Electric Vehicle and Charging Station Study

Western Connecticut Council of Governments

Prepared by:
WestCOG
1 Riverside Rd, Sandy Hook, CT 06482

Version 1.0 (06/19/2017)

Acknowledgment of Funding Sources

This document was prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration, State of Connecticut Department of Motor Vehicles (DMV), and the State of Connecticut (CT) Office of Policy and Management. The opinions, findings, and conclusions expressed in this publication are those of the authors and do not necessarily reflect the official views or policies of the Western Connecticut Council of Governments.

Report Summary

This report evaluates the level of electric vehicle (EVs) usage and accompanying charging infrastructure installation in the Western Connecticut Region (Region) using data from the Connecticut Department of Motor for the model years 2011-2015 and with the attributes of SUV, Passenger, and Van. After processing, cleaning, and subsetting there are 753,060 vehicle records for CT as a whole and 158,432 vehicle records (21.03%) for the Region. For the purposes of this report, EV ownership includes both zero emission and plug-in electric vehicles. Ownership rates of EVs are much higher in the Region (0.71%) than the rest of the state (0.31%) excluding the 18 towns of the Region. The Region has 37.77% of EVs in CT. We found 20,332 hybrid cars registered in the five-year period in CT with 2,971 EVs (0.39%) and 17,361 hybrids (2.70%) of which 1,235 (0.16%) are zero emission EVs. In the Region, 1122 EVs are registered for the same period.

There are 58 public EV charging stations (charging stations) within the Region (14.58%) and 401 within the state of CT and there are 19 EVs per charging stations in the Region and 5.2 EVs per charging stations in the rest of the region.

Gaps in the geographic distribution of these charging stations exist along Route 7, especially north of I-84, along the Merritt Parkway, and in the I-84 corridor, except near Danbury. EVs and charging stations purchase incentives should be reevaluated as electric vehicle usage appears highest in wealthier Connecticut communities and lowest in rural or lower income communities. In addition, many gaps exist in the charging infrastructure outside of the interstate corridor of I-95 so incentives should target geographic gaps.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Introduction

With increasing concerns about the impact of Green House Gases (GSGs) on climate change, improvements in battery technology, and the geopolitical worries related to unstable petroleum producing countries, interest and usage of EVs is on the rise in the United States. Recent policy initiatives by the Federal Government such as the Plug-in Electric Drive Vehicle Credit[1] program and the State of CT CHEAPR program, are targeted toward incentivizing the purchase of these vehicles[2] and the installation of related EV charging infrastructure.

While state-level information about EV usage is widely available, little is known about how many EVs are purchased in each municipality within CT, how they are utilized, and what is the geographic relationship between the EV domiciles[3] and public charging stations. Answers to these questions may help determine investment priorities, efficacy of current EV policy in CT, and the relative adoption rate in the Region.

Using ownership data from the CT DMV, other complimentary data, and a literature review, this report has the following goals:

- Synthesize background information on the EV market and usage patterns from a literature review;
- Provide baseline information on the use of EVs and related charging station locations for the 18 municipalities in the Region;
- Identify potential infrastructure gaps and policy recommendations to increase the usage of EVs.

Background

EVs are a general category of vehicles which are propelled by an electric motor and can include passenger cars and commercial vehicles. The term EV invokes images of passenger cars like the Tesla S, Chevy Volt, or Nissan Leaf. These vehicles can run on electric motors alone or have supplemental internal combustion engines (ICE). The terminology of EVs can be confusing with many different acronyms for the specific subtype of EVs such as Plug-in Hybrid Electric Vehicle (PHEV)[4], Fuel Cell Electric

[1] It is not yet clear whether the Trump administration will try to change alternative energy vehicle incentives but the political climate is changing.

[2] For instance, the Connecticut Hydrogen and Electric Automobile Purchase Rebate Program (CHEAPR) offers substantial incentives for EV and hydrogen vehicle purchases

[3] EV domiciles refers to the location at which the EV is garaged.

[4] PHEVs have both a gasoline-powered engines and an electric motor. They can drive exclusively on electricity charged by plugging into a charging station or a typical household outlet. PHEV do not emit GHGs while using their electric engines.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

Vehicle (FCEV)[5], and Zero-emission Vehicles (ZEV).[6] A comparison between the characteristics of EVs versus ICE vehicles is summarized in Table 1. In this report, EVs collectively refer to both PHEVs (e.g. Chevy Volt) and ZEVs (e.g. Nissan Leaf) passenger vehicles.

Even though EVs are typically more expensive than conventional ICEs, manufacturers have been rapidly introducing new EV models and technologies because of higher Federal Corporate Average Fuel Economy (CAFE) standards, concerns about GHG emissions, energy prices, and regulatory requirements from the pioneering California Environmental Protection Agency's Air Resources Board Zero Emission Vehicle Program (California, 2017) – a state where EVs have by far the greatest market penetration.

Increasing EV use is an essential piece of the *CT Comprehensive Energy Strategy* which guides state energy policies (DEEP, "CT's Path to Clean Vehicle Future, 2015). In 2013, Governor Malloy joined seven other states in the *ZEV Memorandum of Understating ("State," 2013) and Multi-State ZEV Action Plan (Multi-State, 2014)* which pledged 3.3 million ZEVs on the road by 2025 for states that adopted the plan as well as, "to develop the infrastructure, coordinating policies, codes and standards to facilitate 3.3 million ZEVs" (CT DEEP, "Electric Vehicles 101", 2015). As a member of the international ZEV Alliance, Connecticut agrees to make all passenger vehicles ZEVs in their jurisdiction by 2050 (Multi-State, 2014).

Comparison Between Electric and ICE Vehicles

EVs	ICE
Reduced GSGs emissions	GSGs emissions
Less range	More range
Local travel only (typ)	Capable of regional travel
Hours to recharge batteries	Minutes to fill tank
Energy sources can be renewable	Primarily non-renewable energy sources (petroleum)
MSRP is higher than comparable ICE vehicle	MSRP is lower than comparable EV

[5] FCEVs use fuel cells, and not batteries to drive an electric drivetrain.

[6] ZEV is a regulatory term, and while these vehicles typically do not emit GHGs, in Connecticut this class of vehicle can include PHEVs that emit GHGs when the batteries are depleted.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

Despite these policy initiatives, CT is behind states such as California, Hawaii, Texas, New York, and Oregon in the installation and usage of alternative energy infrastructure like wind and solar, or the use of hydroelectric power. Nonetheless, it has a cleaner energy grid than most states mostly due to reliance on nuclear power and natural gas. CT continues to invest in lower polluting and renewable energy creation (Idaho, "How", 2014) and consequently the conversion of ICE vehicles to EVs will make a significant impact on CO_2 emissions (DEEP, "Electric Vehicles 101", 2015). Incentivizing EV purchases for CT residents is a logical component of the State's energy and transportation policy because of our comparatively small geographic area, lack of local fossil fuel production, large urban population, and cleaner energy grid.

Nationally, EV sales were up by 38% in 2016 after being down slightly in 2015. California is the overwhelming leader in total and percentage of EV usage with 8 to 10 times more EVs than the other states in the top five: Florida, New York, Washington, and Texas. By percentage of vehicle sales, CT is eighth in ZEV sales for 2016 (Global, "Sales", 2017) in the United States. Still in 2015, only 0.28% of registered cars were EVs in CT (U.S. Department of Energy, "Fact #876", 2015). The Chevy Volt and the Tesla Model S were the most popular models (Tronchaniak, 2016).

To encourage acceptance and purchase of these vehicles, significant federal and state tax credit incentives are provided to consumers – up to a combined total of $10,500 in Connecticut through the CHEAPR program (DEEP, "Electric Vehicles 101", 2015). This incentive program continues through 2017. Federal programs include funding from the U.S. Department of Energy and the Federal Highway Administration (FHWA) (Energy, 2016).

