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Assessment of Charging Infrastructure for Plug-in Electric Vehicles at Marine Corps Base Camp Lejeune: Task 3

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November 2015

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ABSTRACT

Battelle Energy Alliance, LLC, managing and operating contractor for the U.S. Department of Energy's Idaho National Laboratory, is the lead laboratory for the U.S. Department of Energy's advanced vehicle testing. Battelle Energy Alliance, LLC contracted with Intertek Testing Services, North America (Intertek) to conduct several U.S. Department of Defense-based studies to identify potential U.S. Department of Defense transportation systems that are strong candidates for introduction or expansion of plug-in electric vehicles (PEVs).

Task 1 consisted of a survey of the non-tactical fleet of vehicles at Marine Corps Base Camp Lejeune to begin the review of vehicle mission assignments and types of vehicles in service. Task 2 selected vehicles for further monitoring and involved identifying daily operational characteristics of these select vehicles. Data logging of vehicle movements was initiated in order to characterize the vehicle's mission.

The Task 3 vehicle utilization report provided results of the data analysis and observations related to the replacement of current vehicles with PEVs. Finally, this report provides an assessment of charging infrastructure required to support the suggested PEV replacements.

Intertek acknowledges the support of Idaho National Laboratory, Marine Corps headquarters, and Marine Corps Base Camp Lejeune Fleet management and personnel for participation in this study.

EXECUTIVE SUMMARY

Federal agencies are mandated[a] to purchase alternative fuel vehicles, increase use of alternative fuels, and reduce consumption of petroleum used for transportation. Available plug-in electric vehicles (PEVs) provide an attractive option in the selection of alternative fuel vehicles. PEVs, which consist of both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), have significant advantages over internal combustion vehicles in terms of energy efficiency, reduced petroleum consumption, and reduced production of greenhouse gas emissions and they provide performance benefits with quieter, smoother operation. This study intended to evaluate the extent to which Marine Corps Base Camp Lejeune could convert part or all of their fleet of vehicles from petroleum-fueled vehicles to PEVs.

BEVs provide the greatest benefit when it comes to fuel and emissions savings because all motive power is provided by energy stored in the onboard battery pack. These vehicles use no petroleum and emit no pollutants at their point of use. PHEVs provide similar savings when their battery provides motive power, but they also have the ability to extend their operating range with an onboard internal combustion engine. Because a PHEV can meet all transportation range needs, the adoption of a PHEV will be dependent on its ability to meet other transportation needs such as cargo or passenger carrying. Operation of PHEVs in battery-only mode can be increased with opportunity charging at available charging stations. However, it should be noted that not all PHEVs have a mode where the battery provides all of motive power at all speeds. The Task 3 report on vehicle utilization focused on the mission requirements of the fleet of vehicles. The objective was to identify vehicles that may be replaced with PEVs with emphasis on BEVs that provide maximum benefit. This report follows that vehicle use analysis with an evaluation of the electric vehicle charging infrastructure required to support those PEVs.

The Task 3 report on vehicle utilization observes that a mix of BEVs and PHEVs are capable of performing most of the required missions. Replacement of vehicles in the current fleet could result in significant reductions in the emission of greenhouse gases and in petroleum use, as well as reduced fleet operating costs. PEVs that currently are commercially available cannot replace certain vehicles and missions, such as those requiring heavy-duty trucks and specialty usage vehicles. However, based on data collected for the monitored vehicles, 59 of the 60 vehicles have potential replacement PEVs available and the 59-vehicle fleet subset could possibly consist of 25 BEVs and 34 PHEVs. This report shows that 25 alternating current (AC) Level 2 and 34 AC Level 1 charging stations should be sufficient to support these PEVs.

[a] Energy Policy act of 1992, Energy Policy Act of 2005, Executive Order 13423, and Energy Independence and Security Act of 2007.

The monitored vehicles represent 60 vehicles of 784 on-road rated vehicles in these represented fleets. Assuming that the balance of these fleets operates in a manner similar to those monitored and without consideration of specific cargo or other mission requirements not previously identified, Intertek suggests the total fleet composition could consist of 53 conventional heavy-duty specialty vehicles, 418 BEVs, and 313 PHEVs. Because daily utilization of these vehicles is low and many vehicles will be assigned at the same buildings, sharing of electric vehicle supply equipment is possible with management attention. Intertek suggests 278 AC Level 2 and 208 AC Level 1 electric vehicle supply equipment should meet recharging requirements.

Installation of PEV charging stations requires pre-planning and this report provides some highlighted areas of interest in this preparation. In general, the electrical supply is not a concern but location relative to that supply is a significant cost factor for installation. Several potential sites were identified for charging station locations.

The information presented in this report and the prior Task 3 report on vehicle utilization will be considered in the Task 4 effort to identify an adoption approach for incorporating PEVs into the fleet.

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ACRONYMS

AC	Alternating current
BEV	battery electric vehicle
DC	direct current
DCFC	direct current fast charger
EVSE	electric vehicle supply equipment
ICE	internal combustion engine
Intertek	Intertek Testing Services, North America
MCBCL	Marine Corps Base Camp Lejeune
MCIE	Marine Corps Installations East
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
POV	privately owned vehicle
SUV	sports utility vehicle
V2G	vehicle to grid

Assessment of Charging Infrastructure for Plug-in Electric Vehicles at Marine Corps Base Camp Lejeune: Task 3

1. INTRODUCTION

The U.S. Department of Energy and the U.S. Department of Defense signed a memorandum of understanding on July 22, 2010, for strengthening the coordination of efforts to enhance national energy security and to demonstrate federal government leadership in transitioning the United States to a low carbon economy. The memorandum of understanding included efforts in the areas of energy efficiency, fossil fuels, alternative fuels, efficient transportation technologies and fueling infrastructure, grid security, smart grid, and energy storage.

In support of the memorandum of understanding, the Idaho National Laboratory, with funding provided by the U.S. Department of Energy's Vehicle Technologies Office and Federal Energy Management Program, contracted with Intertek Testing Services, North America (Intertek) to conduct several U.S. Department of Defense-based studies. These studies identified potential transportation systems that are strong candidates for introduction or expansion of plug-in electric vehicles (PEVs). Intertek previously conducted similar fleet, city, state, and countrywide studies using the micro-climate assessment process, which consists of the following four main tasks:

- Task 1: Conduct a non-tactical vehicle fleet assessment
- Task 2: Select vehicles for mission and fleet characterizations
- Task 3: Perform detailed assessment of selected vehicles and charging infrastructure needs
- Task 4: Prepare adoption approach for PEV and charging infrastructure.

Assessment of the potential for replacing Marine Corps Base Camp Lejeune (MCBCL) fleet vehicles with PEVs starts with assessment of the fleet vehicles' missions and vehicle characteristics. This assessment was conducted with a thorough review of fleet records and discussions with MCBCL personnel. The Task 1 report titled, *Assessment of Fleet Inventory for Marine Corps Base Camp Lejeune*, dated January 2015, provided a summary and fleet assessment.

PEVs generally are classified into two vehicle types: battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). A BEV contains an onboard battery that provides all motive power. PHEVs also have an onboard battery that provides some motive power and is supplemented by another power source (such as a gasoline engine). Collectively, BEVs and PHEVs are referred to as PEVs.

The Task 1 effort led to identification of fleet vehicles that appear to be good candidates for replacement by PEVs. The Task 2 report titled, *Identification of Vehicles for Installation of Data Loggers for Marine Corps Base Camp Lejeune*, dated February 2015, identified 60 vehicles within the candidate groups for further monitoring and analysis through addition of vehicle data loggers. The data loggers were installed and data collected on these selected vehicles. The results of that analysis were reported in *Utilization Assessment of Target Electrification Vehicles at Marine Corps Base Camp Lejeune: Task 3*, dated August 2015. Finally, this report assesses the electric vehicle charging infrastructure necessary to support the recommended electric vehicle replacements.

Infrastructure recommendations depend on the type of PEV to be charged, time available for charging, locations of typical vehicle parking, fleet management attention, and electrical power availability. Other considerations (such as providing charging opportunities for assigned military, base employees, or visitors) may be of interest. While vehicle-to-grid (V2G) power transfer capabilities are currently under study at military facilities, this topic will be discussed but not evaluated as part of this report.

2. FLEET VEHICLE PLUG-IN ELECTRIC VEHICLE RECOMMENDATIONS

MCBCL identified 60 vehicles for further study; this study was completed and reported in the Task 3 vehicle utilization report. In summary, this subset of vehicles contains four sedans, five minivans, nine sports utility vehicles (SUVs), twenty-eight pickup trucks, four cargo vans, eight passenger vans, and two specialty vehicles. This distribution intended to be representative of the entire non-tactical fleet.

PEVs that currently are commercially available cannot replace certain vehicles and missions, such as those requiring heavy-duty trucks and some specialty use vehicles. However, the Task 3 vehicle utilization report suggested that, based on the data collected for the monitored vehicles, the 60-vehicle fleet subset could possibly consist of one conventional heavy-duty specialty truck, 25 BEVs, and 34 PHEVs. Table Table 1 shows the replacement summary.

Table 1. Monitored vehicle replacement summary.

	Sedan – Compact	Sedan – Midsize	Sedan – Large	Minivan	SUV	Van Cargo	Van Pass	Pickup	Specialty	Total
ICE	—	—	—	—	—	—	—	—	1	1
BEV	—	2	—	1	2	2	5	13	—	25
PHEV	2	—	—	4	7	2	3	15	1	34
Total	2	2	—	5	9	4	8	28	2	60

ICE = internal combustion engine

The monitored vehicles represent 60 vehicles of 784 on-road, rated vehicles in these represented fleets. Assuming that the balance of these fleets operate in a manner similar to those monitored and without consideration of specific cargo or other mission requirements not previously identified, Intertek suggests the total fleet composition could consist of 53 conventional heavy-duty specialty trucks, 418 BEVs, and 313 PHEVs. Table 2 shows this replacement summary.

Table 2. Total fleet replacement summary.

	Sedan – Compact	Sedan – Midsize	Sedan – Large	Minivan	SUV	Van Cargo	Van Pass	Pickup	Specialty	Total
ICE	—	—	—	—	—	—	—	—	53	53
BEV	3	14	7	35	34	38	64	223	—	418
PHEV	3	9	36	32	42	24	45	113	9	313
Total	6	23	43	67	76	62	109	336	62	784

The 60 vehicles monitored in the study at MCBCL generally belong to two groups: Tennant Commands (i.e., Commands) and Marine Corps Installations East (i.e., MCIE). PEV replacements and recommendations for the total 784 vehicle replacements are separated by these groups. Specific analysis by fleet group is provided in Section 4. Figure 1 illustrates the final suggested vehicle summary.

3. PLUG-IN ELECTRIC VEHICLE CHARGING

Refueling electric vehicles presents some challenges and some opportunities not encountered when refueling petroleum-fueled vehicles. Recharging the battery of a PHEV follows the same methodology as that for BEVs. This section provides basic information about recharging PEVs.

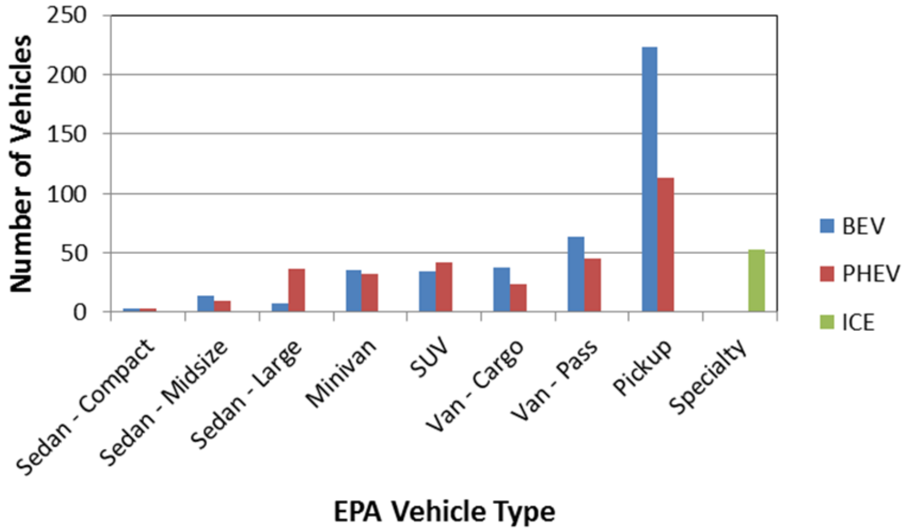

Figure 1. PEV type distribution for all vehicles.

3.1 Electric Vehicle Supply Equipment Design

3.1.1 Charging Components

Electric vehicle supply equipment (EVSE) stations deliver electric power from the electric grid to the applicable charge port on the vehicle. Figure 2 illustrates the primary components of a typical alternating current (AC) Level 2 EVSE.

