

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

EVS 29
June 20, 2016



Mark Kosowski
Jamie Dunckley
Dan Bowermaster

Program Summary

The purpose of this \$95M program was to develop a path to migrate plug-in hybrid vehicle technology to medium-duty vehicles by demonstrating and evaluating in diverse applications. The vehicles were delivered to the field prior to July 2015.

The Plug-In Hybrid Medium-Duty Truck Demonstration and Evaluation Program was sponsored by the

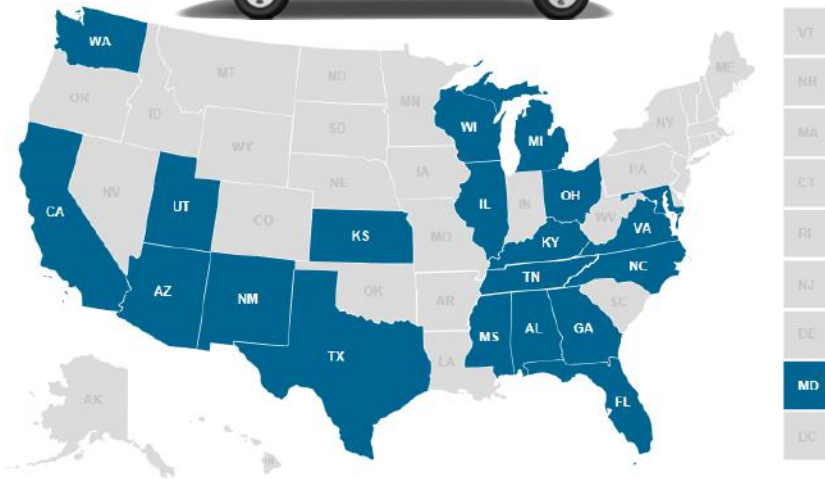
1. United States Department of Energy (DOE) using American Recovery and Reinvestment Act of 2009 (ARRA)
2. South Coast Air Quality Management District (SCAQMD)
3. California Energy Commission (CEC)
4. Electric Power Research Institute (EPRI)
5. VIA Motors, Inc.
6. Odyne Systems, LLC.
7. Utility Industry

This paper provides the results from the analysis of the data generated by these vehicles.

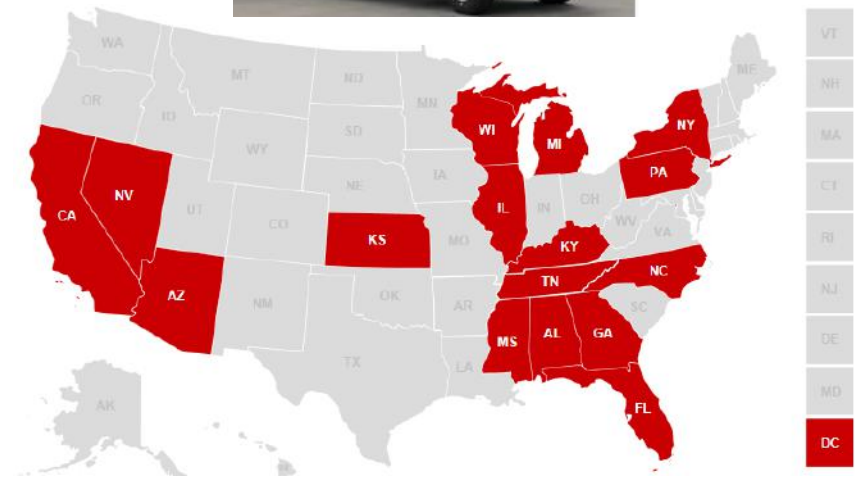
Truck Statistics

Total of 296 trucks and vans

62 different fleets in 23 States plus DC, British Columbia and Manitoba



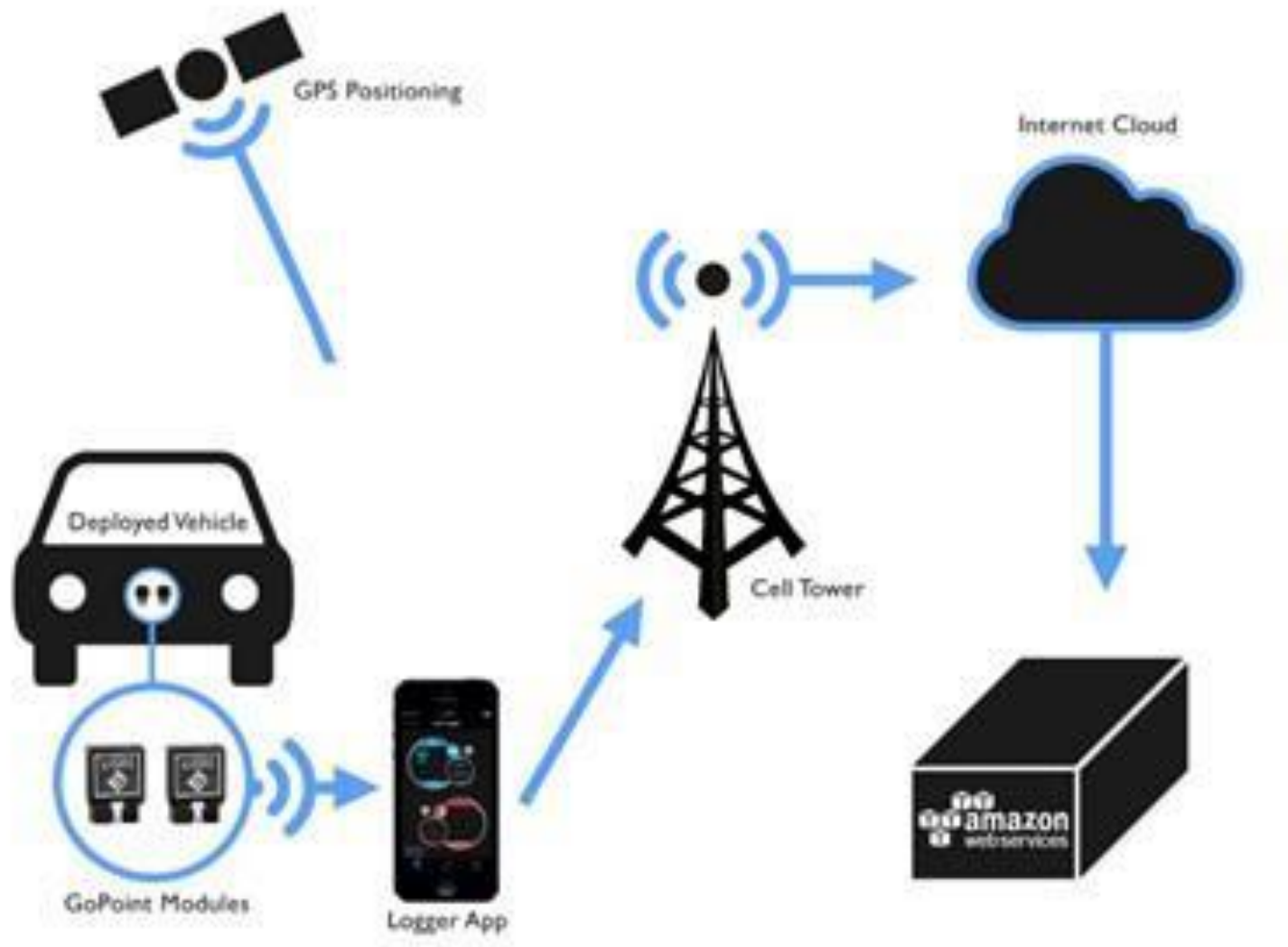
20 VIA States



16 Odyne States + DC

Trucks are all at diverse locations and fleets

Data Acquisition System



This system is provided on all 296 trucks

Data Acquisition System

Kind of Data Collected

- Motor current and voltage
- Battery current and voltage
- Charger current and voltage
- Motor and engine torque and speed
- Export power current and voltage
- Time
- Odometer
- Vehicle speed
- Accelerator and brake pedal position
- Fuel used
- Charge time
- Software and calibration level

Data has been collected on a 1 Hz basis

Data was summarized by Events

An Event is a:

- Drive (Drive Period)
- Charge (Charge Period) or
- Operate (Operate or Stationary Period)

Drive Events have different three modes:

- Charge Depleted (CD)
- Charge Sustained (CS)
- Charge Depleted and Sustained (CD/CS)

Data was summarized in event form as well as discretely

Program Data Summary

Variable	Total	Units
All Event Types		
Number of events	59,295	Events
Number of active vehicles	269	Vehicles
Duration of all the events together	72,533	Hours
Number of Drive Events	45,525	Events
Number of Charge Events	6,554	Events
Number of Operate Events	7,216	Events
DRIVE INFORMATION		
Drive: Total Duration	10,324	Hours
Drive: Total Distance	245,558	Miles
Drive: Distance on Electric	79,592	Miles
Drive: Number of Events (CD+CS)	12,111	Events
Drive: Number of Events (CD)	28,328	Events
Drive: Number of Events (CS)	5,086	Events
Drive: Fuel used during Drives	16,029	Gallons

Variable	Total	Units
CHARGE INFORMATION		
Charge: Plugged in Duration	57,078	Hours
Charge: Charging Duration	21,397	Hours
Charge: Wall Energy	75,921	kWh
Charge: Battery Energy	58,395	kWh
OPERATE INFORMATION		
Operate: Duration	6,896	Hours
Operate: Fuel Used	500	Gallons
Operate: Fuel used during non work time	430	Gallons
Operate: Export Electric Energy Used	963	kWh
Operate: Electricity Used	7,432	kWh
Operate: Electricity used during non work time	5,996	kWh

