Medium and Heavy Duty Vehicle Field Evaluations



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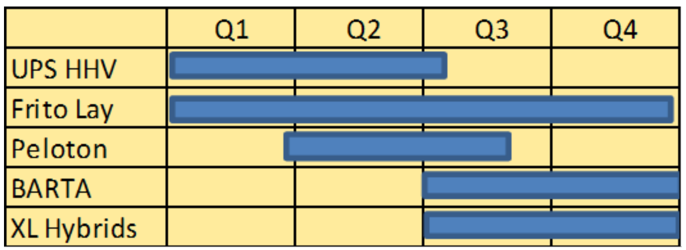
Project ID VSS001

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 FY14:** Some "in-process," some "new"
- **Percent Complete:** ~50%



Budget

- **Total Project Funding FY14 w/industry cost share: ~$700K**
    - **DOE Share: $600K in FY14**
    - Participant cost share: in-kind support (vehicle loans, technical support, data access, data supplied to NREL); varies by individual project
- **DOE Funding Received in FY13: $850K**

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 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)

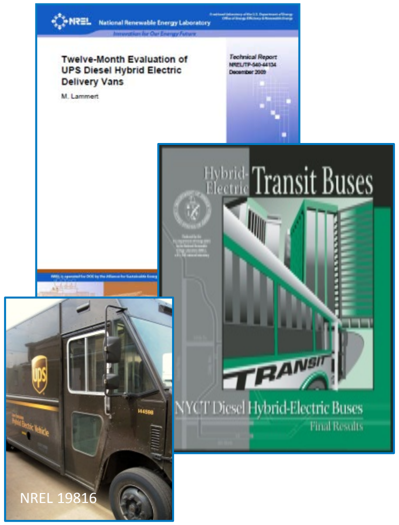
Partners

- **Industry collaboration required for successful studies. Past partners include:**
  New Flyer, Freightliner, Workhorse, International, Orion, Allison Transmission, Eaton, Enova, Azure, Cummins, International, Caterpillar, Coke, NYC Transit, Verizon
- **Current partners in FY14:**
  FedEx, UPS, Eaton, Peloton, Parker Hannifin, Frito-Lay, Momentum Dynamics, XL Hybrids
- **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.

- **3rd 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
Q1	Milestone	Status Report on all Projects	Complete
Q2	Milestone	Status Report on all Projects	Complete
Q3	Milestone	Status Report on all Projects	On-Track
Q4	Milestone	Final Report & Data on all Projects	On-Track

- **In addition to the above reports, the following published (publically available) technical project reports will be completed:**
  - **UPS Hydraulic Hybrid Technical Report – May 2014**
  - **Frito-Lay EV Implementation Report – September 2014**
  - **Peloton Truck Platooning Final Report – June 2014**
  - **BARTA Inductive Charging Startup Report – September 2014**
  - **XL Hybrid Startup Report – September 2014**

Approach: FY14 Projects

In Process Projects	Recently Started Projects
UPS HHV 	AMP / Momentum WPT 
Frito Lay EV 	XL Hybrids Class 3 Vans 
Peloton 	TBD – additional fleet/technology

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

FY14 projects to be discussed:

1. UPS Hydraulic Hybrid Delivery Vans
2. Frito-Lay Electric Vehicle (EV) and Infrastructure Case Study
3. Peloton Truck Platooning Study

<u>New projects starting in FY14 (not discussed today) include:</u>

1. Berks Area Regional Transport Authority (BARTA) evaluation of EV buses with inductive charge (WPT = wireless power transfer)
2. XL hybrid evaluation of service vans and Class 4 box trucks

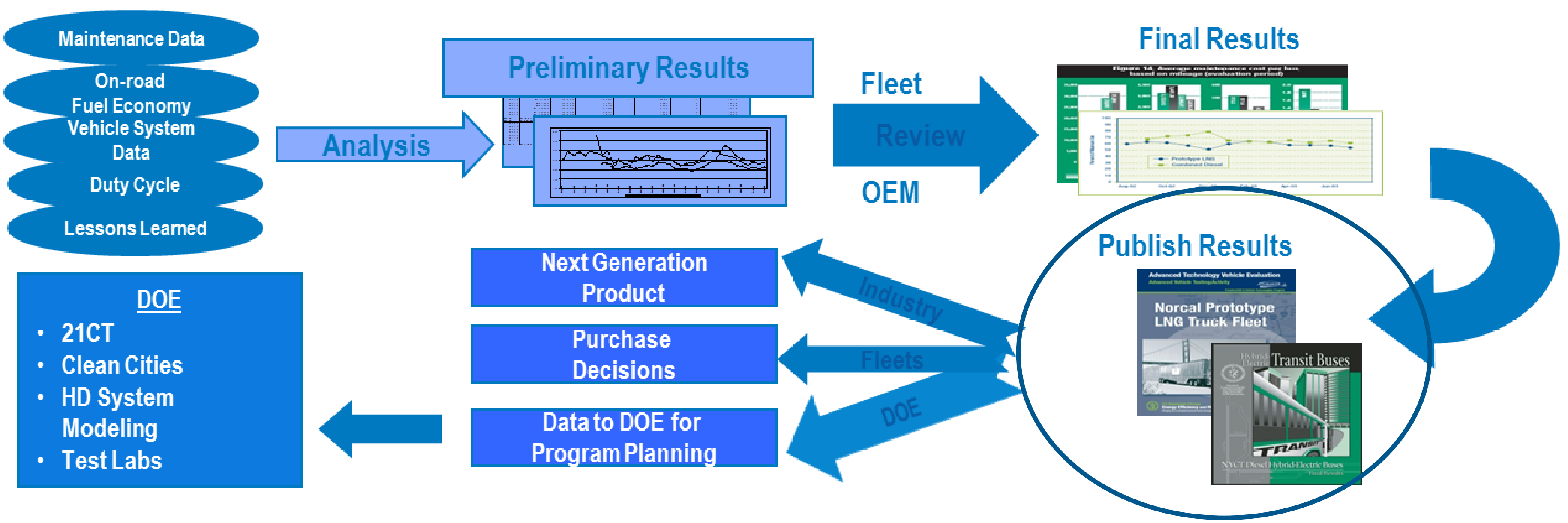
Approach – Selection and Data Flow

This project will collaborate with fleet and OEM partners to select, test, and validate advanced technologies in commercial vehicle applications.