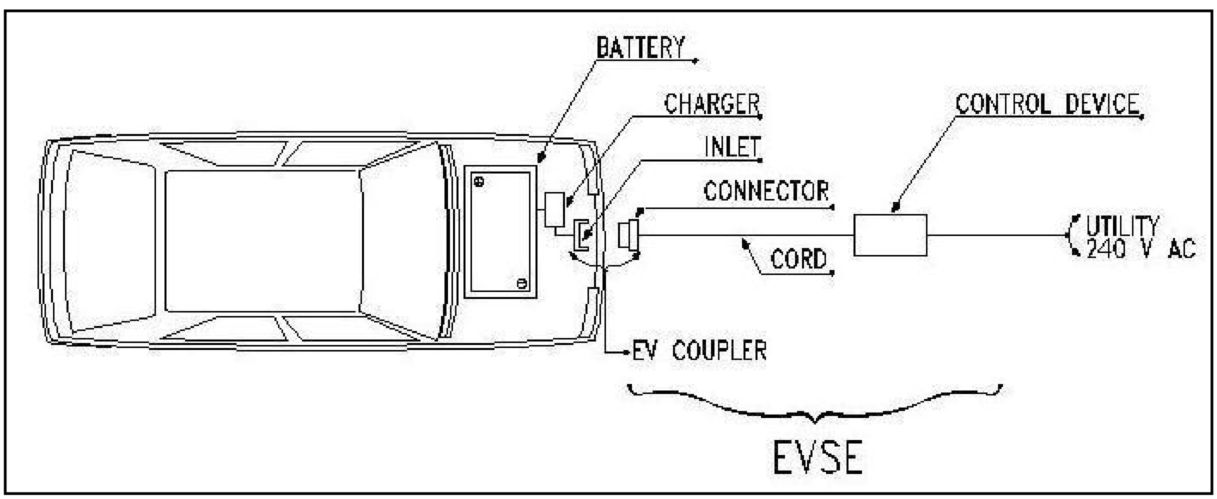

Figure 2. AC Level 2 charging diagram.[2]

The electric utility delivers AC current to the charging location. The conversion from AC to the direct current (DC) electricity necessary for battery charging can occur either on or off board the vehicle. Section 3.5.1.2 provides further explanation of the different EVSE configurations. For onboard conversion, AC current flows through the PEV inlet to the onboard charger. The charger converts AC to

[2] http://avt.inl.gov/pdf/EVProj/EVChrgInfraDeployGuidelinesPhoenixVer3.2.pdf [accessed March 7, 2015].

the DC current required to charge the battery. A connector attached to the EVSE inserts into a PEV inlet to establish an electrical connection to the PEV for charging and information/data exchange. Off-board conversion, also known as DC charging, proceeds in a similar manner except that the AC to DC conversion occurs in a charger that is off board the vehicle and, thus, bypasses any onboard charger. For both AC and DC charging, the PEV's battery management system on board the vehicle controls the battery rate of charge, among other functions. All current PEVs have an onboard charger; some BEVs (but no PHEVs currently available in the United States) accommodate DC charging.

3.1.2 Charging Configurations and Ratings

The Society of Automotive Engineers standardized the requirements, configurations, and equipment followed by most PEV suppliers in the United States in the J1772^{TM} Standard. Figure 3 summarizes these attributes and the estimated recharge times. Actual recharge times depend on the onboard equipment, including the charger, battery, and battery management system.

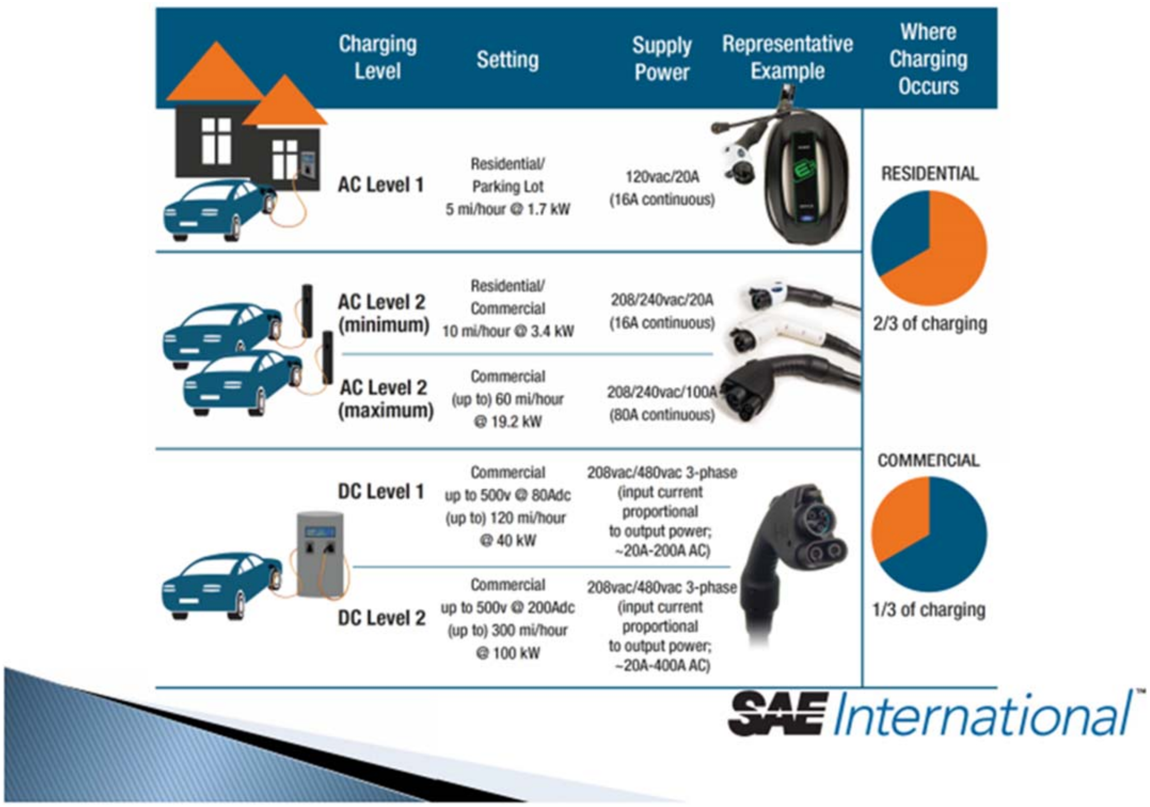

Figure 1. Society of Automotive Engineers charging configurations and ratings terminology.[3]

PEVs are typically sold with an AC Level 1 cordset included. This cordset is generally intended to be used when a 120-volt electrical outlet is available (and a slower charge rate is acceptable) or in emergencies when the vehicle is away from installed AC Level 2 EVSE. A typical cordset is shown in Figure 4. AC recharging capabilities found in the public arena more typically are AC Level 2. Figure 5 depicts a typical J1772-compliant inlet and connector for both AC Levels 1 and 2.

The J1772 standard also identifies requirements for DC charging. For PEVs that accept both AC and DC inputs, the Society of Automotive Engineers approved a single connector and inlet design known as

[3] http://www.sae.org/events/gim/presentations/2013/pev_charging_standards_status.pdf [accessed June 25, 2015].

the combined charging system. Figure 6 shows this connector, which is colloquially known as the J1772 "combo connector."

Figure 4. Chevrolet Volt AC Level 1 cordset.[4]

Figure 5. J1772 connector and inlet.[5]

Some BEVs delivered in the United States prior to approval of the J1772 standard for DC charging employed the CHAdeMO (designed in Japan) standard for connector and inlet design. Figure 7 shows this connector. EVSE units that are either J1772-compliant or CHAdeMO-compliant are both known as DC fast chargers (DCFCs). Tesla Motors has installed proprietary EVSE units for their vehicles because these vehicles do not meet either DCFC standard; however, Tesla offers adapters for their vehicles that allow for charging at J1772 AC Level 2 and CHAdeMO EVSE. Tesla has also developed a network of "superchargers" for use with their vehicles that provide up to 120-kW power.[6]

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[4] www.pluginamerica.org.

[5] http://carstations.com/types/j09 [accessed March 7, 2015].

[6] http://www.teslamotors.com/supercharger [accessed March 7, 2015].

Figure 6. J1772-compliant combo connector.[7]

Figure 7. CHAdeMO-compliant connector.[8]

Presence of the three separate standards for DC charging presents challenges for vehicle owners to ensure the EVSE accessed provides the appropriate connector for their vehicle inlet. Not all PEV suppliers include DC charging options. BEV suppliers have provided DC inlets, where PHEV suppliers have not because the rapid recharging provides opportunities for expanded vehicle range with minimal operator wait times. PHEV operators can rely on the gasoline drive in the event they deplete the vehicle's battery (and for comparison to the energy transfer of the charge rate, the energy being added by the gasoline pump is about 10 MW). At present, no PHEV on the market or near commercialization has DC charging capability (although the upcoming Mitsubishi Outlander PHEV may offer DC charging capability as an option).

Because the battery of a BEV is typically much larger than that of a PHEV, recharge times are longer (see Figure 3). BEVs that see daily mileage near the limits of the advertised range do better when recharged using AC Level 2 EVSE or DCFC, because AC Level 1 recharge times are usually extensive. PHEVs, on the other hand, generally can use AC Level 1 EVSE for overnight charging to ensure a fully charged battery at the start of daily use. AC Level 2 EVSE units provide greater range in the shortest amount of time when intermediate or opportunity charging. DCFC provides the fastest recharge capability for those vehicles equipped with DCFC inlets.

[7] http://www.zemotoring.com/news/2012/10/sae-standardizes-j1772-fast-dc-charging-up-to-100-kw [accessed March 7, 2015].

[8] https://radio.azpm.org/p/azspot/2012/5/10/1632-electric-cars/ [accessed March 7, 2015].

3.2 Electric Vehicle Supply Equipment Stations

Figure 8 provides an example of a public AC Level 2 EVSE unit.[9] The unit shown is known as a "pedestal" or "bollard" unit because it is a self-standing unit. Wall or post-mounted models are also available by several suppliers.

Figure 8. AC Level 2 unit.

AC Level 1 EVSE is also available in permanently installed models and is similar in appearance to that of AC Level 2 units.

AC Level 2 charging is the predominant rating of publicly accessible EVSE because of its wide acceptance by auto manufacturers and faster recharge times than AC Level 1. Purchase and installation costs are more manageable than DCFCs and less space is required. There are several manufacturers of AC Level 2 equipment and the agency should review brands for comparison purposes.

DCFCs also are available from several manufacturers. Figure 9 illustrates one such charger.[10] This particular unit uses the CHAdeMO connector standard.

In general, installation costs are higher for DCFC because of the higher voltage requirements and inclusion of the AC to DC converter and other safety and design features. Installation costs for both types are highly dependent on site characteristics such as distance to the nearest power source, asphalt or concrete cutting and repair, conduit requirements, and payment systems, if any.

Payment and equipment control systems included by some suppliers provide the potential for use by privately owned vehicles for a fee, but allow agency fleet vehicle use without direct payment. These systems allow for accurate record keeping of vehicle charging requirements.

EVSE designs also include dual port or multi-port options that feature charging vehicles simultaneously or sequentially depending on the design.

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[9] http://www.chargepoint.com/files/73-001061-01-2_BR-CT4000-01.pdf [accessed March 7, 2015].

[10] http://evsolutions.avinc.com/products/public_charging/public_charging_b [Accessed March 7, 2015].

Figure 9. Public DCFC.

At times, fleet vehicles obtain benefit from using public charging infrastructure. Figure 10 displays the availability of public charging at the time of this writing for the MCBCL area. The green-colored sites are AC sites, indicating either AC Level 1 or Level 2 public charging locations.

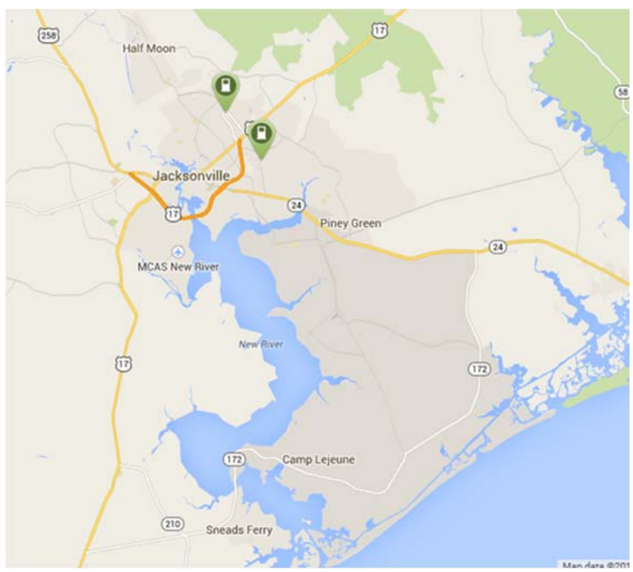

Figure 10. Public EVSE in MCBCL region.[11]

Not shown in Figure 10 is the high density of publicly accessible EVSE in the greater Raleigh-Durham area that reflects the high local interest and adoption of PEVs. This also illustrates the potential for adoption of PEVs by MCBCL attached military, civilian employees, and local contractors who may be interested in PEV charging locations.

[11] http://www.plugshare.com/ [accessed February 10, 2015].

3.3 Electric Vehicle Supply Equipment Installation

Numerous factors must be considered before installation of EVSE can occur. The *Electric Vehicle Charging Infrastructure Deployment Guidelines* document provided by The EV Project[12] provides specific information related to commercial fleet charging. While military bases may not be required to address all of these considerations, this information may be of use in site selection. Figure 11 provides a flowchart of installation considerations for fleet applications. Specific considerations include the following:

1. AC Level 1, Level 2, or DCFC Units:

   The Task 3 vehicle utilization report provided recommendations related to the power level needs of the associated vehicles. This will be discussed in detail in Section 4.

