NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Medium and Heavy-Duty Vehicle Field Evaluations






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National Renewable Energy Laboratory
2014 DOE VTO Annual Merit Review
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Project ID # VSS001

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

- **Multiple Sites**: varies by project
- **Project Length:** typically 12–18 months start to finish (including startup and report)
- **For FY15:** Some "in-process," some "new"
- **Percent Complete:** ~50%

	Q1	Q2	Q3	Q4	Notes
UPS HHV					Completed in FY15
Line-haul Platooning Phase 1					Completed in FY15
Frito-Lay EV					Planned FY15 completion
PG&E PHEV Utility Trucks					Planned FY15 completion
UPS Renewable Diesel Test					Planned FY15 completion
Miami-Dade Refuse HHV					Kicked off in FY15 – ending FY16
Foothill Transit Bus EV					Kicked off in FY15 – ending FY16
EV V2G School Bus					Kicked off in FY15 – ending FY16

Budget

- **Total Project Funding FY14 w/industry cost share: ~$700K**
  - **DOE Share: $600K in FY15**
  - Participant cost share: in-kind support (vehicle loans, technical support, data access, data supplied to NREL); varies by individual project
- **DOE Funding Received in FY14: $600K**

Barriers

- **Unbiased Data:** Commercial users and original equipment manufacturers (OEMs) need unbiased, third-party new technology evaluations for better understanding of state-of-the-art technology performance to overcome technical barriers

- **Variable Commercial 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. Past partners include:**
  New Flyer, Freightliner, Workhorse, International, Orion, Allison Transmission, Eaton, Enova, Azure, Cummins, International, FedEx, Caterpillar, Coke, NYC Transit, Verizon
- **Current partners in FY15:**
  UPS, Eaton, Peloton, Parker Hannifin, Frito-Lay, Proterra, Foothill Transit, Miami-Dade, TransPower, PG&E, Efficient Drivetrains Inc., Altec, Clean Cities/National Clean Fleet Partnership
- **Project Lead:** National Renewable Energy Laboratory (NREL)

Relevance: Providing Unbiased Data and Analysis

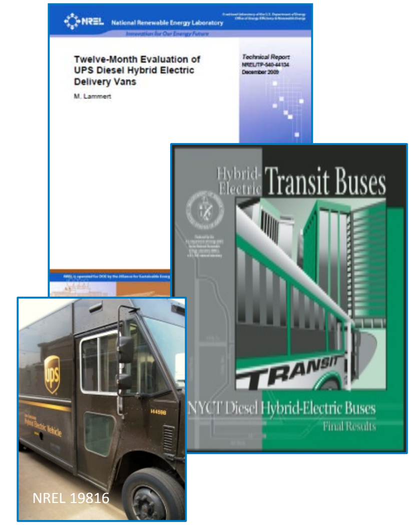
This project provides medium-duty (MD) and heavy-duty (HD) test results, aggregated data, and detailed analysis.

- **Third-party unbiased data:** Provides data that would not normally be shared by industry in an aggregated and detailed manner

- Over 5.6 million miles of advanced technology **MD and HD truck data have been collected, documented, and analyzed** on over 240 different vehicles since 2002

- **Data, Analysis, and Reports** are shared within DOE, national laboratory partners, and industry for R&D planning and strategy.

- **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



Milestones and Deliverables

Reports highlighting fleet data collection efforts and analysis of data:

Month / Year	Milestone or Go/No-Go Decision	Description	Status
FY14 Q3	Milestone	Status Report on all Projects	Complete
FY14 Q4	Milestone	Final Report & Data on all Projects	Complete
FY15 Q1	Milestone	Status Report on all Projects	Complete
FY15 Q2	Milestone	Status Report on all Projects	Complete

- **In addition to the above reports, the following published (publically available) technical project reports have been completed since 2014 AMR:**
  - **UPS Hydraulic Hybrid Technical Report – October 2014**
  - **Frito-Lay EV Implementation Report – September 2014**
  - **Peloton Truck Platooning Final Report – August 2014**
  - **Miami-Dade HHV Implementation Report – May 2015**
  - **Foothill Transit Implementation Report – June 2015**
  - **EV School Implementation Report – June 2015**
  - **Frito-Lay Final Technical Report – December 2015**

MD & HD Field Testing Approach

Evaluate the performance of alternative fuels and advanced technologies in MD and HD fleet vehicles, in partnership with commercial and government fleets and industry groups vehicles.

Collect, analyze and publicly report data:

- Drive cycle and system duty cycle analysis
- Operating cost/mile
- In-use fuel economy
- Chassis dynamometer emissions and fuel economy
- Scheduled and unscheduled maintenance
- Warranty issues
- Reliability (% availability, MBRC)
- Implementation issues/barriers
- Subsystem performance data and metrics (energy storage system, engine, after-treatment, hybrid/electric vehicle (EV) drive focus)

Data stored in FleetDNA for security and limited public accessibility

Frequent interactions and briefings with stakeholders – fleets, technology providers, researchers, and government agencies

Fleets

UPS, FedEx, Coke, Frito-Lay, Foothill Transit, PG&E, Miami-Dade, Verizon, Walmart, Waste Management

+

Vehicle & Equip Mfg's

Proterra, Navistar, Smith EV, Eaton, Allison, BAE, EDI, Altec, International, PACCAR, Oshkosh, Odyne, Parker-Hannifin, Cummins

=

Useful Data, Analysis and Published Reports

Approach: Field Data & Analysis Tools

Data from field evaluations helps populate FleetDNA database

DOE Fleet Tools (DRIVE, FASTSim, AFleet, etc.) used to analyze and investigate impacts – data used to validate and improve tools

Published information and data used by fleets, industry, DOE and other research programs, and other agencies

- **Collect Lab and Field Data**
- **Capture, Store and Analyze**
- **Explore & Optimize**
- **Communicate & Inform**
- **Identify Barriers and New R&D Opportunities, Validate Efforts**

NATIONAL Clean Fleets PARTNERSHIP
U.S. Department of Energy

21st CENTURY TRUCK PARTNERSHIP

Partnership with Fleets and Technology Providers = Relevant Results & Optimized Solutions for Real World Applications

Approach: FY15 Projects and Selection Process

Active Fleet Evaluation Projects

Frito Lay EV with facility loads and battery testing

Miami-Dade Hydraulic Hybrid Refuse Trucks

EV School Bus With Vehicle to Grid Capability

PG&E Electrified Utility Trucks

UPS-Solazyme Renewable Diesel

Battery EV Transit Bus with Fast Charging

Projects Completed in FY15

UPS Hydraulic Hybrid Package Delivery

Line-Haul Platooning

Photo credits from upper-left clockwise: NREL 28804, NREL 32783, Cosgrove- NREL, Ragatz-NREL, courtesy UPS, Eudy-NREL, courtesy UPS, NREL 31236

FY15 Technical Accomplishments covered in this presentation:

1. Miami-Data, Gen 2 Parker-Hannifin hydraulic hybrid refuse haulers
2. Update on Frito-Lay EV project progress
3. PG&E plug-in hybrid electric vehicle (PHEV) utility trucks
4. Foothills Transit – Proterra EV transit bus with Eaton 500-kW fast chargers
5. EV school bus with vehicle-to-grid (V2G) capability

Typically 3–4 projects in process at any given time with some starting and some finishing.

