**FAIRFAX COUNTY PLANNING COMMISSION**
**ENVIRONMENT COMMITTEE**
**THURSDAY, MAY 2, 2013**

PRESENT: Frank A. de la Fe, Hunter Mill District
Jay P. Donahue, Dranesville District
James R. Hart, At-Large, Chairman
Janyce N. Hedetniemi, At-Large
Kenneth A. Lawrence, Providence District
Timothy J. Sargeant, At-Large

ABSENT: Ellen J. Hurley, Braddock District

OTHERS: Earl L. Flanagan, Mount Vernon District
Lorrie Kirst, Zoning Administration Division (ZAD), Department of Planning and Zoning (DPZ)
Andrew Hushour, ZAD, DPZ
Noel H. Kaplan, Senior Environmental Planner, Environment and Development Review Branch, Planning Division, DPZ
Michelle Stalhut, Planning Division, DPZ
William Marsh, Tysons Coordinator, Department of Public Works and Environmental Services (DPWES)
Lisa Feibelman, Zoning Evaluation Division, DPZ
Ellen N. Eggerton, Green Building Ombudsman, Land Development Services (LDS), DPWES
Barbara Lippa, Executive Director, Planning Commission Office
Kara A. DeArrastia, Clerk to the Planning Commission
Stephen Schey, Director, Infrastructure Planning and Analysis, ECOtality, Inc.
Matthew Olson, The MITRE Corporation
Flint Webb, Environment Chairman, Fairfax Federation

ATTACHMENTS:

A. ECOtality: The EV Project
B. The MITRE Corporation: Electric Vehicle Charging Infrastructure Recommendations to Fairfax County

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Chairman James R. Hart called the meeting to order at 7:02 p.m., in the Board Conference Room, 12000 Government Center Parkway, Fairfax, Virginia 22035.

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Noel Kaplan, Senior Environmental Planner, Environmental Design Review Board, Planning Division (PD), Department of Planning and Zoning (DPZ), introduced Stephen Schey, Director, Infrastructure Planning and Analysis, ECOtality, Inc.

Mr. Schey delivered a PowerPoint presentation from ECOtality regarding the EV Project. He explained that ECOtality had been involved in EV initiatives since 1989 and installed the majority of on-road charging systems throughout the country, adding that the company was also the primary contractor to the Department of Energy (DOE) in the EV sector. He also noted that ECOtality provided products for on-road and at-home EV charging as well as commercial and industrial support products. He said that while the company did not deal with Level 1 charging outlets for single family garages, it provided the Level 2 wall-mounted units that were appropriate for commercial and multi-family residential parking lots and garages. He added that the DC Fast Charger was one of ECOtality's products and briefly described its charging capabilities.

Commissioner Hedetniemi referenced Slide Number 4 and asked about the DC Fast Charge unit. Mr. Schey explained that it was a free-standing unit that stood taller than a standard gas pump and described its features. When Commissioner Hedetniemi asked about its charging capability, Mr. Schey said that it contained two charge points.

Mr. Schey described the EV Project, which began in 2009, funded by the DOE and ECOtality and its partners. He stated that the goal of the Project was to provide charging stations to encourage EV adoption, the premise being to look at communities where both could be done. He added that the Project provided public infrastructure for the Nissan LEAF and Chevrolet Volt to test their use as part of the learning process. He pointed out that 13,000 AC Level 2 units would be delivered nationwide. He added that, of the 13,000 units, 8,000 were residential, pointing out that the residential component of the Project had been completed. He added that the installation of 5,000 public units was near completion and said that the Project would also include 200 DC Fast Chargers. He added that the Project was scheduled for completion at the end of 2013. Mr. Schey described the EV Project planning and deployment process, beginning with five major areas across the country and recruiting stakeholders to help plan the deployment of the Project and publish findings and lessons learned. He said that since its inception, seven metropolitan areas, including Washington, DC, had been included in the Project, thereby providing a broader study group for marketing, development, and comparison. He also explained the planning process, which would include development of deployment guidelines and long-range planning, in addition to short-term micro-climate plans to be implemented in each area. Mr. Schey noted that the plan included projections to 2020 regarding density of vehicle ownership and use and charging station locations.

Referencing Slide Number 8, Mr. Kaplan asked if the EV Micro-Climate plan showed EV ownership or charging station locations. Mr. Schey said that it reflected both. In addition, he pointed out that land use and traffic patterns would determine the infrastructure rather than placing the chargers first and then building around them.

Mr. Schey explained that the planning stage of the Project was complete and the target for 8,000 residential EV owners had been met. He added that 3,600 public AC Level 2 units had been installed and another 1,400 were under contract for installation, with a further 76 DC Fast Chargers due by September 2013.

Commissioner Sargeant asked how long charging on a DC Fast Charge would take. Mr. Schey said a typical charge would last approximately 20 minutes, compared to 3 or 4 hours on an AC Level 2 charger.

Commissioner Lawrence asked if there were issues with charging in extreme heat. Mr. Schey explained that charging could be problematic if the battery was already hot.

When Chairman Hart asked about the maintenance and breakdown of the charging units, Mr. Schey explained that maintenance was minimal. He noted that each area had its own network of trained contractors who could respond quickly to repair any down chargers. He further noted that the anticipated lifespan of the units was approximately ten years. Chairman Hart then asked about the turn-around for service calls. Mr. Schey said that repairs would be done within hours, adding that most repairs consisted of replacing parts rather than repairing them.

Commissioner Donahue asked about locating the charging facilities. Mr. Schey said that studies were ongoing and that information had recently been posted on customer preferences. Commissioner Donahue questioned the feasibility of placing units along roadways like Route 7 towards Tysons Corner. Mr. Schey reiterated that studies were ongoing, adding that public infrastructure also played a large part in the planning process for areas like Tysons Corner.

Commissioner Flanagan noted that a high percentage of the county's citizens owned a single-family detached home and asked if ECOtality planned to locate any of its units in the parking lots for big box home improvement stores. Mr. Schey said that ECOtality was in talks with the larger retailers, adding that it would not be economically feasible at the moment, since their Blink™ charging units contained smart equipment that tracked customer vehicle information the energy usage for each charging unit.

Mr. Schey described the planning process for the Washington, DC area and noted that 340 residential charging units had been installed as well as 39 public AC Level 2 units. He discussed the current local participation in the Project and explained processes for gathering data on EV usage and driving behaviors to determine charge unit utilization and ideal locations. He added that information regarding lessons learned was available on the EV Project website. He talked about residential and commercial charging units and their energy output and briefly explained the impacts on both the EV owners and utility companies. Mr. Schey added that programming the electric vehicle supply equipment (EVSE) had helped to resolve issues related to higher utility fees and pointed out that ECOtality recommended basing vehicle charging fees on the amount of time spent charging rather than the amount of energy used. In addition, he noted that utility companies were beginning to recognize the importance of smart equipment for data compilation and feedback. He further added that a smart phone app was available to notify customers if their vehicle was disconnected from a charger.

There was a brief discussion between Commissioner Sargeant and Mr. Schey regarding EV battery performance in cold weather conditions.

Mr. Schey responded to questions from Commissioner Flanagan, Chairman Hart, and Mr. Kaplan regarding the boundaries and extended limits of the vehicles depicted on Slide Number 16, entitled *Leaf Trip End Points: Average 50+ Miles Per Day.*

Commissioner Lawrence asked if current smart feature data were being used to project future EV and charger usage. Mr. Schey confirmed that current usage was one of the best measurements for deciding placement of charging facilities. When Commissioner Lawrence asked what the difference in cost was between a basic and smart charger, Mr. Schey stated that the smart chargers ranged from $2,000 to $3,000 for home and public units, as opposed to $600 for a "dumb" unit that could be installed in a home.

Mr. Schey responded to an additional question from Commissioner Hedetniemi on Slide Number 16, and several questions from Commissioner Flanagan and Chairman Hart regarding the boundaries and extended limits of the vehicles shown on Slide Number 17, Volt, entitled All Trip End Points. He added that the information and analyses on the LEAF and Volt were available on the EV Project website.

Commissioner Sargeant noted that drivers commuted to the Washington metropolitan area from as far away as Richmond and suggested that Mr. Schey look beyond the borders depicted in Slide Numbers 16 and 17 and expand its view of commuters to the area.

Mr. Schey briefly described the user charging data and the costs involved, including permit fees for EVSE installation, adding that the fees varied greatly from city to city.

When Commissioner Sargeant asked if the data were reflective of energy usage for both vehicles, Mr. Schey confirmed that they were. Commissioner Sargeant pointed out that he programmed his EVSE to charge during certain hours to avoid higher utility fees. Mr. Schey replied that many other owners did the same in other parts of the country where fee differentials existed.

Mr. Schey answered questions from Commissioner Flanagan about EVSE programming and confirmed that other jurisdictions were interested in EV use. He noted, however, that the National Institute of Building Sciences was not one of the agencies included in the EV Project, but would likely be interested in the results from its analyses.

Commissioner Sargeant asked if there was any discussion regarding load shedding during peak use periods. Mr. Schey confirmed there was, adding that "demand/response" alternatives were being considered to provide users the energy necessary without overloading the electrical grid.

Mr. Schey discussed the report on Electric Vehicle Charging Infrastructure Recommendations to Fairfax County submitted by the MITRE Corporation in 2011. He pointed out that the report was two years old and the data within somewhat outdated. He said that fast charging had moved from questionable use to a standard reliable and stated that it was advanced enough for auto makers to develop their own fast chargers. In addition, he noted that AC Level 1 chargers were gaining more interest for public use, particularly office buildings, and noted that pre-wiring for charging facilities during building design and construction would be important for commuters and visitors to both the business and retail entities on a site.

Commissioner Flanagan asked if EV drivers might receive preferential parking status as incentive for using an EV instead of a gasoline-fueled vehicle. Mr. Schey said that while some employers might provide better parking to EV owners, many people expressed distaste with preferential treatment towards a specific group and said that the majority of EV owners were satisfied with their current parking situations.

Mr. Schey and Commissioner Sargeant briefly discussed vehicle charging cords, charging capability, and maintenance of the chargers.

Commissioner Hedetniemi asked if projected usage information could help develop more informed recommendations regarding infrastructure construction during development. Mr. Schey noted that the information not only affected recommendations but also deployment.

Commissioner Lawrence pointed out that consideration and thought must be given to Tysons Corner, which would have a great deal of parking, much of it contained within parking podia.

Chairman Hart thanked Mr. Schey for his presentation. He then asked Committee members about upcoming meetings in July.

Mr. Kaplan said that the Committee was scheduled to receive presentations from EVGo and ChargePoint on their methods for providing EV charging, although the latter might not be available. After that, with the presentations complete, he said that he envisioned developing a set of questions that the group would need to go through to reach a policy recommendation. He said that he could provide that at the meeting on Thursday, June 20, 2013, for discussion at the first meeting in July.

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Chairman Hart announced that the Committee would next meet on the following dates at 7 p.m. in the Board Conference Room:

- Thursday, July 11, 2013 (Continued discussion on electric vehicle supply equipment) (*This meeting was subsequently canceled.*)
- Thursday, July 18, 2013 (Continued discussion on electric vehicle supply equipment)

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The meeting was adjourned at 8:15 p.m.
James R. Hart, Chairman

An audio recording of this meeting is available in the Planning Commission Office, 12000 Government Center Parkway, Suite 330, Fairfax, Virginia 22035.

Minutes by: Jeanette Nord

Approved: October 18, 2013

John W. Cooper, Clerk to the
Fairfax County Planning Commission

THE EV Project

# Fairfax County Planning Commission – Environment Committee

Stephen Schey

May 2, 2013

# Overview

- Intro to ECOtality
- The EV Project
- Lessons Learned
- Observations
- Questions

# ECOtality Corporate Overview

- Electric Transportation Engineering Corp (eTec)
  dba ECOtality North America
- Provides advanced transportation R & D, engineering & testing
- Focused on being a leading provider of EV charging systems

**EXPERIENCE**

- Involved in EV initiative since 1989
- Installed majority of on-road charging systems
- Primary Contractor to U.S. Dept. of Energy in EV sector
  - 10+ million miles of testing on 200+ advanced fuel vehicles
- Extensive battery performance testing, cycling and development
- Leading EV consultant to Utilities, OEMs and Governments

# Blink EV Charge Stations

Level 2 Residential


Level 2 Commercial


DC Fast Charger

# The EV Project

## The largest Department of Energy EV Infrastructure Program

**PROJECT MANAGER:** *ECOtality North America (eTec)*

**PROJECT SCOPE:** *Approx. 13,000 Charging Stations*

*8,000 Nissan LEAFs, GM Volts, Smart ForTwo*

**TOTAL VALUE:** ***$230 million project***

***($115m grant from US DoE, $115m ECOtality/Partner match)***

**OBJECTIVES:**

- *Plan, build and evaluate mature EV charge infrastructure*
- *Collect and analyze data on EV driving and charging*
- *Evaluate business models for public EVSE*
- *Generate lessons learned to guide policy makers, industry planners and investors*
- *Lay foundation for shift to EVs in broader market*

