

Medium and Heavy Duty Vehicle Field Evaluations



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Project ID: VSS001

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Overview

Timeline

Multiple Sites: varies by project

Project Length: typically 12-18 months start to finish (including startup and report)

For FY13: Some "in-process," some "new"

Percent Complete: ~50%

Budget

Total Project Funding FY13 w/industry cost share: ~\$1,300K [\$850K Field Evaluations + \$200K Medium Duty (MD) Electric Vehicle (EV) Data Collection]

DOE Share: \$1,050K

Participant cost share: in-kind support (vehicle loans, technical support, data access, data supplied to NREL) and varies by individual project

DOE Funding Received in FY12: \$1,150K

Barriers

Unbiased Data: Commercial users and OEMs need unbiased, 3rd party new technology evaluations for better understanding of state-of-the-art technology performance to overcome technical barriers

Variable Vehicle Use: Variable performance by technologies due to multiple and wide-ranging duty cycles (makes data and analysis of data valuable in overcoming this barrier)

Partners

Industry collaboration required for successful studies. Partners (past and present) include:

New Flyer, Freightliner, Workhorse, International, Orion, Allison Transmission, Eaton, Enova, Azure, Cummins, International, Caterpillar, UPS, FedEx, Coke, NYC Transit

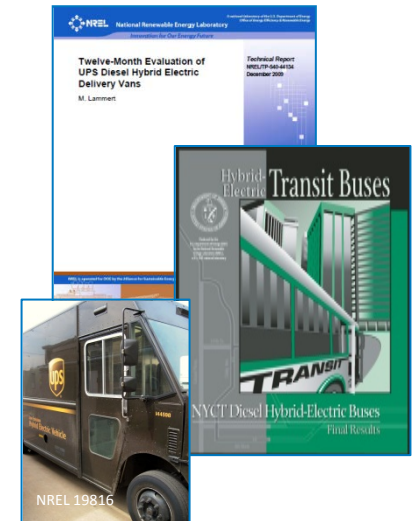
Current Partners in FY13:

FedEx, UPS, Verizon, Eaton, Navistar Corporation, Smith Electric Vehicles, Parker Hannifin, Frito Lay, Cascade Sierra, Odyne, PACCAR

Relevance

This project provides unbiased medium-duty (MD) and heavy-duty (HD) test results, aggregated data, and detailed analysis to industry :

- **3rd party unbiased data:** Provides data that would not normally be shared by industry in an aggregated and detailed manner
- Over 600,000 miles of **medium-duty all electric truck** operation have been **collected, documented, analyzed** and used for additional research by DOE labs, OEMs and users.
- Over 5.1 million miles of advanced technology **medium and heavy-duty truck data have been collected, documented, and analyzed** on over 200 different vehicles since 2002
- **Data, Analysis, and Reports** are shared with DOE, National Lab Partners, and Industry for technology R&D - Results help:
 - guide R&D for new technology development
 - help define intelligent usage of newly developed technology
 - help fleets/users understand all aspects of advanced technology



Objectives

Support the VT Program's Vehicle and Systems Simulation and Testing goal (from MYPP):

Collect and analyze advanced vehicle characteristics and performance data that are used to predict market potential and petroleum displacement, which then inform program-wide research

2 Specific Technical Objectives in FY13: Field Evaluations and MD EV Data Collection

- **In-Use Vehicle Evaluations:** Evaluate technology in multiple fleets : FedEx® HEVs in California, UPS hydraulic hybrid vehicles (HHVs) in Maryland, Frito Lay EV Delivery Trucks in Washington, and one additional fleet TBD
- **Data Collection from Commercial EVs:** Collect and analyze data and provide performance metrics from MD vehicles deployed across the United States: Smith EVs, Navistar® EVs, Cascade Sierra Truckstop Electrification

Milestones

Milestone 1: Draft interim report highlighting fleet data collection efforts and analysis of data (September 2013) – Status: On-Track

- **Provides a year-end summary report on overall status and results of each project**
- **In addition to the Milestone Report, the following published (publically available) technical project reports will be completed:**
 - **FedEx Freightliner M2 box truck (Ontario, CA) –final report published in June 2013**
 - **UPS Hydraulic Hybrid (Baltimore, MD) – startup and interim results published in 2013**
 - **EV Fleet Case Study: Frito Lay – startup and interim results published in 2013**
 - **Telecom Fleet Analysis – analyzing use to predict best technology option – technical backup**
 - **UPS HEV Final Results – published in September 2012 – technical backup**

Milestone 2: Draft interim report on all MD EV projects (Sept 2013) – Status: On-Track

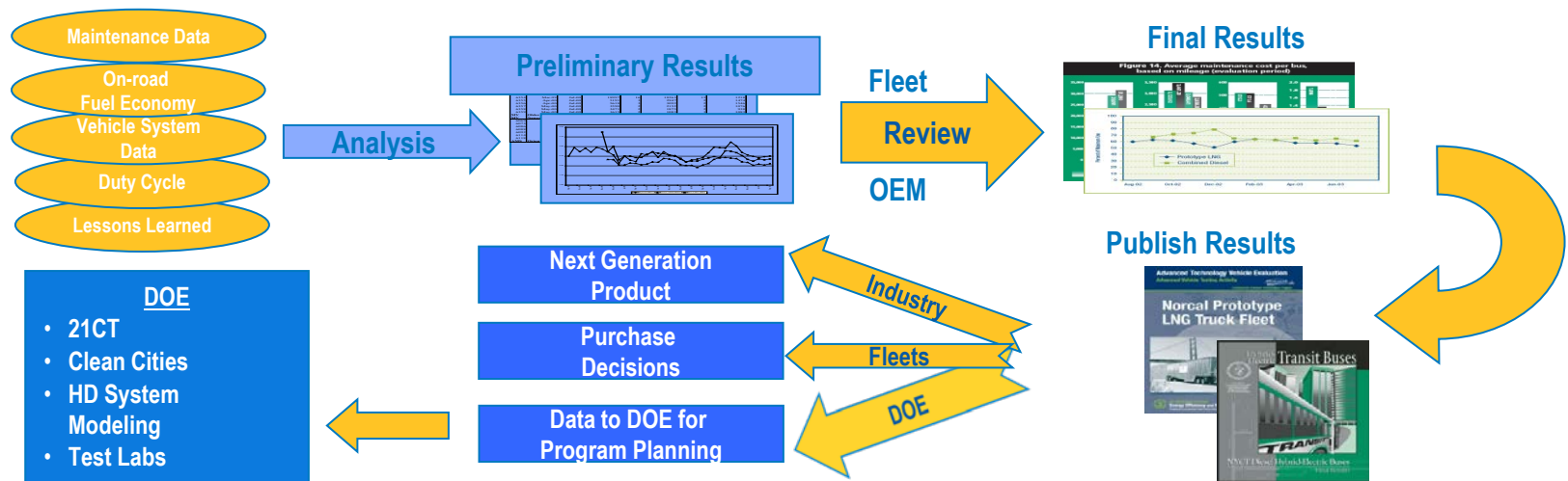
- **Smith EV, Navistar EV, Cascade Sierra Truckstop Electrification**
- **Usage data summarized, will include metrics such as charge characteristics, battery state of charge (SOC), driving characteristics, etc.**
- **In addition to Milestone Report above, the following quarterly updates will be completed in FY13:**
 - **Smith Quarterly Reports (Q4 2012, Q1-Q2 2013 – published in April, July)**
 - **Navistar Quarterly Reports (Cumulative YTD published in May 2013) – technical backup**
 - **Cascade Sierra Report (Cumulative and 1st Quarterly published May 2013)**

Approach – Selection & Data Flow

This project will collaborate with fleet and OEM partners to select, test, and validate advanced technologies in commercial vehicle applications. Specific technologies are selected based on:

1. Their potential for reducing fuel consumption (current fuel usage and potential for reduction)
2. Their potential for widespread commercialization and availability to cooperate with deploying fleets
3. The interest of the DOE (including 21st Century Truck partners and other DOE program managers)

General approach:



Approach – Data Acquisition & Analysis Tools

Enhanced data collection capabilities:

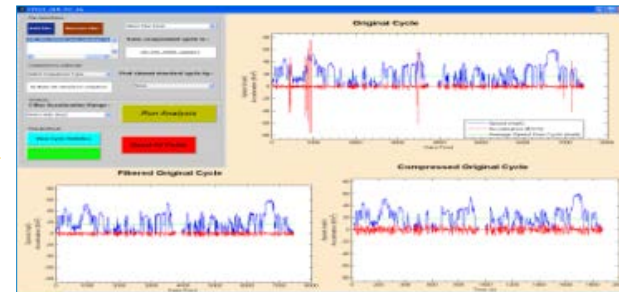
- Controller Area Network (CAN) Data Loggers (standard and advanced technology parameters)
- GPS Data Loggers – drive cycle data collection for chassis dyno and simulation testing

**On-Board
Data
Collection**



DRIVE™

**Drive Cycle
Analysis Tool**

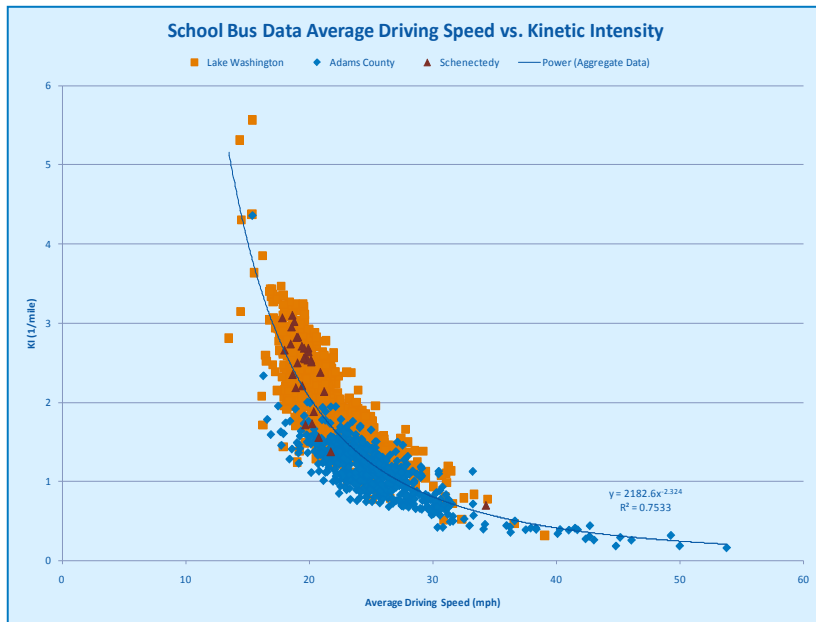


Collect sets of GPS,
CAN, & analog data
(per day or per
shift)

- Full understanding of supplied data: daily variation info; 150 stats for original, filtered, and shortened data
- User-specific test cycle generated

capability = over 40
data loggers in use

Approach – Most Data Made Available to Public



Data from Field Studies from this project as well as data from other National Labs and industry partners....

...into Fleet DNA – a vocational database developed by NREL in partnership with ORNL to capture and analyze MD & HD data:

- develops industry standard drive cycles
- enhances modeling and simulation
- helps develop codes and standards

Technical Accomplishments – FedEx HEV Class 7 Trucks

Accomplishment:

Completed on-road, 6-month evaluation of 6 FedEx HEV Class 7 trucks in operation in Ontario, CA, versus 6 conventional 2010 diesel trucks

Data collected:

- Fuel economy and maintenance records
- Drive cycle characterization
- NREL-ReFUEL dynamometer testing

Fleet Details:

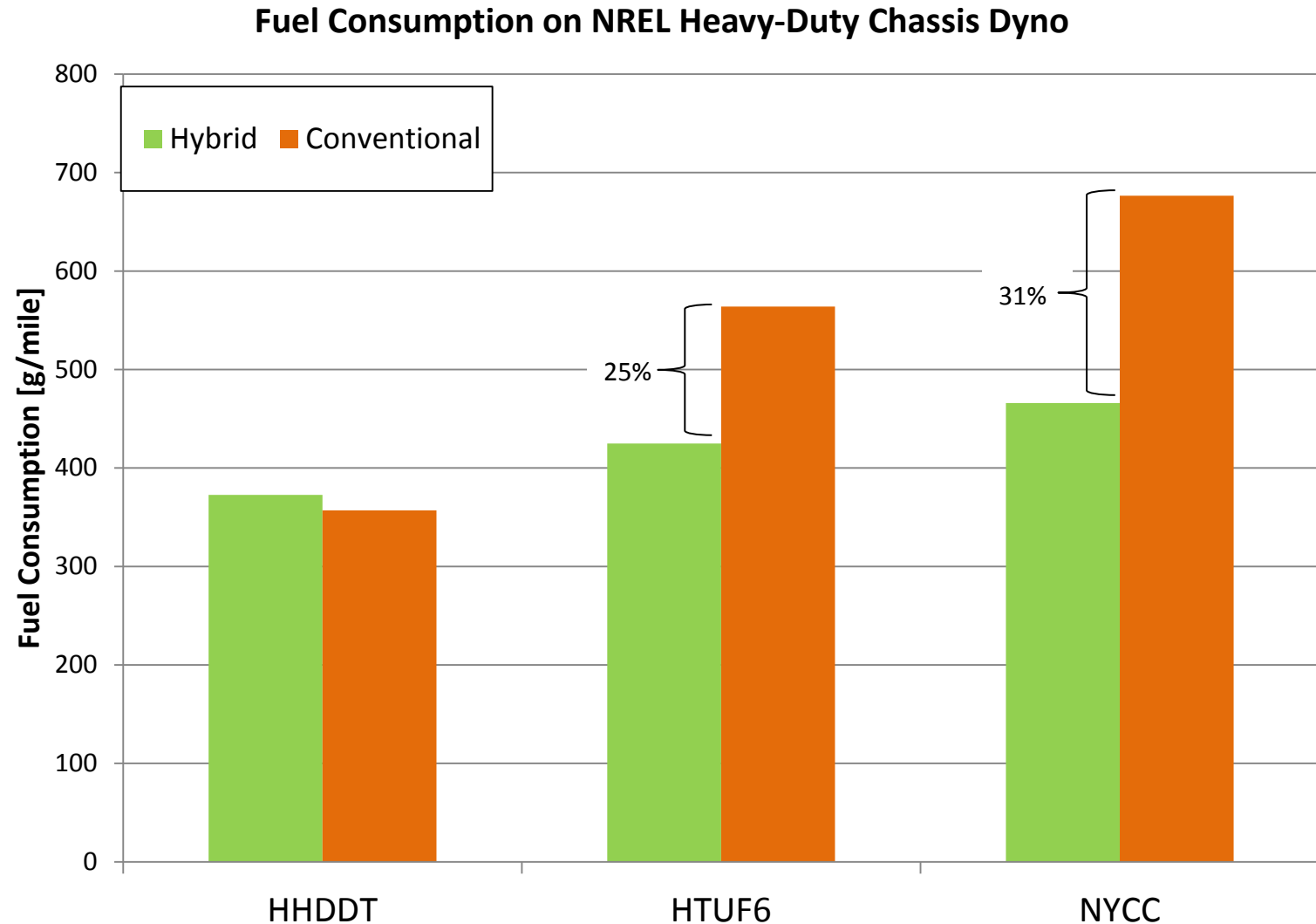
- Ontario, CA, Depot
- Six 2010 hybrid trucks (2010 engine certified)
- Six 2010 conventional trucks (2010 engine certified)
- Eaton Hybrid System

Usage and fuel economy

- On-road fuel economy of the hybrid group over the reporting period was 15% better than that of the diesel group
- Chassis Dynamometer results show a 0 to 31% advantage in fuel economy for the hybrids versus the conventional vehicles

