington Main & Church Street	175 Main St	Burlington	24 Hours (metered parking)	2 Level 1
City Market - Onion River Co-op	82 S. Winooski Ave	Burlington	Business hrs	1 Level 1
Lakeview Garage (Macy's)	45 Cherry St	Burlington	Business hrs (pay lot)	2 Level 1
Shearer Chevrolet	1675 Shelburne Road	South Burlington	Business hrs	1 Level 2

Station Name	Street Address	City	Access Days/Time	Number and type of EVCE Available
Freedom Nissan	1095 Shelburne Rd	South Burlington	Business hrs	2 Level 2
Burlington Mitsubishi	1835 Shelburne Rd	South Burlington	Business hrs	2 Level 2

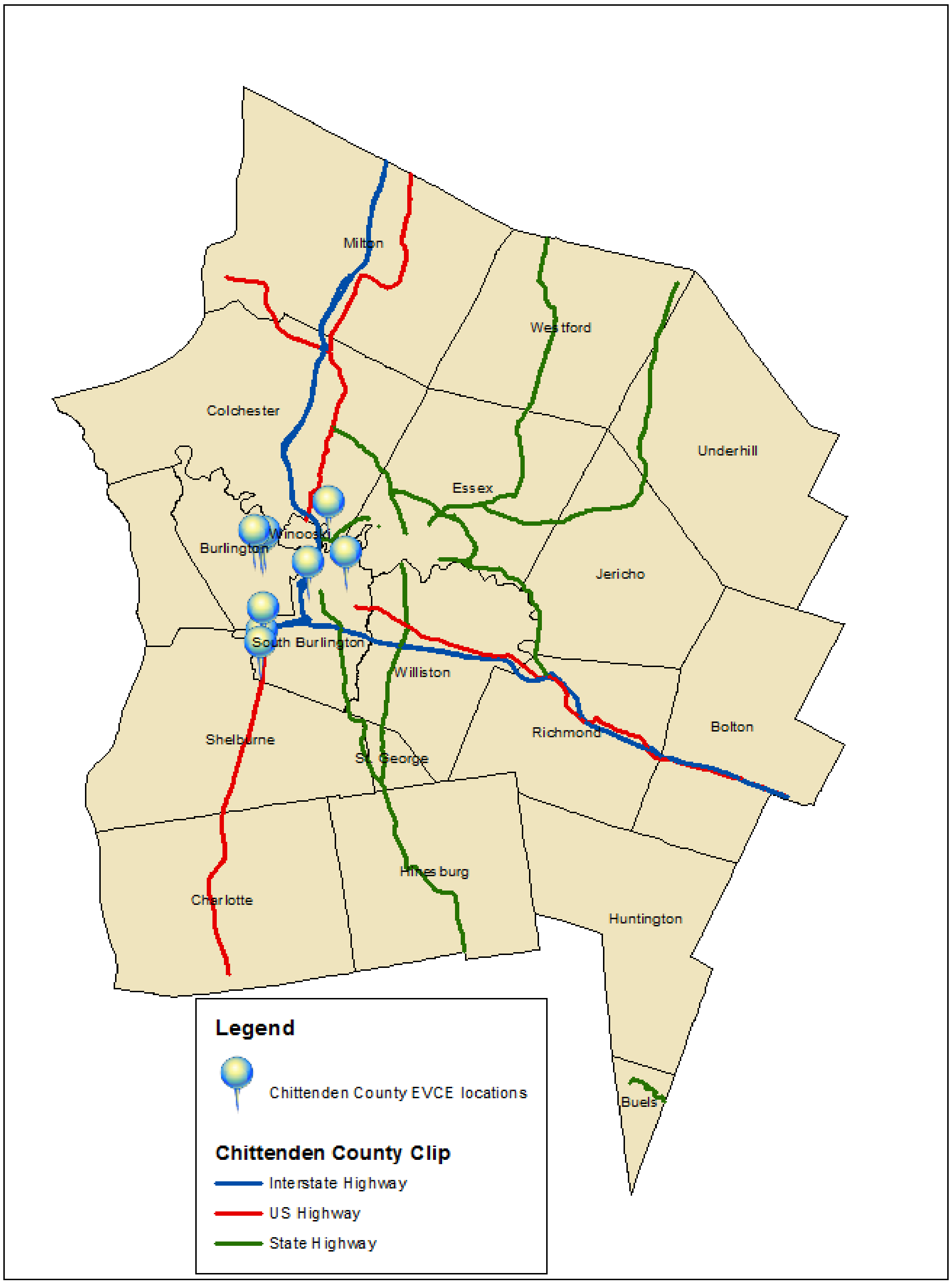

Figure 5. Chittenden County Public EVCE locations

2.4 Charging activity at Public EVCE Locations in Chittenden County

The only locations in Chittenden County with precise usage data available were Saint Michael's College, Burlington Main & Church Street, and Healthy Living Natural Market and Café. Total monthly energy used from February 2012 to January 2013 at these stations is shown in Figures 6 through 8. As can be seen, despite growth in EV ownership in Chittenden County over the 12 month period observed, use of EVCE at St. Michael's College and at the Church & Main intersection in Burlington declined and exhibited erratic variation from month to month. Conversely, use of EVCE at Healthy Living Natural Market increased over this period, growing fairly steadily each month.

