INL/MIS-14-32720

AVTA Federal Fleet PEV Readiness Data Logging and Characterization Study for the National Park Service: Rocky Mountain National Park

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The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

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July 2014

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Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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 light-duty Advanced Vehicle Testing Activity. Battelle Energy Alliance, LLC contracted with Intertek Testing Services, North America (Intertek) to collect and evaluate data on federal fleet operations as part of the Advanced Vehicle Testing Activity's Federal Fleet Vehicle Data Logging and Characterization Study. The study for the Advanced Vehicle Testing Activity seeks to collect and evaluate data to validate the utilization of advanced electric drive vehicle transportation.

This report focuses on the Rocky Mountain National Park (RMNP) fleet to identify daily operational characteristics of select vehicles and report findings on vehicle and mission characterizations to support the successful introduction of plug-in electric vehicles into the agencies' fleets.

Individual observations of these selected vehicles provide the basis for recommendations related to electric vehicle adoption and whether a battery electric vehicle or plug-in hybrid electric vehicle (collectively plug-in electric vehicles) can fulfill the mission requirements.

Intertek acknowledges the support of Idaho National Laboratory, ICF International, and RMNP for participation in the study.

Intertek is pleased to provide this report and is encouraged by enthusiasm and support from the U.S. National Park Service and RMNP personnel.

EXECUTIVE SUMMARY

Federal agencies are mandated to purchase alternative-fuel vehicles, increase consumption of alternative fuels, and reduce petroleum consumption. 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 engine vehicles in terms of energy efficiency, reduced petroleum consumption, reduced production of greenhouse gas emissions, and they provide performance benefits with quieter, smoother operation. This study intended to evaluate the extent to which Rocky Mountain National Park (RMNP) 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 the energy stored in the onboard battery pack. These vehicles use no petroleum for transportation and emit no pollutants at their point of use. PHEVs provide similar savings when their battery provides the 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. This study focuses on the mission requirements of the fleet of vehicles, with the objective to identify vehicles that may be replaced with PEVs and with emphasis on BEVs that provide maximum benefit.

RMNP contains over 265,000 acres of land in northern Colorado. The geographic size of RMNP creates significant travel demands on its vehicle fleet and likewise provides opportunities for conversion of some vehicles to PEVs. RMNP identified 212 vehicles in its fleet (not including construction vehicles), with eight of them being identified as representative of the fleet and instrumented for data collection and analysis. Fleet vehicle mission categories are defined in Section 4, and while the RMNP vehicles conduct many different missions, three (i.e., pool, enforcement and support missions) were selected by agency management to be part of this fleet evaluation. These three mission categories accounted for 189 of the 212 total fleet vehicles.

This report observes that a mix of BEVs and PHEVs are capable of performing most of the required missions and providing an alternative vehicle for the pool, support, and enforcement vehicles, because the group could support some BEVs for the short trips and PHEVs for the longer trips. The recommended mix of vehicles will provide sufficient range for individual trips and time is available each day for charging to accommodate multiple trips per day. These charging events could occur at the vehicle home base. Replacement of vehicles in the current fleet would result in significant reductions in the emission of greenhouse gas emissions and petroleum use and would reduce fleet operating costs.

PEVs that currently are commercially available cannot replace certain vehicles and missions (such as those requiring heavy-duty, load-hauling trucks, some of which were included in this study). However, based on the data collected from the monitored vehicles and extrapolating to the 189 vehicles, a fleet consisting of 25 heavy-duty trucks, 78 BEVs, and 86 PHEVs may meet the park's needs.

Electric power generation in the RMNP region relies heavily on coal as the fuel source. However, replacement of the 189 internal combustion engine vehicles with PEVs could result in a potential annual greenhouse gas savings of over 1,200,000 lb-CO_2e (50% reduction) and an annual fuel cost savings of over $369,000 (88% reduction).

PEV charging stations could be located in various locations of RMNP and could benefit not only RMNP's own fleet vehicles but also the visiting public that own PEVs.

CONTENTS

FIGURES

TABLES

ACRONYMS

AC	alternating current
BEA	Battelle Energy Alliance, LLC
BEV	battery electric vehicle
CD	charge depleting
DC	direct current
EPA	U.S. Environmental Protection Agency
EVSE	electric vehicle supply equipment
GHG	greenhouse gas emissions
GSA	General Services Administration
ICE	internal combustion engine
Intertek	Intertek Testing Services, North America
PEV	plug-in electric vehicle (includes BEVs and PHEVs, but not hybrid electric vehicles)
PHEV	plug-in hybrid electric vehicle
RMNP	Rocky Mountain National Park
SUV	sport utility vehicle

1. INTRODUCTION

Federal agencies are mandated by the Energy Policy Act of 1992[1], Energy Policy Act of 2005[2], Executive Order 13423 (President Bush 2007)[3], and the Energy Independence and Security Act of 2007[4] to purchase alternative fuel vehicles, increase consumption of alternative fuels, and reduce petroleum consumption.

Battelle Energy Alliance, LLC (BEA), managing and operating contractor for Idaho National Laboratory, is the lead laboratory for the U.S. Department of Energy's Advanced Vehicle Testing and manages the Advanced Vehicle Testing Activity Federal Fleet Vehicle Data Logging and Characterization Study, which promotes utilization of advanced electric-drive vehicle transportation technologies. The Advanced Vehicle Testing Activity focuses its testing activities on emerging and newly commercialized plug-in electric vehicle (PEV) technologies because of the high-energy efficiencies and reduced consumption of petroleum by the use of electric-drive vehicles. BEA selected Intertek Testing Services, North America (Intertek) to collect data on federal fleet operations and report the findings on vehicle and mission characterizations to support the successful introduction of PEVs into federal fleets.

Because of the large number of vehicles in federal fleets in the United States, these fleets provide a substantial opportunity for the introduction of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) (collectively known as PEVs). However, to assess the scale of this opportunity, additional data are required to characterize the various missions performed by each fleet and to determine which existing vehicles are most suitable for replacement by a PEV.

The Rocky Mountain National Park (RMNP), located in northern Colorado, contains over 265,000 acres of land (Figures 1 and 2 and Appendix E)[5]. Known for its scenic beauty, wilderness areas, trails, campgrounds, and varied recreational uses, the park receives approximately 3 million site visitors a year.[6] Appendix E provides a detailed map of RMNP because several references are made to specific locations throughout this report.

According to the National Park Service, temperatures are often moderate at elevations below 9,400 ft (2,865 m). At higher points (such as Bear Lake, Trail Ridge Road, or Longs Peak), it may snow even in July. A wide variation between day and nighttime temperatures is also typical of mountain weather. Summer days in July and August often reach the 70 or 80°F marks and drop into the 40°F range at night. RMNP is an excellent site for fleet evaluation, not only due to its size, diversity of terrain, diversity of weather, and vehicle types, but because of its accessibility by the public. RMNP has an opportunity to be a leader in the adoption of BEVs and PHEVs for its fleet.

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[1] http://thomas.loc.gov/cgi-bin/query/z?c102:h.r.776.enr [accessed January 10, 2014].

[2] http://www.gpo.gov/fdsys/pkg/BILLS-109hr6enr/pdf/BILLS-109hr6enr.pdf [accessed January 10, 2014].

[3] http://www.gsa.gov/portal/content/102452 [accessed January 10, 2014].

[4] http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf [accessed January 10, 2014].

[5] http://www.nps.gov/romo/index.htm [accessed June 7, 2014].

[6] https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Annual%20Park%20Recreation%20Visitation%20Graph%20(1904%20-%20Last%20Calendar%20Year)?Park=ROMO [accessed June 3, 2014].

Figure 1. Rocky Mountain National Park location.

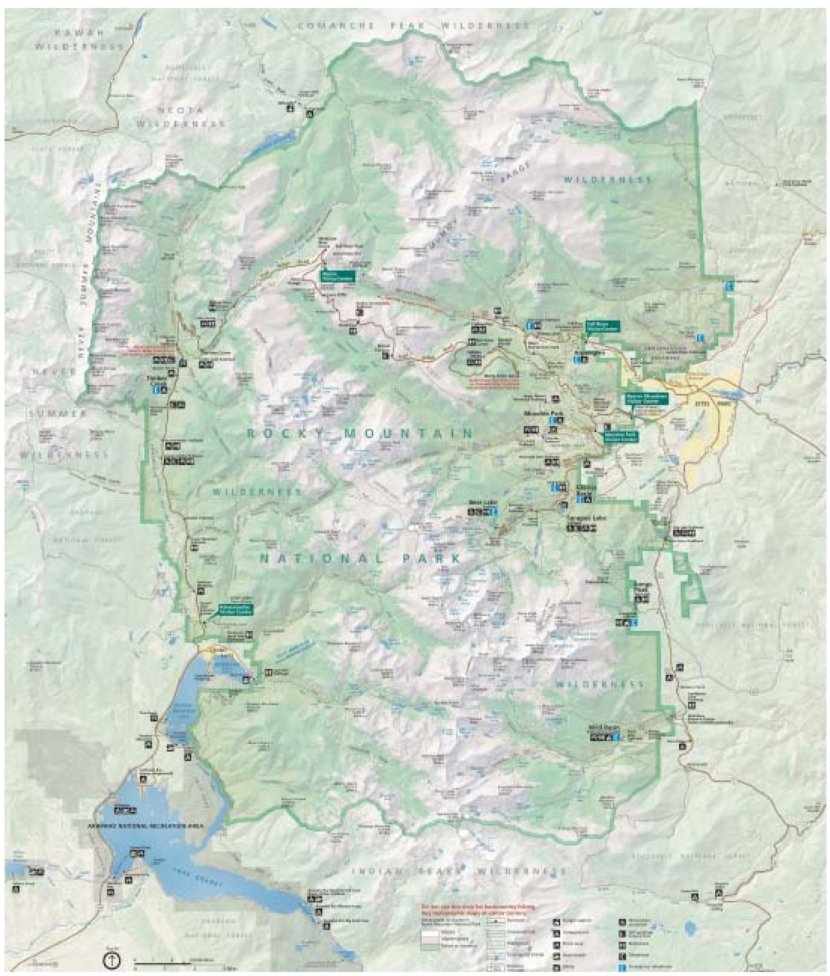

Figure 2. Map of Rocky Mountain National Park.

2. PROJECT OBJECTIVE

This study explores federal fleet vehicles and their usage characteristics, with a primary goal of supporting the goals of Presidential Executive Order 13514, which includes the following:

- Pursuing opportunities with vendors and contractors to address and incentivize greenhouse gas (GHG) emission reductions and petroleum use reductions
- Implementing strategies and accommodations for transit, travel, training, and conferences that actively reduce carbon emissions associated with commuting and travel by agency staff
- Meeting GHG emissions reductions associated with other federal government sustainability goals
- Implementing innovative policies and practices that address agency-specific Scope 3 GHG emissions.[7]

Because of the large number of vehicles in the federal fleets, there is a substantial opportunity for PHEV and BEV adoption. Federal fleets offer an opportunity as a first market replacement for alternative fuels due to their scale, refueling patterns, and regular vehicle turnover.[8]

This project has the following four defined tasks:

1. **Data collection:** Coordinate with the fleet manager to collect data on agency fleet vehicles. This includes collecting information on the fleet vehicle, and installing data loggers on a representative sample of the fleet vehicles to characterize their missions.
2. **Data analysis and review:** Examine the data collected by the loggers and fleet vehicle characteristics to describe typical fleet activity. Incorporate fleet manager's input on introducing PEVs to the agency's fleet.
3. **PEV implementation feedback:** Provide feedback to fleet personnel and BEA on the selection criteria for replacement PEVs in their specific fleet vehicle missions.
4. **Observations and recommendations:** Provide actionable information to introduce PEVs into agency fleet operations and assess any related impacts for the facility.

Data collected from vehicles included trip distance, idle time, time between uses, and stop locations. Data collection continued for 30 to 60 days using a non-intrusive data logger, which gathered and transmitted information using global positioning satellites and cellular service. The loggers collected data at 1-minute intervals and transmitted when an active signal was present.

Extrapolating the results of this analysis to the larger fleet provided an estimate of potential savings in gasoline consumption and GHG emissions. This report also provides recommendations relating to fleet management of BEVs and PHEVs for additional consideration.

Fleet managers may use the information supplied in this report to help them to identify which vehicles are candidates for replacement by a BEV or PHEV, based on their use. BEVs are preferred because of the greater potential reduction of GHG emissions, fuel cost, and petroleum usage, but they are not likely to be suitable for all vehicle missions.

The information in this report supports a final report to BEA/Idaho National Laboratory and the U.S. Department of Energy. The aggregated results for all agencies' fleets will provide an overview of federal

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[7] http://energy.gov/sites/prod/files/2013/10/f3/eo13514.pdf [accessed February 5, 2014].

[8] *Fleet Purchase Behavior: Decision Processes and Implications for New Vehicle Technologies and Fuel*, Nesbitt, Sperling, University of California, Davis 2001.

fleets, vehicle missions, vehicle uses, and agencies needs to plan and establish a more systematic method for the adoption of BEVs and PHEVs.

3. METHODS

3.1 Fleet Vehicle Survey

Agency fleet managers selected fleet vehicles for this study and provided basic information for each vehicle, including its managing agency, home base for the vehicle, contact information, primary vehicle mission, vehicle ownership, fuel type, and annual mileage driven. This information was collected using the vehicle information form shown in Appendix A.

RMNP identified 212 fleet vehicles (Table 1). (Note that Section 4 provides descriptions of the vehicle mission types.) Intertek coordinated with the RMNP fleet manager to identify the specific vehicles for data collection for inclusion in the study. The fleet manager assessed their wide range of vehicles and made selections of high-interest, representative vehicles based on vehicle missions and vehicle type/class. Selection also favored vehicles used at least twice a week. Because data loggers rely on the vehicle's battery power, non-use of the vehicle can result in the vehicle having a depleted battery. Intertek received no reports of depleted batteries during the study at RMNP. Eight vehicles were selected, with three pool vehicles, two enforcement vehicles, and three support vehicles.

Table 1. Fleet evaluation.

Vehicle Mission	Study Vehicles	Total Fleet Reported	Percentage Studied
Pool Vehicles	3	23	13%
Enforcement Vehicles	2	36	6%
Support Vehicles	3	130	2%
Transport Vehicles	—	21	0%
Specialty Vehicles	—	1	0%
Shuttle/Bus	—	0	0%
Low Speed Vehicles	—	1	0%
Total Fleet Vehicles	8	212	4%

3.2 Data Collection

Individual privacy concerns exist when monitoring vehicle movement with data loggers. Data collection occurs by vehicle identification as identified by Intertek, data logger number, and vehicle identification number or agency assigned vehicle number. Intertek receives no information related to the vehicle operator and provides no raw data to the fleet managers. In this manner, Intertek does not collect, analyze, or report on individual driving habits.

3.2.1 Data Logger

Non-intrusive data loggers, produced by InTouchMVC9 and depicted in Figure 3, were inserted into the vehicle's onboard diagnostic port to collect and transmit the relevant data. The installation of the data logger and the manual recording of information about the vehicle that ties the logger and vehicle together in the data, typically takes less than 5 minutes. Once installed and activated (during vehicle use), the data loggers collect vehicle information once every minute during vehicle operation and transmit by cellular communication to the data center.

[9] www.intouchmvc.com [accessed January 10, 2014].

Figure 3. InTouchMVC data logger.

Intertek maintains the data logger's connectivity and verifies data transmission weekly. Missing data (reported as "null" values) are frequently the result of lost global positioning system reception, logger device removal, or extended periods in regions with insufficient cellular reception. Intertek filters the vehicle and data logger information if these null values present a significant impact on the data collected and no resolution is possible. This report also identifies the statistics on this validation process.

RMNP requested and installed eight data loggers into the selected fleet vehicles. The agency removed and shipped the data loggers to Intertek at the conclusion of the data collection period.

3.2.2 Data Captured

Data consist of key-on events, key-off events, and position updates logged every minute while the vehicle is keyed-on. InTouchMVC converted these data points into records of trip events, stop events, and idle events.

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.

3.3 Data Analysis

3.3.1 Definitions

Figure 4 illustrates a vehicle outing, which is comprised of trips, stops, and idle events, that may occur during one day or over 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.

Definitions of additional analysis and survey terms are as follows:

1. *Operating shift*: Fleet manager-defined period worked.
2. *Study days*: Days during which the data loggers are connected.
3. *Vehicle days*: Study days during which a vehicle is used.
4. *Null values*: A null value is a data record that is unusable for analysis for various reasons.

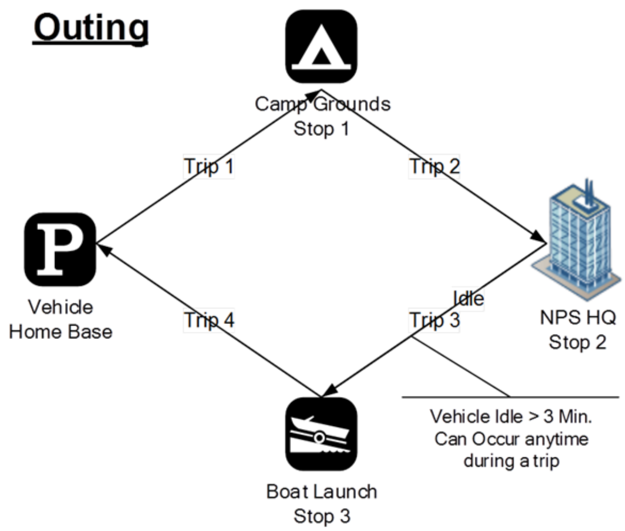

Figure 4. Vehicle outing.

3.3.2 Data Evaluation

Processing the data involves removal of null values and aggregation by different spatial and temporal scales. Aggregation was by day, by trip, and by outing to produce figures showing the patterns of use. Aggregation by vehicle mission followed in order to characterize use for the agency fleet. Section 5 presents these results. Data were extrapolated to provide the overall fleet usage and benefit analysis when fleet information was provided. Section 6 presents these benefits. Intertek observations are included in Section 7.

Statistical data analysis uses Python 2.7 with the MATLAB Plotting Library graphics environment (Matplotlib) and spatial display with ESRI ArcGIS.[10] Frequency distributions summarize the travel behavior of each vehicle and vehicle mission during the study period. Rounding of the tables and figures are to three significant digits.

4. VEHICLES

4.1 Vehicle Missions

The vehicle mission is an important characteristic in the fleet study. Information used to define the vehicle mission includes the vehicle's configuration, vehicle use, classification per 40 CFR Part 600.315-82 and Environmental Protection Agency (EPA), the participating agency use, and general vehicle use. Based on fleet information gathered, Intertek has established the following seven mission/vehicle categories for analysis (examples are depicted in Figure 5):

[10] www.esri.com [accessed January 10, 2014].

1. **Pool vehicles**: A pool vehicle is any automobile (other than the low-speed vehicles 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. Appendix C provides further definition.
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.
4. **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.
5. **Specialty vehicles**: Vehicles designed to accommodate a specific purpose or mission (such as ambulances, mobile cranes, and handicap controls).
6. **Shuttles/buses**: Vehicles designed to carry more than 12 passengers and further outlined in 49 CFR 532.2.
7. **Low-speed vehicle:** Vehicles that are legally limited to roads with posted speed limits up to 45 mph and that have a limited load-carrying capability.

Figure 5. Vehicle missions.

4.2 Alternative Fuel Vehicles

As the operating agency, RMNP has a unique opportunity to plan for the adoption of BEVs and PHEVs, along with planning for the supporting infrastructure. The adoption of PHEVs and BEVs is a primary goal of the General Services Administration (GSA) and supports the directives previously referenced.

As GSA increases its certification of PHEVs and BEVs, agencies can plan for vehicle replacement through GSA for passenger vehicles and trucks. Table 2 presents the replacement requirements for fleet vehicles. Note that both the age and mileage requirements need to be met in order for the vehicle to qualify for replacement, except where noted as "or."

Table 2. General Services Administration vehicle replacement requirements.

GSA Vehicle Replacement Requirements[11]			
	Fuel Type	Years	Miles
Passenger vehicles	Gasoline or alternative fuel vehicle	3 4 5 Any age	36,000 24,000 Any mileage 75,000
	Hybrid	5	Any miles
	Low-speed BEV	6	Any miles
Light trucks 4 x 2	Non-diesel	7	65,000
	Diesel	8 or	150,000
	Hybrid	7	Any mileage
Light trucks 4 x 4	Non-diesel	7 or	60,000
	Diesel	8 or	150,000
	Hybrid	7	Any mileage

4.3 Battery Electric Vehicle and Plug-in Hybrid Electric Vehicle Benefits/Challenges

BEVs are fully powered by the battery energy storage system available onboard the vehicle. The Nissan Leaf is an example of a BEV. Because the BEV has no other energy source for propulsion, the range, power requirements, and mission of the needed vehicle factor greatly in purchasing decisions. Maximizing BEV capabilities typically requires batteries more than an order of magnitude larger in capacity than the batteries in hybrid electric vehicles.

PHEVs obtain their power from at least two energy sources. The typical PHEV configuration uses a battery and an internal combustion engine (ICE), powered by either gasoline or diesel. PHEV designs differ between manufacturers. All have a charge-depleting (CD) mode, in which the battery is depleted of its stored energy to propel the vehicle, and a charge-sustaining mode (or extended range mode), in which the battery and the ICE work together to provide propulsion, while the state of charge of the battery is maintained between set limits.

4.3.1 Battery Electric Vehicle Benefits/Challenges

EPA identifies the following benefits of BEVs[12]:

- **Energy efficient:** Electric vehicles convert about 59 to 62% of the electrical energy from the grid to power at the wheels, whereas conventional gasoline vehicles only convert about 17 to 21% of the energy stored in gasoline to power at the wheels.
- **Environmentally friendly:** PEVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear, hydro, solar, or wind-powered plants causes no air pollutants.
- **Performance benefits:** Electric motors provide quiet, smooth operation and exhibit maximum torque at zero and low speeds, while also requiring less maintenance than ICEs.

[11] http://www.gsa.gov/graphics/fas/VehicleReplacementStandardsJune2011Redux.pdf [accessed January 10, 2014].

[12] http://www.fueleconomy.gov/feg/evtech.shtml [accessed December 27, 2013].

- **Reduce energy dependence:** Electricity is a domestic energy source.

EPA also identifies challenges associated with BEVs, including the following:

- **Driving range:** Most BEVs can only travel about 100 to 200 miles (or less) before recharging, whereas gasoline vehicles can often travel over 300 miles before refueling and some much further.
- **Recharge time:** Fully recharging the battery pack can take 4 to 8 hours. With a high-power direct current (DC) fast charger, restoration from a depleted state to 80% capacity can take approximately 30 minutes.
- **Battery cost:** The large battery packs are expensive and may need to be replaced one or more times.
- **Bulk and weight**: Battery packs are heavy and take up considerable vehicle space.

4.3.2 Plug-in Hybrid Electric Vehicle Benefits/Challenges

EPA identifies the following benefits of PHEVs[13]:

- **Less petroleum use:** PHEVs are expected to use about 40 to 60% less petroleum than conventional vehicles. Because electricity is produced primarily from domestic resources, PHEVs reduce dependence on oil.
- **Fewer emissions:** PHEVs are expected to emit fewer GHG emissions than conventional vehicles, but similar to BEVs, the difference depends largely on the type of power plant supplying the electricity.

