



# Electric Vehicle Charging Micro-Climate™ Plan for the Greater Houston Area



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## Acknowledgments

The City of Houston and the Clinton Foundation would like to thank the following organizations for their participation and contribution to this Greater Houston Area Long Range Plan:



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## Acronyms

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<b>BEV</b>	Battery Electric Vehicle—Vehicle powered 100% by the battery energy storage system available on-board the vehicle.
<b>CCID</b>	Charge Current Interrupting Device—a device within EVSE to shut off the electricity supply if it senses a potential problem that could result in electrical shock to the user.
<b>EV</b>	Electric Vehicle
<b>EREV</b>	Extended Range Electric Vehicle—see <i>PHEV</i>
<b>EVSE</b>	Electric Vehicle Supply Equipment—Equipment that provides for the transfer of energy between electric utility power and the electric vehicle.
<b>ICE</b>	Internal Combustion Engine
<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>NEC</b>	National Electric Code—Part of the National Fire Code series established by the National Fire Protection Association (NFPA) as NFPA 70. The NEC codifies the requirements for safe electrical installations into a single, standardized source.
<b>NEMA</b>	National Electrical Mfg. Association—Group that develops standards for electrical products.
<b>PHEV</b>	Plug-in Hybrid Electric Vehicle—Vehicles utilizing a battery and an internal combustion engine (ICE) powered by gasoline, diesel, or other liquid or gaseous fuels.
<b>REEV</b>	Range Extended Electric Vehicle—see <i>PHEV</i>
<b>RTP</b>	Real Time Pricing—a concept for future use whereby utility pricing is provided to assist a customer in selecting the lowest cost charge.
<b>SAE</b>	Society of Automotive Engineers—standards development organization for the engineering of powered vehicles.
<b>TOU</b>	Time of Use—an incentive-based electrical rate established by an electric utility that Bases price of electricity on the time of day.
<b>V2G</b>	Vehicle to Grid—a concept of using battery storage on electric vehicles to supply power to the electrical grid.
<b>VAC</b>	Voltage Alternating Current often referred to simply as AC.

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## Executive Summary

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The *Electric Vehicle Charging EV Micro-Climate™ Plan for the Greater Houston Area* (Micro-Climate Plan) considers the first few years of the *Electric Vehicle Charging Long Range Plan (Long Range Plan)*, along with available local resources to develop a specific location driven approach to the EV infrastructure. It takes projections from the Long Range Plan to predict the EV penetration and EVSE needs to support that penetration in the very near future. The objective of this Micro-Climate Plan is to narrow in to specific geographic locations for the placement of publicly available Level 2 and DC Fast Charge EVSE infrastructure.

This process defines the roles of each stakeholder, establishes interfaces to coordinate their activities, defines value chains for each type of charge infrastructure (residential, commercial, workplace, fleet, and publicly available), documents plans for realizing the value associated with each value chain, and scopes support programs required for successful adoption of EVs within the Micro-Climate area. The Plan is part of the City of Houston's *EV Project Community Plan*. The report, *Recommended Electric Vehicle Charging EV Infrastructure Deployment Guidelines for the Greater Houston Area (Guidelines)*, was prepared in the early part of this planning process in 2010. The *Guidelines* were prepared in coordination with the City of Houston, The Clinton Foundation, ECOtality North America, and the Houston EV Project Advisory Team (Advisory Team). The *Guidelines* and *Long Range Plan* help focus stakeholders and have provided a good foundation for the *Micro-Climate Plan*.

The City of Houston is the fourth largest city in the nation with a population of 2.1 million within a metropolitan area of 5.9 million people. The area is home to the country's largest petrochemical and refining complex, the country's second-largest port, and on-road travel that exceeds 140 million vehicle miles traveled per day. Houston is also a leader in addressing the challenges of energy efficiency and air quality, including reduced greenhouse gas emissions (GHG), through initiatives such as the Emissions Reduction Plan (ERP), which set forth actions for reducing three key sources of GHG emissions: buildings and structures, waste, and mobile sources. For mobile source emissions and fuel efficiency, the City has restructured its fleet management and acquired one of the largest city hybrid electric fleets in the country. Prior to this Micro-Climate planning process, the City became part of *Project Get Ready*, an EV initiative for cities, acquired funding for EVs and EV charging infrastructure, and joined the *C40 Cities Climate Leadership Group*.

Just like the Long Range Plan, the Micro-Climate Plan for an EV charging infrastructure is a blueprint for an accessible, effective EV network, one that provides sufficient public charging stations for the number of EVs that need to be served. The Micro-Climate Plan addresses two key questions:

- (1) What are current travel characteristics relevant to electric vehicles and charging?
- (2) How will charging infrastructure be deployed and implemented?

Electric vehicles have fueling requirements that are unfamiliar to consumers. Therefore, it is important to understand how vehicles are used day-to-day, particularly the cars and trucks that most people rely on. National data show that the average vehicle trips are less than 10 miles, and most trips are even shorter. Such distances are well within the capabilities of available EVs or models that will be in the market next year (80 to 120 miles). Most households have more than two vehicles providing choices for longer trips. However, the range of travel is an important concern that must be addressed in the Long Range Plan. To address this concern, the Micro-Climate Plan establishes a guideline for public charging to be available within one-mile of every point in the 1,300 square mile urbanized area.



Nissan LEAF  
Introduced in Texas in Houston

Electric vehicles are already available for Houston buyers, including the Nissan (LEAF) and General Motors (Volt). The Ford Focus electric and other vehicles will become available late in 2011. The characteristics of various types of EVs and their charging requirements are discussed in detail including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and extended range electric vehicles (EREV).

EVSE systems provide for the safe transfer of energy between the electric utility power supply and the electric vehicle. The charging process needs to be comfortable, convenient, and reliable. With the penetration of EVs into the automotive market, a corresponding penetration of this charging equipment will be required. Section 2 addresses the types of EVSE: Level 1 (110/120 v), Level 2 (220/240 v), and DC Fast Charge (440v), with DC Fast Chargers providing the shortest charging time, more like that of current gasoline refueling. Level 2 and DC Fast Chargers are the key components for the public charging infrastructure. Level 2 is also likely to be the preferred EVSE for home charging. The acceptance of EVs by the general public requires a readily available public EVSE infrastructure as part of the overall EV owner's charging patterns, which will likely include home and possibly workplace charging.

The early market launch of EVs in the Houston area is helping to create a more informed public and enhanced public awareness of EVs. Section 3 addresses the Micro-Climate Plan, which focuses on four major factors for developing publicly available charging infrastructure: geographic coverage, destination planning, refueling stations, and readily available infrastructure. As part of the Micro-Climate planning process, detailed density was produced as well as distribution mapping for the greater Houston Area. This mapping will serve as a tool to guide EVSE site selection and help determine the appropriate number of units at the selected sites. Three types of data were gathered: special traffic generators and/or points of interest identified by cities, traffic volumes (state and local), and employment location information by industry type. In addition employment data, traffic patterns, and Nissan hand raiser data were used to consider possible EVSE locations.

The Long Range Plan illustrated that for most drivers, a significant number of trips are for family and personal reasons to a variety of destinations every day of the week. These trips can be lengthy, as well. In Section 4, our review of the number of destinations in the Houston metropolitan area (approximate 30-mile radius from Houston center) reveals some of the potential EVSE locations. The destinations chosen are where EV drivers will stay for 45 minutes to three hours. Such locations will be able to support more than two EVSE, and demand will increase the quantity of EVSE. These destinations are some of the ideal locations for Level 2 EVSE.

The distribution and density of EVSE are affected by the location, density, and intensity of activity associated with each destination. Multipurpose activity areas are more likely to retain users for longer periods of time, a better fit with charging needs and duration. Looking at Land Use Projections, Travel Patterns, and Employment Density in Section 4, provide some basis for factors on appropriate distribution and density of EVSE. The resulting mapping of these Level 2 and DC Fast Chargers is shown in Section 6.

DC fast chargers will be distributed in the greater Houston area at much closer intervals to help support the large population and diverse trip purposes. The plan for the Houston area includes support for programs that reduce congestion and air pollution such as the electrification of car sharing, taxi services, and distribution of goods. Section 5 discusses that the Houston area will benefit from NRG's plan to install approximately 50 eVgo Freedom Stations by mid-2011 at major shopping and business districts, and along all major freeways from downtown Houston to approximately 25 miles from the city center. The longest stretch between stations is about 25 miles. This is approximately 25% of the total range of current EVs. For planning purposes, corridor EVSE locations should provide 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.

As this Micro-Climate Plan describes, Houston has a strong market for vehicles, and significant support to create a readily available EVSE infrastructure. As examples, ECOtality is providing home charging for qualifying Volt purchasers and publicly available EVSE as an extension of The EV Project; NRGs eVgo is building a program for home and public charging; the City is deploying EVs and EVSE for its fleet, and vehicle manufacturers are looking to Houston as an early vehicle market. Therefore, Houston is well positioned to be an EV leader.

This next step in the Community Planning process, the EV Micro-Climate Plan, will help clarify short-term actions that will achieve the long-term goals.

# 1 Introduction

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The City of Houston (City) is the fourth largest city in the nation, with an estimated 2009 population of 2.26 million<sup>1</sup>. At 5.9 million people, the Houston metropolitan area is the sixth largest in the U.S. and in the last ten years has grown by more than 1.1 million people. The Houston area is home to the country's largest petrochemical and refining complex, the country's second-largest port, and on-road travel that exceeded 140 million vehicle miles traveled per day. Consequently, Houston faces significant challenges in air quality, including emissions of greenhouse gases (GHG). In response, the City has been a leader in addressing these challenges. In August of 2008, the City issued an Emissions Reduction Plan (ERP) setting forth actions on three key sources of GHG emissions: buildings and structures, waste, and mobile sources. The City has implemented and continues to implement numerous other actions to improve air quality and reduce GHG emissions.