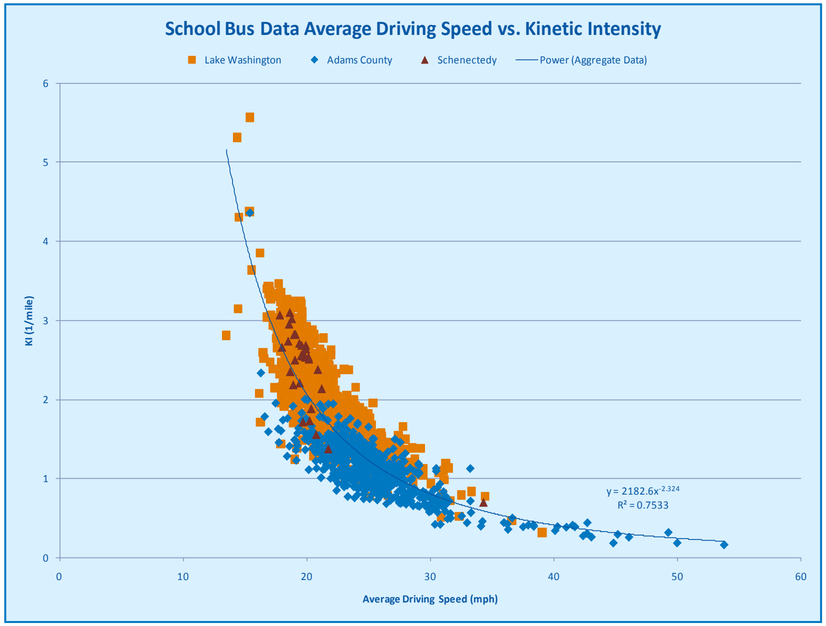
Specific technologies are selected based on:

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 DOE (including 21st Century Truck partners and other DOE program managers)

General approach:



Approach – Most Data Made Available to Public



Data from field studies from this project as well as data from other national laboratories and industry partners…

…into Fleet DNA – a vocational database developed by NREL in partnership with Oak Ridge National Laboratory to capture and analyze MD and HD data:

- Develops industry standard drive cycles
- Enhances modeling and simulation
- Helps develop codes and standards

Technical Accomplishments: Frito-Lay EV Delivery Truck Case Study

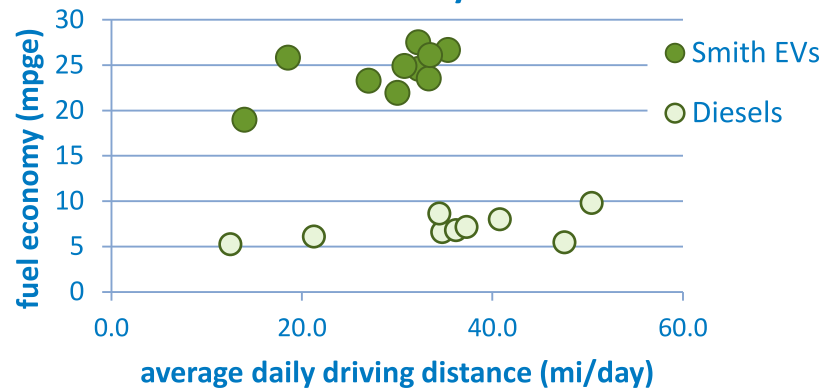
Background

- Frito Lay North America (FLNA) is planning to operate 269 all-electric delivery vehicles by the end of 2013
- Data from Smith EVs in FLNA's fleet are monitored and reported to NREL as a part of Smith's ARRA grant

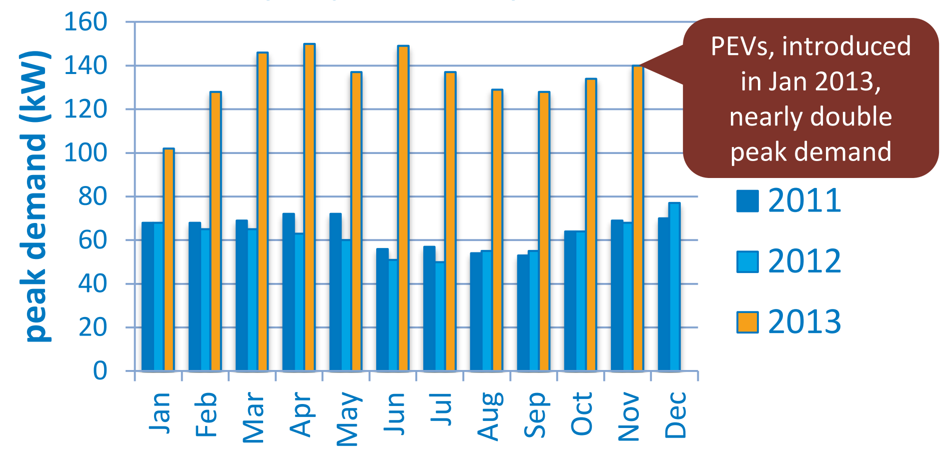
Objectives

- Quantify commercial PEV total cost of ownership
  - Analyze 10 PEVs at FLNA's Federal Way, WA depot and compare with diesels at that site
- Explore potential value of grid integration for commercial PEVs
  - Analyze various charge management schemes
  - Avoid increased site demand charges
  - Explore V2G demand reduction savings
  - Federal Way currently shows $9/kw demand charge which equates to $70/veh/month