THE EV Project

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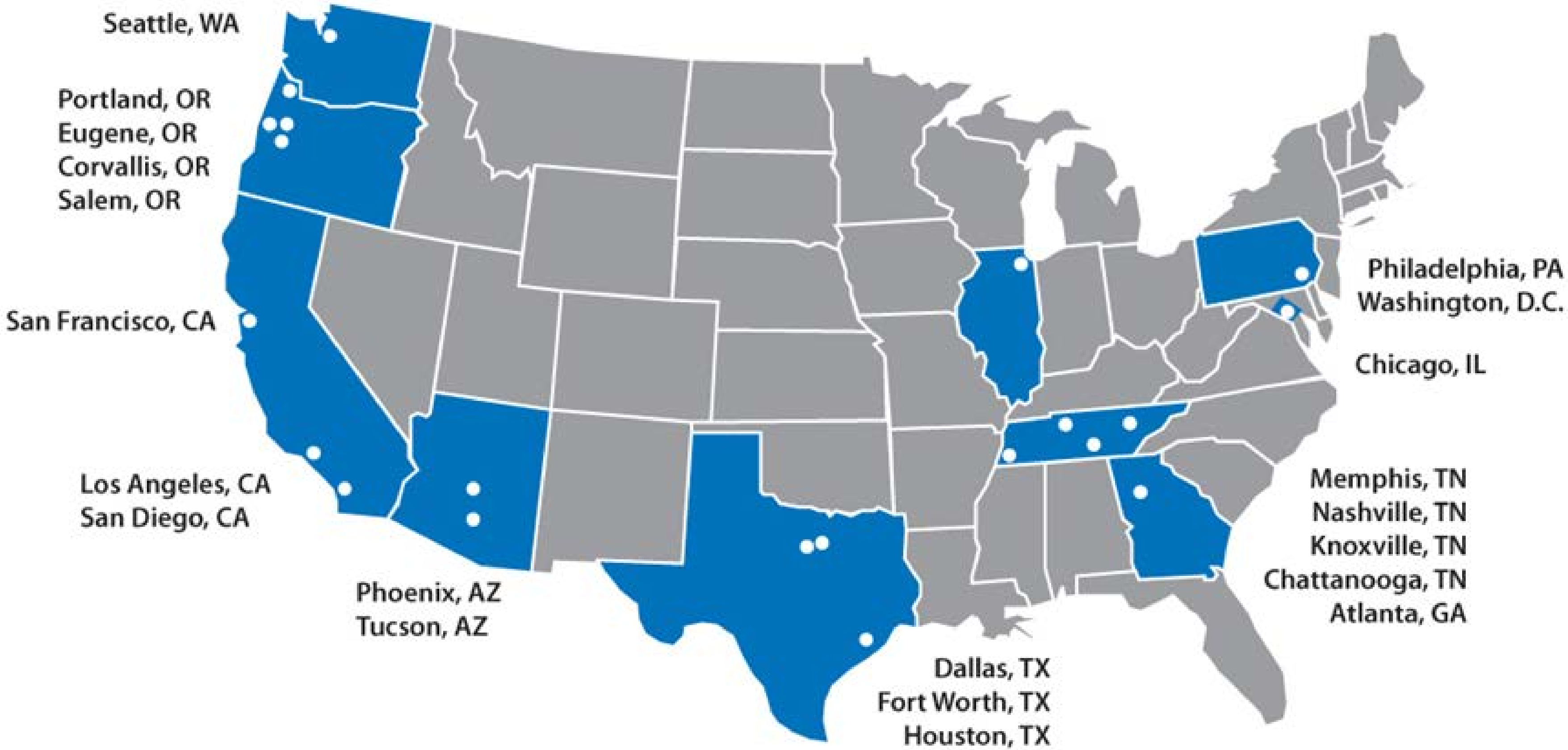
# The EV Project

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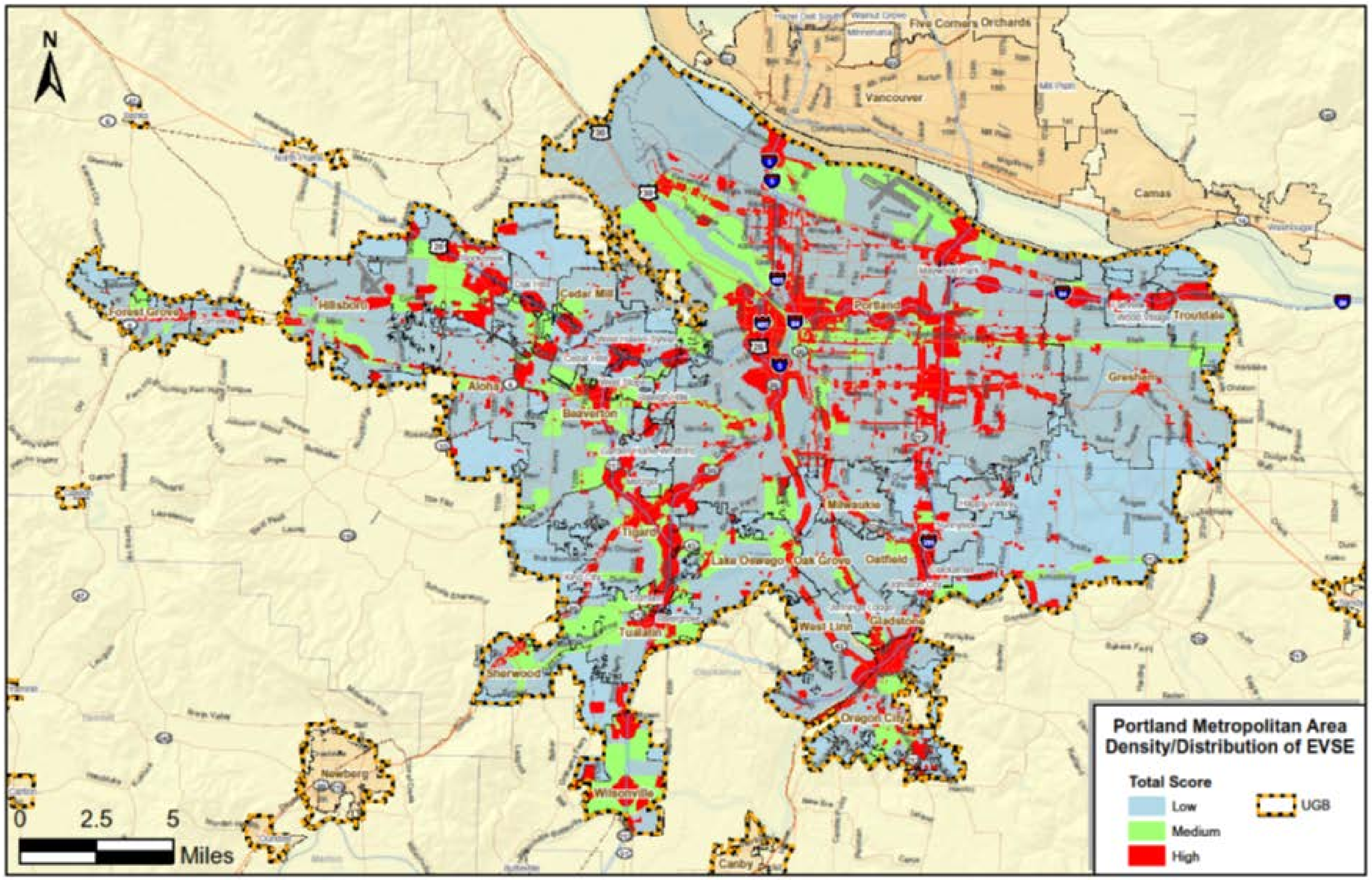
# EV Micro-Climate™

## ECOtality established program for PEV Readiness

- Organize Regional Stakeholders
  - State/Local Government
  - Utilities
  - Enthusiasts
  - Universities
  - Others
- Develop Deployment Guidelines
- Develop Long Range Plan
- Develop Short Term Micro-Climate Plan
- Build teamwork, synergy
- Prepare for PEV Deployment/Charging Infrastructure

# EV Project Planning

**EV Micro-Climate™ Long Range Plan Portland**

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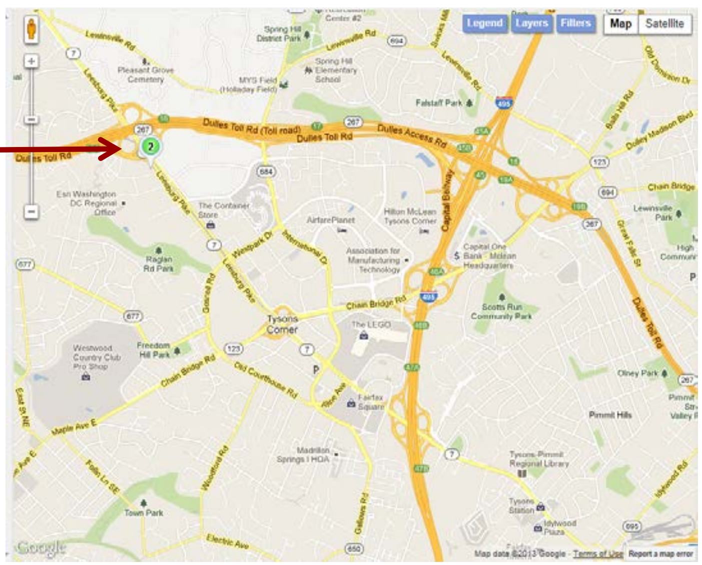
# EV Project Status

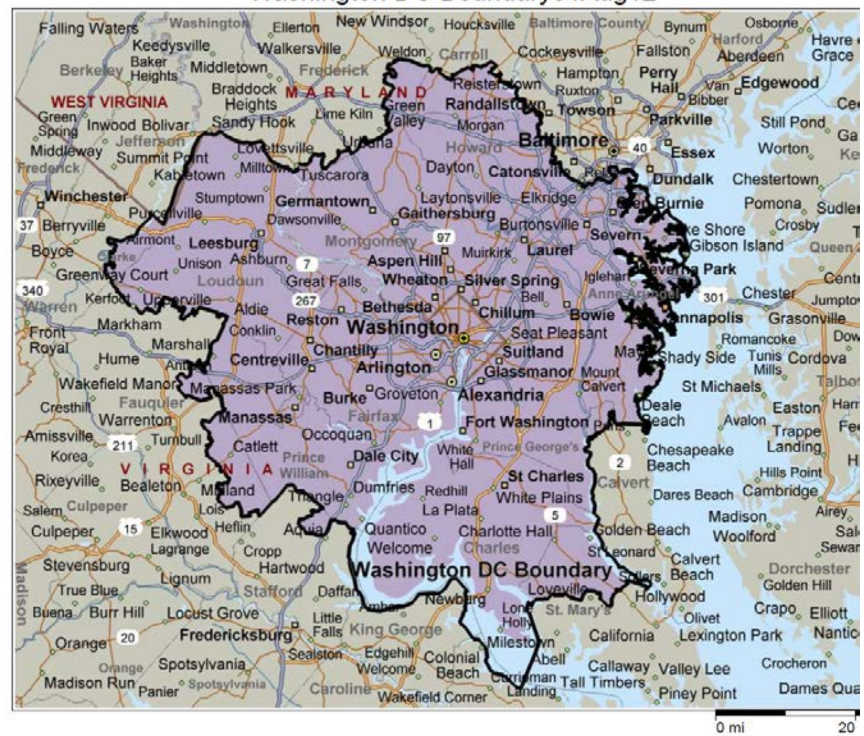
- **Planning Phase**
  - Completed in all original 5 markets
- **Installation Phase** (April 26, 2013)
  - 8,127 residential EVSE installed
  - 3,674 public AC Level 2 EVSE installed
  - 76 DC Level 2 (DC Fast Chargers) installed
  - 6,080 Nissan Leafs Enrolled
  - 2,060 Chevrolet Volts Enrolled
  - 322 Smart ForTwo Enrolled (Car Share)
- **Data Collection Phase**
  - Over 81 million vehicle miles of data
  - 2.5 million charge events recorded
  - Over 20,000 MWh energy transferred

# The EV Project

- **Washington DC Boundary**
  - 341 residential EVSE installed
  - 39 public AC Level 2 EVSE installed
  - 0 DC Level 2 (DC Fast Chargers) installed
  - 50 Nissan Leafs Delivered
  - 291 Chevrolet Volts Delivered

Sheraton Tysons Corner



# Lessons Learned / Observations

**EV Project Website**: www.theevproject.com

- Lessons Learned Reports
  - First Responder Training
  - Accessibility at Public EV Charging Locations
  - BEV Driving and Charging Behavior Observed Early in the EV Project
  - Signage
  - A first look at the Impact of EV Charging on the Electric Grid
  - DC Fast Charge – Demand Charge Reduction
  - The EV Micro-Climate Planning Process
  - Greenhouse Gas Avoidance and Fuel Cost Reduction
  - Regulatory Issues and Utility EV Rates
  - Electric Vehicle Public Charging – Time vs Energy
  - EVSE Programming