More than 59,000 events were recorded over 245,500 miles and 72,500 hours

VIA Vans and Pickup Trucks

Plug-in Series Hybrid
Vehicles

$\frac{3}{4}$ Ton Vans

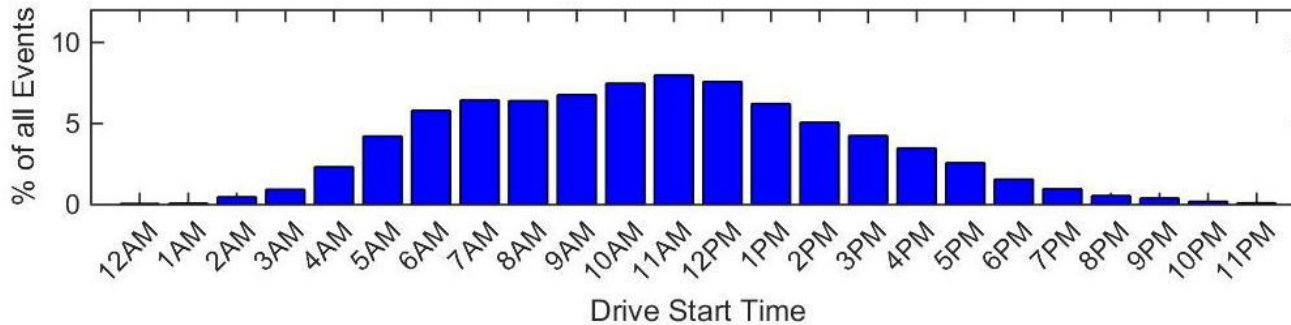


$\frac{1}{2}$ Ton Pickup truck with
AWD

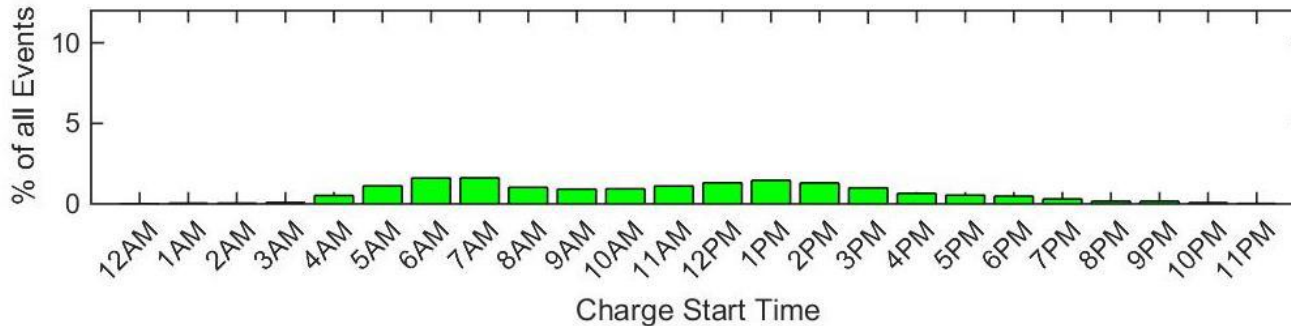


177 VIA plug-in series hybrid pickup trucks and vans are in the fleets

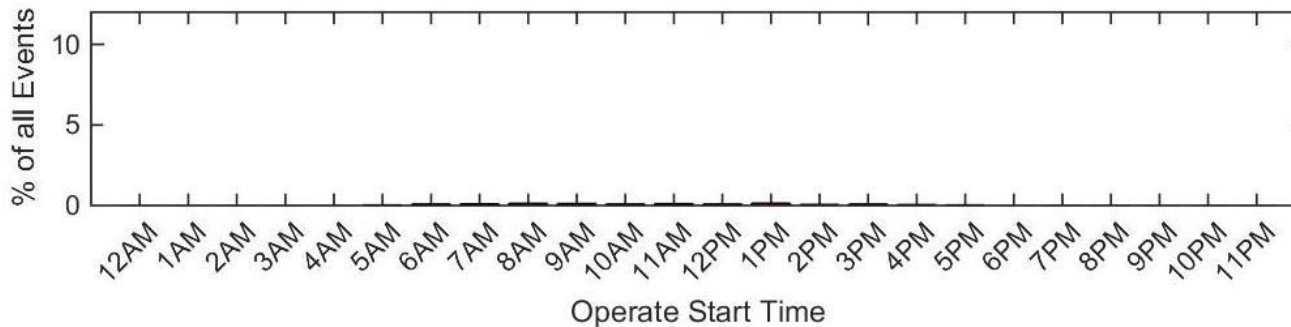
VIA Event Times



85% Drive Events



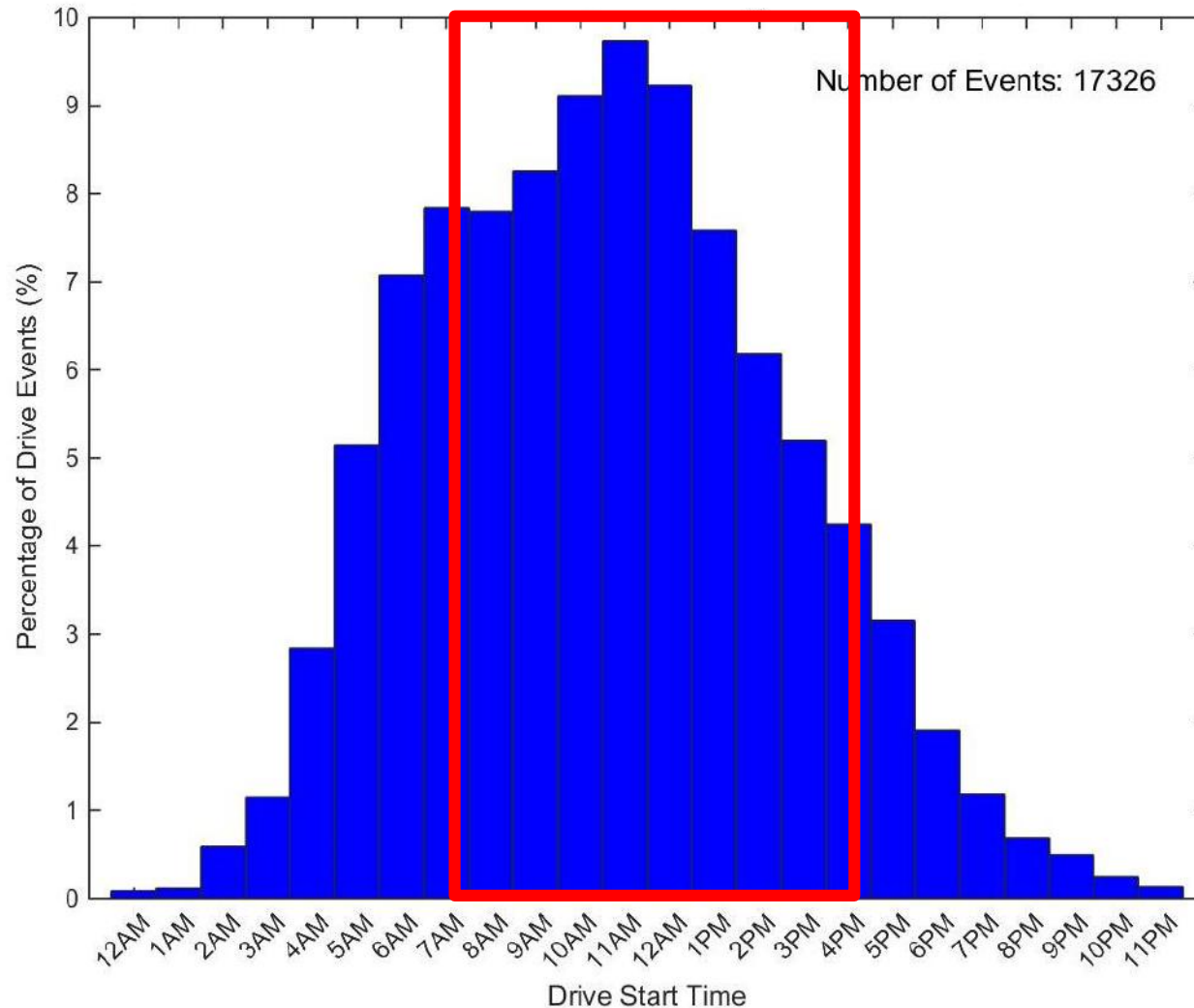
14% Charge Events



1% Operate Events

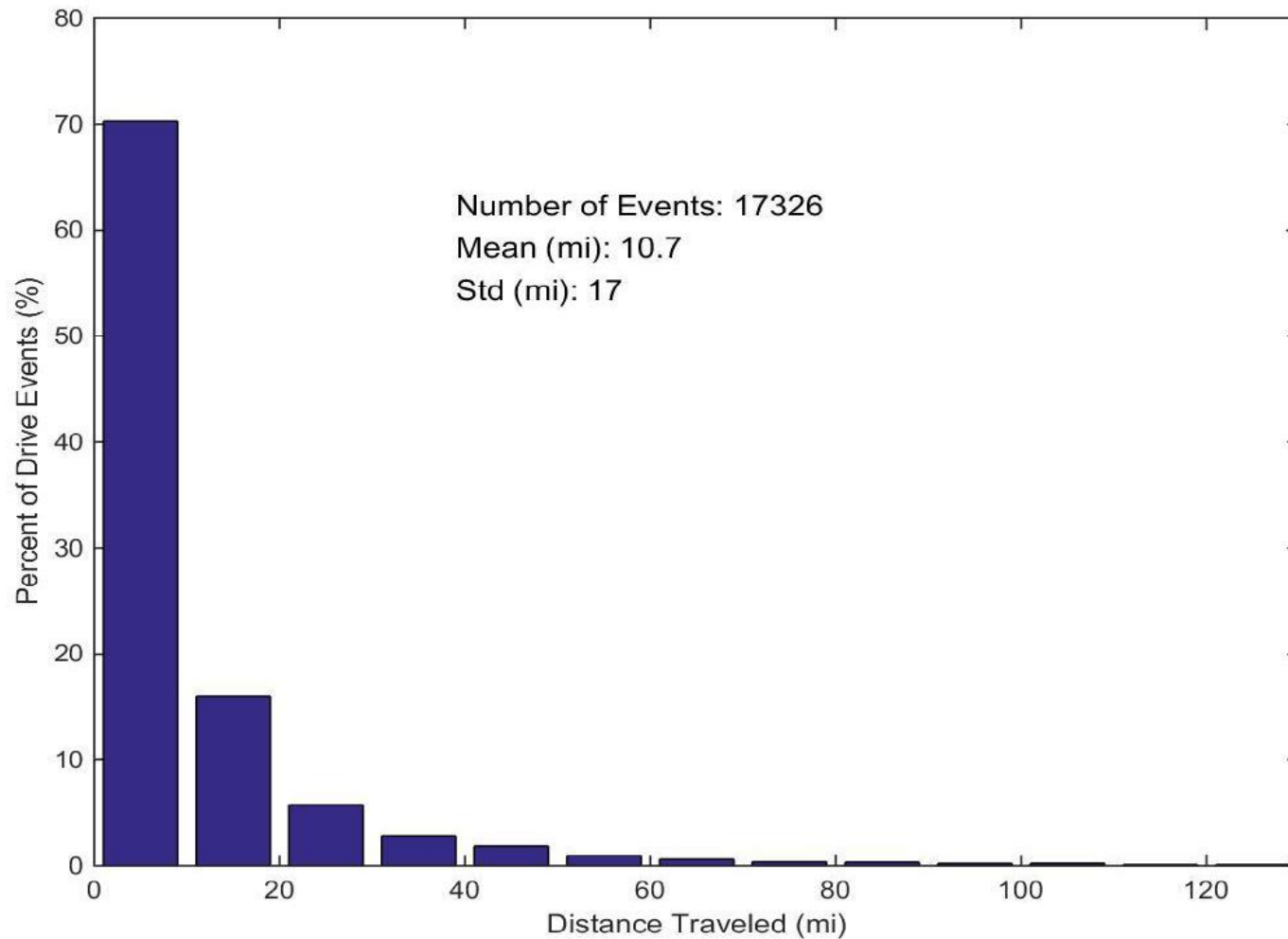
Driving had the most events

VIA- Drive Event Start Times



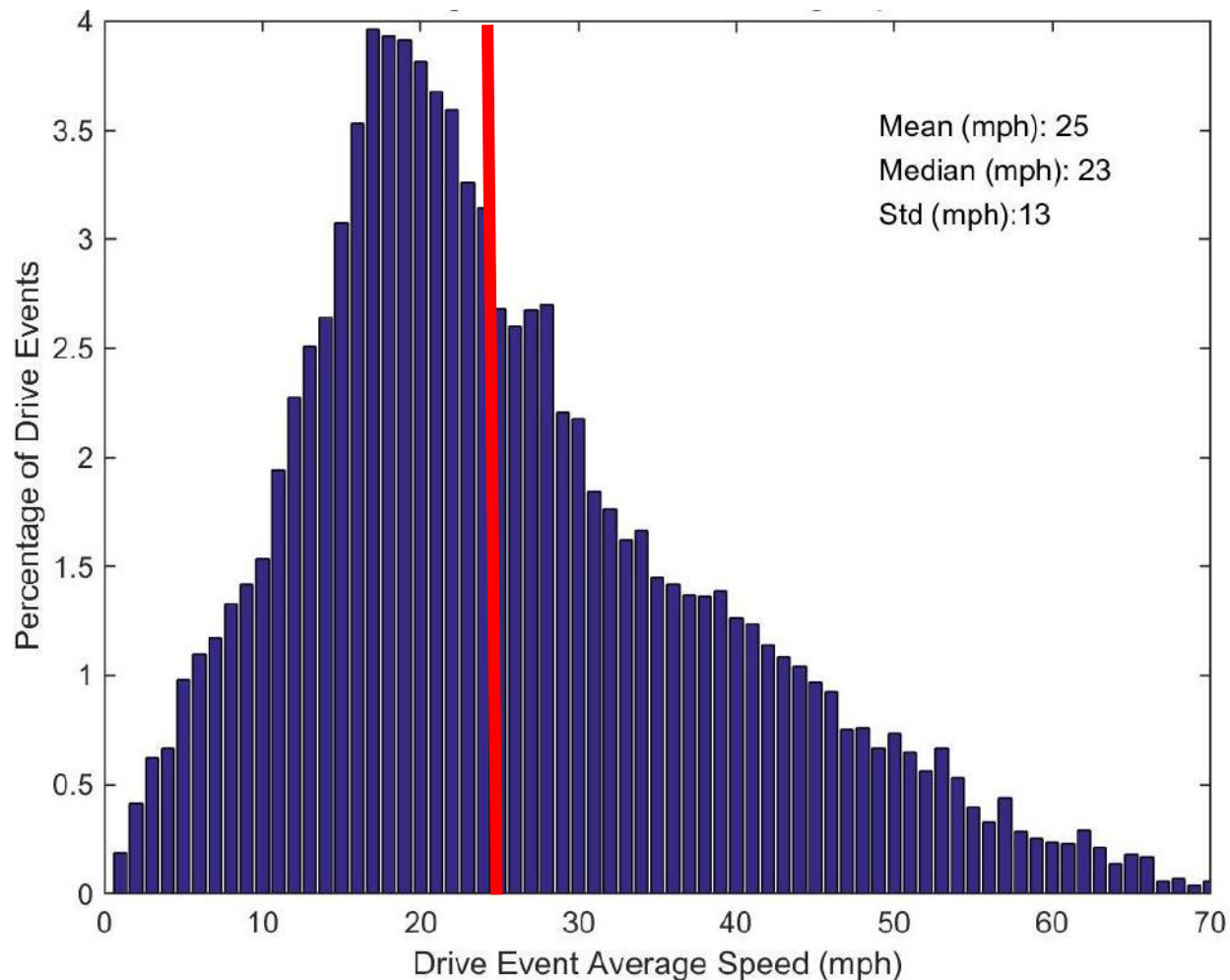
About 78% of the Drive events were during the Day shift