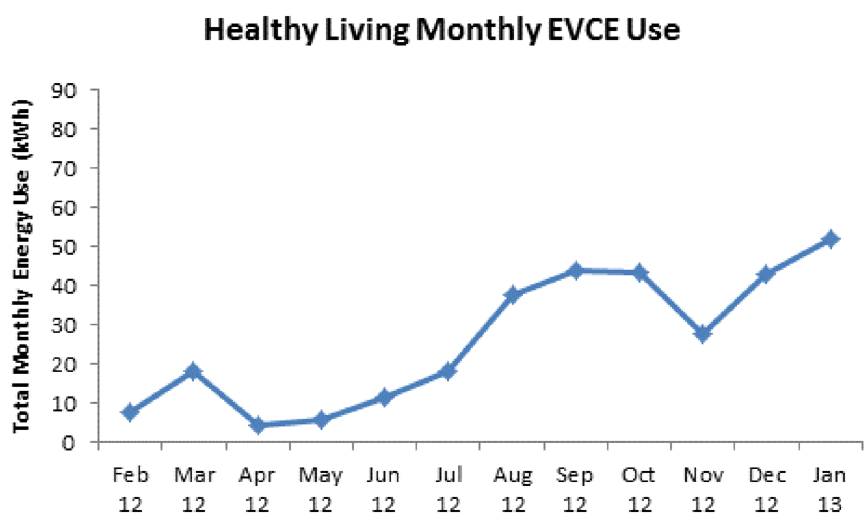

Figure 6. Healthy Living EVCE Charging Activity, February 2012- January 2013

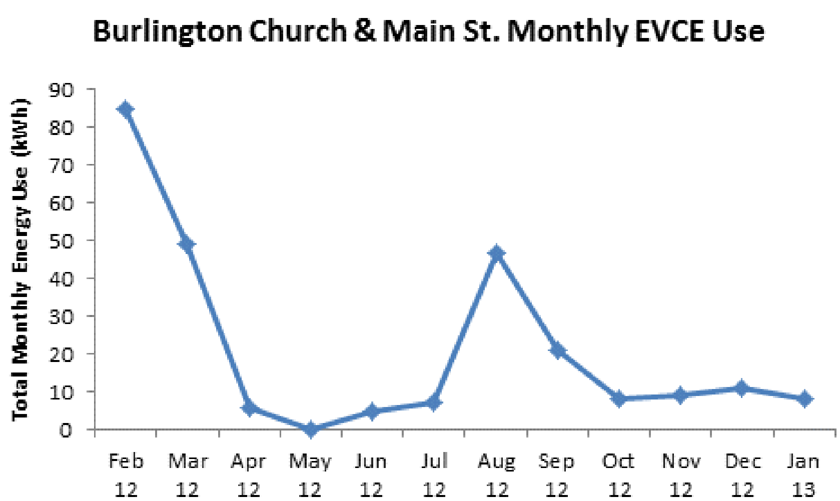

Figure 7. Burlington Church & Main St. EVCE Charging Activity, February 2012- January 2013

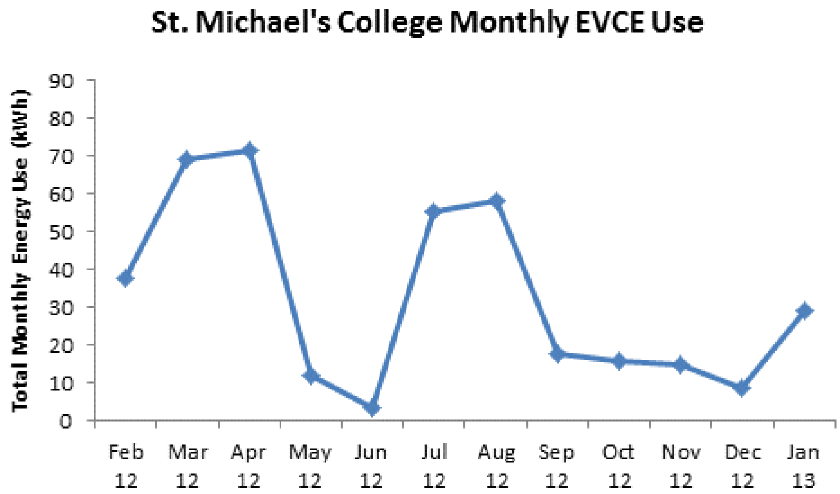

Figure 8. St. Michael's College Charging Activity, January 2012- February 2013

2.4.1 Distribution of charge timing

EVCEs at Saint Michael's College and Healthy Living Natural Market are equipped with software that records the details of each individual charge event. Use of EVCE at St. Michael's College appears to be concentrated on Mondays, Wednesdays and Fridays with a peak start time of 7 and 9 in the morning (64% of charge events) and second peak from 1 to 4 PM (27% of charge events). The average charge time was 1.82 hours per charge event, enough time to add about 18 miles of range on a 3.3 kW Level 2 EVCE. Healthy Living charging times averaged 38 minutes and charge events were more evenly distributed throughout the day and throughout the week. Peak usage appears to occur between noon and 5 PM (56% of charge events) and a secondary high demand period between 7 and 10 AM (23% of charge events). Weekdays received slightly higher usage than weekends.

