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Results of Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program

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Summary

The Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program was sponsored by the United States Department of Energy (DOE) using American Recovery and Reinvestment Act of 2009 (ARRA) funding as well as the South Coast Air Quality Management District (AQMD). The purpose of the program was to develop a path to mitigate plug-in hybrid vehicle technology to medium-duty vehicles by demonstrating and evaluating in diverse applications. The program allows the fleets to develop interest in the technology. The 62 participants have deployed these vehicles into the field with their operators to achieve real—life experience with the vehicles in 23 different states. A total of 296 vehicles were delivered to the field prior to July 2015. This paper provides the results from the analysis of the data generated by these vehicles.

Keywords: PHEV (Plug in Hybrid Electric Vehicle), Medium-Duty, Bucket Truck, Data Acquisition, Charging

1. Introduction

The primary goal of this project was to develop a near-production plug-in hybrid electric vehicle (PHEV) powertrain system that is suitable for widespread utility use in service vehicles. The project required simultaneous execution of two advanced hybrid powertrain development projects along with chassis integration efforts. This project has developed a path to migrate PHEV technology to medium-duty vehicles by accomplishing the following:

- Demonstrating and evaluating vehicles in diverse applications
- Developing two production-ready PHEV systems—one for Class 1 to 2 trucks and vans (less than 10,000 lb gross vehicle weight) and the other for Class 6 to 8 trucks (19,501 lb to greater than 33,001 lb gross vehicle weight)
- Using project results for system development to optimize performance and reduce costs

1.1 Project Activities

Both Odyne and VIA went through extensive design, development, validation, manufacturing, and service phases. Design reviews were held to determine the levels of the design and whether to proceed to the next milestone. The VIA developments required getting both United States Environmental Protection Agency (EPA) and California Air Resources Board (CARB) executive orders for emissions. The Odyne system was approved by the EPA, and CARB provided an executive order for the trucks. The trucks are currently in the field with their owners and will remain in the field until the owners no longer value the trucks. Significant

fuel economy benefits have been seen and are described later in this report. Odyne and VIA are now taking orders from new customers for their products.

1.2 Timeline and Budget

The original Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program was approved in August 2009 and officially began on November 30, 2009. The program was a $95.8-million program that consists of $45.4 million from the United States Department of Energy (DOE) using American Recovery and Reinvestment Act of 2009 (ARRA) funds, $5 million from the California Energy Commission (CEC), and $45.4 million of cost share from the program participants. The reference project numbers are DOE FOA-28 award number EE0002549 and South Coast Air Quality Management District (SCAQMD) contract number 10659.

2. Truck Types and Locations

Sixty-two different utilities, municipalities, or companies participated from 23 states; Washington, D.C.; British Columbia; and Manitoba (see Figure 1). These participants are demonstrating and evaluating 296 vehicles (52 vans with VIA systems, 125 pickup trucks with VIA systems, and 119 medium duty trucks with Odyne systems). Data have been collected on each participant's trucks during normal working times to establish data for analysis.

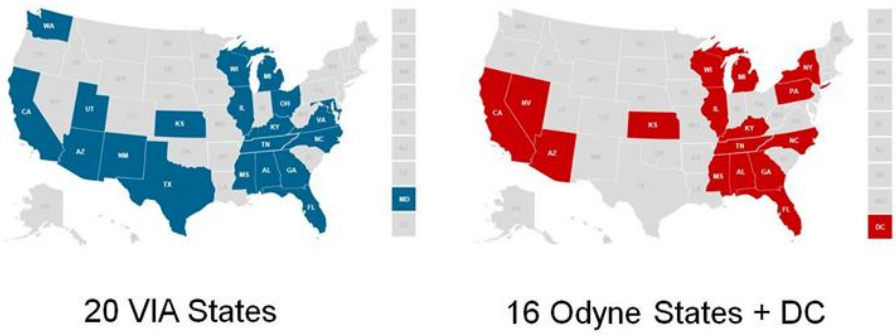

Figure 1: States that have program vehicles

The trucks with the Odyne hybrid system included five types of bodies—bucket trucks, walk-in vans, digger derricks, compressor trucks, and tanker trucks (see Figure 2). The bucket trucks represented the largest number of trucks, with 72% of the fleet. The bucket trucks are used to put an operator up onto a pole for repairing or maintaining utility lines. The walk-in vans provide workspace and electric power for a work crew on the job. The digger derricks provide a large drill bit and mechanism for drilling a hole in the ground for a utility pole to be set into and jaws that are used to pick up a pole to set it into the hole. The compressor trucks are used to run an air compressor for providing fresh air into manholes while workers are in the chamber. Three fuel tankers were built, and they are used on the grounds of a nuclear site to dispense fuel into vehicles on the grounds rather than taking the vehicles off the site.