EPA also identifies challenges associated with PHEVs, including the following:

- **Higher vehicle costs, lower fuel costs:** PHEVs will likely cost $1,000 to $7,000 more than comparable non-PHEVs. Fuel will cost less because electricity is much cheaper than gasoline, but the fuel savings depends on how much of driving is done with the off-board electrical energy.
- **Recharging takes time:** Recharging the battery typically takes several hours. However, PHEVs do not have to be plugged in to be driven. They can be fueled solely with gasoline, but will not achieve maximum range, fuel economy, or fuel savings without charging.
- **Measuring fuel economy:** Because a PHEV can operate on electricity alone, gasoline alone, or a mixture of the two, EPA provides a fuel economy estimate for gasoline-only operation (charge-sustaining mode), electric-only operation (all-electric CD mode), or combined gasoline and electric operation (blended CD mode).

In most cases, PEV retail cost is higher than a non-PEV model. This incremental purchase cost may be a fleet budget challenge; however, many original equipment manufacturers have offered incentives to encourage the use and adoption of BEVs and PHEVs. Some original equipment manufacturers have recently reduced the vehicle cost, while also increasing vehicle range. Additionally, federal and state incentives have increased the attractiveness of purchasing a PEV. A common assumption is that increasing PEV sales will result in a reduction in this incremental purchase cost and a positive feedback loop will ensue.

4.4 Plug-In Electric Vehicle Availability

GSA provides a summary of the light and medium-duty passenger vehicles available for lease or purchase through the GSA portal[14], even though not all BEVs and PHEVs currently on the market are ‘certified’ to be GSA replacements. Vehicles not on the GSA list of ‘certified’ vehicles require an agency to self-certify a functional need or provide alternative measures for exemptions. Table 3 summarizes the

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[13] http://www.fueleconomy.gov/feg/phevtech.shtml [accessed July 19, 2013].

[14] http://www.gsa.gov/portal/content/104224 [accessed March 6, 2014].

vehicles that may be suitable replacements and are certified replacements through GSA. The Nissan Leaf and Mitsubishi i-MiEV are not included in the alternative fuel guide for 2014, but they have appeared in previous guides.

Replacement is dependent on vehicle configuration characteristics and vehicle mission. Further evaluation related to vehicle purpose and mission follows in Section 5.

Tables 4 through 7 provide summaries of PHEVs and BEVs either currently available or near commercialization in both passenger cars and pickup trucks, but do not appear on the GSA ‘certified’ vehicle list. These vehicles may qualify for use by the agency through demonstrating a functional need.

Table 3. General Services Administration-certified plug-in electric vehicles.

Make/Model	GSA Class	Type	City/Highway	GSA Incremental Price
Chevrolet Volt	Sedan, Subcompact	PHEV	101/93 MPGe	$17,087.18
Ford C-MAX Energi	Sedan, Subcompact	PHEV	108/92 MPGe	$14,899.52
Ford Focus Electric	Sedan, Subcompact	BEV	110/99 MPGe	$16,573.09
Ford Fusion Energi	Sedan, Compact	PHEV	108/92 MPGe	$19,289.99

Table 4. Original equipment manufacturer plug-in hybrid electric vehicle cars and availability.

Make	Model	Model Year
Audi	A3 eTron PHEV	2015 (estimate)
Chevrolet	Volt	2011
Honda	Accord PHEV	2013
Toyota	Prius PHEV	2012
Volvo	V60 Plug-in	2016 (estimate)
BMW	i3 with range extender	2015 (estimate)

Table 5. Original equipment manufacturer battery electric vehicle cars and availability.

Make	Model	Model Year
BMW	i3	2014
Chevrolet	Spark	2015
Fiat	500e	2014
Ford	Focus Electric	2012
Honda	Fit EV	2013
Kia	Soul EV	2015 (estimate)
Mercedes	B-Class E-Cell	2015 (estimate)
Nissan	Leaf	2011
smart	ED	2014
Tesla	Model S	2012
Tesla	Model X	2017 (estimate)
Volkswagen	Golf Blue-e-Motion	2015 (estimate)
Volvo	C30 Electric	2016 (estimate)

Table 6. Original equipment manufacturers plug-in hybrid electric vehicle trucks, vans, and availability.

Make	Model	Model Year
Land Rover	Range Rover Sport	2016 (estimate)
Mitsubishi	Outlander PHEV	2016 (estimate)
Via	VR300	2013

Table 7. Original equipment manufacturers battery electric vehicle trucks, vans, and availability.

Make	Model	Model Year
Nissan	eNV200	2015 (estimate)
Toyota	RAV4 EV	2014 (California only – elsewhere 2015 estimate)

4.5 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 on recharging PEVs.

4.5.1 Electric Vehicle Supply Equipment Design

4.5.1.1 Charging Components. Electric vehicle supply equipment (EVSE) stations deliver electric power from the utility to the applicable charge port on the vehicle. Figure 6 illustrates the primary components of a typical EVSE, which in Figure 6 is an alternating current (AC) Level 2.

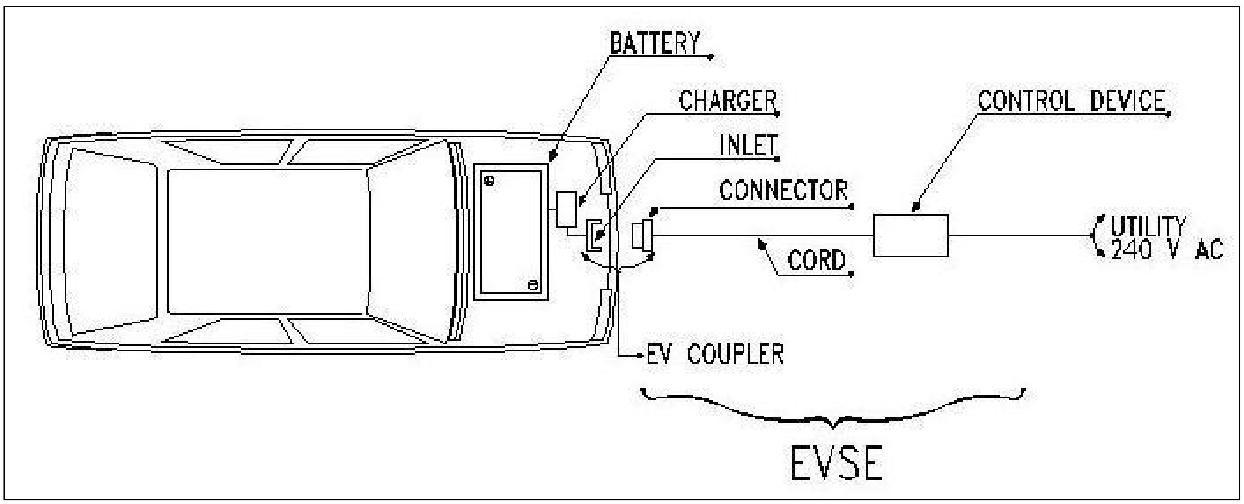


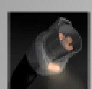
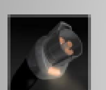
Figure 6. AC Level 2 charging diagram.[15]

The electric utility delivers AC current to the charging location. The conversion from AC to DC electricity necessary for battery charging can occur either on or off board the vehicle. Section 4.5.1.2 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 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

[15] http://www.theevproject.com/downloads/documents/Electric%20Vehicle%20Charging%20Infrastructure%20Deployment%20Guidelines%20for%20the%20Greater%20Phoenix%20Area%20Ver%203.2.pdf [accessed January 15, 2014].

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 accommodate DC charging.

4.5.1.2 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 Standard. Figure 7 summarizes these attributes and the estimated recharge times. Actual recharge times depend on the onboard equipment, including the charger, battery, and battery management system.

SAE International	SAE Charging Configurations and Ratings Terminology		
AC level 1 (SAE J1772™)	PEV includes on-board charger	*DC Level 1	EVSE includes an off-board charger
	120V, 1.4 kW @ 12 amp 120V, 1.9 kW @ 16 amp		200-450 V DC, up to 36 kW (80 A)
	Est. charge time:		Est. charge time (20 kW off-board charger):
	PHEV: 7hrs (SOC* - 0% to full)		PHEV: 22 min. (SOC* - 0% to 80%)
	BEV: 17hrs (SOC – 20% to full)		BEV: 1.2 hrs. (SOC – 20% to 100%)
AC level 2 (SAE J1772™)	PEV includes on-board charger (see below for different types)	*DC Level 2	EVSE includes an off-board charger
	240 V, up to 19.2 kW (80 A)		200-450 V DC, up to 90 kW (200 A)
	Est. charge time for 3.3 kW on-board charger		Est. charge time (45 kW off-board charger):
	PEV: 3 hrs (SOC* - 0% to full)		PHEV: 10 min. (SOC* - 0% to 80%)
	BEV: 7 hrs (SOC – 20% to full)		BEV: 20 min. (SOC – 20% to 80%)
	Est. charge time for 7 kW on-board charger		
	PEV: 1.5 hrs (SOC* - 0% to full)	*DC Level 3 (TBD)	EVSE includes an off-board charger
	BEV: 3.5 hrs (SOC – 20% to full)		200-600V DC (proposed) up to 240 kW (400 A)
	Est. charge time for 20 kW on-board charger		Est. charge time (45 kW off-board charger):
	PEV: 22 min. (SOC* - 0% to full)		BEV (only): <10 min. (SOC* - 0% to 80%)
	BEV: 1.2 hrs (SOC – 20% to full)		
*AC Level 3 (TBD)	> 20 kW, single phase and 3 phase		

*Not finalized
Voltages are nominal configuration voltages, not coupler ratings
Rated Power is at nominal configuration operating voltage and coupler rated current
Ideal charge times assume 90% efficient chargers, 150W to 12V loads and no balancing of Traction Battery Pack

Notes:
1) BEV (25 kWh usable pack size) charging always starts at 20% SOC, faster than a 1C rate (total capacity charged in one hour) will also stop at 80% SOC instead of 100%
2) PHEV can start from 0% SOC since the hybrid mode is available.
Developed by the SAE Hybrid Committee ver. 031611

Figure 7. Society of Automotive Engineers charging configurations and ratings terminology.[16]

Most PEV manufacturers supply an AC Level 1 cord-set with the vehicle, which provides sufficient capabilities for some drivers, but often provides an emergency backup capability because of the long recharge times. AC recharging capabilities found in the public arena more typically are AC Level 2. Figure 8 illustrates a typical J1772-compliant inlet and connector for both AC Levels 1 and 2.

[16] http://www.sae.org/smartgrid/chargingspeeds.pdf [accessed January 15, 2014].

Figure 8. J1772 connector and inlet.[17]

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. Figure 9 shows this connector, which is called the J1772 combo connector.

Figure 9. J1772-compliant combo connector.[18]

Some BEVs introduced in the United States prior to the approval of the J1772 standard for DC charging employ the CHAdeMO (designed in Japan) standard for connector and inlet design. Figure 10 shows this connector.

The presence of the two 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

[17] http://carstations.com/types/j09 [accessed January 15, 2014].

[18] http://www.zemotoring.com/news/2012/10/sae-standardizes-j1772-fast-dc-charging-up-to-100-kw [accessed January 15, 2014].

battery; therefore, at present, no PHEV on the market or near commercialization has DC charging capability (although the Mitsubishi Outlander PHEV is rumored to be offering DC charging capability as an option). It is noted that DC Level 1 and DC Level 2 charging are commonly combined and labeled "DC fast charging."

Figure 10. CHAdeMO-compliant connector.[19]

Because the battery of a BEV is typically much larger than that of a PHEV, recharge times are longer (see Figure 7). BEVs that see daily mileage near the limits of the advertised range do better when recharged using AC Level 2 EVSE or DC fast charging, 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 with intermediate or opportunity charging. DC fast charging provides the fastest recharge capability for those vehicles equipped with DC fast charge inlets.

4.5.2 Electric Vehicle Supply Equipment Stations

AC Level 2 charging is the predominant rating of publicly accessible EVSE because of its wide acceptance by auto manufacturers and recharge times that are faster than AC Level 1 charging. Purchase and installation costs are more manageable than DC fast chargers and less space is required. There are several manufacturers of AC Level 2 equipment and the agency should review brands for comparison purposes. Figure 10 provides an example of a public AC Level 2 EVSE[20].

DC fast chargers also are available from several manufacturers. Figure 12 illustrates one such charger.[21] This particular charger uses the CHAdeMO connector standard.

In general, installation costs are higher for the DC fast charger because of the higher voltage requirements and the inclusion of the AC to DC charger and other safety and design features. 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 can allow agency fleet vehicle use without direct payment. These systems also allow for accurate record keeping of vehicle charging requirements.

[19] https://radio.azpm.org/p/azspot/2012/5/10/1632-electric-cars/ [accessed January 15, 2014].

[20] www.eaton.com/ [accessed January 29, 2014].

[21] http://evsolutions.avinc.com/products/public_charging/public_charging_b [Accessed April 16, 2014].

Figure 11. Alternating current Level 2 electric vehicle support equipment.

Figure 12. Direct current fast charger.

5. ROCKY MOUNTAIN NATIONAL PARK ANALYSIS

5.1 Survey Results

Eight vehicles were included in the study at RMNP. One vehicle assigned to enforcement responsibilities operated as a pool vehicle and was included with other pool vehicles. Therefore, three vehicles have pool missions (all are sport utility vehicle [SUV]), two are enforcement vehicles (all are SUVs), and three are support vehicles (all are pickup trucks). Table 8 presents a summary of these vehicles and Table 9 provides details of the monitored vehicles.

Table 8. Vehicle study summary.

Mission	SUV	Truck	Total
Pool	3	—	3
Support Vehicle	---	3	3
Enforcement Vehicles	2	—	2
Total	5	3	8

Table 9. Detailed Rocky Mountain National Park vehicle index.

Vehicle Index					
Logger	Make	Model	Year	Fleet Vehicle Id	Mission
74	Chevrolet	Tahoe	2012	101/I-514483	Enforcement
76	Ford	Explorer	2009	102/I-510556	Enforcement
69	Dodge	Dakota	2009	103/I-510561	Support
73	Chevrolet	Silverado 2500HD	2008	104/I-510545	Support
70	Ford	Escape	2008	105/I-510533	Pool
68	Ford	Explorer	2004	106/ I-410506	Pool (Enforcement)
75	Ford	Explorer	2002	107/ I-263766	Pool
71	Ford	F350 SD	2013	108/ I-515081	Support

Specific vehicle references may be made to the vehicle ID or logger ID in this report.

Appendix D provides the analysis of each individual vehicle included in this study. Grouping the vehicles by mission creates an aggregated view of mission requirements to provide observations related to PEV replacement. The missions of these three categories vary considerably; therefore, these missions are only evaluated separately, because fleet-wide operations provide little useful information.

5.2 Data Validity

RMNP data collection took place from February 19 through March 18, 2013. Vehicle data sheets (presented in Appendix D) detail the collected data for each vehicle.

Of the data collected, validation occurred for 99.3%, while null values exist for the balance. Table 10 shows this information by mission type.

Table 10. Vehicle data logger reporting summary

Vehicle Data Logger Reporting Summary			
Mission	% Collected	% Null Values	Total
Pool	98.5	1.5	100%
Support Vehicles	99.4	0.6	100%
Enforcement Vehicles	99.2	0.8	100%
All Vehicles	99.3	0.7	100%

5.3 Pool Vehicles Evaluation

5.3.1 Survey and Site Information

Pool vehicles are typically light-duty motor vehicles for use in passenger transportation, with not more than 10 passengers. Pool missions can vary by agency, location, and jurisdiction; however, they typically utilize sedans, minivans, SUVs, vans, or small pickup trucks and typically do not carry specific cargo or equipment.

Incorporation of BEVs and/or PHEVs into the pool mission is a definite possibility. Pool vehicles used for shorter trips or outings qualify for BEV or PHEV replacement, while other pool vehicle activities that are associated with longer trips may require PHEV capabilities.

5.3.2 Summary for Pool Vehicles

Appendix D provides the vehicle data sheets for each of the pool vehicles monitored. This section aggregates data for all pool vehicles. Table 11 summarizes pool travel during the study period for those days in which the vehicle was driven. Vehicle use occurred primarily between 0800 and 1600 hours daily. The vehicles were driven 358 miles, logged 16.6 hours, and idled for 1 hour during the 27-day study period. The Interpretation and Education Division of RMNP operated two vehicles and the Resource Protection and Visitor Management (enforcement) operated one pool vehicle.

Table 11. Pool vehicles travel summary.

Pool Vehicles Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	19.9/80.0	13.2/80.0	5.3/40.0	358
Travel Time (Minutes)	55.4/144	37.0/144	14.7/72.0	998
Idle Time (Minutes)	4.1/NA	2.7/NA	1.1/NA	74

5.3.3 Pool Vehicles Daily Summary

Figure 13 identifies daily travel distance and time for all the pool vehicles. The green line and bars indicate the typical electric range on a single charge for a PHEV, while the blue line and bars (including the green bars) indicate the same for a BEV. Figures 14 and 15 show the composite history in distance and time traveled for the pool vehicles. In these stacked bar charts, the contribution of each vehicle is indicated by a different color.

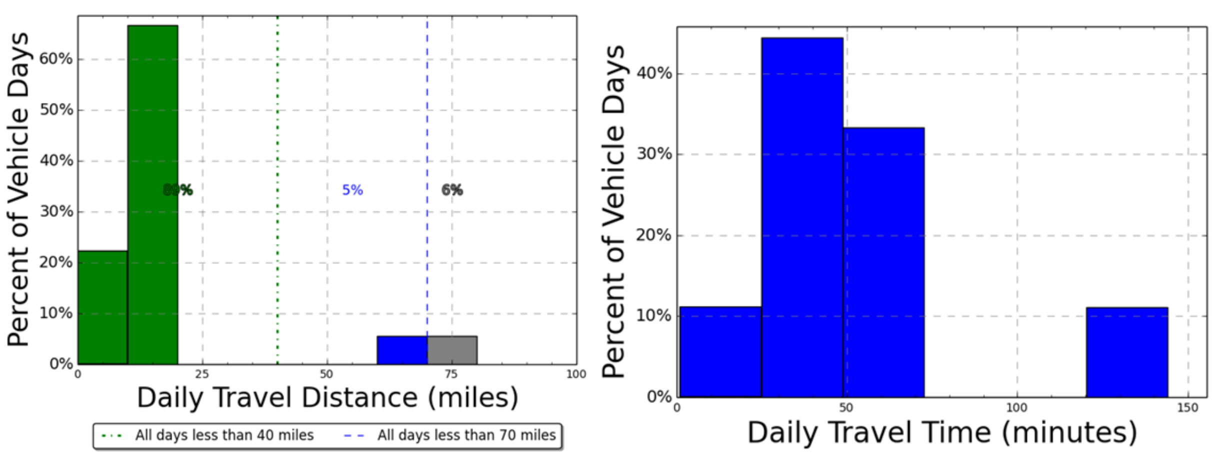


Figure 13. Pool vehicle daily travel miles and time (all vehicles).

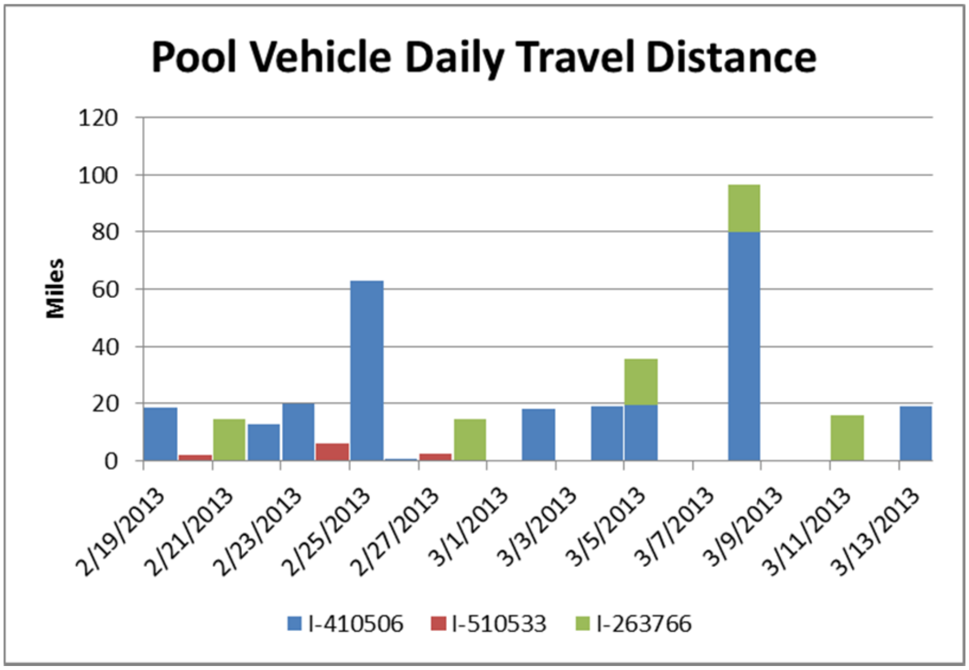


Figure 14. Pool vehicle daily travel history (all vehicles).

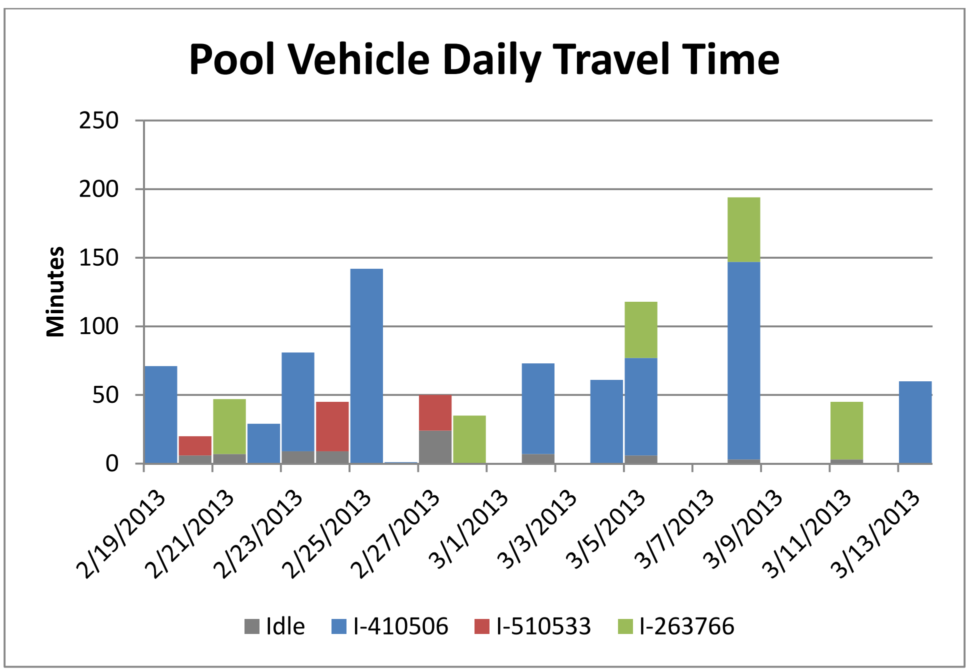


Figure 15. Pool vehicles travel time (all vehicles).

