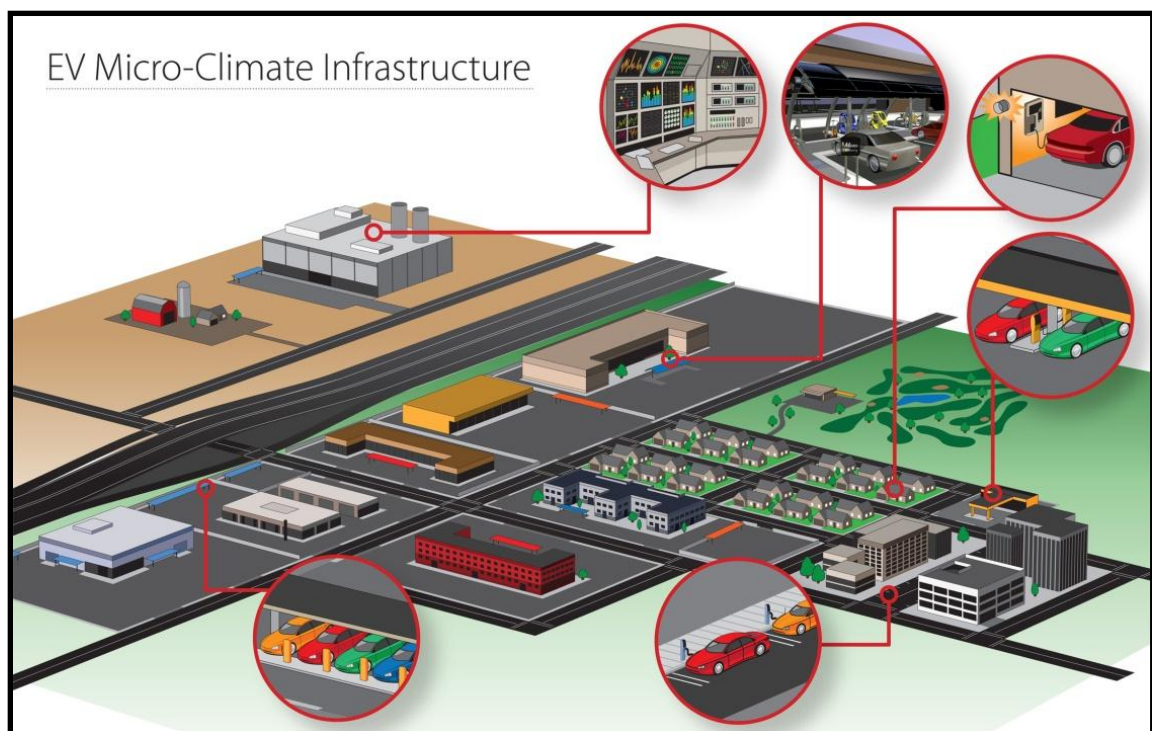


# Long-Range EV Charging Infrastructure Plan for the State of Tennessee



**November 2010**

**Version 4.1**



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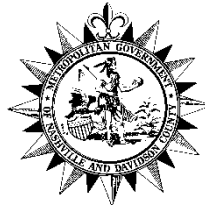
The Long Range Plan for the State of Tennessee for the EV Project was created through the ECotality process of involving stakeholders and interactively creating content.

The EV Project provides an opportunity to develop and study a rich charging infrastructure typical of a fully mature EV environment. Data will be collected characterizing the full utilization of charge infrastructure, the interaction between vehicle use and charger availability, the effectiveness of various revenue collection methods for public charging, the interaction of charge infrastructure with the electric grid and the effectiveness of various charge infrastructure locations.

This document was authored through the ECotality process specifically for the EV Project. Working in conjunction with project partners and local area stakeholders through the creation of State and Area Advisory Boards, ECotality received content contributions and content review from the following Advisory Board Member Organizations:



State of  
Tennessee



ELECTRIC POWER  
RESEARCH INSTITUTE



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## Acronyms

<b>AC</b>	Alternating Current
<b>AMI</b>	Advanced Metering Infrastructure
<b>ARRA</b>	American Reinvestment and Recovery Act
<b>BEV</b>	Battery Electric Vehicle - vehicle powered 100% by the battery energy storage system available on board the vehicle.
<b>DC</b>	Direct Current
<b>DCFC</b>	Level 2 DC Fast Charger
<b>DOE</b>	U.S. Department of Energy
<b>EE</b>	Energy Efficiency
<b>EPRI</b>	Electric Power Research Institute
<b>EV</b>	Electric Vehicle
<b>EREV</b>	Extended Range Electric Vehicle – see PHEV
<b>EVSE</b>	Electric Vehicle Supply Equipment – equipment that provides for the transfer of energy between electric utility power and an electric vehicle.
<b>HAN</b>	Home Area Network
<b>ICE</b>	Internal combustion engine
<b>IWC</b>	Infrastructure Working Council
<b>kW</b>	Kilowatts. A measurement of electric power. Used to denote the power an electrical circuit can deliver to a battery.
<b>kWh</b>	Kilowatt hours. A measurement of total electrical energy used over time. Used to denote the capacity of an EV battery.
<b>LEED</b>	Leadership in Energy & Environmental Design, an internationally-recognized green building certification system
<b>NHTS</b>	National Household Travel Survey
<b>OEM</b>	Original Equipment Manufacturer – In this document, this term refers to automobile manufacturers.
<b>PHEV</b>	Plug-in Hybrid Electric Vehicle – vehicle utilizing both a battery and an internal combustion engine (ICE) powered by either gasoline or diesel.
<b>REEV</b>	Range Extended Electric Vehicle – see PHEV.
<b>TOU</b>	Time of Use - an incentive-based electrical rate established by an electric utility, intended to balance the load by encourage energy use during non-peak times.

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**U.S. GBC** U.S. Green Building Council

**VAC** Voltage Alternating Current. Public utilities generally provide electricity in an alternating current, which allows high incoming voltage to be changed by a transformer to the lower voltage required for consumer use.

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## 1 Introduction

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The development of a public charging infrastructure is critical to the success of electric vehicles (EVs). Public education is merging with electric vehicle introduction and public policy to create an enthusiastic framework for the long-held dream of electrified, private-use transportation.

ECotality, Inc. (NASDAQ: ECTY), headquartered in San Francisco, California, is a leader in clean electric transportation and storage technologies. Its subsidiary, Electric Transportation Engineering Corporation (eTec) dba ECotality North America (ECotality), is the leading installer and provider of charging infrastructure for EVs. ECotality has been involved in every major EV or plug-in electric vehicle (PHEV) initiative to date in North America and is currently working with major automotive manufacturers, utilities, the U.S. Department of Energy (DOE), state and municipal governments, and international research institutes to implement and expand the presence of this technology for a greener future.

ECotality designed and currently manages the world's largest EV infrastructure demonstration - the EV Project. With a budget of over \$230 million, the EV Project will deploy and study Level 2 alternating current (AC) electric vehicle supply equipment (EVSE) stations for residential use, Level 2 AC EVSE stations for commercial and Level 2 direct current (DC) fast charge (DCFC) stations representing thousands of field assets, utilized in concert with the deployment of Nissan LEAF™ vehicles and Chevrolet Volt vehicles.

The EV Project is a public-private partnership administered by the DOE through a federal stimulus grant, made possible by the American Recovery and Reinvestment Act (ARRA) and by the private investment of ECotality and its partners.

The EV Project is an infrastructure study. The EV Project will deliver to ECotality, the Government and the general public a wealth of directly-applicable technical and professional experience for jumpstarting regional EV adoption and replicating business models that lead to sustainable, market-based charge infrastructures.

The EV Micro-Climate process starts with the development of *EV Charging Infrastructure Deployment Guidelines* to organize and drive the preparations for this infrastructure. With significant input from local stakeholders, this foundation paves the way for a long-range plan.

This document examines the potential maturation of the EV market and EV infrastructure over the long term. It is difficult to achieve consensus on long-term plans due to unknowns in the economy, transportation issues, technological advances, human behavior, and related costs. However, there is wide acceptance that EVs are in fact a growing force in automotive transportation, and EV penetration is fully expected to achieve a significant market share within the next 10 years.

---

The actions of local communities will have an impact on EV market share. This *Long-Range EV Charging Infrastructure Plan for Tennessee* provides a review of the current behavior of vehicle operators and industry projections of EV sales as a means of understanding the expected EV population in the targeted area in Tennessee by the year 2020. The projected EV population will require the EV charging infrastructure to support and encourage further increases in market share. This Plan seeks to uncover the quantities and locations of publicly-available charging systems that will do just that.

ECotality is partnering with Nissan North America, General Motors, and several other companies to deploy up to 5,700 zero-emission electric vehicles (Nissan LEAF), 2,600 Extended Range Electric Vehicles (Chevrolet Volt), and approximately 15,000 charging systems to support them, in private and public locations in strategic markets in six states – Arizona, California, Oregon, Tennessee, Texas, and Washington – as well as Washington, DC.

The EV Project will collect and analyze data to characterize vehicle use in diverse topographic and climatic conditions, evaluate the effectiveness of charge infrastructure, and conduct trials of various revenue systems for commercial and public charge infrastructure. The ultimate goal of the EV Project is to take the lessons learned from the deployment of these first 8,300 EVs, and the charging infrastructure supporting them, to enable the streamlined deployment of the next five million EVs.

The EV Project provides a starting point in Tennessee to achieve the region's long-range goals. It cannot by itself complete the necessary infrastructure, but the long-range plan will provide guidance for planning this infrastructure growth and focus on the near term for locating EV Project resources.

This long-range plan starts in Section 2 by looking at driver behavior revealed by national surveys. Information specific to Tennessee is also included. Certain behavior patterns that run counter to common thought about EVs help inform the discussions in the following sections.

Before the discussion on locating charging systems can begin, the expected market penetration of EVs into this region needs to be understood. That penetration is built upon national projections described in Section 3 and Appendix A.

The penetration of EVs into the market is tied to the availability of publicly-available charging infrastructure. EV drivers must be assured that they will be able to complete their daily travel needs without fully depleting their vehicle's battery. Likewise, the availability of charging infrastructure is tied closely to the number of EVs on the road; businesses are unlikely to install charging stations unless there are EVs to use them. EVSE projections and their methods are discussed in Section 4 and Appendix A.

Section 5 projects the expansion of EV and EVSE use in Tennessee, based on the projected national growth of EV adoption and EVSE infrastructure.

The planning for the DCFC is quite different from that for the rest of the charging infrastructure, but is also integral to it. Section 6 is devoted to the DCFC.

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Having been informed by all these factors, the detailed discussion on where and how to expand the development of the charging infrastructure can begin. Section 7 develops the approach and plan to accomplish this in Tennessee. Input from local stakeholders and prior work on these topics provides support for this plan. By understanding the characteristics of EVs and the capabilities of the charging systems, as well as expected driver demographics, an effective plan for wise deployment of available resources is possible. That is the goal of this document.



## 2 Driver Behavior – National Household Travel Survey

The National Household Travel Survey (NHTS) serves as the nation’s inventory of daily travel. Data are collected on daily trips taken in a 24-hour period, providing a better understanding of travel behavior. In this survey, respondents are asked to complete a diary of their travel for a 24-hour period. The survey specifies a trip date and the diary starts at 4 a.m. on that date, even if it is an unusual travel day for the respondent. This date can be any day of the week, including weekend days. The diary then continues through the destinations reached by the respondent during that day. As noted in Section 2.3 below, these destinations fall into several categories, including “Home”, since daily travel generally involves at least one trip home.

The survey provides for all modes of transportation, from personal car to bus to airplane to walking. The vehicles of interest for planning electric vehicle charging infrastructure are cars. Many other vehicle types may become electric vehicles, but it is our assessment that the vast majority of future electric vehicles will be cars.

### 2.1 Daily Trips All Vehicles

The following figures present data provided in the NHTS 2009 survey information. Comparisons are drawn from the initial survey in 1969 through the most recent NHTS survey in 2009. Figure 2-1 shows the average number of daily vehicle trips for all types of vehicles. Since a trip would generally involve going from home to destination and back home, the minimum response would be about two trips. (Note, some may have started away from home and traveled home, resulting in only one trip.) Overall, the total vehicle miles traveled on a daily basis appears to have leveled off since 1995.

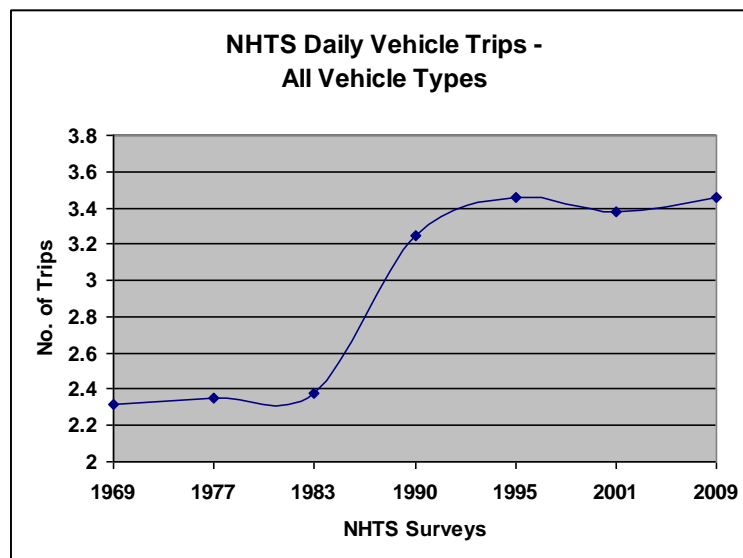


Figure 2-1 Average Daily Vehicle Trips for All Types of Vehicles

The average vehicle trip length for all vehicle types continues an upward climb as shown in Figure 2-2.

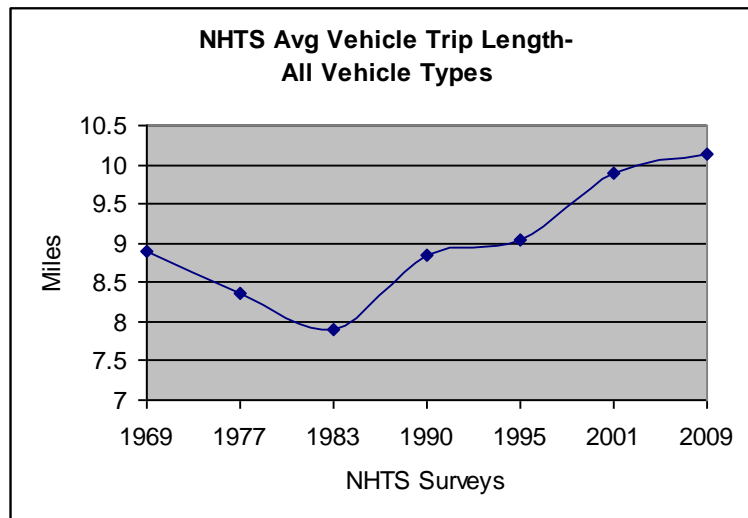


Figure 2-2 Average Vehicle Trip Lengths for All Types of Vehicles

Combining these two averages indicates that average daily travel is approximately 35 miles, well within the range of near-term EVs. The daily travel required by individuals will be a factor in their decision to obtain an EV. Because these are average travel lengths and numbers of trips, many can be longer. Publicly available charging stations may be a factor in this decision.

## 2.2 Daily Trips by Car

The 2009 average weekday daily vehicle miles traveled by cars was 31.14 miles. For the daily trips by car, Figure 2-3 identifies the percentage of trips for each of ten purpose categories. Other than trips home, the single most common purpose for a car is to go shopping or run errands, followed by work and social activities. When this information is combined with that of the average number of trips per day, it shows that most drivers make several stops per day. Driving to and from work also generally involves a side trip and stops along the way. Errands may also include a stop for school. Destinations for stops become important in the evaluation of charge infrastructure developed later. Intuition might suggest that charging infrastructure at home and work would be sufficient, but these data indicates otherwise.

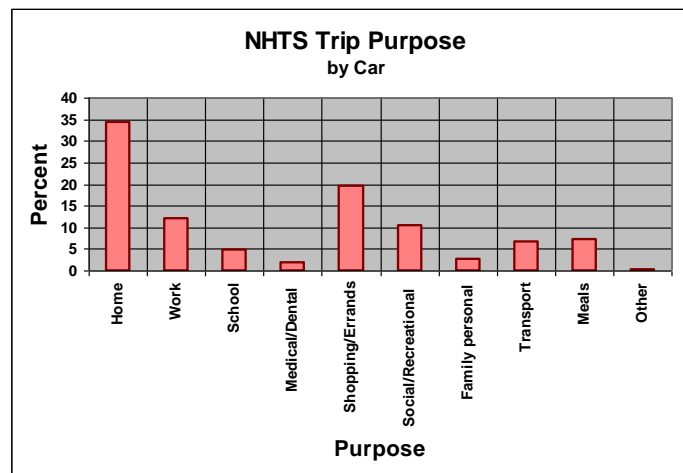


Figure 2-3 Percentage of Daily Car Trips by Purpose NHTS 2009

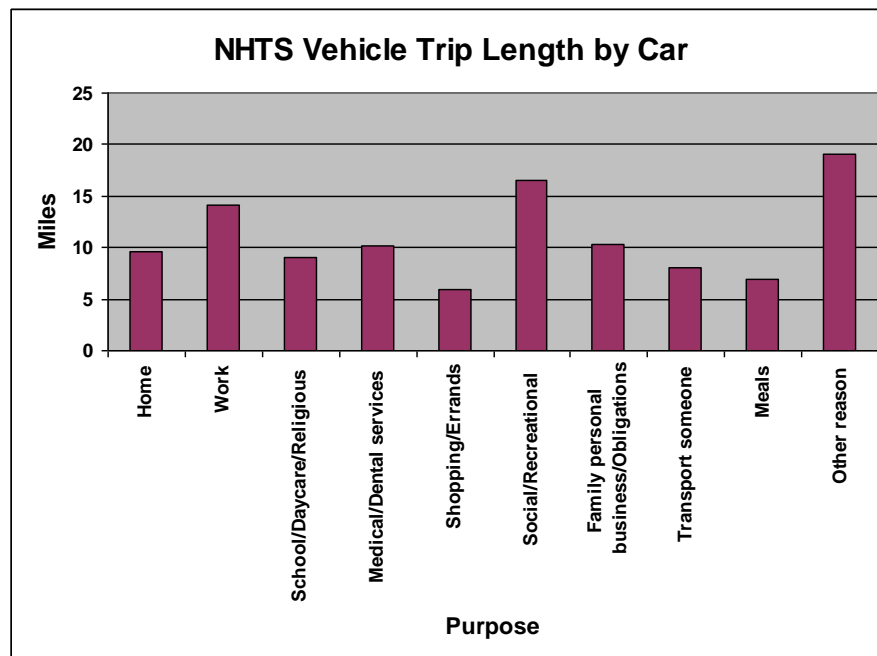


Figure 2-4 Vehicle Trip Length by Car by Purpose NHTS 2009

Distances traveled to and from work are not necessarily the longest trips taken on a daily basis. The data show that drivers are willing to travel further distances for social or recreational activities or other trips of importance. This would make the charging infrastructure at these destination points at least as important, and perhaps more important, than work locations.

## 2.3 Vehicle Information

The chart in Figure 2-5 identifies that the two-vehicle household is the most common, followed by an equal percentage of households having one or three vehicles. As will be seen later, it is expected that households that will own an EV likely will have two or more vehicles. Approximately 80% of the overall population would fit that profile.