Despite these tax credit incentives EVs are still more expensive than comparable cars even as the prices of the crucial battery technologies continue to fall (Table 1). EV use at the state level appears to be positively related to state incentives such as those found in CT and California, higher family incomes,[7] and adjacency to the West Coast. It is negatively related to rural land

[7] California, New York, Washington, and Texas are all at or above the U.S. median income for 2015.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

use and below average family income (U.S. Department of Energy, "Fact #876", 2015).[8]

Table 1: Comparison of MSRP of ICE and EVs for 2017 models

EV Models			ICE Models	
Rank	Make/Model	MSRP	Make/Model	MSRP
1	Tesla Model S	$68,000	Audi A6	$47,600
2	Nissan Leaf	$34,200	Nissan Altima	$22,500
3	Volkswagen E-Golf	$33,220	Volkswagen Golf	$19,895
4	Ford Focus Bev	$33,120	Ford Focus	$16,775
5	Smart Fortwo Electric	$12,490	Smart Fortwo Pure	$14,650

EVs, especially ZEVs, still have limited driving range in comparison to ICE vehicles. In addition, they can lose battery capacity in the winter because low temperatures reduce the capacity of the batteries, and in the summer when air conditioning is utilized. Many of the production ZEVs have a range of 80-120 miles while PHEVs typically have an electric-only range between 20 and 50 miles. The recent introduction of innovative models has expanded the driving range per charge to 238 miles for a 2017 Chevy Bolt (Chevrolet, 2017) and 282 miles for the 2016 Tesla S models per charge (Tesla, 2017).[9]

EV Charging Stations and Usage Patterns

EV charging stations are identified by the Federal Government as a necessary component for wide-spread and regional EV usage and private companies are investing in these facilities as well (Kane, 2016). Incomplete infrastructure combined with the limited range of current EVs impacts method of usage and purchase choices by consumers.

CT is still building out its charging station infrastructure to facilitate regional and commuter electric vehicle usage[10] and minimize commuter "range" anxiety. CT needs to make it easier to find and access charging stations (Figure 3) to facilitate EV use and acceptance.[11] This is often cited as a "causality dilemma" for EV usage.[12] There are 58 charging stations within the Region and 401 within the state of CT.

[8] The five lowest EV registration rates are for Mississippi, Louisiana, Arkansas, Wyoming, and North Dakota, Mississippi, Louisiana and, Arkansas have median family incomes that are well below the U.S. median incomes for 2015 while Wyoming and North Dakota are large, rural states.

[9] The change in EV range will likely impact policy decisions related to EV incentives.

[10] It is unclear whether the Trump administration will renew these incentives.

[11] "Range anxiety" refers to the concern of ZEV users that they will run out of charge while on a trip and can't find a place to plug-in for a charge.

[12] Chicken and the egg problem

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Surprisingly, most EV drivers charge at home -- about 85% of the time -- and favor just a few charging stations such as their offices (CT DEEP, "Electric Vehicles 101", 2015) and few owners ever take their EVs to charge depletion. EVs such as the Nissan Leaf and Chevy Volt average about 750 miles per month or 25 miles per day and rarely go over 1500 miles per month while virtually no EVs travel more than 2000 miles per month (Idaho, "How many", 2014).

The usage data suggests that drivers utilize their EVs within a charge "*local driveshed*" for commuting to work and running errands like getting groceries.[13] Drivers appear to be cognizant of the limitations of their vehicles. Another alternative EV driving model is a "*regional model*" where drivers go to destinations that require visits to charging stations at locations along highways and interstates for trips beyond their driveshed.[14] The regional model appears to be implicit in the State of CT policy and is the method that Tesla Motors is promoting. Few people currently use their EVs in this manner.

Costs for both home and public chargers are not excessive but will likely limit the number of conversions of ICE to EVs households. A home charger with parts, labor, and permitting costs about $1200 while a public charger may range in price from about $5,000-$10,000 for a curbside or garage charge. The more desirable "Level 3" station installations will cost upwards of $50,000 to $100,000 (Holland, 2015).

In CT, existing incentive programs for charging stations closed for 2016 (CT DEEP, "EV Connecticut- EV Charger," 2017)[15] and the Federal Government has done the same (U.S. Department of Energy, "Federal", 2017). Charging stations may also be in private residences as EVs are likely the second or third car available for use in a household. Public EV infrastructure such as charging stations are likely not as critical for these owners because they possess multiple vehicles.[16] For EV owners with only one vehicle, public EV charging stations are critical to facilitating regional, business, and inter-municipality trips because their economic viability is dependent on having a

[13] The "driveshed" would extend out to 30%-40% of range capacity so EV drivers can get home before range anxiety kicks in.
[14] The regional model are for trips beyond 50% of range capacity and require the identification and usage of EV charging stations to complete the trip or return home.
[15] Additional funding for 2017 has not been announced.
[16] The data did not allow us to determine the mix of vehicles per household but is an important policy issue.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

vehicle available for accessing work though this number is likely small. [17] Most people; however, are likely charging at home as public-electric car charging stations often sit idle (Russo, 2015). We were unable to determine how many people used EVs as primary or supplemental vehicles.

Figure 1:Tesla at charging station (http://www.afr.com/lifestyle/teslas-electric-car-highway-on-the-road-to-gundagai-20151002-gjzpw3

Methodology

To determine EV usage in the Region, data was requested and obtained from the CT DMV databases in the summer of 2016. Two different types of vehicle registration information are included in the data from DMV. One table identifies where the vehicles are parked (*i.e. the domicile table*) and the other locates where the owner live and pay taxes (*i.e. the residence table*).[18] The domicile vehicle location data is utilized because it better reflects the origin of the vehicle's trips.

The DMV extracted the attributes that allow the identification of electric vehicles through their Vehicle Information Number (VIN) including date of purchase, town, and type of vehicle. To protect the privacy of owners, this data was transferred from DMV to the CT OPM to de-identify address data and aggregated to Block Group and municipal geographies. The intention was to relate EV ownership information and demographic data from the Census Bureau but much of the Block Group information was lost or corrupted in the

[17] This information was not available in the DMV data set procured for this project.

[18] In some regions, this would not be important but because of the wealth in Western CT, many people have multiple homes so the domicile of the EV is considered more important than where the tax bill is paid.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

transferred file. This information was cleaned from the data. The smallest unit of aggregation for this data is the municipality.

The DMV provided WestCOG with 3,062,975 records of vehicle registration, of which 643,276 were null values that were removed and cleaned from the data set. Thus 2,596,154 records constitute the primary data set for the **car model years** 1900 to 2017 and 818,564 records for the **car model years** of 2011 to 2015.[19] Only data for the model years of 2011-2015 and for the attribute vehicle_type "passenger", "SUV" and "van" are included in this study (total number of records = 753,060 in CT and 158,432 records for the Region (21.03% of CT total)) because 2016 and 2017 models were still being sold when this data was acquired. In addition, virtually no modern EVs (e.g. the Volt or Tesla S) were available before 2011 and these are all passenger vehicles or SUVs.[20]

Attribute coding errors were found in the DMV data set for plug-in and hybrid vehicles (such as the Ford Energi vehicles) and differences between SUVs and passenger cars which caused further difficulties in subsetting the data set. The EV data was intended to have Block Group level geographic specificity but this attribute appeared corrupted. Additional spatial attribute point data was obtained from the United States Department of Energy for the locations of electric vehicle charging stations within the borders of Connecticut, New York, Rhode Island and Massachusetts. This data was plotted in a GIS using latitude and longitude coordinates.