Vehicle electrification is a key action that Houston has instituted working with the Clinton Climate Initiative, the Houston Advanced Research Center, ECOtality North America, the Rocky Mountain Institute, Texas A & M University, and the University of Texas at Austin. The Houston Electric Vehicle Initiative is building capacity within communities and working through partnerships across multiple stakeholder groups to create ongoing air quality improvements and GHG reductions. These efforts support the achievement of the City's broader environmental, economic, health, and social co-benefits.

As part of this initiative, the City has asked ECOtality North America to work with its partners and stakeholders to develop an EV Micro-Climate program that will help ensure that Houston is well prepared to support the consumer adoption of electric transportation. Beginning with extensive feasibility and infrastructure planning studies, the program provides a blueprint that will create a rich EV charging infrastructure in the Houston area. The program is being developed with all pertinent stakeholders, including governmental organizations, utilities, private-sector businesses, and automotive manufacturers.

The EV Project provides a continuation of the work that has been done in Houston to achieve the region's long-range goals. It cannot by itself complete the necessary infrastructure, but the Long Range Plan will provide the guidance for planning this infrastructure growth and focusing on the near term for locating infrastructure. 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 the 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 the Greater Houston area to achieve the region's long-range goals. It cannot by itself complete the necessary infrastructure, but the long-range plan will provide the guidance for planning this infrastructure growth and focusing on the near term for locating EV Project resources.

ECOtality developed the Micro-Climate Plan as an integrated program to ensure an area is well equipped with the needed infrastructure to support the consumer adoption of electric transportation. Beginning with extensive feasibility and infrastructure planning studies, the program provides a blueprint to create a rich EV infrastructure. The program is developed with stakeholders including government

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<sup>1</sup> U.S. Census Bureau, <http://factfinder.census.gov>

organizations and jurisdictions, non-profit organizations, utilities, private-sector businesses, and automotive manufacturers.

ECOtality introduced the EV Micro-Climate process in Houston in August 2010 with its first Houston EV Project Advisory Team meeting. The process has three main deliverables:

- Deployment Guidelines
- Long Range Plan
- EV Micro-Climate Plan

## 1.1 Deployment Guidelines

The report entitled *Electric Vehicle Charging Infrastructure Deployment Guidelines for the Greater Houston Area (Guidelines)* was completed in December, 2010. The Guidelines are intended to create a common knowledge base of EV requirements for stakeholders involved in the development of EV charging infrastructure. Electric vehicles have unique requirements that differ from internal combustion engine vehicles, and many stakeholders are currently not familiar with these requirements. The Deployment Guidelines develop a foundation for implementation of EV charging infrastructure, including topics such as information on technology, charging scenarios, codes and standards, and utility integration. The City of Houston, HARC, HGAC, and other Houston advisory group stakeholders contributed content and also proactively set in motion procedural changes that will expedite deployment of Electric Vehicle Supply Equipment (EVSE).

## 1.2 Long Range Plan

The *Long-Range EV Infrastructure Plan for the Greater Houston Area (Long Range Plan)*, completed in March 2011, creates a long-term look toward a mature EV market and the implications for successful development of public charging infrastructure. The Plan 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 greater Houston area by the year 2020.

The Long Range Plan describes the unfolding EV technology and the needed EV charging support infrastructure. Houston's Long Range Plan projections increase from 2011 with new vehicles reaching 6.7% of new vehicles purchases by 2020. The projected number of EVs on the road in 2020 would total 73,000 vehicles. Early deployment (the next one to two years) of EVSE charging infrastructure is essential for this growth to occur.

The Long Range Plan shows maps of density and distribution patterns for both Level 2 and DC Fast Charging infrastructure. These maps were developed as part of the Micro-Climate Plan effort and are more fully described in this document.

## 1.3 EV Micro-Climate Plan

The Long Range Plan is used as a starting point to develop the near-term strategy for infrastructure deployment and provides a basis for the direction of future deployment. The Micro-Climate Plan considers the first few years of this Long Range Plan along with available local resources to develop a specific location-driven approach to the EV infrastructure. It takes projections from the Long Range Plan to predict the EV penetration and EVSE needs to support that penetration in the very near future. Most automotive manufacturers have announced plans for plug-in vehicles and over the next ten years it is projected that there will be vehicles that will appeal to all demographic profiles. However, that may not be the case for the initial years of EV penetration. Rather than blanket the area with infrastructure, this

plan looks at the demographics of the likely innovators and early adopters of EVs to provide the rich EV infrastructure that will continue to encourage the adoption of EVs.

The objective of this plan is to narrow in to specific geographic locations for the placement of publicly available Level 2 and DC Fast Charge EVSE infrastructure. The purpose of this document is to record the process used by The EV Project for distributing, locating, and selecting EVSE sites. An important output of this document is a series of maps of potential geographic locations for publicly available Level 2 EVSE and DC Fast Charge equipment. The Micro-Climate Plan will be used in selecting specific EVSE hosts leading to contracts and EVSE installations.

## 2 Electric Vehicles and EV Charging Station Background

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### 2.1 Electric Vehicle Types

#### **Battery Electric Vehicle (BEV)**

Battery Electric Vehicles (BEVs) are powered 100% by the battery energy storage system available onboard the vehicle. The Nissan LEAF is an example of a BEV. Refueling the BEV is accomplished by connection to the electrical grid through a connector that is designed specifically for that 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. Manufacturers of PHEVs use different strategies in combining the battery and ICE. Some vehicles, such as the Chevrolet Volt, utilize the battery only for the first 40 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 may include Range Extended Electric Vehicle (REEV) or Extended Range Electric Vehicle (EREV). The Chevrolet Volt is an example of an EREV.

### 2.2 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.

### 2.3 Electric Vehicle Charging Stations

An EV charging station, more correctly called “electric vehicle supply equipment” (EVSE) provides 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 increasing sales of EVs into the automotive market, a corresponding deployment of charging equipment will be required. This section identifies the equipment that will be available to serve the EV market.

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 sold by automakers in the United States will conform to a single connector design, known as the *J1772 Standard*.<sup>2</sup>

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<sup>2</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.



**Figure 2-1 J1772 Connector**



**Figure 2-2 J1772 Inlet (right side)**

The J1772 connector and EV inlet will be used for both Level 1 and 2 charging levels, as 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 and in the industry.

## **2.4 Level 1 and Level 2 Charging**

The Level 1 method uses a standard 120 volts AC (VAC) branch circuit, which is the lowest common voltage level found in both residential and commercial buildings. Typical voltage ratings are 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 the EVSE for both private and publicly-available facilities, specifying 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 amperage levels that high are rare. A more typical rating would be 40 amps AC, which allows a maximum current of 32 amps; or as another example, 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 Table 2-1: EV Charge Times for typical recharge times at these levels.

Because charge times can be very long at Level 1 (see Table 2-1), 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 charge.

## 2.5 Fast Charging

DC fast charging is used 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.

There is currently no US standard for the DC fast charge connector. The Japanese fast charge standard, called CHAdeMO, will be used for vehicles like the Nissan LEAF. The EV Project will be deploying DC fast charge stations with two CHAdeMO connectors that will be capable of charging two EVs sequentially (as shown in Figure 2-3). In the future, one of the connectors can be retrofitted if the US develops a different standard.



Figure 2-3 Blink DC Fast Charge Station

### Electric Vehicle 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 2-1 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 fully depleted battery, assuming the onboard battery management system allows each power level.

Table 2-1: 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
PHEV-10	4	3 h 20 m	2 h 30 m	35 m	n/a
PHEV-20	8	6 h 40 m	5 h	1 h 15 m	n/a
PHEV-40	16	13 h 20 m	10 h	2 h 30 m	16 m
BEV	24	20 h	15 h	3 h 40 m	24 m
BEV	35	29 h 10 m	21 h 50 m	5 h 20 m	35 m
PHEV Bus	50	n/a	n/a	7 h 40 m	50 m

**Note:** Power delivered to the battery is 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 2-2 provides a comparison based upon a vehicle efficiency of 4 miles/kWh of charge. It is important to note that the number of miles achieved per charge time is independent of battery size.

**Table 2-2: Miles Achieved per Charge Time**

<b>Miles Achieved per Charge Time*</b>					
<b>Charge Time</b>	<b>Circuit Size and Power in kW Delivered to Battery**</b>				
	<b>Level 1 120 VAC, 15 amp 1.2 kW</b>	<b>Level 1 120 VAC, 20 amp 1.6 kW</b>	<b>Level 2 240 VAC, 20 amp 3.3 kW</b>	<b>Level 2 240 VAC, 40 amp 6.5 kW***</b>	<b>DC Fast 480 VAC, 85 amp 60 kW</b>
<b>10 min</b>	0.8	1.1	2.2	4.3	40
<b>15 min</b>	1.2	1.6	3.3	6.5	>50****
<b>30 min</b>	2.4	3.2	6.6	13	>50****
<b>1 hour</b>	4.8	6.4	13.2	26	>50****

\* Vehicle efficiency 4 miles/kWh.

\*\* EVSE efficiency assumed at 85%.

\*\*\* Vehicles such as model year 2011 Nissan LEAF have chargers rated only for 3.3 kW, so even though Level 2 40 amp EVSE will produce 6.5 kW, the vehicle can only use 3.3 kW.