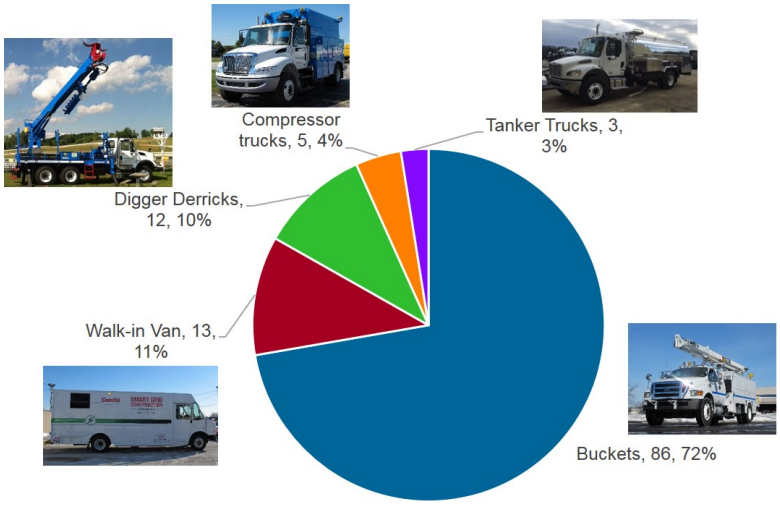

Figure 2: Odyne truck body types

The Odyne hybrid system is capable of being installed on numerous original equipment manufacturer (OEM) vehicles. This program has used trucks from four different OEMs—Freightliner, International, Ford, and Kenworth. The participants selected almost 50% of the Odyne fleet as the large Class 8 trucks with Class 7 being the second most. Class 6 trucks have a gross vehicle weight rating (GVWR) of 19,501–26,000 lbs, Class 7 trucks have a GVWR of 26,001–33,000 lbs, and Class 8 trucks are 33,000 lbs and greater.

VIA delivered two different body types, a pickup truck and a van. There were more pickup trucks than vans. Vans were 29% of the total trucks. The vans came in three configurations—a passenger van with multiple seats, a cargo van without extra seats, and an accessible cargo van that has access into the van through the side panels. Figure 3 shows the breakdown of the vehicle types.

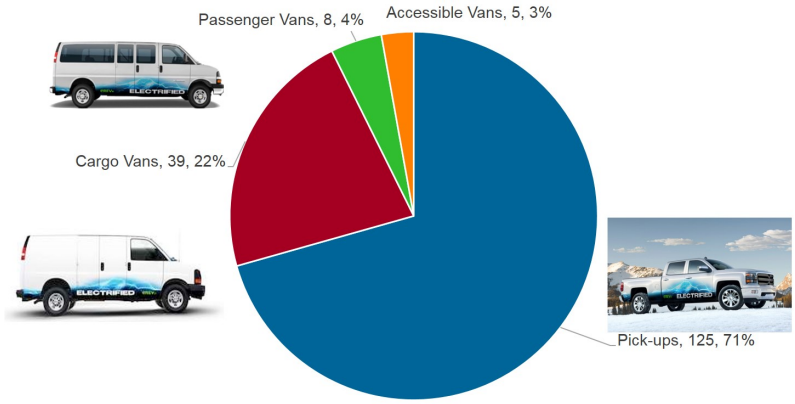

Figure 3 VIA van and truck body types produced

3. Data Acquisition System

The data acquisition system used on both the VIA vehicles and the Odyne trucks is shown in Figure 4. The system is relatively inexpensive and simply includes two GoPoint Technology modules, each connected to different CAN buses and an iPhone for storage and transmittal. The GoPoint modules collect up to 64 CAN messages per second, and the data are sent via Bluetooth to an iPhone in the vehicle, which stores the data. Once a day or whenever the phone gets a good signal, the data are broadcast to a server that holds the program data.

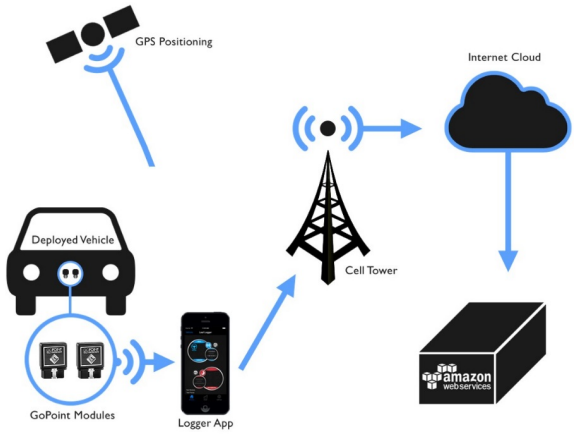

Figure 4: Data acquisition system used on both Odyne and VIA vehicles

Once the one second data with the 64 parameters was captured, the data was summarized into event statistics. There are three different kinds of Event Summaries, Drive, Charge and Stationary. The drive events were events that stated with turning the key on until the key was turned off. The drive event summary contained the duration, total distance, electric distance, the fuel used, the electricity used, and others. The charge events began with plugging in and ended with unplugging. The charge event summary contained the state of charge (SOC), energy used at the wall, energy used at the battery, power level, and others. The stationary events included events using the hydraulics or export power devices with the same data as the others.

While event summaries were used for fleet statistics, if there was an event in question, the raw data generating the event summary information could be used.

4. Data Analysis

4.1 Odyne

Figures 5 to 7 show examples of typical days for the trucks. The charts plot the SOC of the battery over a daylong period. Several modes are illustrated (shown in colors), including SOC while plugged in, SOC change due to the Power Take-off unit, engine charge SOC, drive SOC, and idle SOC. These charts have become known as *SOC V charts* because, under optimum conditions, the plot looks like a V. Ideally, the V would start at or near the 100% SOC point, go to 0%, and then return to 100%. The left side of the V uses the energy from the battery to drive or move the hydraulics, and the right side (green) is the battery charge.