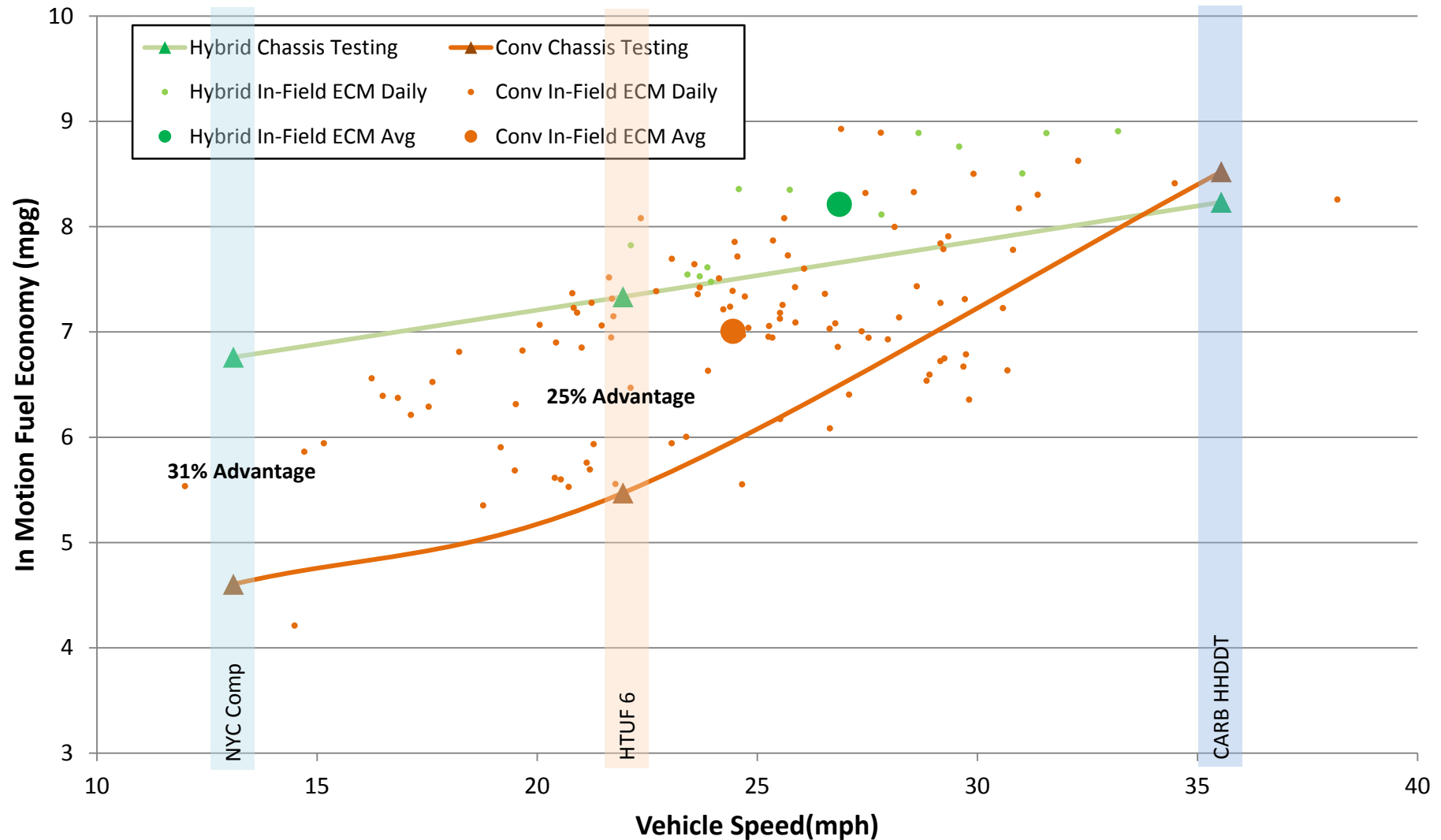


Technical Accomplishments – FedEx HEV Class 7 Trucks

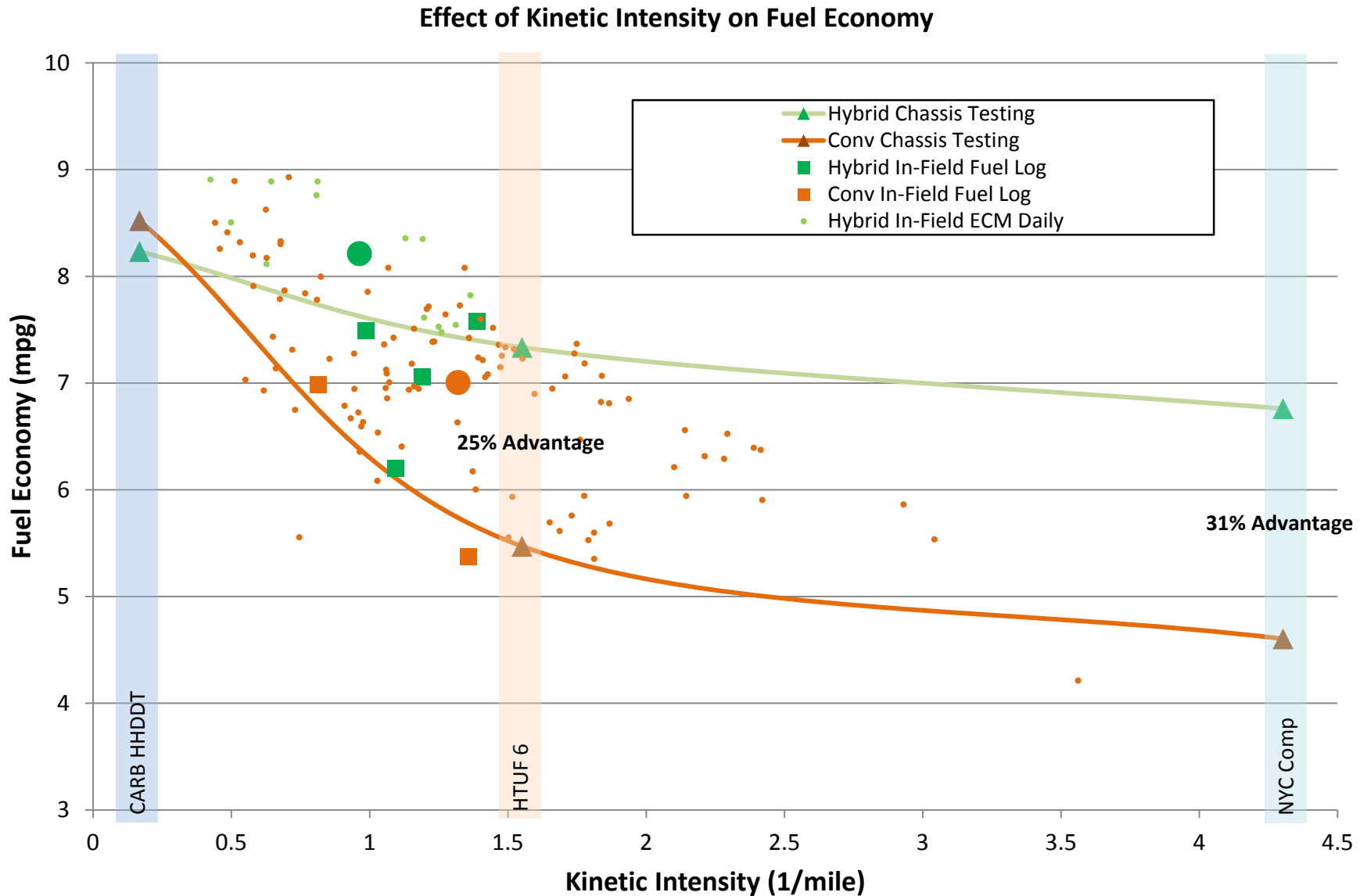


Technical Accomplishments – FedEx HEV Class 7 Trucks

Effect of Average Vehicle Speed on Fuel Economy



Technical Accomplishments – FedEx HEV Class 7 Trucks



Technical Accomplishments – UPS HHV Study

Project Background & Accomplishment:

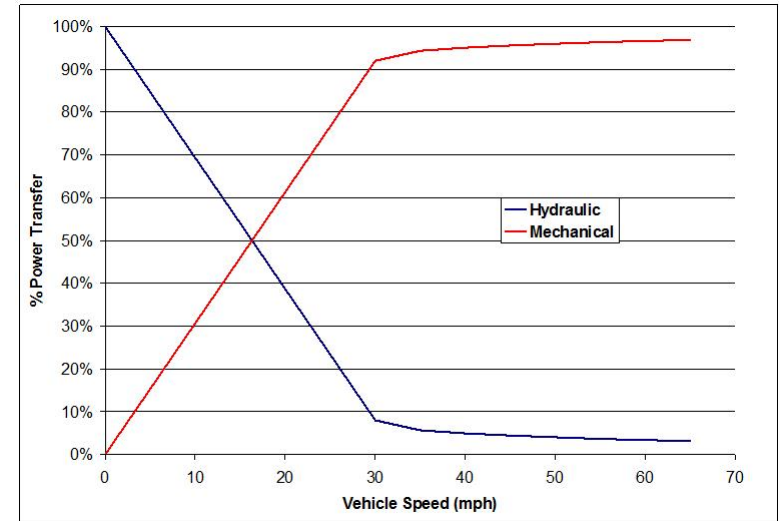
On-road and laboratory evaluation of Parker's hydraulic hybrid system in package delivery application at UPS. Final report expected in 3Q 2014.

