Medium- and Heavy-Duty Vehicle Field Evaluations

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Presenter: Robert Prohaska
National Renewable Energy Laboratory

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
Overview

Timeline

- **Multiple Sites**: varies by project
- **Project Length**: typically 12–18 months start to finish (including startup and report)
- **Percent Complete**: FY16–FY18 lab-call award (60%)

### Project ID

<table>
<thead>
<tr>
<th>Project ID</th>
<th>FY17 Q1</th>
<th>FY17 Q2</th>
<th>FY17 Q3</th>
<th>FY17 Q4</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frito-Lay EV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Complete - final technical report published FY17 Q1</td>
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<tr>
<td>Miami-Dade Refuse HHV</td>
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<td>Planned FY17 completion</td>
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<tr>
<td>Foothill Transit EV</td>
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<tr>
<td>EV V2G School Bus</td>
<td></td>
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<td>Duke Energy / Odyne PHEV</td>
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<td>UPS / Workhorse extended range PHEV</td>
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<tr>
<td>Long Beach Transit EV with wireless charging</td>
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<td></td>
<td></td>
<td></td>
<td>Kicked off in FY17 - ending in FY18</td>
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</tbody>
</table>

Budget

- **DOE Share**: FY16 Lab Call $3.3M – 3 years (planned)
  - Participant cost share: in-kind support (vehicle loans, technical support, data access, data supplied to NREL); varies by individual project
- **DOE Funding Received in FY16**: $1,100K
- **DOE Funding Received in FY17**: $850K

Barriers

- **Unbiased Data**: Commercial users and original equipment manufacturers (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:**
- **Current partners in FY17:**
- **Project Lead**: National Renewable Energy Laboratory
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 **11.5 million miles** of advanced technology MD and HD truck data have been collected, documented, and analyzed on over **1,700** 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

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Relevance: Widespread Application of Data & Analysis

- Delivery Vehicle Example**

** Several other FOAs, DOE programs, and other partners are supported beyond these examples

* Baseline conventional data also included

** Project Partners**
- DOE Vehicle Technology Evaluations*
- Fleet DNA Duty Cycle Analysis
- Expanded Uses

** Federal Agencies**
- US EPA
  - HD Phase II GHG
  - MOVES Model

** Model Development and Validation**
- Representative Test Cycles

** State Agencies**
- California Air Resources Board
- Hybrid Voucher Incentive Program
- South Coast Air Quality Management District
- SCAQMD Fleet DNA Roadmap

** Expanded Uses**
- Eaton Multi-Speed EV Gearbox
- Bosch Medium-Duty Urban Range Extended Connected Powertrain
- Cummins - Electric Truck with Range Extending Engine
- Blossman Gas Propane DI Engine

** UPS**
- Frito-Lay
- FedEx
- Coke
- Aramark
- Shamrock

* Baseline conventional data also included
Milestones and Deliverables

Reports highlighting fleet data collection efforts and analysis of data:

<table>
<thead>
<tr>
<th>Month / Year</th>
<th>Milestone or Go/No-Go Decision</th>
<th>Description</th>
<th>Status</th>
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<tbody>
<tr>
<td>FY16 Q3</td>
<td>Milestone</td>
<td>Status Report on all Projects</td>
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<tr>
<td>FY16 Q4</td>
<td>Milestone</td>
<td>Annual Report on all Projects</td>
<td>Complete</td>
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<td>Milestone</td>
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</tr>
<tr>
<td>FY17 Q2</td>
<td>Milestone</td>
<td>Status Report on all Projects</td>
<td>Complete</td>
</tr>
</tbody>
</table>

In addition to the above reports, the following publications, presentations, and web-based tools have been completed since the 2016 AMR with data made available through Fleet DNA:

- “Heavy-duty Drayage Drive Cycle Clustering,” SAE COMVEC – Sep 2016
- “Evaluating Options in Today’s Market: How to Select the Best Fuels & Technology for your Fleet,” Midwest Green Fleets, Sep 2016
- “Electric Drayage Truck In-use Evaluation,” EEVC 2017 – Mar 2017
- “Bayesian Parameter Estimation for HD Vehicles,” SAE WCX – Apr 2017
- Drive Cycle Analysis Tools - www.nrel.gov/transportation/drive-cycle-tool/
**Approach: FY16/17 Projects and Selection Process**

### Project Selection Criteria
- New and emerging technology with active fleet demonstration
- Technology supports DOE program research and deployment mission & interests
- Fleet and industry partners as willing and active participants – i.e., providing data, vehicles, technical data and information
- Fleet has adequate number of advanced vehicles, controls in similar service, and robust 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