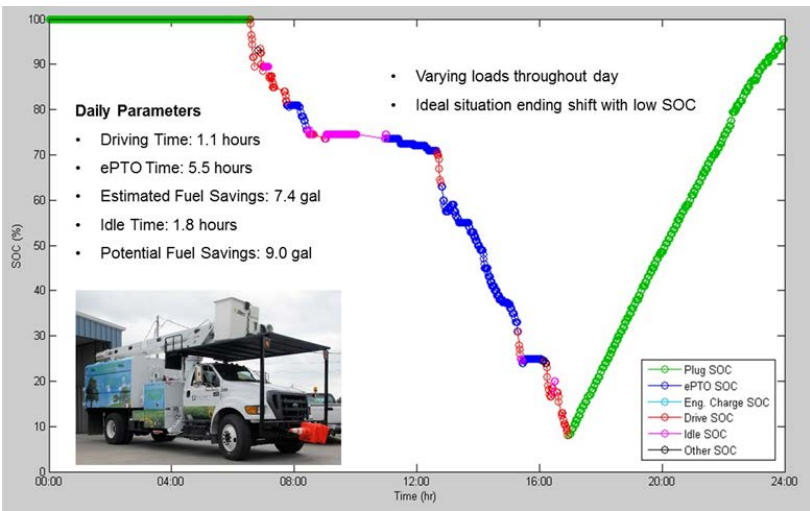

Figure 5: State of charge, large aerial truck over a day

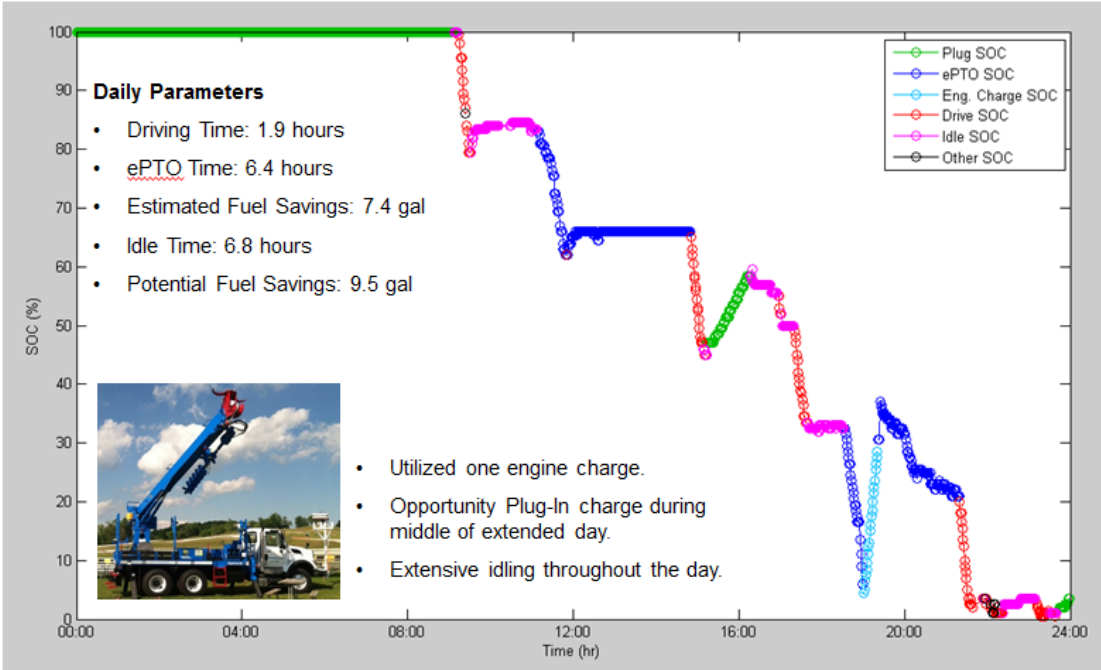

Figure 6: State of charge, digger derrick over a day

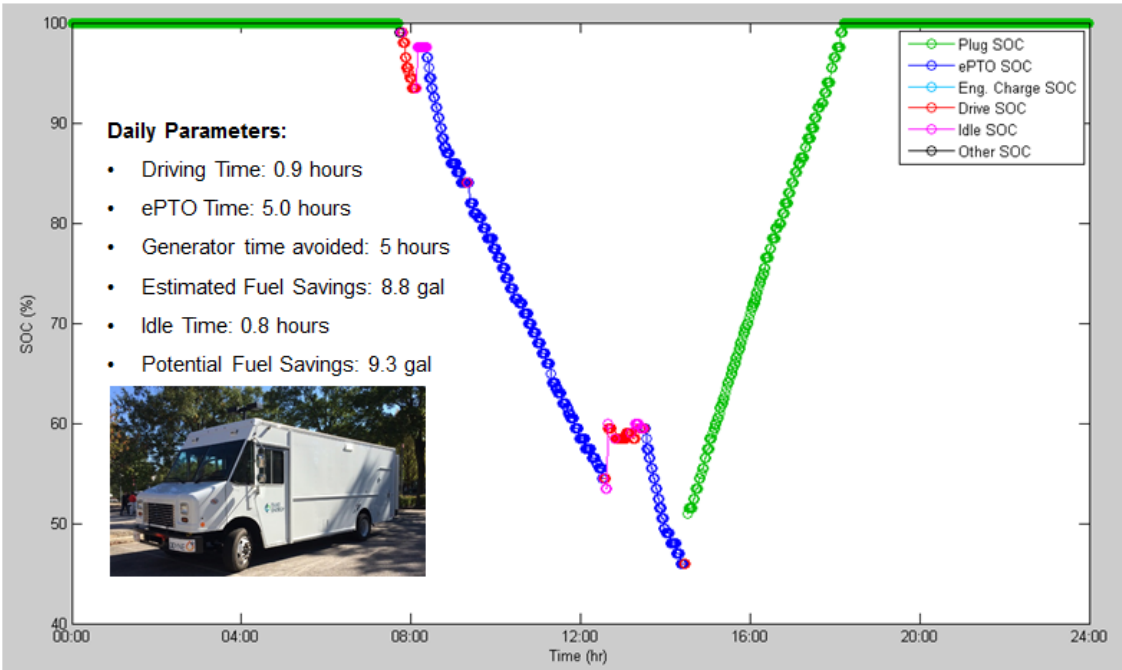

Figure 7: State of charge, walk-in van over a day

As one can see from Figures 5 to 7, there was some unwanted idle time that was not necessary because it is a hybrid and does not require idle time. If the idle time can be eliminated, there is a potential to achieve more fuel savings. In Figure 5, it is estimated that 7.4 gallons of fuel were saved over a conventional vehicle. If the idle time could be eliminated, a total of 9.0 gallons of diesel fuel could be saved. Figures 6 and 7 show other examples of this. Figure 6 has an example of an engine charge. The truck was run until the battery energy was gone, and then the engine came on near the 19:00 hours mark to charge the battery.

Simple charts like Figure 10 show how the vehicles are being used. The layout of the data is by day of the month, like a calendar. The data shown are SOC versus time of day, or an SOC V chart, as defined earlier. Figure 8 shows the SOC of a project truck for one month. The vehicle shows significant activity, including