2. Proximity to Power Supply Connections:

   Installation of EVSE in a commercial facility typically will consist of installing new dedicated branch circuits from the central meter distribution panel to a Level 2 EVSE. In a commercial fleet, typically, many such EVSE units are in adjacent parking stalls. Proximity to the electrical service is an important factor in locating this parking area. The length of the circuit run and the number of EVSE units will have a significant impact on the cost.[13]

   In addition, costs for installation will be influenced by whether concrete or asphalt cuts will be required, along with restoration of these surfaces. Conduit runs through landscaped areas will be less expensive.

   Consideration should also be given to the potential for adding PEVs in the future. Installing additional conduit and conductors to feed future EVSE units reduces future costs, while not adding significantly to current costs.

3. Parking Space Restrictions:

   Determination should be made in advance whether the EVSE parking space will be restricted to PEVs only. If so, dedication of these spaces may reduce the availability of spaces for conventional vehicles. This may affect the functional needs of the existing operation. On the other hand, non-PEVs parking in charging locations will inhibit the recharge ability of the PEVs and may interfere with their mission. Intertek recommends dedicating charging stations to PEV charging only.

4. Americans with Disabilities Act Considerations:

   The Americans with Disabilities Act provides requirements on accessibility for many situations, but it does not directly address PEV charging stations. The EV Project provided recommendations to maximize compliance within the specific restraints and constraints of PEV operation. While the exact requirements may not be applicable to military bases, the recommendations may present best practices for MCBCL consideration.[14]

5. Physical Protection of the Equipment:

   Unless de-energized by the local disconnect, EVSE are considered electrically energized equipment. Because EVSE operates above 50 volts, Part 19 Electrical Safety of the Occupational Health and Safety Regulation requires guarding live parts. EVSE may be positioned in a way that requires a

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[12]http://avt.inl.gov/pdf/EVProj/EVChrgInfraDeployGuidelinesSanDiegoVer3.2.pdf [accessed March 7, 2015].

[13] Ibid.

[14] http://avt.inl.gov/pdf/EVProj/EVProjectAccessibilityAtPublicEVChargingLocations.pdf [accessed March 7, 2015].

physical barrier for its protection. Frequently, wheel stops, curbs, or bollards are used to provide physical protection.

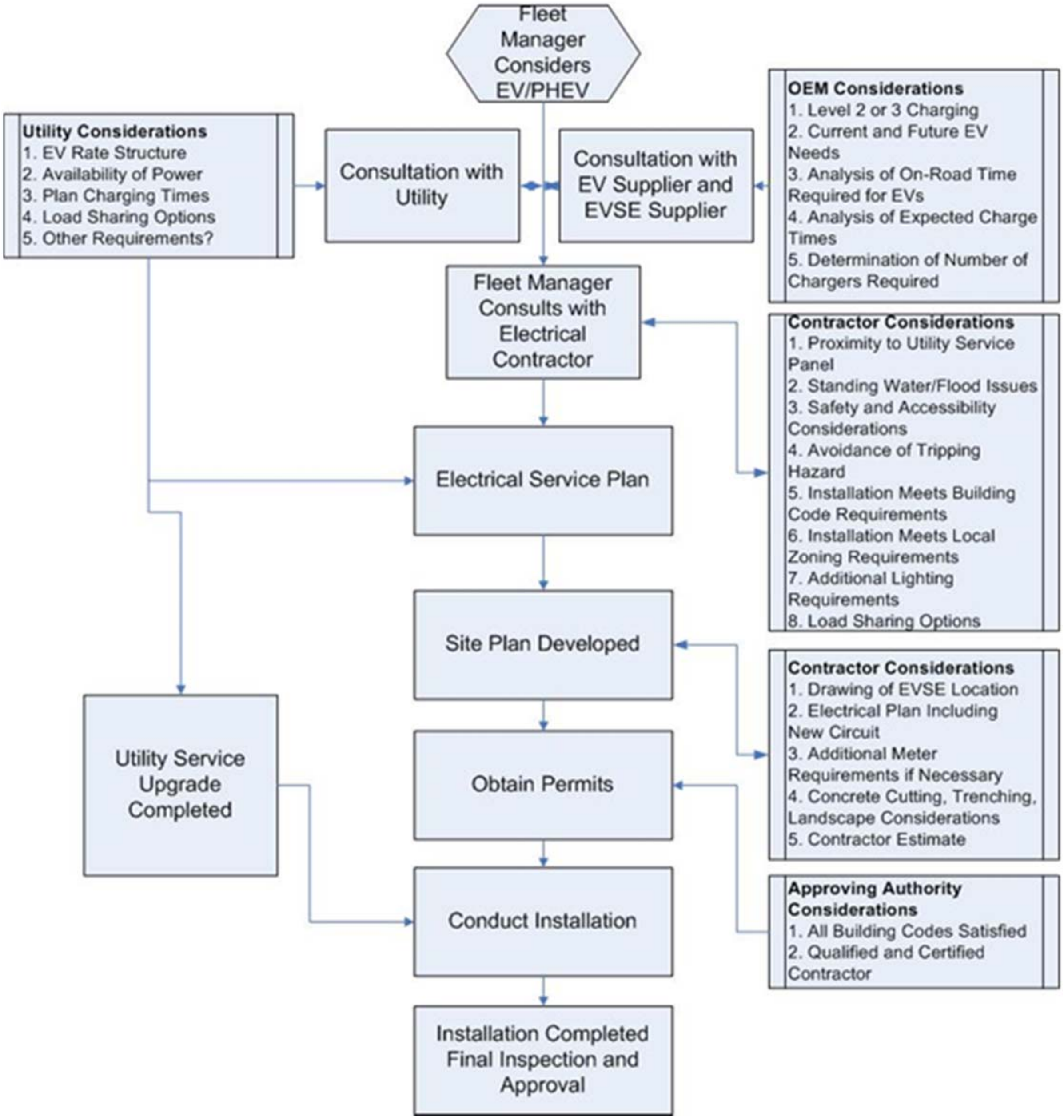


Figure 11. Installation process for commercial fleet operation.[15]

6. Accessibility and Usage:

EVSE units typically will be powered from the electrical grid near the parking location. The base provides this electrical supply for general use to carry out its mission on the base. The power delivered to fleet vehicles supports their U.S. Department of Defense mission. However, federal restrictions do not allow use of federally provided electrical power to be utilized by privately owned

[15] Ibid.

vehicles (POVs). For each EVSE installed, the installing agency fleet must decide whether access to the EVSE will be restricted to fleet vehicle sonly or whether POVs will be allowed to utilize these units.

Restricting use to agency fleet vehicles can be accomplished by physically segregating the charging infrastructure to restricted parking locations that can be fenced and gated or by electronically segregating the usage by use of access control cards. Several EVSE suppliers provide access cards capable of allowing usage only by authorized cardholders.

Another option may be to allow use by POV drivers with access cards that assess a fee for the charging opportunity. Under this option, the fleet drivers' cards allow access without the fee but the POV driver is charged the fee. The fee structure can be based on the cost of electrical energy dispensed or by the amount of time connected. EVSE suppliers have options related to these structures. Fleets managers will need to monitor EVSE usage to ensure their fleet vehicles have charging priority to complete their mission.

7. Data Acquisition and Reporting:

   It is likely that accounting for the electrical energy used for recharging vehicles will be required. Typically, the electrical energy supplied to a building is a facility cost, but energy delivered to PEVs will be fuel costs. While supply to the EVSE can be metered, Intertek suggests use of "smart" EVSE that are capable of data collection and transmittal, which can be very useful for identifying usage associated with specific vehicles and enhancing fleet management.

8. Base Cyber Security:

   Smart EVSE are likely to collect data locally in the EVSE or network of EVSE and transmit via internet or cellular communications to an offsite data center. Transmittal of the data back to the U.S. Department of Defense facility may create issues with cyber security for the facility. Local transmittal to the appropriate fleet manager could be a benefit.

Figure 12 shows a fleet EVSE installation with a significant number of stations having physical protection barriers. This site is not accessible to the public or for use by POVs.

Figure 12. Typical fleet charging installation.[16]

[16]http://avt.inl.gov/pdf/EVProj/EVChrgInfraDeployGuidelinesSanDiegoVer3.2.pdf [accessed March 7, 2015].

EVSE installations intended for use by POVs may be required to follow other requirements. Figure 13 shows a public installation site complying with the Americans with Disabilities Act requirements. Note the accessible EVSE and parking location on the right.

Figure 13. Publicly accessible EVSE.[17]

The General Services Administration provides information and guides related to PEVs. The Installation Guide linked on their website provides specific installation instructions for the ChargePoint Networked Charging Station.[18] These instructions apply once all other site conditions have been resolved and provide detailed systematic instructions for installing a ChargePoint-brand EVSE.

3.4 Electric Vehicle Supply Equipment Advanced Design Considerations

Several other charging topics may be of interest to MCBCL in evaluating EVSE designs.

3.4.1 Public Charging Access

Figure 10 identifies local public charging infrastructure in the MCBCL region. While interest in PEVs is high in the Raleigh Durham area, local interest has yet to develop significantly. For vehicles that travel off base, available infrastructure can provide backup support for charging vehicles. Because PHEVs provide their own backup motive power, this feature may be more important for BEV drivers. However, analysis suggests BEV replacements for current vehicles do not depend on any outside charging availability.

3.4.2 Electric Utility Demand Charges

Duke Energy Progress (formerly Progress Energy) provides electrical supply to MCBCL. Electric rate Schedule LGS-32 (i.e., large general service) for commercial or industrial customers includes electrical supply demand charges.[19] The demand charge is billed at the highest measured demand for the month. Not only is the energy (kWh) consumed billed to MCBCL, but power (kW) delivered is also billed. PEV charging costs are impacted by this demand charge.

Figure 3 identifies power requirements for EVSE charging. Up to 19.2 kW power is identified for AC Level 2. The power is controlled by the PEV's onboard battery management system and the capability of the onboard charger, which are typically rated at 3.6 or 7.2 kW. The power required by DCFC is up to 90 kW, but typical DCFC installed in the MCBCL area deliver up to 60 kW; again, this is controlled by

[17] https://www.flickr.com/photos/blinknetwork1/page3/ [accessed March 7, 2015].

[18] http://gsa.gov/portal/mediaId/184507/fileName/Charging_Station_Installation_Guide.action [accessed March 7, 2015].

[19] http://www.duke-energy.com/pdfs/G9-NC-Schedule-LGS-dep.pdf [accessed August 6, 2015].

the vehicle's battery management system. Duke Energy Progress' demand charge for Schedule LGS-32 is at minimum $11.23/kW. There is a cost impact for operation of both AC Level 2 and DCFC. The impact of DCFC is up to eight times that of AC Level 2, although simultaneous operation of AC Level 2 EVSE can have the same impact.

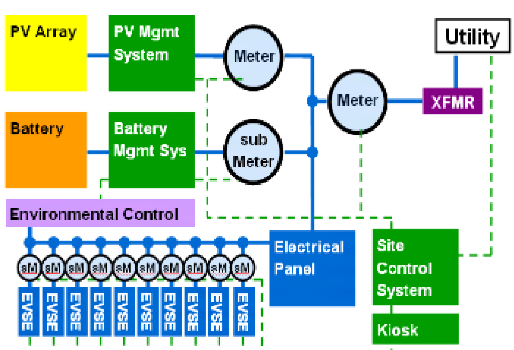
The electric vehicle industry is concerned with this impact, especially for those EVSE installed in public locations by retailers. Methods are being tested to mitigate the impacts of these demand charges. Options for AC Level 2 may include the following:

- Staggering the EVSE start times – This avoids all EVSE operating at high power at the same time.
- Shifting EVSE start times to evening and night hours –Highest usage by MCBCL would typically occur during daytime hours; therefore, the charging peak would not add to the non-charging peak.
- Limiting the power delivered by the EVSE – However, this also reduces the energy returned to the PEVs, resulting in longer recharge times, which defeats many of the benefits of faster charging.
- Augmenting EVSE supply power – Storage-assisted recharging, which is discussed below, is one method to reduce demand from the utility.
- Smart grid charging – Some EVSE are equipped with features, including communications with the electric utility. Automatic controls can be set to reduce or curtail charging upon specific signals from the utility related to overall demand. These features could also be integrated with the site power to assist in lowering charging demand.

All features designed to mitigate power demand may affect recharging of vehicles because power is interrupted or curtained in response, thus influencing the actual power delivered to the PEV.

3.4.3 Storage-Assisted Recharging

Storage-assisted recharging utilizes a storage battery to augment power delivered from the electric grid to provide the PEV recharge energy. Figure 14 provides a conceptual sketch of this system. The system may be available for AC Level 2 or DCFC charging stations. The local storage battery is discharged during the PEV charging operation at a rate that limits power demand from the electric utility, thus limiting the demand charges. The battery may be recharged using renewable energy sources (i.e., wind or solar) or directly from the grid during non-charging operations. System design will depend on the number and ratings of the EVSE and the availability of renewable energy sources and anticipated PEV charging requirements.



Sample System Parameters	
(values are per parking space)	
Solar PV Array	2kW
Battery Storage	5kW/5kWhr
Vehicle Charging	240V, 32A (7.68kW)

Figure 14. Conceptual design of storage-assisted recharging.[20]

[20] http://et.epri.com/Charging_Vehicles_with_Solar_Power_and_Energy_Storage_2011.html [accessed March 7, 2015].