A geographic buffer of 2 miles was used to identify a charging station service area which we assume to be the maximum distance someone can travel when they deplete their battery. A spatial join was performed between the charging stations buffer and a layer containing the interstate road system, attained from the Federal Highway Administration (FHWA), to create a count of charging stations within the charging station service area. The five most common vehicle types are listed in table 2.

[19] For attributes within DMV data set Fuel_type equals gas, electric, hybrid, flex fuels and Vehicle_type equals passenger, SUV, van, and truck.

[20] This count does not include four unusual models from before 2011.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

Table 2: Top 5 car models for years 2011-2015 (State of CT)

Make	Model	# Registered
Toyota	Prius Plug-in	773
Telsa	Model S	763
Cheverolet	Volt	601
Nissan	Leaf S/sv/sl	267
BMW	I3 Rex	120

Figure 2: Commercial EV charging station (https://www.chargepoint.com/products/commercial/ct4000/)

Results & Discussion

EV Sales Trends

Despite the media attention and a public policy focus, the rate of EV ownership is still very low in CT (0.38%). 2,971 EVs (0.39%) and 17,361 hybrids (2.70%) are registered for the model years 2011 to 2015, of which 1,235 (0.16%), are zero emission vehicles. The rate of EV ownership is more than twice as high within our Region (0.71%) than outside our Region (0.31%) and includes 37.77% of all the EVs within CT. About half of the EVs in the Region are zero emission.

From 2011-2015, EV registration increased more than ten times in CT (Table 3). In the last model year, 821 EVs were registered, a 12% increase from the previous year. For the model years 2013-2015 the percentage of EVs remains roughly stable. The three most popular models are the Toyota Prius Plug-in, Tesla Model S, and the Chevy Volt (Table 2).

The sale of EVs appears to somewhat related to the price of gasoline though advances in EV technology, such as battery capacity, have allowed plug-in EVs to become more attractive and cost-effective even as the price of gasoline dropped in 2015. Some consumers appear to be interested in both reducing GHG

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

emissions and using the electric drivetrain in EVs which provided "instant torque." With the improving battery capacity, drive quality, and lower costs, a further decoupling of EV sales and the price of gasoline is expected.

Table 3: Registered EVs by count and percent within CT by year with annual average gas prices

State of Connecticut			
Registered Domicile Evs			Retail Gasoline Price
Model Year	# of Evs	% of EV	(2015 dollars/gallon)
2011	63	0.04%	$3.75
2012	514	0.32%	$3.80
2013	851	0.51%	$3.62
2014	722	0.42%	$3.40
2015	821	0.42%	$2.45
Total (2011-2015)	2971		

The municipalities of the Region lead in EV usage with eight municipalities ranked in the top 10 state-wide and 11 of the top 20 (Table 4). Greenwich, Westport, and Stamford are in the top three. Greenwich has about a quarter of the EVs in the Region. By percentage, Westport has the highest ownership rate of EVs (1.55%) and Danbury (0.30%) and New Milford (0.23%) having the lowest. Five towns have more than 1 percent EVs (Table 5) while more Housatonic Valley towns are in the bottom of half of percent ownership list than towns in the southern municipalities in the Region.

The most popular EV model in the Region is the Tesla Model S with 508 registered vehicles (45.28%) reflecting a recreational rather than utilitarian orientation. The Model S is stylish and more luxurious than competing models—the typical cost is about $90,000(Tesla, 2017). The Toyota Prius Plug-in EV (194 vehicles) and Chevrolet Volt (164 vehicles) cost less than half the price and are the second and third most popular EVs. Though the pricing of EVs has fallen and the features and performance continue to improve, the purchase of EVs currently appears to be the purview of wealthier consumers and function primarily as lifestyle vehicles rather than the primary household vehicle. The desirability of the Tesla S and not the vehicle cost appear to be driving the market in the Region.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Table 4: Connecticut towns ranked by the number of registered EVs, WestCOG municipalities in bold (2011-2015)

Rank	Town	# of Evs
1	**Greenwich**	**256**
2	**Westport**	**146**
3	**Stamford**	**142**
4	Fairfield	113
5	**New Canaan**	**93**
6	**Norwalk**	**82**
7	West Hartford	76
8	**Darien**	**61**
9	**Wilton**	**57**
10	**Ridgefield**	**50**
11	**Danbury**	**50**
12	**Weston**	**45**
13	New Haven	45
14	**Newtown**	**41**
15	Glastonbury	40
16	Guilford	39
17	Hamden	39
18	Middletown	35
19	Avon	34
20	Farmington	34

Table 5: Rank order of municipalities by %EV of all registered cars

WestCOG Rank Based on %EV				
Rank	Town	All	# of EVs	% EV
1	Westport	9421	146	1.55%
2	Weston	3385	45	1.33%
3	New Canaan	7055	93	1.32%
4	Bridgewater	477	6	1.26%
5	Greenwich	20740	256	1.23%
6	Wilton	5996	57	0.95%
7	Darien	6735	61	0.91%
8	Sherman	975	8	0.82%
9	Redding	2616	19	0.73%
10	Ridgefield	7759	50	0.64%
11	Newtown	7212	41	0.57%
12	Stamford	29620	142	0.48%
13	Norwalk	19774	82	0.41%
14	New Fairfield	3750	15	0.40%
15	Bethel	4752	18	0.38%
16	Brookfield	4876	18	0.37%
17	Danbury	16713	50	0.30%
18	New Milford	6576	15	0.23%
	Total	158432	1122	0.71%

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

CT Geographic Patterns of EV Usage

The Western CT area has much higher levels of EV ownership than other regions (Figure 3 and 4) of CT. This pattern mimic the nation as a whole where wealthier and more urban states tend to have more EVs than poorer and more rural states (Global, "Sales", 2017). In addition, higher rate of EV usage are found along major transportation corridors like I-95 and I-91 rather than in rural CT. This pattern could reflect household incomes, level of education, or commuting trends near the interstates. Five municipalities in northwestern CT and 24 municipalities statewide do not have any EVs at all. Nationally, a similar pattern exists where EV use is much lower in rural states or state that have large commodities industries. Even within the Region the rural communities to the north have far fewer EVs than areas near the Long Island Sound.

EVs and the WestCOG Region

The Western CT area is in the forefront of EVs use but geographic adoption of EVs and charging stations are not evenly dispersed. In the more rural parts of Connecticut, east of I-91 and the northwest corner, the majority of the towns have less than 20 EVs for each municipality while coastal municipalities (especially the municipalities with the Region) and municipalities located along the major interstates tend to have much higher rates of EV ownership.

Within the WestCOG region, the eight southern WestCOG municipalities have about 80% of the EVs (882 vehicles) compared to the 10 northern municipalities (240 vehicles). The municipalities near Long Island Sound also have higher density of EVs and EV charging stations than the northern region.