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

Because of Level 1’s limited miles achieved per charge time, it is not recommended for publicly available charging. Level 2 charging will provide higher amounts of range for the one to two hours of parking typical for publicly available charging stations.

## **2.6 Charging Station Locations**

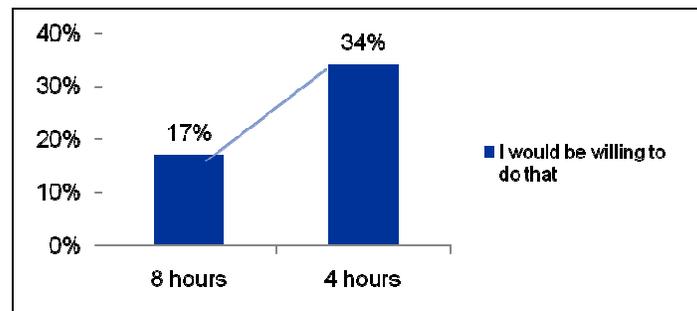
The Micro-Climate Plan provides guidance for choosing locations for charging stations. The focus of the Houston EV Project is on building out a readily available infrastructure of publicly available infrastructure in commercial and public locations. The following is a discussion of locations for publicly available charging. Also discussed is workplace charging and the potential role it might play in charging infrastructure.

### **2.6.1 Residential**

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. 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. The preferred method of residential charging will be Level 2 (240VAC/single-phase power) in order to provide the EV owner with 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. If EV owners charge nightly, as recommended and as needed for the electric power grid, fast charging is less important. For other PHEV owners, a dedicated Level 1 circuit may adequately meet the owner’s charging needs.

BEV owners who have the option of Level 2 charging at work or in public areas may find that the vehicle battery remains at a higher charge, meaning home charging time is not a concern and Level 1 will suffice. See Figure 2-1 (page 10) for relative battery sizes and estimated recharge times.

Even so, 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, which gets into the range of the DC Fast Charging. Charging discussion seems to imply that owners will be recharging depleted batteries, rather than daily and even multiple charging during a day (keeping batteries charged up as often as possible). The Deloitte question about whether consumers would prefer 8 hours or 4 hours for charging duration misses the change in refueling behavior.



**Figure 2-4 Preferences for Home Charging Duration<sup>3</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 issues for the electric utility. When electric utilities begin to offer demand reduction 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. For example, CenterPoint determined that system-wide impacts from EVs are likely to be relatively minimal within the next decade, with additional peak load growing by no more than five percent. However, the localized impact of EVs, including excessive transformer loads, is of more concern. In particular, the analysis shows potential clustering of EVs which can result in high EV loads at a given transformer. Low charging levels during off-peak periods could notably limit overloading. However, as the number of EVs increases and the charging levels rise over the next ten years, transformer overloading is highly probable for certain regions of CenterPoint Energy’s territory. Careful management of EV loads could potentially mitigate such impacts. At the same time, the increasing vehicle battery capacity will require longer recharge times. EVSE will need to be capable of delivering a recharge in much less than the eight hours available at off-peak times. <sup>4</sup>

<sup>3</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

<sup>4</sup> KEMA and CenterPoint Energy Houston Electric, LLC “Electric Vehicles in Houston: Motivations, Trends, and Distribution System Impacts”, June 23, 2010

In the next few years, incentive programs and consumer demographics will favor more Level 2 home installations. However, a significant number of people live in residences where a home charger may not be feasible – as an example, apartments or older urban neighborhoods with limited off-street parking. The US Census Bureau, 2005-2009 reports lists single family detached housing units as being an average of 68.8% of total housing units or 1,287,074 in the Brazoria, Fort Bend, Galveston, Harris, Montgomery, and Waller counties that make up the greater Houston area.<sup>5</sup>

### 2.6.2 Fleet

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 fleet managers may desire a mix of a few DC Fast Chargers 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 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.

### 2.6.3 Commercial EVSE

“Commercial EVSE” refers to those placed in retail or privately-owned locations (other than residences) that are publicly available. 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 or personal, transporting someone, and meals. We could also easily add nightclubs, 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. As demand grows, good business models will expand the population of commercial Level 2 EVSE.

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<sup>5</sup> US Census Bureau, 2000 Selected Housing Characteristics: 2005-2009

#### **2.6.4 Public EVSE**

“Public EVSE” refers to equipment placed on public-owned land that is publicly available. Like residential equipment, EVSE in these locations will focus on Level 2 and Level 1 EVSE will become increasingly irrelevant. These locations will be those where the EV owner is likely to remain 45 minutes to three hours 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.

#### **2.6.5 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.

##### ***2.6.5.1 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, CO2 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 with a concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions.<sup>6</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.

##### ***2.6.5.2 Employee Need or Convenience***

Workplace charging will be important for those who may live at a significant distance or have no designated overnight vehicle parking location (see Section 2.6.5.6, page 15).

##### ***2.6.5.3 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 to 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.

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<sup>6</sup> U.S. Green Building Council, [www.usgbc.org](http://www.usgbc.org)

#### ***2.6.5.4 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. Level 1 might be good option for employer based locations since most employers don't own their own buildings. The bigger challenge may be ensuring that charging locations don't have non-EV cars parked in them.

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 will 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 to assure 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.

#### ***2.6.5.5 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 likely will incentivize companies to preclude charging during peak load times.

#### ***2.6.5.6 Undesignated Parking***

Undesignated on-street parking may be one of the few options available for many residences that do not have off-street parking or do not have adequate electrical service at their parking site. Some multi-family dwellings do not or will not allow private charging systems or their managers could see the EVSE as a nuisance and target for vandalism. On-street EVSE is likely to require higher maintenance because of increased exposure to traffic and vandalism.

As a result, EV enthusiasts will require alternate locations to charge their vehicles. The charging may be accomplished at nearby Level 2 retail locations or the safety net DC Fast chargers, but could also be accomplished at the workplace. Management could provide this service and thereby increase the number of workplace chargers. 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 some predict. The requirement to evaluate the benefits provided to employees versus the desire to avoid providing 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 will limit the number of EVSE stations the employer will install. It is anticipated that publicly-available charging will have a much higher impact on vehicle charging than workplace charging.

### 2.6.6 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 readily available infrastructure, where the number and availability of public charging locations results in convenient charging for EV owners. 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 readily available infrastructure is critical for a smooth transition from gas to electric and for consumer acceptance of electric transportation. We must stress that home charging will be a key element and first step in this direction.

The deployment of DC Fast Charge equipment will be addressed in Section 7.

### 3 Two-Year Planning Horizon: the EV Micro-Climate Plan

Most recharging of electric vehicles will occur overnight at the owner's residence. However, studies of consumer attitudes towards electric vehicles point to the need for publicly available charging stations to make the transition to electric transportation successful.

“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>7</sup>

Beginning in 2011, EVs will be on the roads in Texas and will need publicly available EVSE. In terms of numbers, most EVs entering the Houston area in 2011 will be Nissan LEAFs or Chevrolet Volts, which are the primary vehicles being supported by The EV Project. By late 2011 and 2012, many other manufacturers are expected to deliver vehicles to the Houston area that will also be able to use the J1772™ connector associated with Level 2 charging. A more limited number of vehicles will be equipped to utilize the DC Fast Charge units, because no U.S. national standard has been adopted for this charging level.

The planning boundaries focus primarily on areas in Brazoria, Fort Bend, Galveston, Harris, Montgomery, and Waller counties (Figure 3-1). The boundaries are based on ZIP codes. The Long Range Plan also considers major highway systems that connect the Houston area to major population centers. The I-45, I-10, U.S. 59, U.S. 290, and I-610 corridors are of particularly high interest. Several of the proposed DC Fast Charging locations along these corridors are described in Section 5.

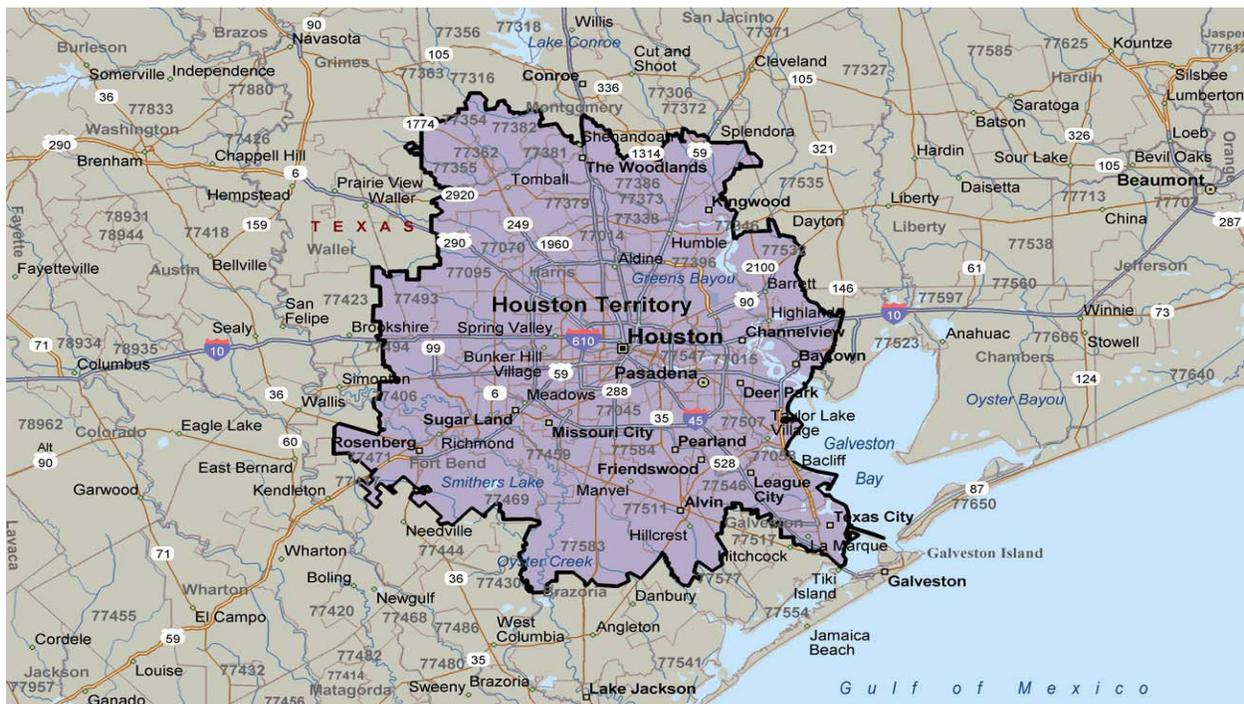


Figure 3-1 Houston Metro Area Long-Range EV Plan Area (based on ZIP codes)

<sup>7</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

### 3.1 Process Overview

The Micro-Climate planning focuses on four major factors for developing publicly available charging infrastructure: geographic coverage, destination planning, refueling stations, and rich infrastructure.