Project Selection Criteria

- New and emerging technology with active fleet demonstration
- Technology supports DOE program research and deployment mission and interests
- Fleet and industry partner as active participant, i.e., providing data, vehicles, technical data and information
- Fleet has adequate number of advanced vehicles, controls in similar service, and strong data collection processes.

Project Selection Process

- NREL maintains awareness of fleet and industry trends through active participation in technical community and stakeholder relationships
- NREL identifies 8–10 possible evaluation projects annually
- NREL reviews candidate project with DOE technology managers to set priorities and down select projects.

Technical Accomplishments:
Miami-Dade Hydraulic Hybrid Fleet Evaluation

NREL Lead: Bob Prohaska (PI)

Partners & Cost Share:

Miami Dade – access to hydraulic hybrid vehicles (HHVs) and baseline vehicles for instrumentation, fuel and maintenance data
Parker – data and technical information on Parker HHV system, demonstration vehicles for chassis dynamometer testing
Southeast Florida Clean Cities Coalition – coordination with the local Clean Cities partnership

Goals/Objectives

- Conduct objective, independent evaluation of hydraulic hybrid technology in refuse hauler application, including performance, fuel savings, emissions, total cost of ownership
- Contribute data to FleetDNA database and knowledge base on refuse hauler technology alternatives

Background and Value

- Miami-Dade is the 7th most populous county in the United States and the third largest municipal hybrid fleet (NYC, CA)
- Miami-Dade County currently operates 35 Autocar E3 refuse trucks with Parker Hannifin "Run Wise" Gen 1 hydraulic hybrid system and recently purchased an additional 29 Gen 2 HHVs
- Claimed 43% fuel savings needs to be evaluated by independent third party

FY15 Accomplishment Highlights

- Kick-off meeting held with Miami-Dade in January 2015
- Draft start-up fact sheet completed
- Fleet agreed to provide electronic maintenance, refueling and other operational data
- Parker NDA completed for vehicle-specific technical data
- Initial duty-cycle data collected on Gen 1 HHVs and conventional diesels: 2/25/2015 – 3/25/2015


NREL 32783


NREL 32729

FY15/FY16 Plan Forward

- Log data from 8–10 Gen 2 vehicles when deployed later this year
- Collect fuel and maintenance data from fleet – baseline, HHV-Gen 1 and Gen 2
- Calculate total cost of ownership, including reliability and maintenance on all projects
- Perform analysis to show optimal placement of new technology (i.e., route vs. benefit)
- Chassis dynamometer tests of HHV and baseline for controlled fuel economy and emissions using representative and standard drive cycles
- Final technical report FY16

Initial Duty-Cycle Data from Miami HHVs

Photo courtesy of Miami-Dade, NREL 32781

HHV Technology Basics

The Miami-Dade test vehicles are Autocar E3 refuse trucks equipped with Parker Hannifin's RunWise hydraulic hybrid drive. The HHVs are reported to recover as much as 70% of the energy typically lost during braking and reuse it to power the vehicle. The system features a two-speed hydrostatic drive combined with a mechanical direct drive, which optimizes vehicle performance at both low and high speeds.

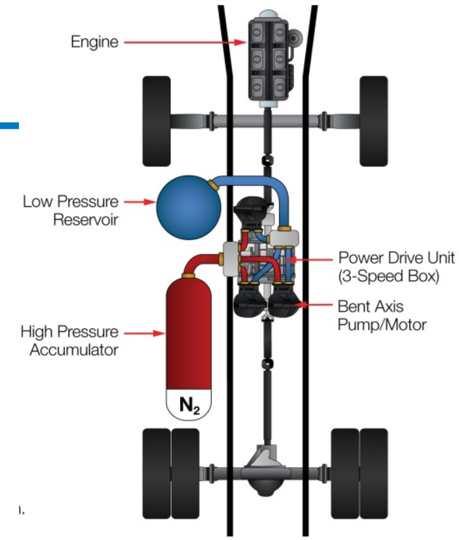
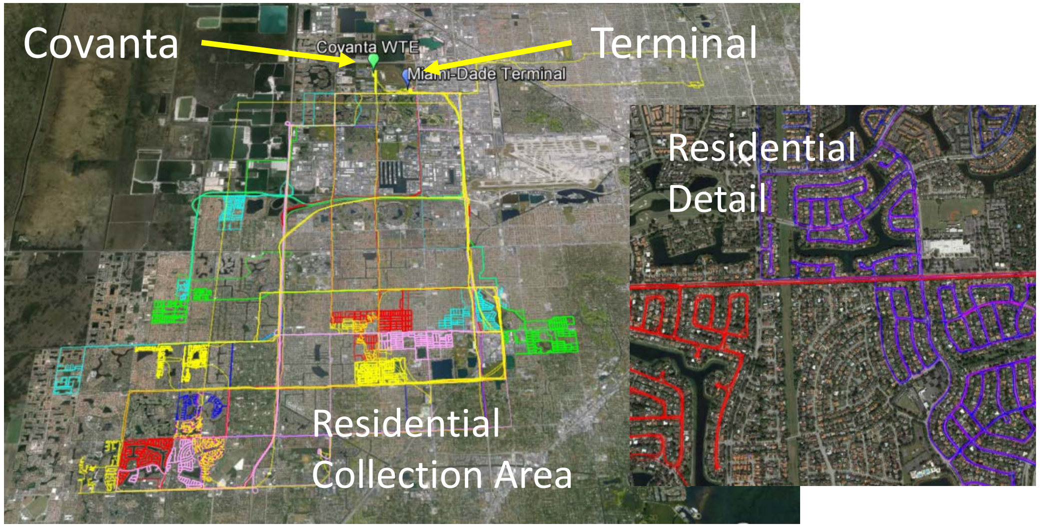


Image courtesy of Parker-Hannifin

Covanta Waste-to-Energy (WTE) plant

Refuse haulers deliver load from residential pickup to Covanta's 77-megawatt WTE plant. Traces in the above image are from actual GPS data collected by NREL.

Initial Duty cycle data



Images above show initial GPS route data collected from the Miami fleet. GPS data are used to develop duty-cycle statistics and are used in vehicle models. Data collected also include vehicle and engine operating parameters, including vehicle speed, fuel rate, engine speed/torque, NO_x sensor, etc.