2013 Fuel Economy Comparison: PEV v Diesel Delivery Trucks

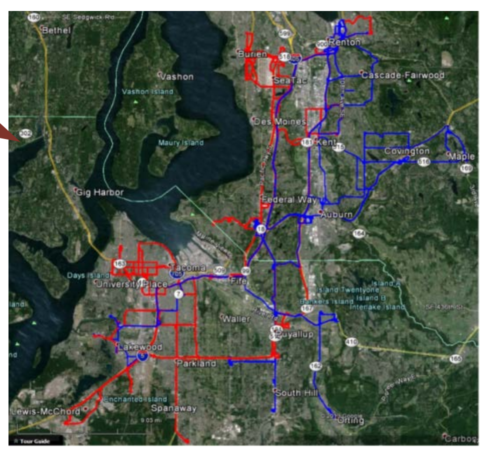


Federal Way Depot Monthly Peak Demand



Found comparable travel patterns between diesels and PEVs

NREL PIX 28804

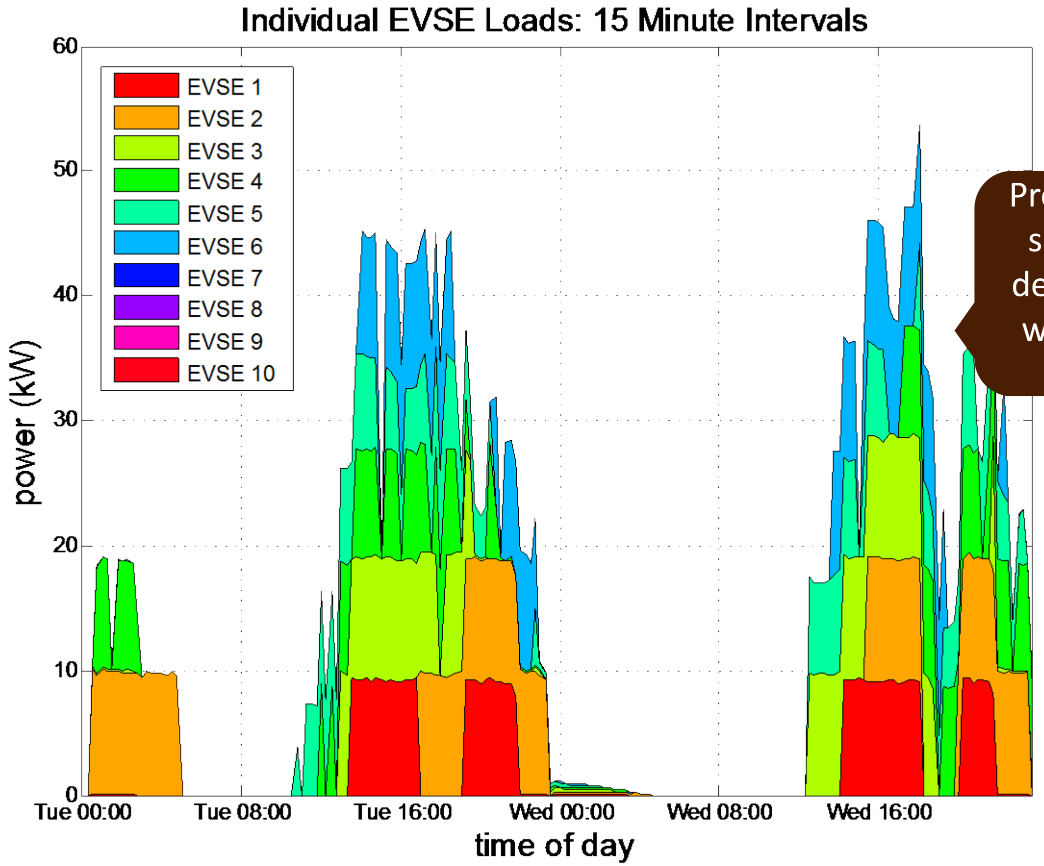


… But EVs Still Save Nearly 2/3 Fuel Costs

	Diesel	EV	
2013 Fuel Cost	$0.54	$0.17	$/mi

Technical Accomplishments: Frito-Lay EV Facility Data

- Communications process established for charging station energy system data collection
  - 15-minute interval power quality on each electric vehicle service equipment (EVSE) (voltage, current, etc.)



Preliminary results show peak EVSE demand may align with peak facility demand

Technical Accomplishments: Frito-Lay Charge Management Simulation

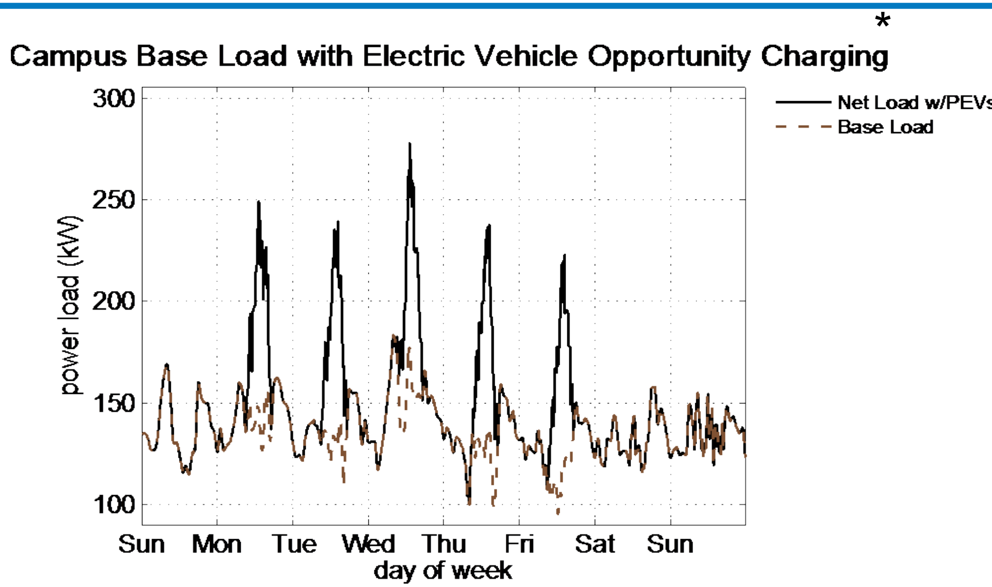
- Model modified to simulate vehicle charging power/energy requirements in conjunction with facility loads

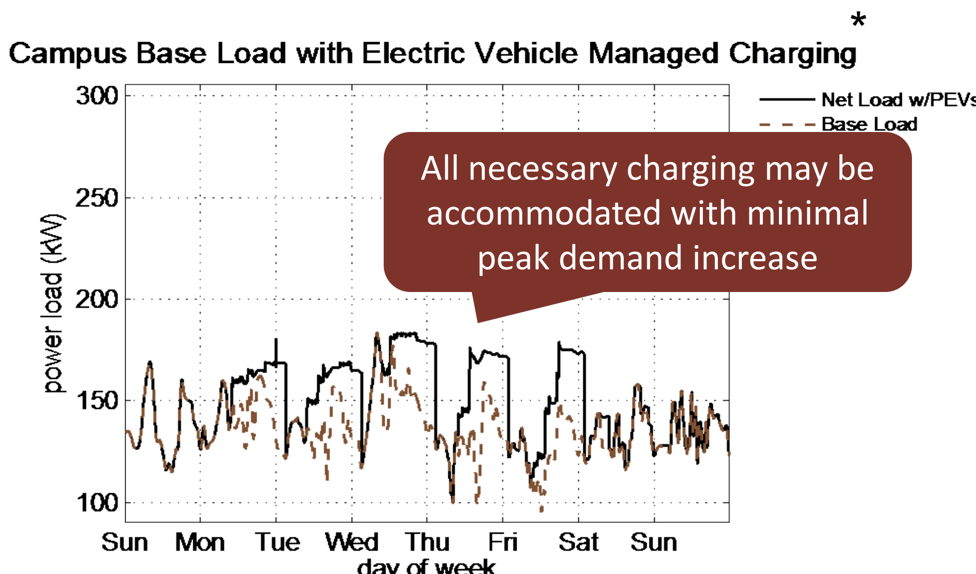
- Originally developed for Fort Carson SPIDERS microgrid V2G assessment