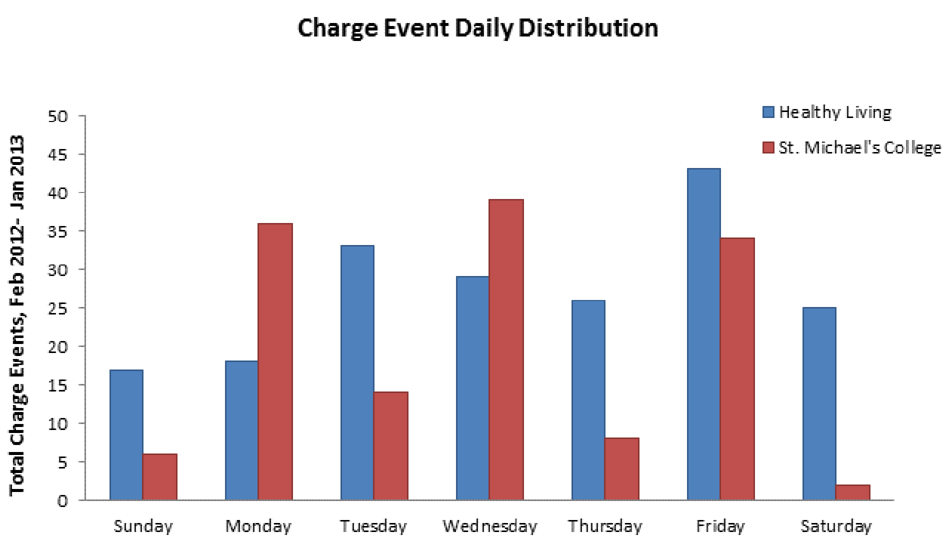

Figure 9. Weekly distribution of charge events, February 2012- January 2013

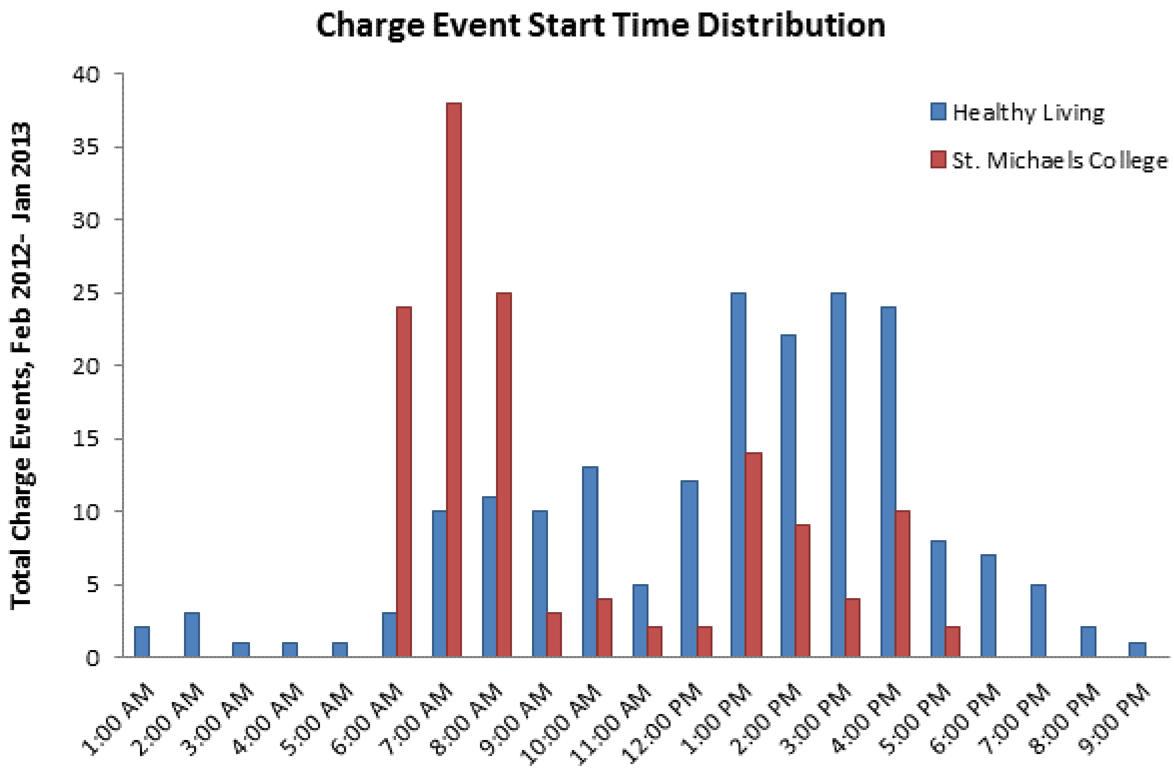

Figure 10. Charge event start time distribution at St. Michaels College and Healthy Living EVCE