Technical Accomplishments:
PG&E – PHEV Utility Truck Data Collection and Analysis

NREL Leads: Adam Ragatz & Jon Cosgrove

Partners & Cost Share:

National Clean Fleet Partnership – funding for data collection, analysis and reporting
PG&E - access to PHEV and baseline vehicles for instrumentation;
Altec – technical vehicle information/data on PHEV system
Efficient Drivetrain, Inc. (EDI) – test vehicle, engineering hours, and technical vehicle information

Goals/Objectives

- Quantify electric power take-off (ePTO) system benefits for jobsite and secondary auxiliary loads
- Collect and analyze duty-cycle information for trouble trucks and material handler vehicle use at a variety of locations through out PG&E's service area
- Contribute data to FleetDNA database and knowledge base on utility truck technology alternatives

Background and Value

- PG&E and the utility industry are interested in learning more about the fleet operations and measuring the value provided by an ePTO and Job-Site Energy Management System (JEMS)
- Altec is interested in optimizing field performance of the ePTO and JEMS systems
- Utility vocational data provided to FleetDNA

Photo by Ragatz, NREL

FY15 Accomplishments Highlights

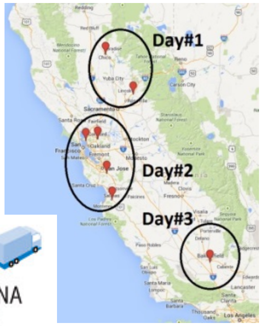
Instrumented 20 PG&E Altec utility trucks
- 10 AT JEMS "trouble trucks" (5 w ePTO/ 5 w/o)
- 10 AM "material handlers" (5 w/JEMS + 5 diesel)

11 weeks of data collection at seven PG&E sites
Collecting data on:
Drive cycle / duty cycle
J1939 CAN (including fuel use and NO_x sensor)
Battery charge/discharge power
Electric AC
Electric hydraulics
Electric auxiliaries

Tech briefings on field data provided to DOE, fleet, and vehicle manufacturer
Field data were used to develop chassis dyno test cycles

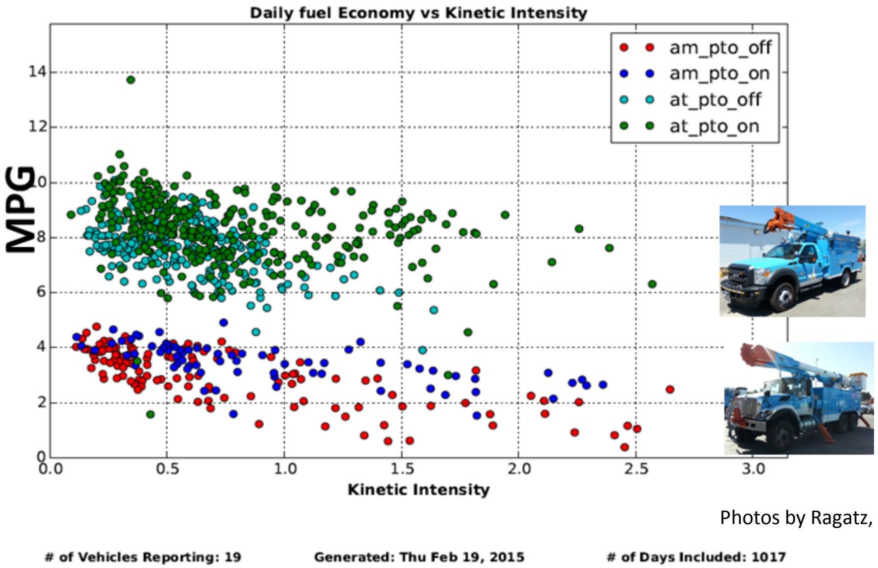
Plan Forward

- Complete analysis of jobsite operations to quantify impacts and potential of hybridization for the utility truck vocation
- Include analysis of component sizing opportunities using modeling tools in order to look for opportunities for best use cases for this technology type
- Deeper analysis of duty cycle operation to quantify loads added due to on road vs plug-in charging
- Final publication and report to interested parties, including PG&E and Altec

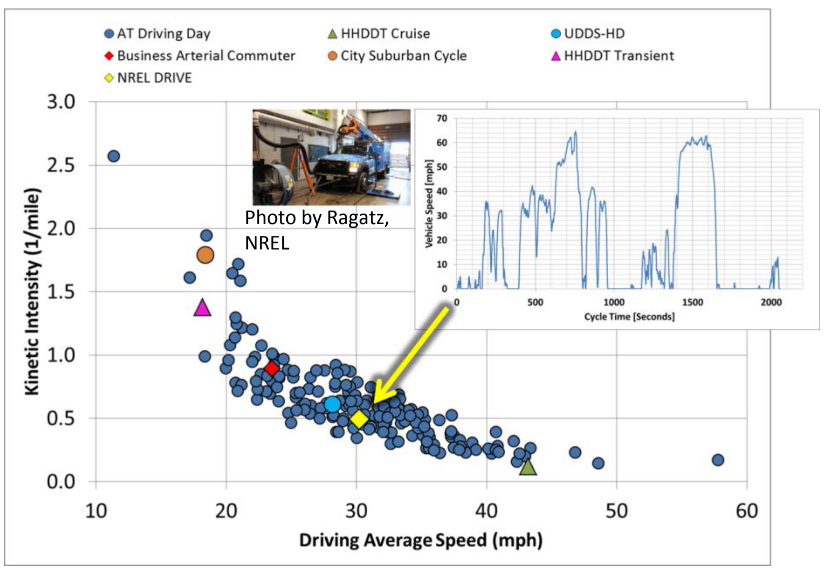


Fleet DNA Project

Preliminary Results from Field Data and Testing



Photos by Ragatz, NREL



Collaboration with PG&E and industry partners is helping develop a new generation of PHEV utility trucks with export power capability

Field Data

- Data collected from 20 PG&E vehicles were used to characterize the driving behavior and jobsite energy usage profiles including:
  - Detailed drive cycle characteristics
  - Fuel economy
  - Jobsite idle fuel consumption on conventional vehicles vs. ePTO operation

Chassis Dyno Testing of Prototype PHEV

- Duty-cycle data were analyzed using DRIVE to develop a representative chassis dynamometer drive cycle (see figure)
- Chassis dynamometer tests were performed on a PG&E prototype PHEV developed by Electric Drivetrains, Inc. (EDI) with export power capability
- Baseline conventional vehicle tests were conducted on a vehicle provided by Altec
- Results were used by PG&E to specify next generation vehicle requirements, by EDI to refine hybrid system, and by Altec to enhance understanding in-field vehicle operations

Technical Accomplishments:

Frito-Lay Medium-Duty EV Fleet Evaluation

NREL Lead: Bob Prohaska (PI)

Partners & Cost Share:

Frito-Lay – access to EV and baseline vehicles, chargers, and facility for instrumentation; fuel and maintenance data

Smith EV – technical information/data on EV system, review and feedback on data analysis

Chateau – EVSE data

Goals/Objectives

- Conduct objective, independent evaluation of MD EV technology in delivery application as compared to conventional diesels
- Understand fleet's experience with EV implementation and overall facility impacts
- Refine modeling & simulation tools using real world facility energy data to understand full potential of smart charging and the use of onsite renewables with EV implementation

Background and Value

- Frito-Lay is an active member of the National Clean Fleet Partnership currently operating 269 electric delivery trucks.
- MD EVs show considerable promise in commercial fleet applications in terms of both cost per mile and emission reduction.