- Objectives:
  - Minimize peak demand (and thus cost) by smoothing added vehicle charging
  - With V2G, flatten net load as much as possible (charging in valleys and discharging to offset peaks)
  - Avoid power penalties

- Status: March–June = gathering 15-minute facility load data to combine with vehicle charging data

- September deliverable will have:
  - Optimized "smart charge" strategy
  - Optimized V2G scenario





*using interpolated preliminary data

Technical Accomplishments: Peloton Truck Platooning Testing Complete

Data collected:

- SAE Type II fuel economy track testing to quantify performance in a controlled setting
  - 55, 65, 70 MPH vehicle speeds; ten total constant-speed tests
  - One variable speed test
    - Using NREL-developed “driver aid” to guide driver for desired speed vs. current speed
    - Based on California Air Resources Board’s (CARB’s) Heavy Heavy-Duty Diesel Truck (HHDDT), the-high speed section increased 10 MPH and repeated 2.5 times
  - 20–75 ft vehicle gaps
    - 65 MPH = 95 feet per second
    - Truckers told to use 6 or 7 second rule, which equates to 570–670-foot following distance
  - 65K and 80K gross vehicle weight (GVW) loading tests
- Gravimetric fuel economy is primary data gathered, weigh tanks used
- J1939 data collection, including some Peloton channels
  - Vehicle following distance measured
  - Coolant temp and “fan on” time to assess lowered ram air cooling effects
  - Aftertreatment temps and NO_x values from J1939

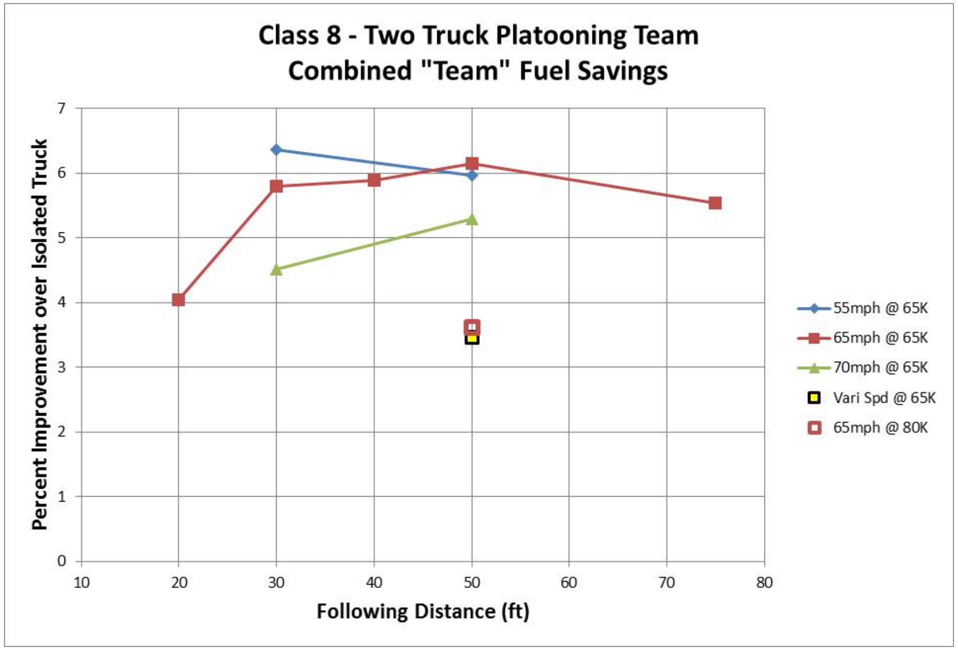
Test Vehicles:

- Two Platooned SmartWay tractors (2011 Peterbilt 386, Cummins ISX 450 hp, 10 spd, 350k miles)
- One SmartWay control tractor (Peterbilt 579)
- All tractors had 53-ft van body trailers with side skirts
- Testing took place March 17 – April 3 at Uvalde track, San Antonio, TX

	Test Conditions					
Trailing Distance	55 mph, 65K	65 mph, 65K	70 mph, 65K	Variable Speed, 65K	65 mph, 80K	Coast Down
20 ft		X				
30 ft	X	X	X			X
40 ft		X				
50 ft	X	X	X	X	X	
75 ft		X				

Technical Accomplishments: Peloton Truck Platooning Results

- "Team" fuel savings ranged from 3.5% to 6.4%
    - Best combined result was for 55 mph, 30-ft gap, 65K GVW
- Percent savings at 70 mph were lower than at 55 and 65 mph
- Higher GVW and variable speed both negatively impacted fuel saved percent
- Closer following distances caused the engine fan on the trail truck to engage, negatively impacting fuel savings