VIA- Drive Events



Most drive events were 10 miles or less

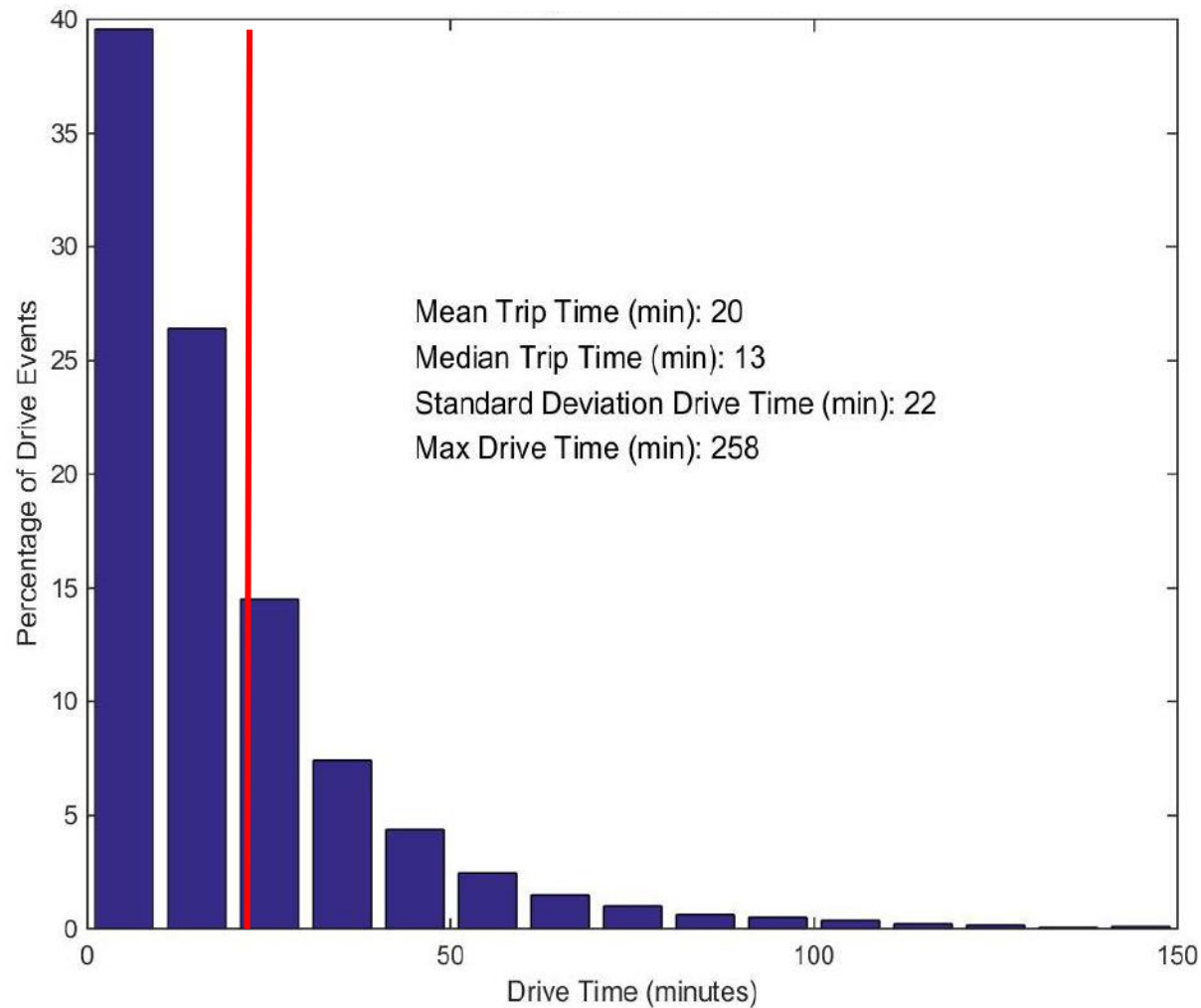
VIA- Vehicle Speed



The vehicle's
governed speed is 75
mph.

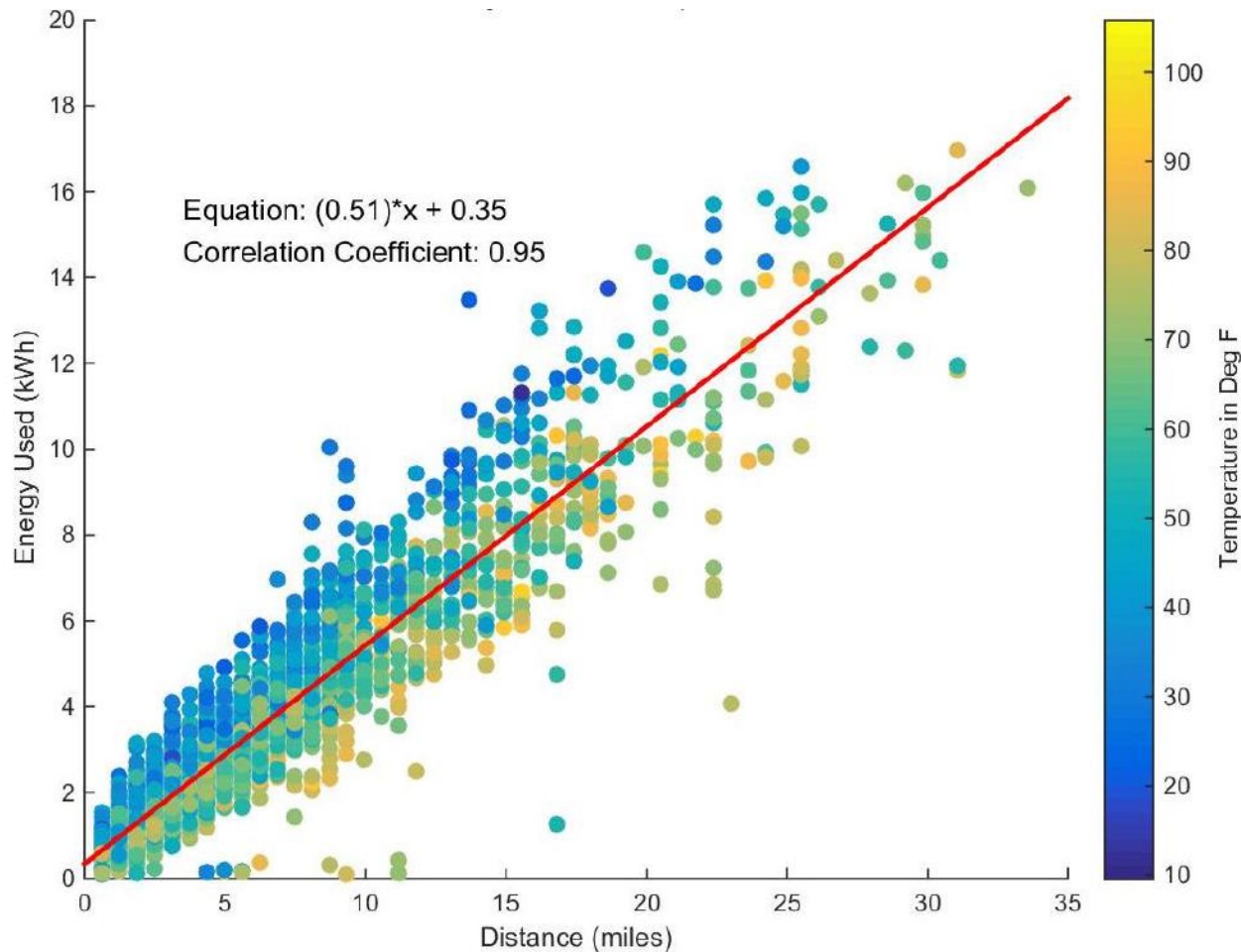
Fleet Average Vehicle Speed is 25 mph

VIA- Drive Time



Average Drive time was 20 minutes and the maximum time was 4.25 hours

VIA Pickup- Energy vs Distance- Charge Depleted



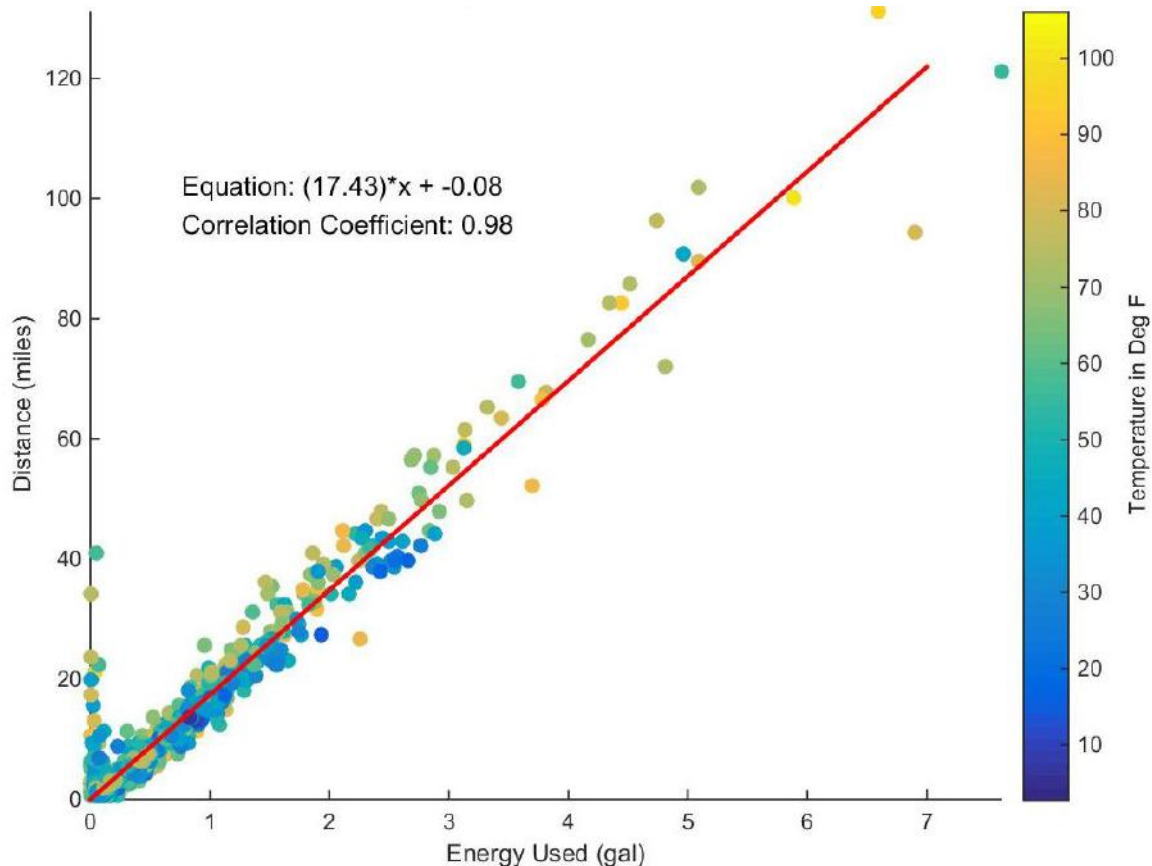
Battery Capacity is 80% of
23 kWh (18.4 kWh)