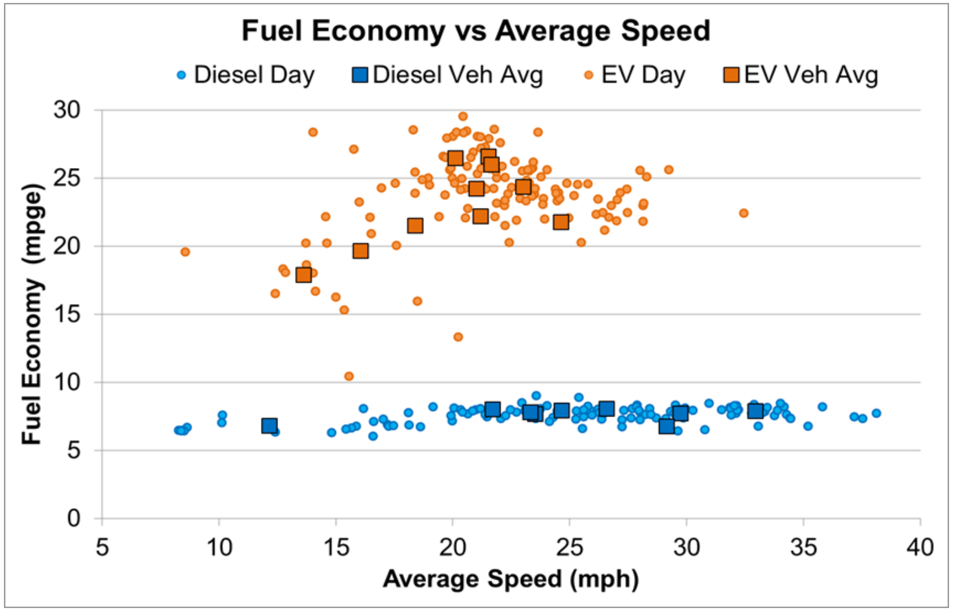
FY15 Accomplishment Highlights

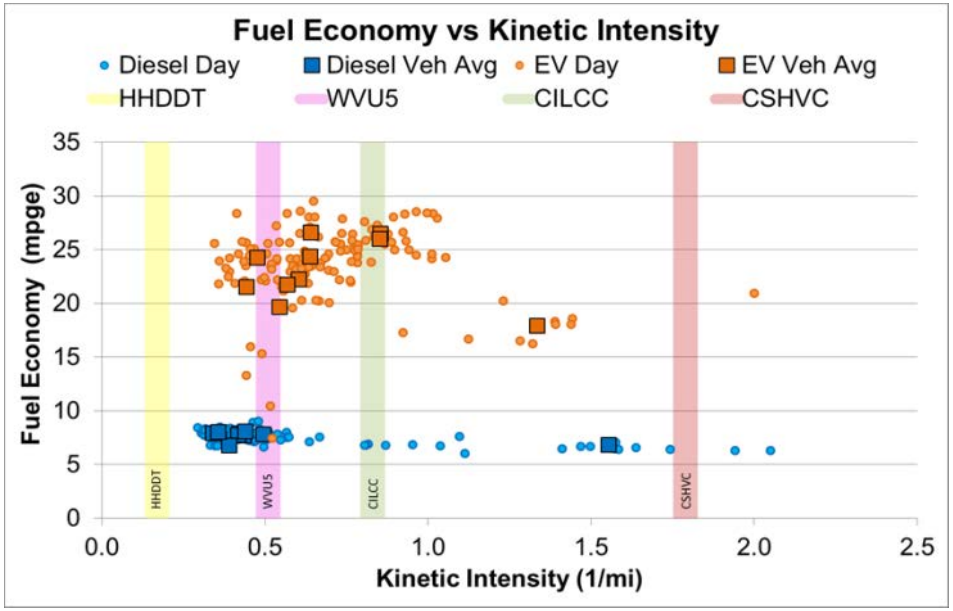
- Completed preliminary performance comparisons between EVs and conventional diesels.
- Installed main feed power meter at Frito-Lay facility with cellular data transfer
- Modified existing model of vehicle and facility electricity demand to simulate effects of vehicle charge management strategies on overall demand charges
- Conducted multiple battery degradation tests at three separate Frito-Lay locations (AZ, WA, NY)
- Conducted monthly technical briefings with Frito-Lay and Smith EV to review progress

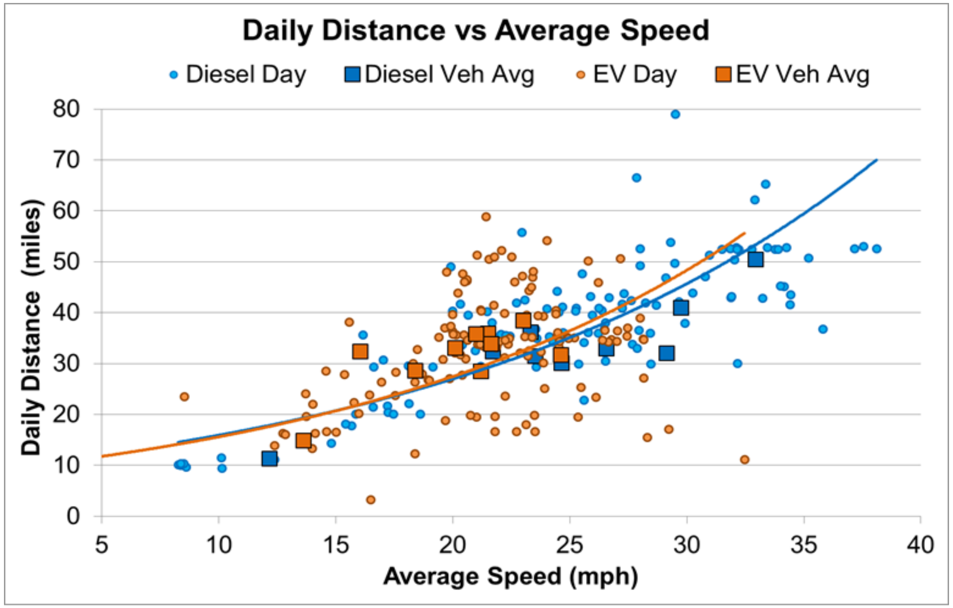
FY15/FY16 Plan Forward

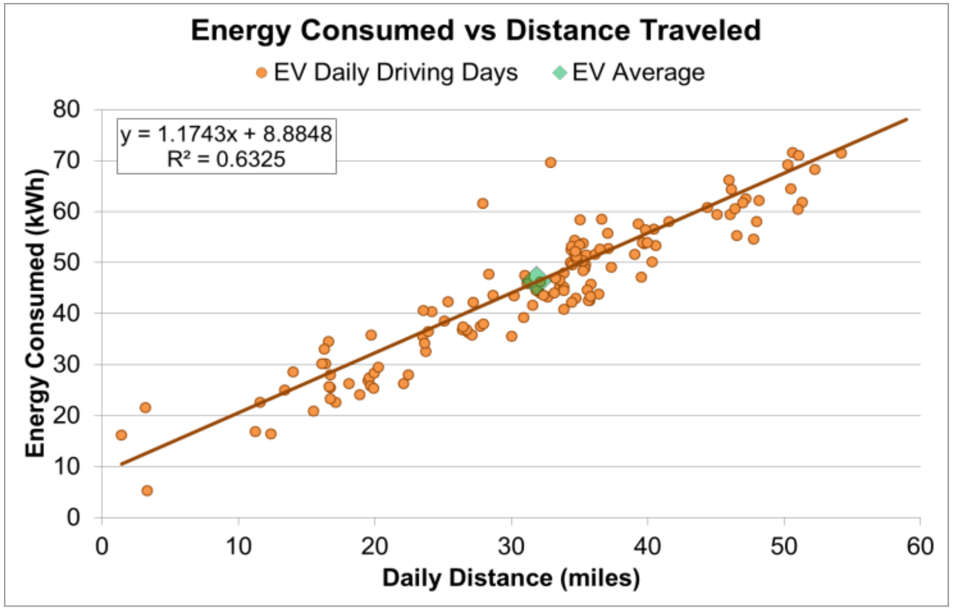
- Complete all data collection, analysis, and reporting in FY15
- Model impact of onsite integration of renewables (i.e., solar, wind) with building and vehicle electricity demands
- Investigate battery usage, sizing and performance in this delivery application.
- Final technical report expected Q4 FY15