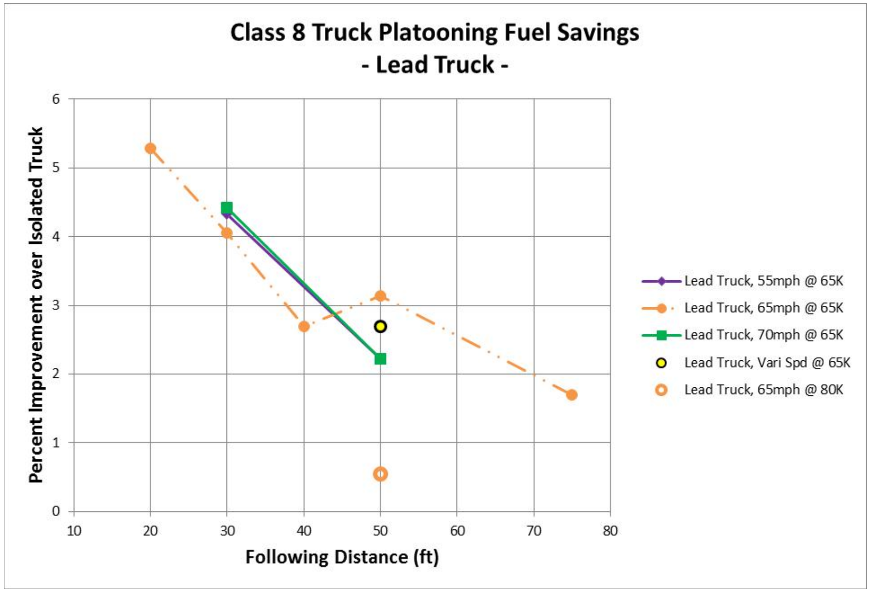


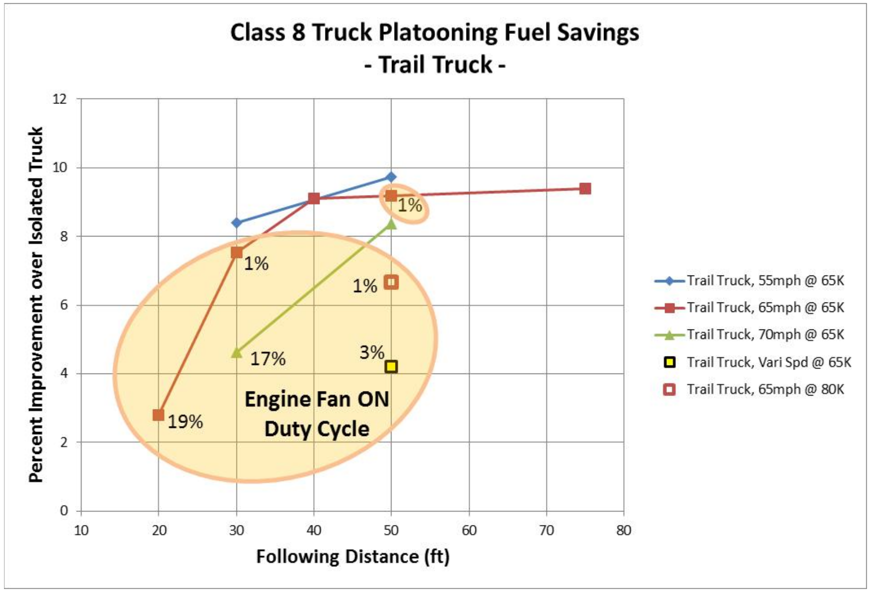
Technical Accomplishments: Peloton Truck Platooning Results

- Lead truck consistently saw the most benefit with closer following distance at all speeds
  - 1.7% to 5.3% savings @ 65K GVW
  - 0.6% savings @ 80K GVW
  - Anomaly at 65 mph, 65K GVW, 50 ft correlates with coolant temp anomaly and is being investigated with regard to ambient conditions

- Trail truck saw savings from 2.8% to 9.7%
  - Tests with no fan on time had savings of 8.4% to 9.7%
  - To maximize savings, coolant temp should be monitored to adjust following distance
    - Function of load, ambient temp, following distance

- Engine coolant temps on the trail truck generally increased as following distances decreased





Technical Accomplishments: Completed UPS Hydraulic Hybrid (HHV) Study

Background and Value

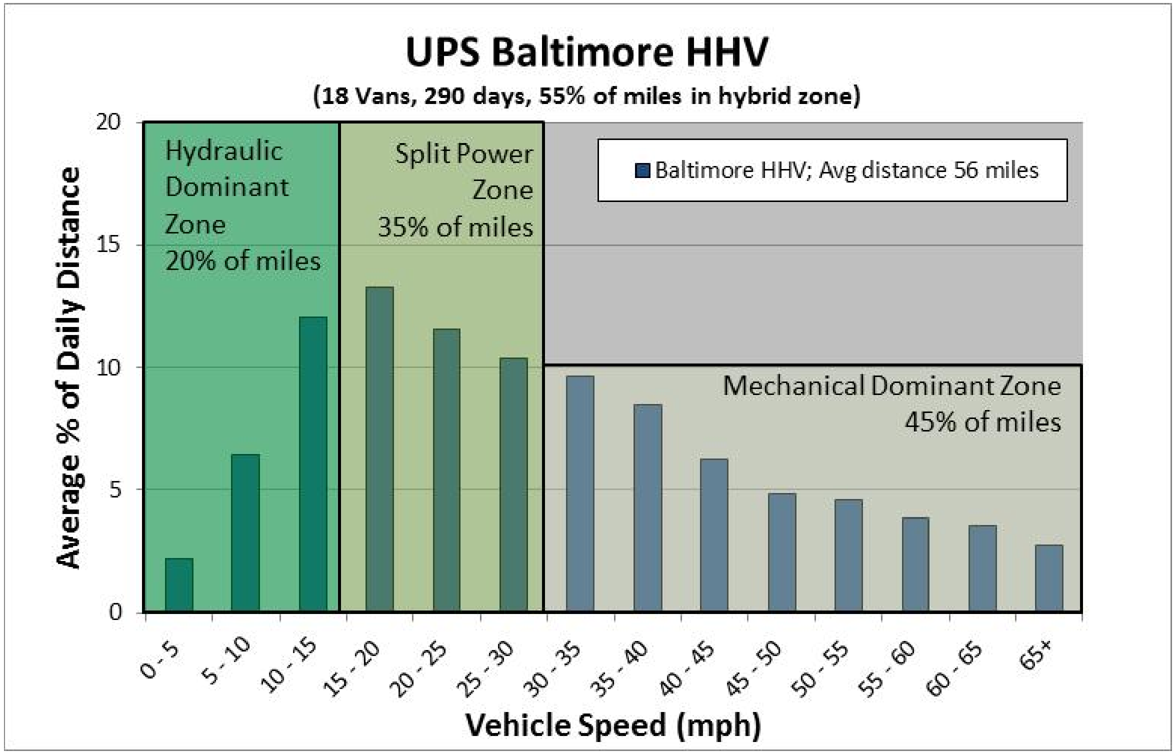
- UPS operating 40 Parker HHVs in Baltimore and Atlanta
- 20 HHVs in Baltimore area are currently being studied

Approach

1. Collect J1939 and GPS parameters for duty cycle study and in-use fuel economy (NREL datalogger)
2. Collect additional GPS and J1939 fuel rate data from Parker Hannifin telematics system
3. UPS records for reliability analysis
4. ReFUEL chassis testing fuel economy on three different vehicles (HHV, diesel, and gasoline)