Data to be collected – 12 months of operation:

- Fuel economy and maintenance records
- Engine control unit (ECU) records downloaded regularly
 - Miles traveled
 - Fuel consumed
 - Percent idle time
 - DPF regenerations
- GPS route data logging
- Laboratory dynamometer testing

Details:

- Baltimore location
- Ten 2012 hybrid vans (2010 emissions)
- Data collection beginning in March 2013
- Engine off capability
- 90% mechanical power by 30 MPH for efficiency

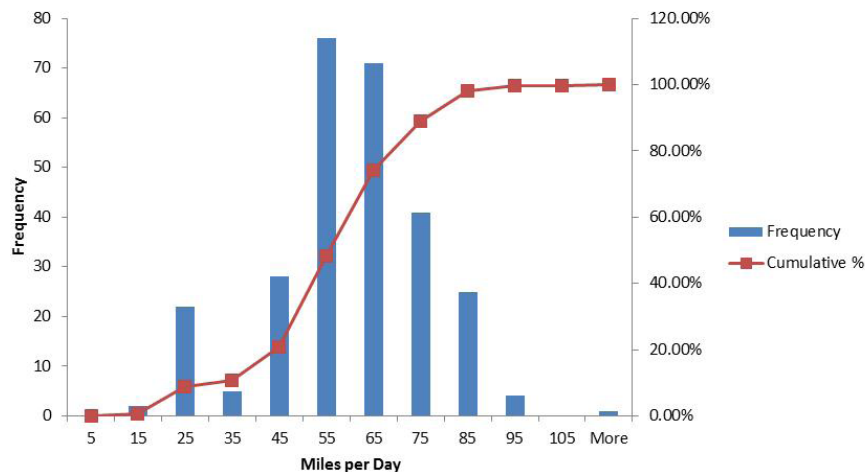


Technical Accomplishments – UPS HHV Case Study

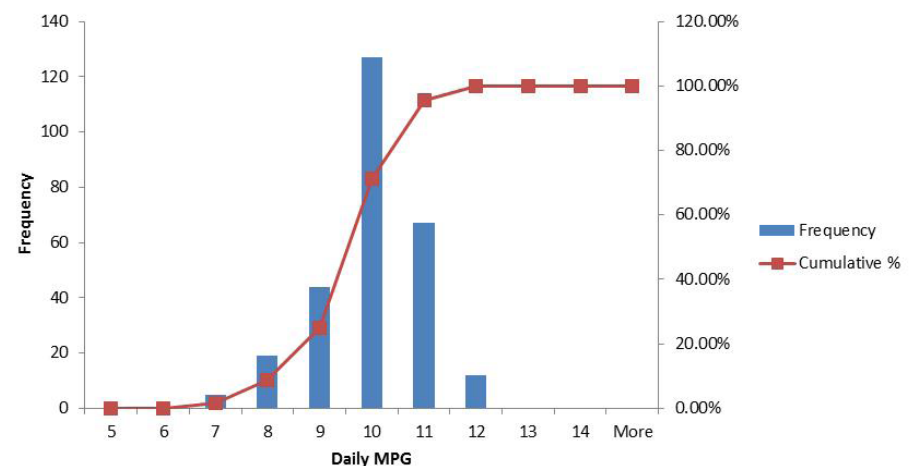
February Data for 20 Baltimore UPS HHV Vans

- Fleet drove over 15,000 miles
- Fuel economy ranged from 7.4 to 11 mpg
- Fleet average fuel economy of 9.5 mpg
- Vehicle average miles per day ranged from 22 to 81
- Fleet average of 50 miles per day

UPS HHV Miles per Day Histogram



UPS HHV Daily MPG Histogram



Technical Accomplishments – Frito Lay EV Study

Project Background & Accomplishment:

On-road evaluation of Frito Lay EV's in Seattle, WA and Phoenix, AZ. Project will utilize data collected from ARRA project on selected group of Frito Lay vehicles and compare to conventional diesel vehicles. 10 vehicles from each group will be studied. Startup experience, performance comparison, costs, facility issues, and battery degradation to be documented

Data to be collected – 12 months of operation:

- Fleet fueling records: Fuel economy and maintenance records on both sets of vehicles
- 1 hz data being collected from vehicles include:
 - Energy usage
 - Driving patterns
 - Battery data
- Route analysis and comparison
- Laboratory dynamometer testing
- Battery Degradation – on site discharge testing

Status / Details:

- Estimated completion date: April 2014
- Data collection beginning in March 2013
- Chassis dyno testing (diesel and EV) in July 2013



Frito Lay truck at charging station

Technical Accomplishments – PEV Data Collection

- ARRA funds helped deploy vehicles and EVSEs, some of which were MD/HD focused:
 - Smith Electric Vehicles - Newton
 - Navistar - eStar
 - South Coast Air Quality Management District/EPRI – Utility bucket trucks and shuttle buses
 - Cascade Sierra Solutions - sleeper cab trucks and electrified truckstops (50 sites and 5,000 trucks)
- AVTA project collecting and analyzing data to understand usage, barriers, and challenges
 - ~30 channels of 1 hz data collected and stored at NREL
 - ~30 distinct data analysis products produced as data received
 - Quarterly reports published on basic usage statistics – similar to ANL format on LD EVs

Quarterly and cumulative summary results are available at:

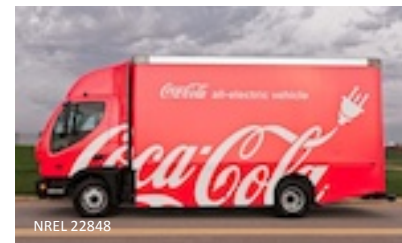
<http://www.nrel.gov/vehiclesandfuels/fleettest/>



Technical Accomplishments – Smith Newton

Smith Newton :

Collecting and analyzing vehicle operating and charging data to understand, usage, barriers, and challenges associated with fleet deployment of medium-duty electric vehicles.