Range	miles
Tested	47.6
Fleet Average	36.1

Slope of the fitted line is the average fuel consumption for charge depleted

~510 Wh /mile providing a fleet average range of 36.1 miles

VIA Pickup- Distance vs Energy- Charge Sustained

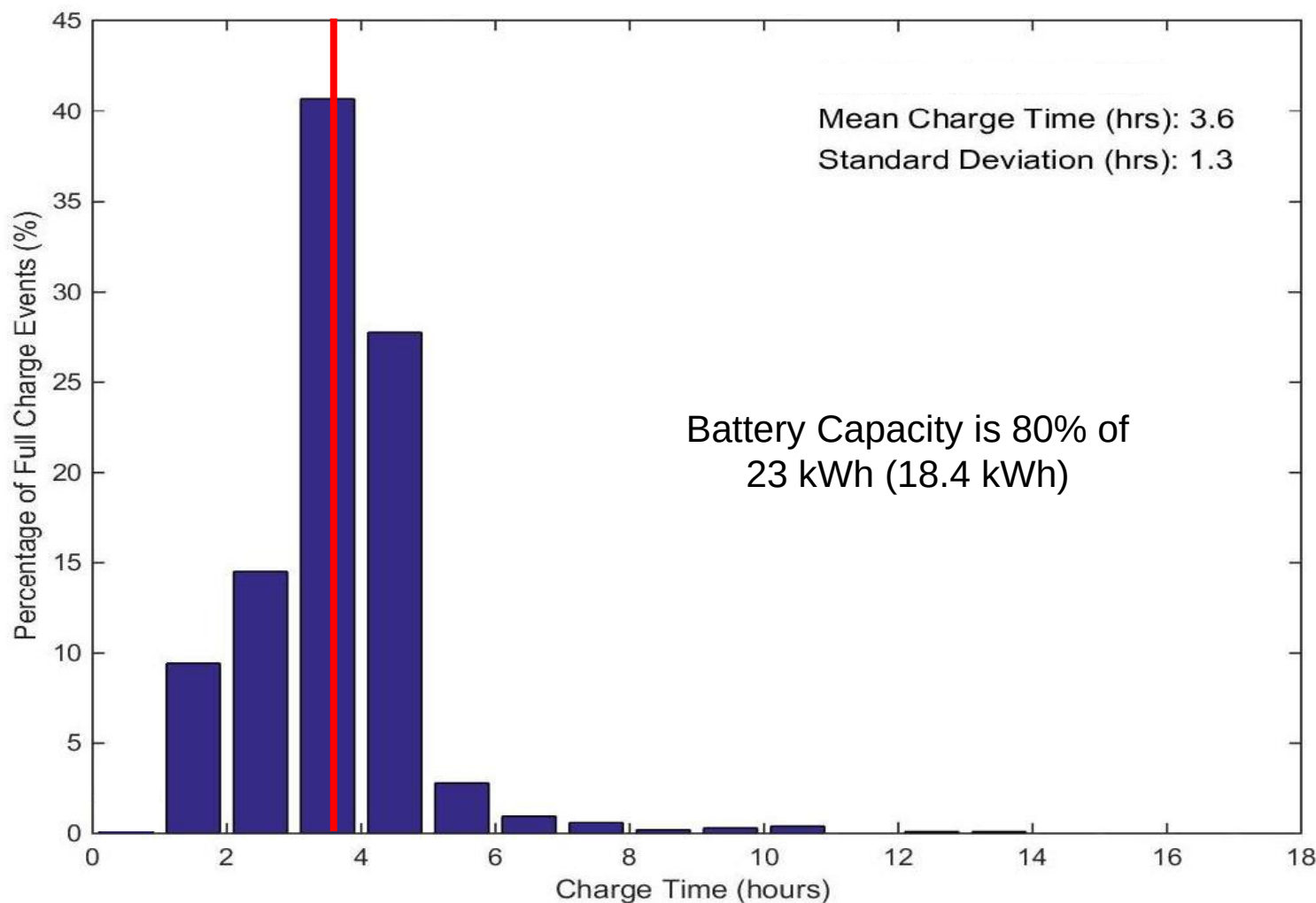


Fuel Economy	mpg
Tested CS	19.6
Fleet Average CS	17.4
Conventional	13.6

Slope of the fitted line is the average fuel economy for charge sustained

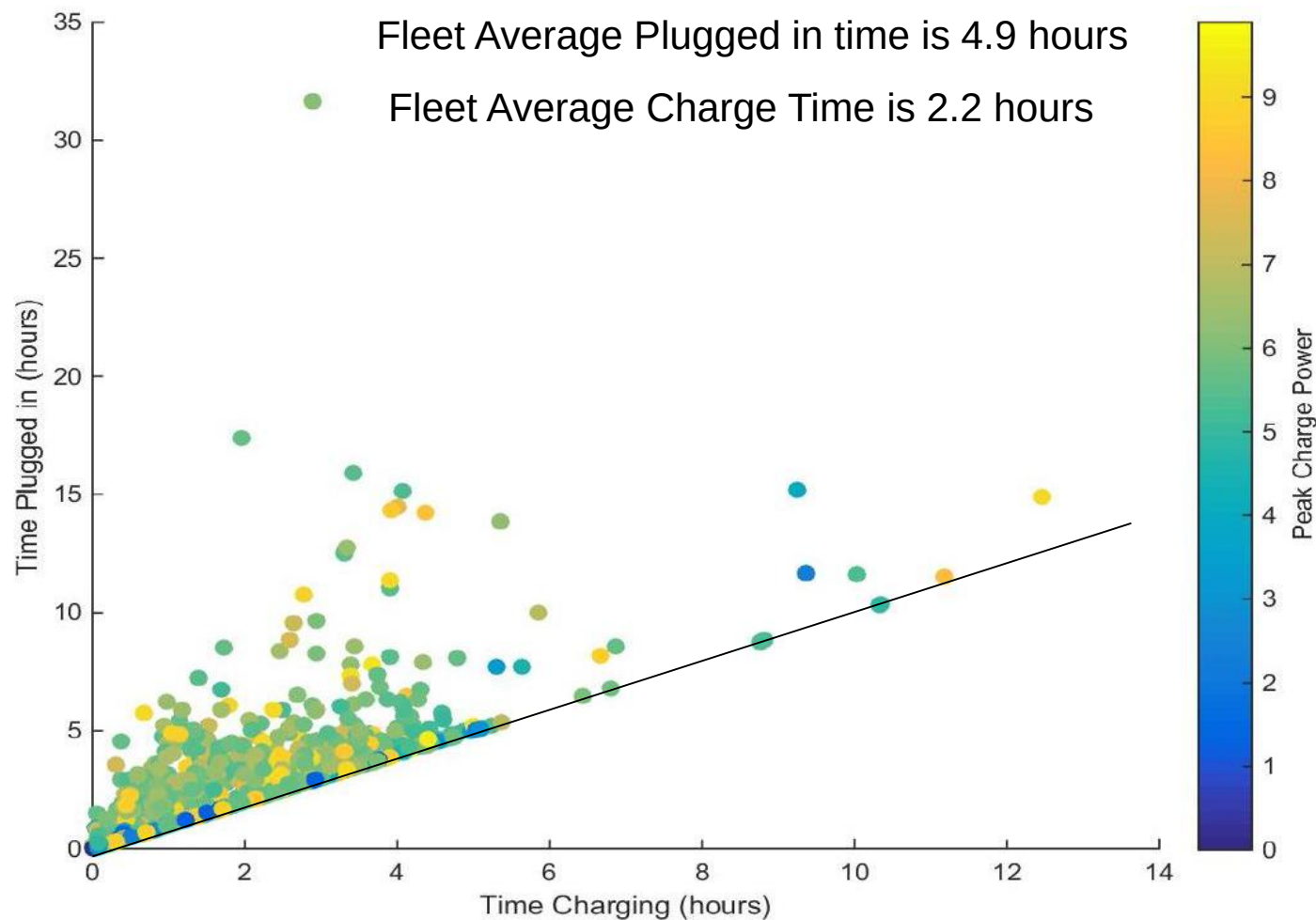
~17.4 mpg

VIA Full Charge Times



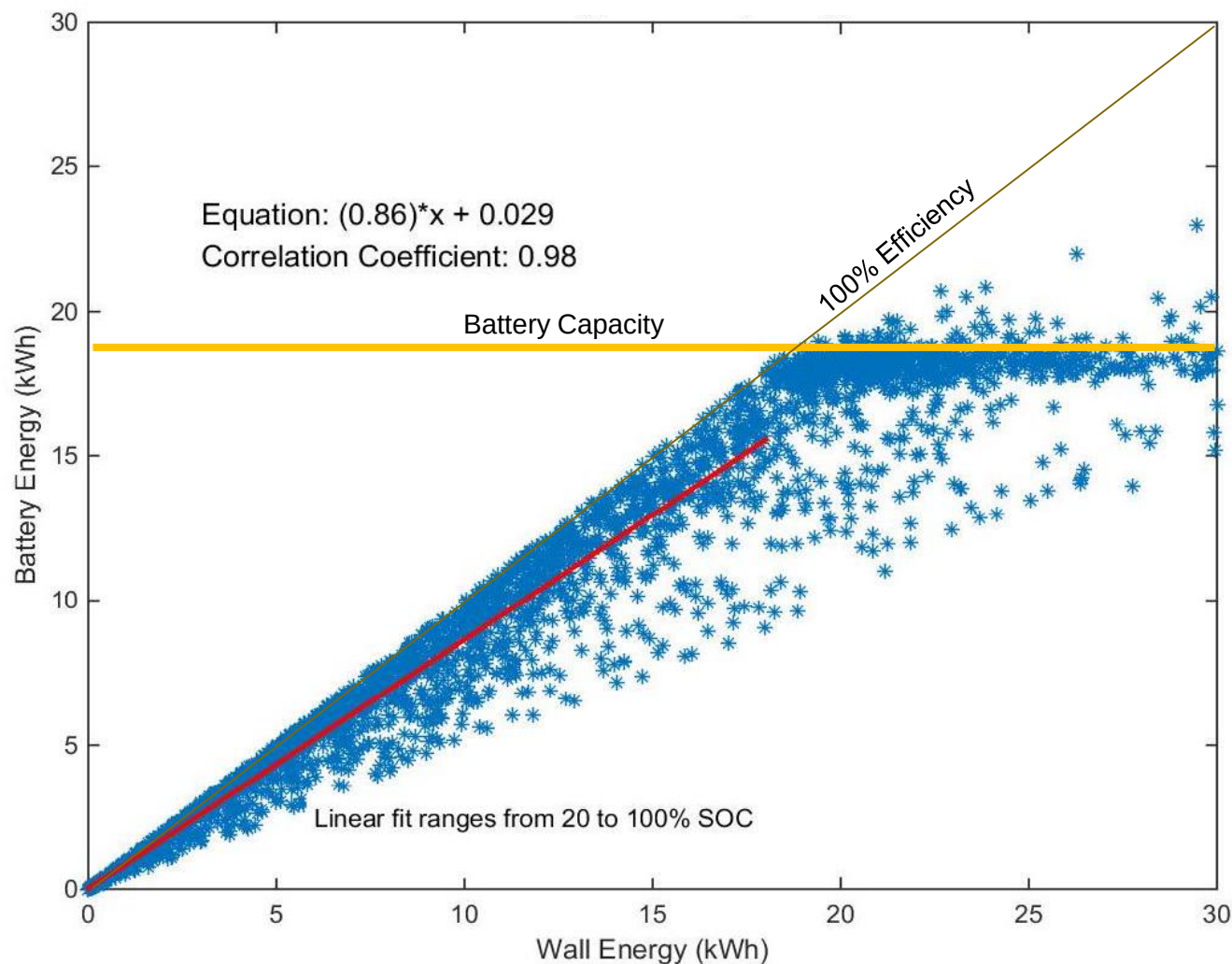
Fleet average for a full charge time is 3.6 hours, but many took advantage of the 14.5 kw charger to reduce charge time

VIA Plugged vs Charge Time



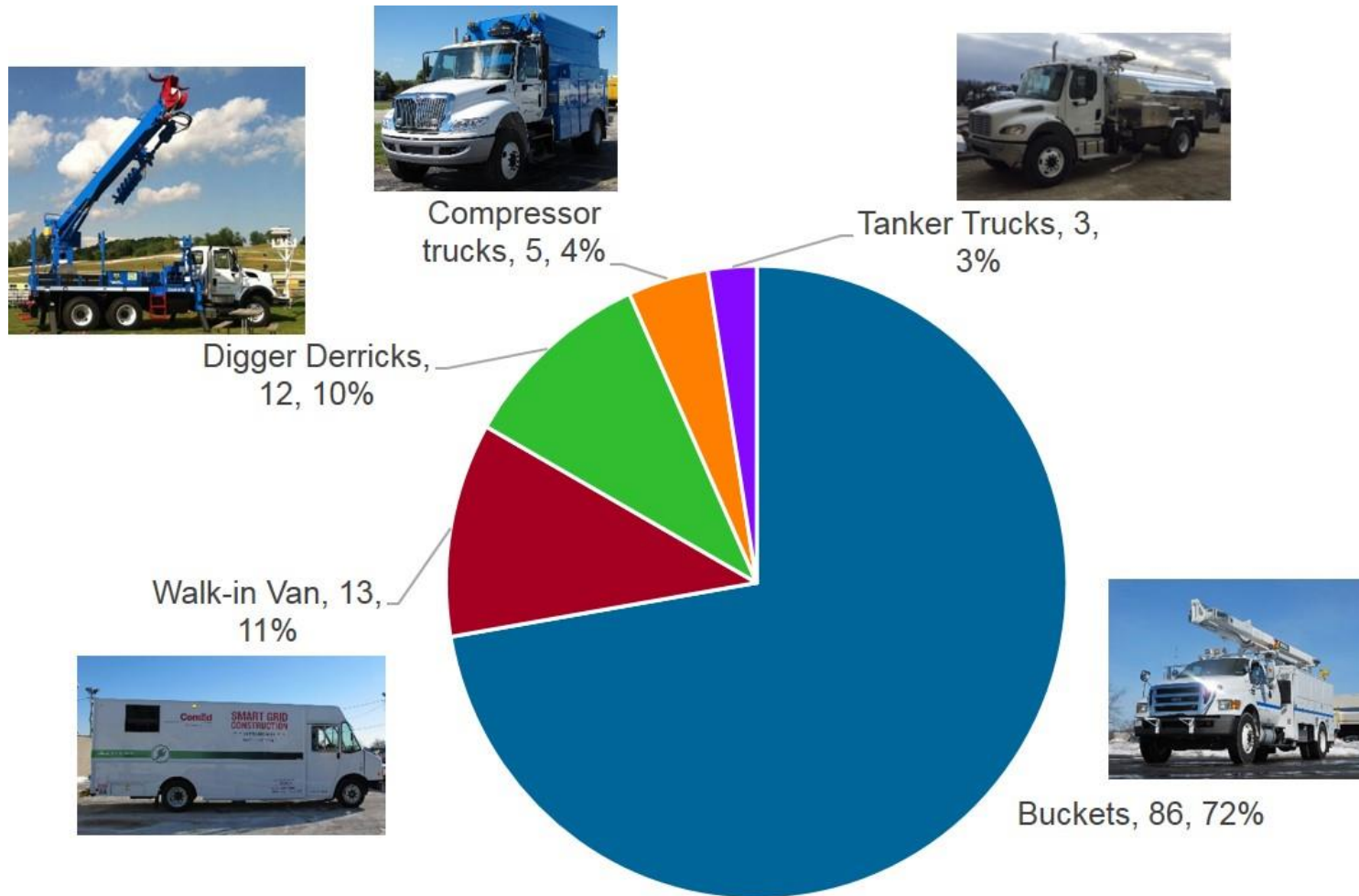
Plugged In Time is greater then the Charge Time