Final report available in FY2014

Technical Accomplishments: UPS HHV Drive Cycle Analysis



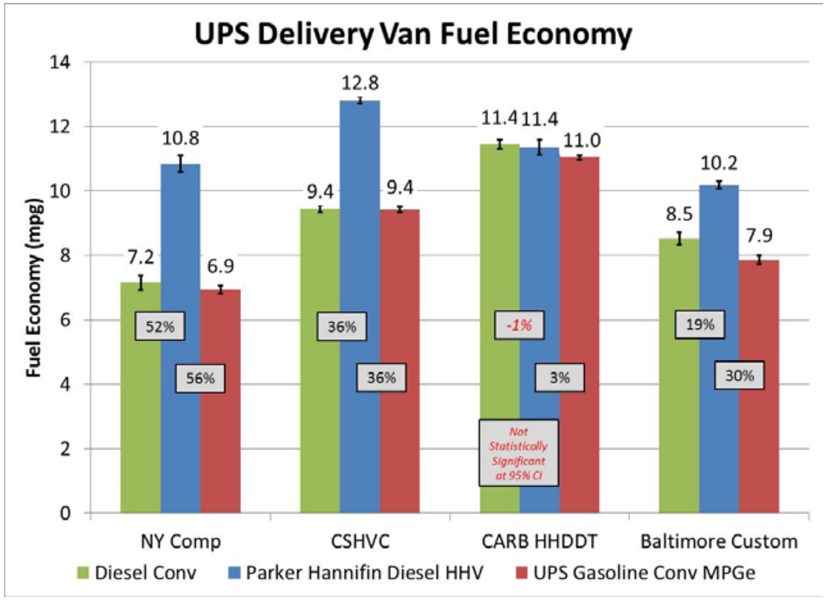
<u>6 weeks of GPS duty cycle data characterized:</u>

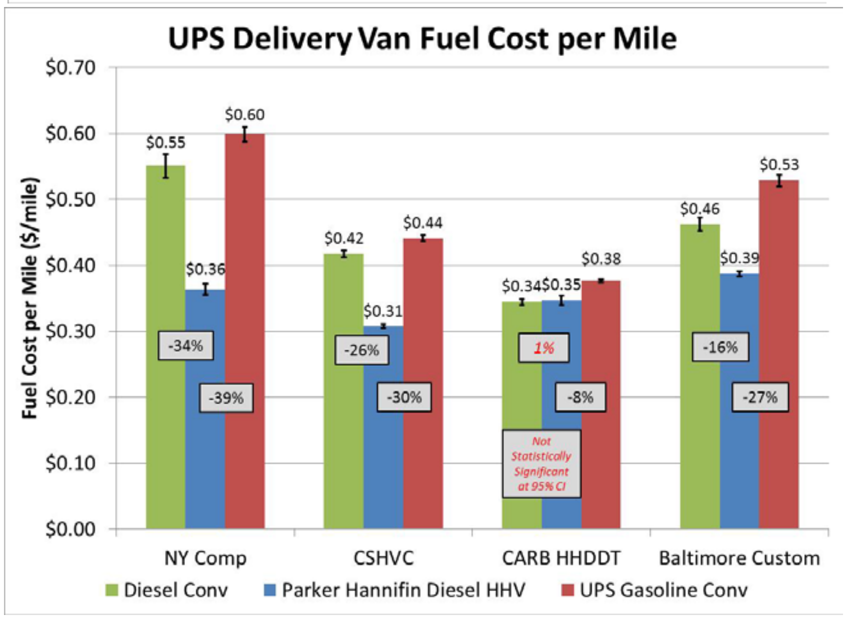
- 18 delivery vans tested
- 290 days of combined operation

- In Baltimore, the HHVs are driving only 55% of their miles at speeds where the hydraulic system can transmit more than 10% of the power – where hybrid advantage can be realized

Technical Accomplishments: UPS HHV Chassis Dynamometer Testing Results

- Three vehicles (HHV, diesel, gasoline) tested on four cycles to replicate observed in-use duty cycle
- The HHV demonstrated 19%–52% better fuel economy than conventional diesel on cycles other than the highway-oriented HHDDT (no statistically significant difference)
- The HHV demonstrated 30%–56% better fuel economy than conventional gasoline on cycles other than the highway-oriented HHDDT, on which it was 3% better.
- The HHV achieved 16%–34% lower fuel cost per mile than conventional diesel on cycles other than the highway-oriented HHDDT (no statistically significant difference)
- The HHV achieved 8%–39% lower fuel cost per mile than conventional gasoline.
  - 1-year average ultralow sulfur diesel cost of $3.94/gal
  - 1-year average regular conventional gasoline cost of $3.46/gal