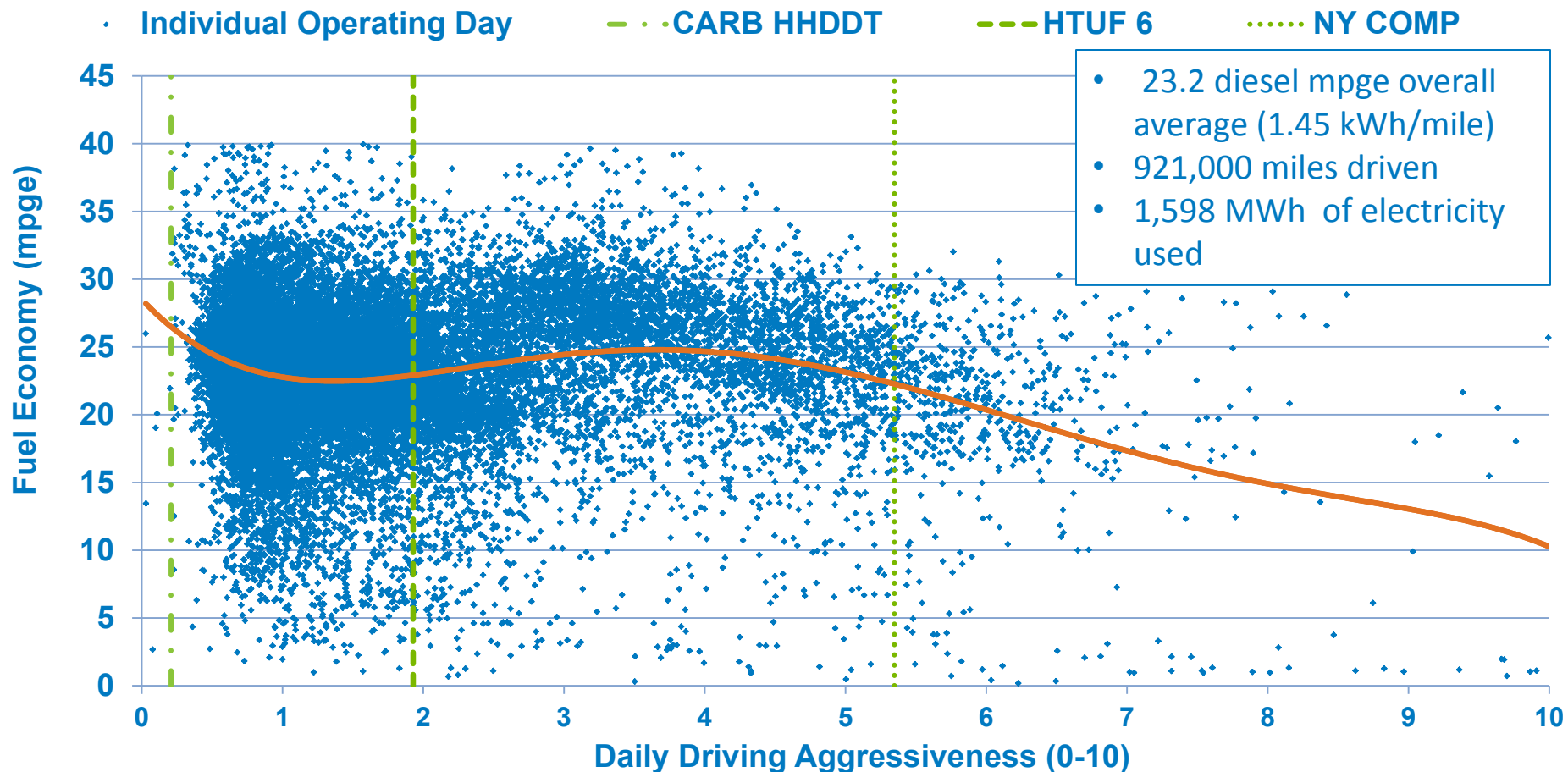
Data collected on Smith Newton vehicles via On-Board Diagnostic (OBD) and Controller Area Network (CAN) data channels. To date:

- 300+ vehicles
- 65,000+ operating days
- ~30 data channels at 1 hz frequency
 - ~5.76 billion data points or roughly 500 Gb of data
 - Vehicle operating/charging information such as driving speed, battery state of charge (SOC), operating status (on, off, charging) charge voltage/current, and battery temperature

5 Quarterly reports published to date (2011 Q4 – 2012 Q4) on basic usage statistics, with an additional cumulative report also published.

Technical Accomplishments – Smith Newton

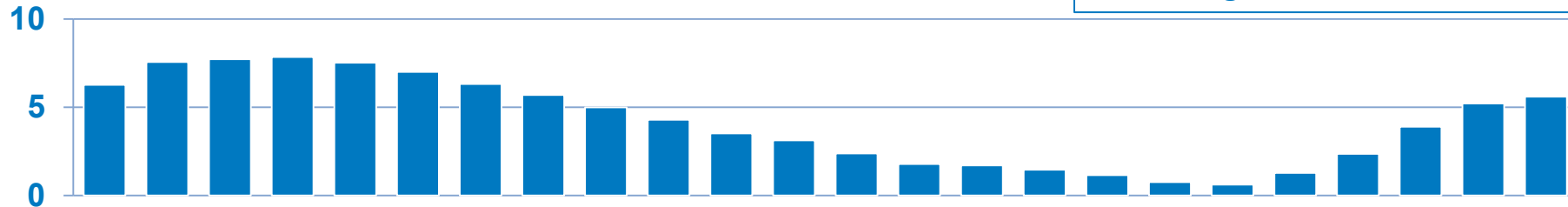
Effect of Daily Driving Aggressiveness on Fuel Economy