In the case of St. Michaels College, the concentration of charge events on specific days—all during the business week—and peak start time of 7-9 in the morning suggests that the EVCE is being used by a single user on a regular work schedule. At Healthy Living, EVCE usage appears to occur during typical shopping hours and for a duration corresponding to the amount of time one would normally spend at a supermarket. At St. Michael's College, where it appears one user makes use of the EVCE during work hours, the average charge time is only 1.82 hours.

These observations are consistent with the fact that 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]. 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 mass 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 not always increase usage of public EVCE.[5]

Although charging will rarely 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 as compared to stores without charging[6]. As EVs become more prevalent, making EVCE available to customers may become a necessity for retailers in highly competitive markets.

Installing EVCE may also offer retail businesses the additional benefit of brand association with environmental leadership and stewardship in the general public. Several national chains have announced their intention to place charging equipment at their facilities.

2.5 Workplace and Multifamily Charging Availability

2.5.1 Workplace charging availability

After home, the workplace is expected to be the second most common location for electric vehicle charging[7,8]. In Chittenden County, no workplaces currently have EVCE available other than those providing charging for the public, St. Michael's College, City Market and Healthy Living. The average commute distance in Chittenden County is approximately 16 miles[9] and therefore most 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, providing a greater margin of range confidence for AEV drivers and reducing the use of backup gasoline engine in PHEVs.

Key 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 use protocol and mitigating demand charges (who is able to use it and when)
- Assigning responsibility for repair and removal if necessary (who owns the equipment?)
- Evaluating fees for use (if provided free to employees, EVCE may be a taxable benefit)
- Assessing current and projected future demand for charging equipment[10]
- Identifying value added to the building including steps toward LEED green building certification for which installation of EVCE provides points

2.5.2 Multifamily charging availability

Access to EV charging on multi-family residential properties in Vermont is limited. Dedicated grounded outlets accessible to the parking or garage space allotted to EV owning tenants is necessary in order for EV ownership to be practical for residents in multifamily dwellings. Installation of EVCE in these settings involves negotiations with landlords or homeowner associations to gain permission to perform the electrical work needed to bring power to parking facilities and make permanent improvements to shared space. Metering of electricity used for EV charging can also involve complexity, particularly when residents do not have complete autonomy over renovation and retrofitting of parking areas.

Like workplace charging, EVCE installation involves dialog and planning between property owners and tenants. The primary considerations in the multi-family context include:

- **Covering costs**: Property owners or homeowner's associations in multifamily dwellings need to assess if EVCE is provided as a free amenity to tenants or a fee for use and how the costs of installation, maintenance and energy will be shared (if provided free these costs will be embedded in the higher rent or association fees paid).

- **Modifying charters, covenants and rental agreements**: Installation of EVCE for tenant use will require reviewing the terms and conditions of rental agreements and any other applicable documents dictating resident conduct on the property and amending them to include EVCE use.
- **Dedicated or common property charging:** EVCE in multi-family dwellings may be provided in a common location for use by multiple tenants or dedicated units at individual residents parking spaces. If provided in a common area, determining which electric meter to assign it to will require discussion as well as reservation or first come first-serve basis, length of time charging can occur, etc.

2.6 Future EVCE 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.

2.6.1 National EV Sales

We reviewed and developed sales projections for the nation as a whole and worked downward estimating Vermont's share of national totals. We used historic hybrid electric vehicle sales in the state as the basis for our calculations. Monthly national sales of EVs have grown over the course of the first two years that mass produced models have become available in the U.S. The monthly sales totaled from across the U.S. since December 2010—the first month the Chevrolet Volt was placed on the market in the U.S.—are shown in the Figure 11.