3.4.4 Vehicle-to-Grid

V2G technology is the transfer of energy from the PEV's onboard storage battery to the electrical grid. Uses for this electrical energy include the following:

- Installation peak power shaving
- Frequency regulation/power regulation
- Voltage and VAR optimization
- Voltage regulation
- Spinning reserve functionality
- Emergency back-up power
- Installation micro-grid connectivity and support.[21]

Figure 15 illustrates some of the opportunities for V2G benefits.

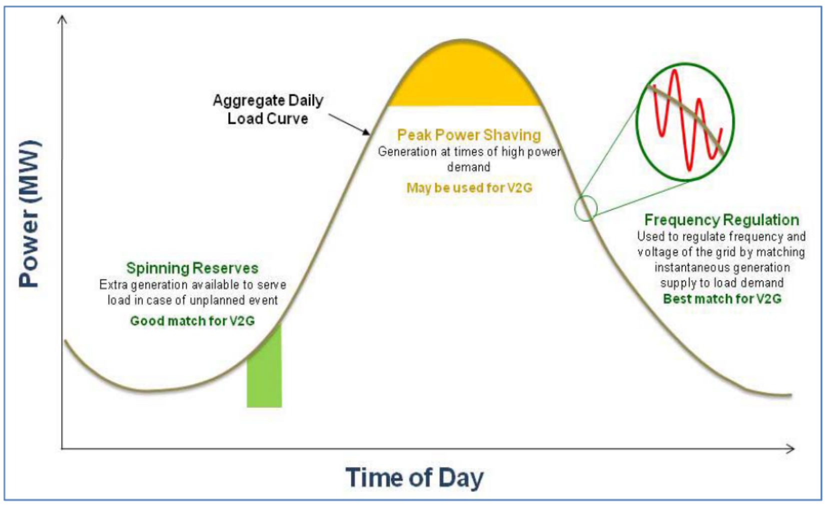


Figure 15. V2G applications.[22]

Electric load for the electric utility typically follows the aggregate daily load curve shown in Figure 15, where peak power demands occur during daylight hours and low power demand occurs in evening and night hours. Utilities match this load by adding or removing generators in their supply. Typically, an electric utility will "base load" generation with their least cost generation capabilities (such as hydroelectric and nuclear). "Spinning reserve" generation is operational and ready to take grid load as demand increases and "peaking" generation covers the peak daily demands with generators that are easier to start and stop (gas) and are typically more costly to run. If sufficient power is available from the storage batteries of the PEVs and that energy can be transferred to the grid, the utility may be able to avoid generation. This saves utility generation costs for which the utility may be disposed to compensate the V2G supplier. In a similar manner, electric utilities may be interested in the other potential benefits noted above.

U.S. Department of Defense is interested in V2G as a potential technology to provide financial support in the adoption of PEVs at U.S. Department of Defense facilities and for support of U.S.

[21] Statement of Work for Grid Services Demonstration – US Army-TARDEC_NAC, April 2, 2012.

[22] Ibid.

Department of Defense energy security in establishing the facility micro-grid. The micro-grid isolates the facility in the event of a sustained loss of utility supplied power and the facility provides its own generation for strategic and tactical missions.

The Smart Power Infrastructure Demonstration for Energy Reliability and Security Program was initiated to address energy security issues in several phases. Each phase increases the size and complexity of the micro-grid as renewable energy sources and V2G are added.[23]

In order to support bi-directional power flow from the vehicle, the vehicle must have the ability to transfer power from the onboard battery off-board to the EVSE. The EVSE must be able to accept the reverse power flow and supply to the local grid. Control systems must be in place to monitor and direct the process and safety and security systems in handling electrical energy and internet/communications systems.

V2G capabilities can be realized with either AC or DC charging equipment. A few DCFC can provide significant power (if the vehicle can support the battery discharge) and the aggregated energy from several AC Level 2 EVSE can also be effective.

V1G capabilities refer to the single-directional power control afforded by controlling the charge rate to the connected PEVs. Rather than reverse power to the grid, grid peak and frequency is controlled by regulating the power delivered to the connected PEVs.

Should MCBCL be interested in possessing V2G or V1G capability, several other design considerations need to be studied and selection of the supplier of the smart EVSE capable of providing bi-directional services would need to be researched.

4. FLEET VEHICLE CHARGING ANALYSIS

Sixty vehicles were included in the study at MCBCL and were assigned to Commands or MCIE. The specific requirements of each group suggest that these data be analyzed by group and by aggregating across all vehicles. The Task 3 vehicle utilization report provides recommendations for PEV substitution for ICE vehicles by these fleets. Several terms were defined during the data collection process and included in that report. Topics directly related to the vehicle-charging infrastructure are emphasized here followed by the analysis by fleet.

4.1 Analysis Background

Non-intrusive data loggers were installed into the monitored vehicle's onboard diagnostic port to collect and transmit relevant data. Data consist of key-on events, key-off events, and position updates logged every minute while the vehicle is keyed on. The Naval Ordnance Safety and Security Activity provided an evaluation of the data transmittal process and approval of the use of these devices.

From these data points, the following information was available for evaluation:

- Trip start and stop time and location
- Trip distance and duration
- Idle start time, location, and duration
- Stop start time, location, and duration.

For charging analysis, the stop locations and durations are the most significant because most recharging will occur at the vehicle's home base.

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[23] *Smart Power Infrastructure Demonstration for Energy Reliability and Security* presentation, USPACOM/USNORTHCOM, May 2012.

It is important to define other terms used in the analysis. Figure 16 illustrates a vehicle outing, which is comprised of trips, stops, and idle events, that may occur over 1 day or several days. The following list provides a definition of these terms:

1. **Outing**: An outing is the combination of trips and stops that begin at the home base and includes all travel until the vehicle returns home.
2. **Trip**: A trip begins with a key-on event and ends with the next key-off event.
3. **Vehicle stop**: A vehicle stop includes a key-off/key-on event pair.
4. **Idle time**: Idle time is the amount of time a vehicle spends stationary after a key-on event when the vehicle is not moving for a period of 3 minutes or longer.
5. **Trip travel time**: Trip travel time is the amount of time required to complete a trip, excluding stops but including idle time.

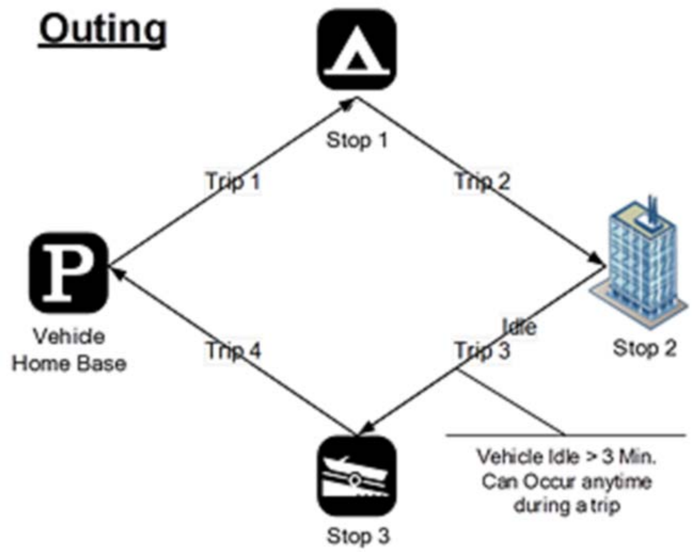

Figure 16. Example vehicle outing.

The vehicle's mission influences PEV recommendations. Based on gathered fleet information, Intertek has established the following seven mission/vehicle categories for analysis (examples are depicted in Figure 17):

1. **Pool vehicles**: A pool vehicle is any automobile (other than the low-speed vehicle identified below) manufactured primarily for use in passenger transportation, with not more than 10 passengers.
2. **Enforcement vehicles**: Vehicles specifically approved in an agency's appropriation act for use in apprehension, surveillance, police, or other law enforcement work. This category also includes site security vehicles, parking enforcement, and general use, but the vehicles are capable of requirements to support enforcement activities.
3. **Support vehicles**: Vehicles assigned to a specific work function or group to support the mission of that group. Vehicles are generally passenger vehicles or light-duty pickup trucks and may contain after-market modifications to support the mission.
6. **Transport vehicles**: Light, medium, or heavy-duty trucks used to transport an operator and tools or equipment of a non-specific design or nature. The vehicle's uses include repair, maintenance, or delivery.

7. **Specialty vehicles**: Vehicles designed to accommodate a specific purpose or mission (such as ambulances, mobile cranes, and handicap controls).
8. **Shuttles/buses**: Vehicles designed to carry more than 12 passengers and further outlined in 49 CFR 532.2.
9. **Low-speed vehicles:** Vehicles that are legally limited to roads with posted speed limits up to 45 mph and that have a limited load-carrying capability.

Figure 17. Vehicle missions.

4.2 Plug-In Electric Vehicle Charging Analysis Results – Commands

This section summarizes and aggregates data collection for the Commands Group. The details of each monitored vehicle are included in Appendix B of the Task 3 vehicle utilization report.

4.2.1 Commands Group Recommended Plug-In Electric Vehicles for Monitored Vehicles

The Task 3 vehicle utilization report recommended replacement of the monitored vehicles with those identified in Table 3 (see that report for vehicle analysis). All the vehicles in the group are support vehicles.

Table 3. Commands Group monitored vehicle replacements.

Vehicle Index					
Fleet Vehicle Id	Make	Model	EPA Class	Replacement PEV	Mission
291073	Ford	E250	Van - Pass	eNV200	Support
301321	Ford	F350	Pickup	eNV200	Support
G41-0762M	Dodge	Grand Caravan	Minivan	Outlander	Support
G41-1846K	Dodge	Grand Caravan	Minivan	Outlander	Support
G41-2399K	Dodge	Dakota	Pickup	eNV200	Support
G42-0216F	Ford	E150	Van - Pass	eNV200	Support
G42-0883M	Ford	E150	Van - Pass	VTRUX Van	Support
G42-0898M	Ford	E150	Van - Pass	VTRUX Van	Support

Vehicle Index					
Fleet Vehicle Id	Make	Model	EPA Class	Replacement PEV	Mission
G43-0326H	Chevrolet	2500HD	Pickup	eNV200	Support
G43-1453G	Chevrolet	G2300	Van - Pass	Soul	Support
G43-1855P	Ford	F350	Pickup	VTRUX PU	Support
G43-2025K	Ford	F250	Pickup	Soul	Support
G43-4073F	Chevrolet	G2300	Van - Pass	eNV200	Support
G61-0594L	Jeep	Patriot	SUV	Outlander	Support
G61-2644P	Jeep	Patriot	SUV	Outlander	Support
G62-0791H	Ford	Expedition	SUV	Outlander	Support
G63-0309R	Ford	F350	Pickup	VTRUX PU	Support
G63-0934G	Chevrolet	K3500	Pickup	VTRUX PU	Support

4.2.2 Commands Group Available Charge Time

The Task 3 vehicle utilization report also identified the aggregated travel time summary for these monitored vehicles. The relevant section from that report is provided in Table 4.

Table 4. Support vehicle travel time summary.

Support Vehicles Travel Time Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Minutes)	133.4/836.0	51.7/1,008.4	22.6/315.0	47,097
Idle Time (Minutes)	2.2/NA	16.7/NA	7.3/NA	14,687

As shown above, average daily usage was just over 2 hours per day. The peak daily usage was 13.9 hours. The peak outing time was higher because of overnight trips away from the home base. The distribution of daily travel times is shown in Figure 18. Further, 28% of daily travel time was of 50 minutes duration or less.

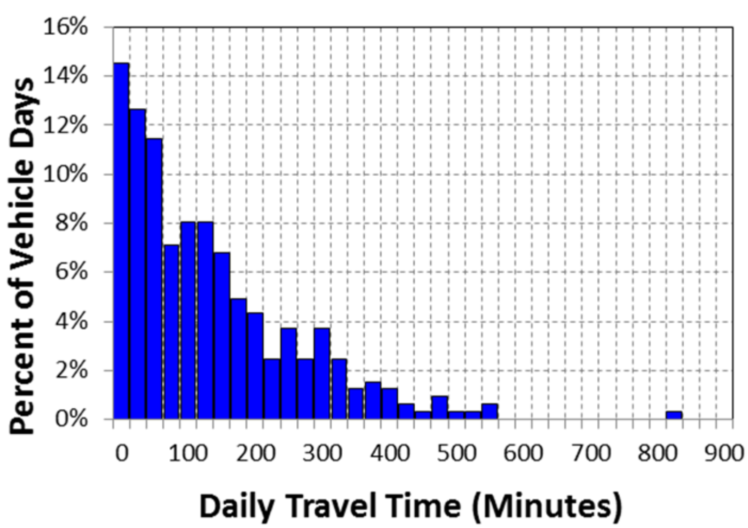

Figure 18. Support vehicle daily travel time.

The Task 3 vehicle utilization report identified that the Commands vehicles were operated on 58% of the study days at an average daily usage of 2.2 hours. In general, the vehicles were used on frequent days, but average usage per day was quite low.

4.2.3 Commands Group Electric Vehicle Supply Equipment Type Information

As reported in the Task 3 vehicle utilization report, AC Level 2 overnight charging of BEVs is typical, whereas overnight charging of PHEVs can usually be accomplished with AC Level 1 charging. This would result in a typical recommendation to provide eight AC Level 2 EVSEs for the BEVs and 10 AC Level 1 EVSEs for the PHEVs. However, daily travel time and distance were typically so low that the time for recharge was not a concern.