VIA- Charge Efficiency



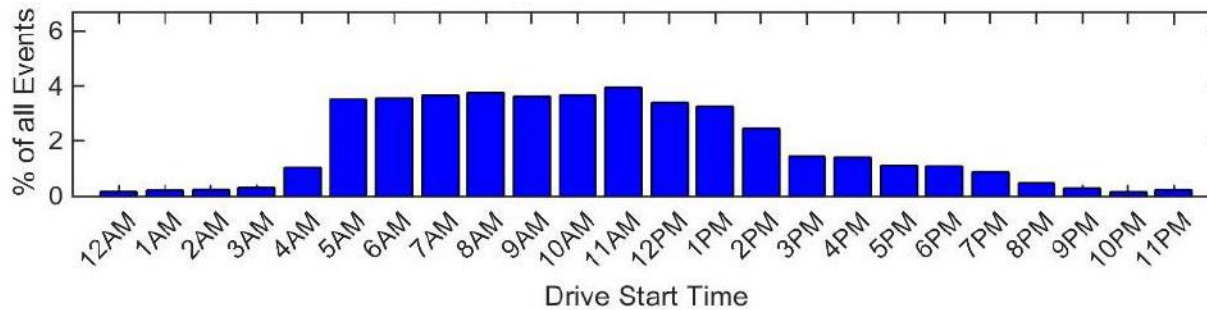
Overall Charge Efficiency is about 86%

Odyne Program Update

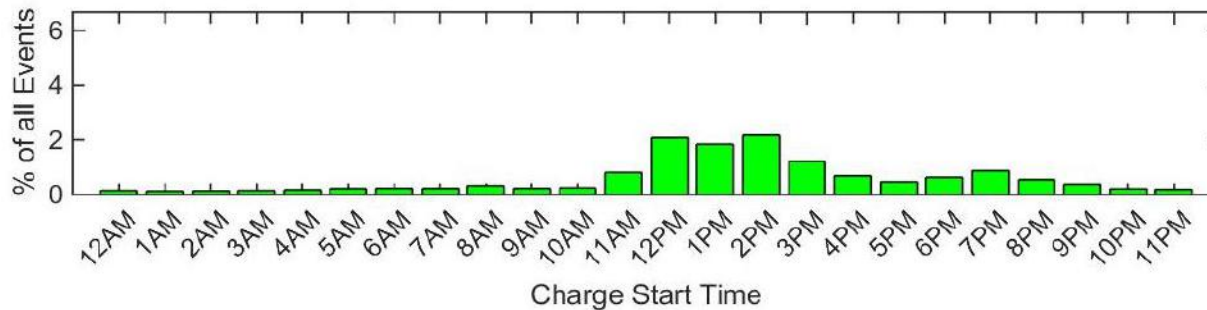


3 out of 4 Class 6 to 8 trucks are bucket trucks

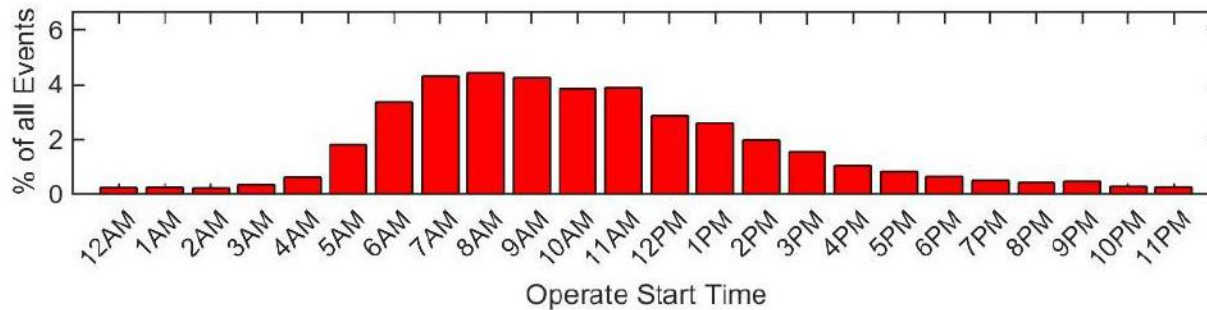
Odyne- Event Start Times



69% Drive Events



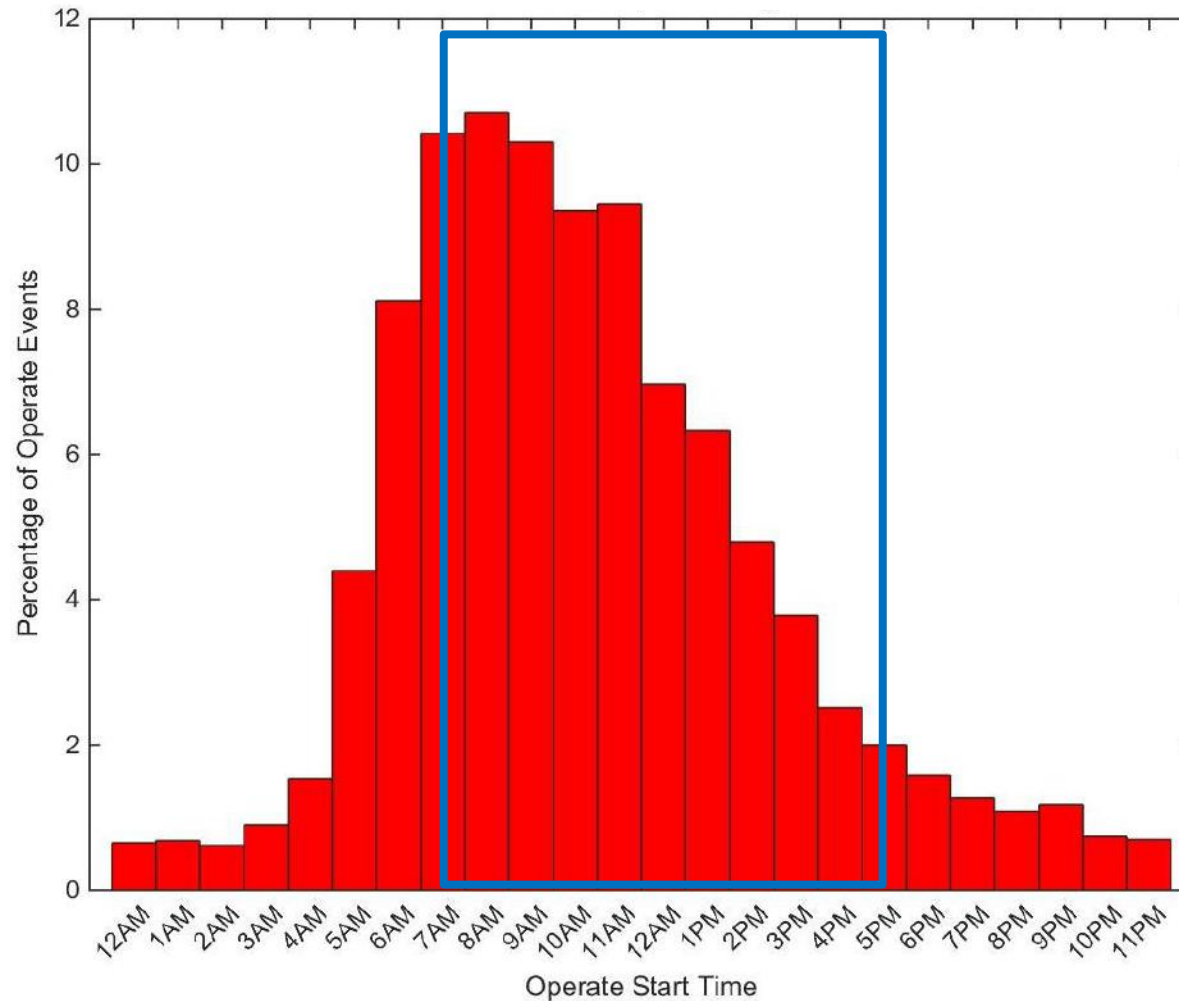
8% Charge Events



23% Operate Events

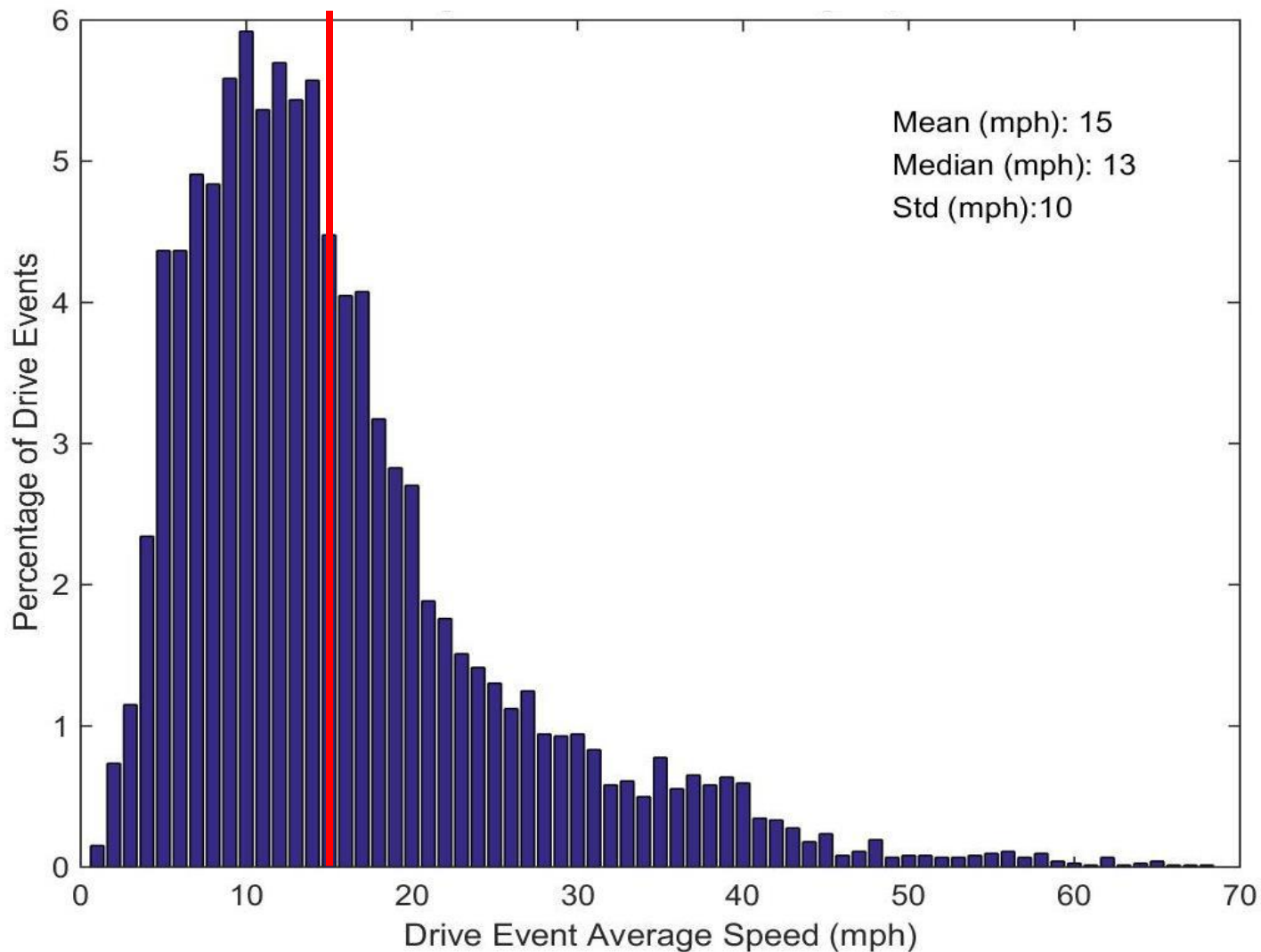
The Class 6 to 8 trucks took advantage of the Operate Mode