### FY17 Technical Accomplishments highlighted in this presentation include:
1. Miami-Dade, Gen 2 Parker-Hannifin hydraulic hybrid refuse haulers
2. Foothill Transit – Proterra EV transit bus with Eaton 500-kW fast-chargers

Short summaries on the status of the other active projects are also provided.
Approach: NREL Field Data, Testing, & Analysis Tools

Data from Field Evaluations helps populate Fleet DNA 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

Laboratory Testing

Explore & Optimize

Communicate & Inform

Identify Barriers, New R&D Opportunities, Validate Efforts

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

Photos by NREL Staff
Background / Relevance
• Miami-Dade is the 7th most populous county in the United States and 3rd largest municipal hybrid fleet
• Miami-Dade County currently operates 35 Autocar E3 refuse trucks with Parker Hannifin’s “Run Wise” Gen 1 hydraulic hybrid system and recently purchased an additional 29 Gen 2 HHVs
• Claimed 43% fuel savings needs to be independently evaluated

FY17 Accomplishments
• Completed all on-board vehicle data collection, analysis of duty cycles, and on-road fuel efficiency
• Developed representative drive cycles from field data
• Completed chassis dynamometer testing of HHV and baseline

Future Plans
• Complete analysis of field data and dynamometer results analysis in FY17
• Collect “end point” maintenance repair data from Miami-Dade fleet
• Calculate total cost of operation including reliability and maintenance considerations
• Complete all analysis and publish Final Technical Report FY17

Any proposed future work is subject to change based on funding levels.
Miami-Dade Field Results

- HHVs demonstrate 52% improvement in fuel economy \([1.55 \rightarrow 2.36 \text{ mpg}]\)
- HHVs accelerate quicker than conventional vehicles, leading to an increase in productivity
Miami-Dade Field Results

- Fueling maps differ between conventional and hybrid vehicles
Miami-Dade Field Results

• Each point represents an acceleration or deceleration event

![Diagram showing MY15 Diesel HHV Accumulator Pressure vs Acceleration Rate]

- Accumulator recharging during deceleration
- Engine recharging accumulator during acceleration
- Higher initial accumulator pressures result in use of more friction braking
- Higher accumulator pressures associated with greater acceleration rate
Miami-Dade Dyno Testing Results

• MY15 HHV compared to conventional MY15 Cummins ISX12

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>MY15 HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Fuel Type</td>
<td>Diesel</td>
<td>Diesel</td>
</tr>
<tr>
<td>Hybrid System</td>
<td>N/A</td>
<td>Parker RunWise</td>
</tr>
<tr>
<td>Engine</td>
<td>MY15 Cummins ISX12</td>
<td>MY12 Cummins ISL9</td>
</tr>
<tr>
<td>Engine Displacement</td>
<td>11.9 L</td>
<td>8.9 L</td>
</tr>
<tr>
<td>EPA Cert. Family</td>
<td>0.20 g/hp-hr</td>
<td>0.33 g/hp-hr</td>
</tr>
<tr>
<td>Emissions Limit (FEL)</td>
<td>350 hp</td>
<td>380 hp</td>
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<tr>
<td>Horsepower Rating</td>
<td>Allison 4500 RDS</td>
<td>Parker RunWise</td>
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<tr>
<td>Transmission Fwd.</td>
<td>6 with 2 Overdrive</td>
<td>2 Hydrostatic, 1 Mechanical</td>
</tr>
<tr>
<td>Gears</td>
<td>4.56:1</td>
<td>4.33:1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Diesel Conventional (MPG)</th>
<th>Diesel HHV (MPG)</th>
<th>Diesel HHV vs. Diesel Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDDS</td>
<td>4.104</td>
<td>3.717</td>
<td>-9.44%</td>
</tr>
<tr>
<td>NRT</td>
<td>2.600</td>
<td>3.045</td>
<td>+17.08%</td>
</tr>
<tr>
<td>Miami Custom</td>
<td>2.321</td>
<td>2.628</td>
<td>+13.22%</td>
</tr>
<tr>
<td>HHDDT Comp</td>
<td>5.701</td>
<td>4.563</td>
<td>-19.96%</td>
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<tr>
<td>HHDDT Creep</td>
<td>0.804</td>
<td>1.092</td>
<td>+35.82%</td>
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<tr>
<td>HHDDT Trans</td>
<td>3.514</td>
<td>3.460</td>
<td>-1.52%</td>
</tr>
<tr>
<td>HHDDT Cruise</td>
<td>6.701</td>
<td>5.069</td>
<td>-24.36%</td>
</tr>
</tbody>
</table>
Background / Relevance
• Project kick-off in FY2015, leveraged existing CARB-funded project
• 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 or exceedingly tough on lithium-ion batteries
• HD EV fast charging adds significant electricity demand to transit facilities buses in Pomona, CA