4.2.4 Commands Group Electric Vehicle Supply Equipment Charging Locations

The home bases of the 18 monitored vehicles as recorded by their stop and overnight logger data are shown in Table 5.

Table 1. Commands Group vehicle home base.

Logger ID	Fleet Vehicle Id	Replacement PEV	Home Base
88	291073	eNV200	PP2
17	301321	eNV200	TC771
95	G41-0762M	Outlander	AS217
86	G41-1846K	Outlander	BA134
83	G41-2399K	eNV200	1707
90	G42-0216F	eNV200	102
92	G42-0883M	VTRUX Van	AS4108
84	G42-0898M	VTRUX Van	FC400
18	G43-0326H	eNV200	G554
103	G43-1453G	Soul	FC306
19	G43-1855P	VTRUX PU	G702
20	G43-2025K	Soul	TC846
110	G43-4073F	eNV200	RR272
87	G61-0594L	Outlander	518
94	G61-2644P	Outlander	AS4122
91	G62-0791H	Outlander	SAW353
99	G63-0309R	VTRUX PU	AS4157
120	G63-0934G	VTRUX PU	RR450

Figure 19 maps the home base locations. The vehicles for the Commands Group typically park overnight at their home base. At times, PEVs may benefit from additional charge opportunities if EVSE are located in areas where they frequently stop.

The number of times a vehicle parks in a location is of little value in determining where to place EVSE. Rather, the length of time a vehicle is parked at a particular location is of more value, because some recharge may occur at the EVSE.

Figure 20 identifies the locations where Commands vehicles parked for more than 2 hours. The size of the symbol indicates the length of time parked; it is capped at 1 week’s duration. The locations identified in Figure 20 were essentially the home base locations. As noted previously, sufficient recharge time was available at the home base locations to reduce the desirability of adding EVSE stations elsewhere. Details of potential EVSE locations are shown in Section 5.

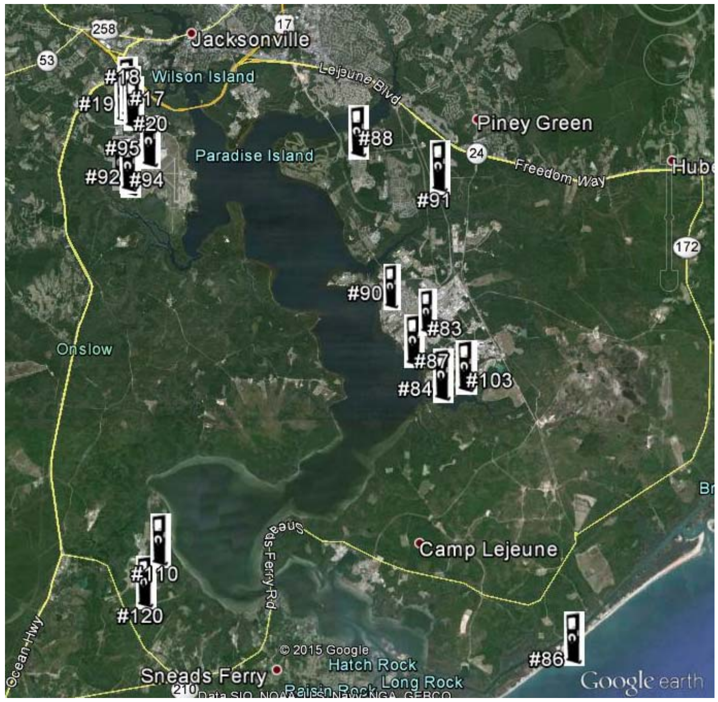

Figure 19. Commands Group home bases.

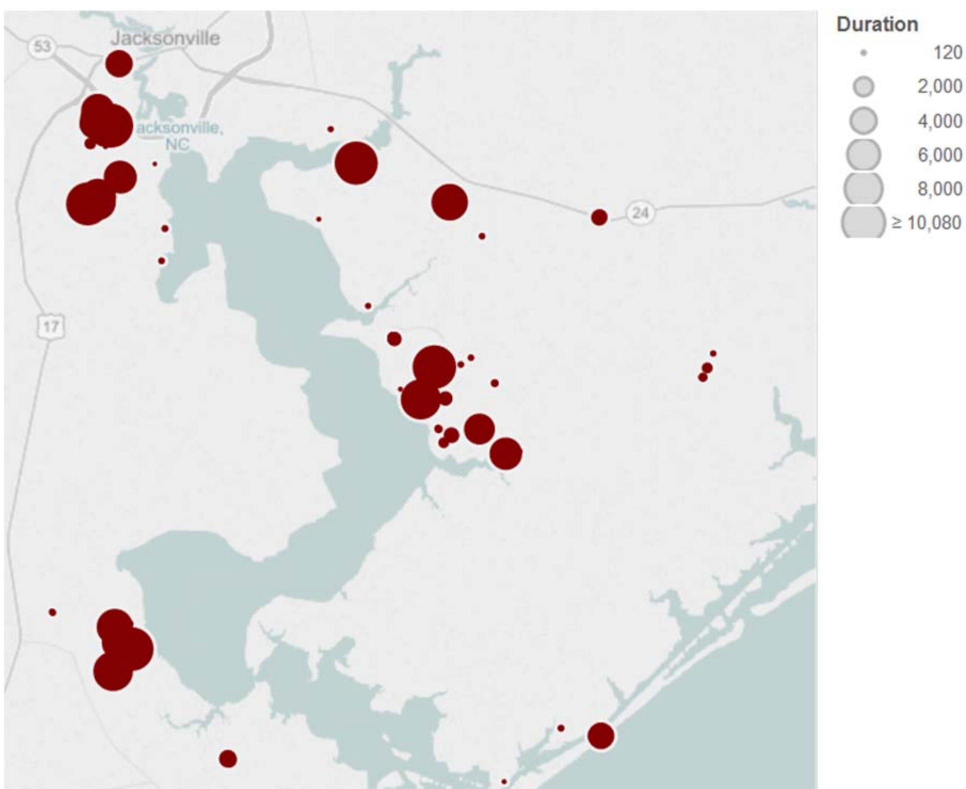

Figure 20. Commands Group vehicle stop locations by duration.

Figure 20 show that although the vehicles may have parked for a significant time away from the home base, the duration is insignificant compared to home-base parking.

4.2.5 Commands Group Electric Vehicle Supply Equipment Observations

Data show that the recommended PEVs should have sufficient time daily for recharging at the home base. The infrequent nature of the away-from-home base charging suggests that such would not be of much benefit. Thus, home base charging only is suggested. Table 5 shows that all Commands vehicles are parked in unique locations. While vehicles may occasionally charge while visiting another site, there is no apparent possibility of PEVs regularly sharing an EVSE.

Eight BEVs and 10 PHEVs suggest that eight AC Level 2 EVSEs and 10 AC Level 1 EVSEs would be appropriate. Table 6 provides identification of the number and type of EVSE for each building. Section 5 provides suggested locations for these EVSE.

When installing EVSE, at least two of the type should be installed to reduce installation costs. However, because many of these sites have single vehicles assigned, the site may benefit from installation of the single EVSE with all preparations made for the second unit without actually installing it. This "stub-up" arrangement would allow the second unit to be installed later when the demand for that unit occurs.

Table 6. EVSE assignments by building.

Building	Vehicles Assigned	BEVs Recommended	PHEVs Recommended	AC Level 2 EVSE	AC Level 1 EVSE
PP2	1	1	—	1	—
TC771	1	1	—	1	—
AS217	1	—	1	—	1
BA134	1	—	1	—	1
1707	1	1	—	1	—
102	1	1	—	1	—
AS4108	1	—	1	—	1
FC400	1	—	1	—	1
G554	1	1	—	1	-
FC306	1	1	—	1	-
G702	1	—	1	-	1
TC846	1	1	—	1	—
RR272	1	1	—	1	—
518	1	—	1	—	1
AS4122	1	—	1	—	1
SAW353	1	—	1	—	1
AS4157	1	—	1	—	1
RR450	1	—	1	—	1

Utilization of these Commands vehicles suggests that eight AC Level 2 EVSE and 10 AC Level 1 EVSE ports will be sufficient. Connecting the vehicles overnight should provide sufficient recharge time for all vehicles.

Both BEVs and PHEVs can benefit from charging at either an AC Level 2 or AC Level 1 EVSE. PHEVs connected to AC Level 2 are recharged faster and present no issues. With additional management attention and knowledge of the vehicle's utilization, BEVs may be charged from AC Level 1, thus reducing the AC Level 2 requirements. However, a more conservative approach is presented here.

4.2.6 Commands Group Fleet Summary

This study provides observations for the vehicles monitored and for the entire non-tactical fleet of vehicles identified within the Commands Group.

The fleet of support vehicles in this study included two minivans, three SUVs, six passenger vans, and seven pickup trucks. Intertek suggests that replacing these 18 vehicles with eight BEVs and 10 PHEVs would meet current mission requirements and that eight AC Level 2 and 10 AC Level 1 EVSE ports should be sufficient for recharging.

Considering a full complement of 249 support vehicles in the Commands Group fleet, Intertek suggests a fleet of one 143 BEVs and 106 PHEVs meets vehicle travel requirements. It is surmised that many of these vehicles will be assigned to the buildings identified above and that, with management attention, the PEVs can share the charging times at the EVSE. All Commands Group vehicles have a support mission and, assuming that the full fleet operates in a manner similar to those monitored, it is likely that 95AC Level 2 and 70 AC Level 1 EVSE could provide the necessary recharge capabilities with management attention to ensure all vehicles are rotated on the equipment and receive their recharge.

These suggestions can be factored into further observations and suggestions related to the business case and schedule for any replacements for the Commands Group. Those observations will be addressed in Task 4 of this project.

4.3 Analysis Results – Marine Corps Installations East Group

This section summarizes and aggregates data collection for the MCIE Group fleet. The details of each vehicle monitored are included in Appendix C of the Task 3 vehicle utilization report.

4.3.1 Marine Corps Installations East Group Recommended Plug-In Electric Vehicles for Monitored Vehicles

The Task 3 vehicle utilization report recommended replacement of the monitored vehicles with those identified in Table 7 (see that report for the vehicle analysis). Ten vehicles had a pool mission, five had an enforcement mission, twenty-five were support vehicles, and two had specialty missions.

Table 7. MCIE Group monitored vehicle replacements.

Vehicle Index					
Fleet Vehicle Id	Make	Model	EPA Class	Replacement PEV	Mission
290597	Ford	E350	Van - Cargo	VTRUX Van	Pool
291007	Ford	F550	Specialty/Refrig.	NA	Specialty
294285	Chevrolet	Malibu	Sedan - Midsize	Leaf	Support
294293	Chevrolet	HHR	SUV	Soul	Enforcement
294315	Chevrolet	3500	Pickup	eNV200	Support
294324	Chevrolet	HHR	SUV	Outlander	Support
300672	Ford	F550	Specialty/Bucket	EDI	Specialty
302039	Ford	F250XL	Pickup	VTRUX PU	Support
302040	Ford	F250XL	Pickup	VTRUX PU	Support
302334	Ford	F350 Stake	Pickup	VTRUX PU	Support

Vehicle Index					
Fleet Vehicle Id	Make	Model	EPA Class	Replacement PEV	Mission
G10-3327L	Chevrolet	Malibu	Sedan - Midsize	Leaf	Pool
G13-0325K	Ford	Focus	Sedan - Compact	Volt	Support
G13-7974P	Ford	Focus	Sedan - Compact	Volt	Support
G41-0379H	Dodge	Grand	Minivan	Soul	Pool
G41-0391H	Dodge	Dakota	Pickup	VTRUX PU	Support
G41-0754M	Dodge	Grand	Minivan	Outlander	Pool
G41-0806P	Dodge	Caravan	Minivan	Outlander	Support
G41-1689L	Ford	Ranger	Pickup	VTRUX PU	Support
G41-3297K	Ford	Ranger	Pickup	eNV200	Support
G41-3300K	Ford	Ranger	Pickup	VTRUX PU	Enforcement
G41-3301K	Ford	Ranger	Pickup	eNV200	Support
G42-0644M	Ford	E150	Van - Pass	eNV200	Pool
G42-0667P	Ford	F150	Pickup	VTRUX PU	Support
G42-0671P	Ford	F150	Pickup	eNV200	Support
G42-0911L	Chevrolet	C1500	Pickup	eNV200	Pool
G42-0915M	Ford	F150	Pickup	eNV200	Support
G42-2985H	Chevrolet	C1500	Pickup	VTRUX PU	Enforcement
G43-0310H	Ford	E350	Van - Pass	VTRUX Van	Pool
G43-0323H	Ford	E350	Van - Cargo	VTRUX Van	Support
G43-0324H	Ford	E350	Van - Cargo	eNV200	Support
G43-1182M	Chevrolet	CG3300	Van - Cargo	eNV200	Support
G43-4075P	Ford	F250	Pickup	VTRUX PU	Pool
G61-0161H	Dodge	Dakota	Pickup	VTRUX PU	Support
G61-0174H	Jeep	Liberty	SUV	Outlander	Support
G61-0879P	Chevrolet	Equinox	SUV	Outlander	Enforcement
G61-1508D	Jeep	Liberty	SUV	Outlander	Pool
G61-1509D	Jeep	Liberty	SUV	Soul	Pool
G62-1583G	Chevrolet	K1500	Pickup	VTRUX PU	Support
G62-4085L	Dodge	1500	Pickup	VTRUX PU	Support
G63-0163H	Chevrolet	K2500HD	Pickup	eNV200	Support
G63-2885L	Chevrolet	K2500HD	Pickup	eNV200	Support
G63-2888L	Chevrolet	K2500HD	Pickup	Soul	Enforcement

4.3.2 Marine Corps Installations East Group Available Charge Time

The Task 3 vehicle utilization report also identified the aggregated travel time summary for these monitored vehicles. The relevant sections from that report for pool, support, and enforcement vehicles are provided in Tables 8, 9, and 10. One of the two monitored specialty vehicles reported sufficient data for analysis, which is included in Table 11.