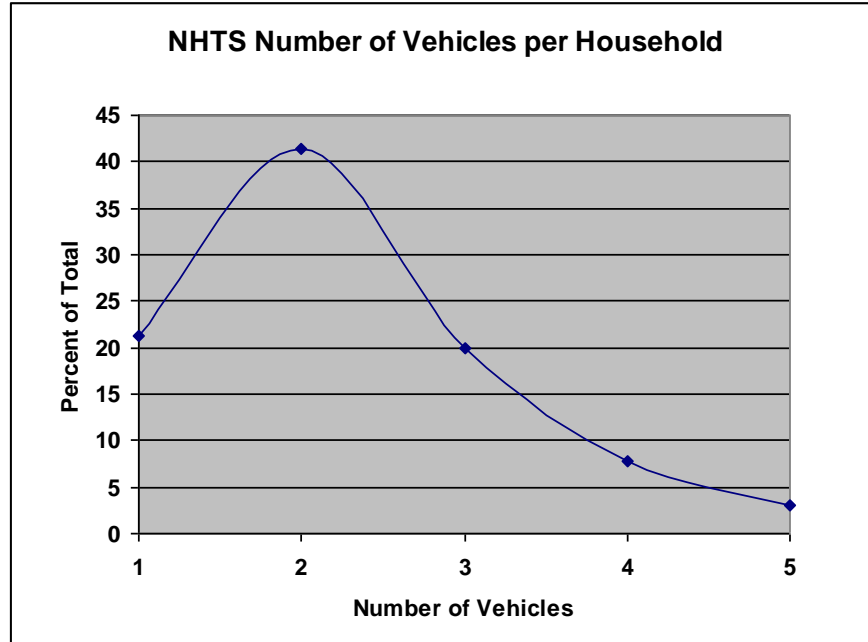


Figure 2-5 Number of Vehicles per Household – NHTS 2009

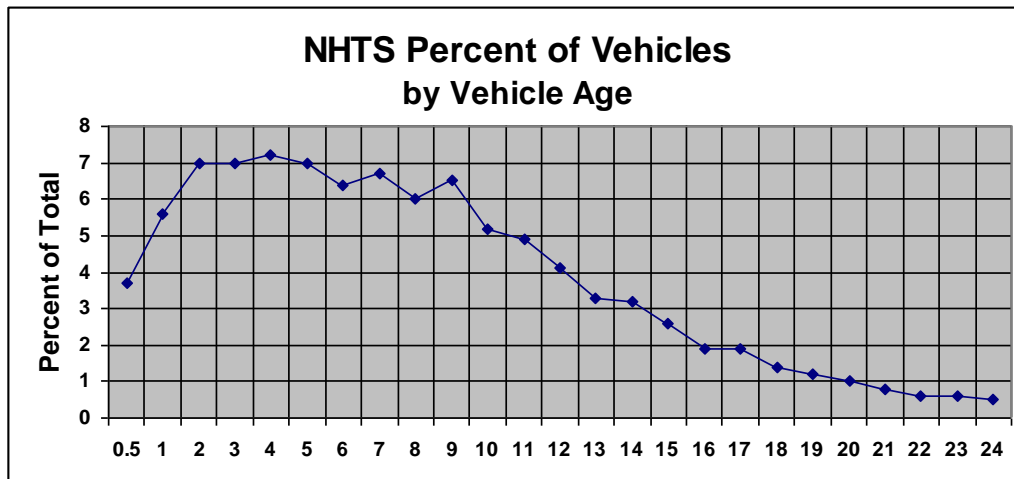


Figure 2-6 Percent of Vehicles by Vehicle Age

When looking at EV penetration rates, it is important to view not only the expected annual sales of EV, but to consider the long life of existing internal combustion vehicles. The average age of personal vehicles today is 8.3 years. A very significant number of vehicles in operation are greater than 10 years old. This will be a significant factor holding back the overall market share of EVs for a long time to come. On the other hand, the used vehicle market will likely extend the use of EVs to most demographics within the decade of the 2010s.

## 2.4 Other Factors

A significant percentage of vehicle traffic during peak travel times of the day is not work-related travel. As seen in Figure 2-4, shopping and errands hold a greater percentage of car trips than work. While the 2009 data are not available specifically on this topic, this is similar to that reported in the 2001 data set.

According to the 2001 NHTS, 85 million workers (two-thirds of all commuters) usually leave for work between 6:00 and 9:00 am, and over 88 percent of these workers travel in private vehicles. However, as shown in Figure 2-7, a significant number of non-work vehicle trips are made during peak periods.

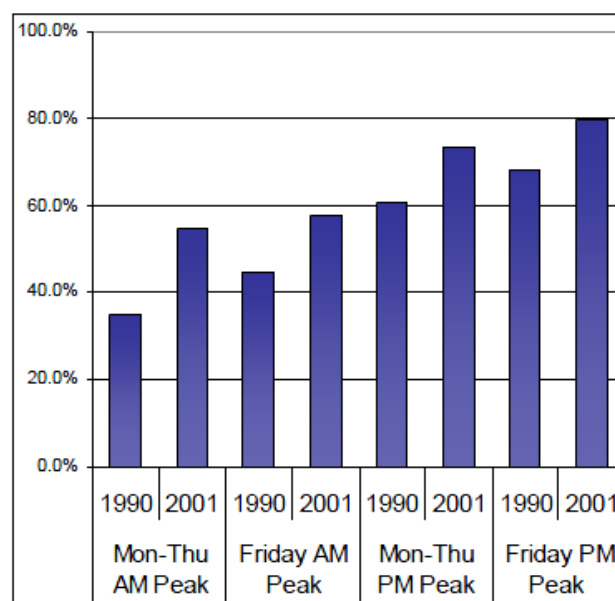


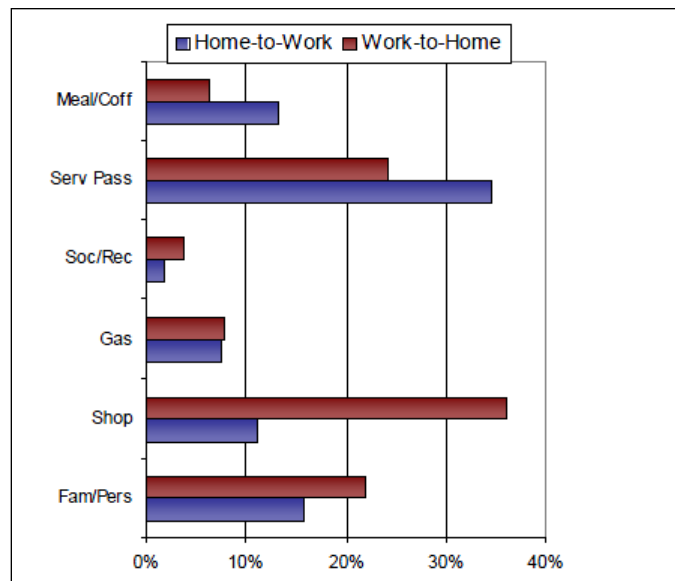
Figure 2-7 Non-Work Trips at Peak Periods NHTS 2001<sup>1</sup>

The amount of travel for non-work purposes, including shopping, errands, and social and recreational activities, is growing faster than work travel. Growth in these kinds of trips is expected to outpace growth in commuting in the coming decades.<sup>2</sup>

<sup>1</sup> ibid

This again supports the suggestion that workplace charging may not be as important as had been expected. In addition to this trend, a number of workers stop to shop, including getting coffee or a meal, during the commute. Commuters stop for a variety of reasons, such as to drop children at school or to stop at the grocery store on the way home from work. Real-life examples show that this *trip chaining* is often a response to the pressures of balancing work and home. But the data also show that some of the growth in trip chaining has been to pick up a coffee or meal (the “Starbucks effect”), activities that historically were done at home and did not generate a trip.

The overall growth in travel for shopping, family errands, and social and recreational purposes reflects the busy lives and rising affluence of the traveling public. The growth in non-work travel not only is adding to the peak periods, but also is expanding congested conditions into the shoulders of the peak and the midday. See Figure 2-8.



**Figure 2-8 Non-Work Trips at Peak Periods NHTS 2001<sup>3</sup>**

In 2009, about one out of six vehicle trips used an interstate highway for part or all of a trip during an average weekday. About 44% were going to or from work, but 56% were traveling for other reasons. Trips involving the interstate are almost three times longer than other trips – nearly 28 miles on average, compared to just 10 miles for other vehicle trips.

<sup>2</sup> NHTS Brief, *Congestion: Non-Work Trips in Peak Travel Times*, U.S. Department of Transportation, Federal Highway Administration, [www.nhts.ornl.org](http://www.nhts.ornl.org) April 2007.

<sup>3</sup> *ibid*

These results suggest that the availability of EV charging stations along the interstate highway system will be important. The longer trips on the highway, coupled with the desire to keep the stops to a short duration, will increase the desire for faster charging systems (See Section 6).

## 2.5 Tennessee Household Travel Survey

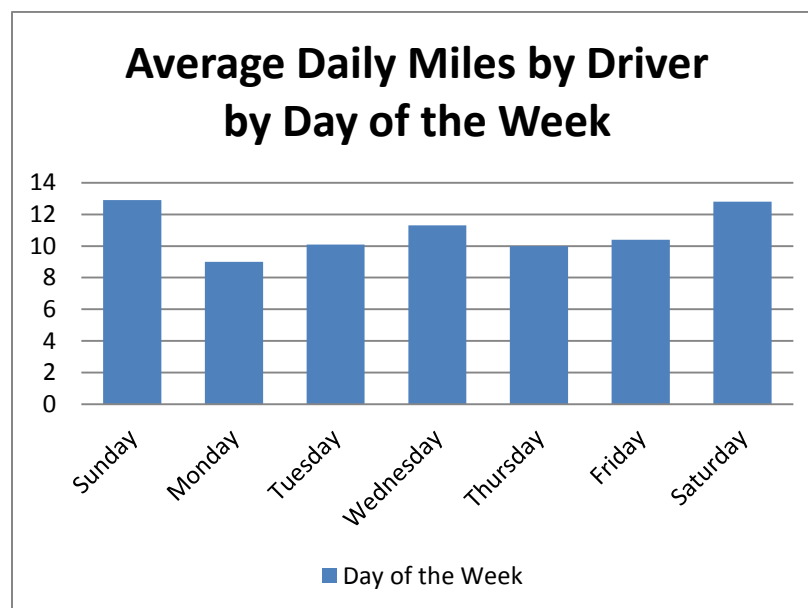
The following tables and charts for Tennessee were drawn from the National Household Travel Survey. They present the same information as the national survey described above, but the data is drawn from only Tennessee respondents.

The average vehicle trip length is 10.7 miles.

Table 2-1 and Figure 2-9 present the average daily miles by driver by day of the week. As the data indicates, there is little difference in average daily miles between the five work days, and weekend miles are slightly higher.

**Table 2-1 Tennessee Average Daily Miles by Driver by Day of the Week**

Day of the Week	Average Total Miles
Sunday	12.9
Monday	9
Tuesday	10.1
Wednesday	11.3
Thursday	10
Friday	10.4
Saturday	12.8



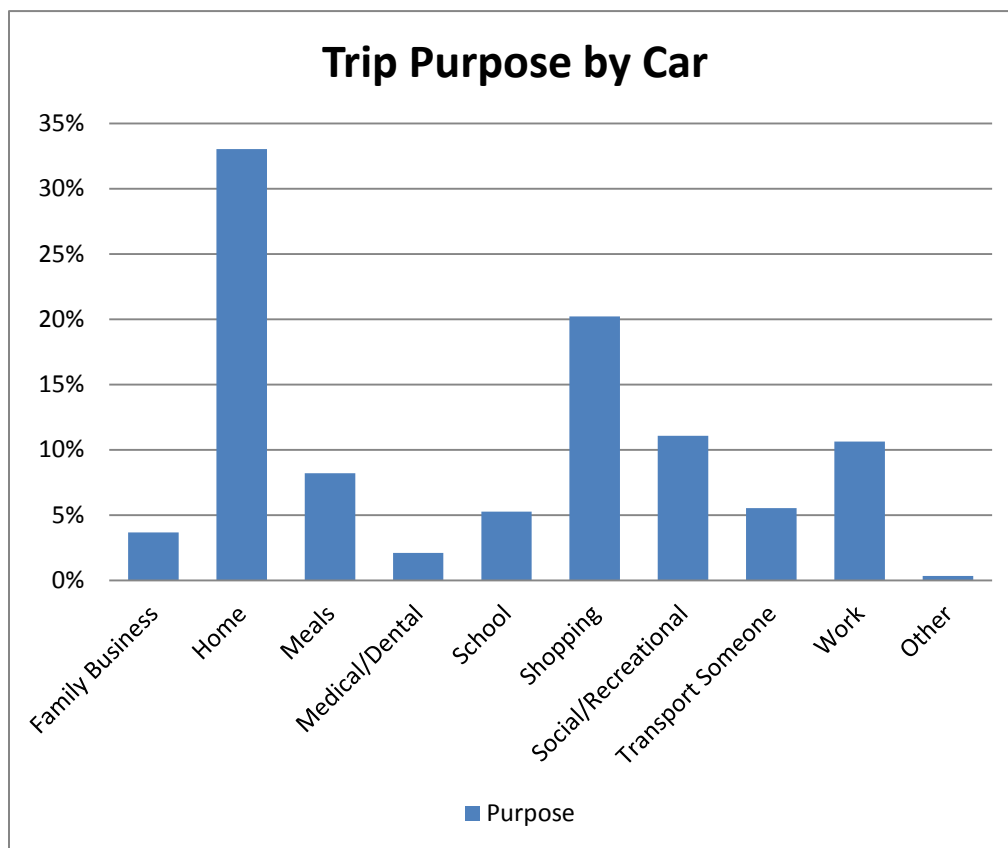
**Figure 2-9 Average Daily Miles**



Table 2-2 and Figure 2-10 present trip purposes. Trips to home is the single largest trip purpose, with shopping trips second and work trips third. These three purposes make up 64 percent of all trips.

**Table 2-2 Tennessee Trip Purpose by Car**

Purpose	Total Trips	% of Total Trips
Family Business	665	4%
Home	5,987	33%
Meals	1,488	8%
Medical/Dental	378	2%
School	951	5%
Shopping	3,665	20%
Social/Recreational	2,004	11%
Transport Someone	1,001	6%
Work	1,924	11%
Other	62	0%
<b>Total</b>	<b>18,125</b>	<b>100%</b>



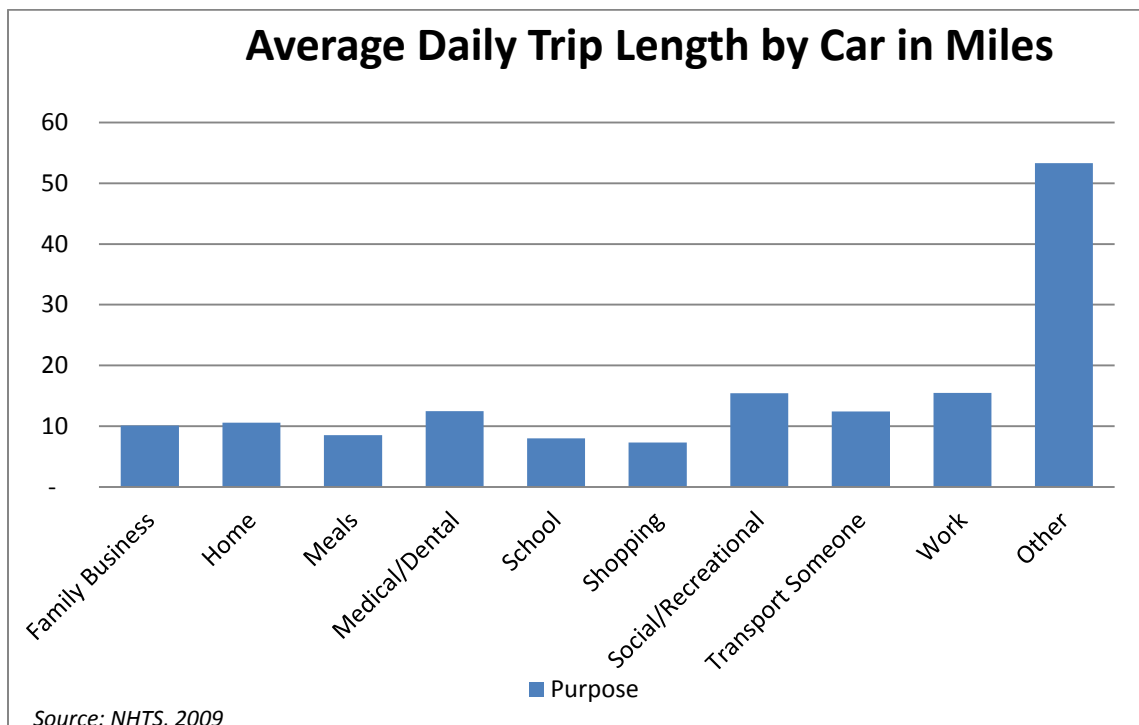
**Figure 2-10 Tennessee Trip Purpose by Car**

Table 2-3 and Figure 2-11 present the average daily trip length by trip purpose in Tennessee.

The Other category was by far the longest trip length. After that, shopping and school trips were the shortest, and work, social/recreational and medical trips were the longest.

**Table 2-3 Tennessee Average Daily Trip Length by Car**

Purpose	Total Miles	Average Miles
Family Business	6,725	10
Home	63,328	11
Meals	12,605	9
Medical/Dental	4,709	13
School	7,598	8
Shopping	26,742	7
Social/Recreational	30,826	15
Transport	12,412	12
Work	29,761	16
Other	3,307	53
<b>Total</b>	<b>198,013</b>	<b>15.4</b>



**Figure 2-11 Average Daily Trip Length by Car in Miles**

Table 2-4 and Figure 2-12 present the number of vehicles per household in Tennessee. One car households in Tennessee make up only 13.7 percent of the total, while over 50 percent of households have three or more vehicles.

Table 2-4 Tennessee Number of Vehicles per Household

Number of Vehicles	Number of Vehicles per Household	% of Total
Zero	116	0.0%
One	661,391	13.7%
Two	1,726,964	35.7%
Three	1,259,509	26.0%
Four	718,090	14.8%
Five Plus	470,244	9.7%
<b>Total</b>	<b>4,836,314</b>	<b>100%</b>

Source:

NHTS, 2009

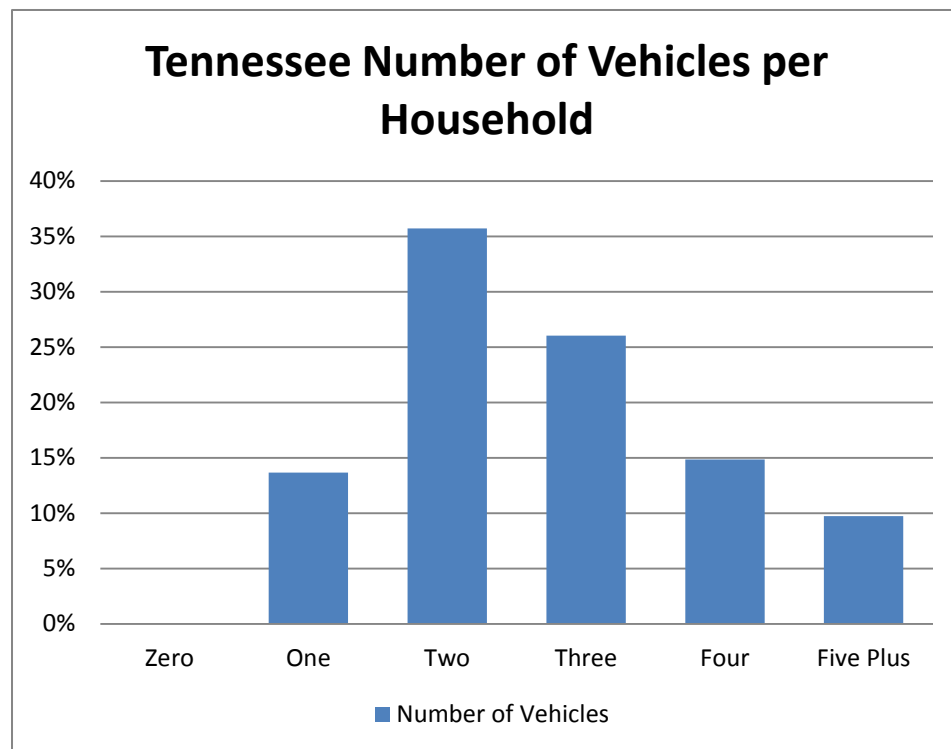


Figure 2-12 Number of Vehicles per Household

Table 2-5 and Figure 2-13 present the percent of vehicles by vehicle age in Tennessee. Only 12 percent of the vehicles in Tennessee are less than 2 years old, but 51 percent are less than 9 years old, and 80 percent are less than 15 years old.