FY17 Accomplishments
• Completed all on-board vehicle data collection from EV and CNG baseline buses
• Developed representative drive cycles from field data
• Completed analysis of CNG baseline and EV duty cycles and on-road fuel efficiency

Future Plans
• Develop FASTSim EV and CNG transit bus models and evaluate other Foothill Transit routes for electrification potential
• Complete project with comprehensive final technical report in FY17

Any proposed future work is subject to change based on funding levels.
Foothill Transit Field Data Collection

- Battery electric buses (BEBs) operating on Line 291 are 3.8x higher in terms of diesel equivalent fuel economy
- CNG vehicles operate across a much broader geographic range

<table>
<thead>
<tr>
<th></th>
<th>CNG</th>
<th>BEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distance</td>
<td>37,892 miles</td>
<td>92,339 miles</td>
</tr>
<tr>
<td>Driving Days</td>
<td>212 days</td>
<td>775 days</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>2.15 kWh/mi</td>
<td>8.35 kWh/mi(a)</td>
</tr>
<tr>
<td>Fuel Economy (Diesel Equiv.)</td>
<td>17.5 mpg_de(a)</td>
<td>4.5 mpg_de(a)</td>
</tr>
</tbody>
</table>

(a) 37.656 kWh/gallon of low-sulfur diesel fuel
Foothill Transit Custom Cycle

- Custom cycle developed using NREL’s DRIVE tool specific to Foothill Transit’s Line 291 route
- Route to be used for modeling and simulation
• BEBs were driven on routes with more stops per mile and driven with both high acceleration and deceleration rates.
TransPower / CA School Districts: V2G EV School Bus

Background / Relevance

• Project kick-off in FY2015, leveraged California Energy Commission and Clinton Global Initiative funding
• Zero-emissions school bus with potential opportunities for vehicle-to-grid integration
• On-road data and results support DOE 1535 FOA EV school bus award to Blue Bird

FY17 Accomplishments

• Field data collected on conventional diesel school buses in Napa and Torrance Unified School Districts in California
• Completed IEEE 1547/SAE J3068 testing relative to grid interconnection standards
• Performed charger efficiency characterization—AC charge to DC discharge efficiency evaluation
• Developed representative drive cycles and completed EV school bus chassis dynamometer testing

Future Plans

• Complete building / grid impact analysis from FASTSim outputs
• Develop FASTSim EV and diesel school bus models and evaluate other routes for electrification potential
• Conduct analysis and compile findings into a final technical report in CY 2017

Any proposed future work is subject to change based on funding levels.

### EV School Bus Vehicle Details

<table>
<thead>
<tr>
<th>Chassis</th>
<th>International / Blue Bird DT466 retrofits</th>
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</thead>
<tbody>
<tr>
<td>System Integrator</td>
<td>TransPower</td>
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<tr>
<td>Motor</td>
<td>150 kW peak / 110 kW continuous</td>
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<tr>
<td>Battery</td>
<td>115 kWh LiFePO4</td>
</tr>
<tr>
<td>Bi-directional inverter</td>
<td>EPC Power Epic 150 150kW inverter / 70kW charger</td>
</tr>
</tbody>
</table>

Photo by NREL Staff
Future Plans:
Projects Kicked Off in FY17 – Wrapping up in FY18

**Duke Energy – Odyne PHEV Utility Trucks**
- Project kicked off in FY2017
- Multiple utility vocations leveraging same Odyne hybrid platform
- Completed initial on-board data collection from 20 aerial lift trucks, utility vans, and fuel tankers in Ohio, North Carolina, and South Carolina

**UPS – Workhorse Range Extended EV**
- Workhorse PEV with BMW range extender and Panasonic battery pack
- Project kicked-off in FY2017: UPS recently purchased 125 vehicles currently being deployed – first test vehicle instrumented in Atlanta
- Opportunities to evaluate geo-fencing with route-based controls

**Long Beach Transit – BYD Battery Electric Transit Bus**
- BYD BEB with wireless charging
- Project kicked off in FY2017 in collaboration with Federal Transit Administration
- First BYD buses put into revenue service in March 2017 (10 total)
- Buses equipped with conductive charging at depot and 50-kW WAVE on-route wireless charging

Any proposed future work is subject to change based on funding levels.
Response to Previous Year Reviewers’ Comments

Many reviewer comments were very positive – thank you. The following replies are to a representative sample of the more constructive reviewer comments – mostly from the Approach section of the review.