When driven, the average travel distance per day for pool vehicles was 19.9 miles. On 94% of these vehicle days, the daily travel was less than the 70 miles that are considered to be within the BEV safe range. This means that while a BEV range can vary based on several factors, most BEVs provide at least 70 miles of vehicle range on a single battery charge. Six percent of the pool daily travel was greater than 70 miles. Further, 89% of vehicle travel days were less than 40 miles, which is considered to be within the CD range of a PHEV.

Figures 14 and 15 show that the vehicles are not used every day. Vehicle I-510533 was not driven on 89% of the days monitored, Vehicle I-410506 was not driven on 63% of the days monitored, and Vehicle I-263766 was not used on 81% of the days. However, there were days where more than one vehicle was in use.

Figure 16 displays the summary of use by time of day for all pool vehicles and Figure 17 shows the outing distances traveled, including data for all pool vehicles.

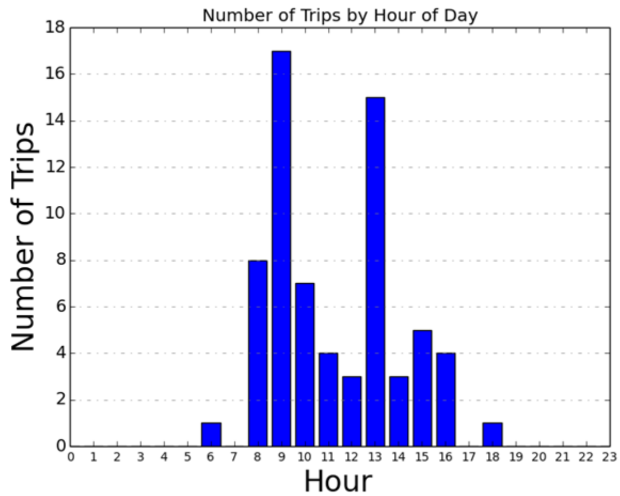


Figure 16. Pool vehicles' hourly usage.

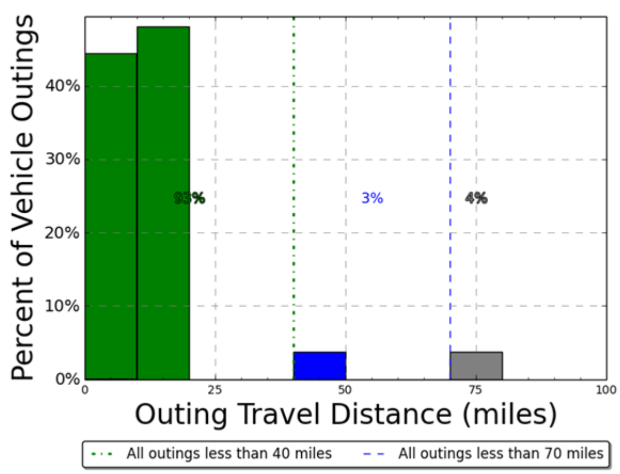


Figure 17. Pool vehicle outings.

Appendix D provides the details of each of the pool vehicle's daily outing travel. Only Vehicle I-410506 exceeded 70 miles of daily travel on a single travel day. The same vehicle also had the only outing that was greater than the 70-mile range.

The average travel outing for pool vehicles was 13.2 miles. On 96% of these vehicle outings, the distance traveled was less than the 70 miles that are considered to be within the BEV safe range. Only 4% percent of pool outing travel was greater than 70 miles. Further, 93% of vehicle travel outings were less than 40 miles considered to be within the CD range of a PHEV.

5.3.4 Seasonal Adjustments

The vehicles were monitored during the period of late February and early March 2013, which is not the busiest visitor time of the season. Figure 18 illustrates the seasonal fluctuation in visitors. Approximately 65% of all visitors enter in the three months of June, July, and August. Approximately 8% each enter in May and September, with the other months averaging about 3%.[22]

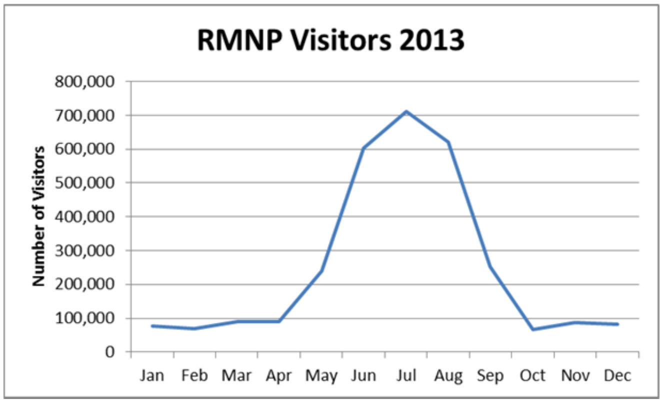


Figure 18. Visitor attendance at Rocky Mountain National Park in 2013.

Permanent park employment is about 170 persons, while seasonal and temporary employees number 243[23]. This does not include the many volunteers donating time at the park. The main travel roads through the park to the several visitor centers and to the many trailheads would be expected to be more heavily traveled during the peak visitor seasons. Furthermore, the Alpine Visitor Center and Trail Ridge Road, which is the main road through the park, close in the winter above 11,500 ft in elevation. The map in Appendix E may be helpful in identifying the referenced park locations.

February and March are still considered winter months in RMNP, with significant snow in March[24]. For these reasons, the analysis reported herein is assumed to be much lighter usage than would be more typical of the summer months. Nevertheless, the data analyzed are useful in making several observations related to vehicle use and the potential for PEV replacement. Most of the camping areas and trailheads are within 20 miles of the typical overnight parking locations of the vehicles studied. However, additional and more distant destinations would open up in the summer months.

The analysis continued here overestimates the vehicle travel demands, which will provide a conservative approach to electric vehicle integration. RMNP may wish to repeat the data collection process during the summer for a more accurate PHEV integration plan. To complete this analysis with the current data, it was assumed that the vehicles are used twice as often during the peak summer months and daily usage is three times that seen during these study months, representing a 6-fold increase in estimated vehicle demand. Intertek suggests this is conservative because the number of employees (both permanent and temporary) is 2.4 times the permanent staff during the peak season, while summer visitation increases to 7 times that of the winter months.

With this in mind, Figures 14 and 17 would be adjusted with the revised values (shown in Table 12), which will be used in the analysis that follows.

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[22] http://www.nps.gov Rocky Mountain National Park Service Facts and Figures C-FAFI-1/14-3000.

[23] Ibid.

[24] http://www.nps.gov/romo/planyourvisit/upload/Weather%20and%20Climate%208x11.pdf [accessed June 7, 2014].

Table 12. Extrapolated pool vehicle daily travel and outing factors

	<40 miles	< 40 miles, < 70 Miles	> 70 miles
Daily Travel	56%	19%	25%
Outings	69%	13%	19%

All vehicles were monitored for 27 days in February and March 2013 and actual miles traveled were used as monthly figures for March values in projecting monthly and annual miles. The remaining months were factored from that month using the assumptions identified above. Figure 19 shows the extrapolated miles traveled throughout the year for the pool vehicles.

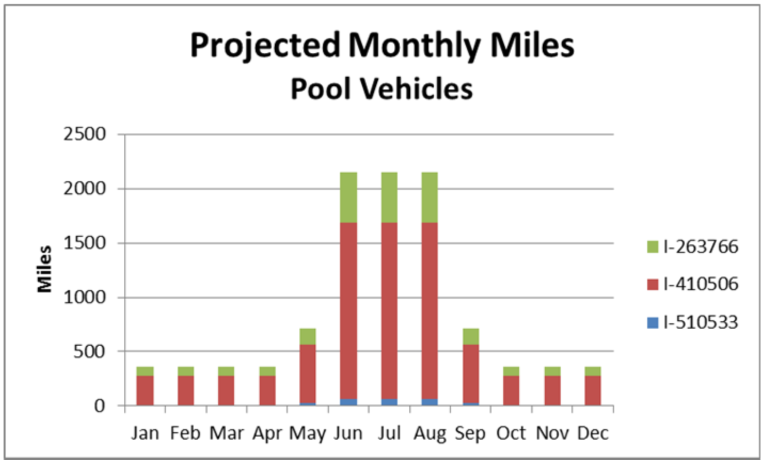

Figure 19. Extrapolated monthly miles for pool vehicles.

5.3.5 Pool Vehicle Observations/Summary

There appears to be three choices for RMNP in implementing PEVs into the pool fleet. It should be noted that the objective would be to incorporate as many BEVs as possible to realize the advantages of reduced petroleum usage and reduced emissions of GHGs.

1. **All BEV fleet:** While some BEV manufacturers report vehicle range exceeding 70 miles, Intertek recommends careful evaluation of experienced range to ensure vehicle missions are accomplished. Nevertheless, assuming the 70-mile safe range for a BEV, an all-BEV fleet does not appear to be possible due to the length of some of the daily travel. In addition, a more conservative approach is warranted due to the time of year of the vehicle analysis.

2. **Mixed BEV/PHEV fleet:** Certainly, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances, because the PHEV's gasoline engine can provide motive power when the battery has been depleted. Using the extrapolated data of Table 12 shows that on 56% of all vehicle travel days, the total daily travel is less than 40 miles, which typically is the maximum distance a PHEV will travel on battery-only power. This represents a significant operating cost savings opportunity, while retaining the ability to go longer distances when needed. In addition, 69% of the outings are less than 40 miles and could be completed on battery power if the battery is fully charged prior to the outing.

   Meanwhile, 81% of the outings are within the typical capability of a BEV; therefore, EVSE at the home base could provide recharge energy for another outing. A mixed fleet requires fleet manager attention to assign vehicles appropriately for the anticipated use on that day.

This would suggest that 25% of the fleet could be PHEVs to handle the travel greater than 70 miles per day without requiring additional opportunity charging during daytime stops and 75% of the fleet could be BEVs. However, this percentage of BEVs would require a greater level of fleet management, with the daily assignment of vehicles based on anticipated driving distance. The actual vehicle usage indicates that vehicles I-510533 and I-263766 would not exceed a typical BEV range. Vehicles with a similar mission as these two vehicles could be replaced with BEVs without increased management. Given that two-thirds of the vehicles studied meet this criterion, a fleet of 40% PHEVs and 60% BEVs could conservatively meet the demand. All monitored pool vehicles are SUVs and replacement PEVs are currently available for this vehicle type.

3. **All PHEV fleet:** As noted above, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances. Replacing all current vehicles with PHEVs only requires an evaluation of the individual vehicle's capabilities of currently available PHEVs to meet current pool requirements. Because these three pool vehicles are SUVs, replacement PEVs are available. Data show that for a significant number of days, the PHEV will operate in a CD mode. The first 40 miles of longer travel days would also be powered by (at least mostly) electricity; therefore, 56% of all pool vehicle travel would be (again, at least mostly) battery powered, with only one charge per day. As above, this represents an opportunity for significant operating cost savings, while retaining the ability to go longer distances when needed. Intermediate charging opportunities provide additional benefit, enhancing the pure-electric mode. Data show significant charging opportunities throughout the day during stop times.

While it would appear that PEVs are suitable replacements for all pool vehicles, additional mission analysis may be required for peak season considerations. Spot-checking vehicles during the peak months may provide this validation.

The vehicle summary shows sufficient time for charging at the base location during the course of the day and additional opportunities at intermediate charging stations are not required. These stations also provide charging opportunities for the visiting public, whose fees may assist in offsetting operating costs. Given the availability of daytime changing, with experience, RMNP may find that a greater fraction of BEVs within the pool vehicle fleet may meet their needs.

Considering a full complement of 23 pool vehicles in the total fleet, Intertek suggests that a mixed fleet may be possible. While the remaining vehicles were not monitored, using the same ratio as above suggests a fleet of 14 BEVs and nine PHEVs conservatively meet vehicle travel requirements. Typically, additional EVSE at frequently visited locations provide recharging for both the BEV and PHEV; however, there appear to be no consistent remote stop locations for these pool vehicles.

The types of vehicles monitored (i.e., SUV) are typical of pool vehicles. The above evaluation assumes the makeup of the balance of the pool fleet is similar.

5.3.6 Pool Vehicle Charging Needs

Upon review of these data, Intertek suggests replacement of the studied pool fleet with two BEVs and one PHEV. No available PHEVs at this writing provide for DC fast charging, nor do the data suggest that this would be a significant benefit for PHEVs in the pool fleet. A DC fast charger at the home base will provide a more rapid recharge for BEVs, but appears to be unnecessary. However, given that our conservative estimate shows that 88% of outings are less than the typical BEV driving range during the high use summer months, a DC fast charger could allow for a greater percentage of pool vehicles to be replaced with BEVs.

As noted above, AC Level 2 overnight charging of BEVs is typical, whereas overnight charging of PHEVs uses AC Level 1 outlets.

Intertek's experience suggests that each vehicle have an assigned charging parking space at their home base. Assigned stations require less management attention to ensure completion of overnight charging. BEVs and PHEVs not assigned to these stations also benefit during visits to the location as part of their normal operation. For the entire fleet of pool vehicles, the 14 BEVs require 14 AC Level 2 EVSE units for overnight charging and the nine PHEVs require nine AC Level 1 outlets at each vehicle's overnight parking location. Intertek recommends a minimum of two EVSE at each location to maximize charge capability without a significant increase in installation costs. The PHEVs can utilize the AC Level 2 EVSE at the home base during the day to increase the amount of vehicle miles traveled in CD mode. For these monitored vehicles, Intertek suggests that the two interpretation and education pool vehicles could be BEVs and charged on Utility Road. The enforcement vehicle could be a PHEV and charged on Mills Drive or Utility Road.

At times, fleet vehicles obtain benefits from using public charging infrastructure. Figure 20 displays the availability of public charging at the time of this writing for the RMNP area. Unfortunately, the only charging station identified is a residential unit and is not available for public charging.

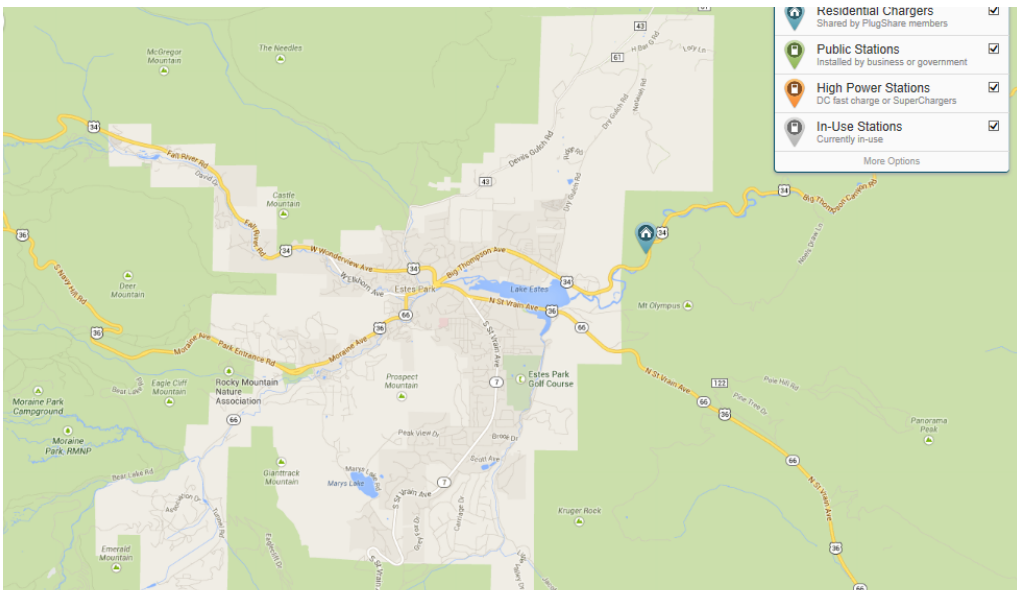

Figure 20. Public electric vehicle support equipment in Rocky Mountain National Park region.[25]

5.4 Support Vehicles Evaluation

Support vehicles provide a specific work function, facilitating the mission of a particular group. The vehicles are generally passenger or light-duty pickup trucks and may contain after-market modifications to support the mission. While assigned to maintenance and service areas, missions may vary depending on agency needs.

5.4.1 Summary for Support Vehicles

Appendix D provides the vehicle data sheets for each of the three support vehicles monitored. This section aggregates the data for all support vehicles.

Table 13 summarizes support vehicle travel during the study period. Vehicle use occurred primarily between 0600 and 1500 hours daily. Support vehicles traveled 1,170 miles, logged 81 hours, and idled for 24 hours during the study period.

[25] http://www.plugshare.com/ [accessed June 7, 2014].

Table 13. Support vehicle travel summary.

Support Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	34.5/70.6	10.2/62.0	3.2/39.8	1,170
Travel Time (Minutes)	143/249	42.3/238	13.3/165.0	4,860
Idle Time (Minutes)	12.7/NA	12.7/NA	4.0/NA	1,460

5.4.2 Support Vehicle Daily Summary

Figure 21 identifies the daily travel distance and time for all support vehicles. The green line and bars indicate the typical electric range on a single charge for a PHEV, while the blue line and bars indicate the same for a BEV. Figures 22 and 23 show the composite history in distance and time traveled for the support vehicles.

The history graphs identify when several support vehicles may be in use at the same time, as well as the total miles driven.

During the February and March study period, the average travel distance per day, when driven, by support vehicles is 34.5 miles. On 97% of these vehicle days, the daily travel is less than the 70 miles considered to be within the BEV safe range. Three percent of support vehicle daily travel is greater than 70 miles, with 47% of vehicle travel days being less than 40 miles considered to be within the battery-only range of a PHEV.

Figures 21, 22, and 23 show that the vehicles are not used every day. For example, Vehicle I-510561 is unused 37% of the days monitored, Vehicle I-510545 is unused 74% of the days monitored, and I-515081 is unused 63% of the days monitored. However, there are periods where several vehicles are in use at the same time. Figure 24 displays the summary of use by time of day for all support vehicles combined. Figure 25 shows the outing distances for all support vehicles.

Appendix D provides the details of each of the support vehicles' daily travel. Vehicle I-515081 was the only vehicle that exceeded the 70 miles of daily travel, with one day at 70.6 miles.

The average travel outing for support vehicles is 10.2 miles. On all of these vehicle outings, the distance traveled is less than the 70 miles considered to be within the BEV safe range. Ninety-three percent of vehicle travel outings are less than 40 miles and considered to be within the battery-only range of a PHEV.

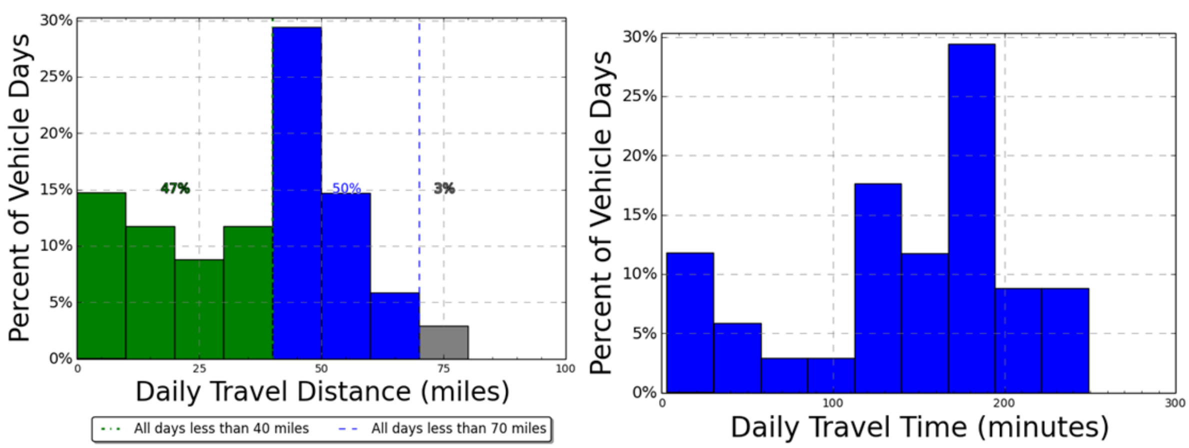

Figure 21. Support vehicles percentage of daily use versus daily travel miles and time (all vehicles).

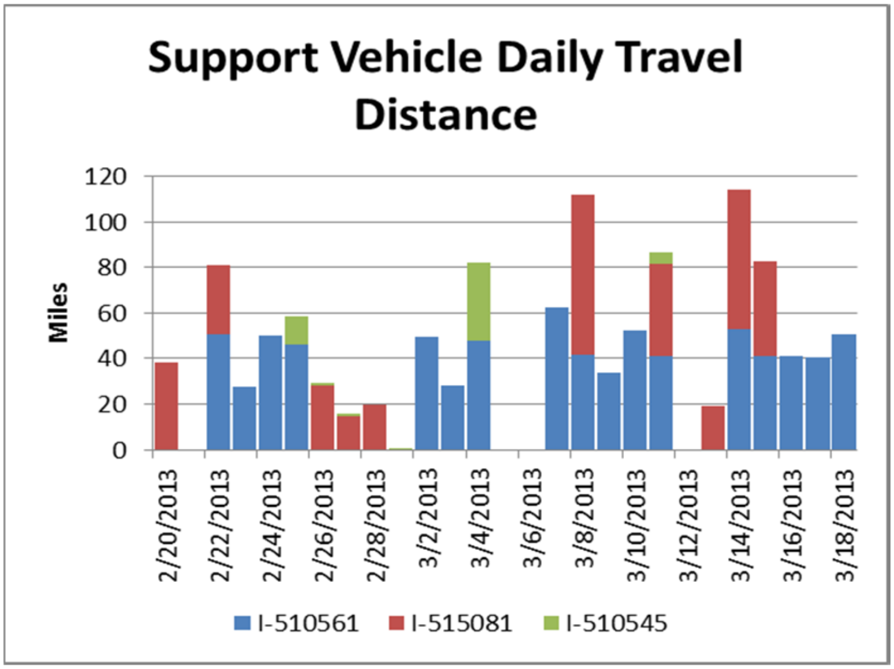

Figure 22. Support vehicle daily travel miles (all vehicles).