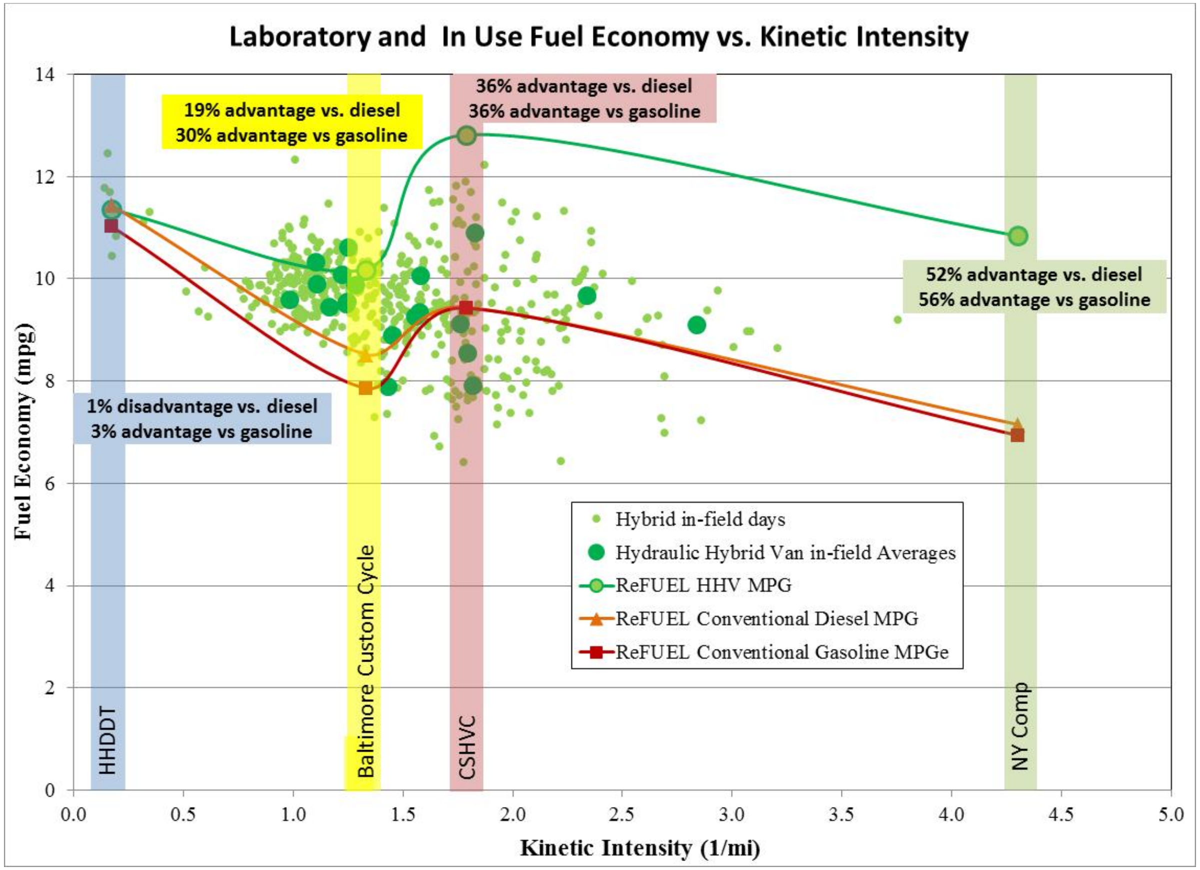


Technical Accomplishments: UPS HHV In-Field vs. Lab Fuel Economy Comparison

- NREL's custom Baltimore cycle, statistically created from pieces of collected field data using DRIVE, most accurately matched observed in-field fuel economy

- City Suburban Heavy Vehicle Cycle (CSHVC) over-predicted the fuel economy for the HHV

- Higher kinetic intensity = bigger advantage for HHV



Responses to Previous Year Reviewers' Comments

Comment #1: The reviewer noted that the project provided a pertinent variety of competing technologies and unbiased comparison of FE attributes in actual real world drive cycles. However, with respect to overall petroleum displacement, the reviewer stated that a measurement of total fuel displaced for the vehicle class, and the impact that the specific vehicle technology would project when broader adoption occurred, needed further examination.

Response: In FY14, funding was made available to purchase and analyze MD and HD market data from a 3rd party source. This data along with in-depth knowledge of the duty cycle data obtained from this work will enable the program to extrapolate nationwide, vehicle class total fuel displacement estimates. This will most likely be documented in upcoming technical reports as well as in the Fleet DNA.

Comment #2: The reviewer indicated that now with the FE or freight efficiency bar being raised at most every vehicle OEM to meet regulations, the baseline bar is also improving, but not necessarily with the adoption of revolutionary technology. The evolutionary technology needs to be assessed, such as advanced transmissions and improved brake thermal efficiency (BTE) powertrains by this project, which will be a more cost-effective market entry before the revolutionary technology is adopted. The reviewer stated that the approach was generally good but suggested improving the evaluation of baseline vehicle with a better understanding of underlying variables that affect differences found between dynamometer and in field testing. The industry needs better vehicle FE analytical prediction tools to displace costly field testing.

Response: An analytical approach to help with this is under development In FY14 using various tools at DOE's national labs. The approach includes: 1) using a methodology to obtain and analyze baseline vehicle use using the DRIVE tool, 2) running measured and estimated technology improvements over drive cycle population using FASTSim, and 3) using Argonne National Laboratory's AFLEET tool to estimate cost benefits for potential users. This approach was rolled out at an industry conference technical session in March.

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 & 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 & 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 = 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

Top 3 Remaining Challenges and Barriers

1. **Availability of New Technology in Fleets**
   - Fleets remain tentative in procurement based on ROI projections – limited rollout of EVs, hybrid electric vehicles, plug-in hybrid electric vehicles
2. **Telematics in Fleets**
   - Many fleets moving toward installation of their own monitoring. How to we compile from various sources rather than collect our own? There is still a need.
3. **Changing greenhouse gas regs and impact on hardware for fleets**
   - EPA HD rules will change how fuel economy is viewed (system vs. engine)
   - Data needed to make best decisions with new testing protocols

Proposed Future Work

FY15 Proposed Work will Include:

1. More "cross-cutting" vocational analysis rather than a single fleet
2. Better "deep dive" analysis approach to address issues discovered in assessments (i.e., root cause analysis of findings)
3. Coordination with SuperTruck and 21st Century Truck to align data and analysis
4. Continued fleet analysis approach (3–4 new projects) of various technologies based on highest potential for fuel reduction and fleet interest (using National Clean Fleets Partnership as forum)
5. Better data coordination and data sharing to enable technology development across VTO offices (i.e., battery data to promote better VTO battery research efforts in MD/HD)

Summary

- MD and HD testing, data collection, and analysis will help drive design, purchase, and research investments:
  - Making data publically available
  - Feeding vocational database for future analysis
  - Data available for more accurate modeling and simulation efforts
  - Analysis of data underway (and more available upon request)
- Unbiased approach to determine in-use duty cycle and make a valid A-B comparison (conventional vs. new technology):
  - Highlights the "multi-functional" characteristics of MD and HD vehicles
  - Provides accurate laboratory and field data to explore range of opportunities for each technology

Acknowledgements and Contacts

Thanks to:

Vehicle & Systems Simulation & Testing Activity – Lee Slezak and David Anderson
Vehicle Technologies Office – 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: Frito-Lay EV Case Study Plan

1. **Acquire data describing <u>Total Cost of Ownership from following sources:</u>**
    1. Smith and NREL on-board data loggers to compare usage
    2. Frito-Lay site-energy monitoring systems
        - Efficiency
        - Charge times
        - Duty cycles
    3. Maintenance and fueling logs (in process)
    4. Infrastructure cost estimates (in process)
    5. Battery degradation tests – see supplement
2. **Develop baseline fuel usage and drive cycle profiles** from diesel trucks to compare with EV performance (potential fuel savings)
3. **Assess potential for grid integration**
    - Simulate charge management schemes that improve business case
    - Target demand charge reduction and use of renewables

Technical Accomplishments: Frito-Lay EV Battery Degradation Testing

- Validate DOE-developed degradation / life models of today's lithium-ion technologies in MD/HD vehicle duty cycles
- Quantify impact of operating conditions on lifetime for commercial fleets
  - Drive cycle (depth of discharge, voltage, cycles, etc.)
  - Climate (temp)
- Developed load bank data acquisition experimental setup
  - Discharges battery over pre-determined profile (C/6 rate)
  - Monitors capacity, cell voltage variation, temperatures
- Initial two rounds of testing have been completed at four locations
  - Periodic tests planned every 6 months – next testing in April 2014
  - More locations being planned

Battery Degradation Load Test Setup

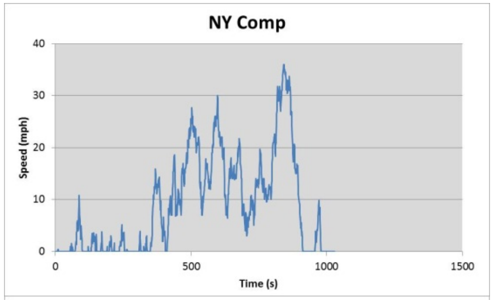
Technical Accomplishments: Background on UPS HHV Chassis Dynamometer Testing