many full charges. The project contains a mix of high- and low-use vehicles; however, usage appears to be increasing with time. To provide reasonable payback, hybrid systems should be targeted toward more high-usage applications.

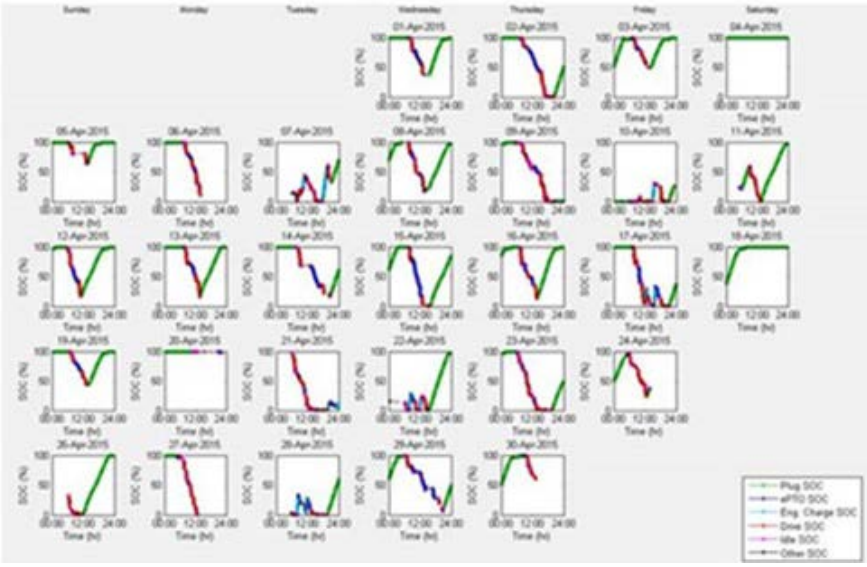

Figure 8: State of charge for a high-usage vehicle

Typically, the vehicles were operated during the early daytime hours and plugged in during the afternoon and night (see Figure 9). Most utilities appear to start their shifts around 5 to 6 a.m. and finish using the vehicles by 1 to 3 p.m. Most of the work outside that timeframe is due to emergencies or local restrictions.

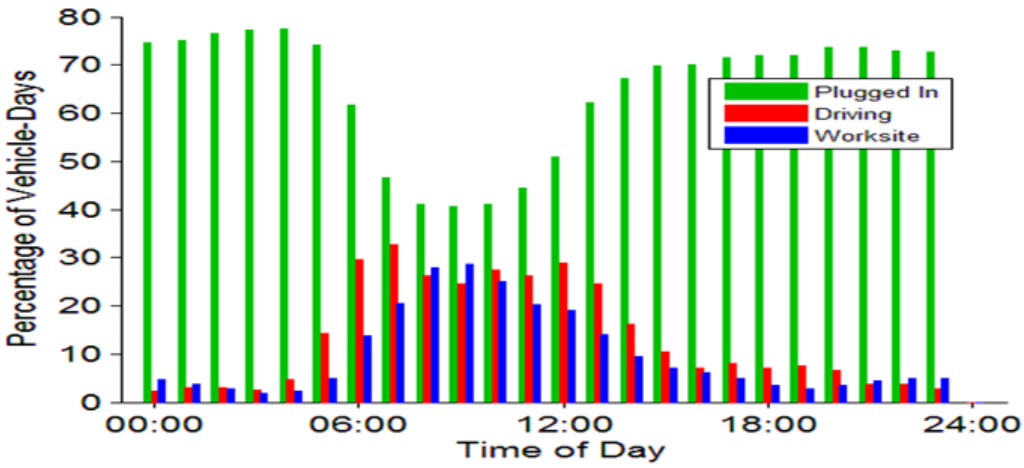

Figure 9: Average vehicle activity throughout the day

As Figure 10 shows, more than 60% of plug-ins occurred between noon and 4 p.m., and the peak load on the grid occurs around 4 p.m. Much of the charging is completed by midnight. This shows the opportunity for smart charging—to delay charging until there is no peak demand for the electricity.