#### ***Geographic Coverage***

Geographic coverage is provided by zones that define the appropriate density of EVSE. For urban planning, three zones of increasing EVSE density are projected, with the city center or specific regional destinations having the highest density of EVSE.

#### ***Destination Planning***

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.

#### ***Refueling Stations***

Deloitte Research indicates that there is a comfort level in the public with the availability of gas stations.<sup>8</sup> Their study shows that the convenience of publicly-available EVSE should at a minimum match the convenience of gas stations.

#### ***Readily Available Infrastructure***

The acceptance of EVs by the general public will require a readily available EVSE infrastructure. The EV owner will be comfortable with densely-distributed 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.

Using the Guidelines and the Long Range Plan as context, The Advisory Team has developed the Micro-Climate Plan for the greater Houston area. The Micro-Climate Plan provides geographic mapping that relies on:

- Analysis of available data sets obtained from Geographic Information Systems (GIS) at State, regional, and local governments, and
- Stakeholder-derived recommendations for locating EV infrastructure

The near-term distribution of EVSE requires a planning process that increasingly focuses at a city and neighborhood level. For the two-year planning horizon, the Advisory Team has heavily relied on city data and advice on locating infrastructure in their communities because of their expertise within their own communities.

### 3.2 Density and Distribution Mapping for EVSE

As part of the Micro-Climate planning process, the Advisory Team produced detailed density and distribution mapping for the greater Houston Area. This mapping will serve as a tool to guide EVSE site selection and help determine the appropriate number of units at the selected sites.

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<sup>8</sup> Deloitte Research, *Gaining Traction, A Customer View of Electric Vehicle Mass Adoption in the US Automotive Market*, January 2010

The Advisory Team and other stakeholders conducted a data search of State, regional, and local data that could be useful in locating EVSE. Initial inquiries included three types of data:

- Special traffic generators and/or points of interest identified by cities
- Traffic volumes (state and local)
- Employment location information by industry type

Therefore, the analysis proceeded with GIS data for traffic generators, employment (by location and type), and travel patterns. To create the density and distribution mapping, the Advisory Team used the three categories to create multiple data layers and associated values mapping. A combined, single map was then produced to show proposed density and distribution patterns for EVSE by using multivariate analysis.

### 3.2.1 Employment Data

Using employment data gathered by governmental entities, we can determine the type of employment undertaken in different neighborhoods and focus on employment types associated with destinations that would support usage of publicly available EVSE. Employment information used for this planning effort sorted the type and number of employees traveling to transportation analysis zones (TAZs).

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. Figure 3-2 shows HGAC's Regional Employment Forecast in jobs per square mile for 2005 and 2035. Figure 3-2a shows projections for the area within Beltway 8.

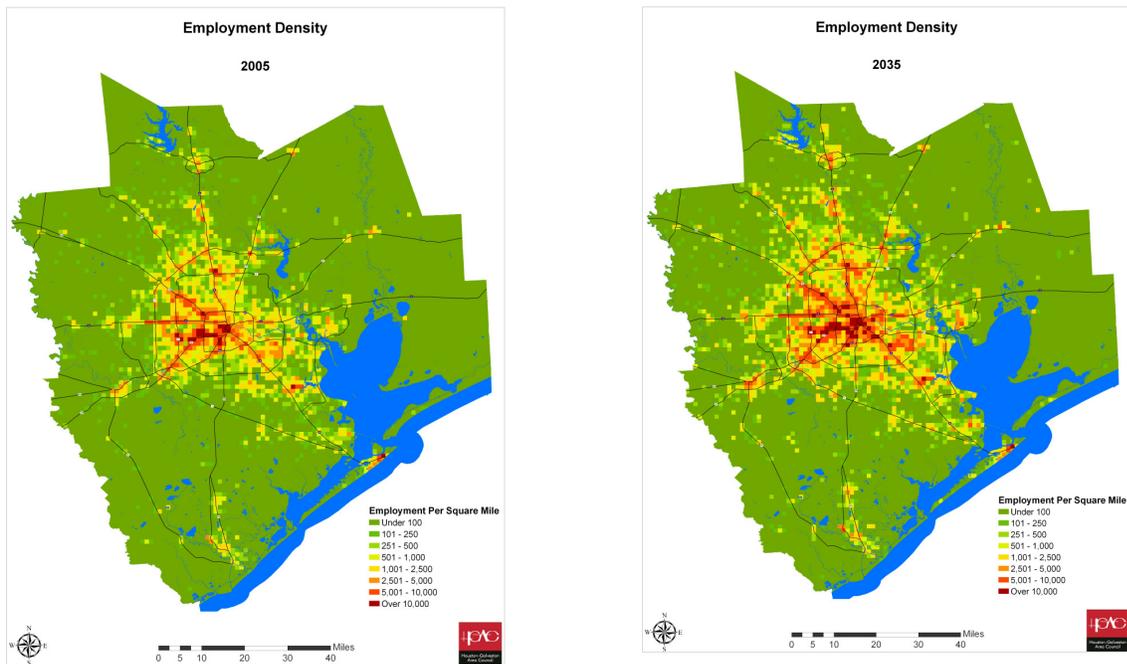
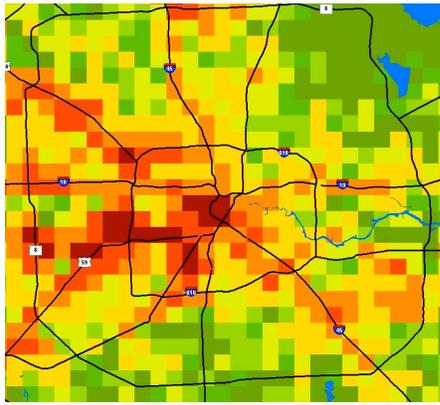
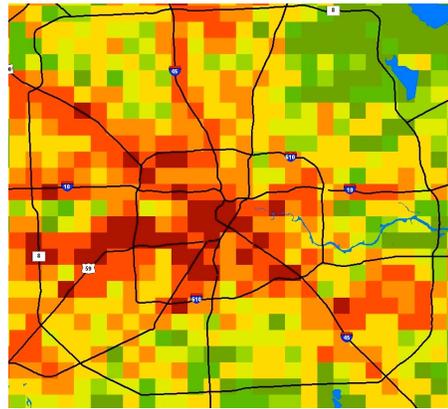


Figure 3-2 Employment Density 2005-2035 – Jobs/Square Mile <sup>9</sup>

<sup>9</sup> HGAC's Employment 2005-2035 Regional Forecast, April 2006



Employment Density 2005



Employment Density 2035

Figure 3-2a Employment Density Within Beltway 8 2005-2035

### 3.2.2 Travel Patterns

Destinations important for EVSE charging are often located near busy streets and highways. Analysts considered the relationship of high traffic to surrounding properties. Two sources of information were used to construct the travel data layer for this analysis:

Busiest Houston Highways	Total Vehicles Peak Period	Travel Time Peak Period	Avg. Speed Peak Period	Avg. Speed Main lanes	Travel Time Main lanes
Total System Utilization		Minutes	MPH	MPH	Minutes
IH 10 W Katy Inbound	4,941	10.83	61.50	54.60	20.67
IH 10 W Katy Outbound	3,979	10.64	62.00	49.70	21.74
IH 45 N North Freeway Inbound	3,739	14.85	61.40	42.10	25.24
IH 45 N North Freeway Outbound	3,806	17.35	52.60	40.00	26.58
IH 45 S Gulf Freeway Inbound	2,737	12.09	58.60	41.70	16.98
IH 45 S Gulf Freeway Outbound	2,731	13.09	54.10	34.30	20.66
US 290 Northwest Freeway Inbound	3,006	12.23	60.60	37.00	21.23
US 290 Northwest Freeway Outbound	3,406	15.24	48.60	25.20	29.18
US 59 S Southwest Freeway Inbound	2,763	8.38	57.60	48.40	9.98
US 59 S Southwest Freeway Outbound	3,183	9.22	52.40	39.60	12.21
US 59 N Eastex Freeway Inbound	1,898	15.39	66.70	61.50	16.69
US 59 N Eastex Freeway Outbound	1,986	15.72	65.30	59.00	17.28

Table 3-1 Busiest Houston Freeways<sup>10</sup>

<sup>10</sup> City of Houston Study, 2009

### 3.2.3 Nissan Registrants Compared to Population Distribution

One question that arose during Micro-Climate planning was how do registration rates for the Nissan LEAF correlate with general population? At the macro level – looking across the Willamette Valley study area, we see relatively minor variations between population and registrants, as shown in Table 3-2 below, which is based on data from August 2010.