Odyne- Operate Start Times



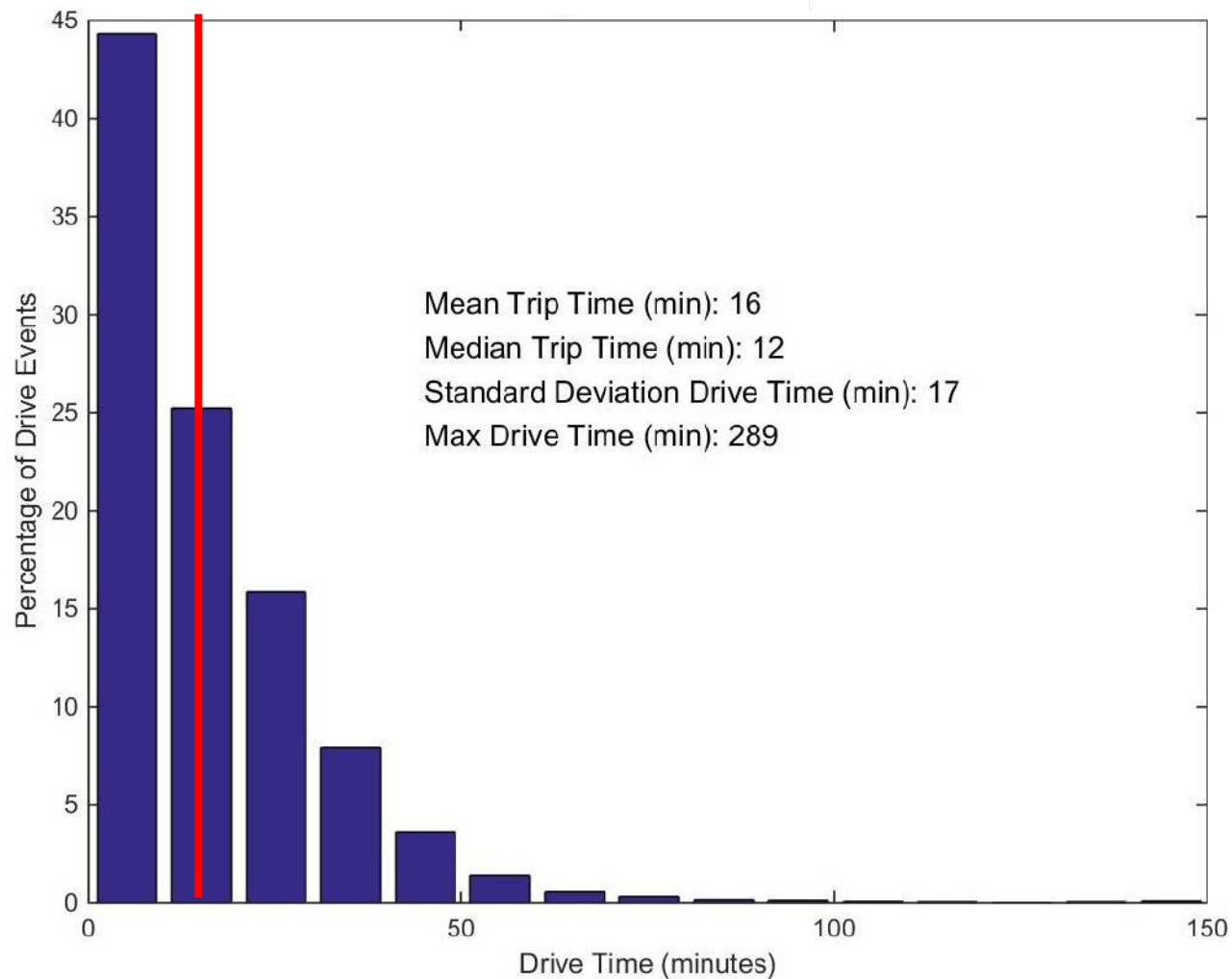
The Class 6 to 8 trucks used the Operate mode ~73% during the day shift