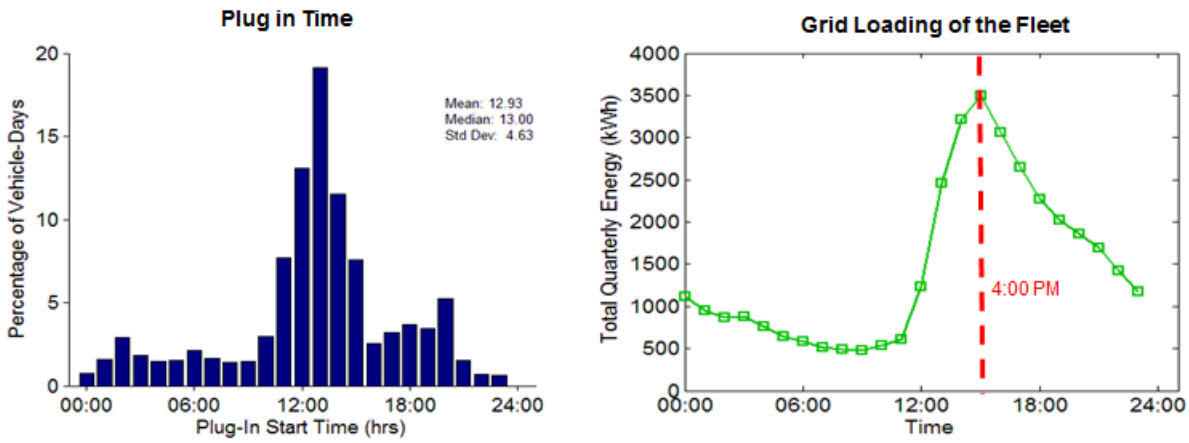

Figure 10: Plug-in time and the charge load time associated plug-in timie

Most utility trucks are driven only a short portion of the working day—the fleet average was about 1.5 hours, 26 miles per day, and about 21 mph (see Figures 11 to 13). These trucks generally work in local communities and respond to problems within a short distance. Two different calibrations were tested on the trucks. One calibration was a mild calibration and the other was a more aggressive calibration with respect to the amount of electric torque added. The calibration differences are shown in Figure 12.

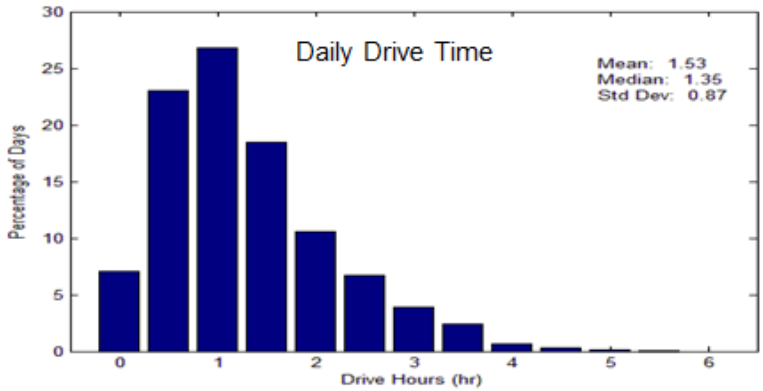

Figure 11: Histogram of the daily driving time over the entire Odyne fleet

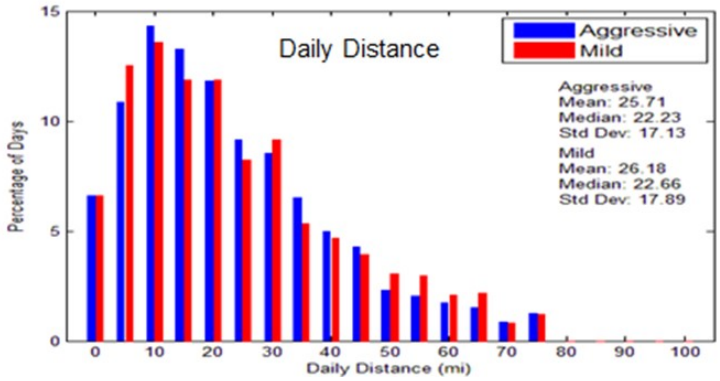

Figure 12: Histogram of the daily drive distance for the entire Odyne fleet

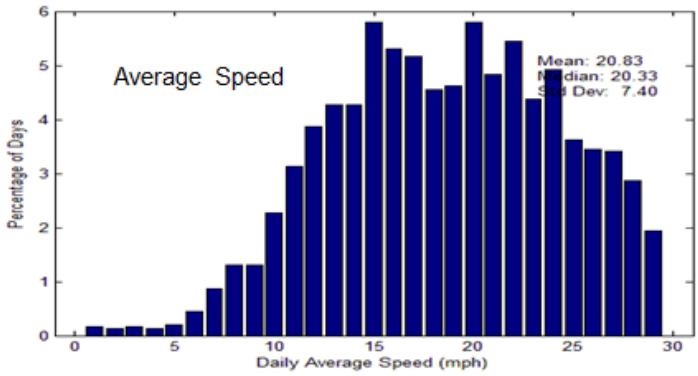

Figure 13: Histogram of the daily average speeds over the entire Odyne fleet

4.2 VIA

The peak driving time for the VIA vans and pickup trucks is midday, and charging occurs primarily during the day (see Figures 14 and 15). The export power was not used significantly during operate mode.