Table 3-2: Nissan Leaf Registrants Compared to Metropolitan Area Population <sup>11</sup>

County Area	2010 Population	# of Hand Raisers	% by County
Brazoria	313,166	50	2.6%
Fort Bend	585,375	128	6.8%
Galveston	291,309	85	4.5%
Harris	4,092,459	1576	84%
Montgomery	455,746	7	0.3%
Waller	43,205	41	1.8%
<b>Totals</b>	<b>5,781,260</b>	<b>1878</b>	<b>100%</b>

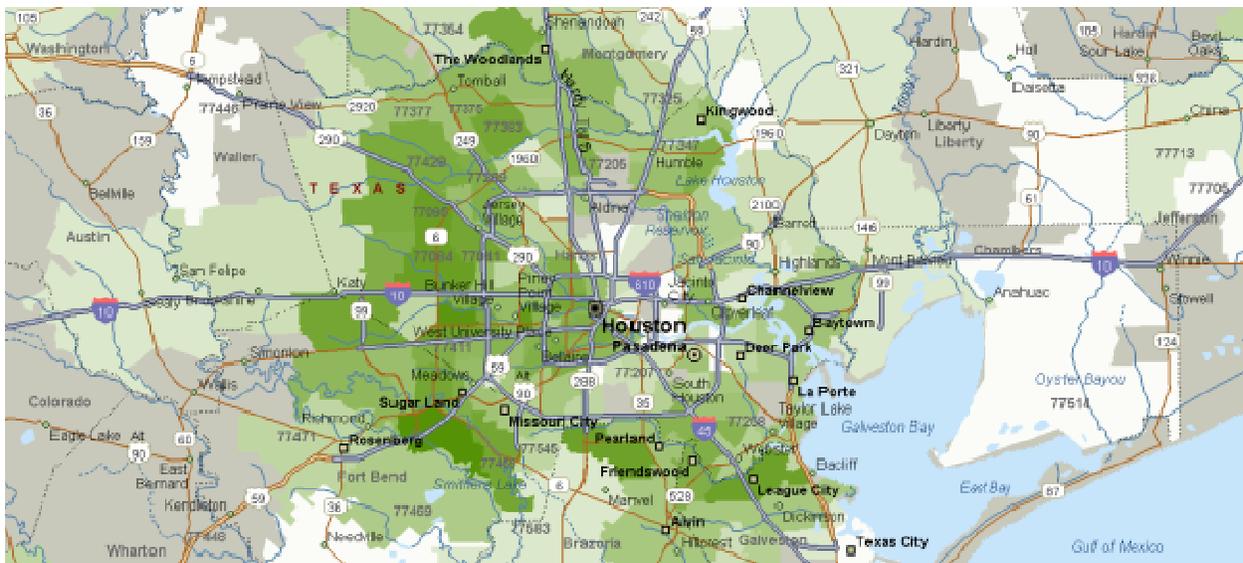


Figure 3-3: Nissan LEAF Registrants by Zip Code

In the greater Houston area, we have relied on the Density and Distribution mapping and also stakeholder input to identify destinations. The Micro-Climate process includes tools to help locate EVSE that feature both data-driven inputs and community-requested locations.

### 3.2.4 Stakeholder Input for Locating EVSE

The Advisory Group has gathered requests and advice on locating EVSE from a variety of sources. Our team will utilize this input as we consider opportunities presented by property owners willing to host publicly-available EVSE.

<sup>11</sup> US Census Bureau

## 4 EV Micro-Climate Plan for the Greater Houston Area

### 4.1 Houston Venues

The Long Range Plan illustrated that for most drivers, a significant number of trips are for family and personal reasons to a variety of destinations every day of the week. These trips can be lengthy, as well. A review of the number of destinations in the Houston metropolitan area (approximate 30-mile radius from Houston center) reveals the following as some of the potential EVSE locations.

Table 4-1 Houston Venues for EVSE Deployment

<b>Airports (Major)</b>	2	<b>Airports (Minor)</b>	12	<b>Amusement parks</b>	6
<b>Churches</b>	14,954	<b>Cinemas</b>	30	<b>Convention Centers</b>	6
<b>Galleries</b>	107	<b>Gas Stations</b>	1,341	<b>Golf Courses</b>	105
<b>Grocery Stores</b>	664	<b>Hospitals</b>	74	<b>Libraries</b>	87
<b>Marinas</b>	24	<b>Museums</b>	45	<b>Nightclubs/Taverns</b>	1,243
<b>Park &amp; Rides</b>	23	<b>Parking lots</b>	140	<b>Pharmacies</b>	526
<b>Middle Schools</b>	172	<b>High Schools</b>	222	<b>Alternate Schools</b>	123
<b>Wineries</b>	1	<b>Restaurants</b>	6,428	<b>Shopping</b>	64
<b>Stadiums/Arenas</b>	23	<b>Theaters</b>	31	<b>Universities/College</b>	61
<b>Elementary Schools</b>	703	<b>Public Parks</b>	486	<b>Pools</b>	40

There are a total of 27,749 destinations listed above within the Houston EV Project Boundary, and all are areas where the driver might choose to stay for 45 minutes to three hours. Additional venues that meet these criteria are City and County Courts and Permit offices, Social Service agencies, Clinics for Dental, Ophthalmology, and Medicine. Such locations will be able to support more than two EVSE, and demand will increase the quantity of EVSE. These destinations are some of the ideal locations for Level 2 EVSE.

The distribution and density of EVSE is affected by the location, density, and intensity of activity associated with each destination. Multipurpose activity areas are more likely to retain users for longer periods of time, a better fit with charging needs and duration. Malls, for example, are more likely to have longer term stays than a big box store or a standalone restaurant without related activity around it. Existing databases can contribute to locating EVSE. For example, traffic modelers use detailed household surveys on driving behavior, including trip destinations – and this information will be utilized in the future as part of The EV Project. The following information provides some basis for factors on appropriate distribution and density of EVSE:

- **Land Use Projections and Real Estate Data:** Detailed land use surveys and real estate data from tax appraisal districts classify properties in ways that can be analyzed as to their likelihood of supporting targeted destinations.
- **Travel Patterns.** Major streets, highways, and interchanges are ranked to identify areas with high levels of traffic and access to destinations.
- **Employment Density.** The number of employees, the location of their employment, and their type of business is mapped to identify targeted destinations.

Using multivariate analysis and geographic information systems (GIS), these datasets contribute to the mapping of planned distribution and density of EVSE. Initial analysis was conducted prior to beginning the Long Range Planning process.

Additionally, planning for initial installation of EVSE will consider the demographic distribution of early adopters and destination data supplied by participating communities. The likely distribution of early adopters can be determined from zip code data for existing hybrid vehicle ownership, as well as data on the addresses of potential EV purchasers.

## 4.2 Public Input

From this pool of suggested locations, the initial infrastructure can take its first step from a plan to a roadmap. This Micro-Climate Plan recommends the target areas, whereas the roadmap identifies specific sites. Ideas to establish possible locations for EVSE are coming from:

- Houston Advisory Team members
- Public presentations
- Media announcements
- Participation in related conferences
- Direct contacts via email, web and telephone
- Community leaders
- EV drivers (ride and drive events) and others requesting information

## 4.3 Methodology

For trip or transportation analysis land uses are broken up into two categories:

- **Trip Generators** - mainly houses/apartments where people start a trip.
- **Trip Attractors** - offices, movie theaters, restaurants, etc. that people go to.

The ultimate goal of our location selection model is to end up with ¼ mile radius locations that have the greatest number of potential optimum EVSE sites.

We used the ¼ mile radius mapping for two reasons:

- First, rather than identify exact properties that should have EVSE, the ¼ mile radius grabbed clusters of properties in areas that make sense for EVSE.
- This (¼ mile) is typically the distance that someone might walk for mass transit connection, to get to a restaurant, etc. So placing an EVSE at the edge of a ¼ mile radius can be defended as possibly serving that whole area.

For mapping purposes, we treated DC Fast charging like L2 (except with slightly different parameters to arrive at the areas that were mapped) and then have described additional siting criteria like proximity to Interstates / State Routes and presence on major arterials or higher as other location selection factors. Notes have been attached on how the model works for internal use only.

### 4.3.1 Level 2 Locations - EVSE Commercial and Public

- High number of users
  - Integrated into daily life
  - Available to many different users
- High frequency of vehicle turnover
  - Vehicle stay times of 45 minutes to approximately 3 hours

- Significant availability
  - Maximize the number of open days per week and per year
  - Maximize the number of open hours per day

#### 4.3.2 DC Fast Charging

- High number of users
  - Integrated into daily life
  - Available to many different users
- Very high frequency of vehicle turnover
  - Vehicle stay times of 5 minutes to 30 minutes
- Significant availability
  - Maximize number of open days per week and per year
  - Maximize number of open hours per day

#### 4.3.3 Level 2 - EVSE Optimization Model 1

Three categories of sites based on typical weekly / weekend schedules and associated driver behavior. (Note: A site may qualify and score within more than just one category.)