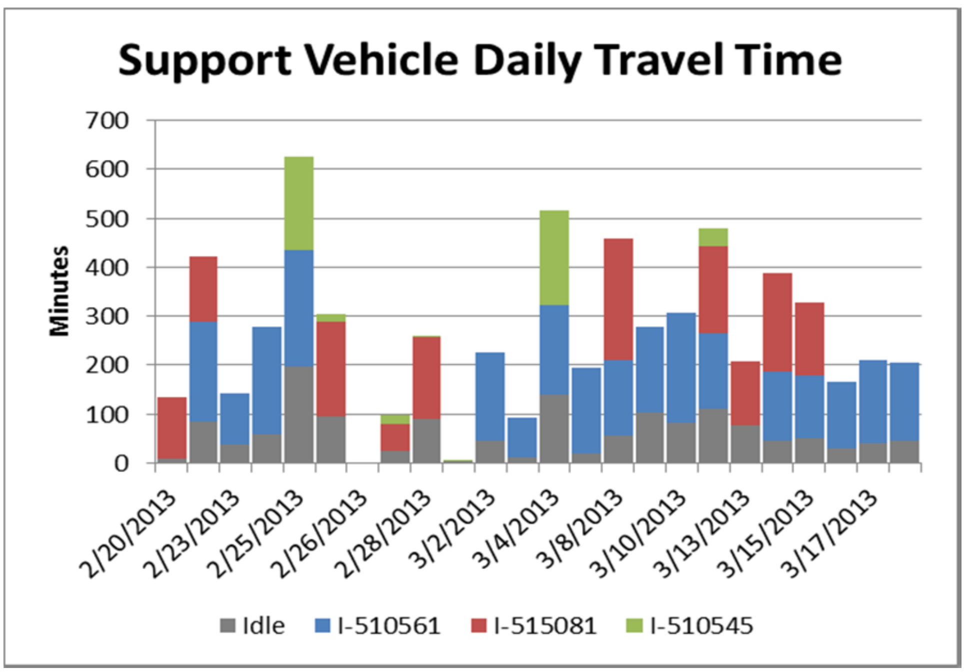

Figure 23. Support vehicle daily travel time (all vehicles).

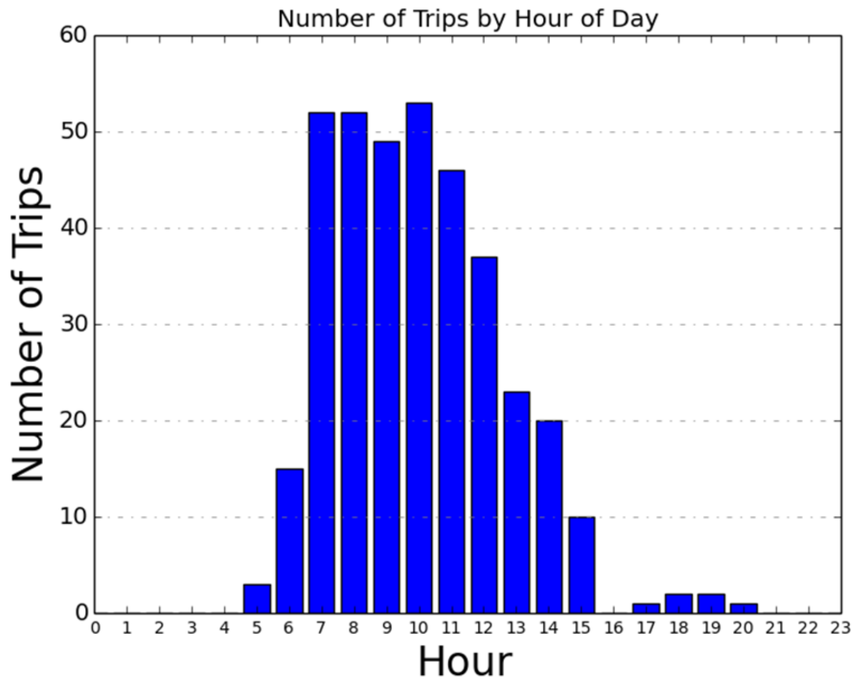

Figure 24. Support vehicles hourly usage.

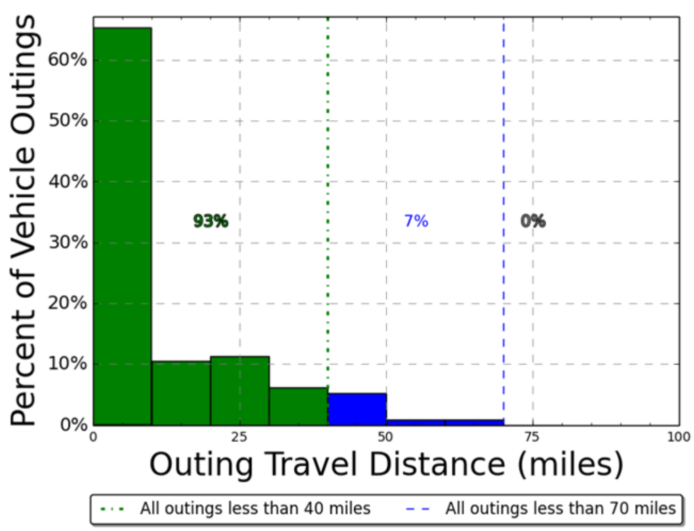

Figure 25. Support vehicle outings.

5.4.3 Seasonal Adjustments

Unlike the pool vehicles, the analysis for seasonal adjustment of the support fleet is less clear. Facility management work is likely to increase with increasing park visitors and construction and maintenance of buildings, roads, structures, etc. Some of these activities are less likely in the winter months when roads may be impassable and weather less favorable. It would be expected that the vehicles would be used more frequently, adding miles, and the daily travel characteristics may be increased. However, most of the park's frequently used facilities are located within a relatively short distance of these vehicle-parking locations. Expectations are that the number of idle days would be reduced as well.

RMNP may wish to repeat the data collection process during the summer for a more accurate PEV integration plan. To complete this analysis with the current data, it is assumed that the vehicles are used twice as often during the peak summer months and daily usage is twice that seen during these study months, representing a four-fold increase in estimated vehicle demand.

With this in mind, Figures 21 and 25 would be adjusted as shown in Table 12. This will be used in the analysis that follows.

Table 14. Extrapolated support vehicle daily travel and outing factors.

	<40 miles	< 40 miles, < 70 Miles	> 70 miles
Daily Travel	56%	19%	25%
Outings	82%	7%	11%

All vehicles were monitored for 27 days in February and March 2013 and actual miles traveled were used as monthly figures for March values in projecting monthly and annual miles. The remaining months were factored from that month using the assumptions identified above. Figure 26 shows the projected monthly miles for these support vehicles.

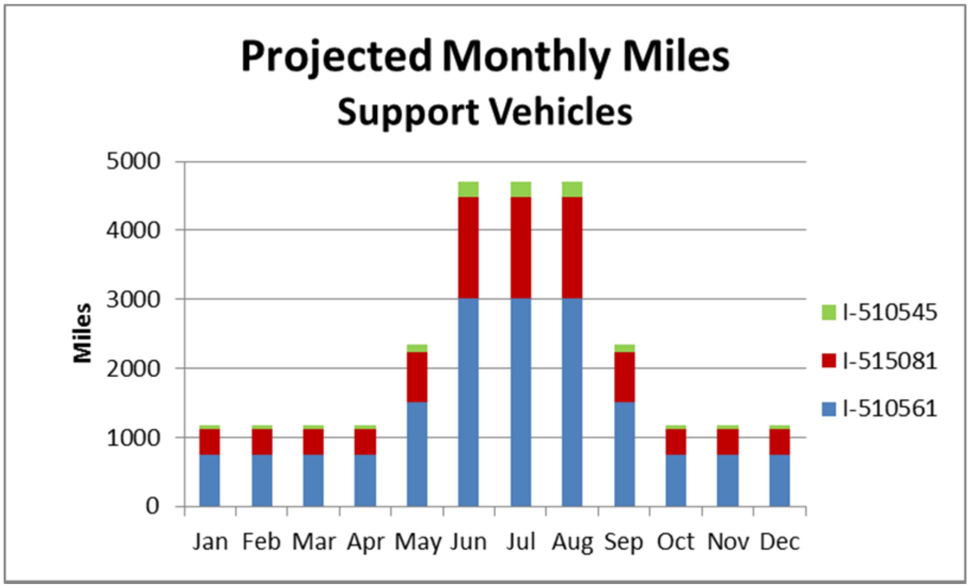

Figure 26. Projected support vehicle monthly mileage.

5.4.4 Support Vehicle Observations/Summary

As a group, the support vehicles had infrequent daily travel distances exceeding 70 miles. Only one daily travel total exceeded the 70-mile range and only by a small amount. However, when incorporating seasonal adjustment, 25% of vehicles exceed the daily travel of 70 miles.

All of the support vehicles are pickup trucks, with two of the three being heavy-duty trucks. Pickup trucks are a popular choice for support vehicles because they are versatile to support various types of support activities needed (i.e., special cargo or equipment transport). In some cases, SUVs or mini-vans can perform the same mission. Section 4.4 provides information on PEV trucks and vans currently or soon to be available.[26]

As before, there appears to be three possible options for RMNP in implementing PEVs into the support vehicle fleet. It should be noted again that the objective would be to incorporate as many BEVs as possible to realize the advantages of reduced petroleum usage and reduced emissions of GHGs.

1. **All BEV fleet:** While some BEV manufacturers report vehicle ranges exceeding 70 miles, Intertek recommends careful evaluation of experienced range to ensure vehicle missions are accomplished. Nevertheless, assuming the 70-mile safe range for a BEV, an all-BEV fleet is not possible for support vehicles due to the long distances experienced by the vehicles and the heavy-duty requirements of the vehicles.

2. **Mixed BEV/PHEV fleet:** Certainly, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances because the PEV's gasoline engine can provide motive power when the battery has been depleted. Using the extrapolated data of Table 14 shows that on 56% of all vehicle travel days, the total daily travel is less than 40 miles, which typically is the maximum distance a PHEV will travel on battery-only power. This represents a significant operating cost savings opportunity while retaining the ability to go longer distances when needed. In addition, 82% of the outings are less than 40 miles and could be completed on battery power if the battery is fully charged prior to the outing.

   Meanwhile, 89% of the outings are within the typical capability of a BEV; therefore, EVSE at the home base could provide recharge energy for another outing. A mixed fleet requires fleet manager attention to assign vehicles appropriately for the anticipated use on that day.

   The data suggest that 25% of the fleet could be PHEVs to handle the travel greater than 70 miles per day without requiring additional opportunity charging during daytime stops and 75% of the fleet could be BEVs. However, this percentage of BEVs would require a greater level of fleet management, with the daily assignment of vehicles based on anticipated driving distance. Actual vehicle usage indicates that none of the vehicles exceeded a typical BEV range. Given that all of the vehicles studied meet this criterion, a fleet of 40% PHEVs and 60% BEVs could conservatively meet the demand.

3. **All PHEV fleet:** As noted above, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances. Replacing all current vehicles with PHEVs only requires an evaluation of the individual vehicle capabilities of currently available PHEVs to meet current support vehicle requirements.

While it may be possible that BEVs are suitable replacements for some support vehicles, additional mission analysis and management input is required. The missions of these vehicles likely include considerations other than mileage (such as power demands and load-carrying capabilities placed on the vehicle).

The vehicle summary shows sufficient time for charging at the base location during the course of the day. These stations also provide charging opportunities for the visiting public, whose fees may assist in offsetting operating costs.

The current fleet contains 130 total support vehicles; however, the vehicle type makeup of this fleet was not provided. Intertek suggests further mission evaluation be given to support vehicles when considering the adoption of BEVs and PHEVs. It may be possible to replace some of the heavy-duty pickups with the Via Motors PHEV pickup. However, to be conservative, it is assumed that some of the

[26] Note that Via Motors has recently added PEV pickup trucks to the PG&E fleet in the San Francisco Bay Area: http://www.viamotors.com/blog/national-plugin-day-2012-cupertino/ [accessed July 19, 2013]

fleet needs to remain heavy-duty ICE trucks. Thus, it is assumed that the composition would include approximately 25 heavy-duty pickup trucks. Of the balance of 105 vehicles, Intertek suggests that 42 BEVs and 63 PHEVs could replace the current fleet and continue to carry out the same mission.

5.4.5 Support Vehicle Charging Needs

Upon review of these data, Intertek suggests replacement of most of the support vehicle fleet with 42 BEV and 63 PHEVs. No available PHEVs at the time of this writing provide for DC fast charging, nor do the data suggest that this would be a significant benefit for PHEVs in the support vehicle fleet. A DC fast charger at the home base will provide a more rapid recharge for BEVs, but appears to be unnecessary. However, given that our conservative estimate shows that 89% of outings are less than a typical BEV's driving range during the high use summer months, a DC fast charger could allow for a greater percentage of pool vehicles to be replaced with BEVs. The majority of the support vehicle's activity occurs during daytime hours, which leaves significant time during the nighttime hours for recharging.

As noted above, AC Level 2 overnight charging of BEVs is typical, whereas overnight charging of PHEVs uses AC Level 1 outlets. Opportunity charging at intermediate stops obtains the greater benefits from AC Level 2 EVSE. However, remote intermediate stop locations were not identified in the data.

For the entire fleet of support vehicles, 42 BEVs require 42 AC Level 2 EVSE for overnight charging and 63 PHEVs require 63 AC Level 1 outlets for home base charging. The support vehicles monitored are home based in the Utility Road or Mills Drive area. The home base of the remaining fleet vehicles is unknown. Intertek recommends a minimum of two EVSE at each location to maximize charge capability without a significant increase in installation costs. As noted above, there are no publicly accessible EVSE in the vicinity to provide significant backup charging resources.

Greater management attention provides the possibility of reducing the overall number of AC Level 2 EVSE. A ratio of two AC Level 2 charging stations to three vehicles typically sustains a normal fleet operation. Fleet managers rotate vehicles on the charger to complete charging of all vehicles in the allotted time. This analysis does assume a fully recharged battery at the start of each day. RMNP will gain experience in this management as the PEV fleet grows.

5.5 Enforcement Vehicles Evaluation

5.5.1 Survey and Site Information

Enforcement vehicles are typically light-duty motor vehicles specifically approved in an agency's appropriation act for use in apprehension, surveillance, police, or other law enforcement work. Enforcement missions can vary by agency, location, and jurisdiction; however, they typically utilize sedans, minivans, vans, or small pickup trucks and typically do not carry specific cargo or equipment.

Incorporation of BEVs and/or PHEVs into the enforcement mission is a definite possibility. Enforcement vehicles used to patrol small areas and for parking enforcement activities qualify for BEV or PHEV replacement, while other law enforcement vehicle activities that are associated with longer trips may require PHEV capabilities.

5.5.2 Summary for Enforcement Vehicles

Appendix D provides the vehicle data sheets for each of the enforcement vehicles monitored. This section aggregates data for both vehicles. Table 15 summarizes enforcement travel during the study period for those days in which the vehicle was driven. Vehicle use occurred primarily between 0700 and 1700 hours daily. The vehicles accumulated 508 miles, logged 30.5 hours, and idled for 6.8 hours during the 27-day study period. The Resource Protection and Visitor Management division operated two SUV enforcement vehicles.

Table 15. Enforcement vehicles travel summary.

Enforcement Vehicles Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	29.9/85.9	8.1/49.0	4.3/41.4	508
Travel Time (Minutes)	108.0/306.0	29.1/162	15.7/101.0	1,830
Idle Time (Minutes)	24.1/NA	6.5/NA	3.5NA	409

5.5.3 Enforcement Vehicles Daily Summary

Figure 27 identifies daily travel distance and time for all enforcement vehicles. The green line and bars indicate the typical electric range on a single charge for a PHEV, while the blue line and bars indicate the same for a BEV. Figures 28 and 29 show the composite history in distance and time traveled for the enforcement vehicles.

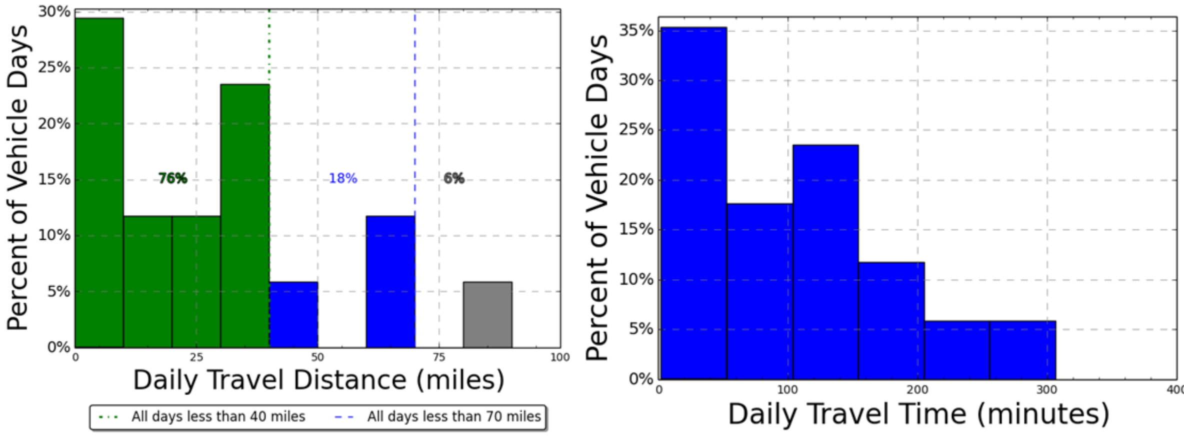

Figure 27. Enforcement vehicles percentage of daily use versus daily travel miles and time (all vehicles).

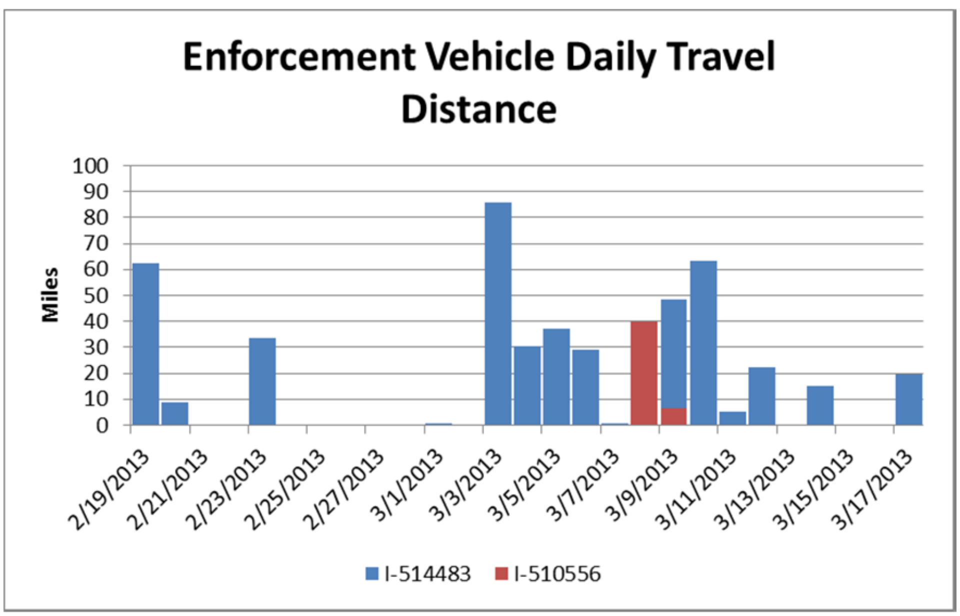

Figure 28. Enforcement vehicle daily travel history (all vehicles).

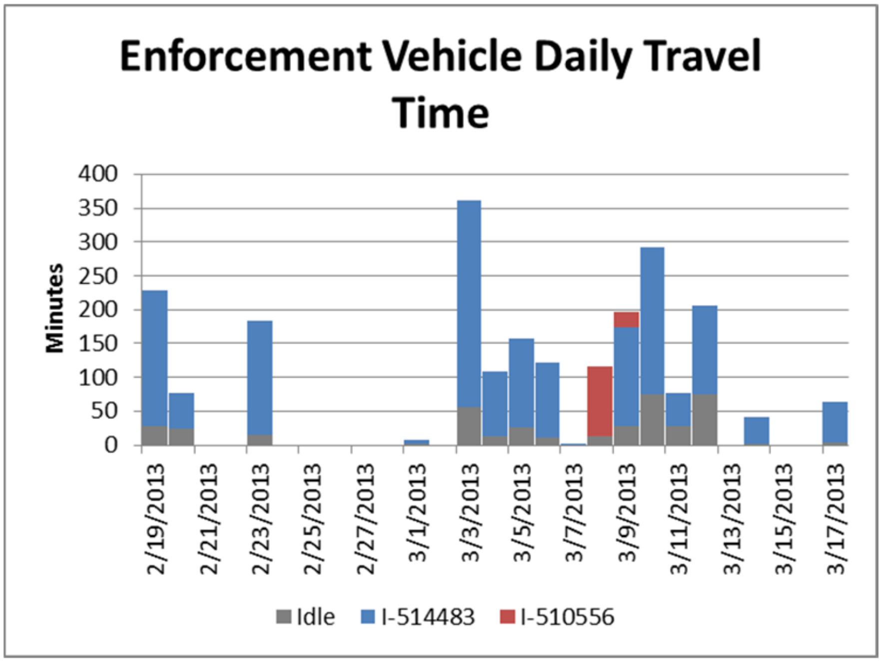

Figure 29. Enforcement vehicles travel time (all vehicles).

When driven, the average travel distance per day for enforcement vehicles is 29.9 miles. On 94% of these vehicle days, the daily travel is less than the 70 miles considered to be within the BEV safe range. Further, 6% percent of enforcement daily travel is greater than 70 miles. Meanwhile, 76% of vehicle travel days are less than the 40 miles considered to be within the battery-only range of a PHEV.

Figures 27 and 28 show that the vehicles are not used every day. Vehicle I-514483 was not driven on 44% of the days monitored and Vehicle I-510556 was not used on 93% of the days. However, there were days where both were used. Only Vehicle I-514483 exceeded 70 miles of daily travel on a single travel day. Figure 30 displays the summary of use by time of day for all pool vehicles.

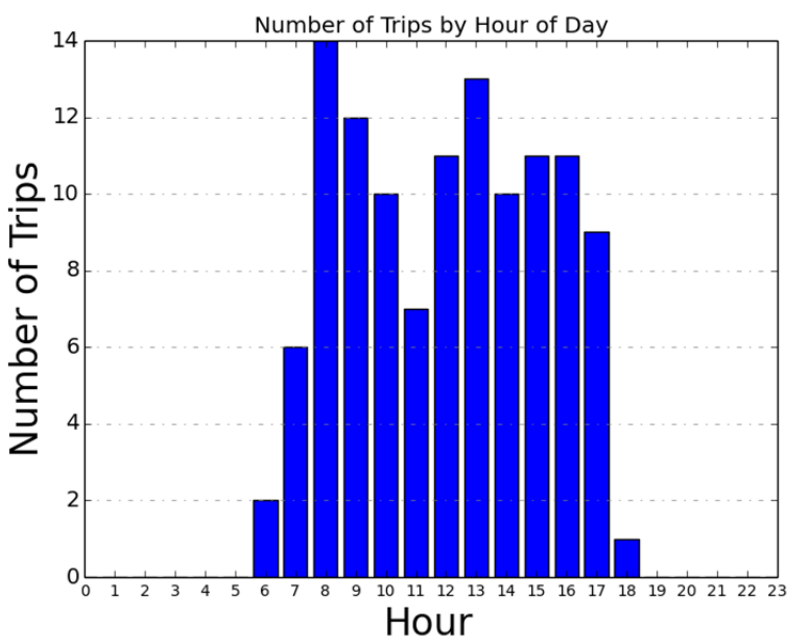

Figure 30. Pool vehicles hourly usage.

Figure 31 shows the outing distance traveled by both enforcement vehicles.