Figure 3: Chevy Bolt (Fitzpatrick, 2017)

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

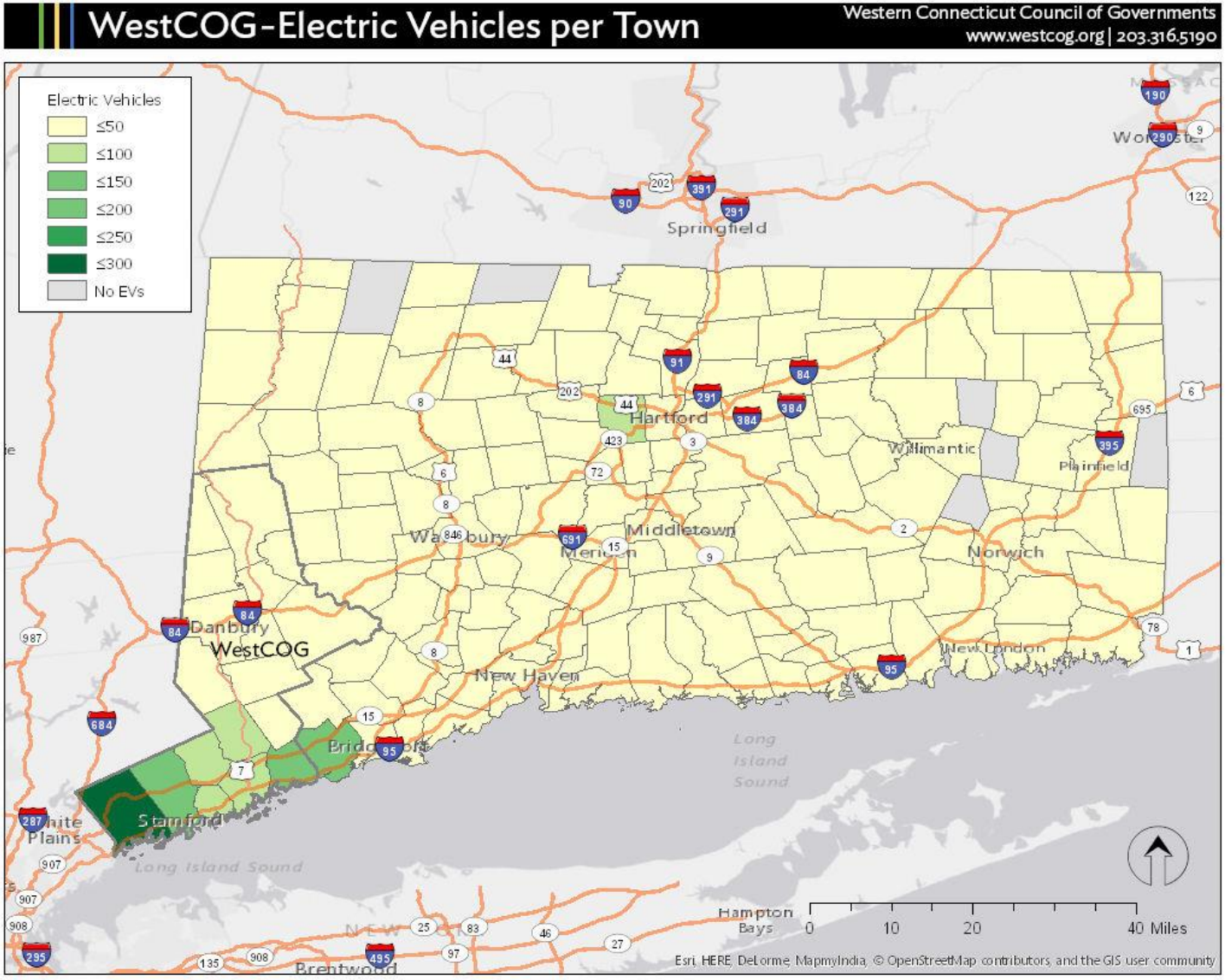

Figure 4: The number of registered EVs per town. Towns with gray shading have no vehicles.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

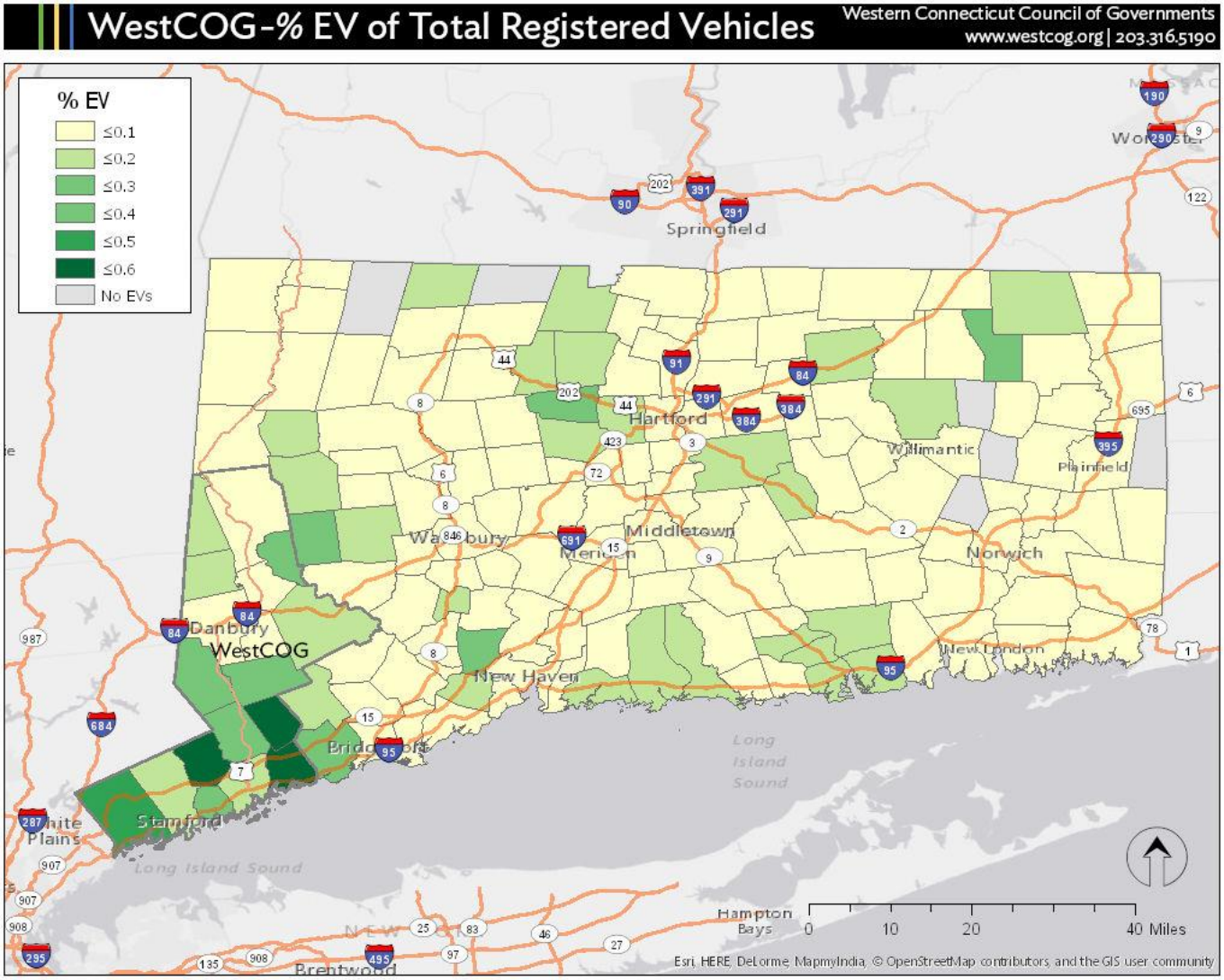

Figure 5: Percent EVs registered per town. Towns with gray shading have no vehicles.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

EV Charging Stations in CT

CT has 401 EV charging stations mostly located adjacent to interstates, U.S. highways, and state roads and 58 (14.46%) charging stations are within the Region. There are 18.6 EVs per charging stations in the Region and 5.4 EVs per charging stations in the rest of the CT suggesting that the Region is currently underserved compared to CT as a whole. The highest concentrations of these charging stations are in the urbanized areas of Hartford, New Haven, and Stamford (Table 6). The I-95 corridor has a particularly higher density of charging stations. Away from major interstates and arterials, the availability of EV infrastructure is limited (Figure 6) and many towns in CT have no charging stations including six communities in the Region. In the Region, Greenwich, New Canaan, Weston, and areas north of Danbury are least served by charging station infrastructure.