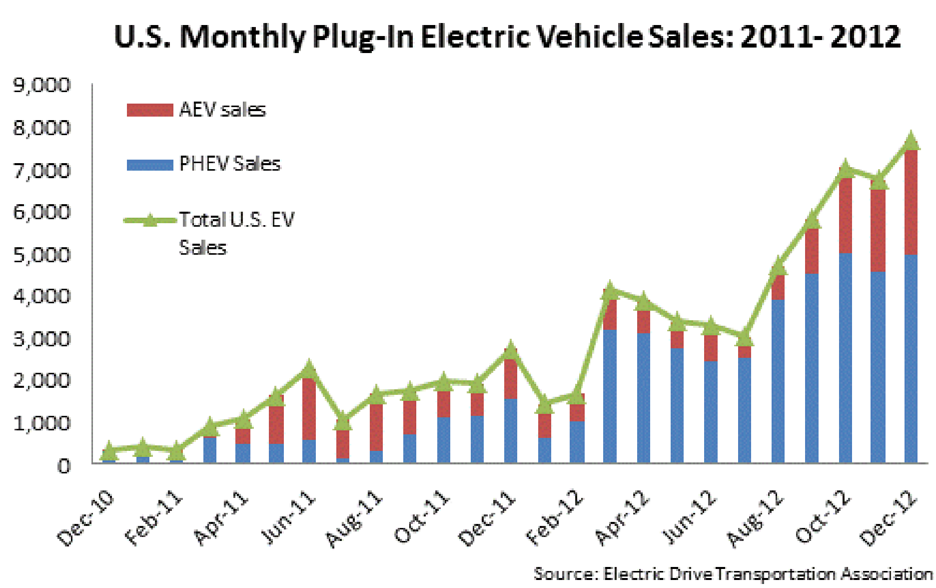

Figure 11. National EV Monthly Sales December 2010 to December 2012

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] The Electrification Coalition has set a goal of 200 million EVs on the road in the U.S. by 2040[13].

2.6.2 Vermont Sales Projections

Due to the large variation in projected EV sales, it is challenging to develop reliable scenarios for Vermont and Chittenden County. In Table 4 below we present two projections: one an adapted version of projections developed by the U.S. Energy Information Administration (2013-2023), and one provided by the Center for Automotive Research (2012-2015). 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 of projected sales based on historic hybrid sales.[14] We used a similar methodology to adapt the EIA's national sales projections for Vermont: we multiplied projected national EV sales 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 often assumed to follow the same demographic as hybrid owners, it has become somewhat common practice to use historic trends in hybrid ownership as a proxy for future trends in EV ownership[15].

Other projections of EV registrations in Vermont can be found in Dowds et al. 2010[16]. These authors assume a baseline scenario of 25% EV penetration of new vehicle sales by 2020. Under this scenario, they estimate that Vermont may have between 30,000 and 70,000 EVs by 2020 and 60,000 to 135,000 by 2030.

Table 4. Projected National and Vermont EV Ownership 2012-2023

	Projected EV ownership scenarios (total # EVs on the road)			
Year	EIA, U.S.	EIA-derived, VT	Dowds et al. 2010	Center for Automotive Research, VT
2013	12,456	238		692
2014	70,256	469		1,180
2015	130,255	759		1,682
2016	151,064	1,073	20,000	
2017	203,726	1,574		
2018	273,714	2,168		
2019	283,648	2,708		
2020	308,944	3,404	50,000	
2021	362,844	4,160		
2022	395,529	4,986		
2023	419,423	5,837		

Additional scenarios of EV deployment in Vermont can be derived from the state's Comprehensive Energy Plan. Vermont's Comprehensive Energy Plan (CEP) calls for 90% renewable energy use across all sectors by 2050. An objective of the CEP is to have 25% of vehicles registered in the state be powered by renewable sources by 2030. Meeting these through the use of renewable electricity would correspond to 142,975 electric vehicles on the road in 2030 and 514,710 electric vehicles on the road by 2050. Although further out than the projections presented in Table 4, achieving these goals through an electrified fleet would require rapid and steady growth in EV registrations in the state.

2.6.3 Chittenden County EV Ownership Projections

The predicted percentage of Vermont EVs registered in Chittenden County used in our calculations was based on the county's portion of state hybrid vehicle ownership in Vermont as of April 2012: 34% of the state total[17]. Per capita hybrid ownership in Chittenden County is the highest of any county in the state. Currently 30% of the state's registered EVs reside in Chittenden County. Census data also show that Chittenden County also possesses the state's highest median household income and education levels, consistent with previous research findings that education level and income are correlated with hybrid and EV ownership[18].

2.7 Demand for home, workplace and public EVCE

One of the most oft cited barriers to EV adoption is the difference in distance these vehicles are capable of traveling compared to internal combustion engine vehicles without stopping to recharge or, in the case of plug-in hybrids, 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, making most[19] EVs on the market capable of meeting the mobility needs of the majority of Vermonters most days. However the lower energy storage capacity of EV battery systems compared with the internal combustion engine has led prospective buyers to concerns of range inadequacy and current EV owners to experience anxiety on occasions when the distance to destination or next charging opportunity is expected to be more than the battery charge can assuredly support. This is often referred to as range anxiety.

EV charging behavior data is available through the EV Project, the U.S. Department of Energy and the Western Washington Clean Cities Coalition (Table 5). 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 for use free of charge. It is unknown how charging for use may affect charging patterns.