Diesel vs. EV Metric Comparisons









Final Technology Assessment Plans – FY15 Final Report

Capture Baseline

Conventional Gasoline/Diesel Trucks
+
Daily Facility Operations

Assess PEV Impacts

Fuel Savings
+
Facility Electricity Demand Increase

Analyze Demand Management Potential

Assure Proper Charging
+
Reduce Facility Demand Charges

Develop Advanced Integration Business Case

Simulate V2G Peak Shaving
Integrate On-site Renewables
Model Battery Size/Life Impacts

Technical Accomplishments:
Foothill Transit – Proterra EV Bus Fleet Evaluation

NREL Lead: Bob Prohaska (PI)

Partners & Cost Share:

Foothill Transit – access to EV and baseline buses and fast chargers for instrumentation; fuel and maintenance data

Proterra – technical information/data on EV system; detailed telematics data on buses

California Air Resources Board – $100K funding to NREL to conduct fleet study

Goals/Objectives

- Conduct objective, independent evaluation of EV bus and 500-kW fast-charger technology in transit bus operation, including performance, fuel savings, emissions, total cost of ownership
- Provide grid integration lessons learned transit fleets and EV technical community

Background and Value

- U.S. transit authorities are beginning to incorporate all-electric transit buses into their fleets at significant numbers
- Transit duty cycles may be well-suited to or exceedingly tough on lithium-ion batteries—unique requirements of heavy duty charging infrastructure further blurs the picture
- HD EV fast charging adds significant electricity demand to transit facilities

Accomplishments

- Project kicked off in FY15
- NDA signed with Proterra to provide vehicle detailed in-use, and component data (1 Hz)
- Vehicle detailed specs provided by Proterra
- EV data protocols defined and initial data received
- Planning three one-month 1-Hz data transfers from all 15 buses from the start of deployment.

Photo by Eudy, NREL

FY15/FY16 Plan Forward

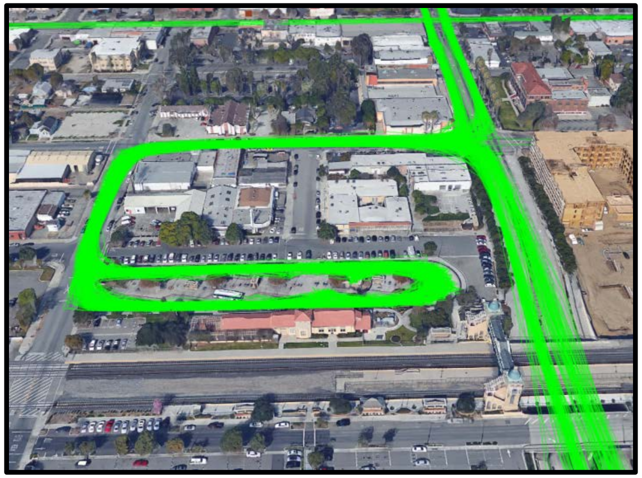
- Complete EV bus 1Hz data collection Q3 FY15
- Develop fast-charger data collection protocols and conduct Eaton 500-kW charger tests
- Develop in-use battery degradation test protocols with Proterra
- Coordinate with NREL/California Air Resources Board (CARB) project evaluation of maintenance and operations data
- Capability assessment of EV charge optimization strategies for transit fleets
- Assess opportunities for expanding EV routes
- FY16 final report documenting EV bus grid integration assessment

Initial Duty-Cycle Data from Foothill EV Buses

Photo by Eudy, NREL

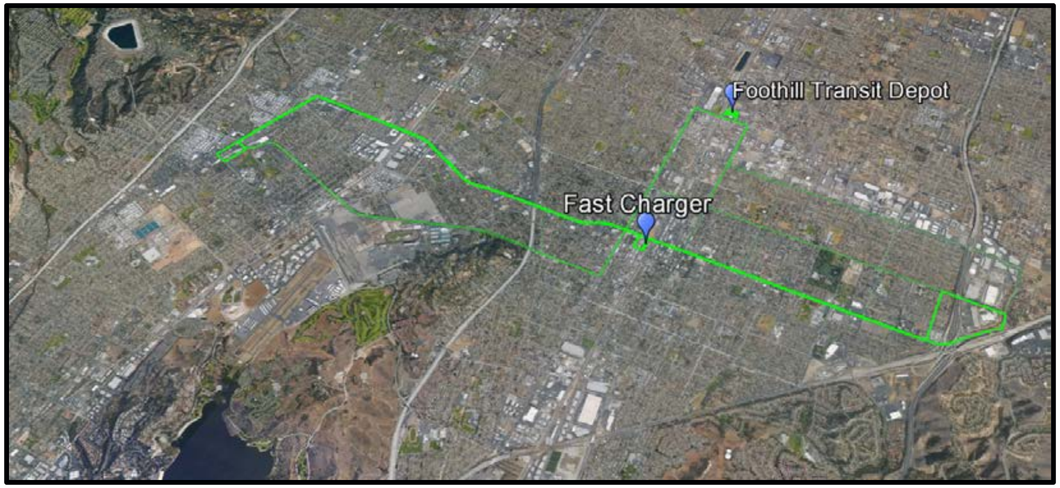
Vehicle Manufacturer	Proterra
Model	BE35
Length, ft.	35
Passenger seats	35
Manufacturer	Altairnano
Energy storage type	Lithium Titanate
Nominal pack voltage	368
Total energy, kWh	88
Motor	UQM
Peak power, kW	220

Foothill Buses at Charging Depot



The image above shows GPS traces of EV buses pulling into the charging depot near the center of the route. The depot includes two 500-kW fast chargers. Charger profile data and energy consumption metrics will be evaluated over the course of this study.

Initial EV Bus Duty-cycle Data



The Foothill Transit EV route includes two 8-mile segments with an EV charging station near the center. The green line shown above is actual GPS data from one bus. Buses typically operate continuously along this route from 5 a.m. to mid-night. The Foothill Transit depot is also shown.