**Table 2-5 Tennessee Percent of Vehicles by Vehicle Age**

Vehicle Age	# of Vehicles	% of Total Vehicles
Less than 2 years	630	12%
3-5 years	1061	20%
6-8 years	981	19%
9-11 years	905	17%
12-14 years	653	12%
15-17 years	418	8%
18-20 years	233	4%
21-23 years	143	3%
24-26 years	90	2%
27-29 years	43	1%
30+ years	137	3%
Totals	5294	100%

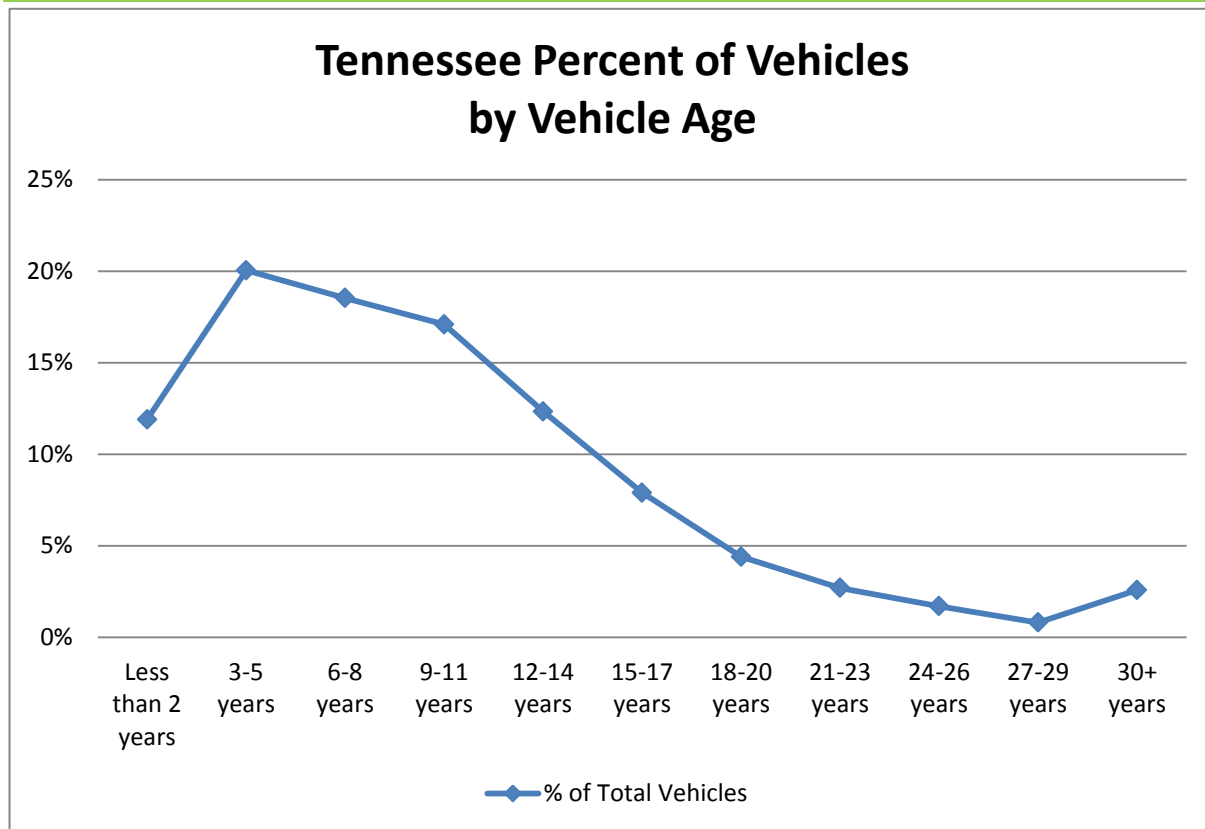
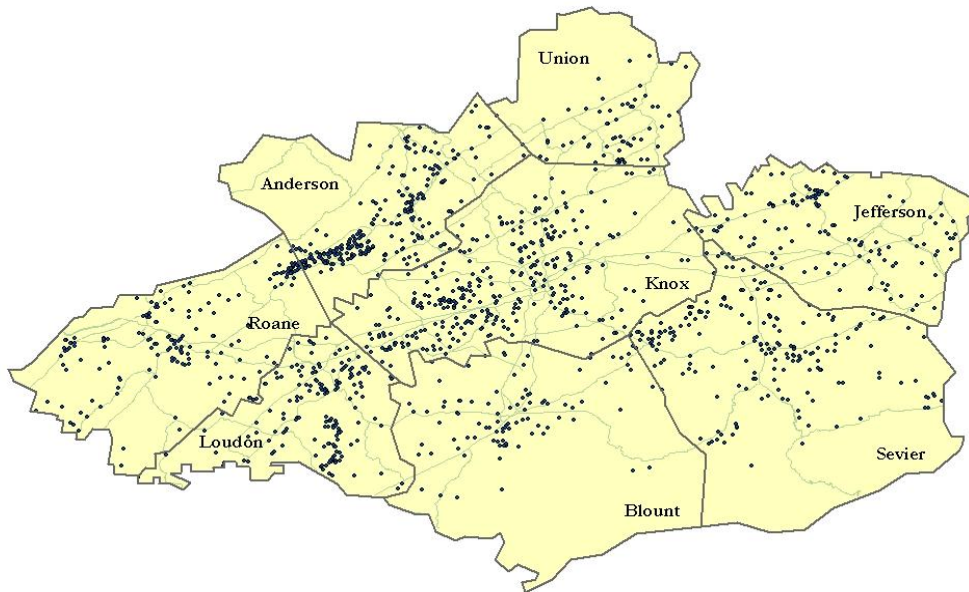


Figure 2-13 Tennessee Percent of Vehicles by Age

## 2.6 Knoxville

The 2008 East Tennessee Household Travel Survey covers Knox, Blount, Anderson, Jefferson, Loudon, Roane, Sevier and Union counties.

The weekday travel characteristics were collected from households by NuStats, a survey research firm, for use by the Knoxville Regional Transportation Planning Organization and local agencies for planning purposes. The survey sampled 1,400 households between February and May 2008.



**Figure 2-14 Map of Counties Surveyed in East TN Household Travel Survey<sup>4</sup>**

Demographic data was collected through a telephone interview (CATI system) using a socioeconomic stratification based upon household size and employment status. Interviews were conducted assessing: household size, number of vehicles, household income, dwelling type, age, gender, drivers' license, work status and address, school status and address. A similar study was conducted by NuStats in 2000 and 22 panel households participated in both of these studies.

In relation to the National Household Travel Survey results, many similarities were present that directly relate to the planning needs for electric vehicle infrastructure. Overall, the trip rates were higher in 2008 than in 2000 and highest among those over the age of 35. Most trips were by auto.

<sup>4</sup> Nustats, 2008 East Tennessee Household Travel Study, [www.knoxtrans.org](http://www.knoxtrans.org)

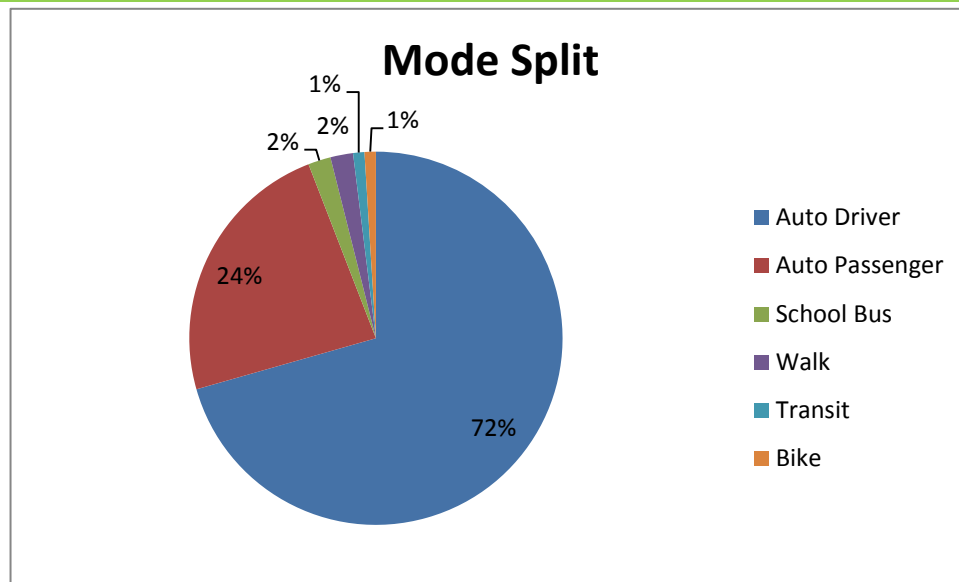


Figure 2-15 Mode of Transportation Chart<sup>5</sup>

The average auto trips took just under 20 minutes per trip. Trips for personal activities at home were the highest (primary purpose of trip).

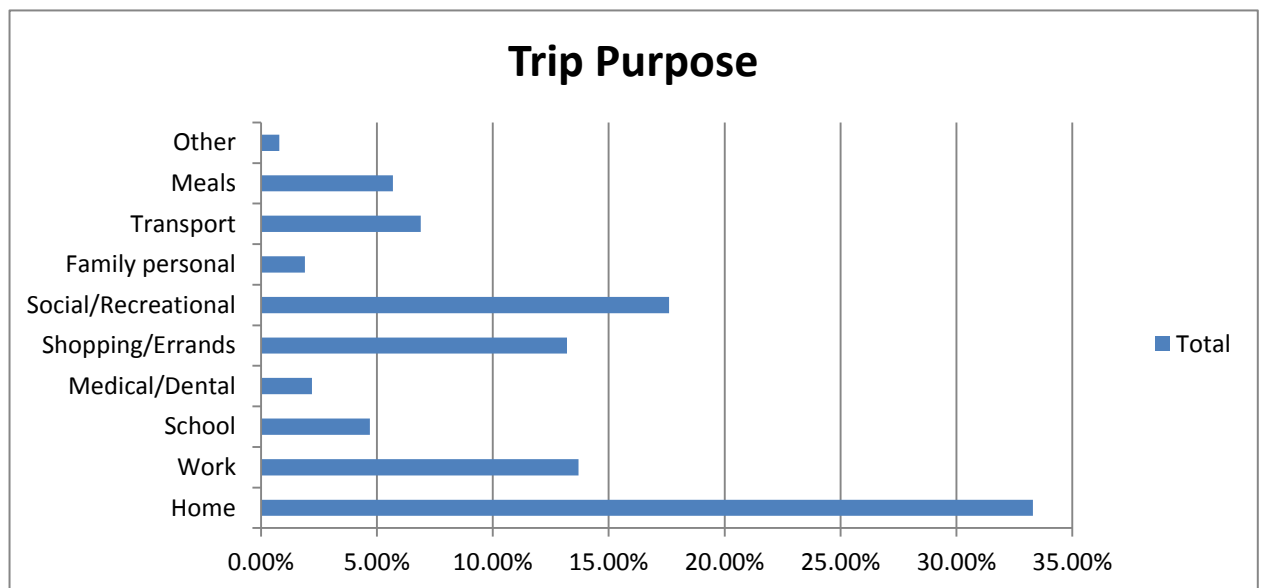


Figure 2-16 Knoxville Trips by Purpose<sup>6</sup>

<sup>5</sup> ibid

<sup>6</sup> ibid



## 2.7 Nashville

The Household Travel Behavior Survey conducted by NuStats (1998) in the Nashville Area was led by the Nashville Area Metropolitan Planning Organization to collect and analyze travel behavior for a five county area: Davidson, Rutherford, Sumner, Williamson and Wilson as well as from travelers coming into or through the region.

Nashville is planning on conducting an updated Household Travel Behavior Survey in the next 3 years; however, the information was similar to that in the 2008 East Tennessee Household Travel Survey for trip rate and trip length and trip purpose.

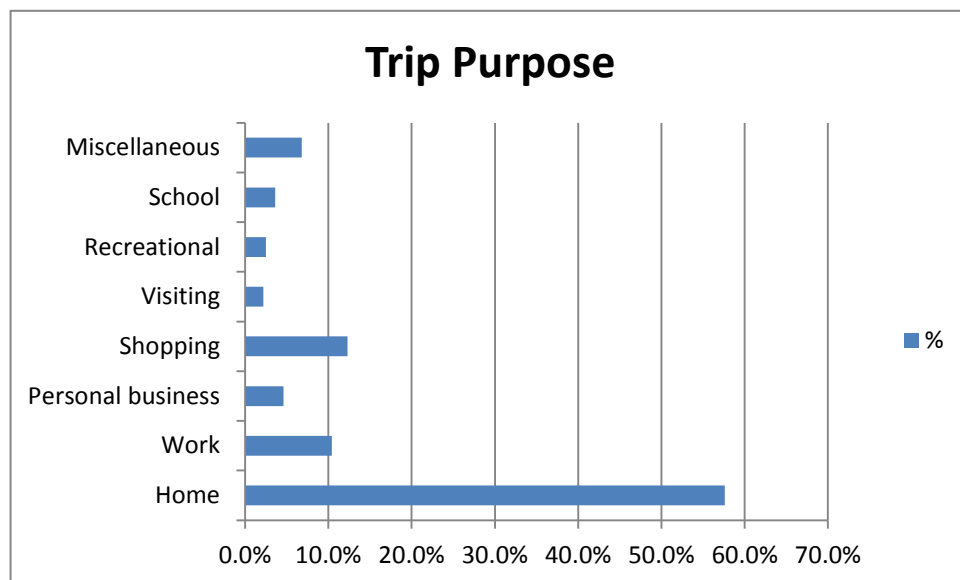


Figure 2-17 Nashville Trips by Purpose<sup>7</sup>

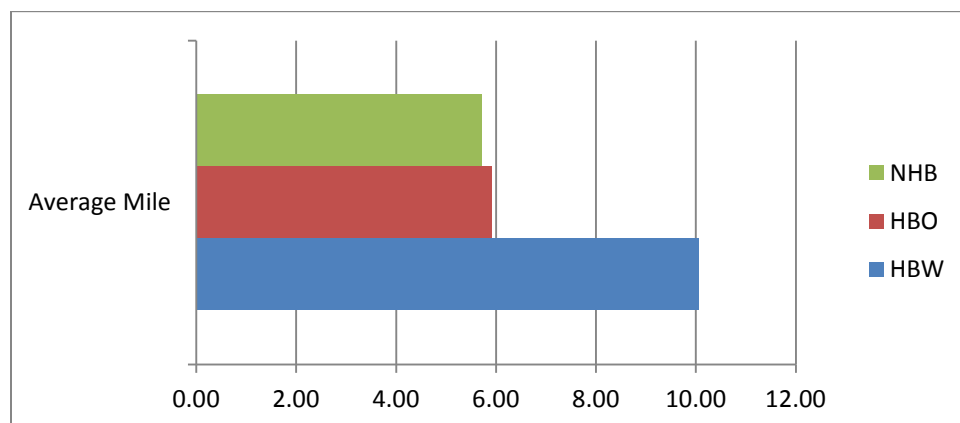


Figure 2-18 Nashville Trip Length<sup>8</sup>

<sup>7</sup> Nustats International, 1998 Nashville Area Travel Behavior Study

## 2.8 Chattanooga

The Chattanooga Travel Demand Forecasting Model by the Chattanooga-Hamilton County / North Georgia Long-Range Transportation Plan 2035, the Network 2007 Base, the Land Use Scenario 2008 and the Model Run 071210 demonstrated that the results were similar to those reflected in the 2008 East Tennessee Household Travel Survey. The average length per trip was 8.07 miles per trip with an average number of trips per person is 3.9.

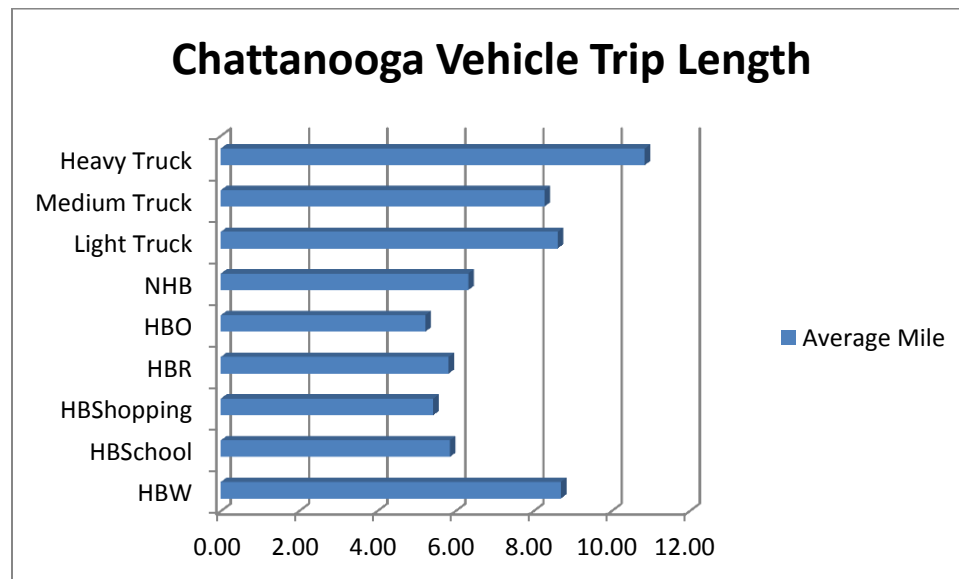


Figure 2-19 Chattanooga Trips by Purpose<sup>9</sup>

## 2.9 Summary

The National Travel Survey indicated, and the local travel surveys reflect, that travelers travel most for activities other than commuting to/from work. Therefore, as in a national electric vehicle infrastructure placement, regional publicly available electric vehicle charging should be placed at way points between home and work to support wide spread EV adoption in Tennessee.

<sup>8</sup> ibid

<sup>9</sup> The Chattanooga Travel Demand Forecasting Model by the Chattanooga-Hamilton County / North Georgia Long-Range Transportation Plan 2035. Network 2007 Base, and Land Use Scenario 2008. Model Run 071210.

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Most drivers make several trips to many different destinations on a daily basis, and the number of those trips does not significantly change from weekday to weekend. The daily travel length for most drivers can easily be accommodated by the 100-mile range of the EVs expected to be available in the near term. The daily purposes of these trips can also be accommodated by these vehicles. The trip destinations will be an important factor in placing the publicly-available charging infrastructure, as discussed later in this document.

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## 3 EV Sales Projections in the United States

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Long-range planning for EV infrastructure must start with the evaluation of how many EVs are expected to be deployed over the next ten years. This section develops a response to that question by beginning with the types of EVs expected and each type's characteristics.

### 3.1 EV Types

- **Battery Electric Vehicle (BEV)**  
Battery Electric Vehicles (BEVs) are powered 100% by the battery energy storage system available on-board the vehicle. The Nissan LEAF is an example of a BEV. A BEV is refueled by connecting it to the electrical grid via a connector system that is designed specifically for this purpose.
- **Plug-in Hybrid Electric Vehicle (PHEV)**  
PHEVs are powered by two energy sources. The typical PHEV configuration utilizes a battery and an internal combustion engine (ICE) powered by either gasoline or diesel. PHEV manufacturers use varying strategies to combine the battery and ICE. Some vehicles, such as the Chevrolet Volt, utilize the battery only for the first several miles, with the ICE providing generating power for the duration of the vehicle range. Others may use the battery power for sustaining motion and the ICE for acceleration or higher-energy demands at highway speeds. Frequently, the vehicles employing the former strategy gain a designation such as PHEV-20 to indicate that the first 20 miles are battery only. Other terms related to PHEVs include Range Extended Electric Vehicle (REEV) or Extended Range Electric Vehicle (EREV).

### 3.2 EV Batteries

Recent advancements in battery technologies will allow EVs to compete with ICE vehicles in performance, convenience, and cost.

From an infrastructure standpoint, it is important to consider that as battery costs are driven down over time, the auto companies will increase the size of the battery packs, and thus the range of electric vehicles.

- **Relative Battery Capacity**  
Battery size or capacity is measured in kilowatt hours (kWh). Battery capacity for electric vehicles will range from as little as 3 kWh to as high as 40 kWh or more. Typically, PHEVs will have smaller battery packs, because they have more than one fuel source. BEVs rely completely on the battery pack's storage for both range and acceleration, and therefore require a much larger battery pack than a PHEV for the same size vehicle.

- **Battery Charging Time**

The time required to fully charge an EV battery is a function of the battery size and the amount of electric power (measured in kilowatts (kW)) that an electrical circuit can deliver to the battery. Larger circuits, as measured by voltage and amperage, will deliver more kW. The common 110-120 volts AC (VAC), 15 amp circuit will deliver at maximum 1.1 kW to a battery. A 220-240 VAC, 40 amp circuit (similar to the circuit used for household appliances like dryers and ovens) will deliver at maximum 6 kW to a battery. This maximum current may be further limited by the vehicle's on-board battery management system. Table 3-1 provides information on several different on-road highway speed electric vehicles, their battery pack size, and charge times at different power levels to replenish a depleted battery, assuming the onboard battery management systems allows the indicated circuit size.

**Table 3-1 EV Charge Times**

EV Configuration	Battery Size (kWh)	Circuit Size and Power in kW Delivered to Battery			
		120 VAC, 15 amp 1.2 kW	120 VAC, 20 amp 1.6 kW	240 VAC, 40 amp 6.5 kW	480 VAC, 85 amp 60 kW
<b>PHEV-10</b>	<b>4</b>	3 h 20 m	2 h 30 m	35 m	n/a
<b>PHEV-20</b>	<b>8</b>	6 h 40 m	5 h	1 h 15 m	n/a
<b>PHEV-40</b>	<b>16</b>	13 h 20 m	10 h	2 h 30 m	16 m
<b>BEV</b>	<b>24</b>	20 h	15 h	3 h 40 m	24 m
<b>BEV</b>	<b>35</b>	29 h 10 m	21 h 50 m	5 h 20 m	35 m
<b>PHEV Bus</b>	<b>50</b>	n/a	n/a	7 h 40 m	50 m

**Note:** Power delivered to battery calculated as follows: 120VAC x 12Amps x .85 eff.; 120VAC x 16Amps x .85 eff.; 240VAC x 32 Amps x .85 eff.; 480VAC x  $\sqrt{3}$  x 85 Amps x .85 eff. (Limited to 60 kW maximum output)

Another way to compare EVSE power levels is to consider what range extension may be achieved during a charge period. Table 3-2 provides a comparison based upon a vehicle efficiency of 4 miles/kWh of charge.