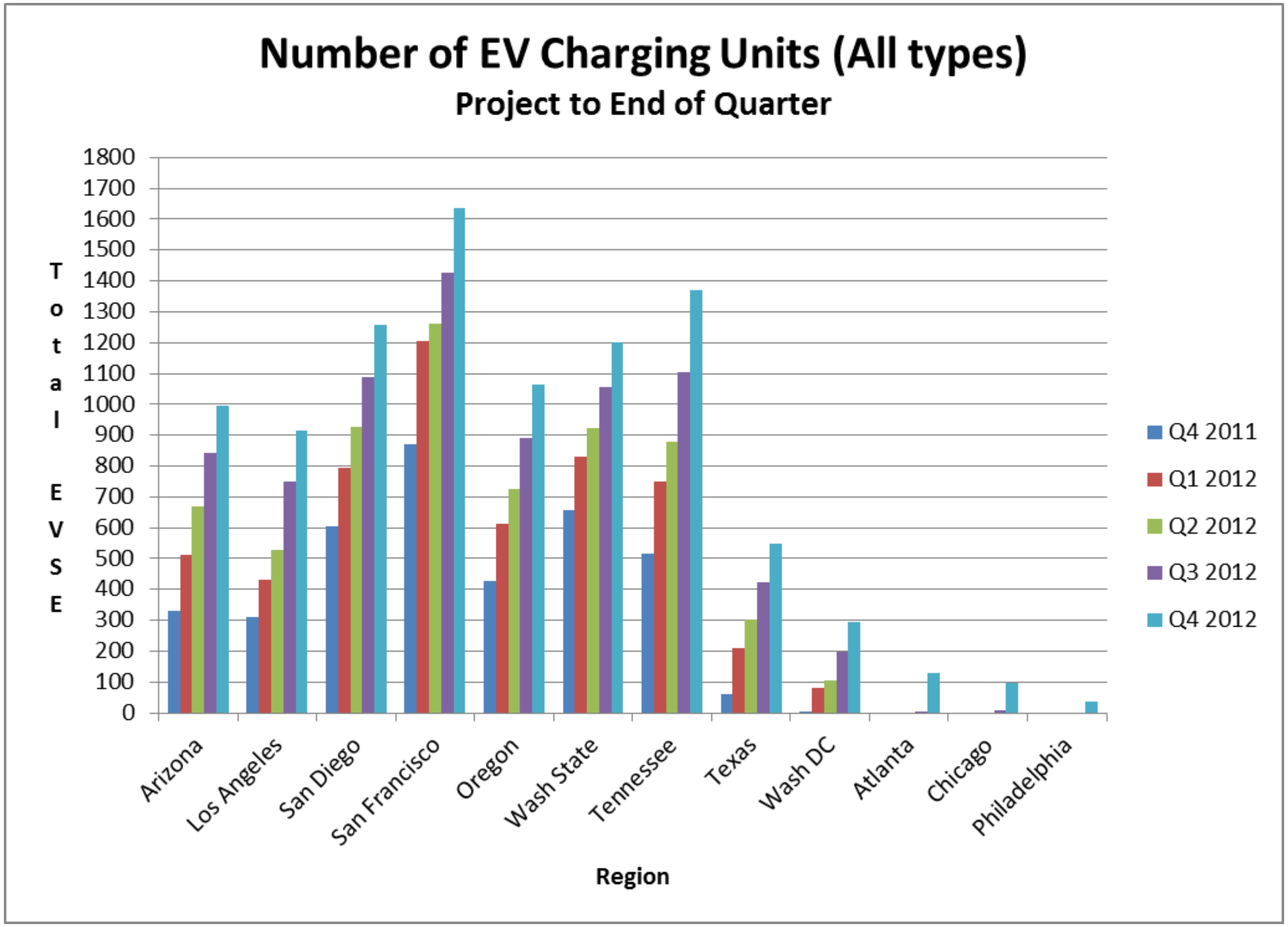
- 7 Quarterly Reports
- Deployment Guidelines
- Long Range Planning
- Micro-Climate Planning
- Presentations

# Smart Charging

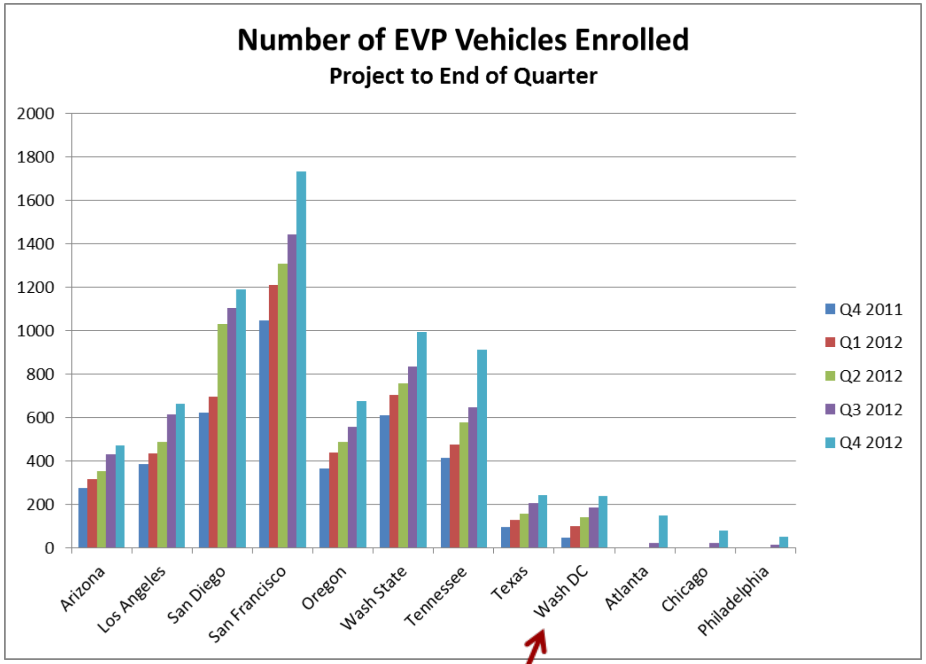
- Data Gathering
  - Internal energy and demand metering
  - Events reporting
- Communications
  - cellular
  - Wireless 802.11g
  - LAN capable
  - AMI capable
- EVSE Features
  - Interactive Touch Screen
  - Access controls
  - Revenue systems
  - Over the Air Programming
- Blink Network
  - Data Reporting
  - EVSE Control & Management
  - Utility Interfaces

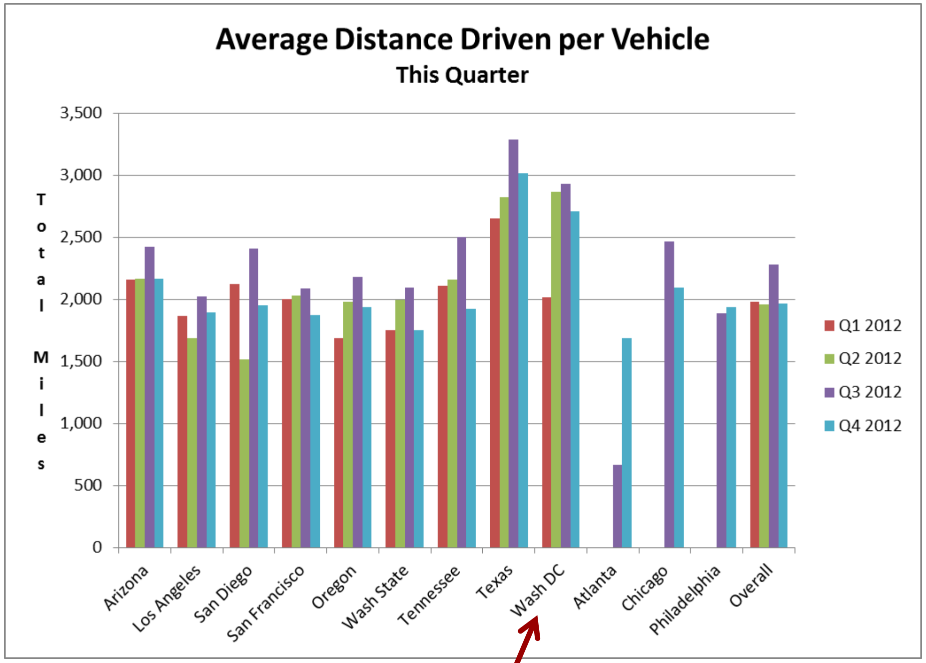

- Smartphone Apps
  - Status reporting
  - Notifications
  - Mapping

# Deployment of EVSE



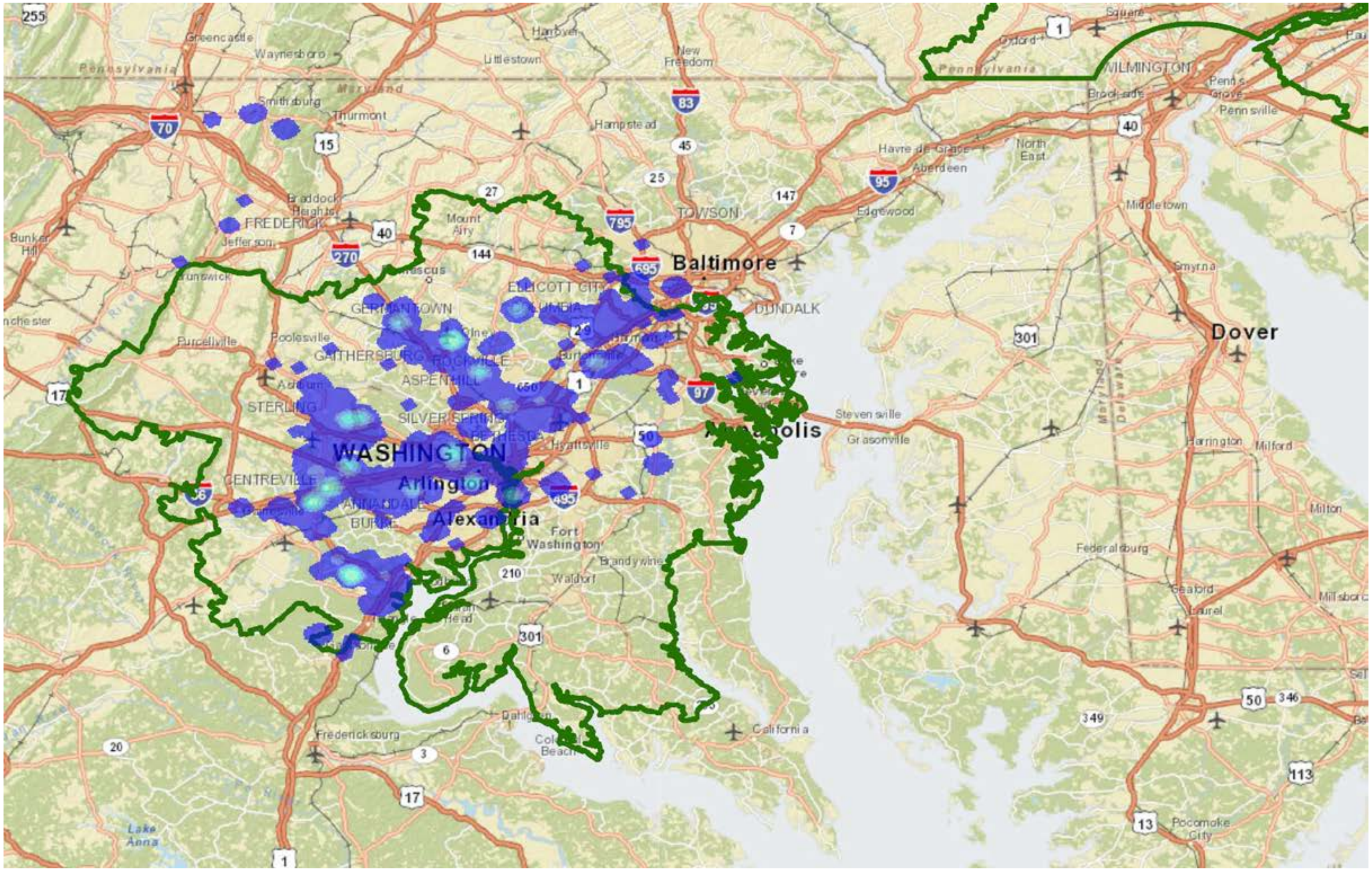
# EV Project Vehicles Enrolled



# EV Project Vehicle Observations

**Leaf All Trip End Points**

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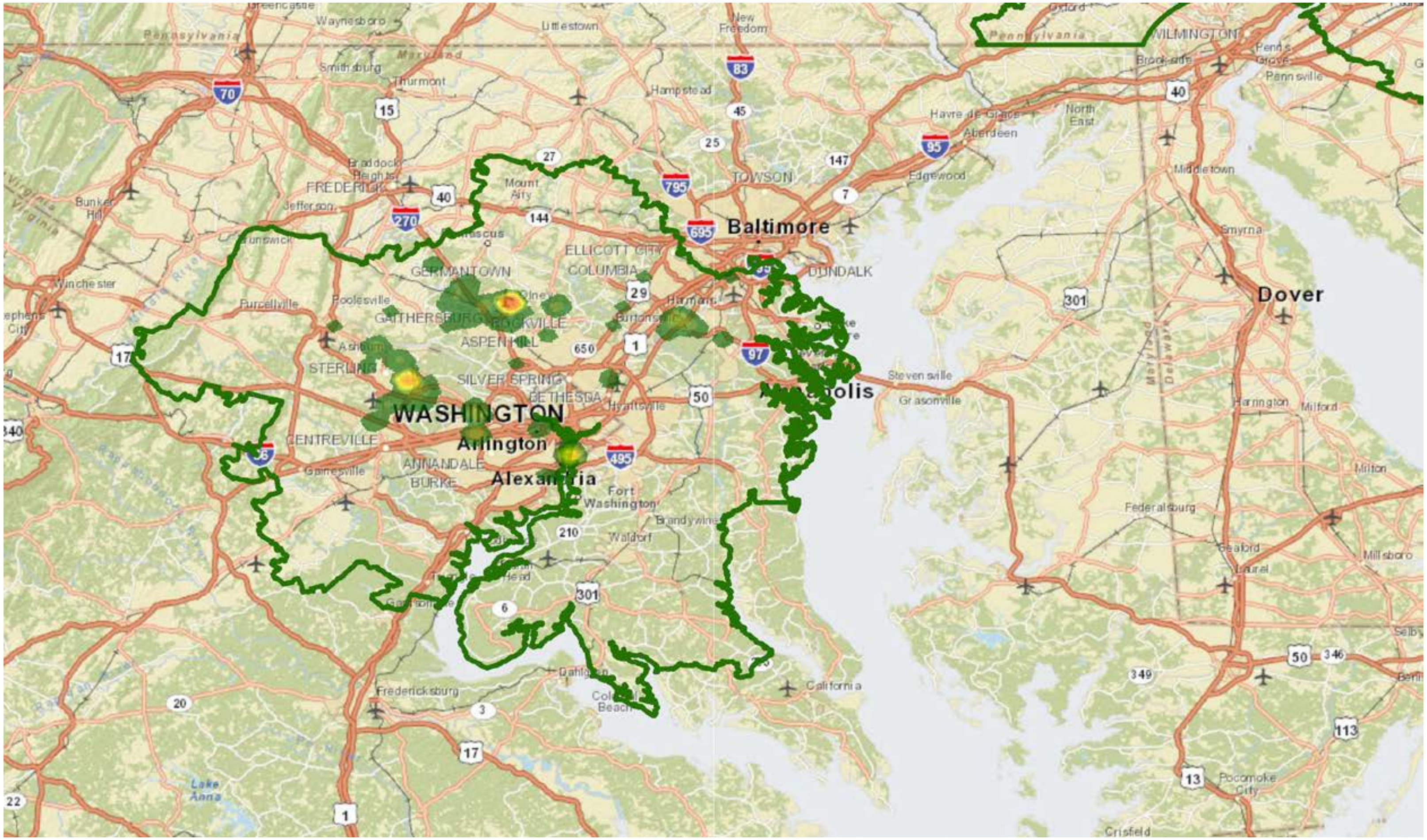
# EV Project Vehicle Observations