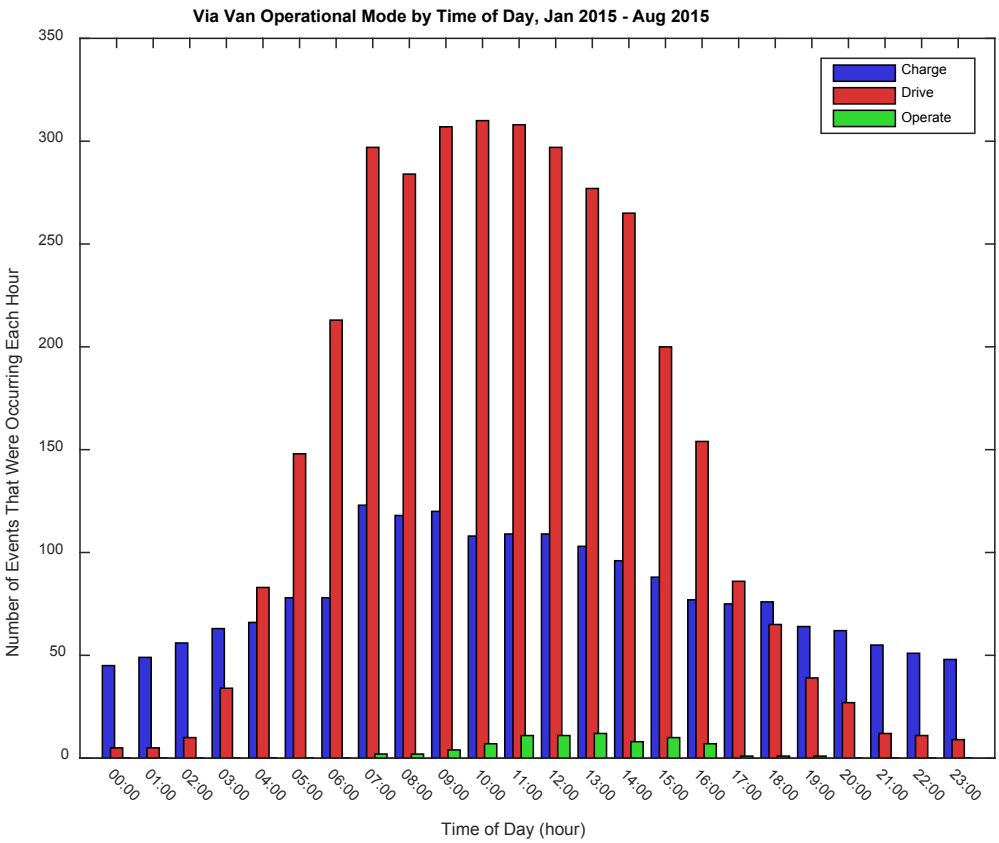

Figure 14: Operational modes by time of day over the entire VIA van fleet

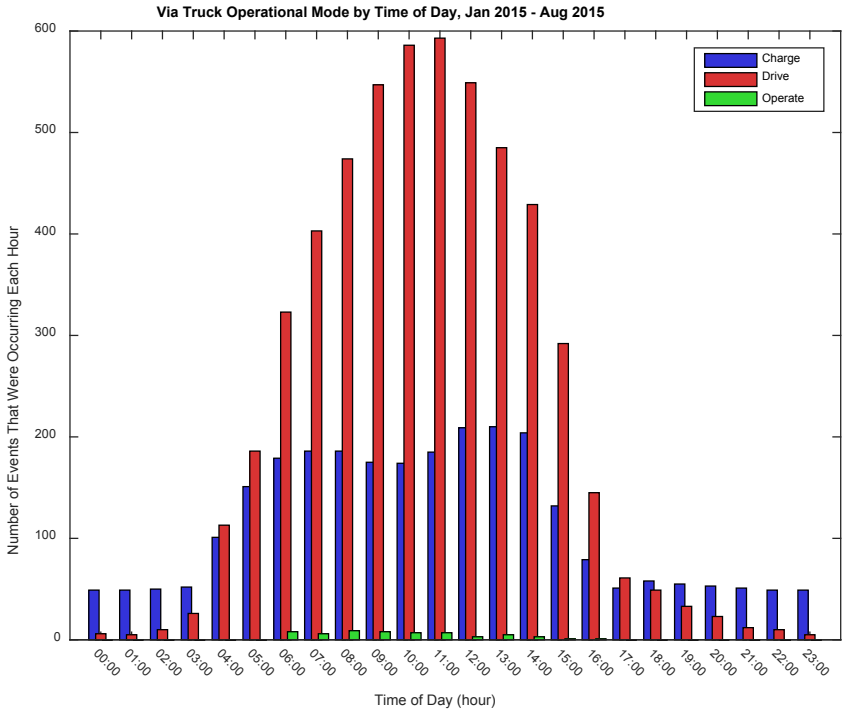

Figure 15: Operational modes by time of day over the entire VIA pickup truck fleet

Most charging was done using level 2 (240 V). There were many short-term (< 5 hours) charges and some overnight charges. More electric power was used on short-distance trips, and more fuel was used on longer-distance trips (see Figures 16 and 17).