Table 3-2 Miles Achieved per Charge Time

Miles Achieved per Charge Time*					
	Circuit Size and Power in kW Delivered to Battery**				
	<i>Level 1</i>	<i>Level 1</i>	<i>Level 2</i>	<i>Level 2</i>	<i>DC Fast</i>
	120 VAC, 15 amp	120 VAC, 20 amp	240 VAC, 20 amp	240 VAC, 40 amp	480 VAC, 85 amp
Charge Time	1.2 kW	1.6 kW	3.3 kW	6.5 kW	60 kW
10 min	0.7	1	1.9	3.7	34
15 min	1	1.4	2.8	5.5	51
30 min	2	2.7	5.6	11	>50***
1 hour	4	5.4	11.2	22	>50***

\*Vehicle efficiency 4 miles/kWh

\*\*EVSE efficiency assumed at 85%

\*\*\*Battery is at or near full charge, depending upon initial state

- **Trends in Battery Capacity**

As the EV industry grows, it is fully anticipated that batteries will increase in capacity, and thus the range of vehicles will increase, as well. Larger-capacity battery packs will require more energy to recharge, and consequently the recharge time will be extended. Charging systems using 110 VAC circuits will become less and less relevant and higher kW chargers become more relevant.

### 3.3 EV Sales Analysis

There is a high degree of uncertainty when projecting sales of conventional automobiles and electric vehicles. Because of the economic downturn, most automotive companies are not publishing forecasts of vehicle sales. Domestic gasoline prices over the next 10 years will serve to drive demand for more efficient vehicles, but price projections are not reliable. Past trends cannot be used to predict future automotive sales either (conventional or electric), due to the loss in sales volume during the past few years. Most automotive original equipment manufacturers (OEMs) have announced plans for EVs in the next few years, and the anticipated diverse vehicle inventory and subsequent out-year enhancements are expected to make EVs competitively priced, even if gasoline prices are in the sub-\$2 per gallon range. The wide range of vehicle platforms is expected to make EVs attractive for most demographic groups. Several investment firms have made projections for sales of electric vehicles and these projections provide a range of possible penetration rates. This information is summarized in Section 3.4, and Appendix A contains details of these projected penetration rates.

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### 3.3.1 BEVs and PHEVs

The early hybrid vehicles that entered the automotive market were very similar to their ICE sister models. The failure of the electric vehicles introduced in the 1990s led some to believe that the consumer was not ready for a dramatic change in the driving experience. Hence, the hybrid was developed as a way to increase gasoline mileage without requiring a dramatic change in customer behavior. Some of that thinking continues with the PHEV. For all types of PHEV, the internal combustion engine will always provide the backup power, so consumers do not really have to change their driving behavior unless they consider the gasoline engine to be just that: a backup to the battery.

The BEV, on the other hand, is a dramatic departure from the ICE vehicles. The consumer will have to be conscious of the vehicle's range and battery capacity, similar to the attention an ICE driver must pay to the fuel gauge. However, as new BEV drivers gain confidence (partly due to a rich EVSE infrastructure) and the vehicle range is extended with higher-capacity batteries, it will become more and more apparent that having two types of technology, battery and ICE, is superfluous. For that reason, many analysts today see the PHEV as a bridge technology.

In any new market, the innovators and early adopters are willing to endure some inconvenience for the privilege of enjoying the new technology. For BEVs, the lure is stronger than usual. All of the benefits of electric drive vehicles toward reducing dependence on foreign oil and increasing environmental cleanliness add to the attractiveness of the EV. For more pragmatic individuals, the reduced cost of ownership becomes important. BEV owners will quickly adapt to the changes that driving a fully electric vehicle require. These same reasons make the electric side of a PHEV much more attractive than the ICE side. It is expected that the PHEV buyer will adjust driving behavior to stay away from ICE operation as much as possible. This new learned behavior will naturally lead to the realization that the ICE is not necessary. The next vehicle will be the BEV.

On the other hand, as battery capacity increases, the recharge times will be extended and even at the 60 kW charge level, restoring a battery charge may exceed the wait time comfort of some drivers. That probably will require an increase in the charging power for DC Fast Charging. For drivers taking long trips, the PHEV may still be the vehicle of choice. While projecting EV penetration is still difficult, it is noted that the first major OEM to deliver mass-produced vehicles is offering a BEV. In subsequent years, many analysts believe that PHEV sales will dominate the market, but will be overtaken by BEV sales by the end of the decade.

Lyle Dennis, EV enthusiast and editor of [gm-volt.com](http://gm-volt.com), had a discussion with Mark Reuss, GM's President in North America, and quoted him as follows.

"Long-term demand (for) BEV could be higher as EREV initially leads the way with battery technology like the lithium ion pack in the Volt...first gen," stated Reuss. The initial EREV technology as he sees it "then feeds BEV-like vehicles."

"While EREV will be wildly popular at first with Volt," says Reuss, "as the technology flows down to BEV in what will be smaller cars to carry smaller packs, that may be the higher-volume play over a longer time."



Since Reuss is newly in charge of GM North America sales and marketing, his opinions are likely to play a significant role in the company's strategy going forward.<sup>10</sup>

### 3.3.2 Probable Consumers

The Everett Rogers Diffusion<sup>11</sup> of Innovations theory identified that typical market penetration of any product follows a standard distribution curve. Different segments of consumers can be identified on this curve.

- The *Product Innovators* are the first to try a new product. Having the newest technology and being first is important to these consumers. They are venturesome and highly educated. Price is not as important as the innovation.
- *Early Adopters* are next, who again are well educated, but take a more reasoned approach where there needs to be value associated with the product.
- The *Early Majority* follows, where the product is selected in a deliberate manner. It meets specific needs and provides the value desired.
- The *Late Majority* follows, who are skeptical and prefer the traditional and standard market products.
- Finally, the *Laggards* are considered, who may never purchase the new product or will do so only if it becomes the only choice.

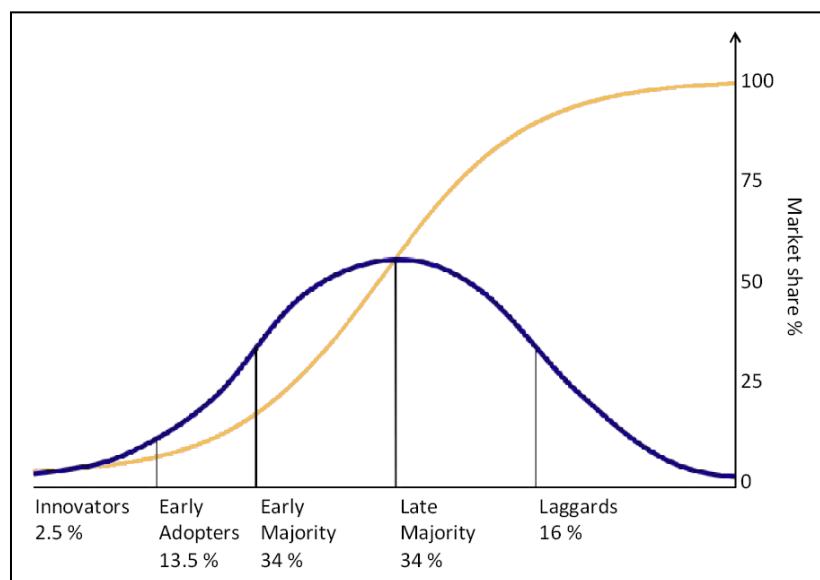


Figure 3-1: The Diffusion of Innovations According to Rogers

<sup>10</sup> GM Exec: Long Term BEV Demand will be greater than EREV, <http://gm-volt.com>, March 2010

<sup>11</sup> Wikipedia, *Diffusion Theory*, [www.wikipedia.org](http://www.wikipedia.org)

Deloitte suggests the Early Adopters from 2010 to 2020 will share demographics as follows:

- Similar to early adopters of hybrids.
- Early adoption will be concentrated around southern California, where weather and infrastructure allow for ease of EV ownership.<sup>12</sup>

Deloitte suggests the Early Majority will share these demographics:

- Highly concerned about foreign oil dependency, as well as environmentally conscious.
- There are 1.3 million men and women in the US who have the demographic characteristics of the Early Majority segment<sup>13</sup>.

### 3.3.3 Automotive Manufacturer Plans

Many OEMs have announced plans for the introduction of EVs or PHEVs in the near future. A summary table of these plans is shown in Table 3-3 below.

Table 3-3 OEM PHEV and EV Plans

Make	Model	All Electric Range (mi)	Battery Size (kWh)	U.S. Target Intro. Date
<b>PLUG IN HYBRID ELECTRIC VEHICLES</b>				
Audi	A1 Sportback	31-62		2011
BYD Auto	F3DM	60		2010
Fisker	Karma	50		2010
Ford	Escape	40	10	2012
General Motors	Chevrolet Volt	40	16	2010
Hyundai	Blue-Will	38		2012
Toyota	Prius Plug-in	12.4-18.6		2012
Volvo	V70	31		2012
<b>BATTERY ELECTRIC VEHICLES</b>				
BMW	ActiveE	100		2011
BYD Auto	e6	205		2010
Chrysler/Fiat	Fiat 500	100		2012

<sup>12</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

<sup>13</sup> *ibid*

Make	Model	All Electric Range (mi)	Battery Size (kWh)	U.S. Target Intro. Date
Coda Automotive	Coda Sedan	90-120		2010
Daimler	Smart fortwo	82	16	For sale now
	Mercedes Benz BlueZero	120	35	2010 low volume
	Mercedes Benz SLS AMG E-Cell	90-130	48-60	2013
Ford	Focus	100		2011
	Transit Connect	100		2010
	Tourneo Connect	100	21	2011
Hyundai	i10 Electric	100	16	2012
Mitsubishi	iMiEV	100	16	2010
Nissan	LEAF	100	24	2010
Rolls Royce	Electric Phantom			2010
SAIC	Roewe 750	125		2012
Tesla Motors	Roadster	245	56	For sale now
	Model S	160, 230, 300		2011
Th!nk	City	113		2010
Toyota	RAV4 EV	100		2011

There remains a strong push to bring EVs and PHEVs to market in the near future. The table above also provides valuable information on the range of vehicles that have been announced. Note that the range figures are published by the OEM and can vary dramatically with driver behavior and climatic and geographic conditions.

### 3.4 EV Sales Projections

As noted in the introduction to this section, projections of EV penetration into the market are difficult to obtain. The vehicle manufacturers are not releasing their information to the public, other than perhaps the next year's forecast. Public acceptance is still a big question that can partly be resolved by the infrastructure, but public policy and incentives will go a long way toward promoting or detracting from that acceptance. Appendix A explores the current projections worthy of note, along with ECOTality's projections to develop the sales estimates used here.

ECotality strongly suggests that this is a conservative projection and should be considered the base for specific planning, with more rapid adoption being highly likely. EV penetration above this minimum would provide additional incentive and demand for increasing EVSE. Figure 3-2 shows this plan in annual sales, as well as cumulative sales. By 2020, a total of almost 2.5 million EVs will be in service.

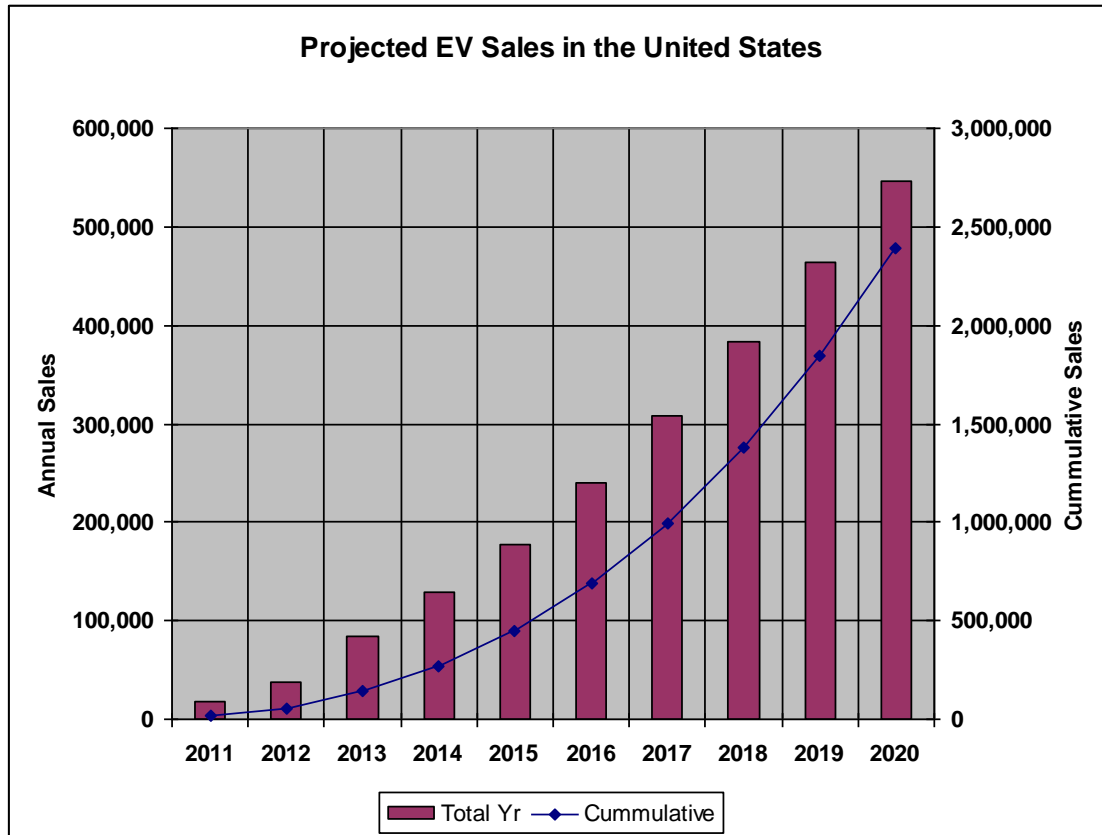


Figure 3-2: Projected EV Sales in the United States

### 3.5 EVs as Part of the Overall Vehicle Mix

The automotive market in the United States has been extremely slow during this economic downturn. Incentives have helped spark sales, but near-term predictions are still below average growth. While few are willing to make projections of sales, most suggest that car sales will start recovering in 2011 or 2012. EVs will contribute to the overall mix of vehicles, as shown in Figure 3-3. By 2020, these EV sales will account for 3.1 to 5.6% of total new car sales.

The total number of passenger cars in the United States in 2007 was 135,932,930.<sup>14</sup> The 2.5 million cumulative EVs expected in 2020 will remain a small fraction of the total number of vehicles. However, the increasing penetration rate for EVs, coupled with the retirement of the older ICE vehicles, will maintain a positive upward trend.

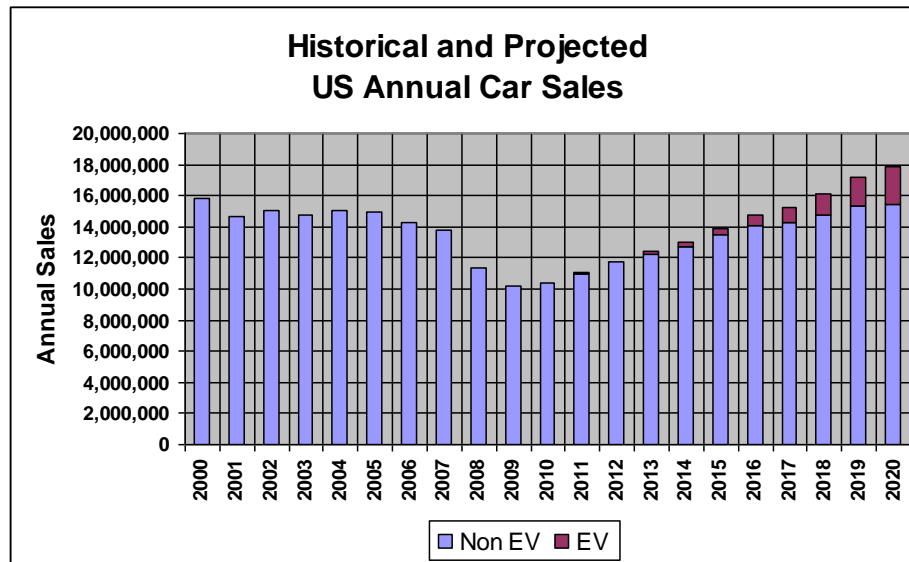


Figure 3-3: Historical & Projected US Annual Car Sales

### 3.6 Fleet Vehicles

Fleet managers will have a wide variety of options when selecting an EV for their purposes. The capabilities of the BEV and PHEV will be widely known, and vehicles can be quickly tailored for the intended vehicle mission. The range of the vehicle/battery combination required by the vehicle's mission likely will determine the vehicle chosen. Where the mission is widely varying, a PHEV may be chosen. BEVs may be chosen when specifically counting on recharging between trips.

Fleet managers are likely to be quite creative in managing their fleets, including maintaining an inventory of varying-range vehicles and providing computer programs to manage the vehicle by mission. These tools will ease the transition of fleets to EVs.

Projections of EVs selected as fleet vehicles are included in the total EV numbers. The percentage of fleet vehicles (versus personal vehicles) is expected to be higher in the early years, as governmental agencies, utilities, and other major vehicle purchasers adopt EVs to encourage their growth. At the end of 2008, there were a total of 4,882,000 cars in

<sup>14</sup> National Transportation Statistics, Table 1-11: *Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, [www.bts.gov](http://www.bts.gov), March 2010

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government, utility, and private fleets in the United States.<sup>15</sup> That accounts for about 3.6% of the total vehicle population at that time.

It should be noted here that the [American Recovery and Reinvestment Act \(ARRA\) of 2009](#) included \$300 million to acquire electric vehicles for the federal vehicle fleet. This grant money is intended to assist in the early transition to EVs in fleet applications.

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<sup>15</sup> Business Fleet, 2009 Fact Book Stats, [www.businessfleet.com](http://www.businessfleet.com)

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## 4 EVSE Sales Projections in the United States

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Vehicle manufacturers face many difficulties in successfully launching electric vehicles. For EVs to succeed, they must provide a comfortable, convenient, and reliable transportation experience. Unless a rich charge infrastructure is in place prior to vehicle launch, EV owners will not be able to comfortably travel without experiencing “range anxiety” that the vehicle battery will run out of energy. To avoid this anxiety, a charge infrastructure must be established that allows EV owners to charge where they live, work, and play. This infrastructure must be sufficiently rich to ensure that EV owners can charge conveniently. It also must include fast-charge stations that can return a substantial amount of energy in a short period of time, to make recharging at commercial locations (restaurants, stores, etc.) as simple and efficient as fueling a gasoline-fueled vehicle. A rich charge infrastructure is critical for a smooth transition from gas to electric, and for consumer acceptance of electric transportation.

These charging systems, more accurately referred to as EVSE, provide for the safe transfer of energy between the electric utility power supply and the electric vehicle. PHEVs and BEVs require the EVSE in order to charge the vehicle’s on-board battery. With the penetration of EVs into the automotive market, a corresponding penetration of this charging equipment will be required. This section identifies the equipment that will be available and probable penetration numbers over the next decade.

During the 1990s, there was no consensus on EV inlet and connector design. Both conductive and inductive types of connectors were designed and in both cases, different designs of each type were provided by automakers. At the present time, however, the Society of Automotive Engineers (SAE) has agreed that all vehicles produced by automakers in the United States will conform to a single connector design, known as the *J1772 Standard*.<sup>16</sup> See Figure 4-1.

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<sup>16</sup> While the J1772 Standard will be utilized by all automakers in the United States, it is not necessarily the standard that will be used in other countries. This standard is the subject of a harmonization project with the Canadian Codes. A common connector is also the goal of European, Asian, and North American designers.



**J1772 Connector**



**J1772 Inlet (right side)**

**Figure 4-1: J1772 Connector and Inlet**

The J1772 coupler and EV inlet will be used for both Level 1 and 2 charging levels, which are described below.

In 1991, the Infrastructure Working Council (IWC) was formed by the Electric Power Research Institute (EPRI) to establish consensus on several aspects of EV charging. Level 1, Level 2, and Level 3 charging levels were defined by the IWC, along with the corresponding functionality requirements and safety systems. Since that time, the term “Level 3” has been superseded by more descriptive terms; “DC Fast Charging” is used in this document.

The *Level 1* method uses a standard 120 VAC branch circuit, which is the lowest common voltage level found in both residential and commercial buildings. Typical voltage ratings can be from 110 – 120 volts AC. Typical amp ratings for these receptacles are 15 or 20 amps.

*Level 2* is generally considered to be the “primary” and “preferred” method for EVSE for both private and publicly-available facilities, and specifies a single-phase branch circuit with typical voltage ratings from 220 – 240 volts AC. The J1772-approved connector allows for current as high as 80 amps AC (100 amp rated circuit); however, current levels that high are rare. A more typical rating would be 40 amps AC, which allows a maximum current of 32 amps or 20 amps AC, which in turn allows a maximum current of 16 amps. This provides approximately 6.6kW or 3.3 kW charge power, respectively, with a 240 VAC circuit. See again Table 3-1 for typical recharge times at these levels.

Because charge times can be very long at Level 1 (see Table 3-1), many EV owners will be more interested in Level 2 charging at home and in publicly-available locations. Some EV manufacturers suggest their Level 1 Cord Set should be used only during unusual circumstances when Level 2 EVSE is not available, such as when parked overnight at a non-owner’s home. As the EV battery gains in energy density with longer range on battery only, the effectiveness of the Level 1 equipment for battery recharge will lessen and greater emphasis will be given to Level 2 and DC Fast Charging.