**Leaf Trip End Points: Avg 50+ Miles Per Day**



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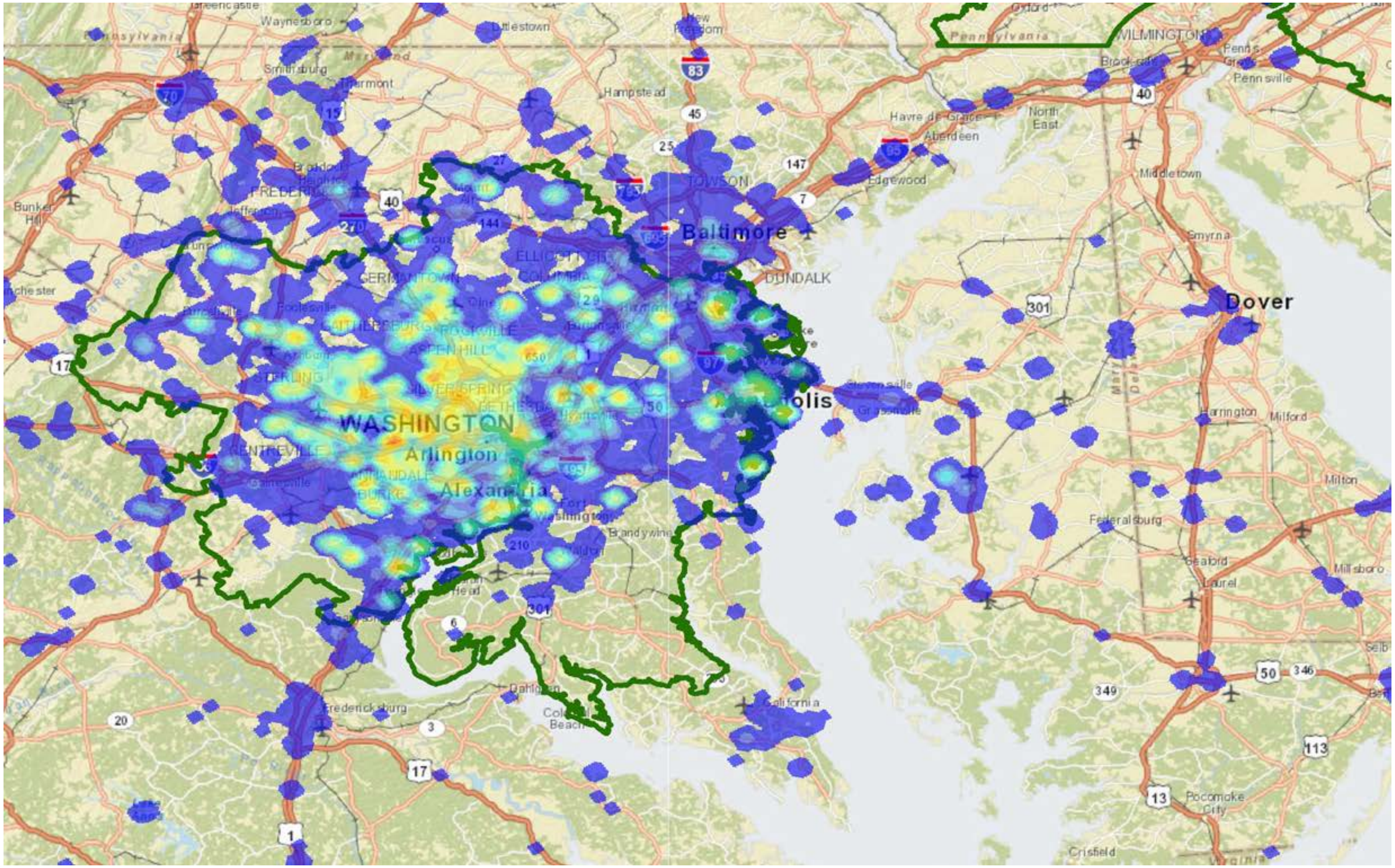
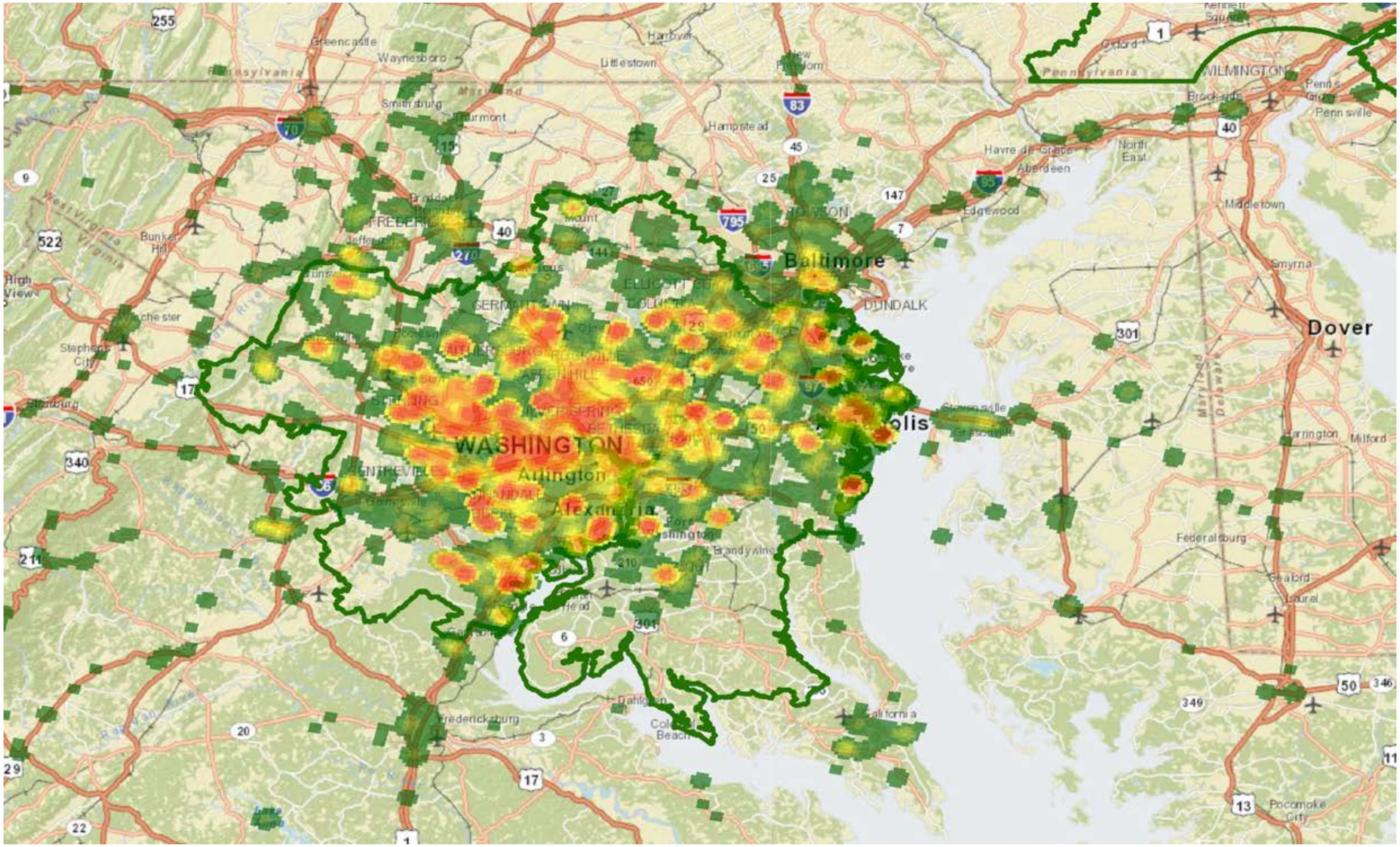
# EV Project Vehicle Observations

**Volt All Trip End Points**



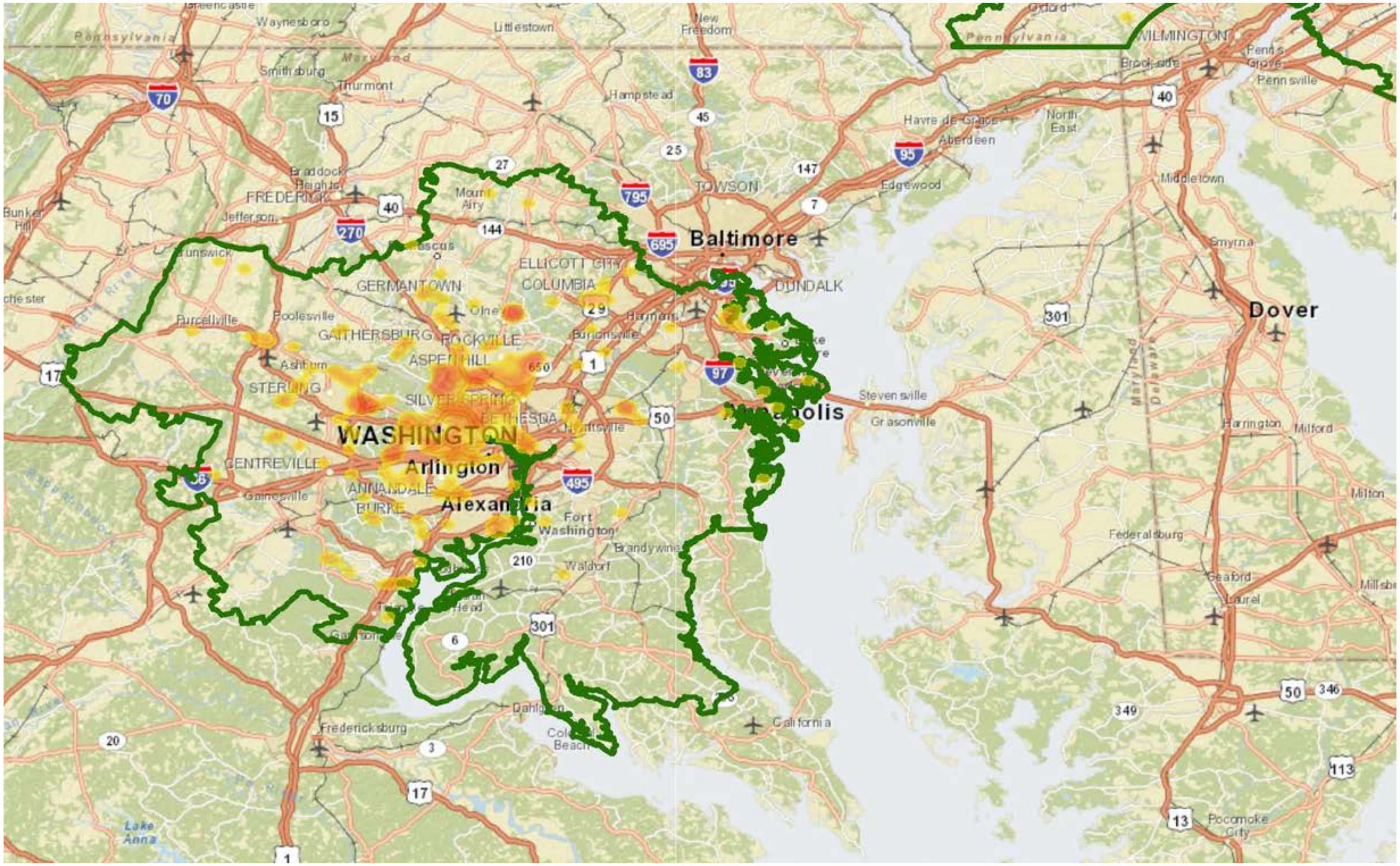
# EV Project Vehicle Observations

**Volt Trip End Points: Avg 35+ Miles Per Day**



# EV Project Vehicle Observations

**Volt Most Frequently Parked Locations**



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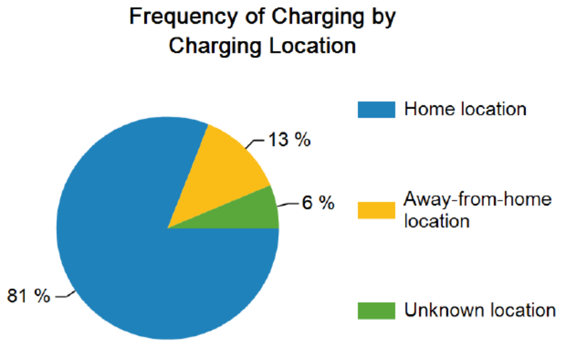
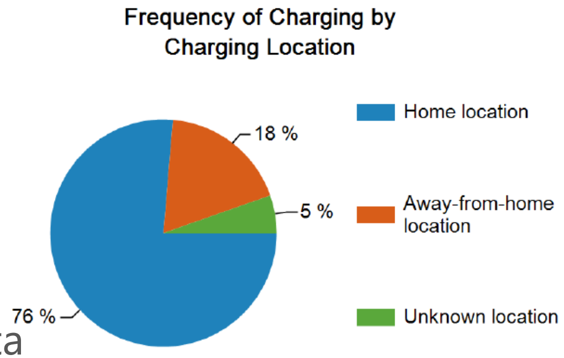
# Early Observations