The average daily usage for the pool vehicles was about 2.4 hours per day. The peak daily usage was about 19 hours. The average daily usage for support vehicles was about 2 hours per day. The longest daily travel was 7.6 hours. The average daily usage for enforcement vehicles was 4.4 hours per day. The longest daily usage was a full 24 hours.

Table 8. Pool vehicles travel summary.

Pool Vehicles Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Minutes)	144.0/1,140.0	35.9/875.0	18.4/504.0	26,781
Idle Time (Minutes)	50.2/NA	12.5/NA	6.4/NA	9,328

Table 2. Support vehicles travel summary.

Support Vehicles Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Minutes)	119.1/456.0	60.2/456.0	18.6/362.0	2,304
Idle Time (Minutes)	23.6/NA	11.5/NA	3.9/NA	466

Table 3. Enforcement vehicle travel summary.

Enforcement Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Minutes)	262.4/1,464.0	105.5/1,209.0	35.0/752.0	31,228
Idle Time (Minutes)	149.7/NA	60.2/NA	20.0/NA	17,726

Table 4. Specialty vehicle travel summary.

Specialty Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Minutes)	126.6/271.0	45.2/171.0	25.8/152.0	1,266
Idle Time (Minutes)	2.1/NA	26.6/NA	5.2/NA	746

The average daily usage for this bucket truck was just over 2 hours. The peak daily usage when driven was 4.5 hours. The distributions of daily travel times for the three major missions are shown in Figure 21.

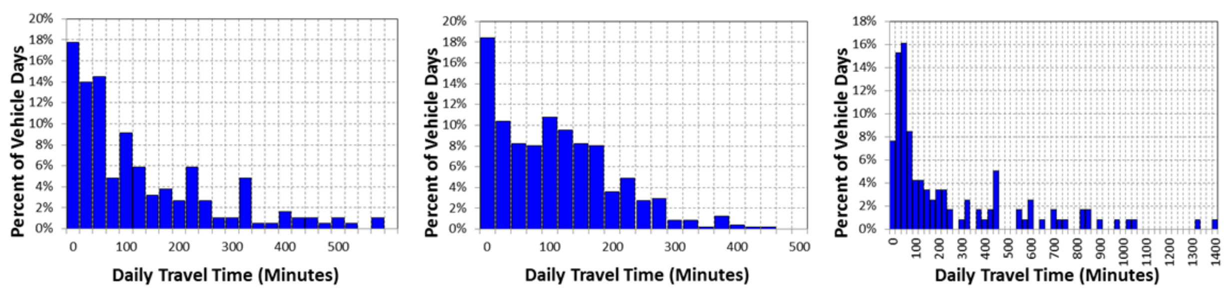

Figure 21. Pool, support, and enforcement vehicle daily travel minutes (all vehicles). NOTE: The pool graph does not show the single highest daily travel of 1,140 minutes. The enforcement graph does not show the highest daily time of 1,464 minutes.

The Task 3 vehicle utilization report identified that the MCIE vehicles were operated on 59% of the study days at an average daily usage of 2.2 hours. In general, the vehicles were used on frequent days, but average usage per day was quite low.

4.3.3 Marine Corps Installations East Group Electric Vehicle Supply Equipment Type Recommendation

As reported in the Task 3 vehicle utilization report, AC Level 2 overnight charging of BEVs is typical, whereas overnight charging of PHEVs can usually be accomplished with AC Level 1 charging. This would result in a typical recommendation to provide 17AC Level 2 EVSE for the BEVs and 24 AC Level 1 EVSE for the PHEVs.

4.3.4 Marine Corps Installations East Group Electric Vehicle Supply Equipment Charging Locations

The home bases of the 42 MCIE monitored vehicles reported by MCBCL and recorded by instrument are shown in Table 12.

Table 12. MCIE Group vehicle home base.

Fleet Vehicle Id	Replacement PEV	Home Base
290597	VTRUX Van	1407
291007	NA	NA
294285	Leaf	1770
294293	Soul	AS302
294315	eNV200	TC701
294324	Outlander	1005
300672	EDI	1023
302039	VTRUX PU	670
302040	VTRUX PU	FC436
302334	VTRUX PU	56
G10-3327L	Leaf	FC500
G13-0325K	Volt	67
G13-7974P	Volt	1117
G41-0379H	Soul	M305
G41-0391H	VTRUX PU	1117
G41-0754M	Outlander	1407
G41-0806P	Outlander	1005
G41-1689L	VTRUX PU	1005
G41-3297K	eNV200	1005
G41-3300K	VTRUX PU	43
G41-3301K	eNV200	1005
G42-0644M	eNV200	58
G42-0667P	VTRUX PU	1005
G42-0671P	eNV200	BA138
G42-0911L	eNV200	327
G42-0915M	eNV200	978
G42-2985H	VTRUX PU	43
G43-0310H	VTRUX Van	1407
G43-0323H	VTRUX Van	670
G43-0324H	eNV200	FC360
G43-1182M	eNV200	1770
G43-4075P	VTRUX PU	316

Fleet Vehicle Id	Replacement PEV	Home Base
G61-0161H	VTRUX PU	TP464
G61-0174H	Outlander	27
G61-0879P	Outlander	979
G61-1508D	Outlander	58
G61-1509D	Soul	28211
G62-1583G	VTRUX PU	54
G62-4085L	VTRUX PU	58
G63-0163H	eNV200	AS427
G63-2885L	eNV200	2600
G63-2888L	Soul	SAW360B

Figure 22 illustrates these home base locations.

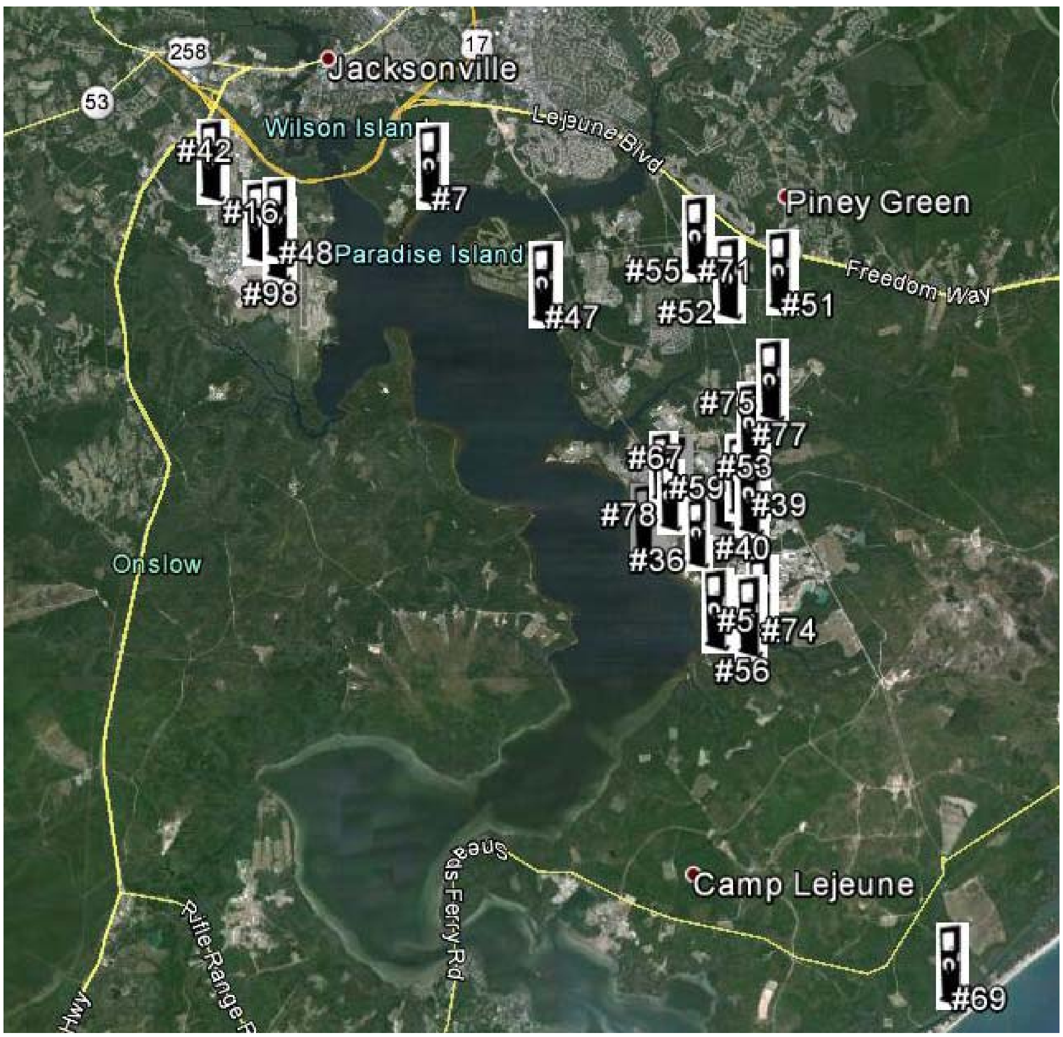

Figure 22. MCIE Group home locations.

The vehicles for the MCIE Group typically parked overnight at their home base. At times PEVs benefit from additional charge opportunities if EVSE are located in areas where they frequently stop.

Figure 23 shows locations where these vehicles parked in the vicinity of the base for more than 2 hours. The size of the symbol indicates the length of time parked at that location capped at 1 week's duration.

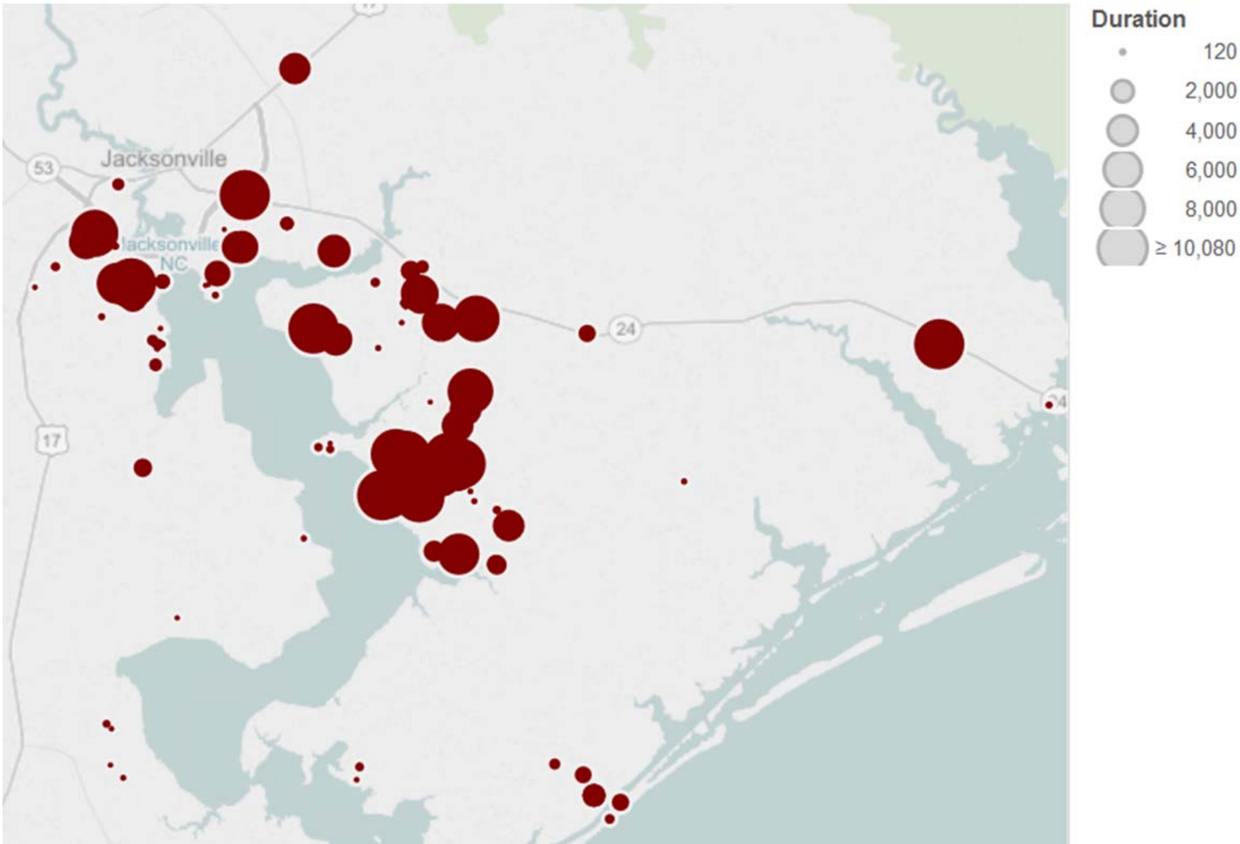

Figure 23. MCIE Group vehicle stop locations by duration.

Significant stops greater than 2 hours occur primarily at the vehicle's home base.