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DC Fast Charging is for commercial and public applications and is intended to perform in a manner similar to a commercial gasoline service station in that recharge is rapid. Typically, DC Fast Charging would provide a 50% recharge in 10 to 15 minutes. DC Fast Charging typically uses an off-board charger to provide the AC to DC conversion. The vehicle's on-board battery management system controls the off-board charger to deliver DC directly to the battery.

## 4.1 EVSE Deployment

The deployment of Level 2 Charging will occur in the residential, fleet, commercial, public, and workplace/employer areas.

### 4.1.1 Residential

For a BEV owner (and some PHEV owners who take advantage of utility time of use rates), the preferred method of residential charging will be Level 2 (240VAC/single-phase power) in order to provide the EV owner a reasonable charge time and to also allow the local utility the ability to shift load as necessary while not impacting the customer's desire to obtain a full charge by morning. For other PHEV owners, a dedicated Level 1 circuit may adequately meet the owner's charging needs.

BEV owners who have the opportunity for Level 2 charging at work or in public areas may find the vehicle battery remains at a higher charge, and thus home charging time is not a concern and Level 1 will suffice. See Table 3-1 for relative battery sizes and estimated recharge times.

Nevertheless, the EV owner will want the convenience of a rapid recharge of their vehicle battery at home, whether the vehicle is a BEV or PHEV. Deloitte research finds that only 17% of consumers are willing to charge from home when it takes eight hours for the recharge. Twice as many found home charging acceptable when the recharge required four hours. Many consumers will desire recharging to occur as fast as refilling the gasoline tank on an internal combustion vehicle. That gets into the range of the DC Fast Charging discussed in Section 6.

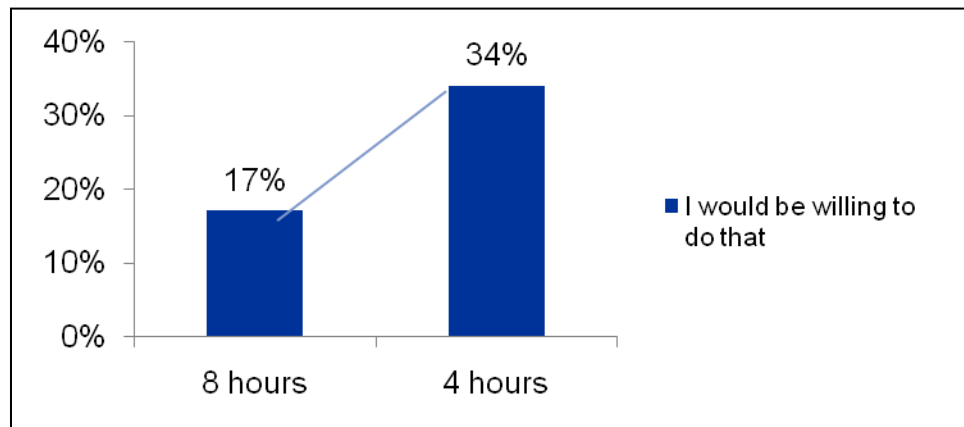


Figure 4-2: Willingness to Charge at Home for Given Number of Hours<sup>17</sup>

Analysts suggest that most recharging will occur overnight at the owner's residence. The advantage for the owner is that most electric utilities that offer off-peak or EV special rates reduce their rates in the evening so vehicle charging can occur during the off-peak, lower-cost hours. Some electric utilities, however, designate the off-peak hours as 10 p.m. to 6 a.m., which is only eight hours. Again, the advantage of charging in less than the eight hours is evident.

Studies show that if all of the EV owners in a single neighborhood were to all set their EVSE to start when the off-peak time starts, the resulting spike could be substantial, which could potentially cause more issues. When electric utilities begin to offer load management programs to their customers and seek to balance loads for neighborhoods, new strategies probably will emerge, including rotating the charge times among neighborhoods powered off the same transformer. At the same time, the increasing vehicle battery capacity will require longer recharge times. (See Appendix B.) EVSE will need to be capable of delivering a recharge in much less than the eight hours available at off-peak times.

As shown before, it is anticipated that most EV and PHEV owners will rely on Level 2 equipment where possible. In the next few years, incentive programs and consumer demographics will favor more Level 2 home use. However, the significant number of people who live in areas where a home charger may not be feasible will reduce that number, as will those consumers who buy used EVs. It is estimated that by 2020, the percentage of EV drivers with home Level 2 EVSE will be about 50% of all EV adopters.

<sup>17</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

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#### 4.1.2 Fleet

As noted in Section 3, fleet managers will have a variety of vehicles from which to choose. For PHEV users, maximizing the vehicle's travel time on the battery is likely, since that approach will be more economical and have less impact on the environment. Consequently, the EVSE chosen will be sized for the recharge required by the vehicle mission. EVSE can easily be shared between vehicles, so some vehicles are charging while others are on the road. Some may desire a mix of a few DCFCs with a larger number of Level 2 EVSE.

Fleet operations that currently provide a vehicle route in the morning and one in the afternoon likely will require one EVSE per vehicle to allow recharge at noon. The on-peak demand resulting from this may encourage managers to either change the route timing or select vehicles with greater range. Either way, managers will find ways to complete the mission with the least impact on electric and equipment costs. Maintaining low costs will likely result in fewer EVSE than vehicles.

Fleet managers are likely to rely on their own EVSE for the recharge of batteries rather than depend upon the network of publicly available EVSE. Publicly available EVSE may not be vacant when needed or be in a location suitable for the mission of the vehicle.

Fleet vehicles may include employer fleets where the EVs are purchased for the use of select employees. In these cases, the employer will determine whether an EVSE is installed at the employee's home, at the workplace, or both. Use of the company EV would likely allow private use of the EV, and thus the use of publicly available EVSE, as well as the home base equipment.

It is expected that fleet managers will find ways to charge more than one vehicle from a single EVSE through fleet vehicle rotations or staggered shift starts. Overall it is estimated that the population of Level 2 EVSE in fleet applications will be approximately 67% that of the EVs.

#### 4.1.3 Commercial

Commercial EVSE refers to those units placed in retail or privately-owned locations (other than residences). Like residential equipment, EVSE in these locations will focus on Level 2 and DC Fast Charging. Level 1 EVSE will become increasingly irrelevant. Locations sought for Level 2 will be those locations where the EV owner is likely to remain for a substantial period of time. That means that these will be destinations for the EV driver for which "purposeful" trips are made. The National Household Travel Survey found such destinations to include daycare, religious activities, school, medical or dental appointments, shopping, errands, social gatherings, recreation, family personal, transporting someone, and meals. We could also easily add night clubs, sporting events, museums, shopping malls, theaters, government offices, attorneys' offices, and numerous other places where people may park for one to three hours or longer. Revenue methods will be employed for retail owners to charge a fee for providing the charging service in the form of parking or membership fees. As demand grows, good business models will expand the population of commercial Level 2 EVSE.

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#### 4.1.4 Public

Public EVSE refers to equipment placed on public-owned land. Like residential equipment, EVSE in these locations will focus on Level 2. Again, Level 1 EVSE will become increasingly irrelevant. These locations will be those where the EV owner is likely to remain for a substantial period of time, and can include government buildings, public parking lots, curbside parking, airport visitor parking, museums, etc. Public funding would be required to provide EVSE in these locations, and thus it is anticipated that the number of public EVSE installations will be substantially lower than the number of commercial EVSE installations.

#### 4.1.5 Employer

Employers and office building managers may install EVSE to encourage employees to purchase EVs and to promote green certification of facilities. There are individuals and organizations that predict employer or workplace charging will closely follow home-based charging as the primary location for EV charging. There are a number of benefits, challenges, and questions for employers who wish to provide EVSE for employee use.

##### 4.1.5.1 LEED Certification and Public Relations

Installation of workplace EVSE contributes to qualification for Leadership in Energy & Environmental Design (LEED) certification. LEED is an internationally-recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO<sub>2</sub> emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

Developed by the U.S. Green Building Council (USGBC), LEED provides building owners and operators a concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions.<sup>18</sup>

Workplace charging provides a significant corporate and public message from management on its environmental policy. Such a message encourages employees to consider their own use of EVs and thus assist in the adoption of EVs in general.

##### 4.1.5.2 Employee Need or Convenience

Transportation studies show that most round-trip commutes are well within the projected range of EVs, so aside from those who may live at a significant distance or have no designated overnight vehicle parking location (see Section 4.1.5.6), workplace charging for most employees is a convenience, not a necessity.

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<sup>18</sup> U.S. Green Building Council, [www.usgbc.org](http://www.usgbc.org)

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#### **4.1.5.3 Employee Benefits**

A question for the employer will be whether or not to provide free charging. The employer will either charge the employee for the use of the equipment or if providing charging at no cost, potentially create a 1099 taxable benefit.

In both scenarios, management will benefit from EVSE units that are highly functional, part of an existing network, and have a point-of-sale interface that provides the ability to collect specific use information for each vehicle connected or bill the driver directly for each use.

Experience has shown that if the employer provides EVSE use without charging a fee, employees will conduct the majority of their EV charges at the workplace rather than at home.

#### **4.1.5.4 How Many Units Should Be Installed?**

There are three possible charging station installation scenarios: dedicated, open, and valet. Providing dedicated Level 2 EVSE for each employee with an EV can quickly become very expensive. Few parking facilities have electrical panels that can handle the load of numerous Level 2 EVSE before an electrical upgrade is required. One option for a dedicated parking scenario is to provide Level 1 EVSE instead. If an employee is parked for eight hours, Level 1 charging may be sufficient and this equipment is less expensive.

Providing electrical vehicle charging on an open basis will likely require that drivers move their vehicles during the day to accommodate other drivers that need a charge. Depending on the location, this could be very inconvenient and would require coordination among the drivers. Level 1 EVSE is not recommended for this scenario because of its very low charge return.

In downtown office buildings, valet parking may be offered as a service by building management. Valet parking provides an easy means of assuring that an employee receives a fully-charged vehicle at the end of the day. In addition, several vehicles can be cycled through a Level 2 EVSE.

#### **4.1.5.5 Electrical Load**

Modern EVs will allow the driver to start the air conditioning or heater 20 minutes before leaving so that they have comfort on the way home without depleting the battery. It will be very convenient for people to pre-condition their vehicle before leaving work. On a wide scale, this can have a very negative impact on the electric grid, putting on a load during peak times. It is likely that in those locations, utilities will incentivize companies to preclude charging during peak load times.

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#### 4.1.5.6 Undesignated Parking

Home-based charging is expected to be the preferred location for charging. There are, however, several residential scenarios whereby home-based charging is not an option. A significant number of residential scenarios exist where people either park their vehicle in undesignated street-side parking or do not have a convenient location for charging at their residence. Some multi-family dwellings do not or will not allow private charging systems or will see the EVSE as a nuisance and a target for vandalism. As a result, EV enthusiasts will require alternative locations to charge their vehicles. Charging could be accomplished at nearby Level 2 retail locations or the safety net DCFCs, but could also be accomplished at the workplace. Management could provide this service and thereby increase the number of workplace chargers. It is also possible that local legislation may be enacted that provides incentives to businesses and subsidizes the installation of workplace EVSE to accommodate this need.

For all of these reasons, it is difficult to predict what role workplace charging will have in the long term. It is likely that it will play a partial role in the charging of EVs, but not the significant role that many predict. The requirement to evaluate the benefits provided to employees and the desire to avoid free charging will likely require fee-based charging at work that will naturally limit the access to those who actually need the charge. Supply and demand then will limit the number of EVSE units the employer will install. It is anticipated that destination charging will have a much higher impact on vehicle charging than workplace charging.

#### 4.1.6 EVSE Requirements

The essential question raised is this: How many EVSE installations will be required to provide the necessary infrastructure? This should be viewed not only as the necessary but the “rich” infrastructure, where “rich” indicates that the number and availability of public charging locations results in readily available charging. When the public sees that a high number of locations are available, they will be more receptive to entering the EV and PHEV markets. A rich charge infrastructure is critical for a smooth transition from gas to electric and for consumer acceptance of electric transportation.

“Even though EVs meet the daily range requirements of most drivers, range anxiety is pervasive. Customers want to be able to charge at home and have the convenience of rapid charging stations (i.e., have the same experience as buying gas).”<sup>19</sup>

The deployment of DCFC equipment will be address in Section 6. The remainder of this section will focus on Level 2 EVSE.

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<sup>19</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

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## 4.2 EVSE Projection

ECotality's methodology for projecting Level 2 EVSE sales over the next 10 years focuses on four major factors: geographic coverage, destination planning, refueling stations, and rich infrastructure. Appendix A provides the details of these projections, but these four factors are summarized below.

### 4.2.1 Geographic Coverage

Because the cost of owning and operating EVs will become increasingly competitive, the EVs available by 2020 will appeal to a wide demographic. This will require the available infrastructure to expand to cover an entire metropolitan area. Outlying communities can expect to have some local infrastructure. While the highest demand will be at destination venues, additional EVSE will be required in the regions away from the city center, much in the way that gas stations are located. That geographic coverage is likely to be provided by zones that define the appropriate density of EVSE.

Three zones of increasing EVSE density are projected, with the city center or specific destination complex having the highest density of EVSE. Total projected EVSE required to provide this geographic coverage is considered the minimum needed to provide EV drivers assurance that they will not be stranded by a depleted battery anywhere in the metropolitan area.

### 4.2.2 Destination Planning

It was shown in the National Household Travel Survey that a significant number of trips for personal reasons to various destinations occur every day of the week. For destination planning, the metropolitan area is canvassed to determine the number of potential destinations and the number of EVSE that would be installed at each venue. The number of destination EVSE grows with the demand created by the introduction of EVs.

### 4.2.3 Refueling Stations

Deloitte research indicates that there is a comfort level in the public with the availability of gas stations. Their study shows that the convenience of publicly-available EVSE should at a minimum match the convenience of gas stations.

### 4.2.4 Rich Infrastructure

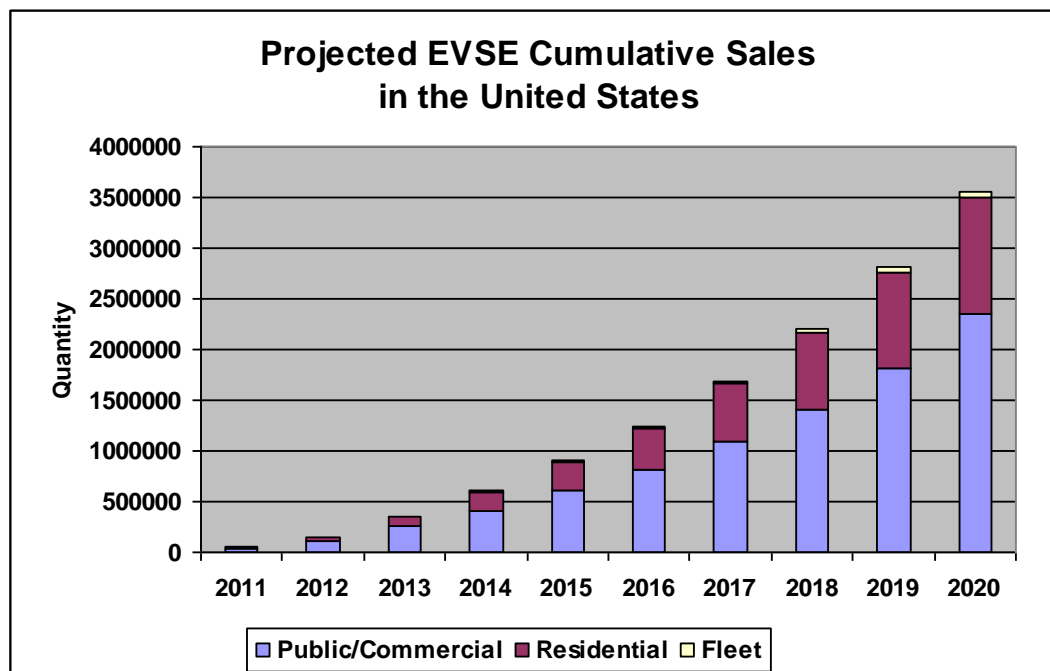
Analysts generally agree that the acceptance of EVs by the general public will require a readily-available EVSE infrastructure. The EV owner will be comfortable with densely-populated Level 2 equipment. Indeed, the visibility of this equipment will encourage others to consider purchasing an EV when they next choose a new car. In the early years of vehicle deployment, the ratio of publicly-available EVSE to the number of deployed EVs likely will be much higher than it might be in a mature market.

### 4.3 National EVSE Sales Projections

Table 4-1 provides the cumulative, calculated number of EVSE installations to be deployed in residential, fleet, and public/commercial locations, based upon the ECOTality methodology provided in Appendix A. This infrastructure is then identified as a percentage of total EVs.

**Table 4-1 Projected Cumulative EVSE Sales in the United States**

Year	Vehicles Fleet	Vehicles Residential	EVSE Fleet	EVSE Residential	EVSE Pub/Comm	EVSE Total	EVSE % EV Total
2011	3,690	14,770	2,470	11,810	41,050	55,330	300%
2012	7,900	48,500	5,290	37,340	113,970	156,600	278%
2013	11,310	130,050	7,580	96,240	256,190	360,010	255%
2014	17,840	252,470	11,950	176,730	416,570	605,250	224%
2015	26,370	420,540	17,670	281,760	609,780	909,210	203%
2016	34,340	652,360	23,000	410,990	815,450	1,249,440	182%
2017	43,780	951,260	29,330	570,760	1,093,950	1,694,040	170%
2018	55,170	1,323,970	36,960	754,660	1,403,410	2,195,030	159%
2019	70,030	1,772,900	46,920	957,360	1,808,350	2,812,630	153%
2020	86,040	2,303,860	57,640	1,151,930	2,349,940	3,559,510	149%



**Figure 4-3: Cumulative EVSE Sales in the United States**



## 5 EV and EVSE Penetrations in Tennessee

The nationwide penetrations of EVs and EVSE assist in providing projections of EVs and EVSE penetrations in Tennessee. The early market launch of EVs into Tennessee will create an informed public and enhance the public awareness of EVs. The infrastructure provided by the EV Project will also create more public awareness and interest. Local promotional materials, incentives, and press releases encouraged by the OEMs and the EV Project also will increase vehicle penetration.

National figures are used as the basis for Tennessee, with local population behavior taken into consideration. The factor is increased based upon increased enthusiasm and awareness resulting from OEM and EV Project marketing. These figures are identified later in this section.

### 5.1 Long-Range Plan Boundaries

The planning boundaries of this long range plan focuses on the State of Tennessee. The long range plan will also consider the major highway systems connecting the state to other major population centers. The I-24, I-40, I-65 and I-75 corridors are included in this boundary. DC Fast Charging along these and other corridors is discussed in Section 6. The boundary selected is shown in Figure 5-1.



Figure 5-1: Tennessee Long-Range EV Plan Boundary

This boundary is not intended to infer that EVs will not be adopted in areas outside the boundary, but rather that the majority of EV owners will work or live within this area. In addition, the boundary area should be the focus of publicly-available EVSE.

## 5.2 Demographics

Developing the EV infrastructure should respond to demographics. Understanding the population densities, likely EV owner's demographics, operator vehicular behavior, existing vehicle use, travel habits, car purchases and growth will help understand the need for EVSE penetration. The demographics of early adopters will be much narrower in range than those of EV users 10 years from now. The rich EVSE population will encourage the general public to accept the EV as an alternative to the internal combustion vehicle. The readily available public and fast charging infrastructure will enhance the EV owner's experience and dispel "range anxiety" for those who fear running out of battery.

### 5.2.1 Population

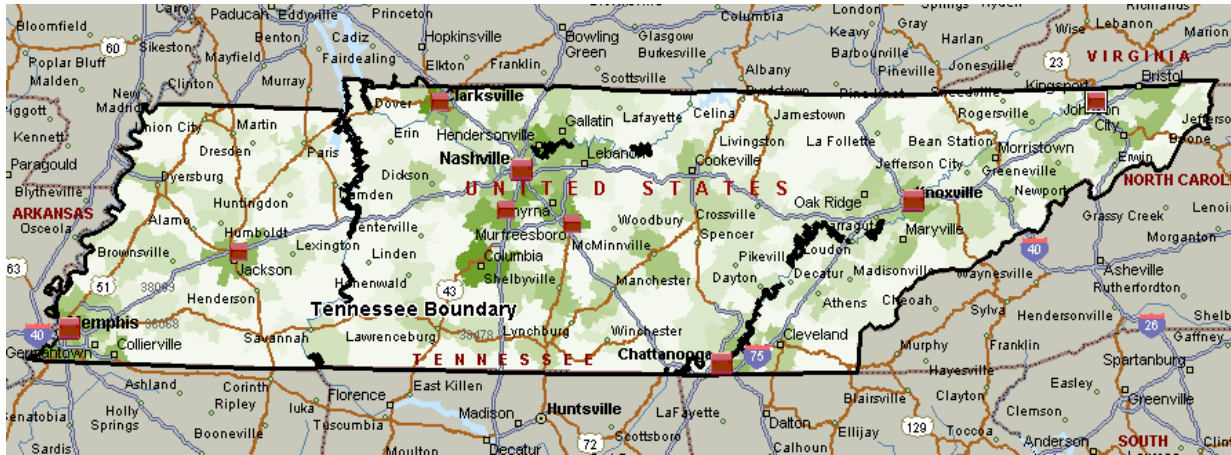
The Tennessee State population was 6,056,890 in 2007.<sup>20</sup> Figure 5-2 shows the population by zip codes.