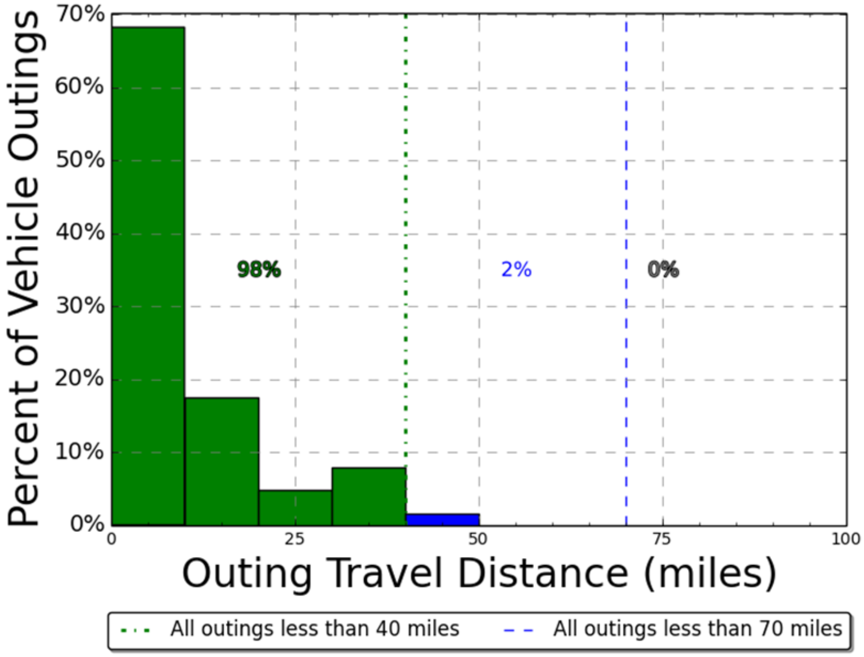

Figure 31. Enforcement vehicle outings.

Appendix D provides the details of each of the enforcement vehicle's daily outing travel. The average travel outing for enforcement vehicles is 8.1 miles. On all vehicle outings, the distance traveled is less than the 70 miles considered to be within the BEV safe range. Further, 98% of vehicle travel outings are less than the 40 miles considered to be within the battery-only range of a PHEV.

5.5.4 Seasonal Adjustments

The vehicles were monitored during the period of late February and early March 2013. As with pool vehicles, it is expected that enforcement activities are related to the number of visitors. RMNP may wish to repeat data collection process during the summer for a more accurate PEV integration plan. To complete this analysis with the current data, it is assumed that the vehicles are used twice as often during the peak summer months and daily usage is three times than seen during these study months.

With this in mind, Figures 27 and 31 would be adjusted as shown in Table 16. This will be used in the analysis that follows.

Table 16. Extrapolated support vehicle daily travel and outing factors.

	<40 miles	< 40 miles, < 70 Miles	> 70 miles
Daily Travel	52%	12%	36%
Outings	82%	2%	16%

All vehicles were monitored for 27 days in February and March 2013 and actual miles traveled were used as monthly figures for March values in projecting monthly and annual miles. The remaining months were factored from that month using the assumptions identified above. Figure 32 shows the projected monthly miles for these support vehicles.

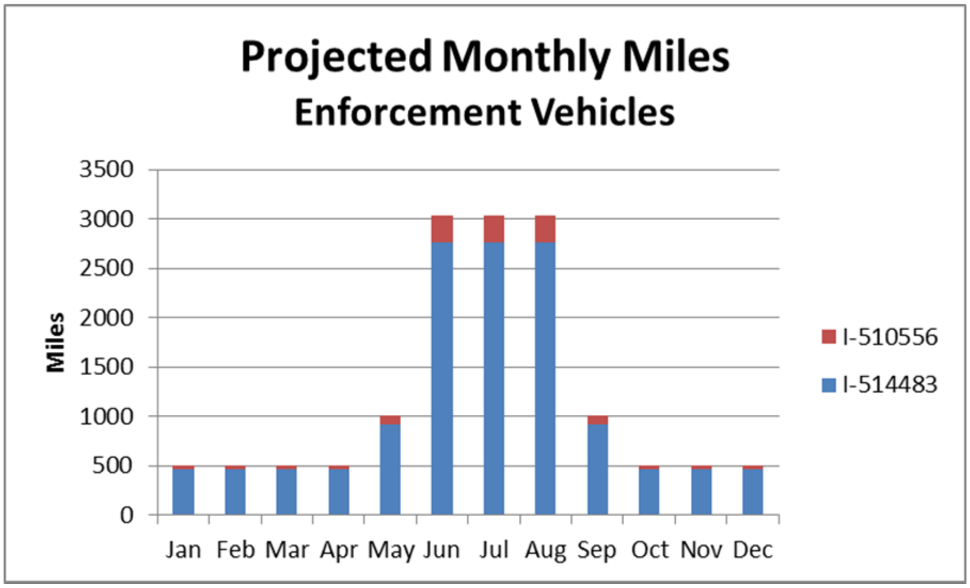

Figure 32. Extrapolated monthly miles for enforcement vehicles.

5.5.5 Enforcement Vehicle Observations/Summary

As a group, the enforcement vehicles have infrequent daily travel distances exceeding 70 miles. For the study period, only one day's travel exceeded the 70-mile range and just barely. However, when incorporating the seasonal adjustment, 36% of the vehicles exceed the daily travel of 70 miles. All of the enforcement vehicles are SUVs. These are a popular choice for enforcement vehicles, along with sedans, because they are versatile for supporting various types of enforcement actions.

As before, there appear to be three possible options for RMNP in implementing PEVs into the enforcement vehicle fleet. It should be noted that the objective would be to incorporate as many BEVs as possible to realize the advantages of reduced petroleum usage and reduced emissions of GHG.

1. **All BEV fleet:** While some BEV manufacturers report vehicle range exceeding 70 miles, Intertek recommends careful evaluation of experienced range to ensure vehicle missions are accomplished. Nevertheless, assuming the 70-mile safe range for a BEV, an all-BEV fleet does not appear to be possible due to the length of some of the daily travel. In addition, a more conservative approach is warranted because of the seasonal adjustments made.

2. **Mixed BEV/PHEV fleet:** Certainly, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances because the PHEV's gasoline engine can provide motive power when the battery has been depleted. The data reveal that on 52% of all vehicle travel days, the total daily travel is less than 40 miles, which typically is the maximum distance a PHEV will travel on battery-only power. This represents a significant operating cost savings opportunity, while retaining the ability to go longer distances when needed. Eighty-two percent of the vehicle outings are less than 40 miles and could be completed on battery power if the battery is fully charged prior to the outing.

   Meanwhile, 64% of the daily travel and 84% of the outings are within the typical capability of a BEV; therefore, EVSE at the home base could provide recharge energy for another outing. A mixed fleet requires fleet manager attention to assign vehicles appropriately for the anticipated use on that day.

   Using the adjustments of Table 16, the data would suggest that 36% of the fleet could be PHEVs to handle the travel greater than 70 miles per day without requiring additional opportunity charging and 64% of the fleet could be BEVs. Because some fleet managers may find managing the BEVs to ensure CD range is not exceeded difficult, this analysis assumes 40% of the fleet is PHEVs and 60% is BEVs. For those vehicles studied, one would be replaced by a BEV and one replaced by a PHEV.

All enforcement vehicles are SUVs. BEV and PHEV replacements are currently available for this vehicle type.

3. **All PHEV fleet:** As noted above, PHEVs can accomplish the same mission as the current fleet when only considering travel times and distances. Replacing all current vehicles with PHEVs only requires an evaluation of the individual vehicle's capabilities of currently available PHEVs to meet current enforcement requirements. Because these two enforcement vehicles are SUVs, replacement PEVs are available. Data show that for a significant number of days, the PHEV will operate in CD mode. The first 40 miles of longer travel days also would be (mostly) powered by electricity; therefore, 67% of all enforcement vehicle travel would be (mostly) battery powered, with only one charge per day. As above, this represents an opportunity for significant operating cost savings, while retaining the ability to go longer distances when needed. Intermediate charging opportunities provide additional benefit, enhancing CD mode. Data show significant charging opportunities throughout the day during stop times.

While it would appear that PEVs are suitable replacements for all enforcement vehicles, additional mission analysis may be required for peak season considerations. Spot-checking vehicles during the peak months may provide this validation.

The vehicle summary shows sufficient time for charging at the base location during the course of the day and additional opportunities at intermediate charging stations are not required. These stations also provide charging opportunities for the visiting public, whose fees may assist in offsetting operating costs.

Considering a full complement of 36 vehicles in the total fleet, Intertek suggests that a mixed fleet may be possible. While the remaining vehicles were not monitored, using the same ratio as above suggests a fleet of 22 BEVs and 14 PHEVs conservatively meet vehicle travel requirements. Typically, additional EVSE at frequent remote locations provide recharging for both BEVs and PHEVs; however, there appear to be no consistent remote stop locations for these pool vehicles.

The types of vehicles monitored (i.e., SUV) are typical of enforcement vehicles. The above evaluation assumes the makeup of the balance of the enforcement fleet is similar.

5.5.6 Enforcement Vehicle Charging Needs

Upon review of these data, Intertek suggests replacement of the studied enforcement fleet with one BEV and one PHEV. No available PHEVs at this writing provide for DC fast charging, nor do the data suggest that this would be a significant benefit for PHEVs in the enforcement fleet. A DC fast charger at the home base will provide a more rapid recharge for BEVs, but appears to be unnecessary if the fleet manager carefully assigns pool vehicles based on anticipated outing lengths. A DC fast charger may allow for a greater percentage of pool vehicles to be replaced with BEVs.

As noted above, AC Level 2 overnight charging of BEVs is typical, whereas overnight charging of PHEVs uses the AC Level 1 outlet.

Intertek's experience suggests that each vehicle have an assigned charging location at their home base. Assigned stations require less management attention to ensure completion of overnight charging. BEVs and PHEVs not assigned to these locations also benefit during visits to the location as part of their normal operation. For the monitored enforcement vehicles, one BEV requires one AC Level 2 EVSE unit for overnight charging and one PHEV require one AC Level 1 outlet for home base. Intertek recommends a minimum of two EVSE at each location to maximize charge capability without a significant increase in installation costs. The PHEVs can utilize the AC Level 2 EVSE at the home base during the day to increase the amount of vehicle miles traveled in electric vehicle mode.

5.6 Balance of Fleet Vehicles

The balance of the RMNP fleet consists of specialty and transport vehicles plus one low-speed vehicle. Certain select PEVs are being demonstrated for various specialty applications, but none are listed in the GSA schedule. The same exists for transport vehicles.

6. GREENHOUSE GAS EMISSIONS AVOIDED AND FUEL COST REDUCTION ANALYSIS

PEV substitution for an existing conventional vehicle avoids GHG emissions and reduces fuel costs. The GHG emissions avoided occur due to the difference in emissions associated with power plant electricity generation versus fuel combustion that occurs in the engine of a conventional vehicle. This analysis does not account for life-cycle emissions that occur outside of electricity generation and fuel combustion phases (i.e., materials and resource extraction, production supply-chains, and decommissioning are not accounted for). These phases are beyond the scope of this report due to the significant effort required to conduct an accurate environmental life-cycle assessment for a transportation system in a very specific setting. Cost reduction also occurs because the cost of electricity is comparable to the cost of gasoline on a unit of energy basis, but PEVs are more efficient than conventional ICE vehicles. Because fuel logs were not kept, the mileage accumulated by each vehicle and the extrapolation to annual miles provide the source of fuel consumption estimates for the study vehicles.

In order to perform the analysis, EPA fuel economy ratings are used. [27] Tables 17 and 18 provide these ratings. Ratings for the PHEVs in Table 18 include CD operation. Because these data are estimates, assumptions include the following:

1. PHEVs operate in CD mode only for the percentage of travel less than 40 miles per outing. This is reasonable for most daily operations (as described in Section 5). This assumption results in savings calculations slightly higher than those realized through the expected operation of combined electric and gasoline motive operations.
2. The fuel economy for the Mitsubishi Outlander is assigned the same value as the RAV4, because EPA has not yet created ratings for the former vehicle. The fuel economy for the Via Motors VTRUX is estimated because EPA has not yet created these ratings.
3. Table 19 suggests that PEVs replace existing fleet vehicles, with the exception of the heavy-duty pickups (see Section 4.4 for vehicle availability). For the entire fleet of support vehicles, where a mix of PHEVs and BEVs are possible, the Toyota RAV4 or Nissan LEAF is suggested for BEVs[28].
4. Most of the heavy-duty pickup trucks are not replaced.

Table 17. U.S. Environmental Protection Agency fuel economy ratings of current fleet vehicles.

Vehicle	Logger	Mission	Make & Model	Model Year	Fuel Economy-Combined (miles/gallon)
I-514483	74	Enforcement	Chevrolet Tahoe	2012	17
I-510556	76	Enforcement	Ford Explorer	2009	17
I-510561	69	Support	Dodge Dakota	2009	17
I-510545	73	Support	Chevrolet Silverado 2500	2008	17*

[27] http://www.fueleconomy.gov/feg/Find.do?action=sbs&id=33558 [accessed February 2, 2014].

[28] An SUV BEV replaces the support vehicle pickup due to current market availability. PEV pickup trucks will be increasingly available in the near future. One example is the PHEV Via Motors VTRUX (http://www.viamotors.com/wp-content/uploads/VIA-Small-Brochure.pdf). [accessed July 19, 2013].

Vehicle	Logger	Mission	Make & Model	Model Year	Fuel Economy-Combined (miles/gallon)
I-510533	70	Pool	Ford Escape	2008	21
I-410506	68	Pool	Ford Explorer	2004	16
I-263766	75	Pool	Ford Explorer	2002	16
I-515081	71	Support	Ford F350	2013	13*

*Diesel fuel economy is not available. Value listed is for lighter-weight gasoline model.

Table 18. U.S. Environmental Protection Agency plug-in electric vehicle fuel economy ratings.

Mission	Make and Model	Model Year	Fuel Economy Combined Wh/mile	Fuel Economy Combined MPGe
Law Enforcement	Chevrolet Volt PHEV	2014	350	98
Law Enforcement	Toyota RAV4 BEV	2014	440	76
Pool	Nissan Leaf BEV	2014	300	114
Pool	Mitsubishi PHEV	2015	440	76
Support	Toyota RAV4 BEV	2014	440	76
Support	Via Motors VTRUX PHEV	2014	475	60

Table 19. Current vehicle replacement plug-in electric vehicles.

	Current Vehicle	Analysis Replacement PEV
Pool SUV	 Ford Explorer	 Mitsubishi Outlander PHEV
Pool SUV	 Ford Escape	 Nissan Leaf BEV
Support light-duty pickups	 Dodge Dakota	 Via Motors VTRUX - PHEV

	Current Vehicle	Analysis Replacement PEV
Enforcement SUV	 Ford Explorer	 Toyota RAV4 BEV
Enforcement SUV	 Chevrolet Tahoe	 Chevrolet Volt PHEV

Calculations provided for GHG emissions and fuel savings include both a total U.S. perspective and a perspective for the local area. The electricity generation mix of power plants for the total United States is different from the local mix of generation in the RMNP area. Likewise, the national average cost for petroleum fuel is different from the local cost for fuel. This analysis includes both approaches in order to allow for local evaluation and to provide the potential benefit for fleet vehicles in other locations of the United States that may be of interest. The final report summarizing results from all sites studied across the U.S. from Intertek to Idaho National Laboratory primarily will consider the national figures.

For the GHG emissions-avoided portion of the analysis, the GHG emissions (in pounds of carbon dioxide equivalent, which also accounts for other GHGs such as methane and nitrous oxide, *lb-CO_2e*) from combustion of gasoline is 20.1 lb-CO_2e/gallon.[29] The United States averages for GHG emissions for the production of electricity is 1.53 lb-CO_2e/kWh[30].

RMNP electric power is provided by the local cooperative, Mountain Parks Electric, Inc., that receives its power from Tri-State Generating. Tri-State Generating reports a mix of generation from several power plants, including coal, gas, solar, and wind generation[31]. EPA reports GHG emissions from the production of electricity. The annual report is available in the Emissions and Generation Resource Integrated Database. The most recent publication is for 2010[32]. Using the generation mix reported by Tri-State Generating and the Emissions and Generation Resource Integrated Database plant reports, emissions for 2010 for the production of electricity were 2.240 lb-CO_2e/kWh. This emission rate reflects the high local dependence on coal as the generation fuel.

GHG emissions avoided are the GHG emitted by the current vehicle (total annual gallons gasoline × GHG emissions/gallon) minus the annual GHG emitted by the replacement PEV (total annual kWh × GHG emissions/kWh). For the PHEVs, the percentages of outings less than 40 miles are counted for the annual miles saved in CD mode, with the balance of the miles accounted as fueled with gasoline.

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[29] http://www.theevproject.com/cms-assets/documents/106077-891082.ghg.pdf [accessed 19 July 2013].

[30] http://www.theevproject.com/cms-assets/documents/106077-891082.ghg.pdf [accessed July 19, 2013].

[31] http://www.tristategt.org/AboutUs/generation.cfm [accessed June 8, 2014].

[32] http://www.epa.gov/cleanenergy/energy-resources/egrid/ [accessed June 8, 2014].

Table 20 shows the calculation of annual miles based on the recorded and extrapolated miles in this study. In addition, the replacement vehicle is identified for each vehicle. It is important to note that the analysis conducted above suggests replacement vehicles for the fleet of vehicles rather than necessarily replacing the exact vehicle monitored. The percent of miles in CD mode is 100% for BEVs because all travel is battery powered. The percent of miles in CD mode for PHEVs is obtained from the daily travel shown in Tables 12, 14, and 16.

Table 20. Charge-depleting mode miles calculations.

Vehicle	Replacement Vehicle	Calculated Annual Miles	Percent of Miles CD Mode	CD Mode Miles
I-514483	Volt PHEV	13,369	52%	4.469
I-510556	RAV4 BEV	1,334	100%	667
I-510561	RAV4 BEV	17,388	100%	7.600
I-510545	NA	1,242	NA	NA
I-510533	Leaf BEV	319	100%	6.148
I-410506	Mitsubishi PHEV	7,830	56%	2.623
I-263766	Leaf BEV	2,233	100%	1.102
I-515081	NA	8,372	NA	NA

For the cost-avoided piece of the analysis, fuel cost assumptions are $3.690/gallon of gasoline for the United States and $3.509/gallon in Colorado[33]. Electrical cost are 0.0984 $/kWh for the United States and 0.0939 $/kWh for the Colorado area[34]. Therefore, fuel costs savings are the current vehicle's calculated annual gasoline cost (total annual gallons gasoline × cost/gallon) minus the electricity cost (total annual kWh × cost/kWh) of the replacement PEV traveling the same distance.

The miles calculated above for CD mode yields estimates for yearly GHG emissions avoided and fuel cost reductions. The results of this analysis (shown in Table 21) demonstrate that the substitution of a conventional ICE vehicle with a PEV can reduce the GHG emissions and fuel costs dramatically. The table also shows the percentage reduction in GHG emissions and fuel costs for ease of comparison. For example, if the Mitsubishi Outlander replaces Vehicle I-410506, a 22% reduction in GHG emissions in Colorado occurs. The Explorer produces 5,508 lb-CO_2e/year for the distance traveled whereas the Outlander produces 4,321 lb-CO_2e/year for that same distance, for a reduction of 1,187 lb-CO_2e/year.

Table 21. Greenhouse gas emissions avoidance and fuel cost reduction analysis summary.

	Mission	Make and Model	Extrapolated U.S. Yearly CO_2e Avoided (lb-CO_2e/year)/ **% reduction**	Extrapolated Local Yearly CO_2e Avoided (lb-CO_2e/year) / **% reduction**	Extrapolated U.S. Yearly Fuel Cost Reduction/ **% reduction**	Extrapolated Local Yearly Fuel Cost Reduction/ **% reduction**
I-514483	Enforce	Chevrolet Tahoe	4,497/**55%**	2,769/**34%**	$1,270/**84%**	$1,206/**84%**
I-510556	Enforce	Ford Explorer	679/**43%**	262/**17%**	$232/**80%**	$220/**80%**
I-510561	Support	Dodge Dakota	8,853/**43%**	3,421/**17%**	$3,021/**80%**	$2,871/**80%**
I-510545	Support	Chevrolet Silverado 2500	NA	NA	NA	NA

[33] http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sco_w.htm [accessed June 8, 2014].

[34] http://www.eia.gov/electricity/state/ [accessed May 12, 2014].

	Mission	Make and Model	Extrapolated U.S. Yearly CO_2e Avoided (lb-CO_2e/year)/ **% reduction**	Extrapolated Local Yearly CO_2e Avoided (lb-CO_2e/year) / **% reduction**	Extrapolated U.S. Yearly Fuel Cost Reduction/ **% reduction**	Extrapolated Local Yearly Fuel Cost Reduction/ **% reduction**
I-510533	Pool	Ford Escape	159/**52%**	91/**30%**	$46/**83%**	$44/**83%**
I-410506	Pool	Ford Explorer	2,557/**46%**	1,187/**22%**	$821/**81%**	$780/**81%**
I-263766	Pool	Ford Explorer	1,780/**63%**	1,305/**47%**	$449/**87%**	$426/**87%**
I-515081	Support	Ford F350	NA	NA	NA	NA
Total			18,525/**48%**	9,035/**23%**	$5,840/**82%**	$5,549/**82%**
Total Pool			4,496/**52%**	2,582/**30%**	$1,317/**83%**	$1,252/**83%**
Total Support			8,853/**43%**	3,421/**17%**	$3,021/**80%**	$2,871/**80%**
Total Enforcement			5,176/**53%**	3,032/**31%**	$1,501/**83%**	$1,427/**83%**

Table 21 shows the high potential benefit in the reduction of GHG emissions in the local RMNP area. This is in spite of the heavy reliance on coal as the generating fuel (which also explains why the reduction experienced based on national figures is greater than the Colorado reduction). In addition, the fuel cost reduction potential benefit is also significant due to the low local cost of power.

As presented in Section 5, 14 BEVs and nine PHEVs could replace the pool fleet of 23 vehicles. The support fleet of 130 vehicles would retain 25 heavy-duty pickups and replace the balance with 42 BEVs and 63 PHEVs. Twenty-two BEVs and 14 PHEVs could replace the enforcement fleet of 36 vehicles. Using an average savings per vehicle, Table 22 provides the avoided GHG and fuel cost savings should these replacements occur. Additional savings result if RMNP includes portions of their fleet with other missions. The table also shows the percentage reduction in GHG emissions and fuel costs for ease of comparison.

Table 22. Extrapolated greenhouse gas emissions avoided and fuel cost savings for the entire fleet.

Mission	Extrapolated U.S. Yearly CO_2e Avoided (lb-CO_2e/year)/% reduction	Extrapolated Local Yearly CO_2e Avoided (lb-CO_2e/year)/% reduction	Extrapolated U.S. Yearly Fuel Cost Reduction ($/year)/% reduction	Extrapolated Local Yearly Fuel Cost Reduction ($/year)/% reduction
Pool	31,312/47%	15,179/23%	$9,895/82%	$9,402/82%
Support	1,452,378/67%	1,124,622/52%	$350,868/89%	$333,507/88%
Enforcement	104,468/59%	71,114/40%	$27,751/86%	$26,374/86%
Total	1,588,158/66%	1,210,915/50%	$388,514/88%	$369,383/88%

7. OBSERVATIONS

Intertek appreciates the opportunity to present the results of this evaluation. Observations for possible follow-up action include the following:

Observation #1:

Implementation: RMNP can move forward in the near future with the replacement of pool, support, and enforcement vehicles with PEVs as current budget and vehicle replacement schedules allow. Certainly, most of the vehicle types studied in this report are candidates for immediate replacement.