4.3.5 Marine Corps Installations East Group Electric Vehicle Supply Equipment Observations

Data show that the recommended PEVs should have sufficient time daily for recharging at the home base. The infrequent nature of the away-from-home base charging suggests that such would not be of much benefit. Thus, home-base charging only is suggested. Most of the MCIE vehicles were parked in unique locations.

Seventeen BEVs and 24 PHEVs suggest that 17 AC Level 2 and 24 AC Level 1 EVSE would be appropriate. Table 11 shows that, in several cases, a single vehicle is assigned to a particular building, thus, a single EVSE will be required at that building. However, several buildings do have several vehicles assigned. Table 13 provides identification of the number and type of EVSE for each building. Section 5 provides suggested locations for these EVSE.

When installing EVSE, at least two of the type should be installed to reduce installation costs. However, because many of these sites have single vehicles assigned, the site may benefit from installation of the single EVSE with all preparations made for the second unit without actually installing it. This "stub-up" arrangement would allow the second unit to be installed later when the demand for that unit occurs.

Table 13. EVSE assignments by building.

Building	Vehicles Assigned	BEVs Recommended	PHEVs Recommended	AC Level 2 EVSE	AC Level 1 EVSE
27	1	—	1	—	1
43	2	—	2	—	2
54	1	—	1	—	1
56	1	—	1	—	1
58	3	1	2	1	2
67	1	—	1	-	1
316	1	—	1	—	1
327	1	1	—	1	—
670	2	—	2	-	2
978	1	1	—	1	—
979	1	—	1	-	1
1005	6	2	4	2	4
1023	1	—	1	—	1
1117	2	—	2	—	2
1407	3	—	3	—	3
1770	2	2	—	2	—
2600	1	1	—	1	—
28211	1	1	—	1	—
AS302	1	1	—	1	—
AS427	1	1	—	1	—
BA138	1	1	—	1	—
FC360	1	1	—	1	—
FC436	1	—	1	—	1
FC500	1	1	—	1	—
M305	1	1	—	1	—
SAW360B	1	1	—	1	—
TC701	1	1	—	1	—
TP464	1	—	1	—	1

Building 1005 shows two AC Level 2 and four AC Level 1 EVSE recommended. With specific management attention, it may be possible for the PHEVs to double up on the AC Level 1 units. However, because this is the only building in this situation for the monitored vehicles, a separate EVSE for each vehicle is suggested here. Utilization of these MCIE vehicles suggests that 17 AC Level 2 EVSE and 24 AC Level 1 EVSE ports will be sufficient.

Both BEVs and PHEVs can benefit from charging at either an AC Level 2 or AC Level1 EVSE. PHEVs connected to AC Level 2 are recharged faster and present no issues. With additional management attention and knowledge of the vehicle's utilization, BEVs may be charged from AC Level 1 and thus reduce the AC Level 2 requirements. However, a more conservative approach is presented here.

4.3.6 Marine Corps Installations East Group Summary

This study provides observations for the vehicles monitored and for the entire non-tactical fleet of vehicles identified within the MCIE Group.

The vehicles monitored in this study included four sedans, three minivans, six SUVs, two passenger vans, four cargo vans, twenty-one pickup trucks, and two specialty trucks. Intertek suggests that retaining the refrigeration specialty truck and replacing the remaining vehicles with 17 BEV and 24 PHEVs would

meet current mission requirements. Thus, 17 AC Level 2 and 24 AC Level 1 EVSE ports should be sufficient for recharging.

Considering a full complement of 535 vehicles in the MCIE Group fleet, Intertek suggests a fleet consisting of 53 conventional heavy-duty trucks, 275 BEVs, and 207 PHEVs should meet mission objectives. Because utilization of these vehicles is low, sharing of EVSE is possible with management attention; therefore, Intertek suggests 183 AC Level 2 and 138 AC Level 1 EVSE should meet recharging requirements.

Some management attention will be required to ensure the vehicles are effectively rotated on the AC Level 2 EVSE for charging and dispatched based on the battery state of charge. It is likely that such attention is already employed when assigning pool vehicles. Connecting the vehicles overnight should provide sufficient recharge time for all vehicles.

These suggestions can be factored into further observations and suggestions related to the business case and schedule for any replacements for the MCIE Group. Those observations will be addressed in Task 4 of this project.

4.4 Analysis Results – All Monitored Fleet

This section summarizes and aggregates data collection for the aggregated fleet of monitored vehicles. The details of each vehicle monitored are included in Appendices B and C of the Task 3 vehicle utilization report.

4.4.1 Aggregated Fleet Available Charge Time

The aggregated travel time summary for all monitored vehicles is provided in Table 5.

Table 5. All vehicle travel summary.

Aggregated Vehicles Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Time (Hours)	2.5/24	0.9/24	0.4/12.5	2,733
Idle Time (Hours)	0.8/NA	0.3/NA	0.1/NA	904

The average daily usage for all vehicles was 2.5 hours per day. The longest daily travel was a full day for one enforcement vehicle.

The frequented stop locations and durations are identified in the previous sections. There do not appear to be many locations other than home bases where the vehicles park frequently for long durations. While a Command assigned vehicle and an MCIE assigned vehicle may have parked in a common location, such instances were very rare and it appears that there are really no common areas. In addition, a review of the base map does not suggest other locations for EVSE installed for official business.

4.4.2 Aggregated Fleet Summary

This study provides observations for the vehicles monitored and for the entire non-tactical fleet of vehicles at MCBCL.

The vehicles monitored in this study included 60 ICE vehicles of types noted above. Intertek suggests that replacing the vehicles with 25 BEV and

34 PHEVs would meet current mission requirements. Further, 25 AC Level 2 and 34 AC Level 1 EVSE ports should be sufficient for recharging.

Considering a full complement of 784 vehicles in the aggregated fleet, Intertek suggests a fleet consisting of 53 conventional heavy-duty vehicles, 418 BEVs, and 313 PHEVs should meet mission objectives. Because the utilization of these vehicles is low and many vehicles will be assigned at the same buildings, sharing of EVSE is possible with management attention. Intertek suggests 278 AC Level 2 and 208 AC Level 1 EVSE should meet recharging requirements.

Some management attention will be required to ensure the vehicles are effectively rotated on the AC Level 2 EVSE for charging and dispatched based on the battery state of charge. It is likely that such attention is already employed when assigning pool vehicles. Connecting the vehicles overnight should provide sufficient recharge time for all vehicles.

These suggestions can be factored into further observations and suggestions related to the business case and schedule for any replacements for the aggregated fleet. Those observations will be addressed in Task 4 of this project.

4.5 Public Charging Electric Vehicle Supply Equipment Locations

The EVSE recommended in the previous sections are intended for fleet operations. Should MCBCL be interested in providing charging stations to support charging of POVs, specific destination locations should be considered. Some of the points that attract the drivers of POVs are fast food restaurants, the post office, theater, clubs, barracks, commissary, chapel, hospital, etc. Some of these locations are sites recommended for fleet EVSE but these EVSE would generally not be available for POVs.

MCBCL has no direct access from an interstate but Highway 24 is a major route. In some cases, installing DCFC at the exit from to the front gate could be advantageous in providing DC fast charging locations for the public from which the base vehicles can benefit as well.

5. MARINE CORPS BASE CAMP LEJEUNE ELECTRIC VEHICLE SUPPLY EQUIPMENT LOCATIONS DETAILS

5.1 Background

Section 3.3 provides guidance on site selection and installation of EVSE. The availability of electrical power near the desired EVSE location is the most important factor affecting installation costs. Locations nearer the electrical supply will result in shorter conduit and conductor runs to minimize costs. Locations near landscaped areas reduce costs by reducing the amount of asphalt or concrete cuts to install the conduit. At the same time, the location for the fleet vehicles should not be in the most ideal of parking locations for the facility if they are to be restricted for PEV charging only because EVSE are not likely to be available to POVs and other non-fleet vehicles.

Section 5.2 provides some suggested locations for the majority of the monitored fleet vehicle EVSE. In most cases, parking areas near the buildings will produce the least distance from the power center. However, for some buildings that will be destinations for POVs and business other than the fleet vehicles; therefore, site selection may not be the closest building approach.

5.2 Marine Corps Base Camp Lejeune Electric Vehicle Supply Equipment Locations

MCBCL provided the Existing Conditions Infrastructure map, Edition CLJN of January 2015 for use with this study. It identifies the major facilities and infrastructure but excludes information related to electrical distribution. Detailed electrical drawings may be classified and are not available for this report. Thus, sufficient electrical supply to each of the buildings to add EVSE is assumed. Potential EVSE locations identified are based on apparent distances from buildings and ease of installation. Google Earth[24] provides the pictorial maps.

5.2.1 Commands and EVSE Locations

Table 5 identifies home base locations for the Command Group's monitored vehicles. As noted in that table, there are no building locations in common for the Command's monitored vehicles.

Figures 24 through 41 identify potential EVSE installation locations near the home-base building as noted in their captions.

Figure 24. EVSE potential location near Building 102 for Vehicle G42-0216F.

Figure 25. EVSE potential location near Building 518 for Vehicle G61-0594L.

[24] http://www.google.com/earth/ [accessed March 7, 2015]

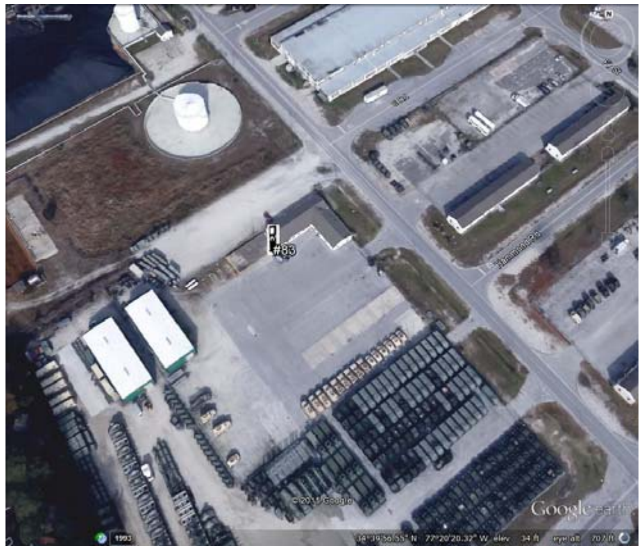

Figure 26. EVSE potential location near Building 1707 for Vehicle G41-2399K.

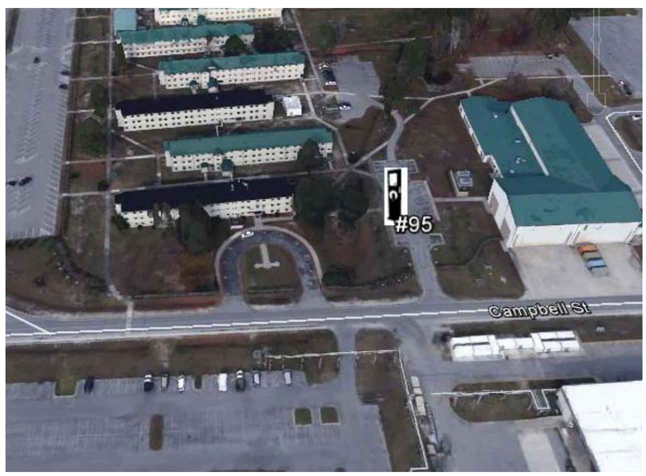

Figure 27. EVSE potential location near Building AS217 for Vehicle G41-0762M.

Figure 28. EVSE potential location near Building AS4108 for Vehicle G42-0883M.

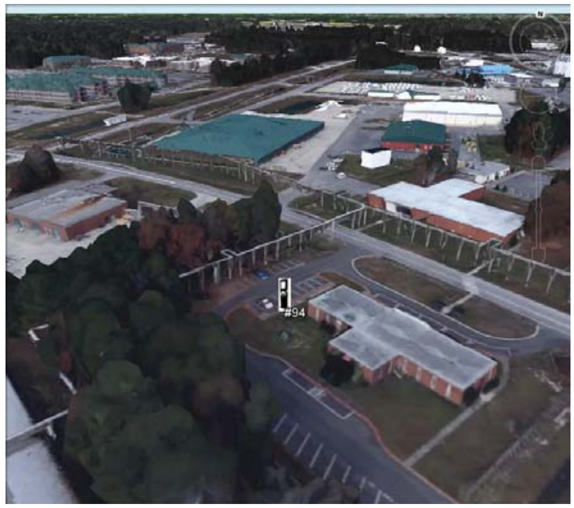

Figure 29. EVSE potential location near Building AS4122 for Vehicle G61-2644P.

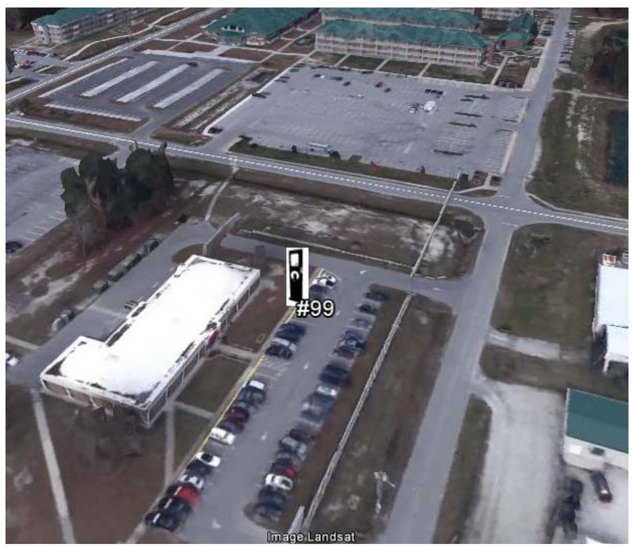

Figure 30. EVSE potential location near Building AS4157 for Vehicle G63-0309P.