- **Around homes with PEVs.** This category is intended to capture work-week morning and evening activities along with non-work week activities routinely performed within close proximity to home (e.g., grocery shopping, recreation, dining out, entertainment, shopping, school, medical, etc.).
- **Between homes with PEVs and major employment locations and along routes to/from major employment locations.** This category is intended to capture work-week activities performed in-route to/from places of employment, and activities performed around places of employment (e.g., dining out, shopping, entertainment, school, medical, education, etc.).
- **Regional attractions.** This category is intended to capture work-week and non-work week (i.e., special occasion) activities at sites that can attract drivers from all over the region (e.g., shopping, recreation, entertainment, education, health care, etc.).

The importance of land uses, distances from home or work, and other characteristics will likely vary under each of the three categories described above. This model hypothesizes and attempts to capture the differences in characteristics for each category.

A particular site is scored on a weighted sum of its score within each of the three categories.

Qualifying and scoring within each category is described below.

#### 4.3.4 Category 1: Around homes with PEVs

For sites to qualify as potential locations for EVSE land use, they would need to fall within one of the specified land uses. If a site is on the qualifying land use list for category 1, the site gains points if it is located within PEV home area zip code and for each PEV home area zip code within four miles. For this category, sites receive a greater weight (multiplier) for their PEV home area zip code. PEV home area zip codes are standardized scores based on probable density of PEVs in the zip code. Each PEV home area zip code score is multiplied by weight (1 if within and .5 if within four miles) of the site's location relative to that PEV home area zip code. The sum of scores for a site from location within and proximity to PEV home area zip codes is multiplied by a standardized average daily traffic count for the road that the use is located on.

#### 4.3.5 Category 2: Between PEV home and work, around work and along route

For sites to qualify as potential locations for EVSE land use, they would need to fall within one of the specified land uses. A site on the qualifying land use list for Category 2 will gain points if it is located within an employment area, within three miles of an employment area, and along a major transportation corridor connecting PEV home area zip codes to employment areas (i.e., within a ¼ mile of a freeway or prime arterial connecting an employment area to a PEV home area). Weights (multipliers) for site scoring are below:

<u>Site Location</u>	<u>Weight</u>
Within employment area	1
Within three miles of employment area	0.4
Along route employment area to PEV home	0.6

Employment areas are standardized scores of density of jobs/employment area. An employment area score is multiplied by the weight of a site’s location relative to that employment area. The sum of scores for a site from location within and proximity to employment areas and along major transportation corridors from employment areas is multiplied by a standardized average daily traffic count for the road that the use is located on.

#### 4.3.6 Category 3: Regional Attractions

For sites to qualify as potential locations for EVSE land use, they would need to fall within one of the specified land uses. A site on the qualifying land use list for category 3 will gain points based on its distance from PEV home area zip codes. Weights (multipliers) for site scoring are below:

<u>Site Location</u>	<u>Weight</u>
40 - 50 miles from PEV home area	1
30-39 miles from PEV home area	0.75
20-29 miles from PEV home area	0.5
<19 miles from PEV home area	0.25

PEV home area zip codes are standardized scores based on probable density of PEVs in the zip code. The PEV home area score is multiplied by the distance weight. The average score for the site in each distance category is then calculated. The sum of average scores for a site based on distance from PEV home areas is multiplied by a standardized average daily traffic count for the road the use is located on. For uses with more than one main entry point the sum of standardized average daily traffic counts shall be the multiplier.

A site’s score from each category is then multiplied by the category weight, as shown in the table below, and then summed for the grand total site score.

<u>Category Weights</u>	<u>Weight</u>
Category 1	0.6
Category 2	0.7
Category 3	0.5

Category weights were assigned based on possible need for public charging and on potential hours a week a PEV driver might have for frequenting the land uses within each category. Need for public charging is primarily attributed to distance from home (where a PEV could leave with maximum range available). The potential hours a week a PEV driver might have for frequenting land uses within any given category are largely a factor of work and non-work periods.

Assumptions are:

- Category 1
  - Activities occur within close proximity to home
  - Five-day work week hours before and after work of approximately five hours a day
  - Two-day non-work week hours of approximately 16 hours a day
- Category 2
  - Activities occur between home and work, and around work
  - Five-day work week with approximately four hours before, during break and after work for activities
- Category 3
  - Activities have higher probability of occurring at greater distances from home than for Category 1.
  - Two-day non-work week hours of approximately 16 hours a day, plus holidays and vacation days
  - Activities are more special occasions that would occur less frequently throughout the year than for Categories 1 and 2

After sites in the greater Houston area are scored a density map of optimum sites can be created, and ¼ mile radius location boundaries (approximately 400 – 500 locations) can be created around the highest densities of optimum sites.

Ideal EVSE densities within the ¼ mile locations created can then be determined based on the sum of standardized average daily trips on the roads (excludes freeways within the locations) within each ¼ mile radius location.

#### **4.3.7 Level 2 - EVSE and/or DC Fast Charger Location Optimization (Sample) Model 2**

Sites scores are determined by multiplying a site's land use score by a standardized average daily traffic score for the road that serves the site. If the site is within a major activity center or employment area the major activity center/standardized employment area score is added to the average daily traffic score before being multiplied by the land use score.

All land use scores are a composite of multiple factors. The following land use factors make up the composite land use score:

- Daily hours of availability
- Average stay of 45 minutes to three hours (for DC Fast charge the stay is five minutes to 30 minutes)
- Availability to many users (takes account of any restrictions, such as employee only use, etc.)
- Availability throughout the year (taking account of seasonality)

After sites in the greater Houston Area are scored a density map of optimum sites can be created, and ¼ mile radius location boundaries (approximately 400 – 500 locations) can be created around the highest densities of optimum sites.

Ideal EVSE densities within the ¼ mile locations created can then be determined based on the sum of standardized average daily trips on the roads (excludes freeways within the locations) within each ¼ mile radius location.

### **4.3.8 National Accounts**

ECotality is developing national accounts to help distribute EVSE. National accounts are corporations and other organizations that have suitable properties for locating EVSE in more than one state. Many of the areas identified on the Nominated Locations will align with locations of properties in ECotality's national accounts database.

Destinations that attract the public will be the primary focus, as identified by the local jurisdictions, other stakeholders, and ECotality.

## **4.4 ECotality EV Project EVSE located on Public Property**

ECotality plans to allocate about 50 publicly-available EVSE (Level 2) on public property, including publicly-owned parking lots, parking structures, and on right-of-way. Locations will include community colleges, city halls, libraries, state offices, state colleges, and other locations as nominated by the local jurisdictions, the Advisory Team, and others.

This distribution will consider centers of government as destinations. The counties of Brazoria, Fort Bend, Galveston, Harris, Montgomery, and Waller will be considered.

ECotality will select sites for charging using the Methodology above, Advisory Team recommendations, National Account Sales and stakeholder involvement.

To be selected, sites should meet the following criteria:

- Likely to meet EV Project data collection requirements,
- Supported by the property owner,
- Cost-effective,
- Safe for the equipment and the user, and
- Consistent with the Density and Distribution Map and/or the Community Nominations Map

## 5 DC Fast Charge Plan

DC fast chargers will be distributed in the greater Houston area at much closer intervals to help support the large population and diverse trip purposes. The plan for the Houston area includes support for programs that reduce congestion and air pollution such as the electrification of car sharing, taxi services, and distribution of goods.

The Houston area will benefit from NRG's plan to install approximately 50 eVgo Freedom Stations by mid-2011 at major shopping and business districts, and along all major freeways from downtown Houston to approximately 25 miles from the city center. The longest stretch between stations is about 25 miles. This is approximately 25% of the total range of current EVs. For planning purposes, corridor EVSE locations should provide 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.

Nearby access to a freeway or state highway is an important consideration for selecting sites for DC fast chargers. According to the Long Range Plan, corridor travel should be supported by DC fast chargers located at intervals of 30 miles or less. For the initial rollout of DC fast chargers, the actual spacing will be greater on the rural corridors – but still well within the range of a Nissan LEAF. Corridor planning should include major Houston freeways such as I-45, I-610, I-10, U.S. 59, U.S. 290, and U.S. 281, as well as the grid of major state highways connecting population centers east to west and north to south. In effect, DC Fast Charge stations can become range extenders for EVs.

The TEPCO and ECotality studies of EV infrastructure provide the methodology for determining the expected sales of DC Fast Chargers as a safety net for publicly-available EVSE. The studies placed 10 DC Fast Chargers in a 50-mile square mile area, roughly the same size as the core part of Houston Micro-Climate area shown in Figure 3-1 (page 16). Per the Level 2 infrastructure analysis, this would suggest that heart of the public infrastructure should include one DC Fast Charger per 5 square mile area or one DC Fast Charger for every 90 Level 2 EVSE. For the purposes of this Long Range Plan, we are assuming EVSE location not the number of ports per EVSE. Vendors vary as to the number of ports per DC Fast Charger, currently either one or two.

Target allocations for DC Fast Chargers are shown on Table 5-1 below. The quantities of DC Fast Chargers are projected to be deployed as shown in Table 5-1. The NRG eVgo project includes 50 DC Fast Charge locations. Figure 5-1 shows their general locations. The average distance varies between stations and is less than 25 miles in many instances. The locations were sited at intersections of state and federal highways, as well as those leading to major residential population concentrations. Included are the most highly-traveled secondary highways in the Houston area.