- Avg distance traveled per day (mi): 40.5
- Avg trip distance (mi): 8.1
- Avg # of trips between charging: 3.5
- Avg distance between charging (mi): 28.2
- Avg # of charging events/day: 1.4

- Avg distance traveled per day (mi): 29.2
- Avg trip distance (mi): 6.9
- Avg # of trips between charging: 3.8
- Avg distance between charging (mi): 26.3
- Avg # of charging events/day: 1.1




4th Quarter 2012 Data

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# Observations – Residential Installation Cost

- Average residential installation cost ~$1,375
- Individual installations vary widely
- Some EV Project program bias to lower costs

| Marlets In Ascending Order Of Residential Installation Cost | Number of Installations | Average Installation Cost | Variation From Project Average |
|---|---|---|---|
| Tennessee (entire State) | 542 | $ 1,113.07 | -19.0% |
| Arizona (Phoenix & Tucson) | 357 | $ 1,148.88 | -16.4% |
| Washington DC | 3 | $ 1,197.44 | -12.9% |
| Oregon (Portland, Eugene, Coralvls & Salem) | 465 | $ 1,229.06 | -10.6% |
| Washington (Seattle & Olympia) | 730 | $ 1,289.56 | -6.2% |
| Maryland | 39 | $ 1,311.75 | -4.5% |
| Washington | 80 | $ 1,321.36 | -3.8% |
| Virginia | 38 | $ 1,341.01 | -2.4% |
| San Fransisco | 1254 | $ 1,386.13 | 0.9% |
| Texas (metro Houston & Dallas) | 128 | $ 1,422.77 | 3.5% |
| San Diego | 726 | $ 1,593.91 | 16.0% |
| Los Angeles | 415 | $ 1,794.64 | 30.6% |

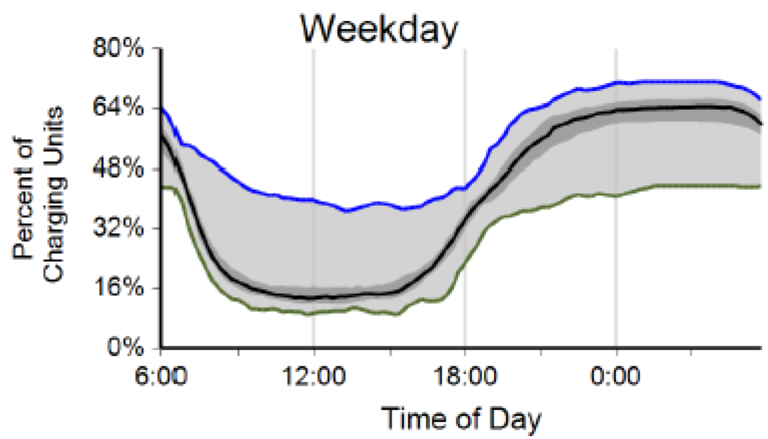
# Residential Installation – Permits

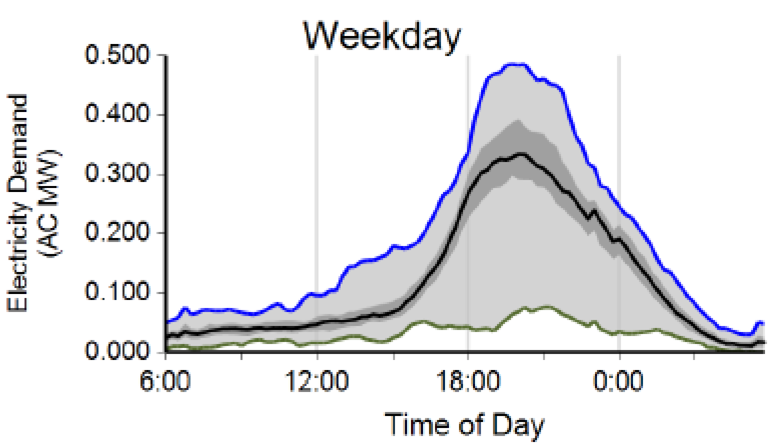
- Permit timeliness has not been a problem
- Majority are over-the-counter
- Permit fees vary significantly

| Region | Count of Permits | Average Permit Fee | Minimum Permit Fee | Maximum Permit Fee |
|---|---|---|---|---|
| Arizona | 66 | $96.11 | $26.25 | $280.80 |
| Los Angeles | 109 | $83.99 | $45.70 | $218.76 |
| San Diego | 496 | $213.30 | $12.00 | $409.23 |
| San Francisco | 401 | $147.57 | $29.00 | $500.00 |
| Tennessee | 322 | $47.15 | $7.50 | $108.00 |
| Oregon | 316 | $40.98 | $12.84 | $355.04 |
| Washington | 497 | $78.27 | $27.70 | $317.25 |

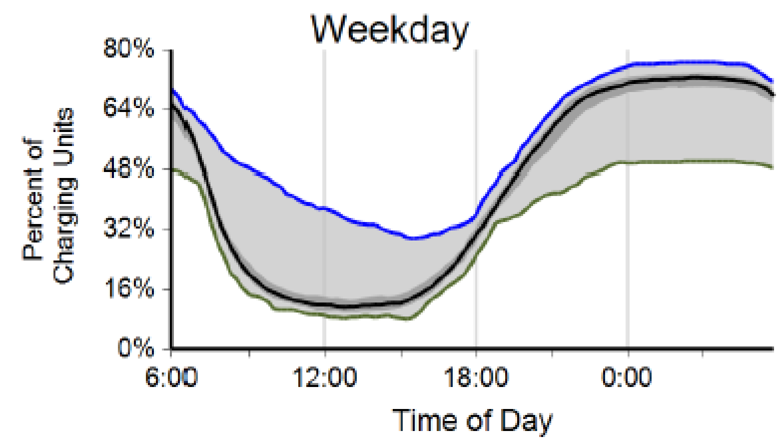
# Vehicle Residential Charging

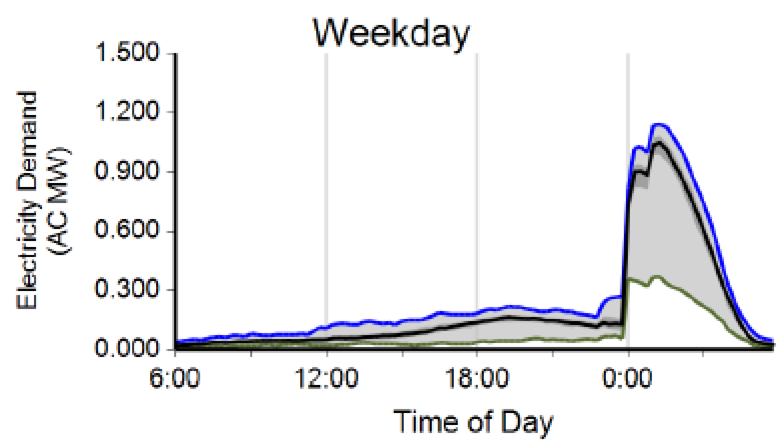
## Nashville




## San Diego (SDG&E)

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# Lessons Learned Commercial

- ADA significantly drives cost
  - Accessible charger
  - Van accessible parking
  - Accessible route to facility
  - Inconsistent application of ADA

- Permit fees and delays can be significant
  - Load studies
  - Zoning reviews


| Region | Count of Permits | Average Permit Fee | Minimum Permit Fee | Maximum Permit Fee |
|---|---|---|---|---|
| Arizona | 72 | $228 | $35 | $542 |
| Los Angeles | 17 | $195 | $67 | $650 |
| San Diego | 17 | $361 | $44 | $821 |
| Texas | 47 | $150 | $37 | $775 |
| Tennessee | 159 | $71 | $19 | $216 |
| Oregon | 102 | $112 | $14 | $291 |
| Washington | 33 | $189 | $57 | $590 |

# Thank You

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www.theEVproject.com
www.blinknetwork.com


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This material is based upon work supported by the Department of Energy under Award Number DE-EE0002194.



**www.theevproject.com**

MITRE

# Electric vehicle charging infrastructure recommendations to Fairfax County

## Task 5 of sustainability study under Proffer #9, RZ 2008-PR-011

**July 19, 2011**

**Approved for Public Release: 11-2916. Distribution Unlimited.**

# Executive Summary

Plug-in vehicles feature prominently in the vision for a livable, sustainable Tysons Corner. They promise cleaner, quieter transportation that is less dependent on the political stability of other parts of the world, but they come at the price of being a fundamentally different way of powering the automobile fleet. Charging will largely be done over long periods of time at distributed locations, rather than at particular fueling stations. As Tysons Corner evolves from a suburban office park to an urban center, the evolution to an electric automotive fleet will affect urban layout, building design, and utility services.

Fairfax County is attempting to determine the effects of widespread plug-in vehicle adoption on infrastructure requirements and to determine design approaches that can be considered through the county's zoning process to encourage appropriate investment. MITRE, in support of the County's sustainability objectives, has considered the problem under Proffer #9, RZ 2008-PR-011. This document is the result.

We present a background for plug-in vehicles, charging stations, and other estimates of plug-in vehicle market penetration. We emphasize the impossibility of a demonstrably accurate estimate of market penetration, the fact that vehicle charging will be done primarily at home, and that modifications to initial parking area construction can reduce the overall cost and risk of installing charging stations. Four primary recommendations result:

1. The County should strongly encourage developers to include the conduit infrastructure – space, conduit banks, conduit, and access points – for relatively easy and inexpensive installation of charging stations in the future. The County should encourage, but place less emphasis on the full installation of electric vehicle supply equipment (EVSE) – the transformers, switches, wiring, and charging stations themselves – at the time of initial construction given the uncertainties surrounding electric charging station demand.
2. The fraction of parking slots for which the infrastructure should be included should represent a fully plug-in fleet for the groups of users that would use charging infrastructure at the facility. This means all parking spaces for a residential building (single- or multi-family). At commercial and retail facilities, this means the fraction of vehicles that arrive from locations geographically situated to require a charge before the return trip.
3. The County can most appropriately seed charging station supply by negotiating for the installation of full charging stations at the lowest expected adoption rate in the near future. Any supply seeding is best done at apartment buildings and should be limited to a maximum of 2% of all parking spaces.
4. The County should coordinate with its peer jurisdictions to encourage charging station manufacturers to form a standard defining the connection of the charging station to the facility in which it is installed. The standard should define both the electrical connection and physical mount with the purpose of making it possible to move charging stations to a new facility relatively easily and quickly.

The objective is to prepare Tysons Corner for widespread plug-in adoption, but to do so as inexpensively as possible so as to encourage the desired population and job growth that will sustain Tysons Corner as a livable urban center.

# 1 Introduction

MITRE fully supports Fairfax County's sustainability objectives for Tysons Corner. As part of Proffer #9, RZ 2008-PR-011, we are conducting an analysis of emerging building, automotive, and energy technologies – specifically, how they may affect future Tysons Corner development and how they can best be harnessed to aid the transformation of Tysons Corner in to a sustainable, livable urban center.

This document concerns plug-in vehicles and plug-in vehicle charging infrastructure. It satisfies Task 5 of the study that MITRE is performing per the aforementioned proffer commitment. The specific components of Task 5 are:

> "Describe the following as they relate to the establishment of electric vehicle charging stations:
>
> a. Guidance regarding the anticipated future need for electric vehicle charging stations in Tysons Corner, including an estimate of the number of charging facilities that may be needed in the future and concentrations relating to broad land use categories (e.g., number of multifamily dwelling units per charging station; office and retail square footage per charging station)
>
> b. Guidance regarding impacts to infrastructure in Tysons Corner that would occur as a result of full implementation of electric vehicle charging stations in Tysons Corner per 5.a above
>
> c. A general overview (not site-specific details) of infrastructure (including voltage requirements and amperage reserves) and site design elements that would be necessary for the establishment of electric vehicle charging stations at typical redevelopment sites in Tysons Corner (including design accommodations that could be made for the possible future establishment of charging stations on sites)."

MITRE's response to this guidance is a series of building construction recommendations that would, if implemented, lower the overall cost for future installation of a full plug-in vehicle charging infrastructure. We show the course of reasoning from which they were derived. We first provide some background information to set the context of the discussion. Population and employment forecasts for Tysons Corner are referenced. We note the various types of plug-in vehicles, and we discuss multiple other studies that have attempted to estimate future plug-in vehicle market penetration. An overview of the current state of charging technology concludes the background review. From the background section, we move into the discussion of recommendations. We make explicit our underlying assumptions and then present their consequences on Tysons Corner charging infrastructure. Finally, we present specific recommendations to the County.

We have excluded from this document a discussion of the effects that plug-in vehicle adoption will have on the electrical grid in general. That analysis is best done in conjunction with the other part of the proffer study on general energy use and system level effect.

# 2 Background

## 2.1 Demographics

### 2.1.1 Fairfax County

Fairfax County currently is home to more than 1 million people and 580k jobs (Fairfax, 2011).

Figure 1 shows the Mid-Atlantic area centered in Tysons Corner. The concentric rings show driving distances (not straight-line distances) from Tysons Corner and are spaced twenty miles apart. Each ring shows estimates of both resident population and the source of commuters into Tysons Corner. The figure shows the data on a map. Table 1 summarizes the data.