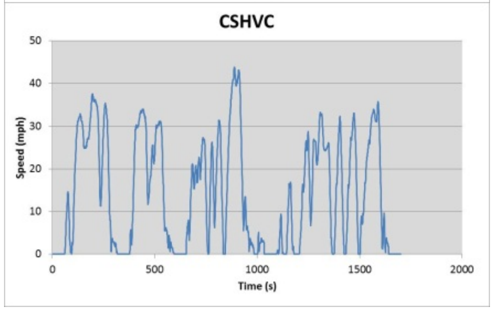
Three vehicle tests at NREL (ReFUEL)

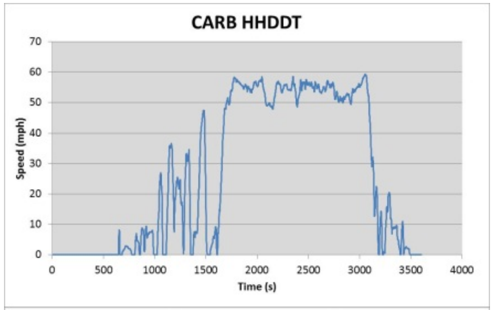
1. Parker Hannifin-owned HHV identical to UPS vehicles **(complete)**
   - 2012 diesel powered
2. 2012 UPS gasoline V8 powered P100 **(complete)**
   - UPS did not buy diesel + selective catalyst reduction - equipped delivery vans in Baltimore, opting for gasoline
3. 2012 Diesel conventional comparison **(complete)**
   - Similar vehicle from another fleet

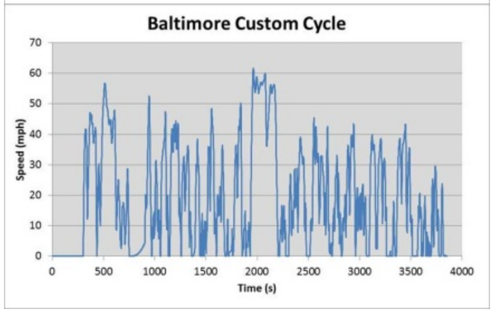
Three standard duty cycles and one representative UPS cycle generated with DRIVE tool

- NY Comp, CSHVC, and HHDDT to bracket field data
  - NY Comp and HHDDT offer direct comparison to Minneapolis study ReFUEL testing
- One custom representative cycle of "typical" observed operation created with DRIVE









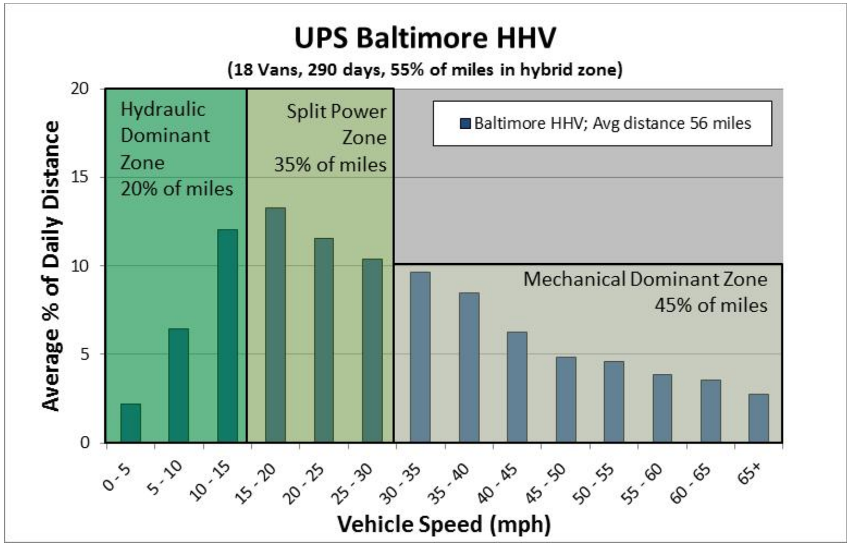
Technical Accomplishments: Additional UPS HHV Drive Cycle Analysis Information

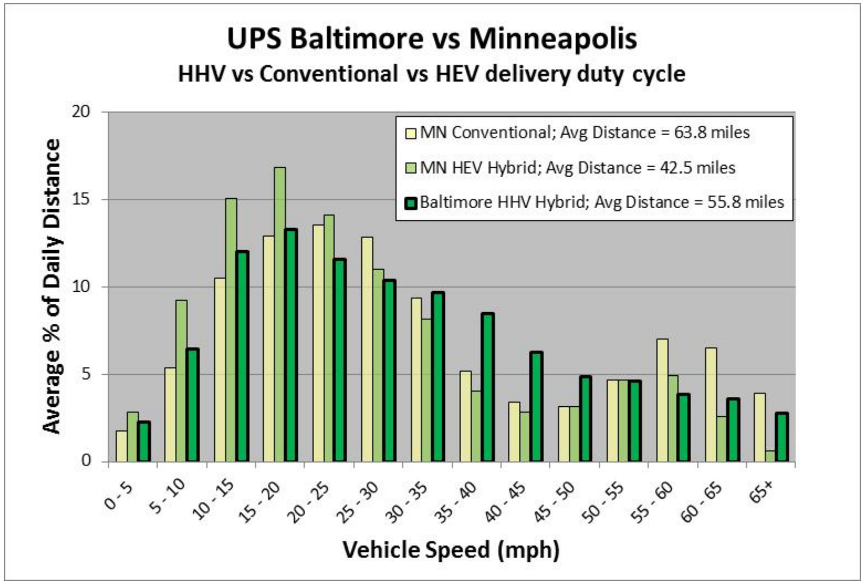
6 weeks of GPS duty cycle data analyzed:

- 18 delivery vans tested
- 290 days of combined operation

- Parker HHVs are being used on routes that are not ideal for maximizing hybrid advantage
- The HHVs are driving only 55% of their miles at speeds where the hydraulic system can transmit more than 10% of the power – where hybrid advantage can be realized
- The HHVs are being used on routes that more closely resemble the "conventional" routes in previous Minneapolis study

  ** Minneapolis UPS HEVs demonstrated only a 13% fuel economy advantage on the “conventional" routes compared to 20% advantage on "hybrid" routes





Technical Accomplishments: HHV Freight Efficiency Comparison

- Freight efficiency based on 4,000-lb cargo weight used for all vehicles
- Ton-mi/gal value based on total vehicle + cargo weight (4,000 lb)