**Table 5-1 DC Fast Charger Projections for Greater Houston Area**

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Annual Installations	50	30	30	40	60	70	90	110	130	140
Cumulative Locations	50	80	110	150	210	280	370	480	610	750



Figure 5-1 DC Fast Charger in Transportation Corridors

## 6 Results – Quarter Mile Radius Maps

### 6.1 Level 2 EVSE Densities

The Long Range Plan estimated appropriate densities of EVSE in the metropolitan regions based on destinations where EV owners will spend 45 minutes to three hours. Data fields for the Greater Houston Area study area considered dwell time, destination data on employment type, and traffic. The mapping in the Long Range Plan show areas of high, medium, and low densities of Level 2 EVSE. High densities tend to occur near:

- High-density land use, especially areas with concentrations of commercial land uses
- High-use road corridors that provide access to adjacent businesses
- Freeway interchanges that have access to adjacent properties

Figures 6-1 to 6-6 illustrate the best places to distribute EVSE within the Houston EV Project boundary area. The maps identify typical densities of Level 2 EVSE expected by 2020. These densities are expected to “blanket” the area providing geographic coverage as well as higher densities of EVSE where the venues described in Section 4.1 exist. The locations for the EVSE will likely consist of destinations such as shopping malls, parking garages, museums, etc. In addition, the North, South, and Central maps denote areas of Level 2 Density outside the downtown areas where publicly available EVSE will be available in densities commensurate with the sale of EVs.



Figure 6-1 Greater Houston Area Level 2 Density - Downtown

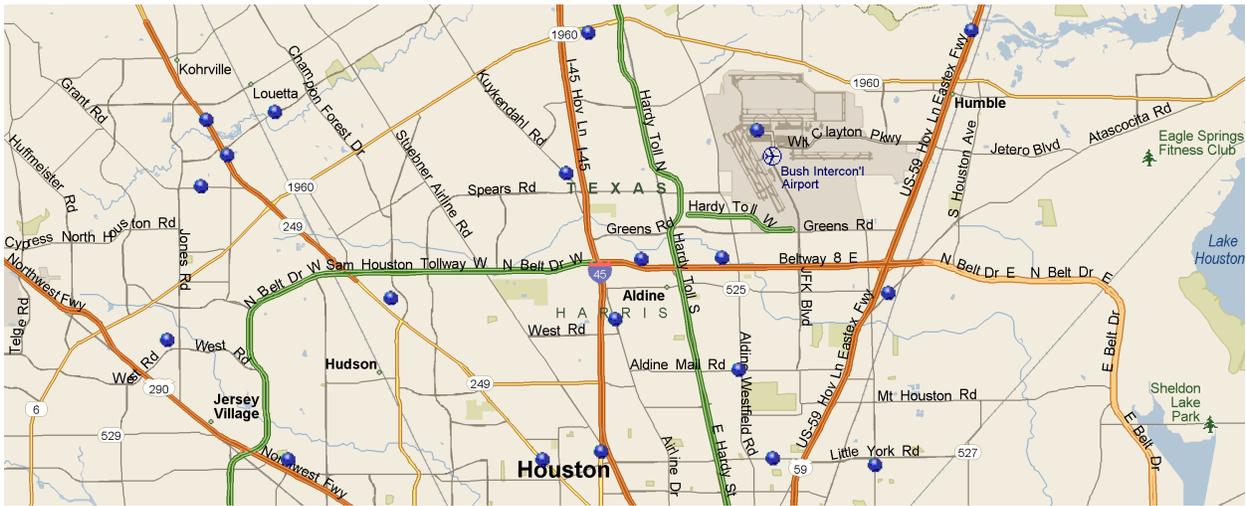


Figure 6-2 Greater Houston Area Level 2 Location Density - North



Figure 6-3 Greater Houston Area Level 2 Location Density - Central



Figure 6-4 Greater Houston Area Level 2 Location Density – South



**Figure 6-5 Greater Houston Area Level 2 Location Density – Southeast**



**Figure 6-6 Greater Houston Area Level 2 Location Density – Southwest**

Here are the ¼ radius compared to percent of people with Bachelor's Degree or greater and greater Houston traffic volumes.

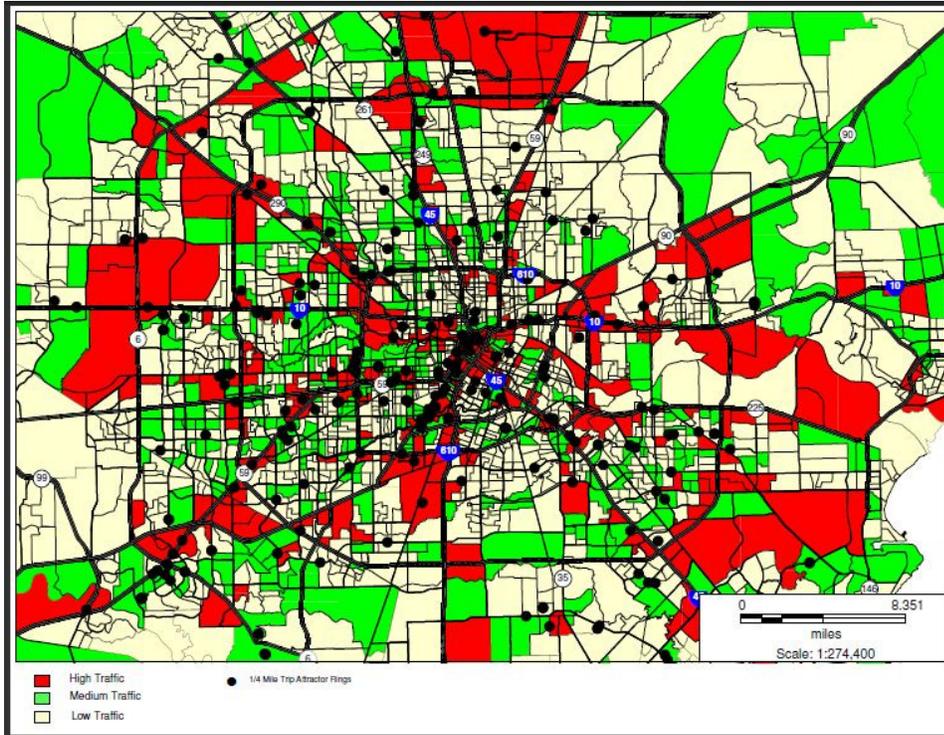


Figure 6-7 Greater Houston Area L2 Location Density compared to High, Medium and Low Traffic Flows

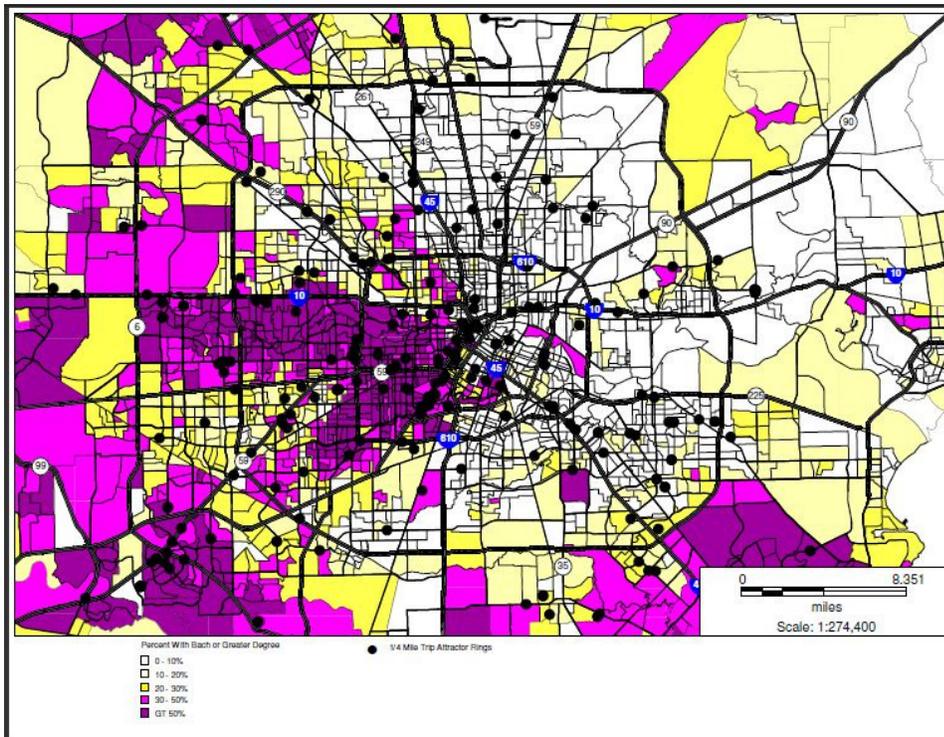


Figure 6-8 Greater Houston Area L2 Location Density compared to Bachelor Degrees and above

## 7 Summary & Conclusions

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As we complete the last document in the EV Project Community Plan, the Micro-Climate Plan, we find that The Houston area is positioned to welcome the newest types of vehicles to reach the market – electric powered passenger cars and trucks – electric vehicles (EVs). Two major manufacturers (Nissan and GM) already have cars in the Houston area which can be ordered from dealers. More vehicles are on the way this year, and the Houston area is in planning, developing, and constructing the vehicle charging infrastructure. This Micro-Climate Plan looked forward at the near term as the Long Range Plan projected the next ten years for ensuring that an effective, well-deployed charging infrastructure is in place.

Planning for the arrival of EVs in Houston began in earnest 2009, and gained speed and participants as it became clear that vehicles could start arriving as early as late 2010. The Houston EV Project Community Plan process completed the EV Charging Infrastructure Deployment Guidelines in December 2010 to organize and drive the preparations for the introduction of the Nissan LEAF, Chevy Volt, and Ford Focus into the Houston market. The City of Houston organized a planning group of several key participants in the community including utilities, energy companies, and other organizations to participate in this planning process.