Table 1: Total resident and Fairfax County commuter populations living within given distance from middle of Tysons Corner

| Driving distance from Tysons Corner | Resident population (millions) | Inbound Fairfax commuters (x100k) | Percent of inbound Fairfax commuters |
|---|---|---|---|
| < 20 miles | 3 | 367 | 67% |
| 20 – 40 miles | 5.4 | 496 | 91% |
| 40 – 60 miles | 8 | 526 | 97% |
| 60 – 80 miles | 9.1 | 539 | 99% |
| 80 – 100 miles | 10.4 | 540 | 99% |
| > 100 miles | | 545 | 100% |

Sources: Total population – US Census, 2010; Commuters – AASHTO, 2011; Driving distances – ESRI Network Analyst.

Two points should be noted about the commuter data. First, the total number of commuters in this table does not match the current 580k jobs because it is a result of statistical sampling done 2006 through 2008. We assume for the sake of this study, that even as the number of commuters increases, the geographic distribution of their homes remains constant. Also, we assume that the geographic distribution of commuters' homes is the same for Tysons as for the entirety of Fairfax. Second, the data is a total count of workers traveling within and to Fairfax County for work. There is no attempt to determine the frequency of those trips.

### 2.1.2 Plan for Tysons Corner Urban Center

Focusing more specifically on Tysons Corner itself, the 2007 Fairfax County Comprehensive Plan, with the 2010 Tysons Corner Urban Center Amendment, plans a more livable area with a sustainable integration of work, play, and home. The plan provides, "… a framework for growth beyond 2030." 17,000 people currently live in Tysons Corner, but studies upon which the amendment are based estimate 31,000 residents in 2020 and up to 86,000 by 2050. Likewise, there are currently 105k jobs in Tysons Corner. In 2020, a forecast suggests that this number may be as high as 140k and by 2050, 210k. The Comprehensive Plan for Tysons Corner indicates goals of 100,000 residents and 200,000 jobs by 2050 (George Mason, 2008).

The recommendations below are made in the context of these projections and in the context of constructing buildings that will stand for the next forty years or more.

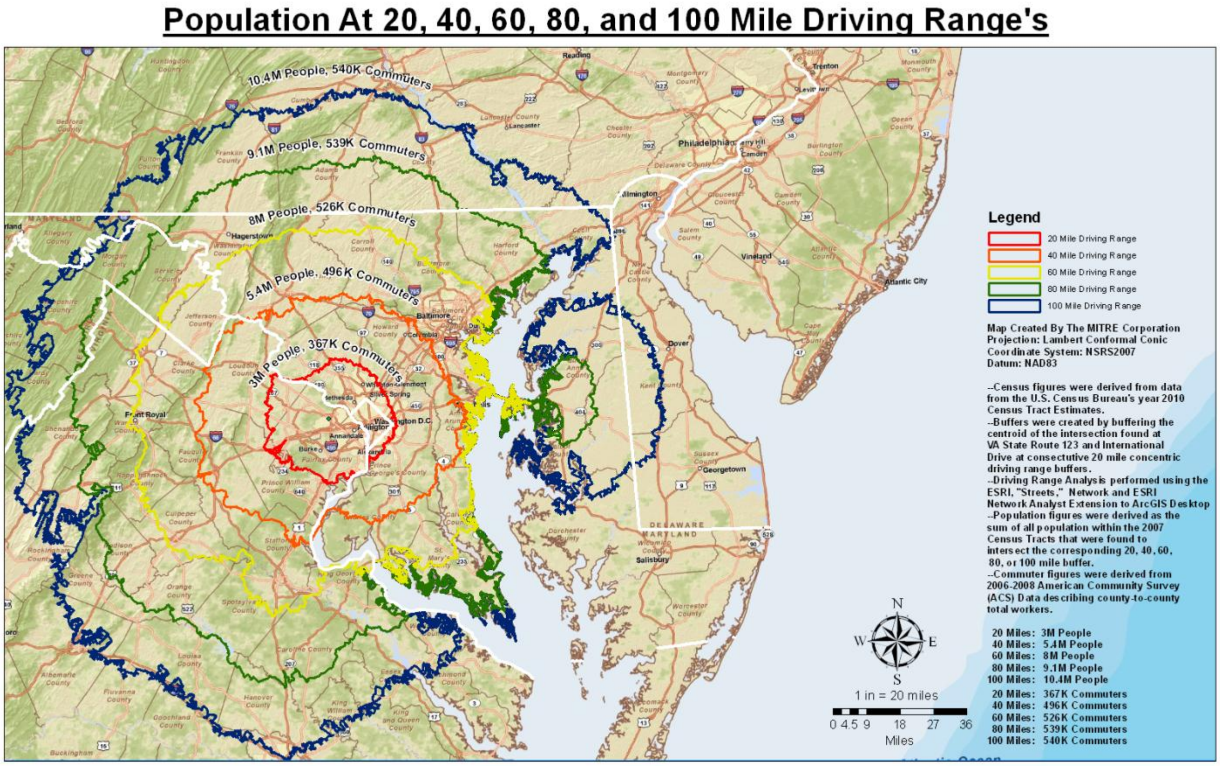


Figure 1: Driving distances from Tysons Corner

## 2.2 Battery electric and plug-in hybrid vehicles

### 2.2.1 Models

We consider two types of vehicles in this document: battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV). As its name implies, a BEV's sole power source is its on-board battery. The Nissan LEAF is the current most visible mass market BEV with a nominal range of 100 miles, although some estimates place a more realistic expected range at 80 miles. A PHEV has both a battery and an internal combustion engine. It operates on a combination of electric and gas or diesel power in a proportion determined by its electronic control system in response to such factors as power demand, temperature and state of charge of the battery. During the first portion of a trip, the battery, which has been charged from the grid prior to the trip, bears a greater burden for moving the vehicle. When the battery charge is used down to a predetermined level, the car automatically reverts to a "charge sustaining" mode and continues to operate just like a non-plug-in hybrid. In this mode, the battery's electrical charge is alternately used for propulsion and replenished by engine power (directly or through regenerative braking) and is "sustained" in a relatively narrow range. The Chevy Volt, the currently most visible example of a PHEV, is designed in such a way as to use only battery power (no engine power) during the "charge-depleting" portion of the trip. Both BEVs and PHEVs, of course, plug into the electrical grid for the bulk of their charge.

Throughout this document the terms *electric vehicle* or *plug-in vehicle* will refer to both PHEV and BEV without distinction. If we need to differentiate between the two, the appropriate acronym is employed.

### 2.2.2 Adoption

#### *2.2.2.1 Market forces*

Estimates of plug-in vehicle market penetration are highly varied, but do cite common factors both pushing and hindering adoption. As we show in the following, each factor includes significant estimates and guesses. We present the list to emphasize the lesson that estimating future electric car adoption is an inexact art and that any such estimate is likely wrong.

##### 2.2.2.1.1 Encouraging adoption

Factors encouraging adoption can generally be boiled down to two: financial and convenience. More altruistic mechanisms certainly exist, but they are not widespread enough to greatly affect aggregate market penetration of plug-in vehicles.

Financial encouragement for electric adoption comes in the form of rising gasoline prices. Average gasoline price has more than doubled in real terms since the late 1990s (US EIA, 2011). As world demand increases, this general upward trend for gasoline will likely continue. This trend will be exacerbated in the face of any future turmoil in oil producing countries. US electricity prices over the same term have not seen the same increases (US EIA, 2011), and locally, if a vehicle is charged at night using time-of-day pricing, even at current prices, gasoline can be an order of magnitude more expensive per mile than electricity delivered from the grid (Dominion, 2011).

Financial encouragement also derives from government policy. At a national level, tax rebates have been offered for the purchase of hybrid vehicles. Should this become a national priority, similar such programs will again be offered. In time, should greenhouse gas regulation come to pass, plug-in vehicles will likely have additional fuel cost advantage over traditional vehicles as greenhouse gas intensity of grid generation is less than that of distributed gasoline-burning engines (EPRI, 2007).

Convenience comes also in the form of government policy. Locally, high occupancy vehicle (HOV) exemptions for hybrids have been a primary force for their adoption by commuters seeking to bypass heavy traffic without the hassle of finding and coordinating with other passengers.

##### 2.2.2.1.2 Discouraging adoption

Factors discouraging adoption are many. We begin with concerns closest to the driver and proceed to more general constraints.

The first concern is general to all new technologies, not specifically those of plug-in vehicles. PHEV and BEV are new to the mass market, and as with the introduction of any new technology, early adopters will have to demonstrate the technologies' fitness before general adoption will begin.

The most obvious car-specific concern is vehicle range. BEVs cannot be driven beyond charging station range. PHEVs can but upon the switch to gasoline, lose the price per mile advantage over a traditional hybrid. Thus the economic benefit of PHEVs is only apparent if they remain close to charging infrastructure.

Vehicle initial cost is the next inhibitor. Include the cost of a charging station and its installation in the home, and plug-in vehicles require a larger up-front investment for the buyer than do internal combustion vehicles. Adoption will only become widespread if the ownership costs of such vehicles (fuel, maintenance, government levies) generally decrease to the point that the return on investment offsets the larger up-front cost.

This initial cost disadvantage for plug-in vehicles will likely fall over time as automakers increase investments in research and development. The ability and willingness of automakers to make such investments, however, depends heavily on the general economic climate, the rate of adoption, and targeted government subsidies, each of which presents its own difficult estimation problem.

A subset of the cost disadvantage is specific to a collection of difficulties in the battery supply chain that limit production. Currently battery manufacturing is constrained by simple production under-capacity, raw material availability, and technical immaturity.

Finally, the electrical grid itself is likely not suitable for large-scale adoption of electric cars. While not a constraint in the near term where numbers will be limited, the grid will require large investments over time to respond to the increased overall demand and the specific use patterns of the electric fleet. This investment will be passed along to the consumer, and if it is specifically passed to electric car owners, plug-in vehicles will lose a degree of their fuel cost advantage.

#### *2.2.2.2 Estimates*

Having presented some of the forces affecting plug-in vehicle adoption, we present three studies – one sponsored out of the Department of Energy (referenced as 'Sentech' below), one from the National Academy of Sciences, and one from an electricity industry group – that estimated the future US plug-in fleet. Each ignores the possibility of revolutionary technology, geopolitical upheaval, or large domestic political shifts. Even without such large market distorting events, we see that each presents a collection of highly variant alternatives.

Noticeably absent are any assessments by the automakers themselves. Such analyses would be proprietary and closely held, but the vastly different approaches the automakers themselves are taking with fleet electrification shows that not even they have a handle on what the market is going to look like in the coming decades. GM entered the EV market in the 1990s with the EV1, but discontinued the model. Non-plug-in hybrids first emerged in the late 1990s. Toyota made the explicit early decision not to include a plug on the Prius, but has reconsidered the decision for future models due to this year's introduction of GM's PHEV Volt. Nissan is skipping hybrid technology altogether with its EV Leaf this year.

The point here is that automotive market experts and even the automakers themselves are uncertain as to what the future holds for plug-in vehicles. The County, therefore, cannot expect to develop a good estimate of plug-in vehicle market penetration, and, as such, it should adopt a posture that does not hinge on a particular estimate.

To provide context for these studies, sales of new passenger vehicles in the US totaled roughly 17 million units annually from 2000 through 2007. With the general economic downturn, that total fell to 13.5 million in 2008 and 10.6 million in 2009 (Census, 2011). Roughly 250 million such vehicles are currently registered in the US (Census, 2011).

Figure 2 summarizes our source studies.

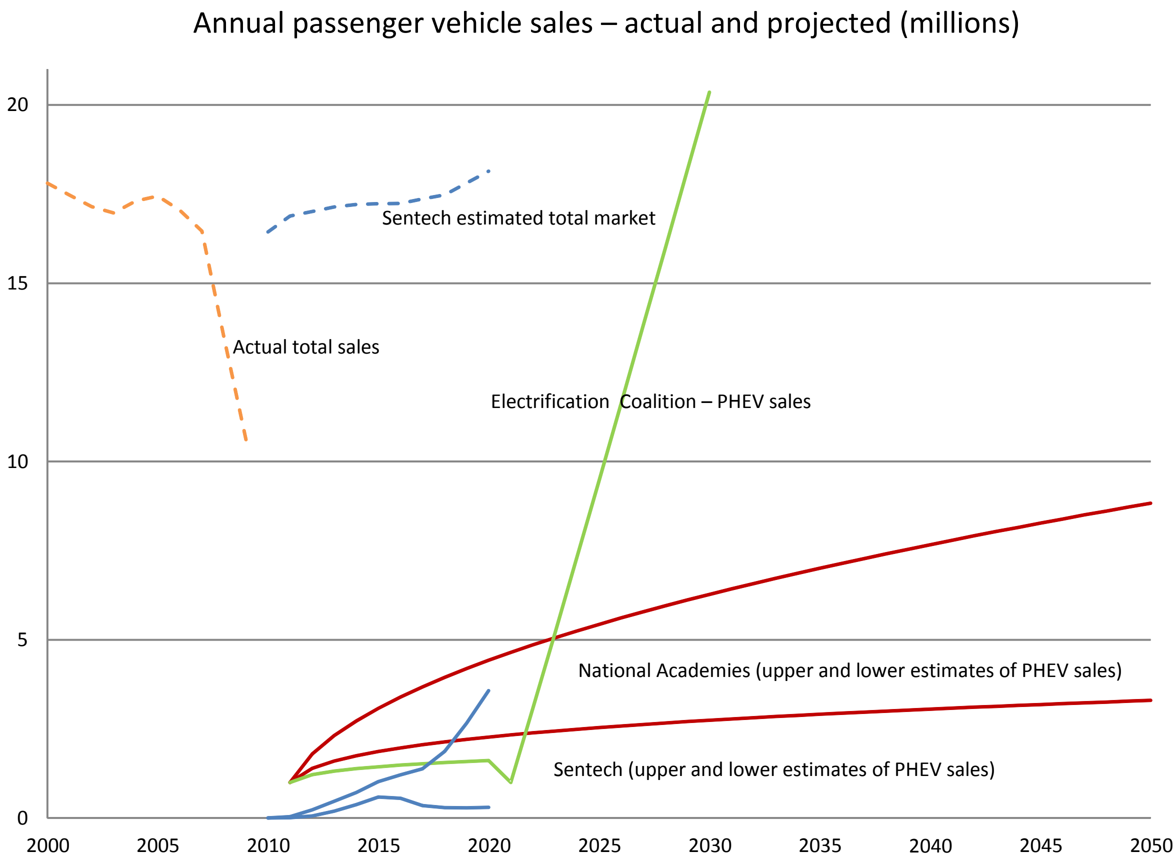


Figure 2: Annual passenger vehicle sales – actual and projected (millions)
Sources: US Census, 2011; Sentech, 2010; derived and estimated from National Research Council, 2010; derived and estimated from Electrification Coalition, 2009.