Technical Accomplishments – Smith Newton

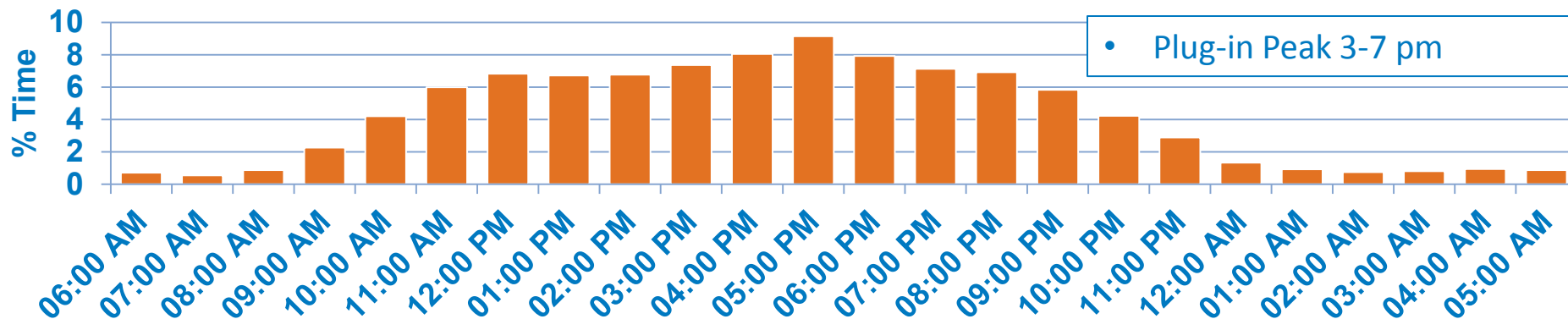
Time of Day When Driving

• Driving Peak 7 - 11 am



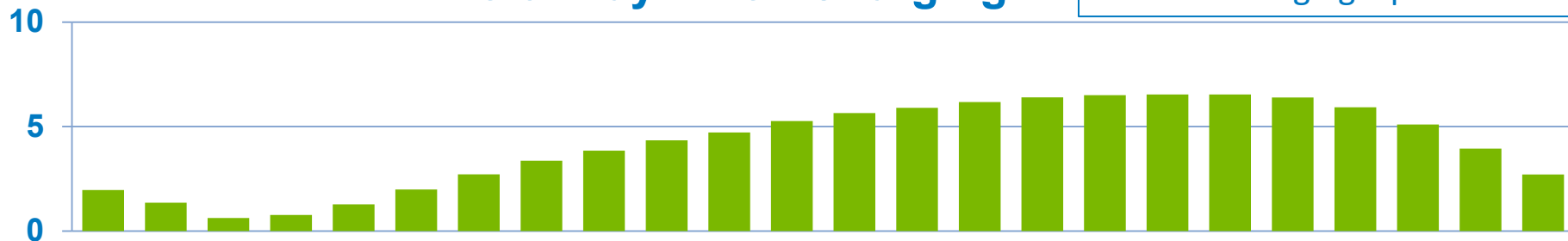
Time of Day When Plugging In

• Plug-in Peak 3-7 pm



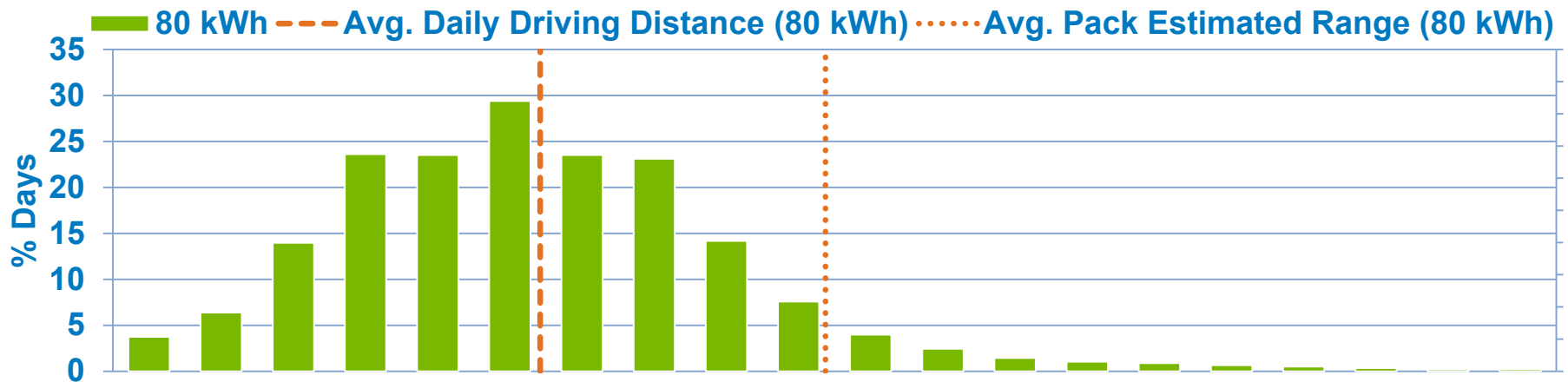
Time of Day When Charging

• Peak Charging 9 pm – 1 am

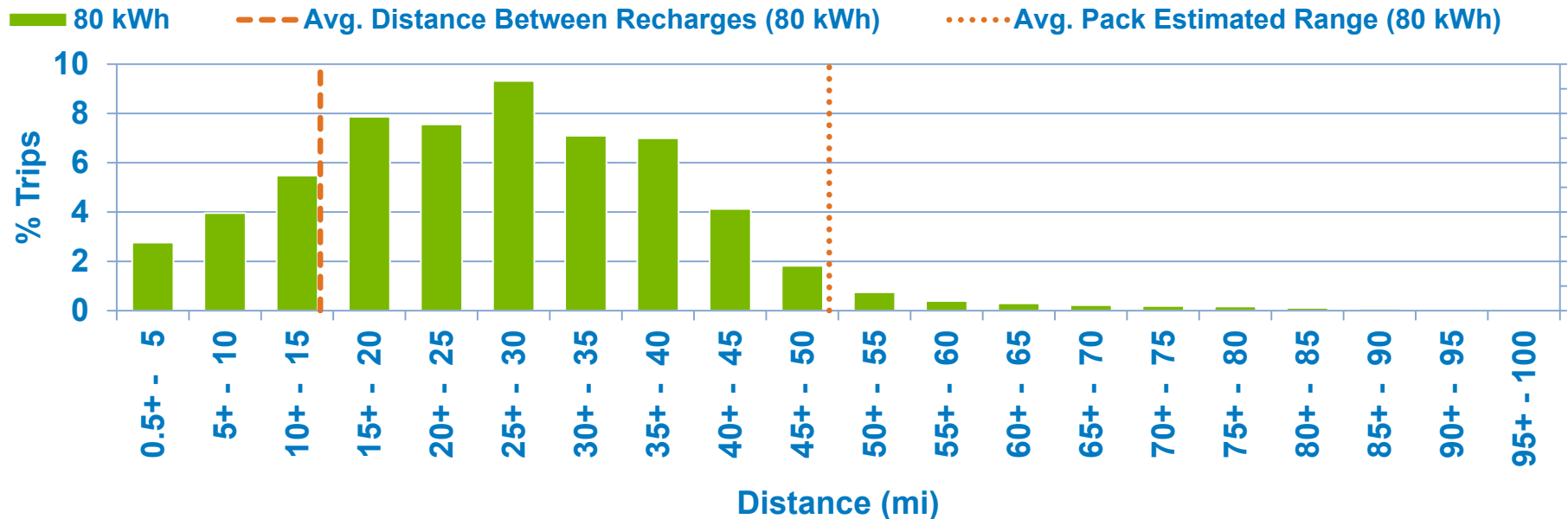


Technical Accomplishments – Smith Newton

Daily Driving Distance



Distance Between Recharges



Technical Accomplishments – Cascade Sierra

Cascade Sierra Solutions :

- Collecting and analyzing data to understand, usage, barriers, and challenges associated with truck-stop electrification.
- Data collected from sleeper cab trucks and electrified truckstops will include:
 - 50 sites (46 installed as of March 2013)
 - 5,000+ trucks with idle reduction equipment
 - 1,000+ plug-in stations at all sites
 - Usage Information (technology type, costs, vehicle make/model/year, energy consumption, and utilization frequency) is being collected now – some rebate/user information in technical backup slides
- Quarterly reports in development for publication on electrified truckstop usage statistics – similar to those developed for Smith and Navistar projects.

Proposed Future Work

- 1. In-Use Performance Evaluations:** Continued on-road, in-use performance evaluations to obtain unbiased data on fleets/vocations/technology.
 - New, evolving technology is entering the MD/HD market; finding the right applications for the technology is critical to commercial success and deployment
- 2. PEV Data Collection and Reporting:** ~500 MD EV and PHEV vehicles to be on the road starting in FY13 and continuing into FY14 - assess data and look at overall trends
 - DOE-funded technology requires unbiased 3rd party to evaluate performance and provide information on technology barriers
- 3. FleetDNA Database Development:** A vocationally based drive-cycle database to aid in the development of drive cycles, provide information to OEMs on vehicle design needs and provide information to fleets to understand usage vs other vehicles in same vocation.
 - Help define the many diverse usages in the MD and HD vehicle industry. No database exists now. Recruiting new partners for FY14
 - Use DOE developed tools and capabilities to simulate/model options based on data set collected - communicated to industry on best applications for technology in MD/HD vocations
- 4. Use Information to Develop Codes and Standards:** Use data and information obtained in field studies to help create useful and necessary codes and standards for the MD/HD industry – including test protocols and vehicle & hardware specifications

Summary

- HD field evaluations directly support the goals of EERE's VT Program by providing early evaluations of advanced powertrains to assess commercial readiness and providing these data to both government and private partners for future development consideration
- These tasks were created out of an overall industry need to understand how new fuels and technologies perform in commercial use and document the implementation and commercial issues surrounding this technology – a 3rd party, neutral analysis approach is valuable
- Fuel savings are a primary focus, but overall operating costs are of significant importance to commercial fleets, which is also a focus of the project
- Many different vocations have been analyzed under this project – results and data have been of value to industry
- Drive cycle metrics are being analyzed in more detail and compiled to ensure the right technology is deployed for the right application
- New tools and methods are being acquired/developed for researchers as well as industry as part of this project

Acknowledgements and Contacts

Thanks to:

Vehicle & Systems Simulation & Testing Activity – Lee Slezak and David Anderson
Vehicle Technologies Program - U.S. Department of Energy

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Technical Back-Up Slides

(Note: please include this “separator” slide if you are including back-up technical slides (maximum of five). These back-up technical slides will be available for your presentation and will be included in the DVD and Web PDF files released to the public.)

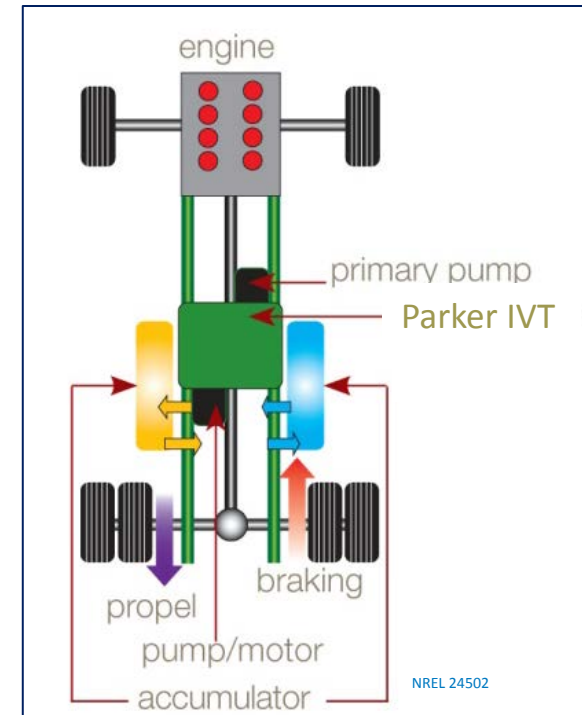
Technical Accomplishments – UPS HHV Case Study

Key Parker IVT system components:

- Primary pump
- Secondary drive pump/motors
- Accumulators
- Electronic controls
- Proprietary infinite variable transmission (IVT)
- Packaging cradle

Key Features:

- Dual Path operating system
 - “Infinite Variable Transmission”
 - Second power source of hydraulic accumulator
 - Linearly increasing mechanical power transfer and decreasing hydraulic power transfer from 0-30 MPH
 - 90% mechanical power transfer by 30 MPH for efficient high speed operation
- Brake Energy Recovery up to 70%
- Engine off capability
- Engine management is decoupled from wheels enabling sweet spot operation



Technical Accomplishments – UPS HEV Gen II

Project Background & Accomplishment:

18 Month on-road and laboratory evaluation of Eaton's latest next-generation hybrid electric system in package delivery application at UPS in Minneapolis. Final NREL/TP-5400-55658 technical report and SAE 2012-01-2049 paper published September 2012.