The Long Range Planning process was an important step for ensuring that the Houston area has a readily available and accessible EVSE infrastructure that will support a strong EV market. The next step, this EV Micro-Climate Plan, hopefully has helped to clarify short-term actions that will achieve the long-term goals.

**Range of Travel:** A key issue for having a well-deployed, readily available charging infrastructure is related to the EVs' range of travel. EVs, particularly all electric or battery electric vehicles (BEVs), have travel ranges that are significantly less than conventional gasoline vehicles. The Micro-Climate Plan examined U.S. and Houston travel data to confirm that most day-to-day travel is well within the EV range, and that most early buyers will have other vehicles available to them for longer trips. Further, it was confirmed that most household vehicle trips are shorter, non-commuting trips that could be achieved without concern about range of travel. Regardless of such data, this concern will remain a consideration for most potential vehicle buyers until there is greater familiarity and experience. The experience of home charging and the accessibility of publicly-available charging will help reduce this concern, but the quality of the charging infrastructure will eliminate it for the most part.

**EV Market Projections:** The Long Range Plan analyzed and projected the number of EVs that are expected to enter the Houston market by 2020. This analysis also provides a key indicator of what the charging needs will be in the Houston area. Several independent organizations have prepared U.S. projections of the electric vehicle market, which provided guidance for the Houston area projections. As might be expected, the national projections varied widely, and a mid-range, conservative market share was adopted for Plan projections.

The Houston area has millions of vehicles and each year another 200,000 to 300,000 new vehicles are purchased. By 2020, market projections suggest that Houston area EV purchases could total 20,000 vehicles with a cumulative total of almost 75,000 EVs. While this will be a very small fraction of the millions of vehicles, they represent a significant step for fuel efficiency, clean air, cost savings, and Texas' energy future.

**Vehicle Charging Needs:** EVs can be charged with various types of equipment, with the primary one expected to be a Level 2 EVSE. A depleted battery system can be recharged overnight with Level 2 EVSE. Most day-to-day charging will occur overnight with partially depleted batteries, more similar to cell

phone or laptop charging. However, there are other types of charging that are essential for an EV charging system, not one based entirely on home charging. In fact, some vehicle owners may not have home charging as an option (for example, in multi-family townhomes or apartments).

The Long Range Plan included five types of charging EVSEs:

- Home-based, single-family residential
- Multi-family residential
- Workplace charging
- Publicly-available charging
- DC Fast Charge

The latter two are particularly important plan recommendations in that they directly address concerns about non-home charging. Publicly-available charging (similar to current refueling locations) includes the availability and accessibility of charging distributed throughout the Houston area. The Plan suggests that this type of charging be available within one mile of every place in the Houston area, which amounts to roughly 400 charging locations. Each location would have one or more plugs (ports). Typically public charging would be Level 2 EVSE at locations where an EV would be charged for 45 minutes to three hours or more. Over time and as the number of EVs grows, the number of charging locations would increase to 1,000 or more. DC Fast Chargers, another publicly available form of charging, are capable of recharging a depleted battery system in less than 15 minutes. These chargers are planned to be more widely distributed across the Houston area. At present, 50 Fast Chargers are planned for implementation in 2011 and 2012 with more than 700 projected by 2020.<sup>12</sup>

The success of electric vehicles will depend on a number of variables, including a robust charging infrastructure, consumer education, and supportive public policies and investment. There are actions that federal, state, and local jurisdictions may consider over the next ten years to assist in the promotion of EVs and EVSE. This list is a starting point for consideration with some activities already underway and others under consideration.

## Federal Policies

There are several federal policies and programs that are supportive of EV and EVSE development in the U.S., including an existing federal tax incentive for both EVs and EVSE.

**Vehicle Tax Credit:** The one most frequently mentioned is the Federal tax credit which provides a credit of up to \$7,500 for the purchase of EVs. The credit amount varies based on the vehicle's battery capacity. Detailed information on the tax credit is available on the U.S. Department of Energy's website at the following location: <http://www.afdc.energy.gov/afdc/laws/law/US/409>. The credit is referred to as the "Qualified Plug-In Electric Drive Motor Vehicle Tax Credit". The tax credit is provided to vehicles that meet the following requirements:

- Manufactured as an electric vehicle rather than converted
- Qualified as a motor vehicle as specified in Title II of the Clean Air Act
- Gross vehicle weight rating (GVWR) of not more than 14,000 lbs.
- Propelled to a significant extent by an electric motor drawing electricity from a battery which meets the following definition:
  - Battery capacity of not less than 4 kilowatt hours and
  - Capable of being recharged from an external electricity source
- Must be a new vehicle – vehicle use commences with the taxpayer

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<sup>12</sup> NRG Energy created eVO Energy to plan and implement charging stations throughout the Houston area. These stations form the Freedom Network and will provide Level 2 and DC Fast Charging at many locations.

- Vehicle is acquired for use or lease by a taxpayer, not for resale; credit is only available to the original purchaser of the new, qualifying vehicle. If leased to a consumer, the leasing company can claim the credit.
- Vehicle must be used primarily in the United States
- Vehicle must be placed in service during or after the 2010 calendar year

Existing production vehicles that qualify for the full tax credit include the Nissan LEAF, Chevy Volt, Wheego LiFe, CODA Sedan, and Tesla Motor's Roadster.

The Federal vehicle tax credit is scheduled to be phased out during 2011 based on a specified volume of vehicles sold by manufacturers. The credit applies to new EVs and PHEVs purchased after December 31, 2009 and before December 31, 2011. The guidelines listed in the LONG RANGE PLAN reflect the current state of the tax credit. Though the infrastructure credit has been granted an extension, the full amount of the vehicle credit will be diminished after the manufacturer has sold at least 200,000 vehicles. Bills have been introduced in Congress to increase the number of vehicles.

**Residential EVSE Tax Credit:** A tax credit is also available for the purchase of EVSE for installation at residence and commercial properties. The Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010 extends a tax credit for residential EVSE up to \$1,000, but no more than 30% of the total cost (to claim the maximum amount, the total EVSE cost would be \$3,333). In 2010, the tax credit was no more than 50% of the total cost.

**Commercial EVSE Tax Credit:** The Federal Alternative Fuel Infrastructure Tax Credit is available for costs of EVSE placed into service after December 31, 2005 and before December 31, 2011. The credit amount is currently up to 30% for equipment placed in service in 2011, with a credit up to \$30,000. Fueling station owners with multiple sites can claim credits for each location. Unused credits that qualify under general business tax credits can be carried back one year and carried forward 20 years.

**Requirements for Federal Vehicle Fleets:** The Energy Policy Act (EPAct) of 1992 requires that 75% of new light-duty vehicles acquired by many federal fleets must be alternative fuel vehicles (AFVs), including electric and plug-in electric vehicles. Furthermore, federal fleets are required to meet greenhouse gas reduction goals in federal fleets of more than 20 vehicles.

**Requirements for State Vehicle Fleets:** The Energy Policy Act (EPAct) of 1992 also requires State fleets to acquire alternative fuel vehicles, including plug-in electrics.<sup>13</sup> The stated purpose of EPAct is to reduce the nation's reliance on imported oil.

## State and Local EV/EVSE Initiatives

There are many options that should be considered at state and local levels that will help achieve successful EV deployment in Houston and statewide. The availability of these options will further efforts for clean air, lower fuel costs, reduce impacts of volatile fuel prices, and reduced reliance on imported sources of petroleum. For Houston, reduced fuel costs for residents and businesses provide money for households and consumers that will be spent in the local economy and for local jobs.

### State Initiatives

- Continue to provide incentives for EVs and EVSE to accomplish clean air and clean energy goals
- Promote State utility policies that support EV charging infrastructure
- Incorporate electric vehicles into state fleet programs
- Incorporate EVSE into state energy and other regulations that affect buildings and development

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<sup>13</sup> Texas has redefined this requirement to apply to "clean" vehicles rather than alternative fuel vehicles.

- Support and deploy permit inspector training for EVSE programs
- Assist cities and regions in conducting consumer outreach efforts for EV/EVSE deployment
- Ensure that building code is as seamless and efficient as possible for basic EVSE installations and EVSE smart-charging standards
- Work with utilities and EVSE providers to integrate EVs into the grid
- Provide leadership to develop electric vehicle fast charging corridors on state highways
- Encourage efforts to bundle EVSE with home solar or home area networks
- Continue state provision of grants for development of EV infrastructure projects and programs as part of air quality and energy efficiency programs

### Local Initiatives

- Update planning and zoning to incorporate electric vehicle infrastructure standards for public use, in new residential construction, and in commercial construction developments, as well as development incentives for retrofitting existing infrastructure
- Work with the local electric utilities in area planning to identify needs for transformer enhancement at utility neighborhood substations
- Incorporate electric transportation as part of regional and municipal transportation planning efforts
- Encourage the inclusion of EVs and associated infrastructure in neighborhood and community planning, such as livable cities, community development programs, corridor improvement plans, and regional sustainable community planning
- Identify and train permit/code workforce on projects that incorporate EVSE; establish an expedited design review process for development and construction projects that include EVSE
- Support development of a residential EV/EVSE assessment program in cooperation with the local utility and the EVSE provider
- Develop an online expedited EVSE permitting and inspection process in cooperation with the local utility and EVSE provider
- Identify local capital improvement program funds or other funds that might be used to support more complex EVSE installations and panel upgrades.
- Develop community outreach and education efforts for residential and commercial EVSE residential and commercial installation
- Include electric vehicle infrastructure in local sustainable construction/green building incentive programs.