A 2-mile buffer (or charging station service area) was added to each EV charging station to represent the distance a person is willing to travel off an interstate or arterial road to recharge a depleted EV battery (Figure 7). Throughout the 111-mile length of I-95 in Connecticut, there are 107 charging stations (Table 7) which is the most of any interstate within Connecticut. Other areas east of I-91 and north of I-84 on the west side of the state have fewer charging stations.

Table 6: The top five CT municipalities with charging stations by count

Muncipality	# of Charging Stations
Hartford	20
Stamford	15
New Haven	12
Fairfield	9
Groton	9

Table 7: Number of charging stations per municipality in the Region

Rank	Town	# of Charging Stations	# of EVs	Ratio
1	Stamford	15	142	9.5
2	Norwalk	8	82	10.3
3	Westport	7	146	20.9
4	Greenwich	6	256	42.7
5	Darien	5	61	12.2
6	Danbury	5	50	10.0
7	Ridgefield	4	50	12.5
8	Wilton	3	57	19.0
9	New Milford	2	15	7.5
10	New Canaan	1	93	93.0
11	New Fairfield	1	15	15.0
12	Bethel	1	18	18.0
13	Weston	0	45	N/A
14	Bridgewater	0	6	N/A
15	Sherman	0	8	N/A
16	Redding	0	19	N/A
17	Newtown	0	41	N/A
18	Brookfield	0	18	N/A
	Total	58	1122	19.3