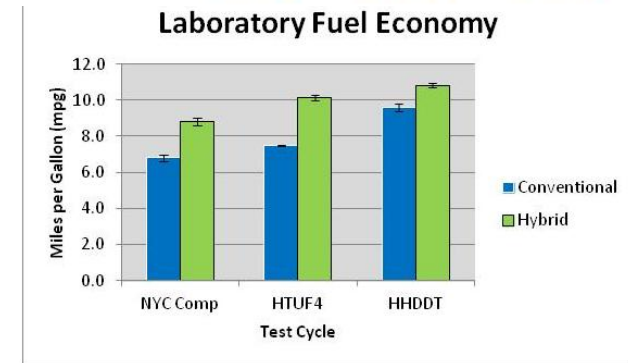
Details:

- Eleven 2010 hybrid vans (2007 emissions)
- Eleven 2010 conventional vans (2007 emissions)
- Groups switched assigned delivery routes midway through study for a better comparison

Results:

- 13% - 36% fuel economy improvement in laboratory testing dependent on test cycle
- 13% in-use fuel economy improvement on less kinetically intense longer daily miles route assignments
- 20% in-use fuel economy improvement on more kinetically intense shorter daily miles route assignments
- Higher KI route assignment had 14% lower fuel economy on conventional vans and only 9% lower mpg for hybrid vans.

Fuel Economy	NYC Comp	HTUF4	HHDDT
Conventional P100D (mpg)	6.8	7.5	9.6
Hybrid P100H (mpg)	8.8	10.1	10.8
Hybrid Advantage (%)	29%	36%	13%
T test P Value	0.0001	0.0000	0.0002



	Conventional Route 1	Conventional Route 2	Effect of Higher KI Route Assignment
Conventional Group	Aug thru Dec 2010	Aug thru Dec 2011	
Mileage	75,404	37,901	-50%
Fuel	8,233	4,822	-41%
Group MPG	9.2	7.9	-14%
MPG Vehicle Months	51	44	
Hybrid Group	Aug thru Dec 2011	Aug thru Dec 2010	
Mileage	62,991	32,149	-49%
Fuel	6,086	3,417	-44%
Group MPG	10.4	9.4	-9%
MPG Vehicle Months	46	39	
Hybrid Advantage	13%	20%	
T test P Value (cumulative mpg of individual vans in the group)	0.0015	0.1468	

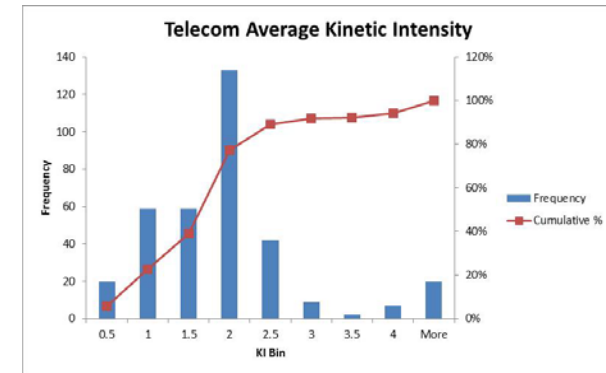
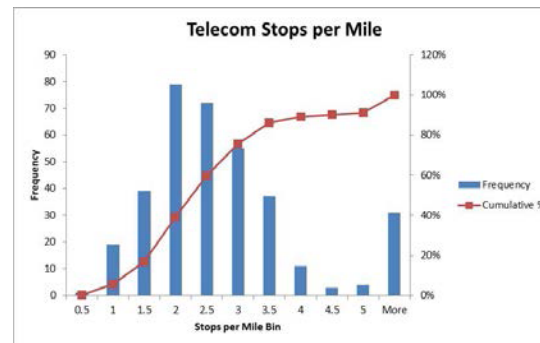
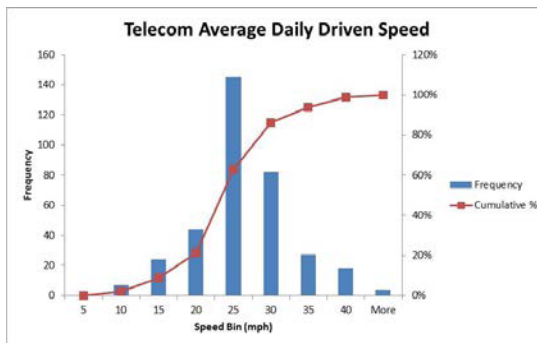
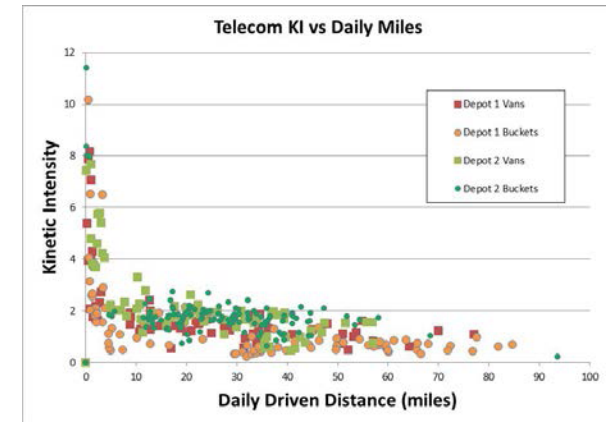
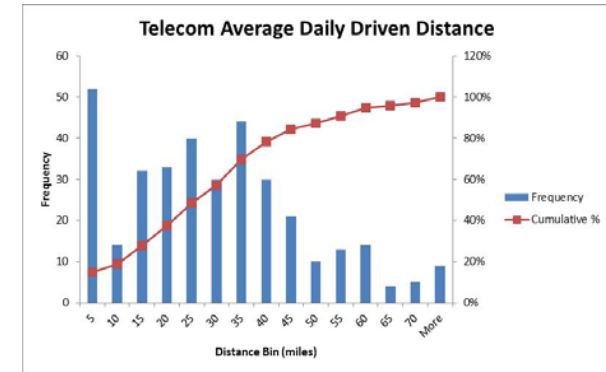
Technical Accomplishments – Telecom Fleet Study

- 2 locations studied to assess hybrid and electric drive opportunity
- NREL instrumented a total of 36 vehicles at the 2 locations for 2 to 3 weeks each and captured vehicle operation for 351 days & over 9600 miles
 - 50 days removed because vehicles didn't get up to 15mph

Location	Vehicle Group	# of Vehicles Logged	# of Op Days Logged	Miles Logged	Total Op Hours	Boom Hours Logged	GenSet Hours Logged
Depot 1	Van	9	63	1597	555		
Depot 1	Light Aerial	10	83	2660	665	25.1	20.4
Depot 1	All Depot 1	19	146	4258	1220		
Depot 2	Van	8	77	1844	856		
Depot 2	Light Aerial	9	128	3551	1124	139.6	106.5
Depot 2	All Depot 2	17	205	5396	1980		
	Total Van	17	140	3442	1411		
	Total Light Aerial	19	211	6212	1789	164.7	126.9
	Total	36	351	9653	3199	164.7	126.9