Figure 5-2: Population: Total Persons (2007) by Zip Code<sup>21</sup>

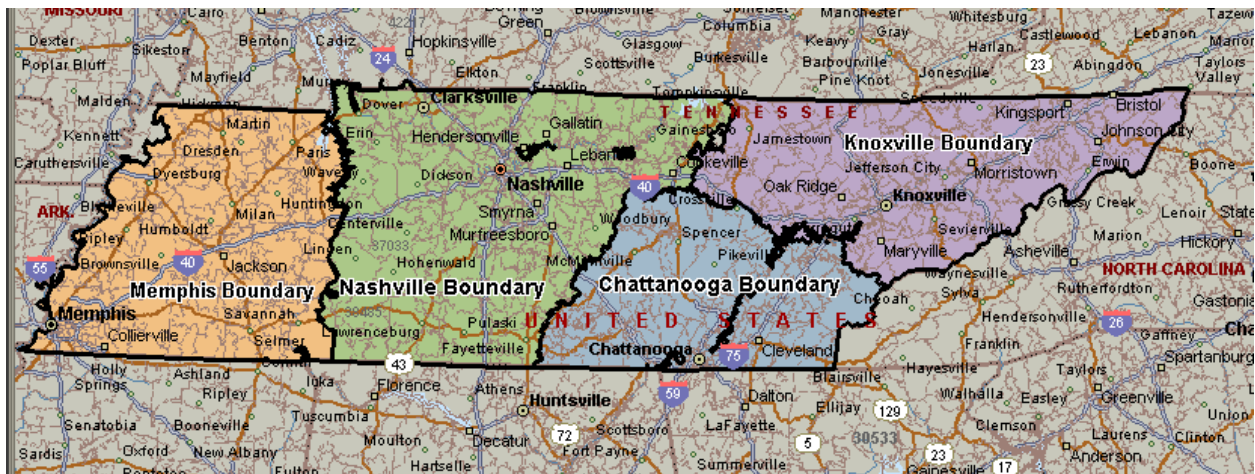
<sup>20</sup> Microsoft MapPoint 2010 United States

<sup>21</sup> ibid



**Figure 5-3: Major Population Centers**

This boundary includes all the major cities of Tennessee. For the purposes of this long range plan, the State is divided into four 4 area as shown in Figure 5-4. Populations for these areas are shown in Table 5-1.



**Figure 5-4: Tennessee Population Zones**

**Table 5-1 Major Population Centers Tennessee 2008<sup>22</sup>**

City Area	Population
Memphis Boundary Area	1,508,780
Nashville Boundary Area	2,064,002
Knoxville Boundary Area	1,613,510
Chattanooga Boundary Area	870,598

<sup>22</sup> <http://www.citypopulation.de/USA-Tennessee.html>



## 5.2.2 Education

The introduction of EVs in the next ten years is expected to provide a wide range of vehicle types and capabilities. This inventory is expected to appeal to the greater population in promoting the adoption of EVs. Analysts project, however, that the innovators and early adopters of EVs will have higher education degrees. The long range plan should involve the greater public but the early years of adoption should consider education when placing the publicly available EVSE. Figure 5-5 illustrates the population percent by zip code of adults with college bachelor degrees and advanced degrees.



Figure 5-5: Percentage of Adults with Bachelor's Degree or Above (2007) by Zip Code<sup>23</sup>

## 5.2.3 Vehicles

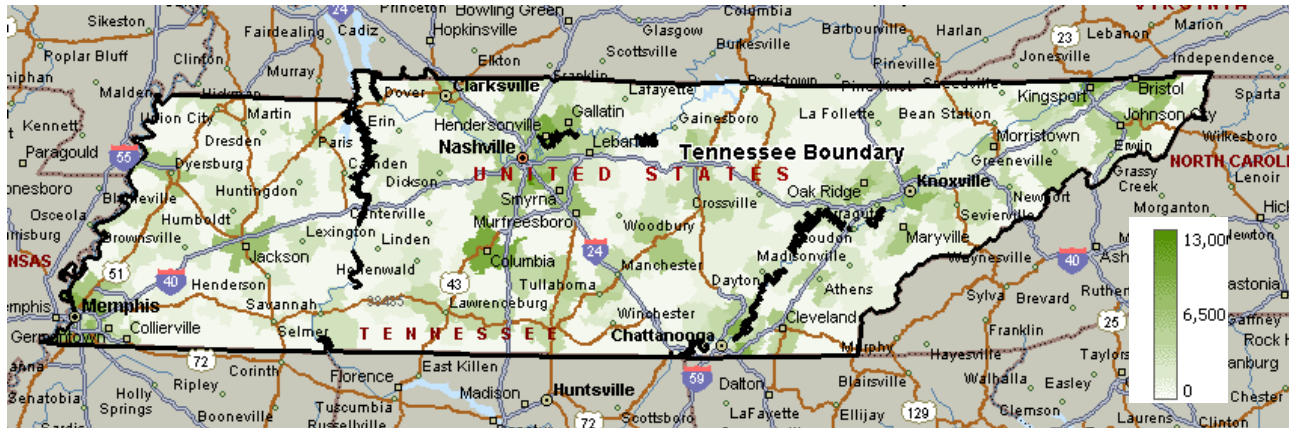
Analysts also suggest that the existing hybrid vehicle users can be an early indicator of who the innovators and early adopters of EVs will be. Figure 5-6 shows locations of existing hybrid vehicles.



Figure 5-6: Hybrid Vehicles by Zip Code

<sup>23</sup> Microsoft MapPoint 2010 United States

It is also likely that EV adopters will have at least two vehicles in the household. **Figure 5-7** below shows locations of households with two or more vehicles.



**Figure 5-7: Households with 2 or More Vehicles (1990) by Zip Code<sup>24</sup>**

## 5.2.4 Traffic Patterns

Significant study has already been completed on identifying traffic flows and patterns on major freeways. Additional studies in the local metropolitan areas will be useful in identifying potential sites for charging infrastructure.

## 5.2.5 Employment Centers

Major employment centers are of interest because they represent a significant destination for EV drivers. They may be an important location for employer or workplace EVSE, but being a destination, EV drivers will likely stop at other destinations between these work centers and their homes. The greatest densities of businesses are in the seven zip codes below.



**Figure 5-8: Numbers of Businesses (2007) by Zip Code<sup>25</sup>**

<sup>24</sup> ibid

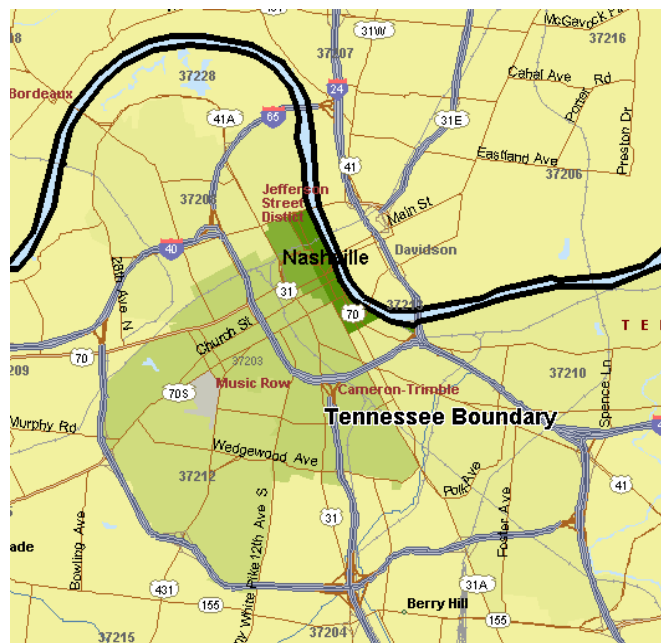
<sup>25</sup> Microsoft MapPoint 2010 United States

Business density is the number of business per square mile. The top seven areas of business density are identified in Table 5-2.

**Table 5-2 Major Business Densities**

Zip Code	City	Density Businesses/Sq Mi
37201	Nashville	2629
37203	Nashville	862
37212	Nashville West End	634
37219	Nashville	1897
37402	Chattanooga	973
37403	Chattanooga	585
38103	Memphis	730

The metropolitan areas of Nashville and Chattanooga are shown in the following figures.



**Figure 5-9: Nashville Major Business Densities**



Figure 5-10: Chattanooga Major Business Densities

### 5.3 EV Sales Projections

Chattanooga, Knoxville and Nashville are among the initial market areas for major production EVs in 2010. The Nissan Leaf is being introduced into this market. Other OEMs will follow as well. The political will and public enthusiasm are driving the interest and motivation to draw the EVs into public acceptance. This will place the Tennessee area on a faster path to EV adoption.

These factors can be applied to the EV market penetration projections of Section 4 to show the following projections by Metropolitan Area.

Table 5-3 Annual EV Sales Tennessee

Annual	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	501	296	371	0	1,168
2012	461	247	328	195	1,231
2013	580	310	412	439	1,547
2014	934	500	664	833	2,493
2015	1,571	841	1,116	1,496	4,191
2016	2,279	1,220	1,619	2,457	6,079
2017	3,300	1,766	2,345	3,849	8,802
2018	4,432	2,372	3,150	5,718	11,823
2019	5,900	3,158	4,193	8,207	15,739
2020	7,498	4,014	5,329	11,370	20,004

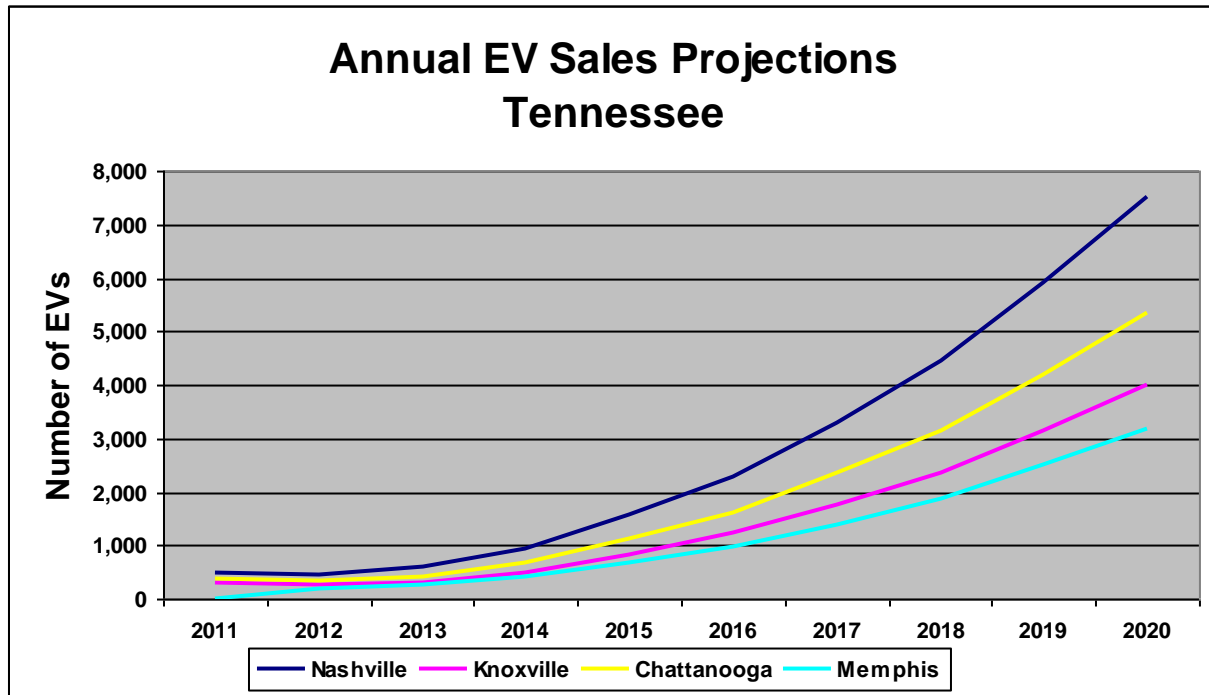


Figure 5-11: Annual EV Sales Projections - Tennessee

Table 5-4 Cumulative EV Sales Projection Tennessee

	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	501	296	371	0	1,168
2012	962	543	699	195	2,399
2013	1,542	853	1,111	439	3,946
2014	2,477	1,354	1,775	833	6,439
2015	4,048	2,194	2,891	1,496	10,630
2016	6,326	3,414	4,511	2,457	16,709
2017	9,626	5,180	6,856	3,849	25,511
2018	14,058	7,553	10,005	5,718	37,334
2019	19,957	10,711	15,198	8,207	53,073
2020	27,456	14,725	19,527	11,370	73,077



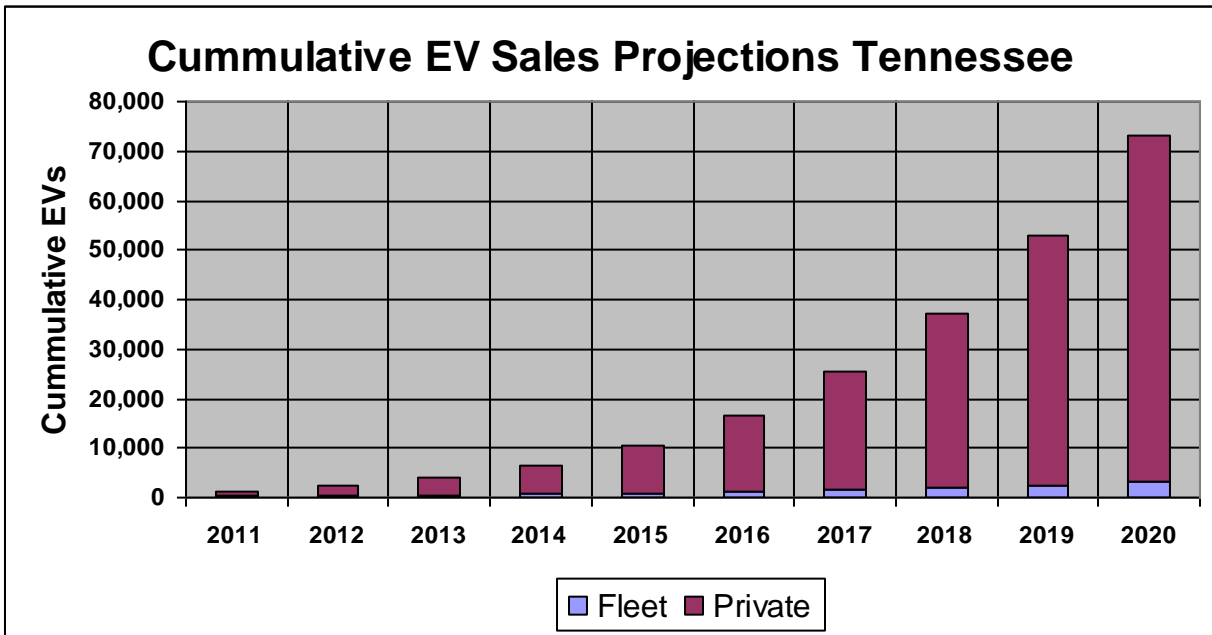


Figure 5-12: Cumulative EV Sales – Tennessee

## 5.4 EVSE Sales Projection

EVSE deployment naturally precedes EV deployment, to provide the rich infrastructure required. The number of EVSE is calculated as before to provide the following tables.

Table 5-5 Annual EVSE Projections

EVSE	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	1,500	888	1,113	0	3,501
2012	1,314	704	934	554	3,507
2013	1,490	798	1,059	628	3,975
2014	2,097	1,122	1,490	884	5,593
2015	3,202	1,714	2,275	1,350	8,541
2016	4,158	2,226	2,955	1,754	11,094
2017	5,621	3,009	3,995	2,371	14,996
2018	7,063	3,781	5,020	2,979	18,843
2019	9,003	4,819	6,398	3,797	24,018
2020	11,179	5,984	7,944	4,715	29,822

Table 5-6 Cumulative EVSE Projections

EVSE	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	1,500	888	1,113	0	3,501
2012	2,814	1,592	2,047	554	7,007
2013	4,304	2,389	3,106	1,183	10,963
2014	6,401	3,512	4,596	2,067	16,557
2015	9,603	5,225	6,871	3,418	25,098
2016	13,761	7,451	9,827	5,172	36,192
2017	19,382	10,460	13,821	7,543	51,188
2018	26,445	14,241	18,841	10,522	70,031
2019	35,448	19,060	25,239	14,320	94,049
2020	46,627	25,044	33,184	19,035	123,871

For each of the metropolitan areas, the individual categories of Level 2 EVSE are projected as follows:

Table 5-7 Nashville Area Annual Deployment

	Fleet	Residential	Publicly Avail
2011	68	320	1,112
2012	34	316	964
2013	27	400	1,064
2014	40	613	1,444
2015	59	993	2,149
2016	69	1,370	2,719
2017	95	1,895	3,631
2018	112	2,431	4,520
2019	151	3,064	5,788
2020	172	3,641	7,386

**Table 5-8 Knoxville Area Annual Deployment**

	Fleet	Residential	Publicly Avail
2011	40	190	659
2012	18	169	516
2013	14	214	569
2014	21	328	773
2015	32	532	1,150
2016	37	733	1,455
2017	51	1,014	1,944
2018	60	1,301	2,420
2019	81	1,640	3,098
2020	92	1,938	3,954

**Table 5-9 Chattanooga Area Annual Deployment**

	Fleet	Residential	Publicly Avail
2011	50	238	826
2012	24	225	685
2013	19	284	756
2014	28	435	1,026
2015	42	706	1,527
2016	49	974	1,932
2017	67	1,346	2,581
2018	80	1,727	3,212
2019	107	2,178	4,113
2020	123	2,573	5,249

Table 5-10 Memphis Area Annual Deployment

	Fleet	Residential	Publicly Avail
2011	0	0	0
2012	14	133	407
2013	11	169	449
2014	17	258	609
2015	25	419	907
2016	29	578	1,147
2017	40	799	1,532
2018	47	1,025	1,907
2019	64	1,292	2,441
2020	73	1,527	3,115

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## 6 DC Fast Charging

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Section 4 provided background information on DC Fast Charging. Studies have found that the inclusion of DC Fast Charging has a significant effect on drivers in relieving “range anxiety”. With the knowledge that there is a facility nearby that can deliver a significant charge in a short period of time, the driver is more comfortable using the full range of the vehicle. Without this safety net, the driver is more concerned about maintaining the vehicle battery at a higher state of charge. Thus the availability of DC Fast Charging will go a long way in the promotion of EVs. There is some question, however, whether the availability of the DC Fast Charging actually causes a higher usage of the equipment. A safety net is only needed in extreme conditions. Consequently, it may be that once established, a network of DCFCs may be sufficient for a substantial time into the long-range plan. This section explores the design and location process for DC Fast Charging.

### 6.1 Design Characteristics

DCFCs require a higher power level than the Level 2 units. 480-volt, three-phase AC is standard, although some equipment can use 208-volt, three-phase and up to 575 VAC. To provide the significant recharge, it is expected most DCFCs would be 40 to 60 kW, which would draw about 80 amps maximum at 480 VAC. Equipment of this size can have an impact on the local electric utility grid. This equipment has two major functions: supporting the local community charging grid and providing the range extension necessary for longer trips.

### 6.2 Customer Usage

The rapid recharge capabilities of DC Fast Charging makes it ideal for locations where the consumer will stop for a relatively short period of time; typically 15 to 30 minutes. DC Fast Charging will not generally be used for completing the charge in a vehicle, but rather to provide a substantial recharge quickly. While DCFC stations may be a destination in themselves, they will likely be placed in existing locations where customers are likely to linger for this amount of time. Locations such as coffee shops, convenience stores, and rest stops, serve as some examples. These are the typical locations for the “trip chaining” discussed in Section 2.4.

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## 6.3 Local Area Impact

The safety net provided by the DC Fast Charging augments the local Level 2 publicly-available charging network. Its placement is strategic, but yet can present challenges.

### 6.3.1 Fast Charging Benefits

Table 3-1 outlines the recharge capabilities of DC Fast Charging. It reduces the battery recharge time from hours to minutes. For many BEVs, receiving 50% battery recharge in 20 minutes is very significant. A charge opportunity lasting 10 minutes can extend the range of a BEV by 25 miles. That short a recharge time can easily be tolerated by the EV driver to gain the benefit of the range extension.

### 6.3.2 Electric Utility Grid Impact

The power required by DC Fast Charging is more typically available in industrial areas and may not be readily available in typical commercial or public areas. Industrial users require the higher power availability to power equipment, lights, material handling equipment, battery charging equipment, freezers, and other very heavy loads. This power is provided by the electric utility through the transformers in the area and is one reason areas are zoned for industrial applications. Because of the significant potential impact on the electrical grid, the electric utility company will have significant input on DC Fast Charging locations.

### 6.3.3 Siting of DCFCs

There are three major factors when siting DCFCs: suitability for charging purposes, suitability for augmenting the Level 2 publicly-available charge infrastructure, and suitability of the electric grid capability.