Technical Accomplishments:
EV Vehicle-to-Grid (V2G) School Bus Project

Photo by Cosgrove, NREL

Lead: Mike Lammert, NREL

Cost Share:

EV V2G Partnership – $1.4M California Energy Commission (CEC) / $2.2M South Coast Air Quality Management District (SCAQMD) funding bus developments, deployment and evaluations

Clinton Global Initiative Partners – overall project management, technical review teams, and hardware providers

TransPower – EV school bus up-fits, technical information/data on EV system; 1-Hz data on EV school buses

School Districts – operating EVs at three California school districts, access to EV and baseline buses, chargers, and facilities for instrumentation / data collection

Goals/Objectives

- Demonstrate and document the total cost of ownership of all electric school buses with V2G capability
- Contribute TransPower bus conversion efforts through the duty cycle characterization of current conventional and hybrid vehicles in service

Background and Value

- Leverages investment of CGI technical and project team with funding from CEC and SCAQMD and many cost share elements
- Collaboration between Fleet Test and Vehicle Grid Integration, i.e., field data will support grid integration efforts and vice versa
- Contribute data to FleetDNA database & knowledge base on school bus duty cycles and electrification potential

FY15 Accomplishment Highlights

- Kicked-off project in Q2 FY15
- Reached agreement with Zonar Systems to provide telematics data on entire Torrance school bus fleet
- Worked with Napa Valley Unified School District to identify 10 buses as targets for data logger installation based on TransPower EV bus potential route operation
- Identified 10 additional buses as targets for data logger installation in the Kings Canyon Unified School District
- Completed initial round of vehicle instrumentation in Napa Valley Unified District.

FY15/FY16 Plan Forward

- Scheduled to transition loggers to Kings Canyon in FY15 Q3
- Data logging completed
- Data analysis used to develop School Bus drive cycle using NREL DRIVE
- Construct vehicle model using FASTSim to investigate performance potential
- Collaborate with TransPower to collect and analyze EV Bus data
- Collaboration with DOE/NREL Grid Integration team to test V2G hardware and controls
- Contribute data to FleetDNA project
- Produce technical report of project status and outcomes

Response to Previous Year Reviewers' Comments

Comment #1: This reviewer noted that the program provided valuable feedback on in-service technology use and effectiveness based on how vehicles are used. Numerous benefits are derived from these efforts including gaining an understanding of technology benefits in use, degree of fit between vehicle and application, real-world benefits in terms of fuel economy, and also identifying technical barriers such as demand charge penalties for an EV fleet. Regarding project planning, the project start/end dates were not clear. The reviewer concluded that it was hard to judge what was accomplished this year and in the past.

Response: Thank you for the positive feedback. With regards to timing of accomplishments, this is an ongoing project with multiple fleet evaluations. Each fleet study has its own planned start and end dates. The overview slide provides timelines for each fleet study. In this year's presentation, we tried to highlight only those accomplishments that were achieved since last year's AMR.

Comment #2: While most of the comments related to collaborations were positive (e.g., "the reviewer applauded the collaboration with numerous partners…"), a couple of comments encouraged expanding the collaboration and outreach "maybe seek out others who could utilize the data and be sure to make them aware of these results for a bigger impact."

Response: This is a very helpful observation. We are addressing this in several ways. First, we are working closely with the National Clean Fleet Partnership (NCFP) and 21st Century Truck Programs (21CTP) both to help identify key areas of need and to serve as forums for getting information to stakeholders. We participate in the monthly 21CTP partnership calls, work directly with NCFP fleets, and present information at their annual events. We are also working with several government organizations, such as South Coast Air Quality Management District, California Air Resources Board, and the U.S. Environmental Protection Agency (EPA), to utilize data, information, and approaches to inform their programs. We try to present results from each project at multiple technical forums—SAE, Green Truck Summit, National Association of Fleet Administrators, Electric Vehicle Symposium, and others. We also hold "one-on-one" technical briefings with project participants, fleets, technology providers, and other stakeholders.

Response to Previous Year Reviewers' Comments

Comment #3: Several reviewers' comments asked the question about how data/results were being used; also one commenter found the platooning study to be in a different category than the other fleet evaluations.

Response: The platooning study was outside the normal fleet evaluation, and so follow-on work in that area has been broken out into a stand-alone project. The previous year's platooning effort provides useful example of how data and results are being applied. The platooning test results showed significant improvements in fuel consumption, but also raised technical questions about the optimal spacing and control strategies. These results were communicated to the technology provider as constructive feedback that are being used to conduct follow-on testing and refine the technology. NREL is also collaborating with Lawrence Livermore National Laboratory (LLNL) to apply its expertise in vehicle aerodynamics modeling and wind tunnel testing.

Additionally, several large fleets have been briefed on the platooning fuel economy improvements and have indicated interest in demonstrated this technology within the real-world fleet service. Other recent examples of where data and results from this program are being used include feedback to UPS to place HHVs on routes with high kinetic intensity; data from PHEV dyno tests and duty cycles are being used by PG&E to refine specifications for next-generation vehicle procurement; and baseline school bus duty-cycle data are being shared with the EV manufacturer to inform the system design.

Collaboration and Coordination with Other Institutions

This project absolutely requires industry collaboration required for successful studies.

Past industry partners included:

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

FY14 Collaborations and Coordination with Others				
Partner	**Relationship**	**Type**	**VT Program or Outside?**	**Details**
FedEx Corporation	Fleet Eval Partner	Industry	VT Program	Provided vehicles and data
UPS	Fleet Eval Partner	Industry	VT Program	Provided vehicles and data
Eaton Corporation	OEM Support	Industry	VT Program	Provided data access and hardware to enable testing
Peloton	OEM Support	Industry	VT Program	Provided vehicles and hardware to test
Parker Hannifin	OEM Support	Industry	VT Program	Provided vehicles, data, and support for testing
Frito-Lay	Fleet Support	Industry	VT Program	Provided vehicles, data, and installed infrastructure (Servidyne/Chateau)
Momentum Dynamics	OEM Support	Industry	VT Program	Providing data and hardware to enable testing
XL Hybrids	OEM Support	Industry	VT Program	Providing data and hardware to enable testing
Smith Electric Vehicles	OEM Support	Industry	VT Program	Providing access to battery data and vehicle data
South Coast Air Quality Management District / CARB	Funding Partner	Gov't Collaboration	Outside	Providing funding for projects to supplement DOE advanced vehicle technology testing (CARB = Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project [HVIP] assessment)
Clean Cities Program	Coordination	Gov't Collaboration	VT Program	Providing funding to assess fleet-specific technology options for National Clean Fleets Partnerships (Verizon, City of Indianapolis, PG&E)
NTEA/GTA	Advisory	Industry	VT Program	Providing access and advisement on tools and protocols
Oak Ridge National Laboratory	Coordination	Gov't Collaboration	VT Program	Coordination of data analysis tools, captured data ,and development of test protocol and procedures