Technical Accomplishments – Telecom Fleet Study

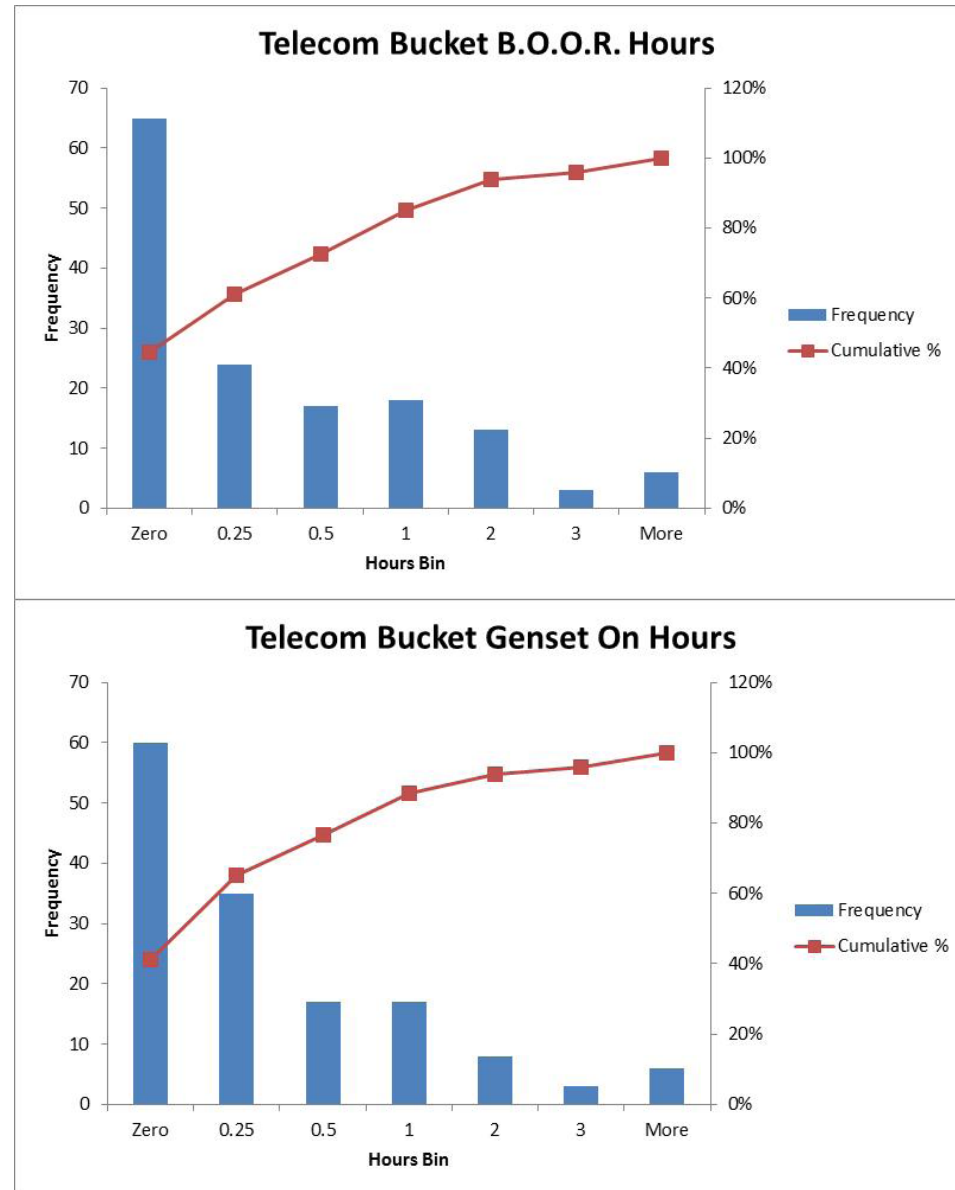
- 57% of vehicle days with fewer than 30 miles driven (201/351)
- 19% of vehicle days with fewer than 10 miles driven (66/351)
- kinetic intensity observations may be similar to package delivery and may offer HEV opportunities
- Low stops per mile as compared to average driven speed indicates longer duration stops and driving on roads with some distance between traffic lights



Technical Accomplishments – Telecom Fleet Study

Light Aerial Use

- Bucket used 55% of recorded days
- 51% of Bucket use is for less than 30 min/day
- 73% of Bucket use is for less than 1 hr/day
- 80% of generator use is for less than 1 hr/day
 - Short usage duration will have small effect on overall fuel consumption compared with driving weight of system around everywhere



Technical Accomplishments – Navistar eStar

Navistar eStar:

Collecting and analyzing vehicle operating and charging data to understand, usage, barriers, and challenges associated with fleet deployment of medium duty electric vehicles.

Data collected on Navistar eStar vehicles via On Board Diagnostic (OBD) and Controller Area Network (CAN) data channels. To date:

- 110+ vehicles
- 10,000+ operating days
- ~30 data channels at 1hz frequency
 - Vehicle operating/charging information such as driving speed, battery state of charge (SOC), operating status (on, off, charging), charge voltage/current, and battery temperature

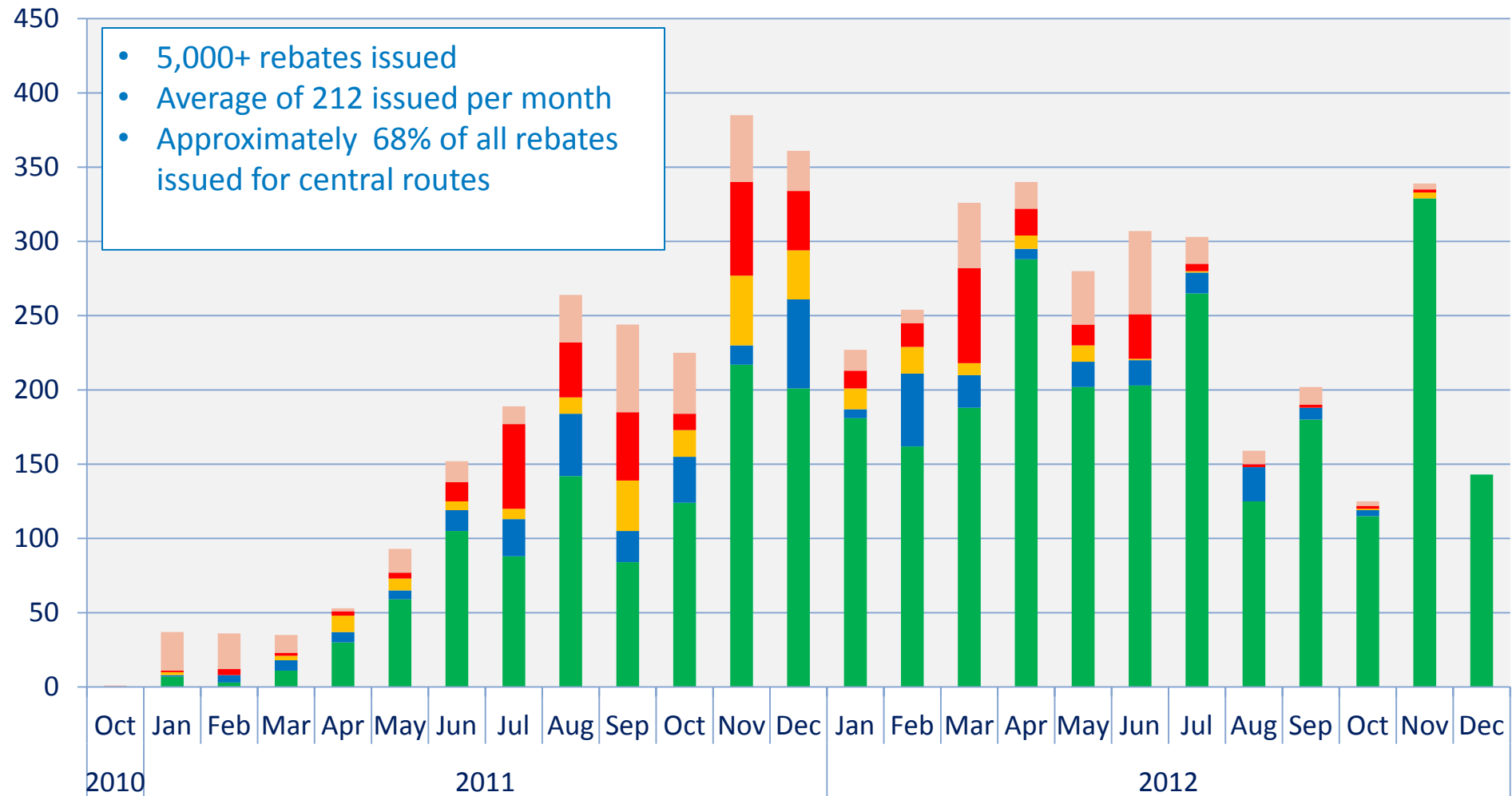


Similar to Smith, quarterly reports under development, with an additional cumulative report also scheduled for publication in May 2013

Technical Accomplishments – Cascade Sierra

Total Rebates by Truck Route

Central Routes East Coast Northern Routes Southern Routes West Coast



Technical Accomplishments – Cascade Sierra

Rebates by Technology Type