Observation #2:

Fleet Inventory: A more thorough examination of the quantities and types of fleet vehicles within each usage category may be beneficial to quantify the potential for replacement with PEVs. While Intertek suggests a mix of BEVs and PHEVs, a more refined look may be possible. In addition, this study did not look at the other fleet vehicle categories (such as specialty, transport vehicles, and shuttles/buses).

Observation #3:

Vehicle Replacement Plan: Development of a detailed vehicle replacement plan could be beneficial. Such a plan would include cost and schedule for vehicle replacement. A more detailed survey and calculation of the use of the fleet vehicles (such as vehicle parking locations, age of vehicle, expected replacement time, expected replacement costs, GSA vehicle costs, EVSE cost, total life costs, and EVSE installation costs) provide support to this replacement plan. A more refined estimate for reduced GHG emissions, petroleum usage reduction, and fuel cost savings flow from this detailed plan.

Observation #4:

Infrastructure Planning: In conjunction with the replacement plan, evaluation of the RMNP sites for the placement of PEV charging infrastructure could be beneficial. Intertek has significant experience in this area and such plans will consider not only fleet vehicle charging needs, but also the convenience that charging infrastructure provides employees and visitors. This planning also considers the existing facility electrical distribution system. Vehicle home base considerations factor into the ratio of PEVs to EVSE units to maintain all vehicles at operational readiness.

Charging stations located at various destination points may provide additional infrastructure for PEV charging of the RMNP fleet. Charging stations at RMNP may also provide an opportunity for charging by the public. RMNP can benefit through collection of charging fees during times when these stations are not required for the overnight charging of fleet vehicles. The fees avoid the questions associated with a federal agency providing fuel for privately owned vehicles and support the costs for installation and operation of the EVSE.

Appendix A
Fleet Survey Form

Fleet Survey Sample	
Project Name:	BEA-FEMP Fleet II
Agency Name:	National Park Service
Location:	Rocky Mountain National Park (RMNP)
Date Requested:	2/2/2013

The following survey questions are used to lead the discussion concerning the mission of the current fleet of vehicles. If responding by e-mail, please use one form for each vehicle.

Please submit the data sheets to Ian Nienhueser at ian.nienhueser@intertek.com by fax at (602) 443-9007. If you have questions, please contact Ian at the email above or by phone at (702) 738-2706.

Vehicle Information			
Today's Date:	2/17/2013	Odometer Reading:	17,589
Make:	Chevrolet	Data Logger ID:	64
Model:	Tahoe	Data Logger Installed:	2/17/2013
Year:	2012	Fuel Type:	Gasoline
Vehicle ID No:	1GNSK2E01CR301102	Miles per Gallon:	23/31
Agency Fleet ID:	NA	Miles per Year:	10,000

1.	Vehicle Mission:	
	☐	Pool Vehicle
	☐	Enforcement Vehicle
	☐	Support Vehicle
	☐	Transport Vehicle
	☐	Specialty Vehicle
	☐	Shuttle/Bus
	☐	Low Speed Vehicle
2.	Vehicle Typical Parking Location: (parking lot name/designation, nearest building number)	

Appendix B
Vehicle Characterization

Table B-1. Rocky Mountain National Park vehicle index.

Vehicle Index					
Logger	Make	Model	Year	Fleet Vehicle Id	Mission
74	Chevrolet	Tahoe	2012	101/I-514483	Enforcement
76	Ford	Explorer	2009	102/I-510556	Enforcement
69	Dodge	Dakota	2009	103/I-510561	Support
73	Chevrolet	Silverado 2500HD	2008	104/I-510545	Support
70	Ford	Escape	2008	105/I-510533	Pool
68	Ford	Explorer	2004	106/ I-410506	Pool (Enforcement)
75	Ford	Explorer	2002	107/ I-263766	Pool
71	Ford	F350 SD	2013	108/ I-515081	Support

Appendix C
Definitions

Alternative fuel	An alternative fuel means any fuel other than gasoline and diesel fuels, such as methanol, ethanol, and gaseous fuels (40 CFR 86.1803-01). A fuel type other than petroleum-based gasoline or diesel as defined by the Energy Policy Act (examples include ethanol, methanol, compressed natural gas, propane, and electrical energy).
City fuel economy (MPG)	City fuel economy means the city fuel economy determined by operating a vehicle (or vehicles) over the driving schedule in the federal emission test procedure or determined according to the vehicle-specific 5-cycle or derived 5-cycle procedures (40 CFR 600.001).
Conventional fuel	A petroleum-based fuel (examples include gasoline and diesel fuel).
Daily travel	The sum of daily trips and stops in one day.
Diesel fuel	Diesel means a type of engine with operating characteristics significantly similar to the theoretical diesel combustion cycle. Non-use of a throttle during normal operation is indicative of a diesel engine (49 CFR 86-1803).
E85	Ethanol fuel blend of up to 85% denatured ethanol fuel and gasoline or other hydrocarbons by volume.
Electric vehicle	Electric vehicle means a motor vehicle that is powered solely by an electric motor drawing current from a rechargeable energy storage system, such as from storage batteries or other portable electrical energy storage devices, including hydrogen fuel cells, provided the following: (1) The vehicle is capable of drawing recharge energy from a source off the vehicle, such as residential electric service (2) The vehicle must be certified to the emission standards of Bin #1 of Table S04-1 in § 86.1811-09(c)(6) (3) The vehicle does not have an onboard combustion engine/generator system as a means of providing electrical energy (40 CFR 86-1803).
Ethanol-fueled vehicle	Ethanol-fueled vehicle-means any motor vehicle or motor vehicle engine that is engineered and designed to be operated using ethanol fuel (i.e., a fuel that contains at least 50% ethanol [C_2 H_5 OH] by volume) as fuel (40 CFR 86.1803-01).
Federal vehicle standards	The document that establishes classifications for various types and sizes of vehicles, general requirements, and equipment options. The GSA Vehicle Acquisition and Leasing Service's Automotive Division issues it annually.
Government motor vehicle	Any motor vehicle the government owns or leases. This includes motor vehicles obtained through purchase, excess, forfeiture, commercial lease, or GSA fleet lease.
Gross vehicle weight rating	Gross vehicle weight rating (GVWR) means the value specified by the vehicle manufacturer as the maximum design loaded weight of a single vehicle (e.g., vocational vehicle) (U.S. Government Printing Office 2009)
GSA fleet	GSA fleet lease means obtaining a motor vehicle from GSA fleet (41 CFR 102-34).

Heavy light-duty truck	Heavy light-duty truck means any light-duty truck rated greater than 6,000 lb. GVWR. The light-duty truck 3 (LDT3) and LDT4 classifications comprise the heavy light-duty truck category (40 CFR 86.1803-01).
Highway fuel economy (Hwy MPG)	Highway fuel economy means the highway fuel economy determined either by operating a vehicle (or vehicles) over the driving schedule in the federal highway fuel economy test procedure or determined according to either the vehicle-specific, 5-cycle equation or the derived 5-cycle equation for highway fuel economy (40 CFR 600.001).
Hybrid electric vehicle	Hybrid electric vehicle means a motor vehicle that draws propulsion energy from onboard sources of stored energy that are both an internal combustion engine or heat engine using consumable fuel and a rechargeable energy storage system (such as a battery, capacitor, hydraulic accumulator, or flywheel), where recharge energy for the energy storage system comes solely from sources onboard the vehicle.
Idle time	Idle time is logged whenever a vehicle idles with the engine running for 3 minutes or longer.
Law enforcement	Law enforcement motor vehicle means a light-duty motor vehicle that is specifically approved in an agency's appropriation act for use in apprehension, surveillance, police, or other law enforcement work or specifically designed for use in law enforcement. If not identified in an agency's appropriation language, a motor vehicle qualifies as a law enforcement motor vehicle only in the following cases: (1) A passenger automobile having heavy-duty components for electrical, cooling, and suspension systems and at least the next higher cubic inch displacement or more powerful engine than is standard for the automobile concerned (2) A light truck having emergency warning lights and identified with markings such as "police" (3) An unmarked motor vehicle certified by the agency head as essential for the safe and efficient performance of intelligence, counterintelligence, protective, or other law enforcement duties (4) A forfeited motor vehicle seized by a federal agency that subsequently is used for performing law enforcement activities (41 CFR Part 102-34.35).
Light-duty motor vehicle	Any motor vehicle with a GVWR of 8,500 lb or less (41 CFR 102-34).
Light-duty truck	Light-duty truck means any motor vehicle rated at 8,500 lb GVWR or less, which has a curb weight of 6,000 lb or less and, which has a basic vehicle frontal area of 45 ft^2 or less, which is as follows: (1) Designed primarily for purposes of transportation of property or is a derivation of such a vehicle (2) Designed primarily for transportation of persons and has a capacity of more than 12 persons (3) Available with special features, enabling off-street or off-highway operation and use. LDT1 means any light light-duty truck up through 3,750-lb loaded vehicle weight. LDT2 means any light light-duty truck greater than 3,750-lb loaded vehicle weight.

	LDT3 means any heavy light-duty truck up through 5,750-lb adjusted loaded vehicle weight. LDT4 means any heavy light-duty truck greater than 5,750-lb adjusted loaded vehicle weight (U.S. Government Printing Office 2009)
Light-duty vehicle	Light-duty vehicle means a passenger car or passenger car derivative capable of seating 12 passengers or less.
Low-speed vehicle	Low-speed vehicle means a motor vehicle (1) That is 4-wheeled (2) Whose speed attainable in 1.6 km (1 mile) is more than 32 kilometers per hour (20 miles per hour) and not more than 40 kilometers per hour (25 miles per hour) on a paved level surface (3) Whose GVWR is less than 1,361 kilograms (3,000 pounds) (49 CFR 571.3 – Definitions).
Medium-duty passenger vehicle	Medium-duty passenger vehicle means any heavy-duty vehicle (as defined in this subpart) with a GVWR of less than 10,000 lb that is designed primarily for transportation of persons. The medium-duty passenger vehicle definition does not include any vehicle which (1) Is an “incomplete truck” as defined in this subpart (2) Has a seating capacity of more than 12 persons (3) Is designed for more than 9 persons in seating rearward of the driver's seat (4) Is equipped with an open cargo area (e.g., a pick-up truck box or bed) of 72.0 inches in interior length or more. A covered box not readily accessible from the passenger compartment will be considered an open cargo area for purposes of this definition (U.S. Government Printing Office 2009)
Model year	Model year means the manufacturer's annual production period (as determined by the administrator), which includes January 1 of such calendar year; provided that if the manufacturer has no annual production period, the term “model year” shall mean the calendar year (40 CFR 86-1803.01).
MPG	“MPG” or “mpg” means miles per gallon. This generally is used to describe fuel economy as a quantity or is used as the units associated with a particular value.
MPGe	MPGe means miles per gallon equivalent. This generally is used to quantify a fuel economy value for vehicles that use a fuel other than gasoline. The value represents miles the vehicle can drive with the energy equivalent of one gallon of gasoline: (c) SCF means standard cubic feet (d) SUV means sport utility vehicle (e) CREE means carbon-related exhaust emissions [76 FR 39527, July 6, 2011].
Non-passenger automobile	A non-passenger automobile means an automobile that is not a passenger automobile or a work truck; this includes vehicles described in paragraphs (a) and (b) of 49 CFR 523.5.
Owning agency	Owning agency means the executive agency that holds the vehicle title, manufacturer’s Certificate of Origin, or is the lessee of a commercial lease. This term does not apply to agencies that lease motor vehicles from the GSA

	fleet (41 CFR Part 102-34.35).
Passenger automobile	A passenger automobile is any automobile (other than an automobile capable of off-highway operation) manufactured primarily for use in the transportation of not more than 10 individuals (49 CFR 523.4 – Passenger automobile). A sedan or station wagon designed primarily to transport people (41 CFR 102-34).
Pickup truck	Pickup truck means a non-passenger automobile, which has a passenger compartment and an open cargo bed (49 CFR 523.2).
Plug-in hybrid electric vehicle	PHEV means a hybrid electric vehicle that has the capability to charge the battery from an off-vehicle electric source, such that the off-vehicle source cannot be connected to the vehicle while the vehicle is in motion (40 CFR 86.1803).
Vehicle class	The designation of motor vehicle types that include sedans, station wagons, ambulances, buses, and trucks, or different categories of vehicles according to federal vehicle standards and further defined in 49 CFR 600.315-82.
Vehicle configuration	Vehicle configuration means a unique combination of basic engine, engine code, inertia weight class, transmission configuration, and axle ratio.
Vehicle days	The number of days a vehicle was driven or utilized during the (vehicle) study period.
Vehicle home base	The primary, assigned outing beginning and ending parking location for the vehicle.
Vehicle study period	The number of days the vehicle was equipped with a data logger.

Appendix D
Vehicle Data Sheets

Vehicle I-514483

Make/Model/Year	Chevrolet Tahoe/2012
EPA Class Size	SUV
Mission	Enforcement
Contact	Bill Thompson
Parking Location	Utility Road, Estes Park
Fleet Vehicle ID	101/I-514483
Fuel Type	Gas/E85
EPA Label/MPG (City/Hwy/Combined)	15/21/17 11/16/13
EPA GHG Emissions (Grams CO_2/Mi)	523/484
Study Vehicle ID	74
Total Vehicle Days/Total Study Days	15/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	30.8/85.9	8.2/49.2	4.3/41.4	461
Travel Time (Minutes)	114/306	30.5/162	15.8/101	1,706
Idle Time (Minutes)	25.9/NA	6.9/NA	3.6/NA	389

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	88	98.9%	Less than 2	67
10 to 20	1	1.1%	2 to 4	6
20 to 40	0	0%	4 to 8	3
40 to 60	0	0%	Greater than 8	13

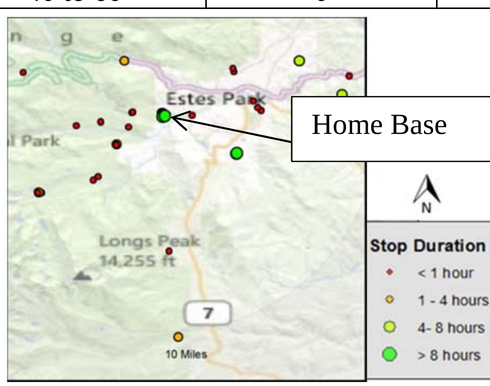

Figure D-1. Vehicle I-514483 stops.

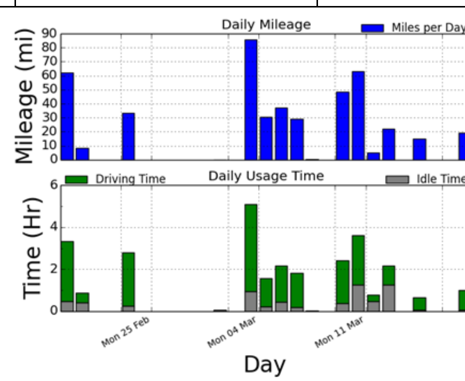

Figure D-2. Vehicle I-514483 history.

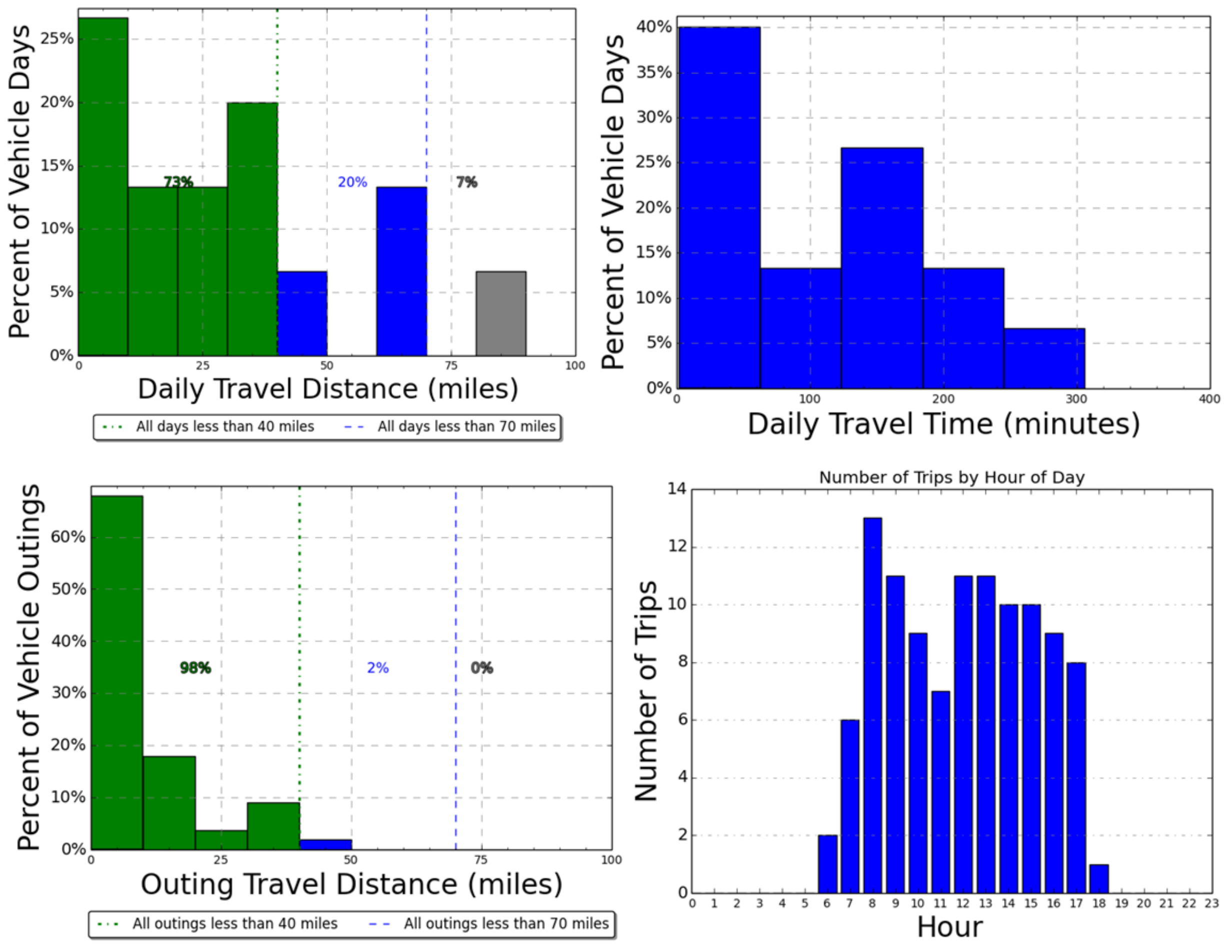

Figure D-1. Vehicle I-514483 travel graphs.

Vehicle I-514483 Observations

Logger 74 collected data on this vehicle for 15 days of the 27-day study period. Data validation occurred on 99.6% of the vehicle data. This vehicle's primary home base is located on Utility Road in Estes Park. This vehicle operates within the Resource Protection and Visitor Management division for enforcement purposes and typically is operated by rangers.

As shown on the history graph (Figure D-2), this vehicle travels a distance in excess of the advertised range of BEVs (i.e., 70 miles). Of all vehicle travel days, 93% were within the 70-mile BEV safe range (the green and blue bars on Figure D-3) and all outings on those days were within this range; 7% of daily travel was outside the BEV range.

The longest single outing of 49 miles occurred in March and it was one of several outings that day. The outing before this longest outing was about 24 miles, but the vehicle was parked at the home base for 2 hours between these trips.

It appears that a BEV could be a suitable replacement for this vehicle if the opportunity charging between outings is utilized. Otherwise, a PHEV is required for the days that involve extended trips. RMNP did not identify other specific mission requirements for this vehicle (such as cargo or other specifications).

Vehicle I-510556

	Make/Model/Year	Ford Explorer/2009
	EPA Class Size	SUV
	Mission	Enforcement
	Contact	Bill Thompson
	Parking Location	Utility Road, Estes Park
	Fleet Vehicle ID	102/I-510556
	Fuel Type	Gas
	EPA Label/MPG (City/Hwy/Combined)	15/21/17
	EPA GHG Emissions (Grams CO_2/Mi)	523
	Study Logger ID	76
	Total Vehicle Days/Total Study Days	2/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	23.2/39.9	6.6/27.1	5.2/19.2	46
Travel Time (Minutes)	63/103.0	18.0/66.0	14.0/46.0	126
Idle Time (Minutes)	10/NA	2.9/NA	2.2/NA	20

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	7	100%	Less than 2	6
10 to 20	0	0%	2 to 4	0
20 to 40	0	0%	4 to 8	0
>40	0	0%	Greater than 8	1

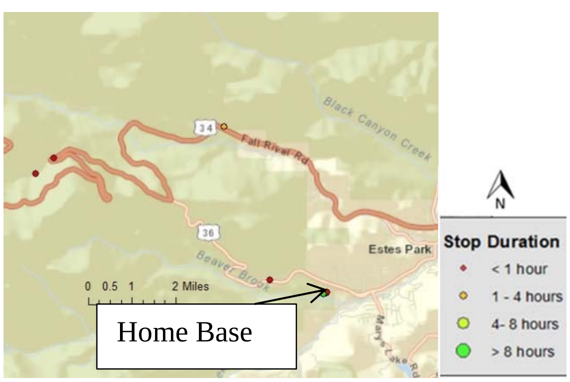

Figure D-4. Vehicle I-510556 stops.

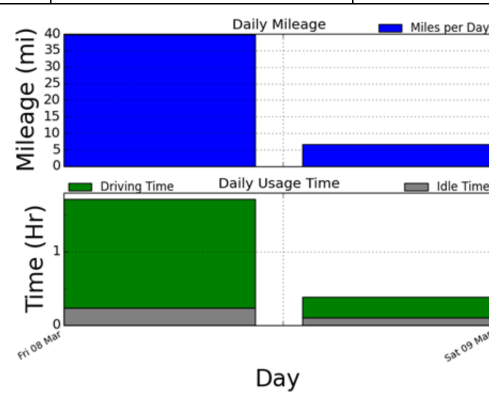

Figure D-5. Vehicle I-510556 history.