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

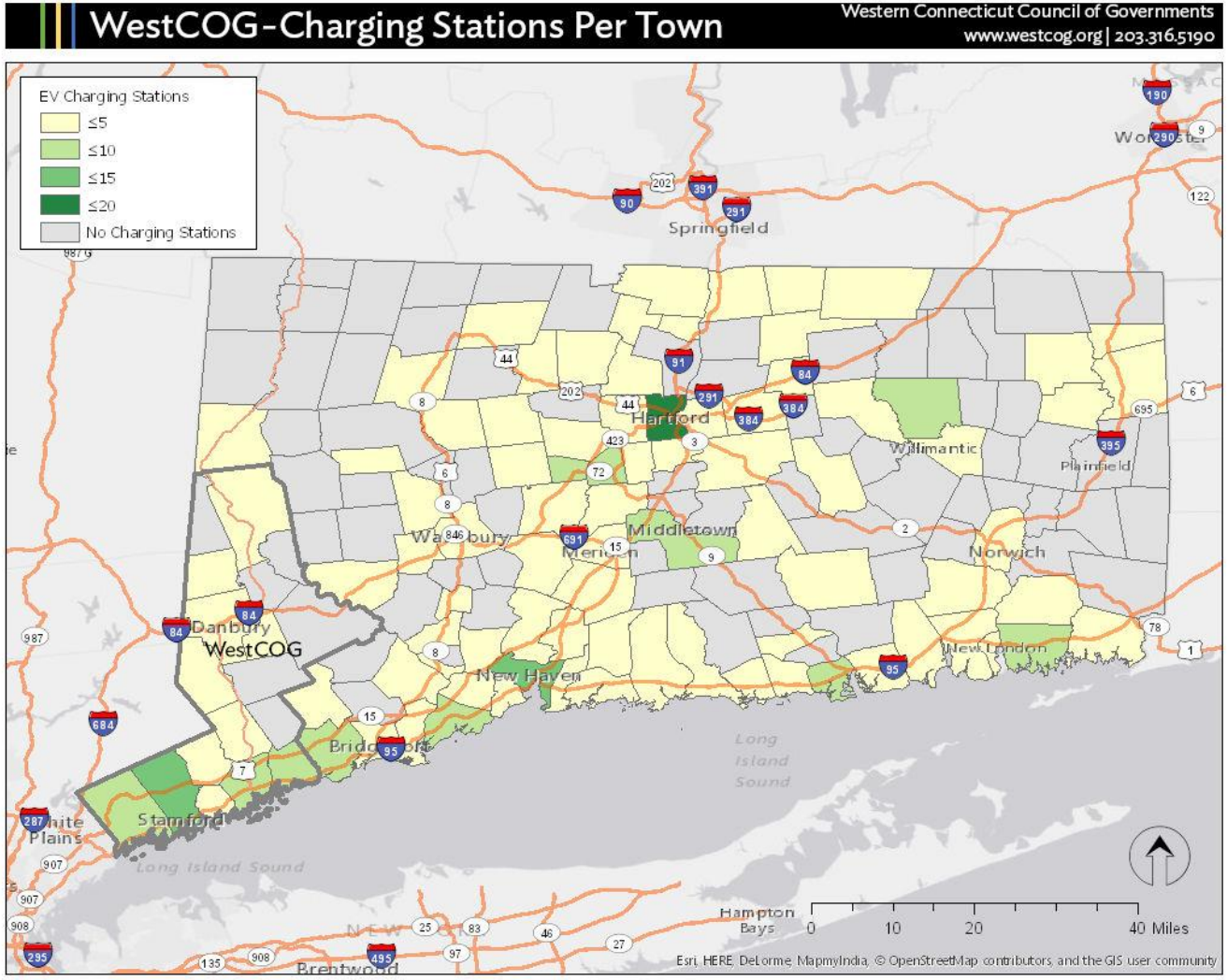

Figure 6: EV charging stations per CT municipality

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

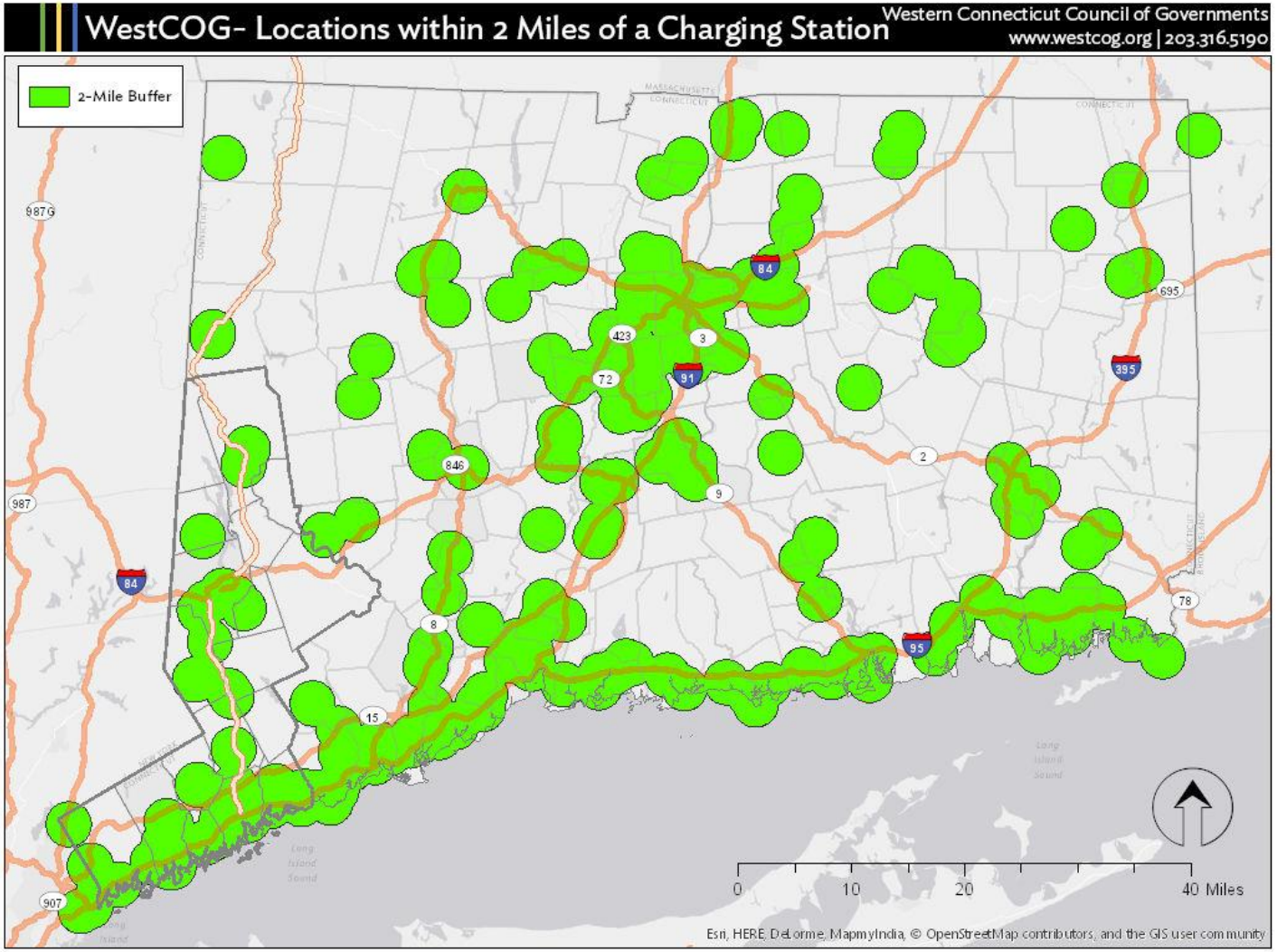

Figure 7: Locations within 2 Miles of public charging stations in CT

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

Table 8: Number of charging stations within a 2-mile buffer of CT Interstates

Major Roadway	# of Charging Stations within 2 miles of major roadway
I-95	107
I-91	52
I-84	48
CT-15	30
CT-8	15
US-7	13
I-395	10

In Connecticut, there are 52 charging stations within 2 miles of the 58 mile length of I-91 interstate and unlike I-95, coverage gaps exist along the interstate corridors. These gaps are found in stretches from North Haven into Wallingford, Cromwell into Rocky Hill and from Windsor into Massachusetts.

There are 48 charging stations within 2 miles of the 98-miles of I-84 (about half the density of I-95) that crosses the CT and most of them are in Hartford. Outside of Hartford, I-84 lacks the EV charging infrastructure density that other major interstates contain in CT and has two large gaps in charging station coverage. One major gap in EV infrastructure is located in northeast CT from Vernon to the Massachusetts border with seven municipalities with no EV charging station. Another gap exists along I-84 west of Waterbury until you reach Danbury which is partially within the WestCOG municipalities.

Charging Station Gaps in the Region

Though having a higher rate of EV adoption than most other municipalities in CT, the public EV charging station infrastructure within the Region has gaps. I-84 has the fewest number with only four charging stations in the corridor (Figure 9 and 10) with all of the charging station located within the city of Danbury. US-7 which traverses Western CT with a north and south orientation has an interesting distribution of charging stations. Five are south of I-84 and only two are north of I-84, located in downtown New Milford. Only four charging stations are located on or next to CT-15. Four areas were identified as having distinct geographic gaps: US-7 north of Danbury, I-84 east of Danbury, US-7 north of the Merritt and south of Danbury and the Merritt Parkway between US-7 and the New York state boundary (Figure 10).

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Table 9: Rank of WestCOG municipalities based on the number of registered EVs (1900-2015)

Rank	Town	# of EVs
1	Greenwich	256
2	Westport	146
3	Stamford	142
4	New Canaan	93
5	Norwalk	82
6	Darien	61
7	Wilton	57
8	Ridgefield	50
9	Danbury	50
10	Weston	45
11	Newtown	41
12	Redding	19
13	Brookfield	18
14	Bethel	18
15	New Fairfield	15
16	New Milford	15
17	Sherman	8
18	Bridgewater	6

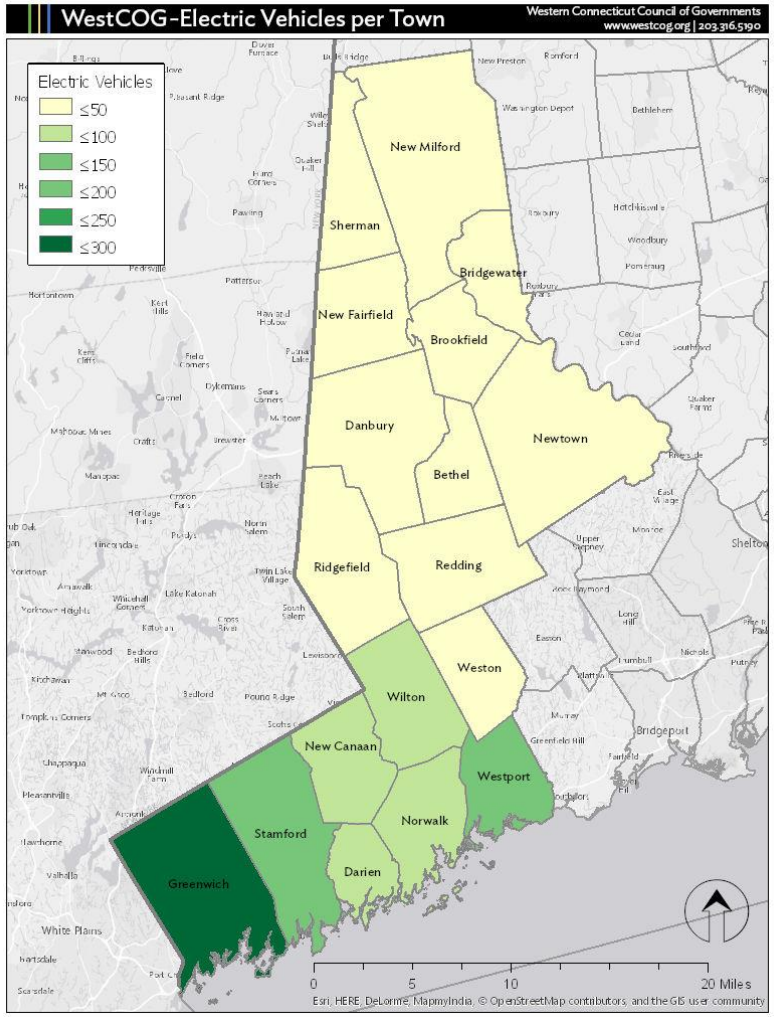

Figure 8: Number of Electric Vehicles registered in WestCOG municipalities (model year 2011-2015)