Collaboration and Coordination with Other Institutions

FY15 Collaborations and Coordination with Others				
Partner	**Relationship**	**Type**	**VT Program or Outside?**	**Details**
Miami-Dade County	Fleet Eval Partner	Local Gov't Fleet	VT Program	Provided vehicles and data
Proterra	OEM Support	Industry	VT Program	Provided vehicles and data
Foothill Transit	Fleet Eval Partner	Transit Operator	VT Program	Provided vehicles and data
Parker Hannifin	OEM Support	Industry	VT Program	Provided vehicles, data, and support for testing
Clinton Global Initiative – EV School Bus Consortium	Funding Partner	Industry	VT Program	Provided vehicles, data, and installed infrastructure (Servidyne/Chateau)
TransPower	OEM Support	Industry	VT Program	Providing data and hardware to enable testing
US Hybrids	OEM Support	Industry	VT Program	Providing data and hardware to enable testing
Pacific Gas and Electric (PG&E)	OEM Support	Industry	VT Program	Providing access to battery data and vehicle data
Con-Way	Fleet Partner	Industry	VT Program	Providing line-haul and regional-haul vehicle data
U.S. Environmental Protection Agency	Funding Partner	Gov't Collaboration	Outside	Providing funding to analyze vocational vehicle data for Phase II Heavy-Duty Greenhouse Gas (GHG) Regulations
California Energy Commission (CEC)	Funding Partner	Gov't Collaboration	Outside	Providing funding for fleet evaluation
Odyne	OEM Support	Industry	VT Program	Providing access to battery data and vehicle data
Altec	OEM Support	Industry	VT Program	Provided vehicles for chassis testing and field data collection
21st Century Truck Partnership	Coordination	Gov't Collaboration	VT Program	Providing funding to assess fleet-specific technology options for National Clean Fleets Partnerships (Verizon, City of Indianapolis, PG&E)
Solazyme	Fuel Provider	Industry	VT Program	Providing renewable diesel fuel for chassis testing

Remaining Challenges and Barriers

1. **Continuing need for information and analysis**
   - Fleets are faced with a long menu of alternatives, including propane, natural gas, electric, fuel cells, aerodynamics devices, low-rolling resistance tires, etc. Fleets need objective information on the performance of these technologies within the context of their operations.
2. **Availability of new technology solutions that are reliable and cost effective for fleets**
   - Fleets remain tentative in procurement based on return-on-investment projections: limited rollout of EVs, hybrid electric vehicles, and PHEVs, and fleets need suppliers that can provide reliable, long-term maintenance and support.
3. **Vehicle emissions performance requirements and changing GHG regulations may impact industry requirements and available technologies**
   - Focus on energy savings while relying on engine emissions certification may lead to in-use emissions challenges. Root-cause analysis and solutions are needed along with information on potential regulatory/process requirements
   - New EPA HD GHG rules likely to cause demand for new cost-effective energy-saving technologies and better un-biased data technology-specific fuel performance

Proposed Future Work

FY16 Proposed Work will Include:

1. Continued fleet analysis approach (3–4 new projects per year) of new emerging technologies based on highest potential for fuel reduction, need for data/information, and fleet interest. Emerging areas of interest include: MD/HD electrification, including grid integration technologies, wireless power transfer demo's, validation of cost-effective HEV up-fits; autonomous vehicle technology in commercial fleet applications; latest natural gas technologies.
2. More "cross-cutting" vocational analysis rather than a single fleet, e.g., evaluate tradeoffs such as HHV technology in package delivery vs. refuse vocations; evaluate "best" vocations/duty cycles for MD/HD EVs
3. Better "deep dive" analysis approach to address issues discovered in assessments (i.e., root cause analysis of findings)
4. Continued coordination with 21st Century Truck and Clean Cities / National Clean Fleets Partners to align data and analysis
5. Better data coordination and data sharing to enable technology development across VTO offices (e.g., field battery data to inform VTO battery research efforts in MD/HD industry needs; field demonstrations of grid/building integrated EV; HD/MD accessory load requirements)

Summary

- MD and HD testing, data collection, and analysis are helping to drive design improvements, purchase decisions, and provide field data for researchers by:
  - Making data and analysis results publically available
  - Technical briefings conducted with fleet and industry stakeholders
  - Feeding vocational database for future analysis
  - Field data from vehicles and components feeds modeling and simulation efforts

- Key technical accomplishments in FY15 include:
  - Completed UPS Hydraulic Hybrid and Line-Haul Platooning studies with technical reports, presented to stakeholder community, with specific recommendations made to fleets and technology providers (e.g., UPS, Peloton, others)
  - Completed data collection activities and preliminary analysis on Frito-Lay EV project and scheduled CY15 project completion and reporting
  - Kicked-off new fleet evaluations, including HHV refuse haulers, Foothill Transit EV buses, EV School Bus, PG&E electrified utility trucks, and UPS renewable diesel projects, leveraging substantial fleet and industry participation
  - Published and presented results at key industry forums with data provided to FleetDNA database for public access
  - Close coordination with other DOE areas, including Clean Cities/National Clean Fleet Partnership members , 21st Century Truck partnership, DOE researcher programs

Technical Back-Up Slides

Acknowledgements and Contacts

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Commercial and Public EV Applications

Opportunities and Challenges Associated with Medium- and Heavy-duty Commercial EV Applications

Photo by Ragatz, NREL

NREL 22848

Photo by Eudy, NREL

Photo courtesy TransPower

Electrified Utility Work Trucks

- Utility fleets expanding use of electrified vehicle alternatives
- Ability to provide off-board power for equipment or to power a small community
- Quiet and clean operation in neighborhoods or other noise-sensitive areas

EV and PHEV Delivery Vehicles

- Currently being demonstrated by large commercial fleets such as UPS, FedEx, Coke, Frito-Lay
- Opportunity to integrate EV with efficient fleet facilities (V2B)
- Large batteries have potential secondary-use applications

Electric Buses

- Clean and quiet operation in urban centers
- Federal funding opportunities promote clean, efficient transit solutions
- Fixed routes and centralized operations allow for innovative solutions such as fast charging, wireless charging, electrified roadways, and integration with transit facilities

Zero Emissions Cargo Transport

- Zero emission cargo transport and major ports, e.g., Port of LA / Long Beach
- Centralized operations – potential for catenary electrification
- Zero idle emissions

Sample Data Protocol

Type of Data	Frequency Recorded	Data Items
Vehicle Descriptions	Once, start of data collection	Bus OEM and model, bus size, engine, any other specification that could affect efficiency
Vehicle Operating Cycle	Once, start of data collection	General description of daily use of vehicles
Vehicle Usage in Service	At each time usage is measured	Odometer reading; hours of vehicle operation
		Daily vehicle assignment
Fuel Consumption	Each time a vehicle is fueled/charged	Amount of fuel/ charge
		Odometer reading
		Date
	Each time the fuel price changes at a given site	Price per unit
Engine Oil Consumption and Changes (baseline buses)	Each time oil is added	Amount of oil
		Odometer reading
		Date
	Each time oil is changed as recommended by the engine manufacturer	Price per quart
		Amount of oil
		Odometer reading
		Date
Maintenance	For each work order	Type of maintenance: Scheduled, Unscheduled, Configuration Change
		Labor hours
		Date of repair
		Number of days out of service
		Odometer reading
		Parts replaced
		Parts cost
		Description of reported problem
		Description of repair performed
Road Call or Road Service	For each occurrence	Same as maintenance
Vehicle Capital Costs	Start of data collection	Capital cost for test vehicles