Table 5. National EV Charging Behavior

Source	Percentage non-home Level 2 charging (PHEV)	Percentage non-home Level 2 charging (AEV)
Western Washington Clean Cities Coalition[20] (No distinction between PHEV and AEV)	22%	
EV Project[21]:		
• 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)[22]	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[23]. This is an early indicator of the distance EVs drivers are comfortable driving.

2.7.1 Estimating Public EVSE Demand in Chittenden County

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 they will wish to charge at a location away from home. Replenishing enough energy to extend 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 some vehicles are equipped with a 3.3 kWh onboard charger and others are 6.6., assuming there is some minor coordination error of EVCE use (e.g., parking without charging), and finally assuming adequate spatial coverage of EVCE in the county. In our calculations we do not consider the number of plugs needed at each charging station. This value will vary with the amount of vehicle traffic, and EV traffic in particular, that each location receives.

We estimate that each away from home EVCE can serve approximately 5 vehicles during peak charging hours (9 AM to 5PM), that is, Chittenden County will have demand for 0.17 away from home EVCE for every EV.

Broadly, away from home EVCE can be grouped into public charging and workplace charging. To estimate the need for purely public, non-workplace charging, we used spatial data of Vermont's employers (obtained from the firm Dunn and Bradstreet) used to identify priority locations where public EVCE would be feasible, namely, locations offering Retail Trade, Arts, Entertainment and Recreation, Personal and Laundry Services, and Public Administration. These destination types are those that have an expected dwell time long enough to allow an appreciable amount of charging (at least one hour). Approximately 22% of all employees working in Chittenden County work at such locations. In our calculations we use this proportion of employees at priority locations rather than the number of locations to appropriately weight each observation. Presumably, the number of employees is some indication of overall traffic to a given location.

We calculated the number of public EVCE required in Chittenden County as:

(0.17 away-from home EVCE/vehicle) * (22%) = 0.04 public EVCE/EV

Combining this with the proportion of EVs projected to reside in Chittenden County (34%, the county's historic share of the state's hybrid fleet), the table below provides estimates of the number EVCE needed under the three scenarios 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 (and our calculations), the county will require 29 public charging stations by 2018 and 79 by 2023. These values are considerably lower than the number estimated using EV projections from the Center for Automotive Research and Dowds et al. 2012. Using values from the Center for Automotive Research, we estimate that 23 public EVCE will be needed by 2015. Using the baseline scenario from Dowds et al. 2012, we estimate that 272 EVCE will be needed by 2016.

Table 6. Projected Public EVCE Demand in Vermont and Chittenden County

	Estimated # Public EVCE needed in Chittenden County		
Year	EIA-derived	Dowds et al. 2010	Center for Automotive Research
2013	3	.	9
2014	6	.	16
2015	10	.	23
2016	15	272	.
2017	21	.	.
2018	29	.	.
2019	37	.	.
2020	46	680	.
2021	57	.	.
2022	67	.	.
2023	79	.	.

3. EVCE Equipment Costs

Costs of EVCE installation vary widely depending on the characteristics of the site 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. In other parts of the country, equipment prices and installation costs have been seen to drop as EVCE became more prevalent[24]. Table 7 below provides some estimates of the per unit costs of the types of charging equipment likely to be seen in Vermont over the next 5-10 years. The different components of commercial EVCE costs include the equipment price, installation, network licensing and software, energy, customer service, and maintenance.

Table 7. 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[25]: Prices vary with system capability to monitor and charge for use.	$3500 - $9000	$25,000 – $60,000[26]
Installation	$200-$450	$3500-$12000	$20,000 - $25,000
Usage monitoring and point of sale systems (optional)	$400: One time cost for a monitoring and payment system device.	$200/year: Fees for access to software and network systems	Unknown
Energy	$470/year to $800/year: Energy costs will vary depending on time of use and total use.	$1650/year - $2500/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)
Maintenance	$400/year	$400/year	Unknown

In our calculations we used estimates of installation costs obtained directly from vendors. Green Power Technologies is the most prolific installer of EVCE in the nation having completed more than 1,500 installations to date. They quoted us a range of installation costs depending on site specific factors. Peck Electric is a local Vermont contractor that has completed 6 EVCE installations.

Table 8. Estimated Cost of Level 2 EVCE Installation

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

3.1 Offsetting Installation Costs

Providing electrical service to parking spaces for EVCE can account for as much as 20% of installation costs.[27] 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 the per unit cost of EVCE by nearly a third[28]. Businesses installing EVCE are currently eligible to claim a tax credit up to 30% of the cost of the system or $30,000 whichever is less. Public sector and non-profit entities may be able to receive some of this benefit passed down through a lease arrangement with a third party vendor.

3.1.2 Offsetting Energy Costs through Solar

Day time 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 may begin to institute variable rates, using price signals to encourage charging during off-peak evening hours if the increased load of daytime charging begins to cause significant costs to the electric grid.

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 photovoltaics (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 the 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 minimum credit of $0.20 per kWh. Currently law stipulates that this premium apply 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 usage 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 usage 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.