Odyne- Average Speed



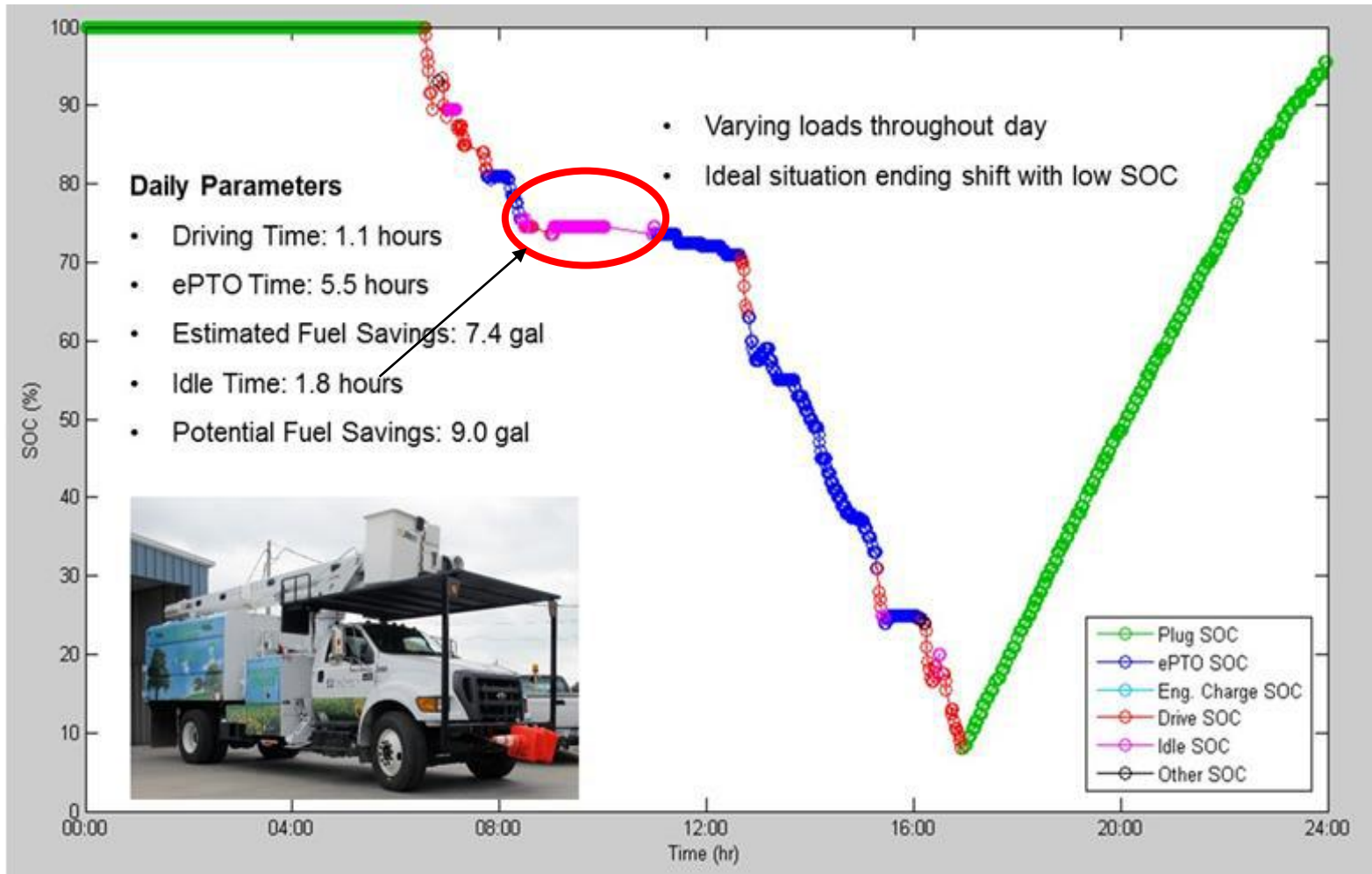
Average Fleet Speed was 15 mph

Odyne- Drive Time



Average Drive Time is 16 minutes with a maximum of 4.8 hours

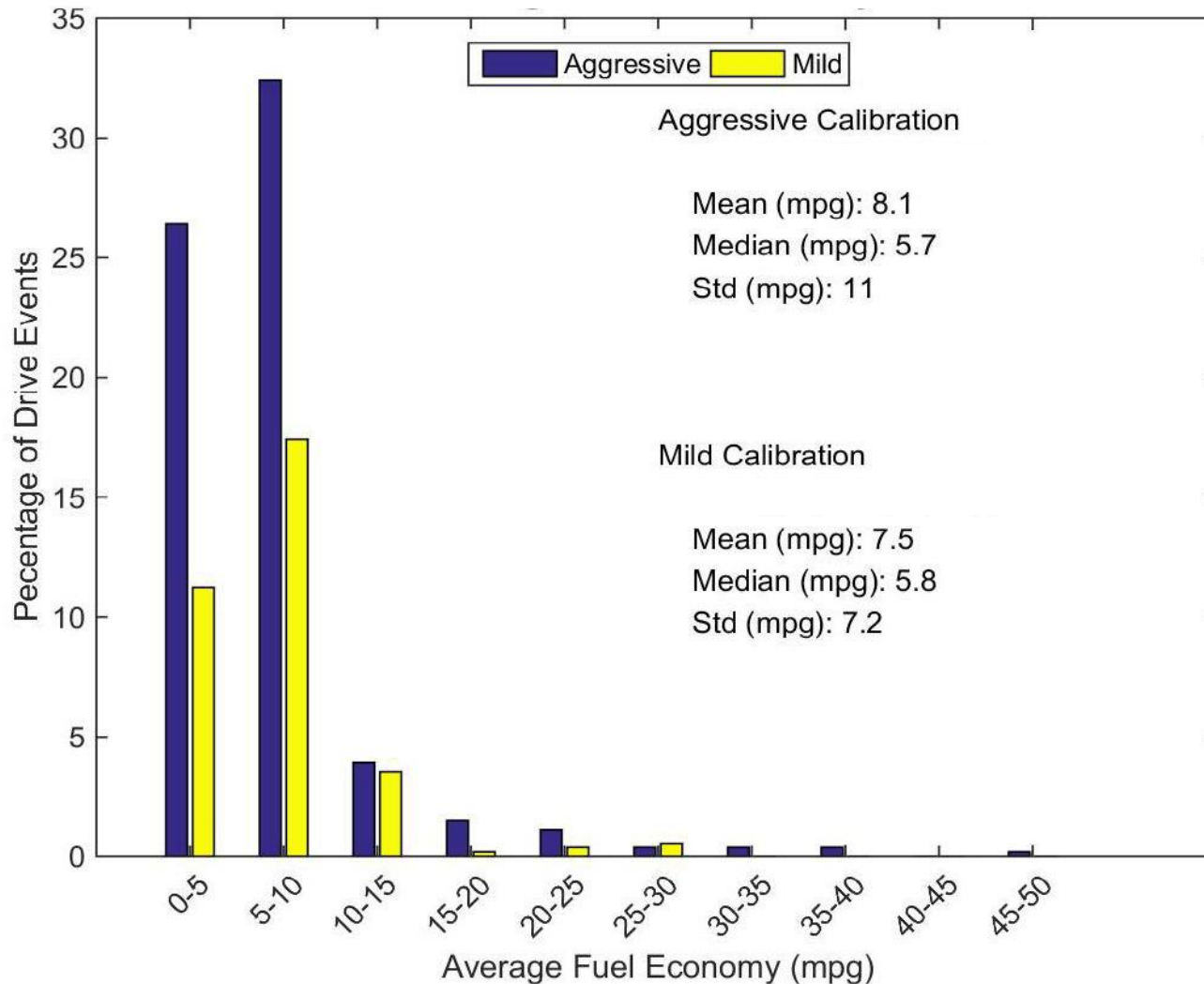
Odyne- State of Charge vs Time of day



The Plug-in Hybrid system saved 7.4 gallons of fuel on this schedule

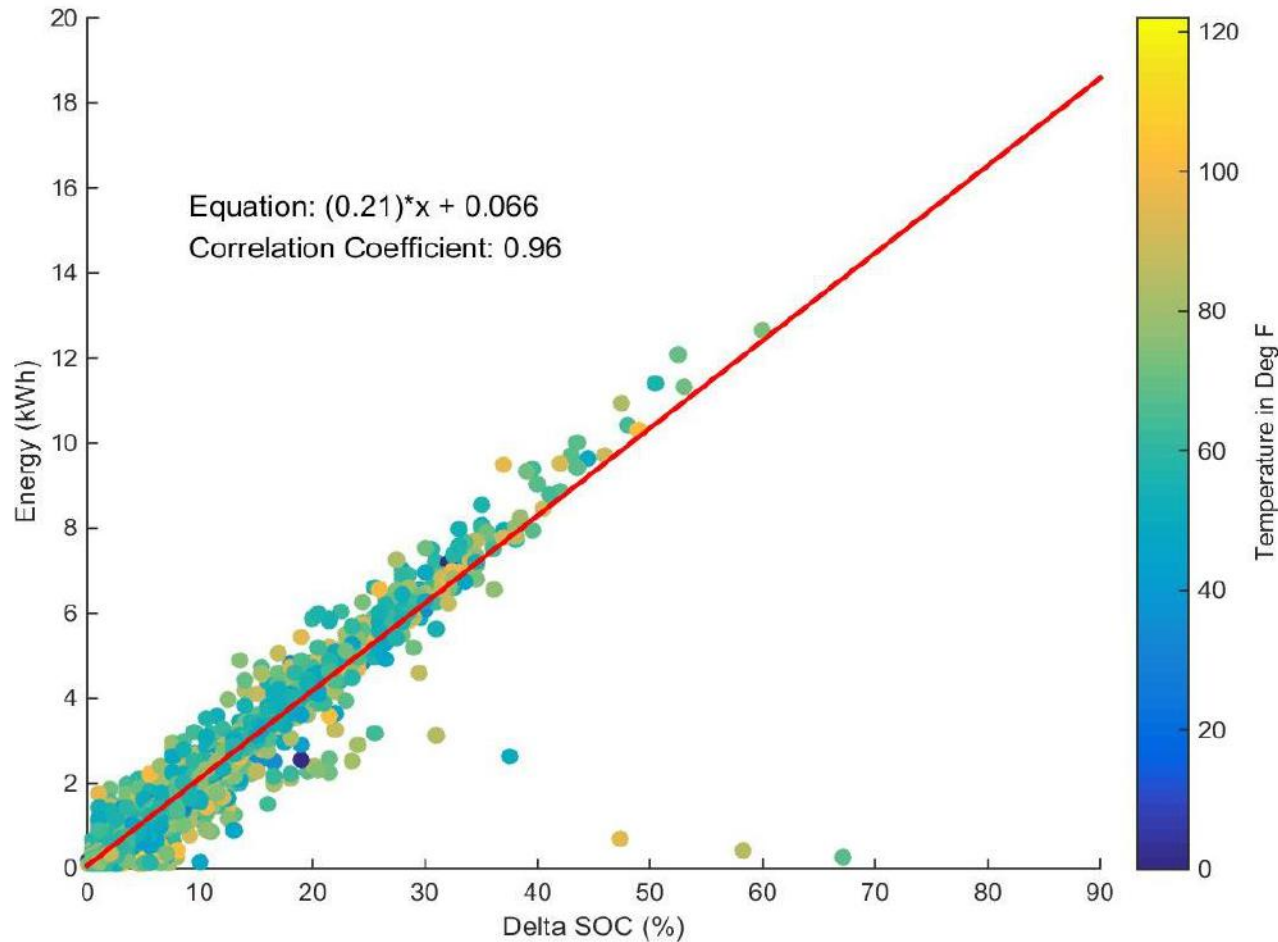
Eliminating Idle time could potentially save a total of 9.0 gallons of fuel

Odyne- Fuel Economy



The Aggressive Calibration shows on average an 8% improvement over the Mild calibration

Odyne- Energy vs SOC

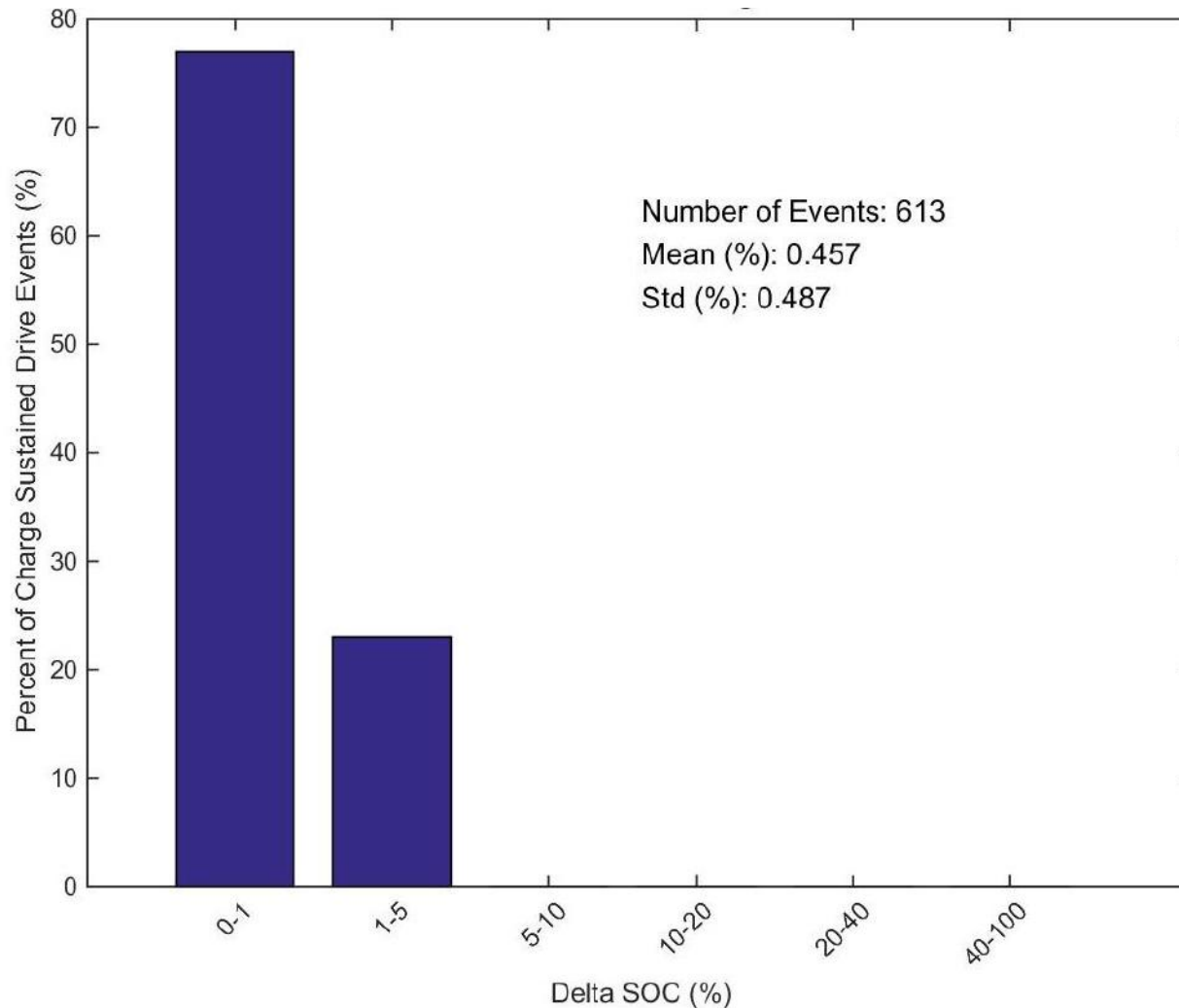


Expected Value =
220 Wh per %SOC

Slope of the fitted line is the average energy per SOC

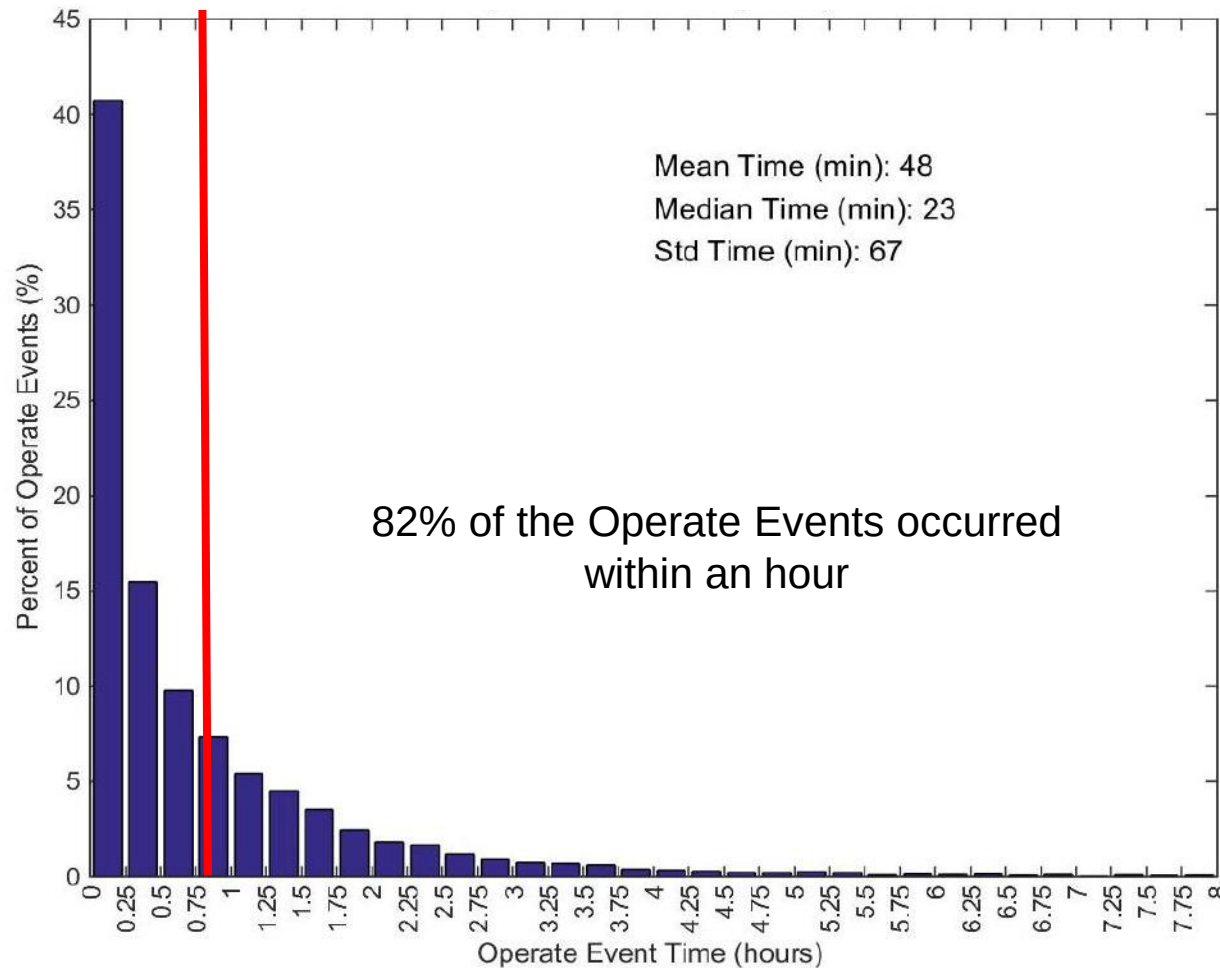
~210 Wh per % SOC

Odyne- Delta SOC during CS



While the vehicle is in Charged Sustained mode the SOC changes minimally.

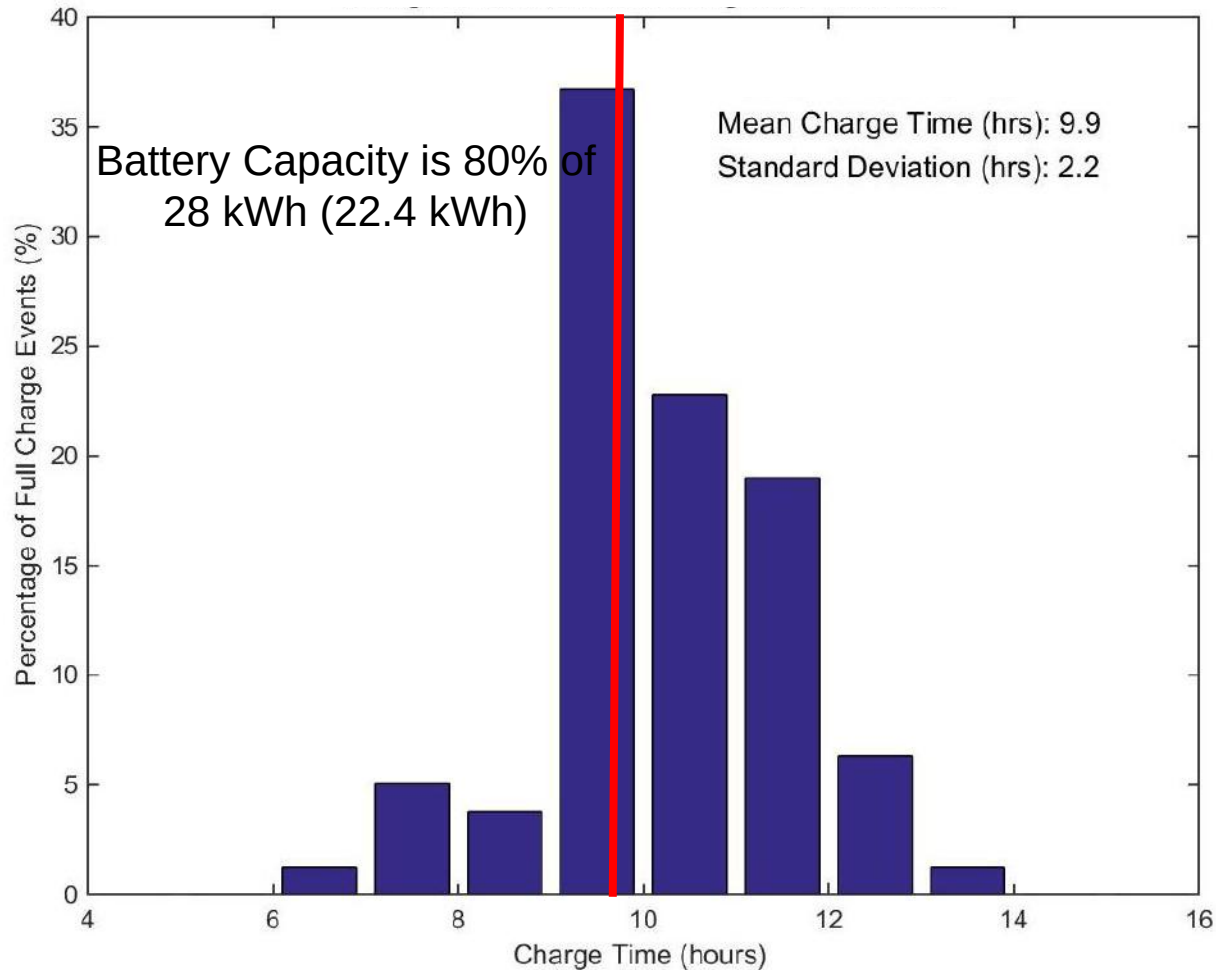
Odyne- Operate Duration



The 82% of the Operate events occurred within an hour, but extended out to an entire shift.