## 6.4 Transportation Corridors

DC Fast Charging is particularly important for transportation between major metropolitan areas. The metropolitan areas will contain the local EVSE infrastructure to support EVs in the area, but the corridors will allow BEVs in particular the ability to traverse the long corridors between metropolitan areas. DC Fast Charging is more suitable here than Level 2, because customer satisfaction will require the shortest recharge time available in order to minimize travel delays. In fact, as batteries gain in power densities and vehicle ranges are extended, it can be expected that the power levels of DCFCs will also be increased. DCFCs expected to be provided in support of the initial rollout of EVs in 2010 and 2011 likely will be 60 kW or less. Larger power electronics have been used in the past and are certainly possible, but power availability would be a concern and such sizes may be unnecessary, given current battery capacities.



Figure 6-1: Chrysler EPIC DC Fast Charging (90kW) circa 1997

#### 6.4.1 Corridor Spacing

Research provided in Section 4.2.3 identified that, from a convenience standpoint, EV charging stations should be as plentiful as current gasoline stations. This translates also to corridor travel. A review of gasoline stations along Interstate 40 from Knoxville to Nashville shows the exits where gasoline stations can be found.

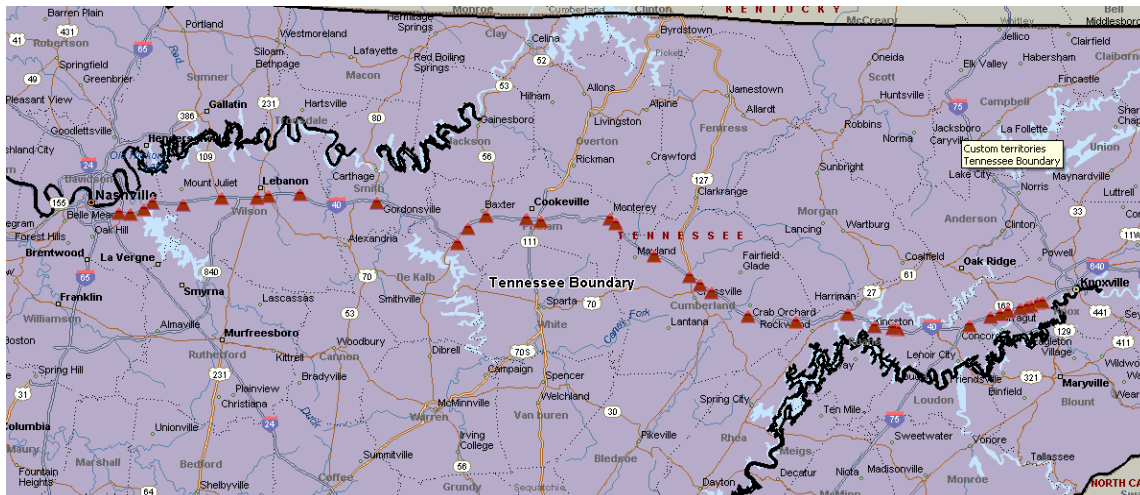


Figure 6-2: Gasoline Stations along I-40

The longest stretch in this trip between stations is about 20 miles. This is about 20% of the range of an EV. 20% of the range of a typical gasoline car is about 60 miles. This 20 mile distance is about the maximum distance that could likely be tolerated by EV drivers. In general for corridor travel, minimum planning should allow DC Fast Charging locations at no more than 30 mile intervals. The number of charge ports at these locations will initially be few but more stations or more ports at existing stations can be added as demand grows.

## 6.4.2 Siting of DCFCs

Corridor planning should involve the major freeways in the Arizona area, as well as the major state highways connecting population centers. The DCFC stations become range extenders for the EVs. Thus, they should also extend from the major highways into the major residential areas.

## 6.5 DC Fast Charging Deployment Projections

### 6.5.1 City Planning

Appendix A provides the methodology for determining the expected sales of DCFCs as a safety net for municipal EVSE. The estimated quantities of DCFCs to be deployed are shown in the following table.

Table 6-1 Annual Deployment of DC Fast Charging per Metropolitan Area

EVSE	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	12	7	9	0	29
2012	11	6	8	5	29
2013	12	6	8	5	31
2014	16	9	11	7	43
2015	24	13	17	10	64
2016	30	16	21	13	81
2017	40	22	29	17	108
2018	50	27	36	21	134
2019	64	34	46	27	171
2020	82	44	58	35	219

Table 6-2 Cumulative Deployment of DC Fast Charging per Metropolitan Area

EVSE	Nashville	Knoxville	Chattanooga	Memphis	Total
2011	12	7	9	0	29
2012	23	13	17	5	57
2013	35	19	25	9	89
2014	51	28	37	16	132
2015	75	41	54	26	195
2016	105	57	75	39	276
2017	145	78	104	56	383
2018	195	105	139	77	517
2019	260	140	185	104	690
2020	342	184	243	139	907



## 6.5.2 Corridor Planning

The guidelines above would suggest the DCFC Locations as noted on Figure 6-3 below. There are 51 DCFC locations identified to provide coverage for the entire State. While the average distance between these stations is less than 30 miles, the stations were sited at intersections of state and federal highways as well as leading to major residential population concentrations.

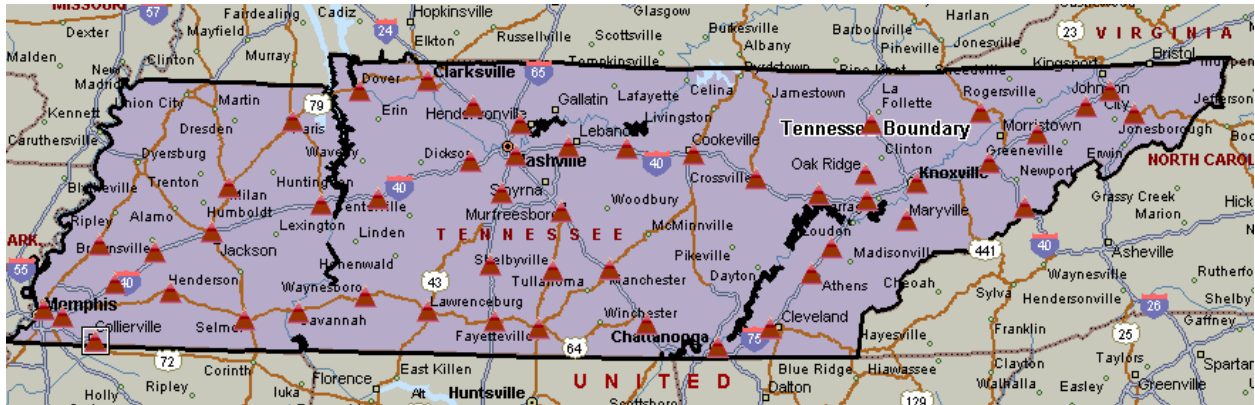


Figure 6-3: Possible DC Fast Charging Locations in 2020

## 7 EVSE Deployment Implementation

The initial groundwork was established in the EV Deployment Guidelines. The expected penetration of EVs and their desired EVSE has now been identified, including the expected penetration per year. Of course, the deployment experienced can be quite different and changes to the approach may be required. However, deployment of the EVSE should now be planned.

### 7.1 EVSE Deployment Cycle

Locating the Level 2 EVSE will start with the identification of available EV options. That availability will determine the likely owner demographics. These demographics will inform the EVSE site selection process. The general public will observe the EVSE and EVs charging at these stations. That will drive increased public EV interest. That interest will demand more EV options that will expand EV driver demographics. This loop is illustrated in Figure 7-1 below. Without outside influence, this cycle would be difficult to expand to provide more EV options. However, several additional factors can influence the desired expansion.

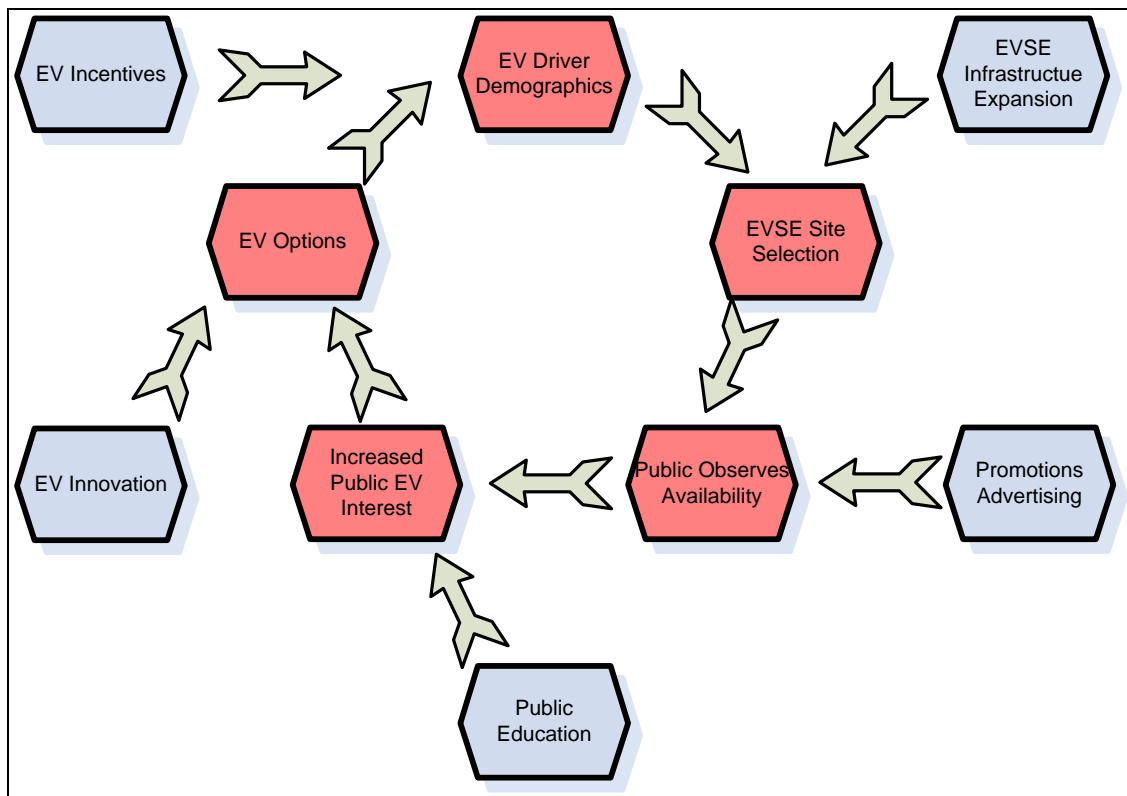


Figure 7-1: EV and EVSE Promotion

EV innovation will develop diverse models of EVs to suit many different demographics. Most OEMs have announced their plans for EVs, and increased choices will expand EV driver demographics. Public education will generate public awareness to drive public interest. Business owners who have installed EVSE will generate public awareness through their advertising and promotions. City planners and forward-thinking businesses will install EVSE beyond the developed infrastructure areas to drive the availability of EVSE.

The starting point for this EVSE infrastructure build-out is EV options. The first mass-produced EVs available for the general public are the Nissan LEAF and the Chevrolet Volt. Both are due to be released in the last quarter of 2010. The demographics of the expected buyers will help direct the initial placement of publicly-available EVSE into target areas.

The employer base and likely entertainment, shopping, and personal venues for these owners will help to focus that target. Geographic coverage as identified in Section 4.2.1 will be employed, with the inner circle focused on the target area. Available EVSE resources are identified, along with public input on suggested locations. Mapping programs are employed to assist in demographic and target identification.

## 7.2 EVSE Resources

Available EVSE resources are targeted at developing a rich EV Micro-Climate. As the target areas are populated with EVSE, the deployment can be expanded outward. Additional targets can be identified as demand increases. Eventually the targets may merge and the geographic coverage expanded. Once the expansion is completed, owner demand will continue to drive the expansion of publicly-available EVSE. The revenue systems used and business cases developed in the deployment of EVSE will drive additional EVSE procurement to meet demand. It will be important to monitor EVSE usage to validate the expansion and placement of resources.

## 7.3 Venues for EVSE Deployment

It was shown in Section 2 that a significant number of trips for personal reasons to various destinations occur every day of the week. These trips can be of substantial length, as well.

A quick review of the major Nashville metropolitan area (approximate 30 mile radius from city center) revealed the following destinations:

Airports (Major)	1	Airports (Minor)	7	Amusement parks	2
ATMs	540	Auto services	1,037	Banks	438
Bus Stations	2	Campgrounds	19	Cinemas	28
City Town Halls	14	Convention Centers	5	Galleries	31
Gas Stations	548	Golf Courses	57	Grocery Stores	271
Hospitals	37	Libraries	43	Marinas	9
Museums	30	Nightclubs	231	Park & Rides	28
Parking Lots	15	Pharmacies	198	Police Stations	14

Post Offices	38	Restaurants	2,111	Schools	426
Shopping	25	Stadiums and arenas	7	Theaters	23
Wineries	2	Restaurants	3,785		

There are a total of 6,236 destinations shown above and all are areas where the driver will likely stay for a substantial amount of time. If just two thirds of these destinations installed EVSE and there were just two EVSE at these locations by 2020, the total number of ports would be about 8,300. Note that the Nashville Level 2 EVSE population shown in Table 5-7 reaches this point in 2020. Many of these locations will be able to support many more than two EVSE and the demand will again increase the quantity of EVSE. These would represent ideal locations for possible Level 2 EVSE.

A similar review of the major Chattanooga metropolitan area shows 3,343 destinations. Knoxville shows 3,945 and Memphis shows 5,200. Again if just two thirds these destinations included two EVSE at these locations by 2020, the total number of ports would be about 4500 in Chattanooga, 5250 in Knoxville, and 6900 in Memphis.

The following list represents the types of venues that will be targeted for the initial deployment of EVSE:

<b>Airports</b>
<b>Community Center/Parks</b>
<b>Convention Centers</b>
<b>Destinations</b>
<b>Educational</b>
<b>Grocers</b>
<b>Hotels</b>
<b>Libraries</b>
<b>Malls</b>
<b>Medical/Hospital</b>
<b>Parking/Park &amp; Rides</b>
<b>Police</b>
<b>Restaurants</b>
<b>Retail</b>
<b>Theaters/Museums/Arts</b>
<b>Universities</b>

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## 7.4 Public Input

Solicitation of ideas from public workshops, public announcements or promotions, or advertising can be used to establish a pool of possible locations. EV drivers may be queried to gain their insight and experience. Forward-thinking business owners and those interested in promoting EV use will be motivated to install EVSE near their businesses. Nationally-known businesses will be eager to promote their image of being environmentally friendly, especially when noting their successes in other locations.

From this pool of suggested locations, the initial infrastructure can take its first step from a plan to a roadmap. The plan suggests the target areas, whereas the roadmap selects specific sites.

## 7.5 Jurisdictional Priorities

Governmental agencies and electric utilities will also create priorities for EVSE infrastructure deployment. Public policy and incentives will create more opportunities for EVSE deployment to expand the infrastructure. Electric utilities will be monitoring the growing demand for EVs to evaluate the impact on the electric grid.

## 7.6 Commercial Interest

The initial availability of EVs will be attractive to fleet owners that are using primarily passenger vehicles. Most governmental agencies and large employers providing pool vehicles will find these vehicles suitable for their daily vehicle mission. The promotion of EVs among their employees will generate new interest that again can expand the infrastructure deployment.

Rental car agencies will gain confidence that their renters will be able to charge in publicly-available locations. Range anxiety and unfortunate battery discharge experience for renters will need to be overcome with driver education. A positive driving experience will promote EV adoption in many geographic areas.

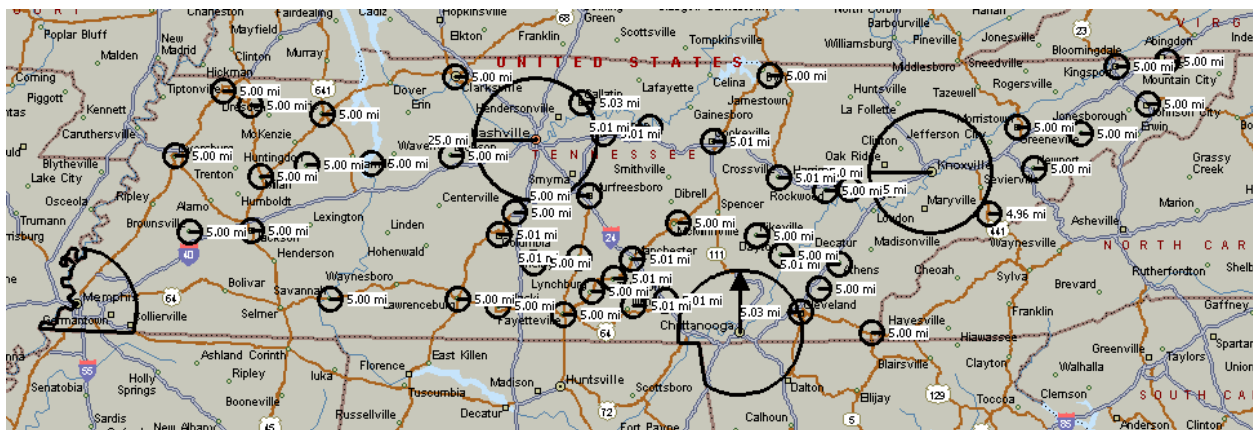
The absorption of EVs into taxi fleets will have a major effect on public acceptance. Taxis will have challenges using BEVs unless destination planning is included in the taxi reservation. A rider will not want to wait while the taxi is connected for charging. However, between fares, the taxi driver can make use of DC Fast Charging to prepare for the next fare.

Both the employer base and rental car companies will take advantage of the publicly-available EVSE network. Their input should be sought for possible locations. Like most fleet users, employer or workplace charging EVSE will be necessary to support these vehicles, but use of the publicly-available EVSE infrastructure can be expected.

## 7.7 EVSE Densities

Figure 7-2 identifies the typical densities of Level 2 EVSE expected by 2020. Each of the major metropolitan areas is surrounded by a 25 mile radius circle wherein the density of Level 2 EVSE is expected to “blanket” the area providing geographic coverage as well as higher densities of EVSE where the destinations of Section 7.3 above exist. The 5 mile radius circles denote areas of Level 2 Density outside the major metropolitan areas where publicly available EVSE will be available in densities commensurate with the sale of EVs.

Note that while DCFC locations for corridors were shown in Figure 6-3, additional DCFC stations will likely be expanded into all the regions shown for support of the local infrastructure as well as range extending charge stations.



**Figure 7-2: Level 2 - Long-Range Plan Densities**

Figures 7-3, 7-4, and 7-5 show radius maps around each of the major metropolitan areas of the EV Project. The larger 25 mile radius circles provide a general area blanket for geographic coverage of the area for range extension. Within the smaller 10 mile radius circles are where there will be a diversity of choice for charging station location type. All the diverse destinations of Section 7.3 above may be targeted within these areas.