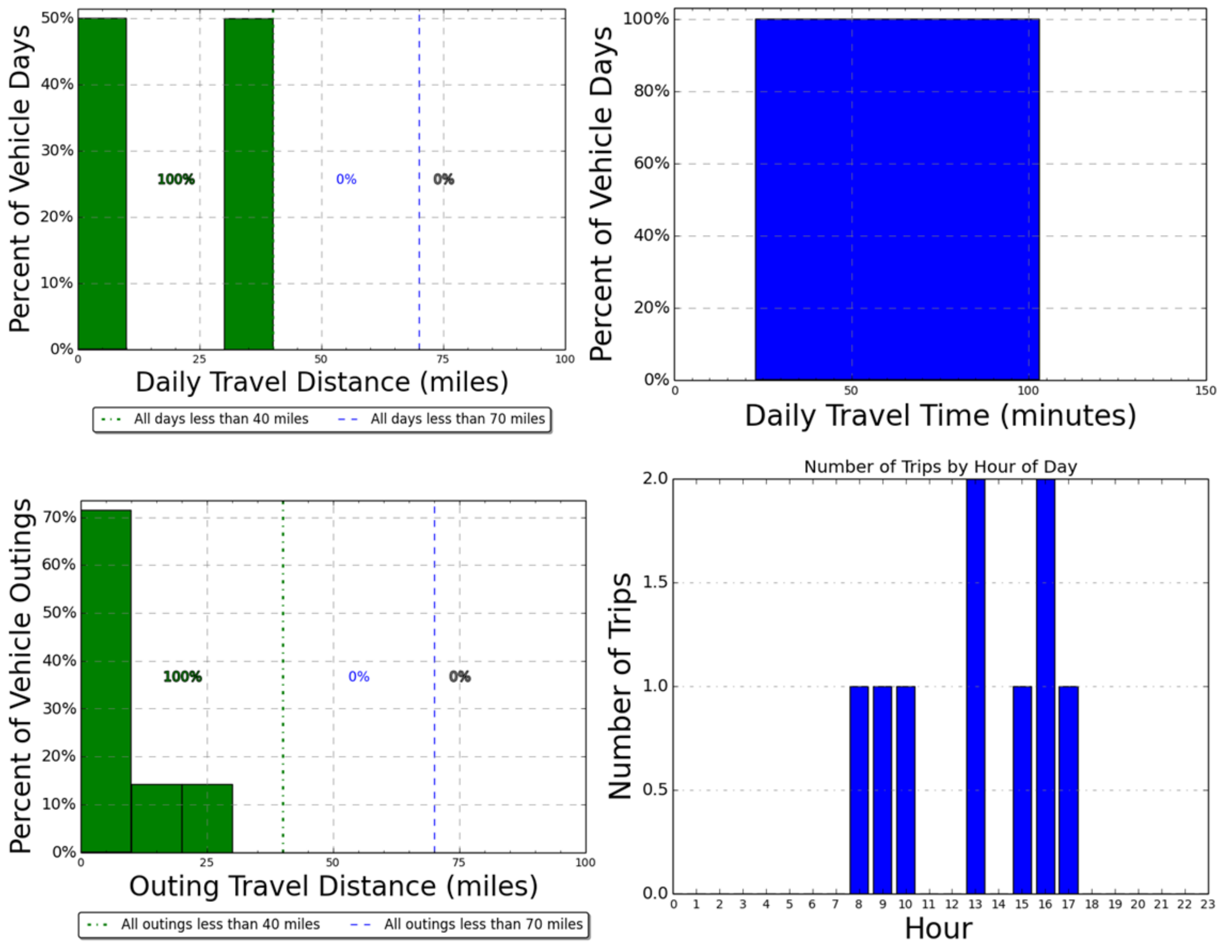

Figure D-2. Vehicle I-510556 travel graphs.

Vehicle I-510556 Observations

Logger 76 collected data on this vehicle for 2 days of the 27-day study period. Data validation occurred on 95.5% of the vehicle data. The 2 days occurred mid-way through the study period, suggesting that this vehicle was not used other than these 2 days. This vehicle operates within the Resource Protection and Visitor Management division for enforcement purposes and typically is operated by rangers.

Both vehicle travel days (and all outings) were within the 70-mile BEV safe range (the green and blue bars on Figure D-6).

Based on this limited information, it appears that a BEV would be a suitable replacement for this vehicle, assuming a BEV can support the other mission requirements of this vehicle (such as cargo or other specifications). RMNP did not identify specific requirements at the time of the survey.

Vehicle I-510561

Make/Model/Year	Dodge Dakota/2009
EPA Class Size	Pickup
Mission	Support
Contact	Bill Thompson
Home Base	Mills Drive, Estes Park
Fleet Vehicle ID	103/I-510561
Fuel Type	Gas/E85
EPA Label/MPG (City/Hwy/Combined)	15/20/17 9/13/10
EPA GHG Emissions (Grams CO_2/Mi)	523/630
Study Logger ID	69
Total Vehicle Days/Total Study Days	17/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	44.5/62.2	13.8/62.2	2.8/17.8	756
Travel Time (Minutes)	166/238.0	51.3/238.0	10.7/81	2,824
Idle Time (Minutes)	43.2/NA	13.4/NA	2.8/NA	735

Total Stops		Stop Duration		
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	229	97.9%	Less than 2	216
10 to 20	5	2.1%	2 to 4	0
20 to 40	0	0%	4 to 8	2
>40	0	0%	Greater than 8	16

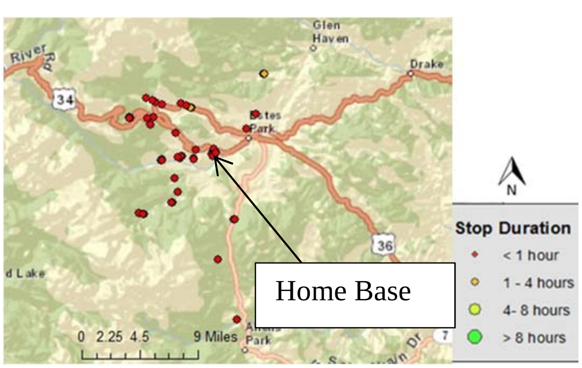

Figure D-7. Vehicle I-510561 stops.

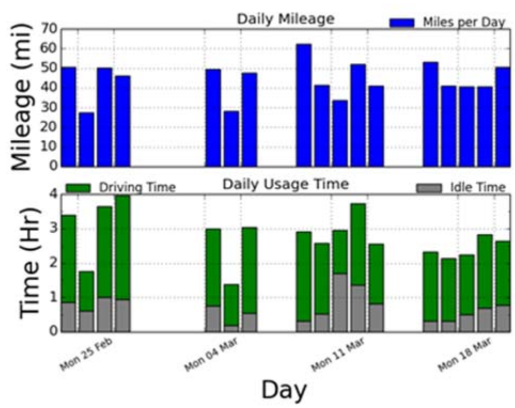

Figure D-8. Vehicle I-510564 history.

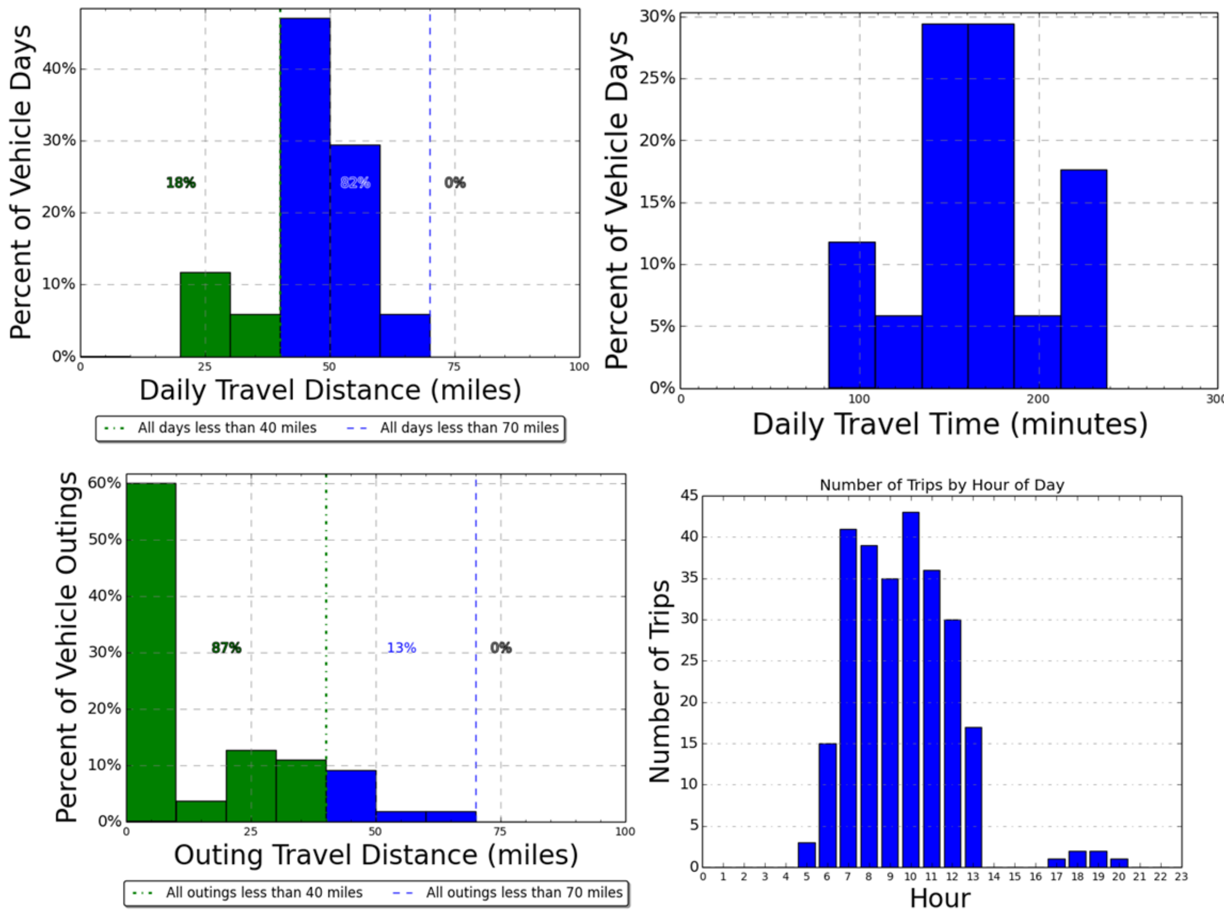

Figure D-3. Vehicle I-510561 travel graphs.

Vehicle I-510561 Observations

Logger 69 collected data on this vehicle for a period of 17 days of the 27-day study period. Validation occurred on 99.7% of the vehicle data. This vehicle is home based at Mills Drive in Estes Park. This vehicle primarily is used by the custodial staff in the Facility Management Division.

As shown on the history graph (Figure D-8) and travel graphs (Figure D-9), all vehicle travel days (and all outings) were within the 70-mile BEV safe range (the green and blue bars on Figure D-9). The longest single daily travel of 62.2 miles occurred on March 7 on an outing of the same length.

It appears that a BEV may be a suitable replacement for this vehicle, assuming a BEV can support the other mission requirements of this vehicle (such as cargo or other specifications). RMNP did not identify specific requirements at the time of the survey.

Vehicle I-510545

	Make/Model/Year	Chevrolet Silverado 2500 HD/2008
	EPA Class Size	Pickup Heavy Duty
	Mission	Support
	Contact	Bill Thompson
	Parking Location	Utility Road or Mills Drive
	Fleet Vehicle ID	104/I-510545
	Fuel Type	Diesel*
	EPA Label/MPG (City/Hwy/Combined)	15/20/17*
	EPA GHG Emissions (Grams CO_2/Mi)	523*
	Study Logger ID	73
	Total Vehicle Days/Total Study Days	7/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	7.6/34.6	3.1/28.1	1.9/6.3	54
Travel Time (Minutes)	66/193.0	27.1/159.0	16.4/116.0	460
Idle Time (Minutes)	40.6/NA	16.7/NA	10.1/NA	284

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	30	100%	Less than 2	25
10 to 20	0	0%	2 to 4	0
20 to 40	0	0%	4 to 8	1
>40	0	0%	Greater than 8	4

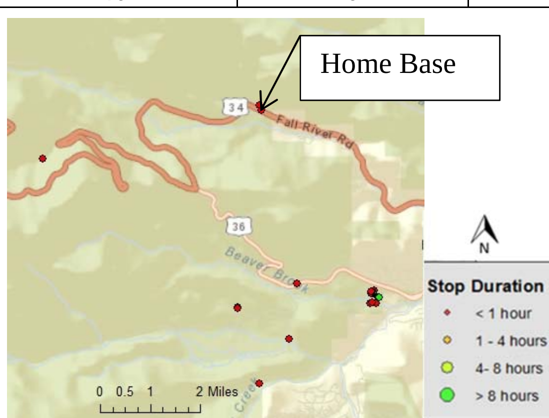

Figure D-10. Vehicle I-510545 stops.

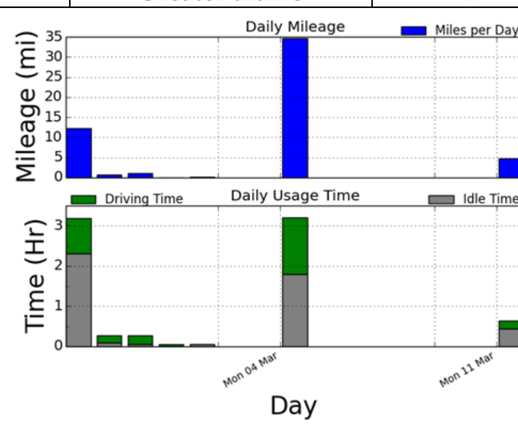

Figure D-11. Vehicle I-510545 history.

*Silverado diesel stats are not available. Figures are for the Silverado C15 gas model.

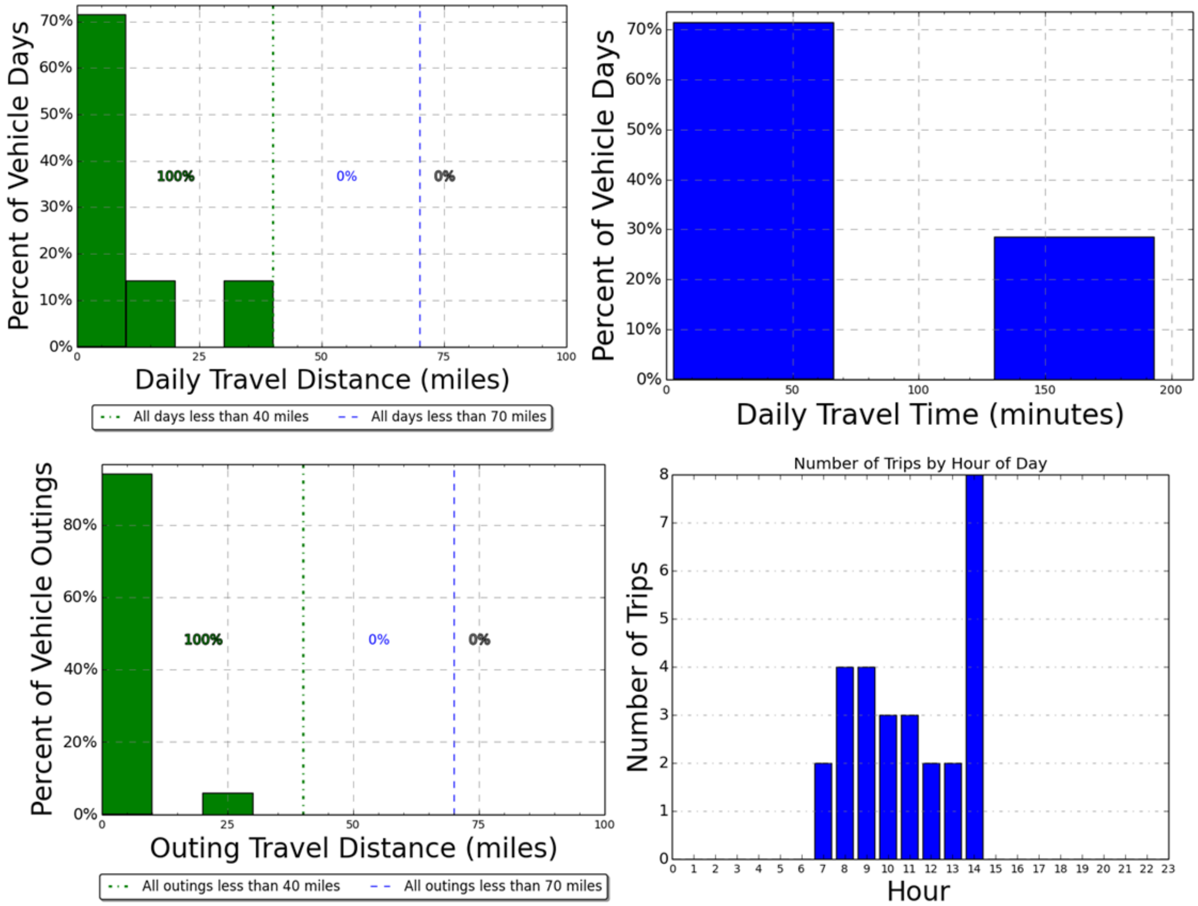

Figure D-4. Vehicle I-510545 travel graphs.

Vehicle I-510545 Observations

Logger 73 collected data on this vehicle for a period of 7 days of the 27-day study period. Validation occurred on 98.8% of the vehicle data. The vehicle parks primarily on Utility Road or Mills Drive and supports the Facility Management Division.

As shown on the history graph (Figure D-11) and travel graphs (Figure D-12), all travel for this vehicle was within the advertised range of BEVs (i.e., 70 miles). All vehicle outings were well within the 70-mile BEV safe range and the battery only range of a typical PHEV (the green bars on Figure D-12).

It appears that a BEV could be a suitable replacement for this vehicle if such were available to replace heavy-duty pickups. Although RMNP did not identify specific cargo or other vehicle requirements that may require the heavy-duty nature, it is assumed that such requirements exist. Thus, no replacement by a PEV is recommended at this time.

Vehicle I-510533

Make/Model/Year	Ford Escape/2008
EPA Class Size	SUV
Mission	Pool
Contact	Bill Thompson
Parking Location	Utility Road, Estes Park
Fleet Vehicle ID	105/I-510533
Fuel Type	Gas
EPA Label/MPG (City/Hwy/Combined)	19/24/21
EPA GHG Emissions (Grams CO_2/Mi)	423
Study Logger ID	70
Total Vehicle Days/Total Study Days	3/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	3.6/6.2	1.3/5.6	0.9/2.8	11
Travel Time (Minutes)	25/36.0	9.5/23.0	6.3/14.0	76
Idle Time (Minutes)	13.0/NA	4.9/NA	3.3/NA	39

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	5	100%	Less than 2	4
10 to 20	0	0%	2 to 4	1
20 to 40	0	0%	4 to 8	0
>40	0	0%	Greater than 8	0

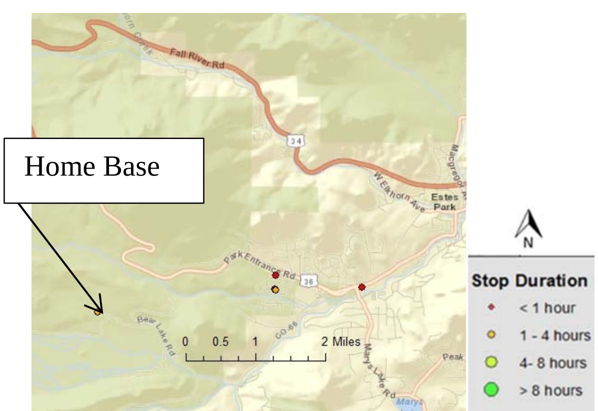

Figure D-13. Vehicle I-510533 stops.

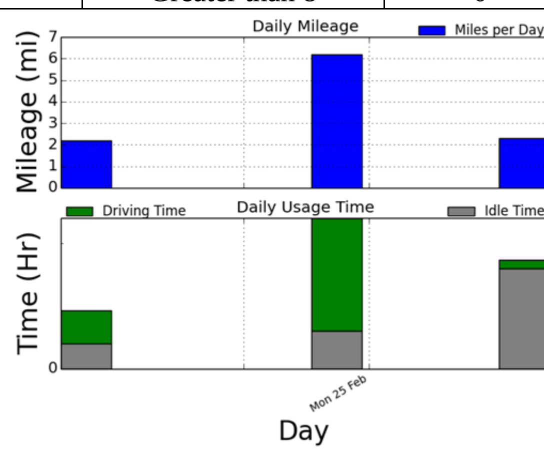

Figure D-11. Vehicle I-510533 history.

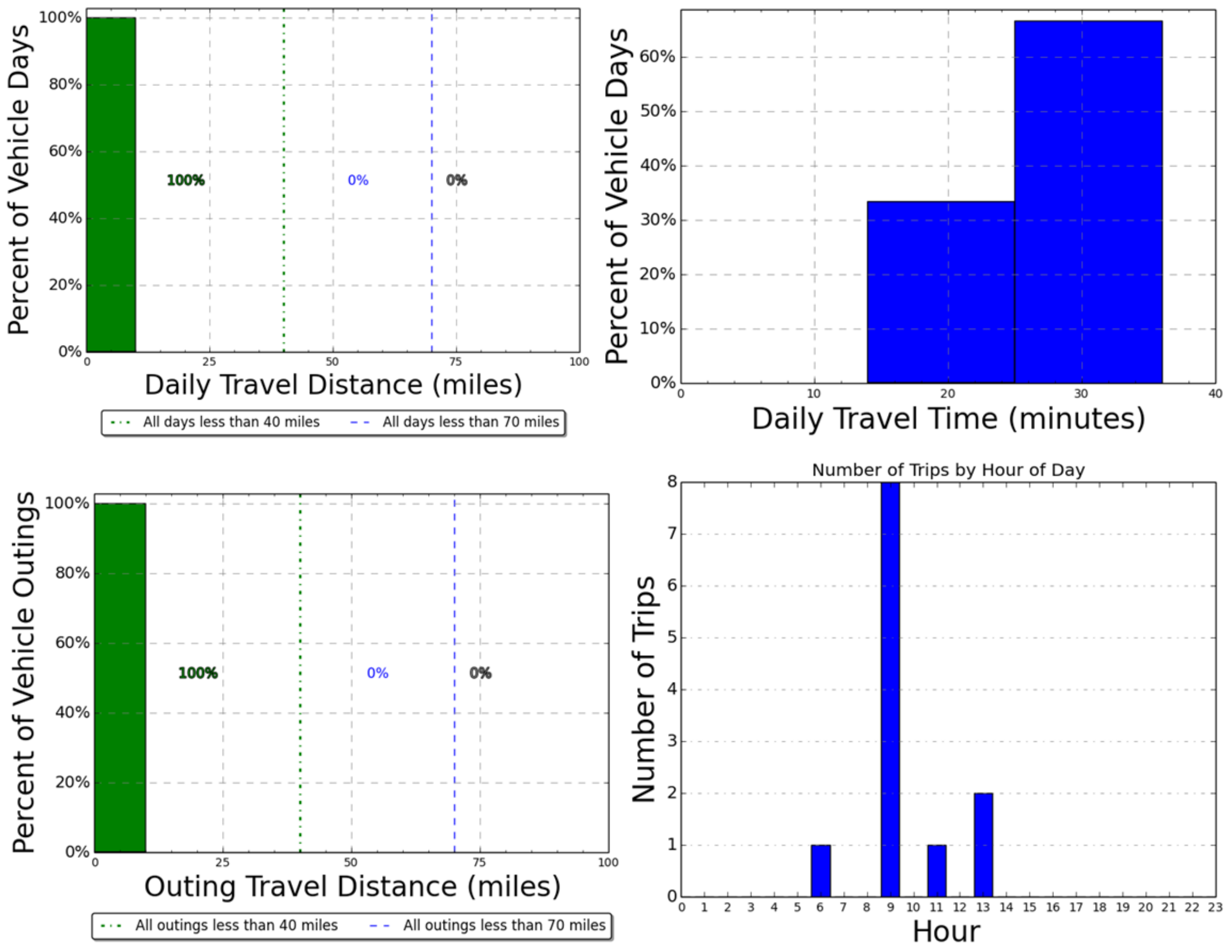

Figure D-5. Vehicle I-510533 travel graphs.