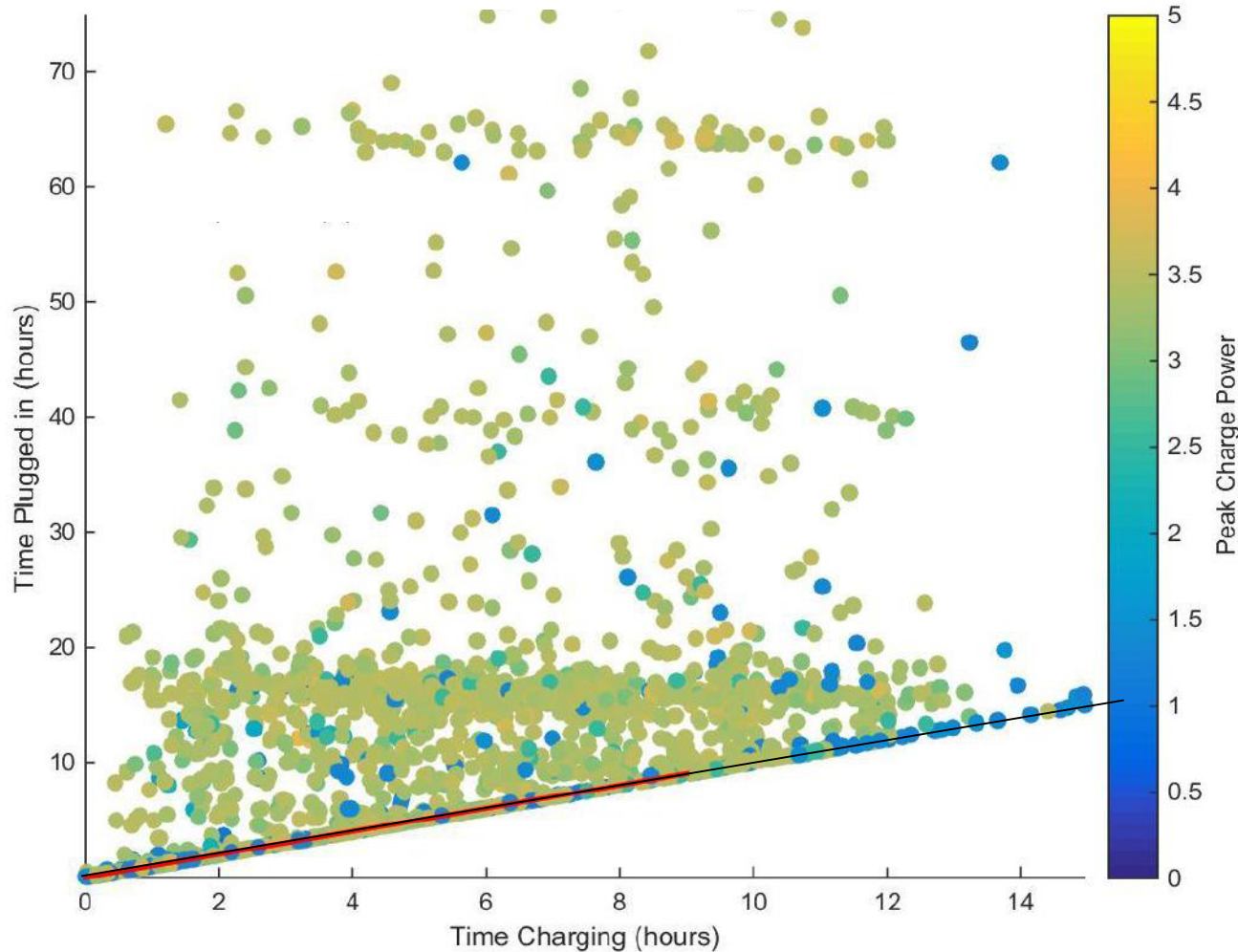
The average duration was about 48 minutes.

Odyne Full Charge Times



Fleet average for a full charge time is 9.9 hours

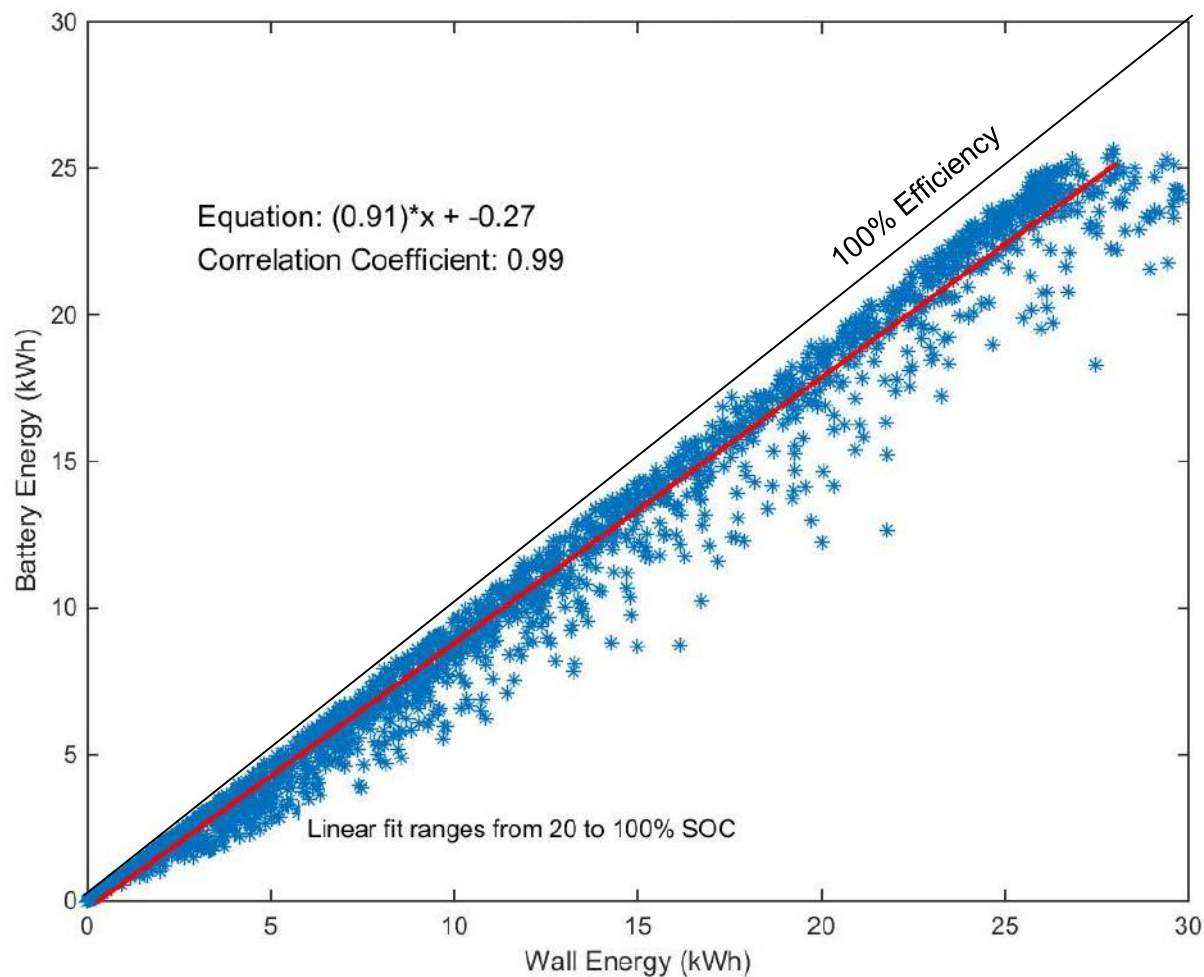
Odyne Plugged vs Charge Time



Fleet Average Plugged
in time is 12 hours

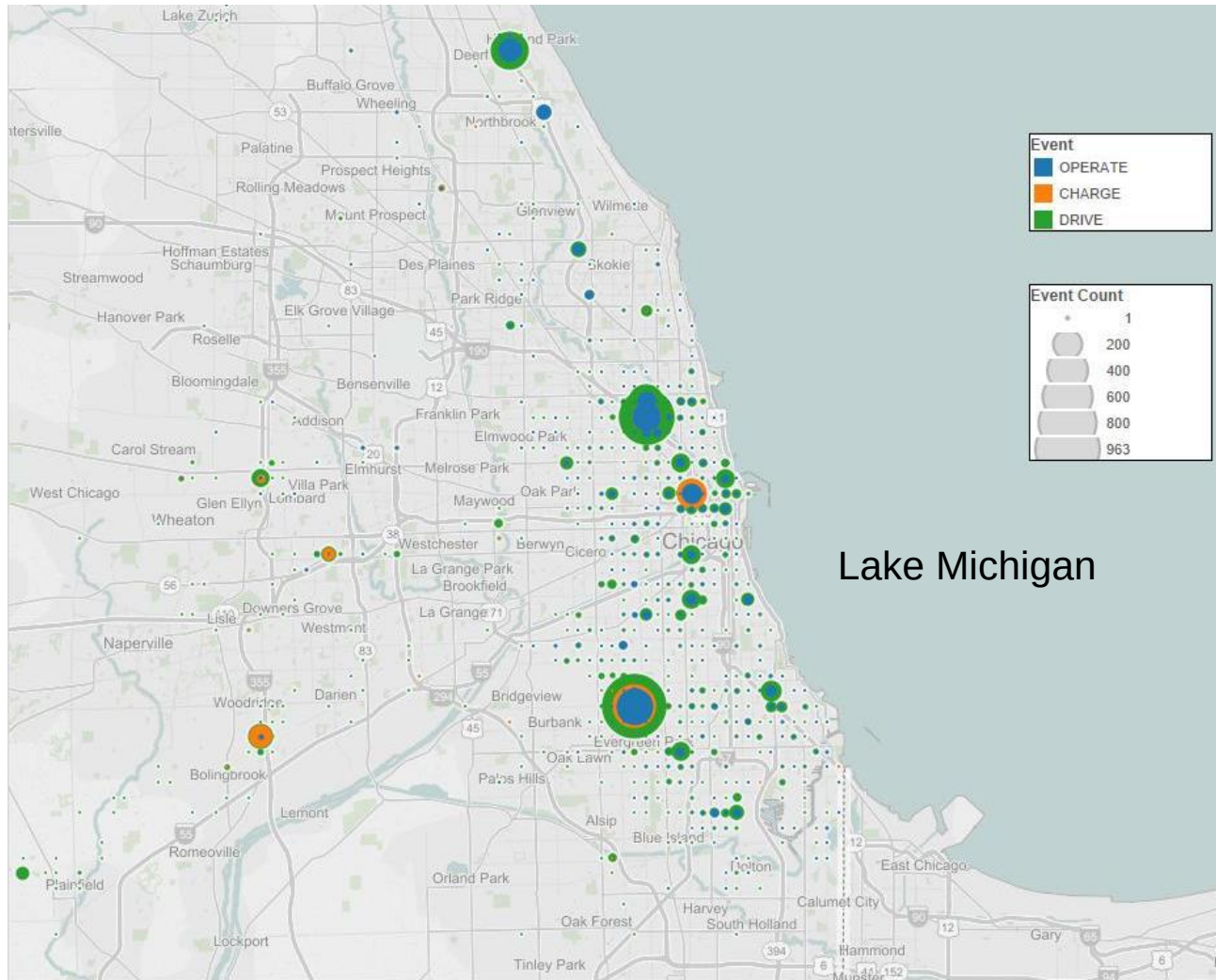
Fleet Average Charge
Time is 5 hours

Odyne- Charge Efficiency



Overall Charge Efficiency is 91%

Chicago Fleet Location- VIA and Odyne



10 Bucket Trucks

5 Digger Derricks

6 Walk-in Vans

10 Cargo Vans

4 Pickup Trucks

Total: 35 Trucks



35 Trucks dispersed all over the Chicago area

Summary

- A large data base for medium-duty truck PHEVs has been established
- Fleet traits have been identified
- Fleet fuel consumption range have been determined
- Charging traits have been identified
- The more powerful charging stations are more prevalent

Thank You

Together...Shaping the Future of Electricity

EPRI Contact

Mark Kosowski

Technical Executive

PHEV Medium Duty Truck

(248) 421-7124

mkosowski@epri.com