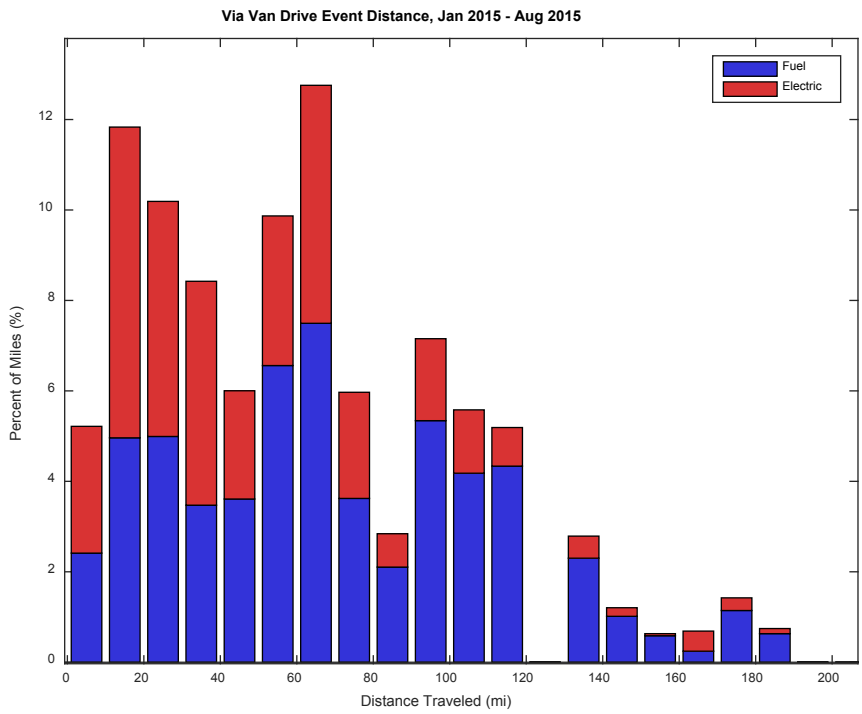

Figure 16: VIA vans—energy type by distance

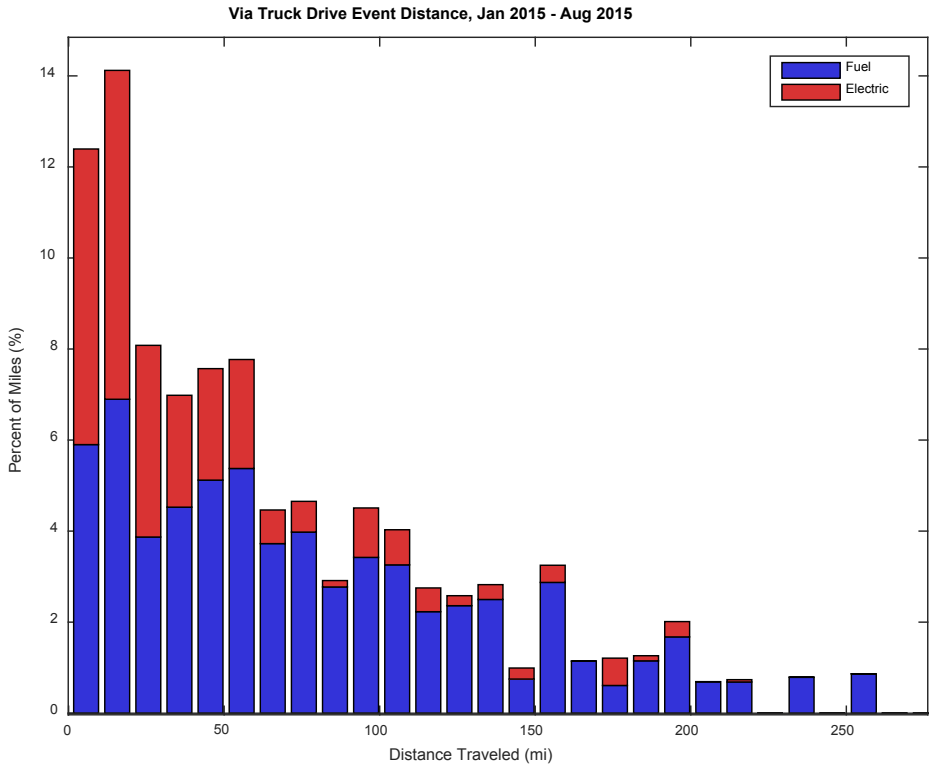

Figure 17: VIA pickup trucks—energy type by distance

About 15% to 20% of the VIA vehicles began their drives with more than 90% SOC. Many vehicles began below 30% or in need of a charge (see Figure 18).