Vehicle I-510533 Observations

Logger 70 collected data on this vehicle for a period of 3 days of the 27-day study period (on February 20th, 24th, and 27th). Validation occurred on 100% of the vehicle data. This vehicle appeared to be home based on Utility Road in Estes Park and is a pool vehicle operated by the Interpretation and Education Division.

As shown on the history graph (Figure D-14) and travel graphs (Figure D-15), all vehicle travel days and all outings were within the 70-mile BEV safe range (the green bars on Figure D-15).

It appears that a BEV may be a suitable replacement for this vehicle, assuming a BEV can support the other mission requirements of this SUV (such as cargo or other specifications). RMNP did not identify specific requirements at the time of the survey.

Vehicle I-410506

Make/Model/Year	Ford Explorer/2004
EPA Class Size	SUV
Mission	Pool (Enforcement)
Contact	Bill Thompson
Parking Location	Utility Road or Mills
Fleet Vehicle ID	106/I-410506
Fuel Type	Gas/E85
EPA Label/MPG (City/Hwy/Combined)	14/20/16 10/14/12
EPA GHG Emissions (Grams CO_2/Mi)	555/525
Study Logger ID	68
Total Vehicle Days/Total Study Days	10/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	27.0/80.0	20.8/80.0	6.6/40.0	270
Travel Time (Minutes)	72/144.0	55.2/144.0	17.5/72	717
Idle Time (Minutes)	1.6/NA	1.2/NA	0.4/NA	16

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	35	94.6%	Less than 2	24
10 to 20	1	2.7%	2 to 4	5
20 to 40	1	2.7%	4 to 8	0
>40	0	0%	Greater than 8	8

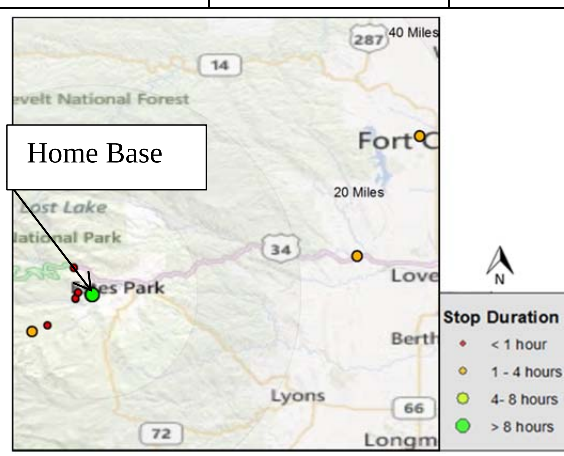

Figure D-16. Vehicle I-410506 stops.

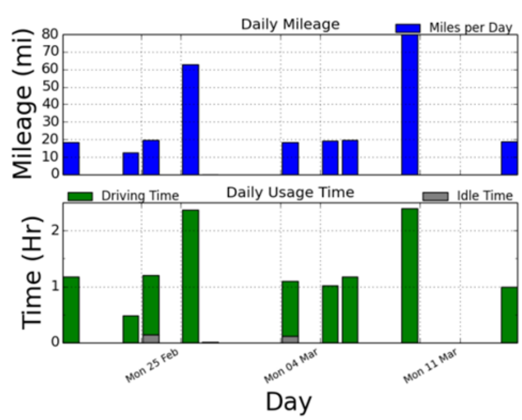

Figure D-17. Vehicle I-410506 history.

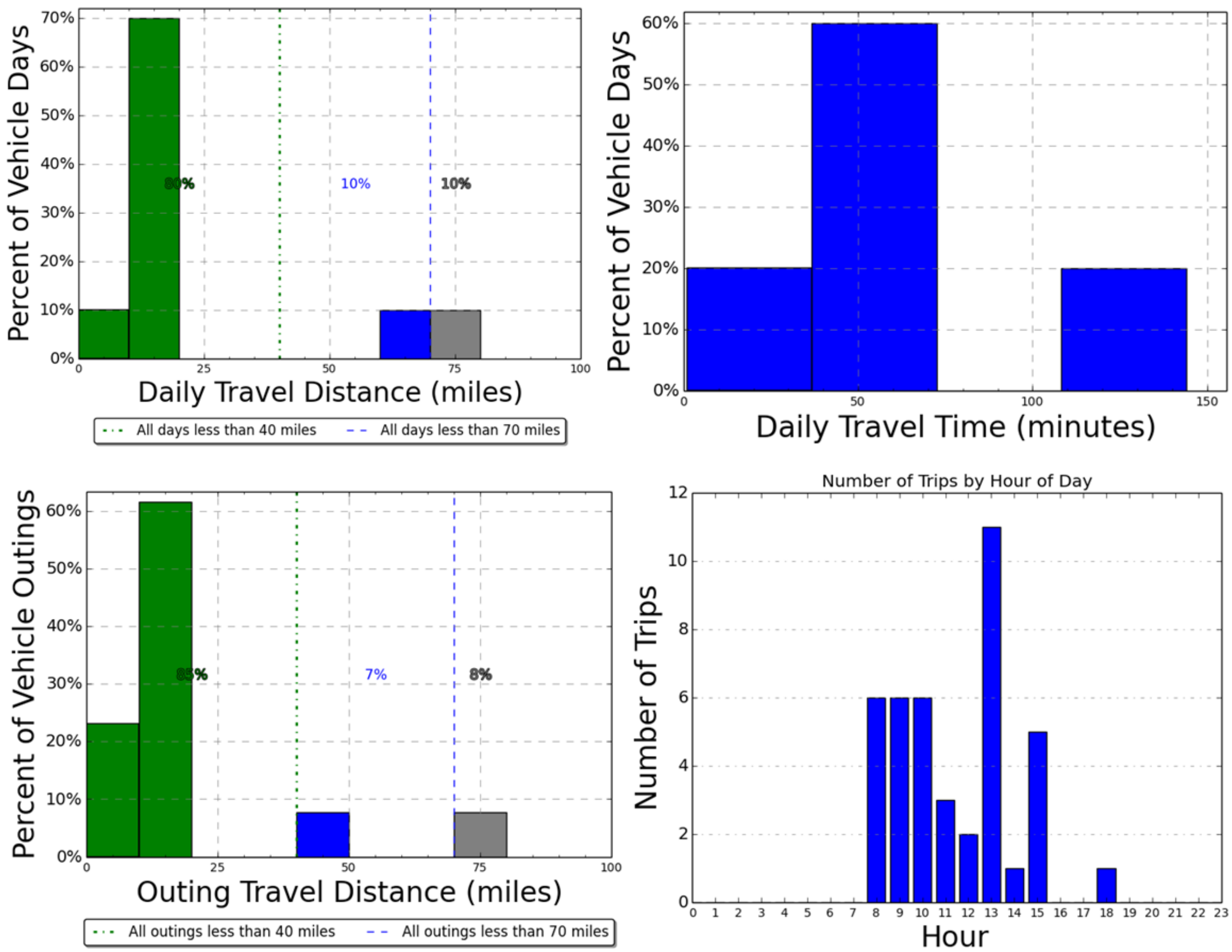

Figure D-6. Vehicle I-410506 travel graphs.

Vehicle I-410506 Observations

Logger 68 collected data on this vehicle for a period of 10 days of the 27-day study period. Validation occurred on 98.8% of the vehicle data. This vehicle appears to be home based on Utility Road, but often parks on Mills. This vehicle operates within the Resource Protection and Visitor Management division and is a pool vehicle.

As shown on the history graph (Figure D-17), one trip's travel distance exceeded the advertised range of BEVs (i.e., 70 miles). This daily travel, which also included the longest outing of 80 miles, occurred on March 8 on an outing to Fort Collins. Of all vehicle travel days, 90% were within the 70-mile BEV safe range (the green and blue bars on Figure D-18), and 80% were within the battery-only range of a typical PHEV. Similarly, 92% of the vehicle outings are within the 70-mile BEV safe range and 85% are within the battery-only range of a typical PHEV.

It appears that a BEV is not a suitable replacement for this SUV. A PHEV is required for the days that involve extended trips, assuming a PHEV can support the other mission requirements of this vehicle (such as cargo or other specifications_. RMNP did not identify specific requirements at the time of the survey.

Vehicle I-263766

Make/Model/Year	Ford Explorer/2002
EPA Class Size	SUV
Mission	Pool
Contact	Bill Thompson
Home Base	Utility Road, Estes Park
Fleet Vehicle ID	107/I-263766
Fuel Type	Gas/E85
EPA Label/MPG (City/Hwy/Combined)	14/19/16 10/15/12
EPA GHG Emissions (Grams CO_2/Mi)	555/525
Study Logger ID	75
Total Vehicle Days/Total Study Days	5/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	15.4/16.4	12.8/15.9	5.1/8.1	77
Travel Time (Minutes)	41/47.0	34.2/43.0	13.7/23.0	205
Idle Time (Minutes)	3.8/NA	3.2/NA	1.3/NA	19

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	12	100%	Less than 2	5
10 to 20	0	0%	2 to 4	3
20 to 40	0	0%	4 to 8	1
40 to 60	0	0%	Greater than 8	3

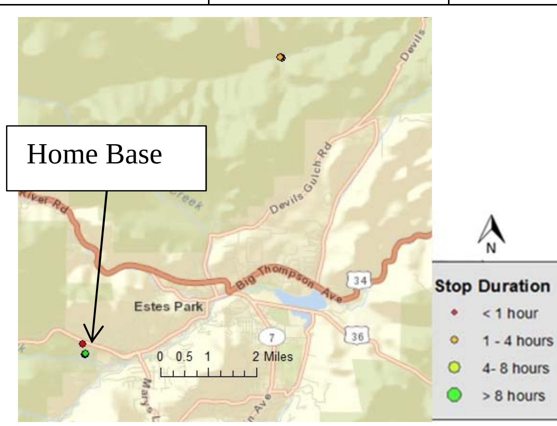

Figure D-19. Vehicle I-263766 stops.

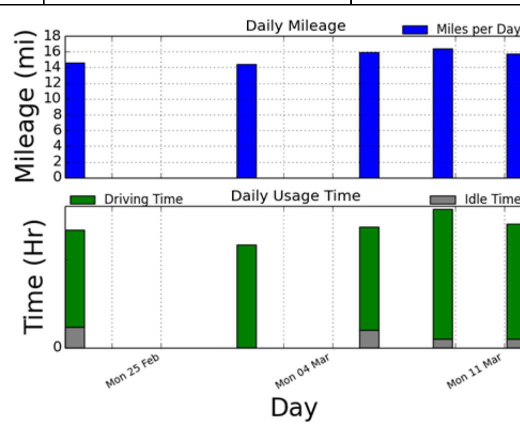

Figure D-20. Vehicle I-263766 history.

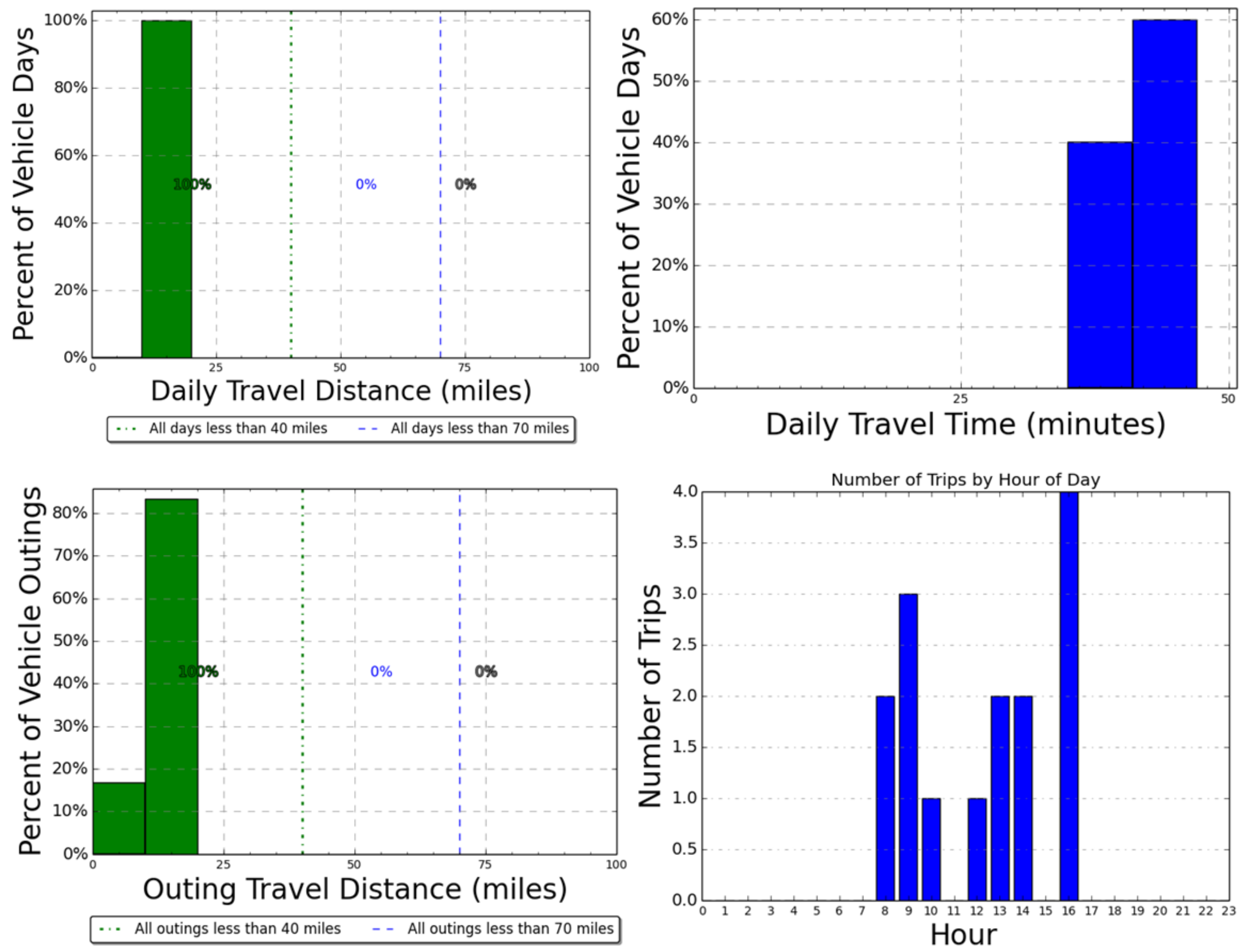

Figure D-7. Vehicle I-263766 travel graphs.

Vehicle I-263766 Observations

Logger 75 collected data on this vehicle for a period of 5 days of the 27-day study period. Validation occurred on 97.0% of the vehicle data. This vehicle is home based on Utility Road in Estes Park. It is a pool vehicle operated by the Interpretation and Education Division.

As shown on the history graph (Figure D-20) and travel graphs (Figure D-21), all vehicle travel days and all outings were within the 70-mile BEV safe range.

It appears that a BEV may be a suitable replacement for this vehicle, assuming a BEV can support the other mission requirements of this SUV (such as cargo or other specifications). RMNP did not identify specific requirements at the time of the survey.

Vehicle I-515081

Make/Model/Year	Ford F-350 SD/2013
EPA Class Size	Pickup Heavy Duty
Mission	Support
Contact	Bill Thompson
Parking Location	Marmot Drive/Utility Road, Estes Park
Fleet Vehicle ID	108/I-515081
Fuel Type	Diesel*
EPA Label/MPG (City/Hwy /Combined)	12/16/13*
EPA GHG Emissions (Grams CO_2/Mi)	668*
Study Logger ID	71
Total Vehicle Days/Total Study Days	10/27

Vehicle Travel Summary				
	Per Day Average/Peak	Per Outing Average/Peak	Per Trip Average/Peak	Total
Travel Distance (Miles)	36.4/70.6	8.5/49.2	5.0/39.8	364
Travel Time (Minutes)	158/249.0	36.7/176.0	21.6/165.0	1,580
Idle Time (Minutes)	44.1/NA	10.3/NA	6.0/NA	441

Total Stops			Stop Duration	
Distance From Home Base (Miles)	Stops	Percentages	Stop Duration (Hours)	Stops
Less than 10	87	100%	Less than 2	73
10 to 20	0	0%	2 to 4	4
20 to 40	0	0%	4 to 8	0
40 to 60	0	0%	Greater than 8	10

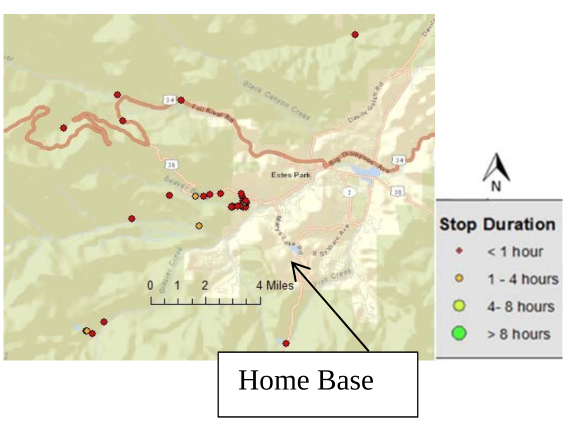

Figure D-22. Vehicle I-515081 stops.

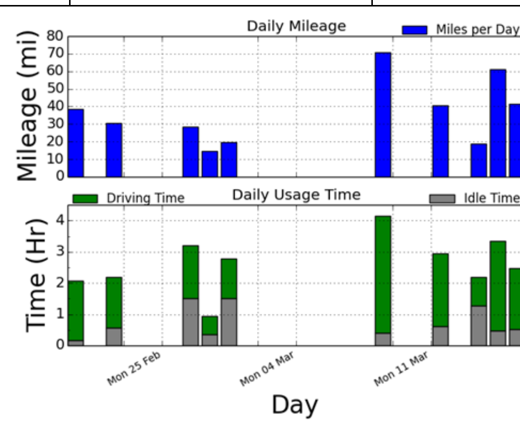

Figure D-23. Vehicle I-515081 history.

*F350 data are not available. Data are for Ford F150 4WD.

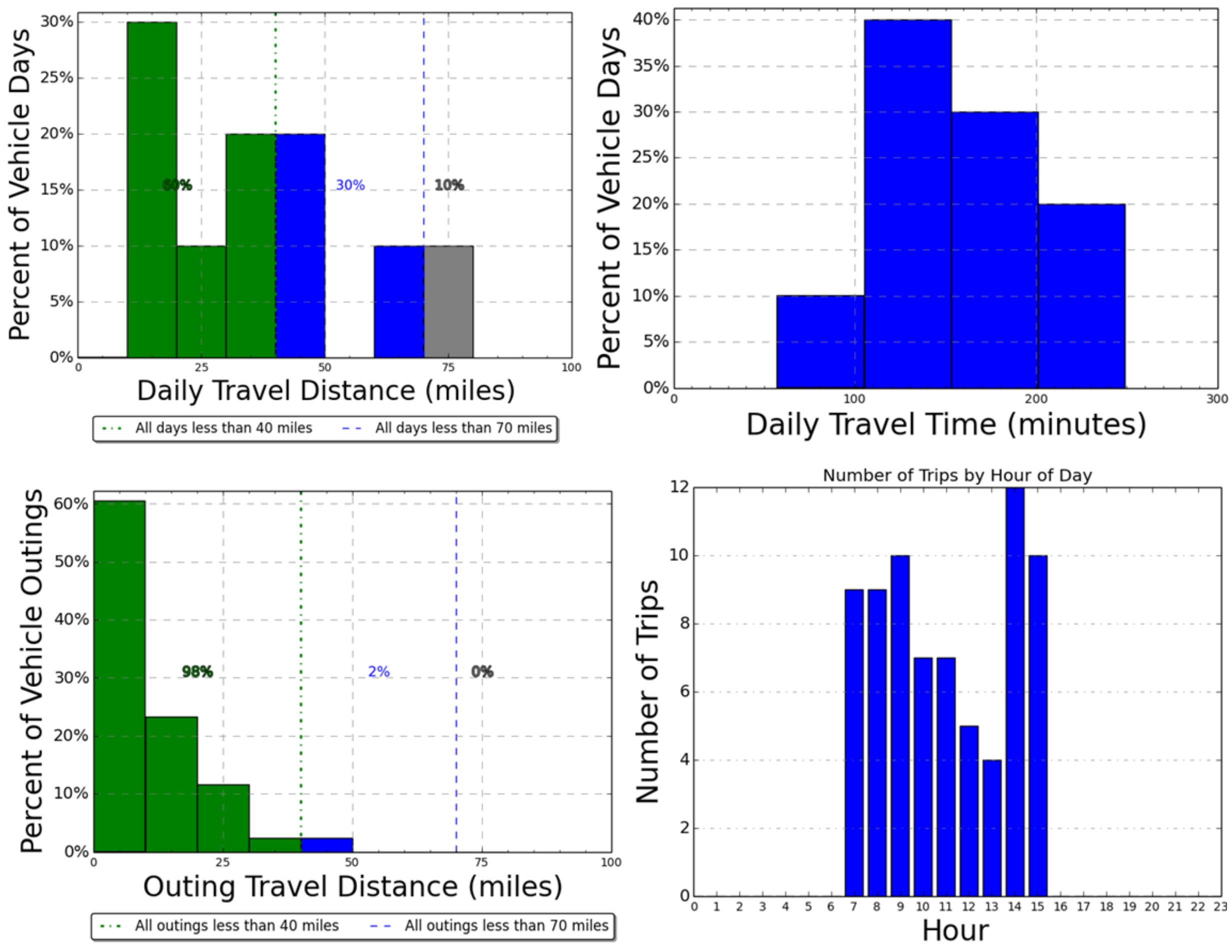

Figure D-8. Vehicle I-515081 travel graphs.

Vehicle I-515081Observations

Logger 71 collected data on this vehicle for a period of 10 days of the 27-day study period. Validation occurred on 99.1% of the vehicle data. This vehicle parks often on Marmot Drive and Utility Road. It is operated by the Facility Management Division and used for roadwork.

As shown on the history graph (Figure D-23), one trip's travel distance exceeded the advertised range of BEVs (i.e., 70 miles). This daily travel occurred on March 8 on trips local to Estes Park. Of all vehicle travel days, 90% were within the 70-mile BEV safe range (the green and blue bars on Figure D-24) and 60% were within the battery-only range of a typical PHEV (green bars on Figure D-24). Similarly, all vehicle outings were within the 70-mile BEV safe range and 98% were within the battery-only range of a typical PHEV.

While one trip technically was outside the range of a BEV, the data show sufficient time between trips at the home base that opportunity charging between trips would allow all travel on that day by a BEV. It appears that a BEV could be a suitable replacement for this vehicle if such were available to replace heavy-duty pickups. Although RMNP did not identify specific cargo or other vehicle requirements that may require the heavy-duty nature, it is assumed that such exists. Thus, no replacement by a PEV is recommended at this time.

Appendix E
Rocky Mountain National Park Map