Figure 31. EVSE potential location near Building BA134 for Vehicle G41-1846K.

Figure 32. EVSE potential location near Building FC306 for Vehicle G43-1453G.

Figure 33. EVSE potential location near Building FC400 for Vehicle G42-0898M.

Figure 34. EVSE potential location near Building G554 for Vehicle G43-0326H.

Figure 35. EVSE potential location near Building G702 for Vehicle G43-1855P.

Figure 36. EVSE potential location near Building PP2 for Vehicle 291073.

Figure 37. EVSE potential location near Building RR272 for Vehicle G43-4073F.

Figure 38. EVSE potential location near Building RR450 for Vehicle G62-0934G.

Figure 39. EVSE potential location near Building SAW353 for Vehicle G62-0791H.

Figure 40. EVSE potential location near Building TC771 for Vehicle 301321.

Figure 41. EVSE potential location near Building TC846 for Vehicle G43-2025K.

5.2.2 Marine Corps Installations East Group Home Base Electric Vehicle Supply Equipment Locations

Table 11 identifies the home base locations for the MCIE Group's monitored vehicles. Figures 42 through 69 identify potential locations near the appropriate building for each vehicle.

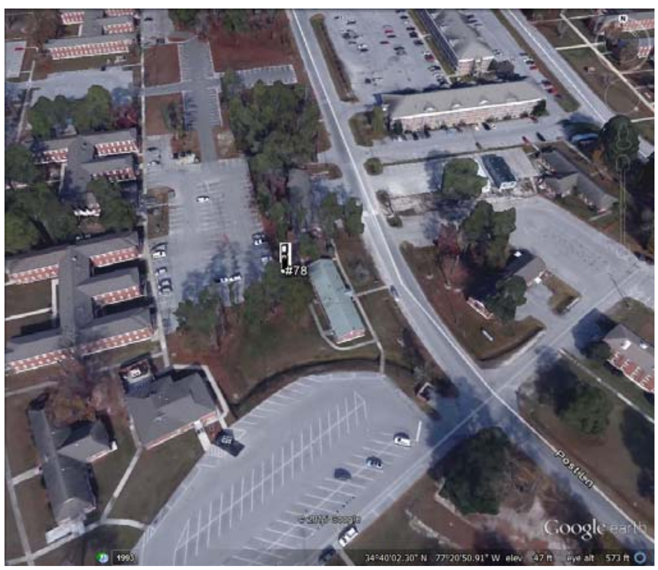

Figure 42. EVSE potential location near Building 27 for Vehicle G61-0174H.

Figure 43. EVSE potential location near Building 43 for Vehicles G41-3300K and G42-2985H.

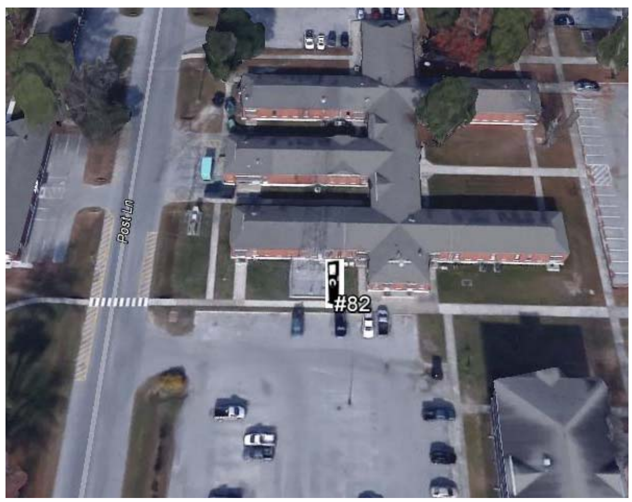

Figure 44. EVSE potential location near Building 54 for Vehicle G62-1583G.

Figure 45. EVSE potential location near Building 56 for Vehicle 301223.

Figure 46. EVSE potential location near Building 58. Three vehicles are home-based near this building: Pool Vehicles G42-0644M and G61-1508D and support Vehicle G62-4085L.

Figure 47. EVSE potential location near Building 67 for Vehicle G43-4075P.

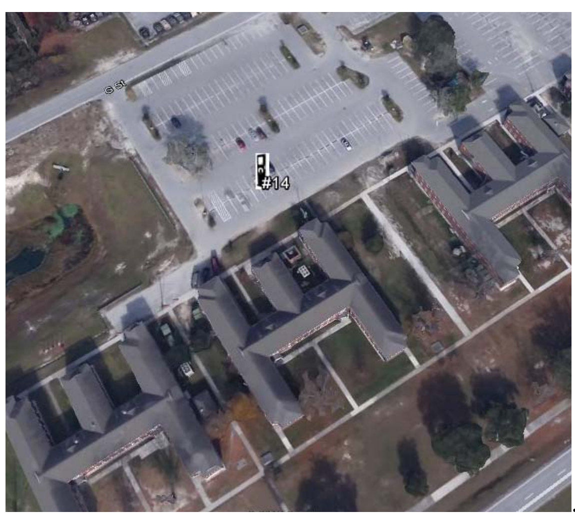

Figure 48. EVSE potential location near Building 316 for Vehicle G13-0325K.

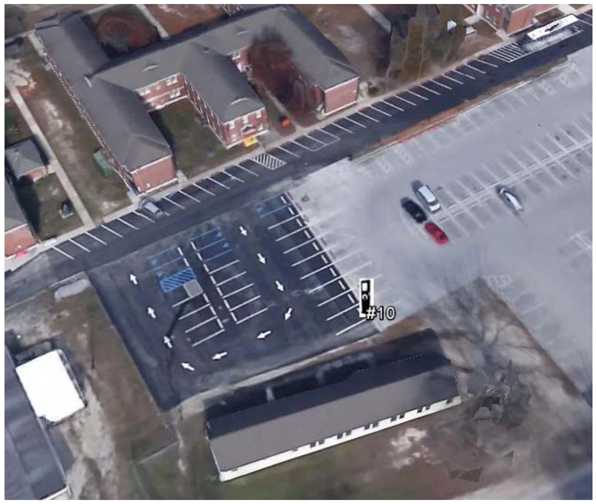

Figure 49. EVSE potential location near Building 327 for Vehicle G42-0911L.

Figure 50. EVSE potential location near Building 670 for Vehicles 302039 and G43-0323H.

Figure 51. EVSE potential location near Building 978 for Vehicle G42-0915M.

Figure 52. EVSE potential location near Building 979 for Vehicle G61-0879P.

Figure 53. EVSE potential location near Building 1005 for multiple vehicles. Six vehicles are home-based near this building: all support Vehicles 294324, G41-0806P, G41-1689L, G41-3297K, G41-3301K, and G42-0667P.

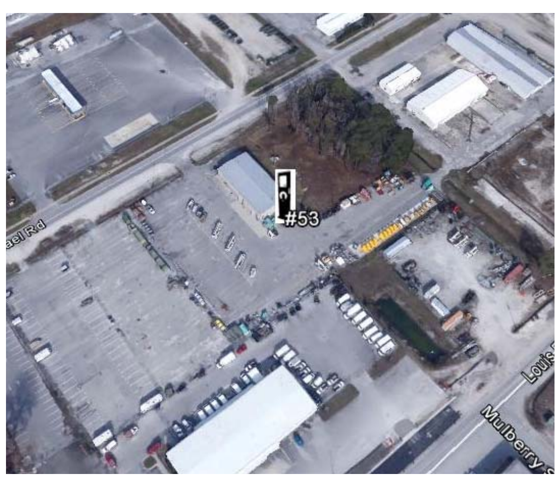

Figure 54. EVSE potential location near Building 1023 for Vehicle 300672.

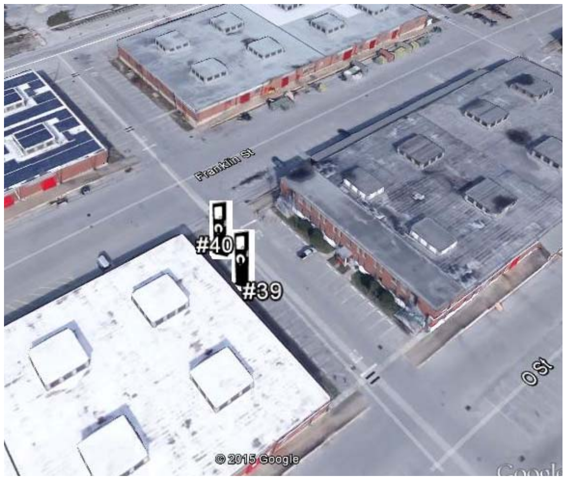

Figure 55. EVSE potential location near Building 1117 for Vehicles G13-7974P and G41-0391H.

Figure 56. EVSE potential location near Building 1407 for multiple vehicles. Pool Vehicles 290597, G41-0754M, and G43-0310H are home based near this building.

Figure 57. EVSE potential location near Building 1770 for Vehicles 294285 and G43-1182M.

Figure 58. EVSE potential location near Building 2600 for Vehicle G63-2885L.

Figure 59. EVSE potential location near Building 28211 for Vehicle G61-1509D.

Figure 60. EVSE potential location near Building AS302 for Vehicle 294293.

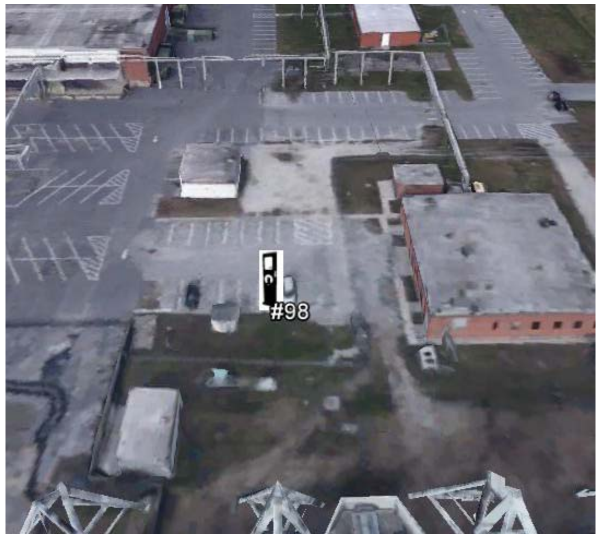

Figure 61. EVSE potential location near Building AS427 for Vehicle G63-0163H.

Figure 62. EVSE potential location near Building BA138 for Vehicle G43-0671P.

Figure 63. EVSE potential location near Building FC360 for Vehicle G43-0324H.

Figure 64. EVSE potential location near Building FC436 for Vehicle 302040.

Figure 65. EVSE potential location near Building FC500 for Vehicle G10-3327L.

Figure 66. EVSE potential location near Building M305 for Vehicle G41-0379H.

Figure 67. EVSE potential location near Building SAW360B for Vehicle G63-2888L.

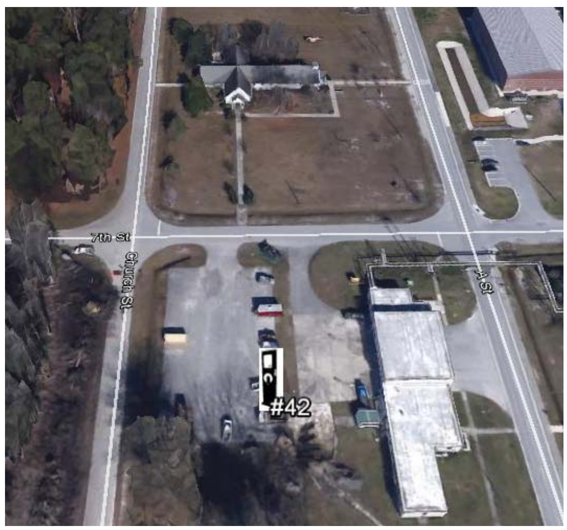

Figure 68. EVSE potential location near Building TC701 for Vehicle 294315.

Figure 69. EVSE potential location near Building TP464 for Vehicle G61-0161H.

6. OBSERVATIONS

Intertek appreciates the opportunity to present the results of this evaluation. Observations reported herein provide input to the next phases of this study, specifically, the following:

- The Task 3 vehicle utilization report and this report suggest PEV replacements and identification of charging infrastructure needs and locations. This information will provide input to the Task 4 effort.
- Suggested PEV replacements can be considered with vehicle age to prepare a replacement schedule as part of Task 4.
- The vehicle replacement schedule will provide input to the charging infrastructure deployment schedule.
- Vehicle and EVSE schedules can factor into budget considerations for implementing vehicle replacements.
- Vehicle and EVSE schedules can factor into base objectives in fuel cost reductions and greenhouse gas emissions reductions.

The analysis shows that the average vehicle travelled approximately 8,000 miles per year. This was an average of 154 miles per week. This was considered here to reduce the number of AC Level 2 EVSE and reduce EVSE costs.

Intertek suggests that MCBCL may wish to move forward in the near future with replacement of pool, support, and enforcement vehicles with PEVs as current budget and vehicle replacement schedules allow. Certainly, the vehicle types studied in this report may be candidates for immediate replacement.