4. Preliminary Cost Estimate of Public EVCE Needs in Chittenden County

When estimating cost of meeting public EVCE needs in Chittenden County, we considered the projected number of EVs on the road in the coming decade, as well the amount of public charging those vehicles will require (described in Section 2.6 of this report), and current costs of EVCE installation (see Table 8). We use only the EIA-derived EV projections in this cost estimate since this was the only projection for which all years were available. Initial installation estimates range from $21,000 to $63,000 for three EVCE in 2013. In subsequent years, EVCE installation costs will either be incremental if public offering of EVCE is expanded annually in response to what will presumably be growing demand, or may be more substantial if large investments in EVCE infrastructure are made in a single year. For instance, if all 29 of the projected EVCE needed in 2018 are built in that year, costs will range from $203,000 to $609,000 (at current estimated installation costs). In Table 9 we present cost estimates for incremental installment of EVCE in the county: in 2013 the table shows the cost of building three charging stations, in 2014 three additional charging stations (to bring the total number of EVCE up to 6), in 2014 the cost of 4 additional EVCE to bring the number up to 10, and so on.

Table 9. Estimated EVCE Installation Costs in Chittenden County, 2013-2023

Year	Estimated # EVCE needed	Green Power Technologies (low estimate)	Peck Electric	Green Power Technologies (high estimate)
2013	3	$21,000	$48,000	$63,000
2014	6	$21,000	$48,000	$63,000
2015	10	$28,000	$64,000	$84,000
2016	15	$35,000	$80,000	$105,000
2017	21	$42,000	$96,000	$126,000
2018	29	$56,000	$128,000	$168,000
2019	37	$56,000	$128,000	$168,000
2020	46	$63,000	$144,000	$189,000
2021	57	$77,000	$176,000	$231,000
2022	67	$70,000	$160,000	$210,000
2023	79	$84,000	$192,000	$252,000

5. Potential EVCE Business Models

A summary of potential EVCE business models can be found in Table 10.

Table 10. 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
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 Renewable Fuel Standards establish criteria for the generation and sale of Renewable Identification Numbers (RINs). RINs help obligated parties (importers and refiners of fossil fuels) meet Federally-mandated Renewable Volume Obligations (RVO's). 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, such as is generated from the Coventry landfill or from GMPs CowPower program 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.

EVCE Business Model	Description
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. By extension, installation of charging equipment and accompanying photovoltaic panels—if erected such that they provide a protective canopy for highways—using private funds may be interpreted as improvements to the highway and thus eligible to serve towards federal transportation match.

5.1 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. Because many states do not allow unregulated utilities to sell electricity, billing is typically done based on time spent at an EVCE or unlimited access for a fixed fee. Examples of subscription and fee 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 $29.99 to $69.99 per month for a Level 2 charging installation. The user avoids the upfront costs of the installation as well as the operation and maintenance costs and eVgo earns a return through these fees[29]. 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.

5.2 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. [30] 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 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.[31] 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[32].

5.3 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. Under full utilization, an EVCE would generate approximately $250 annually if served entirely by electricity generated from biomass.

5.4 Public land or asset swap

When a business makes use of public land for commercial activity--such as sidewalk space for outdoor seating at a restaurant or a piece of municipal park land for a telecommunications box--this is known 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 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 collocating EVCE with these installations.

6. Site Analysis and Charging Equipment Selection Protocols

6.1 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. Broadly, the criteria we propose for public siting of EVCE include:

- Availability of power
- Paved site with parking capacity
- 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)
- Closing gaps in charging coverage (how far is the proposed site from the closest EVCE?)

Presumably, most public charging will be Level 2. Level 3 charging is prohibitively expensive for most public agencies at present and Level 1 charging is really only ideal at those destinations where vehicles will be parked for many hours, such as home and work. The table below provides a summary of the charging speed and rough cost estimate for each type of EVCE.

Table 11. EVCE Type, Charge Time, and Installation Cost

EVCE Type	Charge time	Estimated Installation Cost
Level 1	~14 minutes/mile of driving	$30-$3,000
Level 2	~3-6 minutes/mile of driving	$7,000-21,000
Level 3	~24-48 seconds/mile of driving	$45,000-$85,000

Investment in PEV charging infrastructure should balance the characteristics of the existing landscape and the aspirations for future development. The data used in this report to isolate the locations where public EVCE would be feasible is shown on the map below (Figure 12). These destinations include Retail Trade, Arts, Entertainment and Recreation, Personal and Laundry Services, and Public Administration. They are represented with graduated symbols based on the number of employees at each location which is assumed to be indicative of the number of trips made to the location.