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

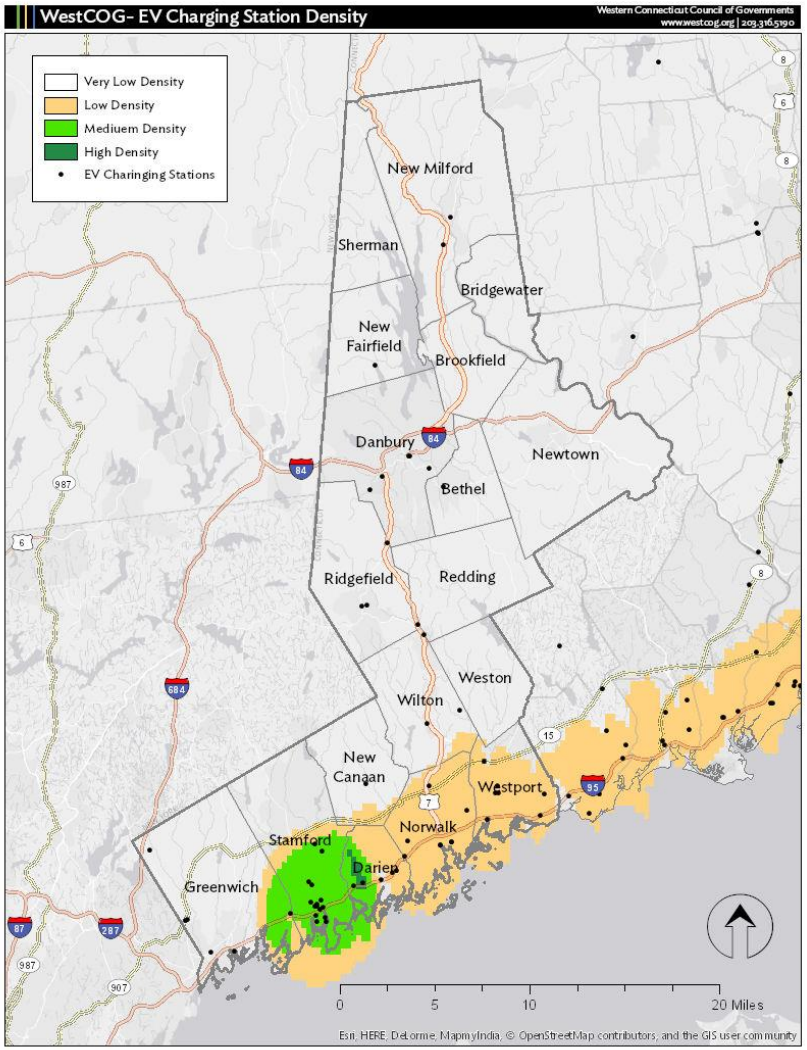

Figure 9: Public EV charging station density with locations

`

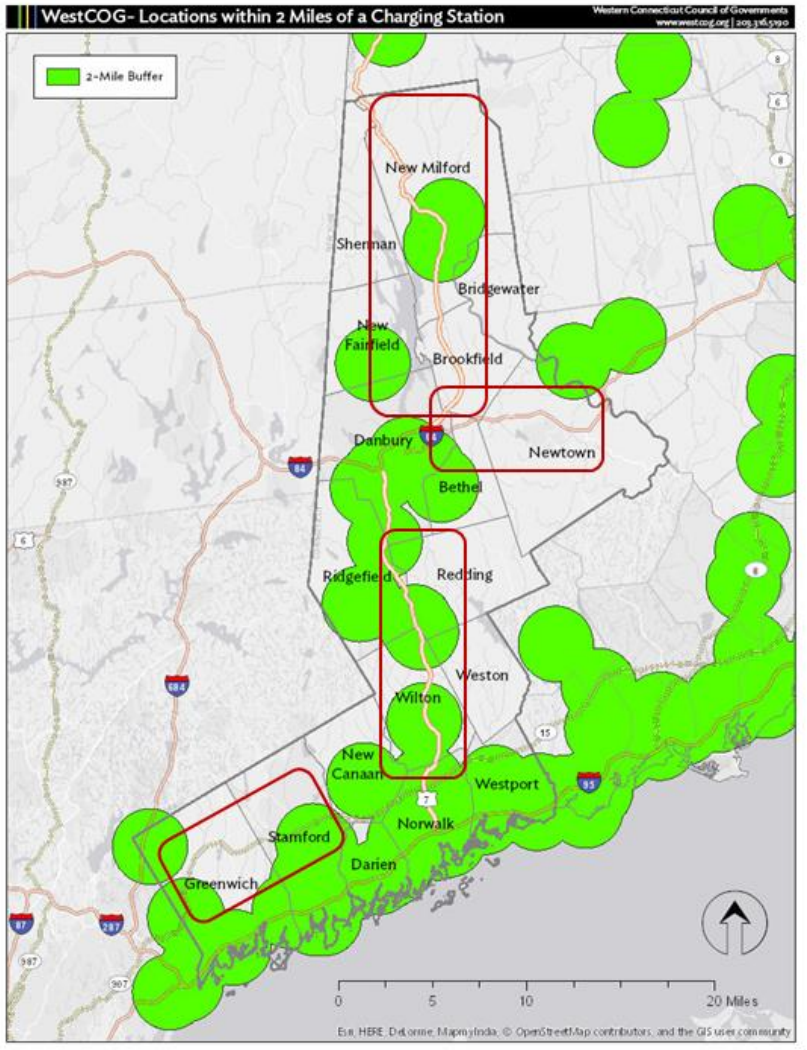

Figure 10: EV charging station service areas. Corridors in red are locations that may benefit from additional EV charging station investment.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Where Do People Work

An evaluation of the commuter patterns for the three largest cities (Norwalk, Stamford, and Danbury) in the Western CT Region using the 2014 LODES employment data provides some guidance to how people commute (U.S. Census, Data, 2015) and hence where they might utilize their EVs. For Stamford, Danbury, and Norwalk, more than half of all the residents work outside of their domicile communities and Stamford, New York City, and Norwalk were the primary destinations. For Stamford, 38.4% of 57,606 job holders work in the city and 61.6% of people work outside town. Four of the top five destination towns are within the I-95 corridor so most EVs can make the trip out and back without charging. In Norwalk, 74.7% of 43,896 job holders work outside the city limits and 25.3% stay within the city limits.

The pattern is different in Danbury where 66.9% of 36,291 workers leave the community for work while 33.1% stay within Danbury. While it does receive some commuters from the I-95 corridor, it functions primarily as an independent entity from the communities to the south. The "commuter shed" of Danbury is more diffuse with no single destination receiving more than 4% of the commuter totals.

Conclusions and Recommendations

The people living in the municipalities of the Western CT Region are leaders in early adoption of EVs within CT though at very low ownership rates. The scale and type of data in this analysis does not allow us to conclusively determine what socio-economic characteristics are associated with being an EV buyers, but none the less, citizens in wealthier towns such as Greenwich and Westport are early adopters of EVs and are purchasing the most expensive models like the Tesla S.

We surmise that buyers from these locations are purchasing EVs not as their primary vehicle but rather for recreational use and as a second or third lifestyle vehicles. These EV buyers may drive an EV around town on the weekend but may not always need choose to commute in the EV as they may have one or more additional cars within their households.

There are geographic gaps of EV infrastructure coverage in the Western CT region. While the I-95 corridor is appears sufficiently populated with EV charging stations for commuting purposes, the US-7 (particularly north of I-84) and the E-W I-84 corridors need additional investment to increase charging

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060
Visit us online at westcog.org

station. The Merritt Parkway is surprisingly underserved between US-7 and the New York Stateline.

The hubs of employment in the region for the southern areas of WestCOG are relatively well-situated (Stamford, Norwalk) in terms of charging infrastructure. Greenwich which leads in EV ownership has comparatively fewer charging station. Danbury is under-supported in terms of EV infrastructure especially as this area functions as a somewhat independent commuting region.

A critical policy question is how do we increase EV usage in more rural and less wealthy communities? The use of EVs and the locations of charging stations in Western CT are greatest in communities that already have significant financial resources so EV purchase programs like CT CHEAPR may not be hitting the correct demographic targets.

Despite subsidies provided by both the State of CT and the Federal government, adoption rates for EV usage are still very low in the Western CT region and throughout CT -- especially as you go north of the coastal towns and in rural areas. Given that EV users are only driving about 25 miles a day, current incentives should be focused on increasing use for around town users such as a second family car, retired people, delivery vehicles, and taxi /Uber-type services -- not regional users. Additional incentives should support multi-modal users such as those commuting to New York City by supporting investments in EV charging infrastructure around multi-modal transit centers and MetroNorth rail stations to encourage EV usage and linkages in the transit system.