The various studies estimate PHEVs to represent anywhere between 2 and 20% of 2020 sales, with estimates diverging dramatically afterwards. The point of showing the disparity between (and even within each of) the studies is to demonstrate the difficulty – if not impossibility – of Fairfax generating an estimate of plug-in vehicle adoption good enough to proceed with large scale installation of charging infrastructure. Instead, as we recommend below, the County should strongly encourage the development of infrastructure that allows for the minimum of retrofit costs and, therefore, the lowest long-term cost of fleet electrification and necessary charging station availability.

## 2.3 Charging stations

Charging stations constitute the plug-in vehicle's connection point to the grid. Table 2 shows a summary of the three general classes of charging stations (Virginia Clean Cities, 2010).

| Level of Charging | Level 1 | Level 2 | DC Fast Charge (Level 3) |
|---|---|---|---|
| Voltage | 120 VAC | 240 VAC | 480 VAC (off board charger provides AC to DC conversion) |
| Amperage | 15 - 20 Amp | 40 - 80 Amp | 85 Amp |
| Instantaneous Demand | 1.2 - 1.6 kW | 3.3 - 7.7 kW | 60 kW |
| **Charge Time** | | | |
| PHEV 40 Vehicle | 5 - 13 hours | 2.5 - 5 hours | N/A |
| EV100 Vehicle | 8 - 15 hours | 3 - 5 hours | 15 to 30 minutes |

Table 2: Charging station summary

Level 1 can be as simple as a standard three-prong plug into a standard wall socket (Level 1 EVSE does exist to improve safety and improve grid integration, but it does not improve charging speed). The time required to fully charge a vehicle at Level 1 makes it an impractical general solution.

Level 2 is the answer to this impracticality. There is a defined standard (Society of Automotive Engineers J1772), and mass produced plug-in vehicles have sockets to fit. Despite their high current rating, the power demand shown is indicative of practical use where less current is used to improve longevity of the battery itself (not the individual charge). Level 2 is the assumed primary mechanism for most charging as it strikes a balance between practical speed and battery protection. It is intended for installation in the home and at other locations where the car is expected to sit unused for a number of hours at a time.

Level 3 is not yet standard, though multiple competing standards have emerged. It is the closest analogy to the current gasoline pump. Multiple rapid charges, however, negatively affect the longevity of current batteries, and so such chargers are assumed to be of use primarily in emergencies (Burke, et al, 2007; Hybrid Cars, 2010).

## 2.4 Construction costs

Construction costs serve as the final bit of input data for the analysis. Cost estimates for the parking structures help frame the analysis. The estimates are drawn from industry standard resources (RS Means CostWorks) and from private historical databases belonging to builders MITRE uses for our own construction efforts. They include design, construction, and labor. They do not include the cost of the land itself.

Table 3: Per parking space new construction estimated costs

| | Estimated per space new construction cost |
|---|---|
| Below grade garage | $33-38k |
| Above grade garage | $12-17k |
| Surface lot | 2.5-3.5k |

With regards to the installation of plug-in vehicle charging infrastructure, the intent is to minimize the overall cost of establishing adequate charging supply. EVSE can be fully installed during initial construction, but if the demand never makes full use of that charging supply, money is wasted. EVSE can also be retrofitted into a building later when demand emerges, but retrofit is more expensive than is inclusion during initial construction. The per space construction costs (Table 3) must be borne regardless of whether EVSE is considered during initial construction or whether it is to be delayed for retrofit. The analysis thus turns on the difference between installation during initial construction and installation as part of a retrofit.

It turns out that conduit installation drives the higher costs of retrofit. It is far cheaper to embed conduit during initial construction than it is to drill through concrete (in a garage) or dig a tunnel and resurface asphalt (in a surface lot). The cost of installing transformers, switches, cable, and the charging stations themselves are equivalent whether they are being done during initial construction or as part of a retrofit. So, since we are considering the difference between initial construction and retrofit, we focus on the additional per space cost imposed by conduit installation.

Table 4 shows the estimates of the costs incurred during initial construction and during retrofit. Again, we rely on a mix of industry standard sources (RS Means) and the private historical databases of contractors with whom we have relationships.

Table 4: Additional per space estimated cost of EVSE conduit installation during…

| | Initial construction | Retrofit |
|---|---|---|
| Surface lots | $1800 | $2900 |
| Garage | $400 | $1200 |

The differences between garage and surface lot installation are a consequence of the fact that the conduits must be buried in a surface lot installation. In the garage, the conduit can be attached to the ceilings or wall.

# 3 Assumptions

This analysis rests on the fundamental assumption that plug-in vehicles will become widespread only if they become as convenient and economical as other non-plug-in vehicles (internal combustion and traditional hybrids). Likewise, plug-in vehicle charging infrastructure will only emerge where and when profit can be derived (after all, we couldn’t put gasoline in our cars if we didn’t put dollars into someone’s pocket in the process). This simple notion leads to a number of consequences that affect the recommendations.

We further assume that plug-in vehicle owners will have the ability to fully charge their vehicles at home. Without that ability, the owner would be utterly reliant on an infrastructure that currently does not exist and will emerge in some currently unknown form. We accept our infrastructure dependence with internal combustion engines because most areas are saturated with gas stations and because the time to fill a car for a range of multiple hundreds of miles is minimal. These conditions are not satisfied for the plug-in fleet, and so home charging is a must.

### 3.1.1 Charging is done at home

With the assumption that the plug-in vehicle owner will spend the money to establish a charging capability at home, the question is how much he will rely on commercial charging stations.

If we consider only convenience, even a Level 3 charging station will likely require 30 minutes to fill an EV100. It is unreasonable to assume plug-in vehicle drivers will line up to fill the batteries before the commute home every day. Additionally, Level 3 rapid charging reduces the battery's useful lifespan (Burke, et al, 2007; Hybrid Cars, 2010). So between the impracticality of the charger and the wear it induces on the battery, we conclude that Level 3 charging (at least in the context of Fairfax County) will be an emergency activity for only a small fraction of plug-in vehicles in the near future.

So we turn to Level 2 charging, where we accept longer charging times and charge where we spend most of our time: at home and at work. Cost considerations push the driver to charge at home in this case. If charging stations become widespread, Dominion will impose time-of-day pricing on the charging station owners (Dominion, 2011). This helps to control peak demand, and it prevents a political fight over raising other rates to provide flat-rate pricing on charging stations. Since most drivers are away from home during the day when wholesale electricity prices are higher, the electricity they use away from home is more expensive.

While the electricity consumed away from home is itself generally more expensive, the fact that the charging station is owned by a for-profit entity – remember, money has to be made – also increases the cost of away-from-home charging. The charging model may simply be the price of electricity plus some fee (now that electricity resale is legal in Virginia for this application) (Virginia, 2011). It may also be in the form of a per session fee, a per minute fee (to absorb the opportunity cost of a car blocking the station but not charging), or an access rights model. In any of these cases, the charging station owner passes along the cost of electricity and then turns a profit for himself. Indeed, home charging is the cheapest charging.

### 3.1.2 Geography and drivers for focus

We now return to the map in Figure 1 **Error! Reference source not found.**to consider the effects of the home charging predominance.

All PHEV and BEV drivers who live in Tysons Corner will primarily charge their vehicles in Tysons Corner at night. The majority of people living in Tysons Corner will reside in large multi-family buildings and, therefore, do not have the individual option to install their own charging station if the building has not already either provided a charging station or the infrastructure into which a charging station can easily be installed. Thus, the County should put particular focus on residential buildings. If charging stations are not available to allow owners to charge their vehicles overnight, they cannot purchase plug-in vehicle, nor can people who already own plug-in vehicles tenant the building. This both slows new adoption of plug-in vehicles and potentially makes the area less attractive to people moving here from locations with better charging resource availability.

Moving outside of Tysons Corner itself, non-residential charging stations encourage PHEV adoption, but they are not sufficient. They make the commute less expensive – electric-only retains a price advantage over gasoline-augmented operations here in Tysons Corner even with a profit-making charging station on a hot summer afternoon (PJM, 2011; EcoWorld, 2006; Toyota,

2011) – and, therefore, build the case for plug-in vehicles, but they are not a necessary condition since the vehicle can continue with its internal combustion engine.

The savings are a function of the electric-only range of the PHEV (the pluggable Prius will be a PHEV12; the Chevy Volt at PHEV40) and the commute distance. The outer extreme of this case is represented by the 20-mile (40-mile return commute) ring which includes all of Fairfax, Arlington, Alexandria, and the District and contains about 65% of the Tysons Corner workforce (we do not have data granularity to estimate the fraction of the Tysons Corner workforce within the 6-mile ring). For commutes less than half of the electric-only range, the non-residential chargers in Tysons are of no use; the charging is done at home. For commutes longer than half of the all-electric range, the non-residential charging stations simply reduce the operating costs of PHEV.

Turning now to all-electric vehicles, the 40-mile and 80-mile rings are of interest. The 40-mile ring is the effective half range of an EV100. EV100 owners inside this ring will require little in the way of charging infrastructure in Tysons. They will charge at home. Roughly 90% of Fairfax's workforce resides within this ring.

At the 80-mile ring (and this may be generous), we reach the effective outer range of the EV100 vehicles. A commuter originating between the 40-mile and the 80-mile rings (roughly 8% of the current workforce) will require charging resources to return home. Outside the 80-mile ring, the trip will not be attempted, and the County can safely ignore such drivers.

In summary, the Tysons Corner charging stations service distinct groups for distinct purposes;

- PHEV and EV ownership within Tysons Corner is made feasible with residential charging. There can be no plug-in ownership without home charging.
- Charging stations available to non-residents make the commute cheaper for PHEV drivers who come from further than half of their all-electric ranges. PHEV owners from inside this distance are unaffected by Tysons Corner charging infrastructure since they can fully charge at home.
- Commutes to Tysons Corner are made feasible for EV owners who live between 40 and 80 miles away. Otherwise outside EV owners are relatively unaffected by Tysons Corner charging infrastructure.

### 3.1.3 Technology evolution

These rings represent the state of 2011 technology, but a building shell is likely to be used for 40 to 50 years, so what happens as technology improves?

In general, improved battery and charging station technology will increase overall demand for plug-in vehicles and, therefore, charging infrastructure. An inspection of the rings, however, reveals consequences for Tysons Corner in particular.

Within Tysons Corner itself, improved technology will increase the fraction of resident vehicles that require home charging, and, any new residential building should assume that a large fraction of the resident fleet will be electric in the coming decades.

In thinking about the population commuting into Tysons, we consider the cases of charging speed and battery capacity independently.

If battery capacity improves, the rings move further out, but the effect on aggregate demand is indeterminate. Drivers from more densely populated inner rings that would have previously used commercial charging stations no longer require that capability to return home. At the same time, plug-in drivers from less densely populated outer regions are newly within range of Tysons. This would indicate a net reduction in demand, but it must be assumed that as technology improves, the total fraction of vehicles that are plug-in will increase.

If charging speed improves then quick charge stations become more feasible, and the infrastructure begins to resemble more that of the current gasoline infrastructure. This may reduce demand for Level 2-style stations at office and retail locations, but it will not affect demand for home charging as home charging will still be the cheapest, most convenient charge mechanism.

If replaceable batteries become more prevalent, then some hybrid of home charging and swap stations will likely emerge. Home charging infrastructure is still required, but the fewer charging stations are required at offices and at retail location. To date, however, no vehicle on the market or proposed for the near future market features such batteries.

# 4 Policy recommendations

The County's development requirements and expectations must balance with the County's other objectives. The county wants to attract business and residents, so the costs it imposes cannot be too high. The county may want to enable and encourage the electrification of region's automotive fleet, so the charging infrastructure it requires should not lag or inhibit demand.

Here, we attempt to strike a balance between these objectives and recommend a course of action for the County. Having described the environment in which these decisions are made and described the assumptions underpinning our analysis, we present our policy recommendations here. We propose a long term, sustainable course; a plan for the short term; and recommendations for data collection, which will aid future market analysis of charging station demand.

## 4.1 Long-term recommendation

### 4.1.1 General

As we saw in the background sections above, considerable uncertainty exists regarding the adoption of plug-in vehicles. This uncertainty induces large financial risks for anyone installing and operating a commercial charging station. If demand is lower than expected, the charging station is a wasted investment. If demand is higher than originally expected and if the infrastructure into which additional charging capacity would be installed is constrained, then there exists a retardant on plug-in vehicle adoption. This uncertainty also induces political risk for the County. If it undertakes any strategy that depends on some assumption of adoption, a critic can always find a competing study arguing for more or less charging structure.