Sample Data Protocol – EV/EVSE Data Collection

Type of Data	Frequency Recorded	Data Items
Vehicle Duty Cycle	On-board data loggers, one month of 1-Hz duty-cycle data collection	On-board data loggers capture GPS/CAN data on vehicle duty cycle (time, location, speed, temperature, acceleration, battery/motor current, voltage, state of charge [SOC], temperature)
Charging Profiles	Electric vehicle supply equipment (EVSE) power quality meters, monthly data collection – several times per year	Meters capture voltage, current, power factor, harmonic distortion at intervals as slow as one per minute (at each EVSE circuit, if possible)
Facility Electricity Demand	Building-level power quality meters, monthly data collection – several times per year to capture seasonal differences	Building meters capture voltage, current, power factor, harmonic distortion at intervals as slow as one per minute (at building level as well as a few dominant circuits such as HVAC, lighting, on-site PV, if possible)
Battery Degradation Tests	One 7-hour battery test conducted every 6 months	NREL battery capacity test (conducted by NREL)
		Odometer reading at time of test
		Battery CAN data for enabling test, ensuring safety and post-processing of Ah and kWh capacity: (1) Pack-level: SOC, T, I, V, Ahcum, contactor status, (2) Cell-level: min/max V and min/max T

EV Vehicle and Component Data – 1 Hz

Vehicle Data Parameters

Vehicle ID
Vehicle weight or mass
Payload
Door Status
Timestamp
Operation state
Shifter position
Transmission gear state (if applicable)
Accelerator position
Brake pedal on state or applied pressure
Vehicle speed
Distance driven
GPS latitude
GPS longitude
GPS elevation
Ambient temperature
Air conditioner state
Air conditioner compressor power
Heater state
Air compressor status / pressure

Component Data Parameters

Battery current
Battery voltage
Battery pack SOC
Battery pack min cell voltage
Battery pack max cell voltage
Battery pack balance mode state
AC charging current
AC charging voltage
Battery pack bulk temperature
Battery pack min cell temperature
Battery pack max cell temperature
Motor temperature
Power electronics/charger temperature
DC/DC voltage
DC/DC current
Motor speed
Motor torque
Motor power (electrical)

UPS Hydraulic Hybrid Delivery Van Study

(completed Q4 FY14)


Photo courtesy UPS

NREL Lead: Mike Lammert (PI)

Partners & Cost Share:

- UPS – access to vehicles, chassis dyno test vehicles, operational cost data, refueling records and maintenance
- Parker-Hannifin – hydraulic hybrid technical information

Goals/Objectives

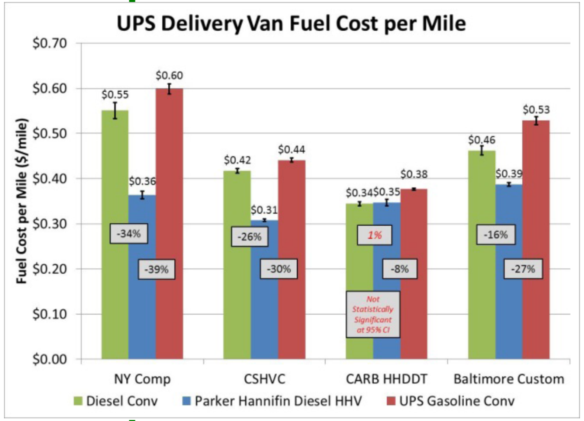
- Conduct objective, independent evaluation of hydraulic hybrid technology in package delivery application, including performance, fuel savings, emissions, total cost of ownership
- Contribute data to FleetDNA database & knowledge base on refuse hauler technology alternatives

Background and Value

- UPS is a member of the National Clean Fleet Partnership and has been active in demonstrating various advanced vehicle technologies
- UPS operating 40 Parker HHVs in Baltimore and Atlanta
- 20 HHVs in Baltimore area are currently being studied
- Being compared to gasoline conventional vehicles

FY15 Accomplishment Highlights

- Project completed in Q4 – FY14
- The hydraulic hybrid parcel delivery van demonstrated 19% – 52% better fuel economy than conventional diesel on cycles
- The hydraulic hybrid parcel delivery van demonstrated 30% – 56% better fuel economy than conventional gasoline
- Recommendations provided to UPS: Hydraulic hybrid parcel delivery vans could maximize their fuel saving potential if deployed on more kinetically intense routes
- Field data incorporated into FleetDNA
- Results published SAE COMVEC, October 2104



FY15/FY16 Plan Forward

- Project is complete with publications and data available
- Results from this study will be incorporated into a cross-cutting analysis comparing several technologies across the package delivery vocation
- This hydraulic hybrid study will be compared against the Miami-Dade refuse hauler application to see how the technology performs in different vocations

Line Haul Truck Semi-Autonomous Platooning Study (completed Q4 FY14)

NREL Lead: Mike Lammert (PI)

Partners & Cost Share:

- Peloton – vehicle platooning hardware and controls, technical data and information
- Intertek (DOE contract) – vehicle procurement and track testing
- PACCAR – test truck CAD files
- Con-Way – fleet data
- LLNL – CFD & Wind Tunnel testing (DOE funded follow-on study)

Goals/Objectives

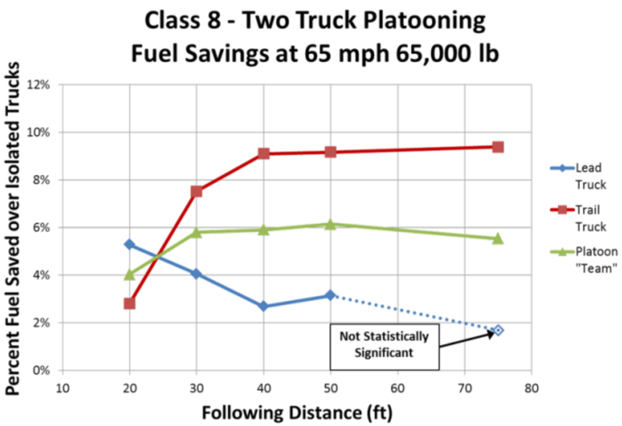
- Define fuel savings for a large fleet that adopts platooning technology
  - Geospatial analysis of current platooning opportunity
  - % of miles platooning capable for one large fleet acting independently.
- Estimate fuel savings if large national trucking fleets adopted platooning independently or cooperatively and achieved savings similar to studied fleet
- Demonstrate optimized configuration fuel savings on track and field tests

Background and Value

- Technology shows potential to reduce fuel use by 6+% (truck pair average)
  - Opportunity exist to further optimize the fuel savings
- Supports development and adoption of connected/automated vehicle (CAV) technology
- High level of interest from fleets and industry

FY15 Accomplishment Highlights

- Project completed in Q4 FY14
- Tests showed fuel savings for the lead (up to 5.3%) and trailing (up to 9.7%) trucks
- The demonstrated "team" savings of 6.4% could be an attractive return on investment for a fleet
- Remaining questions:
  - Engine coolant temperature needs to be monitored/addressed for the trailing vehicle
  - Optimum following distance may depend on ambient temperature and vehicle load (absent some aerodynamic aid for radiator air flow)
- Results published SAE COMVEC, October 2104, transferred lessons learned/recommendations to Peloton
- Follow-on study initiated with LLNL



FY15/FY16 Plan Forward

- Collaboration with LLNL computational fluid dynamics (CFD) and wind tunnel (WT) testing to answer aerodynamic questions raised during FY14 track tests.
- Geospatial analysis of in-use fleet logistics data to define "Big Picture" fuel savings potential at fleet and national levels.
- Track testing to confirm WT and CFD findings
- Fleet testing to validate savings under real world conditions.