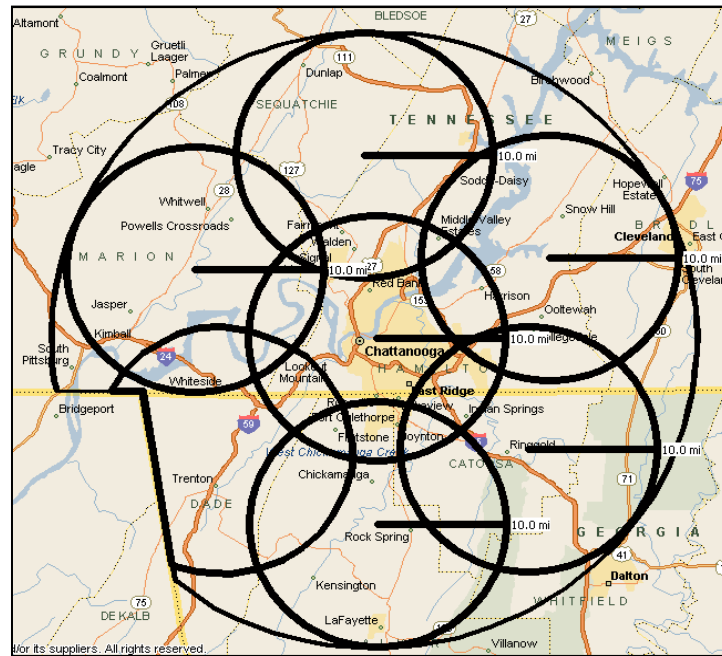


Figure 7-3: Level 2 EVSE Long-Range Plan Densities Chattanooga

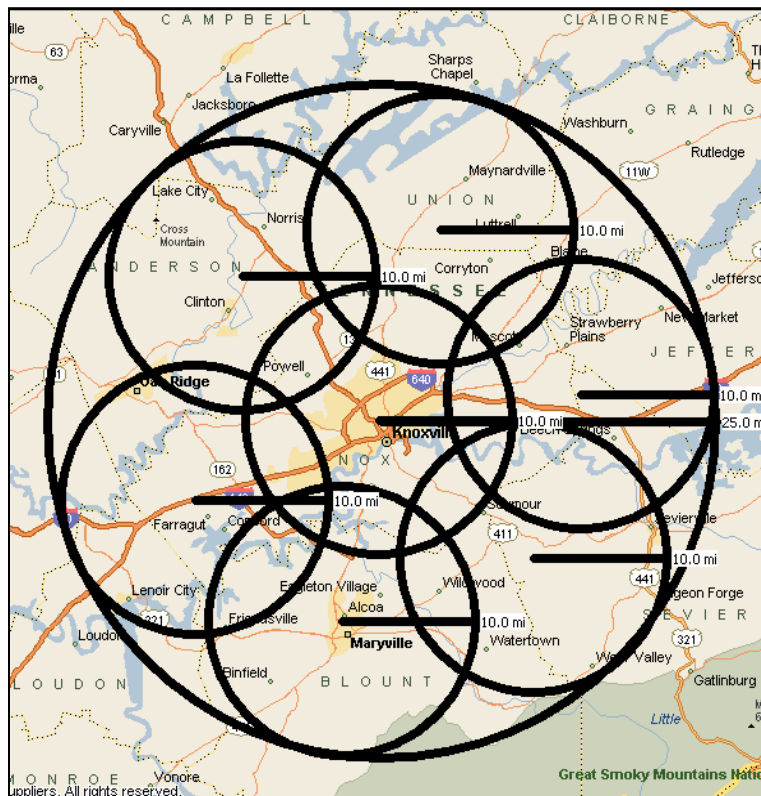


Figure 7-4: Level 2 EVSE Long-Range Plan Densities Knoxville



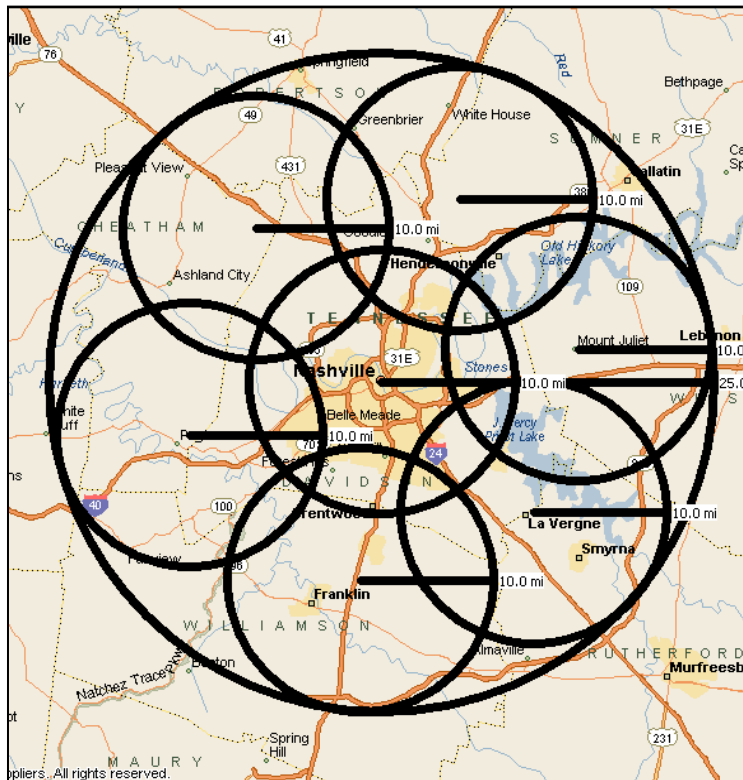


Figure 7-5: Level 2 EVSE Long-Range Plan Densities Nashville

## 7.8 Summary

Figure 7-2 shows the best current representation for the expected growth and densities of publicly available EVSE by 2020. Increasing demand for EVs will continue to drive demand for publicly available EVSE beyond this point, supported by retailers who recognize the beneficial financial aspects of providing a service to EV drivers. Electric utilities may be able to more accurately forecast generation needs along with demand response actions as the industry matures.



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## Appendix A – EV and EVSE Sales Projections

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## Appendix B – Points of Interest for Electric Utilities

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A long-range plan for infrastructure directly involves the electric utilities. Not only will the increased demand for EVs drive the demand for electricity, it could drive it during the most inopportune times for electric load management. There are many topics of interest to electric utilities that are being or will be explored during the timeframe of this long-range plan. Some of these topics are identified below. Solutions may not exist as yet, and some strategies still may be far into the future. Nevertheless, discussions on these topics are underway at this time.

### B.1 Local Grid Reliability – Clustering

A potential result of the introduction of EVs in any community could be the increased interest in obtaining an EV after seeing the neighbor's new car. In a short period of time, clusters of new EVs may appear, meaning that clusters of new residential EVSE will also appear that can have a significant impact on electric utility grid operations.

The concentration of EVSE behind individual secondary distribution transformers can create conditions of excessive current flow for durations that exceed the planned duty cycles of the equipment. This will result in insufficient time for cool-down and subsequently a significant de-rating of expected life for the utility asset. The corresponding financial and operational impact to the business is very meaningful.

The electric utilities will want to prepare for this potential. They will require a proactive or even predictive tracking of where the EVs are appearing and congregating as the initial marketing launch gets underway. This data feed also can tie into the tracking and scheduling of the EVSE installations. Having this information allows utilities to proactively manage the infrastructure rebuilding that will be needed in the worst-prepared areas. Next, the utilities need a method to defer and spread clustered charging into the overnight or off-peak hours so that sufficient cool-down of transformers can be achieved through tempered daily charging duty cycles. Ultimately, smart charging solutions can involve coordinated charging schedules that allow the customers to tailor their individual recharging needs in an optimal “network-balanced” charging solution.

This would allow the utility to better plan and defer emergency capital expenditures, as well as minimize the disruption of unplanned outages.

## B.2 Peak Shaving Strategies

Electric utilities are tasked with providing sufficient and reliable energy. One of the challenges to be overcome is the uneven nature of daily and seasonal power usage. Appendix B Figure 1 shows a typical example of a daily load profile. As demand for electricity varies throughout the day, the utility is required to add or subtract power generators to keep up. It would be more economical for utilities to reduce the peaks and fill in the valleys of this curve. Utilities have various strategies to assist in this goal. One such strategy is to use Time of Use (TOU) rates. For utilities that use such rates, the price charged for electricity during peak times is higher than that at low demand, encouraging users to switch usage to the low demand times.

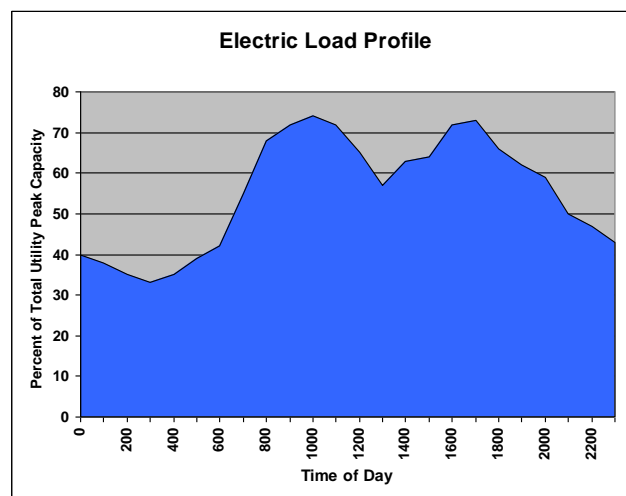


Figure B-1- Typical Daily Load Profile

Widespread adoption of EVs may aggravate this issue. Many EVs will have the feature of allowing “pre-conditioning” of the vehicle. That is, in summer, the vehicle can be programmed to start the air conditioner fifteen or twenty minutes before the end of the work day so that the car is cool when the driver leaves work. This allows the air conditioner to take power from the EVSE, rather than the vehicle battery. However, if every vehicle started the air conditioner at this time, the net result would be to compound the afternoon peak. Likewise, if every vehicle were to be connected to the home EVSE when arriving home at 5:30 in the afternoon, a similar compounded peak could be seen.

Promoting an evening TOU that begins when the peak is over is one strategy to avoid the compounded peak. The EVSE can be programmed to begin the charge at the beginning of this off-peak period. But again, if all EVs were to start charging at the beginning of the off-peak time, another spike in power demand could be seen. Some suggest that this peak could be worse than having no TOU incentives at all.

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In the broader picture, the coincident draw of additional aggregate power through feeder circuits servicing both home and commercial EVSE can lead to imbalances within the overall utility system. This can result in the need for either emergency or economic curtailment of load.

The two primary methods for managing the demand side of excessive load are to automatically or manually drop load or to drive consumer behavior change to shift the timing of the load. Dropping load is the extreme measure and can lead to brown-outs. Simply using TOU rates may not be sufficient to drive consumer behavior. The other choice is to bring on more generating power if available.

EVs connected to “smart” EVSE can support all three strategies. Smart EVSE is designed with communication and control equipment to allow greater utility control of the charge and discharge of the vehicle battery with the consent of the owner. Even though an EV is connected during the off-peak time, the utility may delay the start of the charge several hours for some vehicles to even out the demand. Typically the owner will not care when the EV is charged overnight as long as it is fully charged when needed in the morning. If dropping load is required by the utility, smart EVSE can be turned off during the peak times to curtail load. Again the owner may receive special rate incentives to consent to this drop. Finally, the large electrical storage capacity of the EV battery may be utilized in vehicle-to-grid strategies to augment the electric grid. Technology exists for many of these features, and testing and development continues. The advantage to the owner may be reduced electric rates in exchange for charge flexibility. The benefit to the utility is that it can avoid paying for incremental wholesale power at very high cost to satisfy load. In areas of weaker grid infrastructure, the utility can avoid voltage reduction and/or power outages.

### **B.3 Regulatory Activities for EVSE Penetration**

Regulators are taking dramatic steps to force the utility investment and expenditure for implementing socially beneficial programs involving Advanced Metering Infrastructure (AMI), Smart Grid, and Home Area Network (HAN), as well as the corresponding Demand Response (DR) and Energy Efficiency (EE) applications this enables. In many regions, significant federal aid has initiated large-scale programs for this purpose. Specifically for EVs, regulators are seeking input from utilities on potential impacts of home and commercial charging, and their readiness with cost-effective mitigation solutions. The more aggressive utilities are seeking approval for ownership and rate basing of the EVSE infrastructure. Others are considering support from EV owners, which may allow real-time-pricing incentives to enable these applications.

The capability of smart EVSE to support Smart Grid interoperability will make this a very important part of giving regulators the confidence that utilities are implementing these types of open-standards-based solutions.

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## B.4 Carbon Capture Strategies

Climate change science has precipitated a strong bias toward radical government action (tax or Cap and Trade) to curtail carbon dioxide emissions. While this is a raging debate that incorporates science, technology, health, economics, and politics, there is little doubt that government intervention in the utility, industrial, and transportation sectors is imminent. What this means in an age of electric transportation is that utilities have both a concern: higher power demand for charging the EV requires more generating resources that could produce more carbon against a benefit to claim: EVs displace even higher levels of carbon emission from internal combustion engines.

Legislation will be required to avoid having the utilities accept the penalties of the former without credit for the latter.

## B.5 Public Perception and Jobs

Stimulus funding for Smart Grid deployment and Advanced Technology demonstrations has built an expectation of job creation by the public utility companies that have received the funds. Even when there is no direct stimulus finding, the utility is typically seen as a community leader in stability and economic development, which contains an “unwritten expectation” that they will put rate-based profits back into business expansion. Coupled with the extensive publicity over the Clean Energy revolution, and the coming explosion of EVs as an industrial renaissance for the US, this is setting up a large opportunity for utility public relations.

For utilities, building out the EVSE infrastructure may be seen as sort of a “public works” program. This develops a strong sense of community responsibility fulfilled and excellent customer and regulatory relations.

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## Appendix C – Legislative and Public Policy Points of Interest

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The success of electric vehicles will depend on a number of variables, including a robust charging infrastructure, consumer education, and government support. There are many actions that federal, state, and local jurisdictions may consider over the next 10 years to assist in the promotion of EVs and EVSE infrastructure. This list is not intended to be exhaustive, but rather a starting point for consideration. Some activities are already underway, and others are under consideration.

### C.1 Federal Level

**Establish coherent regulatory policies for electric drive vehicles and infrastructure.**

Currently there are multiple regulatory and standard setting bodies developing policies regarding electric drive technology, including vehicle efficiency metrics, charging and refueling equipment standards, metering, and information management protocols. Regulatory requirements developed should be in the interest of advancing clear goals for the industry.

**Adopt and incorporate electric vehicle transportation into federal fleet programs.**

The adoption and incorporation of electric vehicle transportation at the federal level will not only assist federal agencies in supporting federal legislation efforts to meet national environmental standards, but also expand the awareness and use of this technology to reduce dependence on foreign oil, integrating smart grid technology, and diversifying alternative fuel programs.

**Establish a federal grant program linking the adoption and use of electric vehicles in transportation planning and programming and carbon reduction policy goals.**

Establishing a federal grant program encouraging the adoption and use of electric vehicles in transportation planning and programming to reduce pollution would provide further incentive for states, regions, local governments, and businesses to incorporate this technology in their communities.

**Incorporate electric vehicle transportation in long-range environmental, energy and transportation policy pertaining to clean air programs, alternative fuels programs, national smart grid development, and development of major transportation corridors.**

There is a great opportunity for the U.S. Department of Energy, U.S. Environmental Protection Agency (Sustainable Communities), and U.S. Department of Transportation to develop interagency policy initiatives incorporating electric vehicles and infrastructure to clean air programs, alternative fuels programs, smart grid initiatives, and infrastructure improvement of major transportation corridors to meet renewable energy, environmental, and alternative transportation policy goals.

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**Extend and expand federal tax credit for EV charging infrastructure.**

Continuing to advance the adoption and seamless deployment of electric vehicle charging infrastructure through incentives such as the federal infrastructure tax credit will assist in offsetting costs associated with its purchase and installation process.

**Provide dedicated funding for research and development of electric vehicle battery and charging technology.**

Investing federal funding to accelerate breakthroughs and commercialization of battery and charging technology will allow the industry to refine and enhance the performance of its products for the future and keep the industry globally competitive.

**Continue dedicated funding for electric vehicle and charging infrastructure programs.**

Continuing to support funding for electric vehicle and charging infrastructure programs at the Department of Energy will provide ongoing resources to improve the technology and increase its deployment.

**Expand U.S. electric drive transportation-related manufacturing.**

Expanding electric drive transportation-related manufacturing in the United States will provide significant job creation and help further expand the industry's pipeline of diverse electric vehicles.

**Provide incentives to develop electric vehicle fast charging corridors on federal highways.**

Establish a program at the U.S. Department of Transportation to coordinate development of fast charging corridors with private industry and state agencies along major intrastate and interstate transportation corridors.

**Promote outreach and education to consumers, businesses, and state and local governments, including training of first responders, to increase awareness of the benefits, safety, and requirements of electric vehicle transportation and charging technology.**

Establish funding for industry outreach and education programs to support comprehensive campaigns at the state and local level.

## C.2 State Level

**Provide tax rebates, grant programs, and other tax incentives for EVs and EVSE for residential, public, and commercial use.**

Establishing criteria for state programs to assist in offsetting costs to acquire electric vehicles and charging infrastructure will assist adoption and deployment of the technology and make it accessible to more segments of the population. For example, EV Home Charging Improvement Grants, renewable business energy tax credits, and state energy grants to provide funding for homeowners, businesses, and government entities who purchase an EV to offset costs, including pre-installation assessment, permit, and installation, associated with modifying electrical sources to include an EVSE.

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**Provide incentives by allowing EVs with single occupants to use HOV lanes.**

Work with state transportation departments or motor vehicle departments to issue license plates or permits allowing single-occupant EV drivers to use HOV lanes or toll roads for an established fee.

**Incorporate electric vehicles into state fleet programs.**

The adoption and incorporation of electric vehicle transportation at the state level will not only assist state agencies in supporting state legislation efforts to meet environmental standards, but also expand the awareness and use of this technology to reduce dependence on foreign oil, integrate smart grid technology, and diversify alternative fuel programs.

**Incorporate EVSE into state green building standards code.**

Including EVSE as a green building standard would expand the elements included for green commercial and residential construction and assist in offsetting installation costs associated with adding EVSE post-construction.

**Provide funding for permit inspector training for EVSE programs.**

Local municipalities have incurred dramatic cutbacks in the development services and permitting departments. Due to the novelty of this technology and the high volume associated with these installations, a program providing funding for training of permit inspectors for EVSE programs would greatly assist in increasing the knowledge base associated with this specific product and fast-tracking projects in communities.

**Develop a consumer EV and EVSE outreach program in conjunction with local efforts.**

Creating a statewide outreach campaign through the state's environmental, transportation, and/or energy agencies in collaboration with local jurisdictions would help expand awareness, knowledge, and benefits provided for consumers who own and operate on-road electric vehicles and charging infrastructure equipment.

**Establish, where applicable, building code guidelines for seamless and expedited basic EVSE installations and EVSE smart-charging standards.**

Work with state building code departments to establish guidelines to facilitate seamless and expedited EVSE installations, including model installation scenarios for panel upgrades, multi-family dwelling units, single-family dwelling units, and commercial and public infrastructure, as well as identifying standard elements of smart charging EVSE in cooperation with the requirements of local utilities.

**Work with utilities and EVSE providers on integration of EVs into the grid and ongoing assessment of power plant infrastructure enhancement.**

Facilitate a process by which the state energy agency works with utilities and EVSE providers to assess successful integration of EVs into the grid and monitor any future need for planning additional power plant infrastructure or a renewable energy partnership program with solar, wind, and/or other natural energy sources.



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**Provide incentives to develop electric vehicle fast charging corridors on state highways.**

Work with state transportation departments to identify opportunities to incorporate fast charging infrastructure on high-volume state highways, including private development opportunities.

**Provide incentives to bundle EVSE with home solar or home area networks.**

Develop state and/or utility packaged programs offering leveraged rate and/or tax credit when combining electric vehicle infrastructure with home solar or home area network systems that reduce energy usage impact from the grid.

**Provide grants for EV infrastructure projects and programs.**

Continued funding from state agencies and energy commissions for research and development, infrastructure demonstration projects, grants, training, and/or community outreach and education programs associated with electric vehicles and EVSE technology will greatly assist the integration and deployment of this technology in communities across the country.

### C.3 Local Level

**Update building code to include electric vehicle infrastructure in sustainable construction/green building criteria.**

To incentivize the use of electric vehicles in the community, enhance green building construction, and offset costs associated with EVSE installations, municipalities may update building code criteria to include smart EVSE in sustainable/green commercial and residential construction elements.

**Update planning and zoning districts to incorporate electric vehicle infrastructure standards for public use, in new residential construction, and in commercial construction developments, as well as incentives for retrofitting existing infrastructure.**

To enhance economic development and community redevelopment initiatives, municipal planning departments may designate special zoning overlays incorporating smart charging electric vehicle infrastructure, which may additionally enhance multimodal transportation programs in many communities.

**Work cooperatively with local utility in planning districts to track usage and need for transformer enhancement at utility neighborhood substations.**

Encourage developing energy infrastructure program between appropriate municipal departments and local utility in order to adequately plan and monitor neighborhood substations to address the impact of community EV energy usage on the grid.

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**Encourage incorporation of electric transportation in municipal multi-modal transportation planning efforts.**

Municipal transportation departments would enhance transportation service in the community by incorporating electric transportation and EVSE in multi-modal transportation and transit programs. Including this technology in a municipality's overall transportation program could assist with long-term fuel costs and reduce local pollution issues.

**Identify and train permit/code workforce in municipal building departments to work on projects incorporating EVSE and establish an expedited design review process for development and construction projects incorporating EVSE.**

Dedicating a set of specialized, trained employees to work on projects incorporating EVSE technology will allow technical review of these projects and high-volume permitting to proceed more rapidly.

**Develop a home assessment program and online expedited EVSE permitting and inspection process in cooperation with utility and EVSE provider.**

Developing a home assessment program and incorporating an online expedited EVSE permitting and inspection process to be performed by specially trained and certified inspectors in cooperation with the local utility and EVSE provider, notifies consumers regarding potential incurred costs prior to purchasing an electric vehicle and provides consumers who do purchase an electric vehicle with timely customer service and installation of the technical equipment to support its use.

**Dedicate a portion of local funding to support more complex EVSE installations and panel upgrades.**

At times, more complex scenarios for EVSE installations will occur and the cost associated with upgrading panels may be cost prohibitive. Municipalities that include a high risk of having more complex EVSE installations, for example, where there is a high percentage of multi-family dwelling units or dedicated commercial area to accommodate retrofits, may want to dedicate a portion of local funding to assist consumers offset installation costs.

**Develop a coordinated community outreach and education program regarding EVSE residential and commercial installation equipment, the installation process, and tax credit programs with the local utility and the EVSE provider.**

A locally developed and coordinated community outreach and education program in cooperation with the local utility and EVSE provider will deliver a community-driven message to inform residents about programs and processes associated with electric vehicles and charging infrastructure technology.

**Provide incentives to bundle EVSE with home solar or home area networks.**

Develop local and/or utility-packaged programs offering a leveraged rate and/or tax credit combining electric vehicle infrastructure with home solar or home area network systems that reduce energy usage impact on the grid.