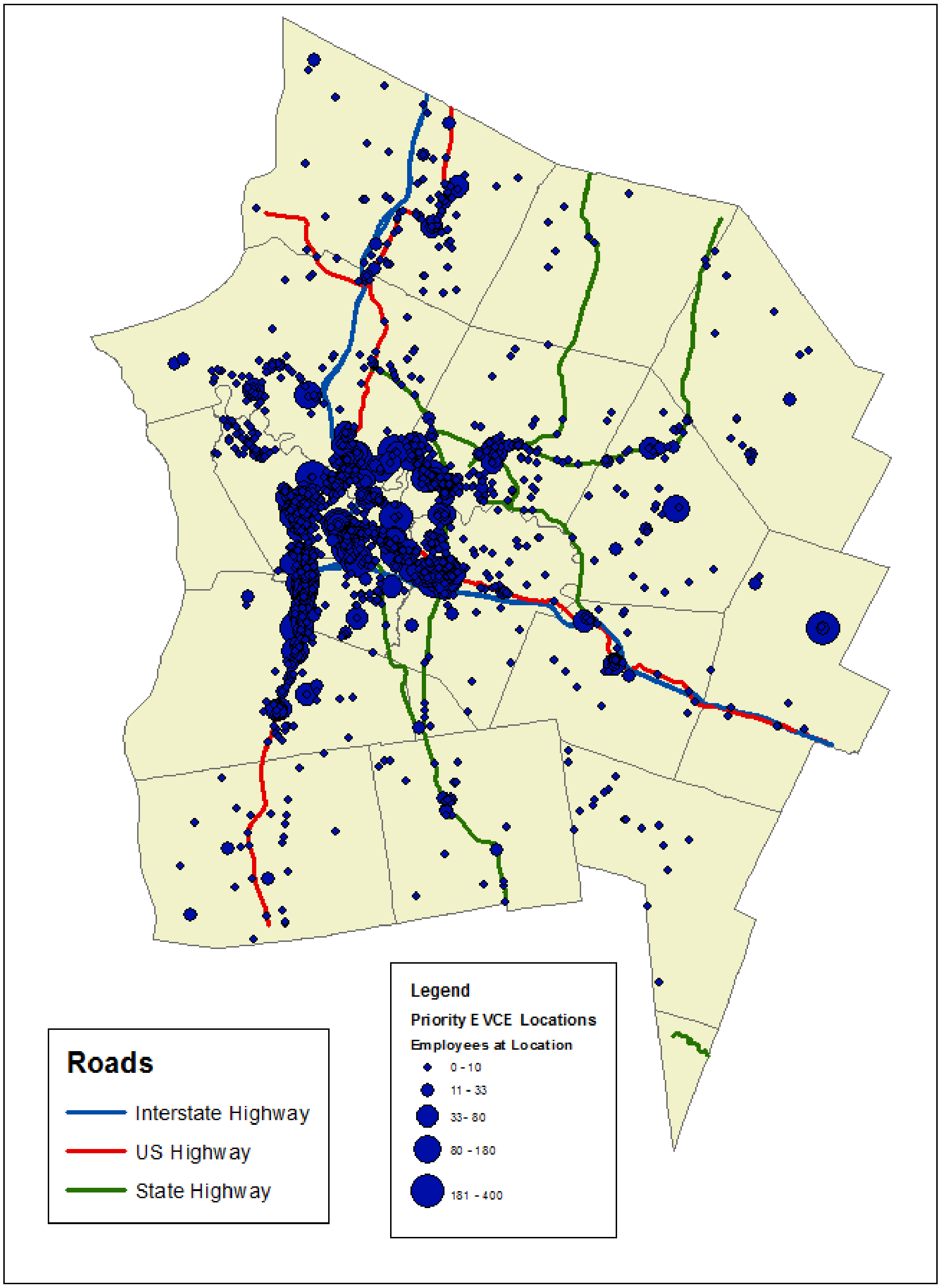

Figure 12. Chittenden County Priority EVSE Locations

While the locations on the map above may be well suited for EVCE, they may not all be ideally situated within the broader vision of future land use specified in the ECOS plan. For example, the smattering of locations in Charlotte along the Route 7 corridor in the southwest corner of the county are types expected to be compatible with EVCE but are not in areas targeted for future growth in the ECOS plan. Siting of EVCE within Center, Metro, Suburban, Village, and Enterprise Planning Areas will help to reinforce efforts to meet ECOS plan goals of concentrating the majority of new development in these areas. EVCE could also serve as a potential tool for promoting economic development by attracting EV drivers to spend time in areas targeted for development of retail and service sector industry.

The need for public investment in EVCE will depend in part on the reaction of the private sector to the onset of transportation electrification. As EVs become more widespread, businesses may begin to invest in charging equipment on their premises in an effort to attract customers and talented employees. Working together with local businesses to overcome barriers to EVCE installation may be a cost effective means of leveraging public resources to meet the EV charging needs of Chittenden County residents. Engaging nearby businesses will ensure that EVCE provides maximum benefit to the local economy and EV drivers at minimum public costs, particularly in those locations that serve as key access points to public transit and commuter bicycle and pedestrian facilities.

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