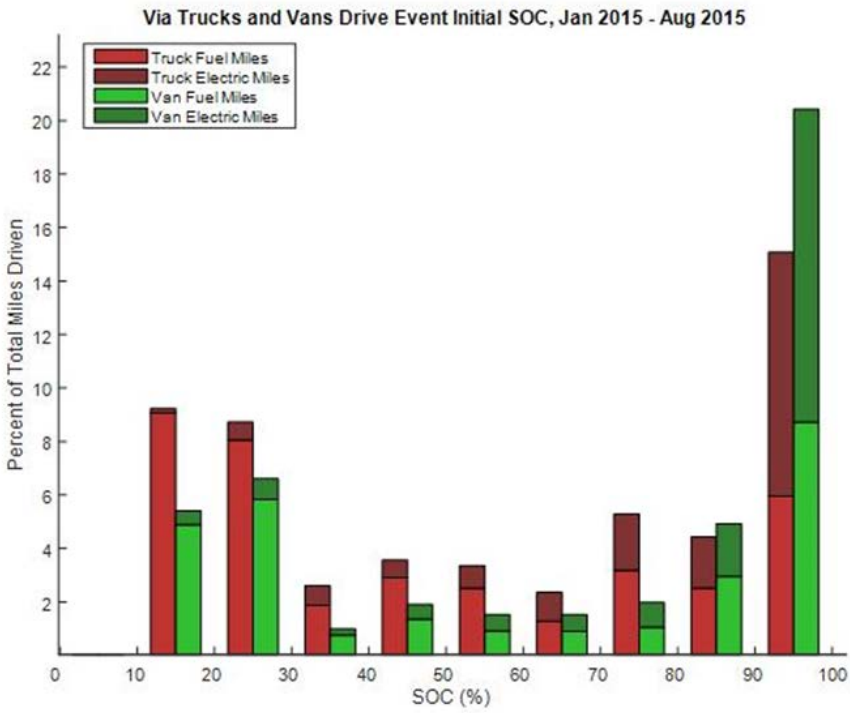

Figure 18: VIA initial state of charge of drive events classified by Van and Pickup Truck

Figure 19 shows the delta SOC used during a drive event. The data show that 12% to 18% of the drive events used less than 10% of SOC, whereas 16% of the drive events used more than 70% SOC.

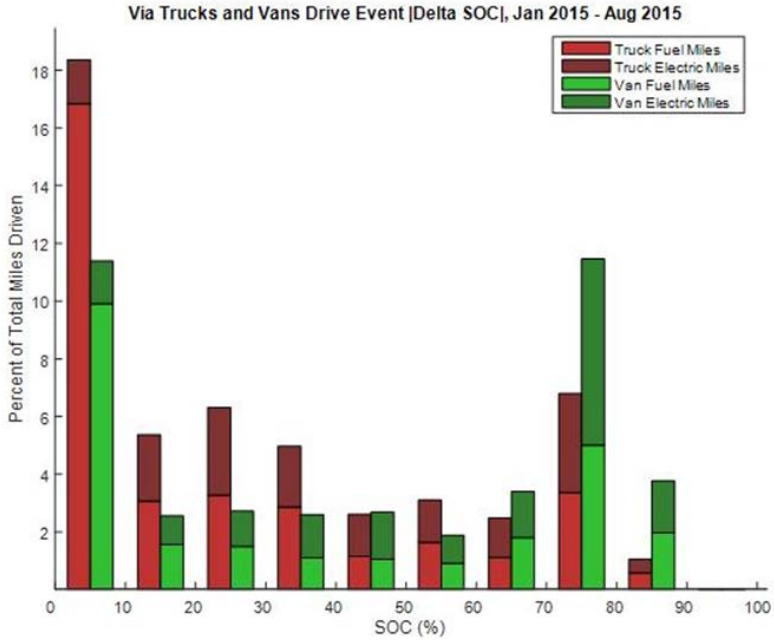

Figure 19: VIA delta state of charge of drive events classified by Van and Pickup Truck

Figure 20 shows the SOC at the end of the drive events. About 38% of the drive events ended with 10% to 30% SOC.

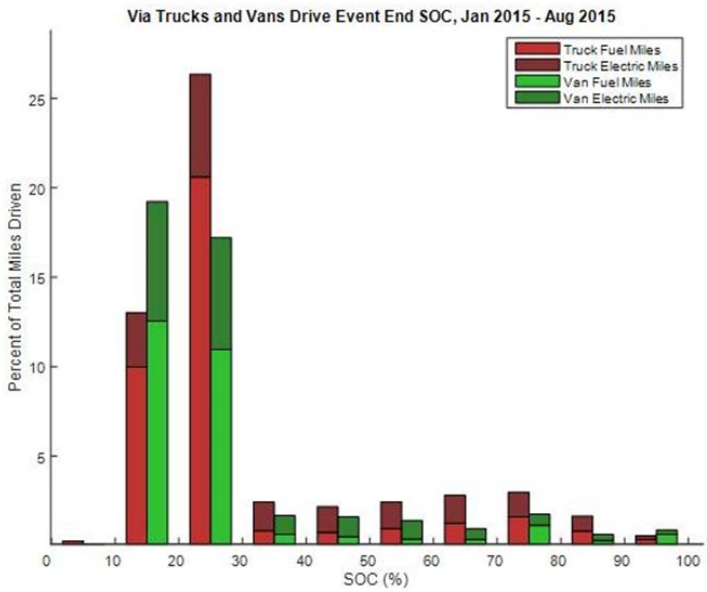

Figure 20 VIA Final state of charge of drive events classified by Van and Pickup Truck

Figures 18 to 20 shows the start SOC, the delta SOC, and the final SOC as histograms.

5. Conclusions

A near-term plug-in hybrid was developed for three sets of trucks Class 1 and 2 as well Class 6 to 8. A wide distribution of these trucks has provided a data set for analysis of truck and charging usage. The high resolution data set resulting from this study will provide usage information of the systems and will influence next generation hardware and software.

Acknowledgements

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References

[1] "Plug-In Hybrid Medium Duty Truck Demonstration and Evaluation." EPRI, Palo Alto, CA: 2015. Product ID: 3002006566.

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