Future investments should also remove geographic and municipal EV infrastructure gaps to improve the ability of EV users to commute longer distances. For the Western CT Region, there are conspicuous EV charging station gaps along the I-84 and CT-15 corridors as well as along US-7 north of I-84. This is likely an inhibitor for purchase and usage of EVs.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

References

California Environmental Protection Agency. "Zero Emission Vehicle (ZEV) Program." *California Environmental Protection Agency Air Resources Board*, 18 Jan. 2017, www.arb.ca.gov/msprog/zevprog/zevprog.htm. Accessed Feb. 2017.

Chevrolet. "2017 Chevy Bolt EV." *The All-Electric 2017 Bolt EV*, www.chevrolet.com/bolt-ev-electric-vehicle.html?ppc . Accessed 2 Mar. 2017.

Connecticut Department of Energy & Environmental Protection. "CT's Path to Clean Vehicle Future." *State of Connecticut*, DEEP: EV Connecticut , 7 Dec. 2015, www.ct.gov/deep/cwp/view.asp?a=2684&q=538646&deepNav_GID=2183. Accessed Feb. 2017.

Connecticut Department of Energy & Environmental Protection. "Electric Vehicles 101." *DEEP: EVConnecticut* , Department of Energy & Environmental Protection, 30 Apr. 2015, www.ct.gov/deep/cwp/view.asp?a=2684&q=562482&deepNav_GID=2183. Accessed Feb. 2017.

Connecticut Department of Environmental Protection. "DEEP: Comprehensive Energy Strategy." *Department of Environmental Protection*, State of Connecticut, Nov. 2016, www.ct.gov/deep/cwp/view.asp?a=4405&Q=500752&deepNav_GID=2183. Accessed Feb. 2017.

Connecticut Department of Environmental Protection. "DEEP: EVConnecticut - EV Charger Incentive Programs." *DEEP: EVConnecticut - EV Charger Incentive Programs*, www.ct.gov/deep/cwp/view.asp?a=2684&q=561884 . Accessed 2 Mar. 2017.

Department of Motor Vehicles, and Office of Personal Management.*DOMICILE_REGISTRATION*. N.p.: n.p., n.d. Text.

Fitzpatrick , Alex. "Driving the Chevy Bolt Turned Me Into an Electric Car Believer" Time, 20 April 2017, http://time.com/4748189/chevy-bolt-gm-review/ Accessed April, 2017.

Global Automakers. "Sales." *Driving ZEV: Zero Emission Vehicles*, 2017, drivingzev.com/sales?sort_by=field_zev_sales_total_value . Accessed Feb. 2017.

Holland, Ben, and Josh Agenbroad. "RMI: What's the True Cost of EV Charging Stations?" *GreenBiz*, 8 May 2014, www.greenbiz.com/blog/2014/05/07/rmi-whats-true-cost-ev-charging-stations. Accessed Feb. 2017.

Idaho National Laboratory. "Electric Vehicle Charging Habits Revealed". Idaho National Laboratory. https://www.inl.gov/article/electric-vehicle-charging-habits-revealed/. Accessed 8 March, 2017.

Idaho National Laboratory. "How many electric miles do Nissan Leafs and Chevrolet Volts in the EV Project travel?". EV Project. May, 2014. https://avt.inl.gov/sites/default/files/pdf/EVProj/eVMTMay2014.pdf . Accessed 8 March, 2017.

Kane, Sean. "The White House Announces a Sweeping Plan to Increase EV Charging Stations." *The Verge*, The Verge, 3 Nov. 2016, www.theverge.com/2016/11/3/13507634/ev-charging-stations-white-house-obama-department-of-energy . Accessed 2 Mar. 2017.

Metro North Railroad. "2015 Ridership Report - Executive Summary." 2016, web.mta.info/mta/news/books/docs/2015-MNR-Annual-Ridership-Report.pdf. Accessed Feb. 2017.

Multi-state ZEV Program Implementation Task Force. "Multi-state ZEV Action Plan." *State of Connecticut*. May 2014, http://www.ct.gov/deep/lib/deep/air/electric_vehicle/path/multi-state_zev_action_plan_may2014.pdf Accessed Feb. 2017.

Russo, Edward. "Public Electric-car Charging Stations Sit Idle Most of Time." Seattle Times, 04 January 2015.

"State Zero-Emission Vehicle Programs Memorandum of Understanding." 24 Oct. 2013, doi:10.1016/s0378-777x(82)80077-2. Accessed Feb. 2017.

Tesla. "Model S." *Tesla*, www.tesla.com/models . Accessed 2 Mar. 2017.

Trochaniak, Sunny. "EV sales in the U.S.: 2016 Final Update." Fleetcarma, http://www.fleetcarma.com/ev-sales-usa-2016-final/. Accessed 16 March 2017.

U.S. Census. "Data." *Longitudinal Employer-Household Dynamics*, U.S. Census, 2015, lehd.ces.census.gov/data/. Accessed 2 Mar. 2017.

U.S. Department of Energy. "Fact #876: June 6, 2015 Plug-in Electric Vehicle Penetration by State, 2014" Dataset. U.S. Department of Energy. https://energy.gov/eere/vehicles/downloads/fact-876-june-8-2015-plug-electric-vehicle-penetration-state-2014-dataset. Accessed 8 March, 2017.

U.S. Department of Energy. "Fact #936: August 1, 2016 California had the highest concentration of plug-in vehicles relative to population in 2015", U.S. Department of Energy. https://energy.gov/eere/vehicles/fact-936-august-1-2016-california-had-highest-concentration-plug-vehicles-relative. Accessed 8 March, 2017.

U.S. Department of Energy. "Federal Tax Credits for Electric and Plug-in Hybrid Cars." *Fuel Economy*, www.fueleconomy.gov/feg/taxevb.shtml . Accessed 2 Mar. 2017.

U.S. Department of Energy. "Guide to Federal Funding, Financing, and Technical Assistance for Plug-in Electric Vehicles and Charging Stations," https://energy.gov/sites/prod/files/2016/07/f33/Guide%20to%20Federal%20Funding%20and%20Financing%20for%20PEVs%20and%20PEV%20Charging.pdf . Accessed 20 March 2017.

U.S. Energy Information Administration. "How Much Carbon Dioxide Is Produced When Different Fuels Are Burned? - FAQ ." US Energy Information Administration (EIA), 14 June 2016, www.eia.gov/tools/faqs/faq.cfm?id=73&t=11. Accessed Feb. 2017.

1 Riverside Road, Sandy Hook CT 06482
(475) 323-2060

Additional Literature

Clement-Nyns, Kristien, Edwin Haesen, and Johan Driesen. "The impact of charging plug-in hybrid electric vehicles on a residential distribution grid." IEEE Transactions on Power Systems 25.1 (2010): 371-380.

Ehsani, Mehrdad, Khwaja M. Rahman, and Hamid A. Toliyat. "Propulsion system design of electric and hybrid vehicles." IEEE Transactions on industrial electronics 44.1 (1997): 19-27.

Emadi, Ali, Young Joo Lee, and Kaushik Rajashekara. "Power electronics and motor drives in electric, hybrid electric, and plug-in hybrid electric vehicles." IEEE Transactions on industrial electronics 55.6 (2008): 2237-2245.

Hadley, Stanton W., and Alexandra A. Tsvetkova. "Potential impacts of plug-in hybrid electric vehicles on regional power generation." The Electricity Journal 22.10 (2009): 56-68.

Khaligh, Alireza, and Zhihao Li. "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: State of the art." *IEEE transactions on Vehicular Technology* 59.6 (2010): 2806-2814.

Lopes, João A. Peças, Filipe Joel Soares, and Pedro M. Rocha Almeida. "Integration of electric vehicles in the electric power system." Proceedings of the IEEE 99.1 (2011): 168-183.

Sortomme, Eric, et al. "Coordinated charging of plug-in hybrid electric vehicles to minimize distribution system losses." *IEEE transactions on smart grid* 2.1 (2011): 198-205.