The best long-term policy response then is one that does not require the County, a resident, or a developer to estimate vehicle adoption or charging station demand. Here, we propose recommendations for initial building construction that are intended to reduce the risk associated with uncertain charging station demand.

The proposed building recommendations are intended to reduce the overall cost of electrifying a parking area with Level 2 charging stations, while allowing the owner or third-party to match demand with investment over time by installing charging stations at minimal cost in the future. In the long-term case, profits can be earned with commercial charging stations. The objective of minimizing future installation costs is to increase the quantity and reduce the price at which supply and demand are equivalent.

Initial parking area construction satisfying three conditions is relatively inexpensive and serves as a basis for future installation at least expense. The following conditions are thus recommended:

- A newly constructed facility should have the physical space to allow the installation of enough transformer capacity to enable intended operations as well as allow electrification of the parking area. The transformer capacity to fully electrify the lot, however, need not necessarily be installed during initial construction. Full installation can occur as demand emerges in the future.
- The building's electrical room should have enough physical space to allow the future installation of a switchboard (with the capacity for sub-metering) for the charging stations. Again, the full switchboard need not be installed immediately.
- Initial parking area construction should include the conduit bank and conduit between the facility's electrical room and the spaces allotted for possible future electrification. An access point (junction box or hand hole) at each possible future charging station location is recommended. Access points (manholes, hand holes, and junction boxes) to draw cable from the electrical room to the charging stations are recommended as well.

The recommendations are a hedge against the uncertainty of charging station demand. The installation of conduit and access points are the primary drivers of difference between the cost of installing a charging station during initial construction and installing one in which the whole of the system is retrofit into a facility. The intent of the recommendation is that of insurance. If the cost is low enough, even if the lot is never electrified, the lost investment is bearable, but if large demand for charging stations indeed emerges, the recommendations greatly reduce the cost of servicing that demand.

### 4.1.2 Building class specifics

The transformer space and empty conduits are relatively small investments during initial construction, but they are not zero. Here, we consider the various classes of buildings and offer bounds on the fraction of parking spaces that should be designated for future charging station installation. In a previous section, we noted the three classes of plug-in vehicle drivers who will use the Tysons Corner charging infrastructure: Tysons Corner residents, PHEV drivers who live further than half of their all-electric ranges from Tysons Corner, and EV owners who live between 40 and 80 miles from Tysons Corner. They define the need.

#### *4.1.2.1 Residential*

It is with the development of residential buildings that the County should be most aggressive in negotiating for commitments from developers. Plug-in vehicles require home charging. If home charging is not available, there will be no plug-in vehicles.

Given the uncertainty of future demand, for residential development, we propose that the transformer space, switch space, and conduit recommendations in the previous section apply to all newly constructed parking spaces. The objective is to allow an inexpensive, full migration to a plug-in fleet within the lifespan of the parking area. In Tysons Corner specifically, since most parking will be in garages – and likely underground garages at that – the cost of this conduit infrastructure is a tiny fraction of total cost, and its initial inclusion is roughly 30% of the costs of retrofit (see Table 4).

Though this analysis is focused specifically on Tysons Corner, we strongly recommend that all residential development (single family homes, townhouses, condominiums, and apartments) in broader Fairfax be subject to this guidance on conduit and space. Because of the dependence on home charging, we have to assume that long-term homeowners will constitute the bulk plug-in vehicle buyers as they have the stability to assume access to home charging for the whole of the vehicle's lifespan. Apartment dwellers may be less inclined to purchase plug-ins because they are generally more transient. The availability of a charging station at the next home is unknown, and without home charging a plug-in becomes impractical. Thus, the payoff for the policy is likely to be highest in developments where the owners are the occupants.

In the house, townhouse, and condominium markets, the developer, by definition, is not the long-term owner of the residence, and so he has the incentive to respond only to current market pressure. The installation of conduit during initial construction is an insurance policy against possible future market forces. Though the developer's cost of initial installation is a larger fraction of the overall construction cost for most home applications – presumably such costs are more in line with surface lot installation – the existence of such conduit greatly affects future adoption rates of plug-in vehicles since any retrofit costs implied by the purchase of a plug-in vehicle will depress demand. Such conduit is not yet a selling point for homes in the region, however, and so it is not yet a commonly-offered feature. Thus, to minimize hurdles to widespread adoption, the County is wise to strongly encourage the inclusion of conduit for all residential development across the county.

#### *4.1.2.2 Commercial office buildings*

For commercial office buildings, we recommend the transformer, switch, and conduit recommendations apply to 35% of newly constructed spaces – the fraction of spaces equivalent to the fraction of vehicles that arrive into Tysons from outside 20 miles. This would allow the full adoption of plug-in in the fleet arriving from outside the 20 mile ring (inside of which the Tysons charging infrastructure largely unnecessary). As zoning ordinances are modified in coming years – presumably, with the arrival of Metro, reducing the number of spaces required for an office building – this fraction would rise on the newer, smaller lots since more of the incoming vehicular traffic would be from outlying areas not served by Metro.

#### *4.1.2.3 Retail*

Most retail activities are substitutable across the Mid-Atlantic region, and so we have to guess that most retail customers in Tysons Corner live within a short radius. However, since retail is fundamentally about attracting customers to a particular destination and since the higher prices of plug-in vehicles imply relatively affluent buyers, retail developers have the incentive to make an adequate number of charging stations available. We thus assume that retail development will require the least nudge from the County to provision for charging stations.

Should the County find itself in the position of having to provide that nudge, we recommend the same guidelines as those for office buildings with conduit infrastructure being encouraged for the fraction of vehicles coming from outside a 20-mile radius. That fraction of traffic, however, is unknown and certainly not presented in the Census resources from which we can determine work commuting patterns. Thus, the county is wise to work with its retail base to determine the source of the populations inbound for retail.

#### *4.1.2.4 Hotels*

Hotels offer the logistical opportunity for a Level 2 charge. We do not have any data describing the mix of vehicles that park in Tysons Corner hotels, so instead, we recommend that the County work with hotels in the region to determine need, with the need for conduit installation being primarily defined by the rental car population in a hotel's garage.

### 4.1.3 Charging station standards

The definition of a standard connection point for the charging station to the vehicle (SAE J1772) has been a necessary step towards the widespread adoption of plug-in vehicles. Without the standard connection point, drivers of the various plug-in models would have to carry around various connectors and adaptors in hopes of accessing charging resources more potent than a standard wall outlet.

We propose that the County coordinate with peer jurisdictions, which are also looking to ease the widespread adoption of plug-in vehicles, in an attempt to force a standard connection point for the charging station itself to the facility into which it is to be installed. The connection point is both the electrical connection and the piece by which the station is physically mounted to the wall, ground, or ceiling. The first and most obvious purpose is simply to reduce the overall cost of installation.

The second purpose of a standard mount is to allow for easy movement of charging station to a new location. We see the standard mount allowing multiple business models that reduce the risk associated with uncertain charging station demand. A third party vendor may manage a fleet of charging stations that it deploys and adjusts to service demand for multiple facilities. An apartment management company may rather provide a connection point and allow plug-in drivers to attach their own (sub-metered) charging stations, so that it does not have to deal with the risk of too many or too few charging stations. In both cases, the facility owner eliminates his need to monitor and respond to developments in the plug-in vehicle marketplace, and the flexibility afforded by a quick, easy installation ensures that supply is more responsive to demand.

From a driver's perspective, the standard mount also reduces risk. As the standard mount becomes more widespread, a plug-in owner knows he can take his charging station with him should he decide to find to a new home, and he knows he can sell his charging station to another plug-in owner should he no longer need the station or upgrade the station. Because the risk of vehicle ownership is potentially decreased, demand for plug-ins is potentially increased.

The definition of such a standard is certainly not the responsibility of Fairfax or any local jurisdiction. The point in making the recommendation here is that Fairfax is in a position with its peer jurisdictions to encourage the charging station vendors to proceed along this path.

## 4.2 Short term

### 4.2.1 Charging stations – seeding supply

Plug-in vehicle adoption has always been considered a 'chicken and egg' problem with cars not being purchased because charging stations are not available and charging stations not being installed because of inadequate numbers of plug-in vehicles. Thus, the County may recommend implementation of a handful of charging stations at each new building site and proffers that deliver charging stations to public areas.

Above, we see that residential charging is the key to widespread plug-in vehicle adoption, and we reasoned that plug-ins are more likely (in the near term) to be purchased by people who own their own homes and intend to stay there for the lifespan of the car. If the County wishes to speed adoption by apartment dwellers inside Tysons Corner, it may recommend the installation of charging stations at new apartment developments. If so, we recommend that the number of full stations be equivalent to the lowest estimate of market penetration for plug-ins (see 2.2.2.2). The region may have a higher rate of hybrid adoption over the recent years, but that margin will be swamped by the broader trends which drive nationwide adoption. In the lowest estimate presented above, plug-ins are estimated to constitute less than 2% of cumulative sales, and so we recommend that the upper-bound of any County negotiation for fully installed charging stations be limited to 2% of the parking spaces at an apartment building in Fairfax. This is in addition to the strong recommendation for the conduit infrastructure.

For office and retail buildings, we have recommended the County pursue commitments to the provision of infrastructure that would allow for inexpensive charging station installation in the future. We do not, however, recommend any expectation for full station installation. Plug-in vehicle adoption will be a function of home charging capacity; charging availability at work or retail locations alone is not sufficient to allow adoption. Luckily, if we return to the map and the concentric rings, office and retail charging is only a necessity for BEV drivers who live between 40 and 80 miles from Tysons Corner (and only 8% of inbound Fairfax commuters live at that distance). For PHEV drivers who live more than half of their all-electric range from Tysons Corner, the charging stations would indeed reduce commuting costs, but we cannot believe that a prospective PHEV owner would purchase such a vehicle while being dependent on cheap workplace charging to make the economic case for purchase. Any proffer for provisioning charging stations thus supports a very small fraction of inbound commuters (BEV owners from 40 to 80 miles away) or a group of drivers who would have purchased their vehicles anyway (PHEV owners). The lesson is that for office and retail development, developers may be able to better benefit the community with proffers that include improvements other than the provisioning of a large number of charging stations.

### 4.2.2 County procedures

The County itself can continue to support plug-in adoption by continuing to maintain its current easy, efficient process for permitting electrical installations at existing facilities. Plug-in buyers need this process to make the installation of charging stations at home to remain as easy as it is. If the process is slowed, then adoption of plug-in vehicles will also be slowed.

## 4.3 Data generation and monitoring

A primary purpose of the recommendations would be to allow charging station deployment to coincide with charging station demand. This would allow the business justification for commercial charging capacity to emerge and, therefore, would make plug-in vehicle ownership more convenient (and feasible for a larger population). To speed the development of the business case, the County (to the extent possible within in the bounds of privacy concerns, proprietary competitive data, and simple data gathering feasibility) is wise to develop the mechanisms to gather and monitor data describing:

- A more precise understanding of the Fairfax work population and where it lives within Fairfax and within the nearby counties;
- The other inbound population of Tysons Corner and where it lives;
- Use patterns for charging stations as they are installed in Tysons Corner. Who uses them? When are they used? On what sorts of vehicles?
- PHEV and BEV registrations for Tysons Corner and the jurisdictions within 100 miles of the area.

With a good handle on this information, the County would be better positioned to respond to changes and trends in the emerging markets of commercial charging stations and plug-in vehicles. Potential charging business owners would be better able to gauge demand. And Dominion would be better able to understand its supply requirements.

# 5 Conclusion

We close with an emphasis on two points. First, no demonstrably accurate estimate of plug-in vehicle market penetration is possible. And second, when plug-in vehicles do arrive to market in large numbers, their owners will completely rely on, will prefer, and will predominantly charge them overnight at home.

These two points naturally lead to the recommendations

1. Developers should be strongly encouraged to include the space, conduit banks, conduit, and access points for easy and inexpensive installation of charging infrastructure in the future. They should not be asked to install the transformers, switches, wiring, or charging stations themselves, however.
2. The fraction of parking slots for which the infrastructure should be included should represent a fully plug-in fleet for the groups of users that would use charging infrastructure at the facility. This means all slots in a residential building. At commercial and retail facilities, this means the fraction of vehicles that arrive from locations geographically situated to require a charge before the return trip.
3. The County can most appropriately seed charging station supply by negotiating for the installation of full charging stations at the lowest expected adoption rate in the near future. Any supply seeding is most efficiently done at apartment buildings and should be limited to a maximum of 2% of all parking spaces.
4. The County should coordinate with its peer jurisdictions to encourage charging station manufactures to form a standard defining the connection of the charging station to the

facility in which it is installed.  The standard should define both the electrical connection and physical mount with the purpose of making it possible to move charging stations to a new facility relatively easily and quickly.

The overall points are that transformer space and conduits are more expensive to retrofit into a facility than to include during initial construction.  Their inclusion at the outset would allow the cheapest possible overall cost of installing a full charging infrastructure, and their inclusion in such quantity would be a low-cost insurance policy against the inability to estimate plug-in vehicle market penetration rates over the expected life spans of newly constructed buildings.

The County thus would ensure that development in Tysons Corner would remain an attractive investment and that the area would be fully prepared for whatever occurs with plug-in vehicle adoption.

# 6 Acronyms

| | |
|---|---|
| BEV | Battery Electric Vehicle |
| BEV100 | Battery Electric Vehicle with 100-mile range |
| EV | Electric Vehicle |
| EV100 | Electric Vehicle with 100-mile range |
| EVSE | Electric Vehicle Supply Equipment |
| PHEV | Plug-in Hybrid Electric Vehicle |
| PHEV12 | Plug-in Hybrid Electric Vehicle with a charge-depleting range of 12 miles |
| PHEV40 | Plug-in Hybrid Electric Vehicle with a charge-depleting range of 40 miles |

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