Comment #1: The reviewer believed that analysis derived from the MD and HD data collection would have increased accuracy if the data collection included frequent direct measurements of the total mass of the vehicles. Several of the fleet data collection involved vehicles that frequently change the mass of their payloads.

Response: We agree with your comment and recognize the value of payload data, but have found it very difficult to obtain accurate payload data from fleets operating in real-world revenue service. Most modern vehicles broadcast engine speed and torque data, so we can correlate fuel consumption with load, but this is complicated by other factors, including road grade. As an alternative, NREL has been developing a methodology using data mining techniques to derive vehicle mass from in-service data. Initial results were published in an SAE paper presented at the 2017 SAE World Congress entitled “Bayesian Parameter Estimation for Heavy-Duty Vehicles,” E. Miller et al.

Comment #2: The reviewer noted that the way in which fleets/applications were targeted could possibly be more methodical. The reviewer questioned where the holes were in terms of possible applications. Still, the reviewer commented that it was a good approach chosen of characterizing the data and then testing on the dynamometer. Also using a validated vehicle model to do what if scenarios was a very good idea. However, the reviewer commented that power characteristics would be helpful.

Response: We continue to refine our selection of vehicle technologies and fleets within the constraints of the program. That process currently attempts to match new emerging technologies, vehicle availability in sufficient quantities, DOE program priorities, and fleets’ willingness to participate. NREL is using aspects of duty-cycle power characteristics in some of the new FOA awards, working with vehicle/technology developers to apply data from the program to optimize new power train development to real-world duty cycle performance requirements. We also presented a study of on-road power demand distributions from various MD and HD EVs at the 2016 Applied Power Electronics Conference.
**Response to Previous Year Reviewers’ Comments**

**Comment #3:** The reviewer commented that the presenter provided evidence to support the idea that the data collection benefited the fleet owners, but did not support the idea that it significantly benefits R&D planning, and strategy for DOE at the national laboratories.

**Response:** We agree that there is potential for further use of results from this project within the DOE. Currently, data, results, and analytical tools stemming from this project are being applied on seven industry-led DOE FOA awards and one ARPAe NEXTCAR award. In the past two years, NREL has also leveraged results of this project with DOE R&D programs, including Energy Storage, Hydrogen and Fuel Cells, Clean Cities National Clean Fleet Partnership, Super Truck, 21st Century Truck, and GREET modeling. Many of these applications resulted in published milestone reports within the DOE technology area.

**Comment #4:** The reviewer stated that there was an excellent focus on future work for existing fleets, but identification of future fleets was lacking

**Response:** Under the current funding plan through FY18, we will be working with UPS / Workhorse and a range extended EV, Duke Energy and Odyne on PHEV utility trucks, and Long Beach Transit with BYD on EV transit buses with WAVE 50-kW wireless charging. We are currently reviewing publically available information on technology development to identify potential new fleets/technologies for evaluation beyond FY18.

**Comment #5:** The reviewer liked the idea of collaborating with the other DOE institutions. However, the reviewer believed that more effort should have been made to target possible other killer applications by modeling in advance. The reviewer asked what power takeoff (PTO) applications are out there that could provide fuel savings and if there are certain cities with terrain, traffic, or other conditions that make hybrids pay off more quickly. The reviewer wondered how the next killer application could be found. Finally, if the project team would be able to make targets for technologies, routes, types of fleets, etc. based on results so far and modeling.

**Response:** In addition to some of the exciting FOA awards such as EV school bus with V2G, this project has spawned work outside the DOE VTO program with organizations like the ARPAe NEXTCAR, SCAQMD Fleet DNA Roadmap, and California Energy Commission’s V2G Electrification—perhaps one of these will be the next “killer application.”
## FY16/17 Collaborations & Coordination with Others

<table>
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<tr>
<th>Partner</th>
<th>Relationship</th>
<th>Type</th>
<th>VT Program or Outside?</th>
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<tr>
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<td>Local Gov’t Fleet</td>
<td>VT Program</td>
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<td>Parker Hannifin</td>
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<td>US Hybrids</td>
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<td>Odyne</td>
<td>OEM Support</td>
<td>Industry</td>
<td>VT Program</td>
<td>Providing access to battery data &amp; vehicle data</td>
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<td>Duke Energy</td>
<td>Fleet Partner</td>
<td>Industry</td>
<td>VT Program</td>
<td>Provided vehicles, data, and support for testing</td>
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<td>Industry</td>
<td>VT Program</td>
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<td>Long Beach Transit</td>
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<td>VT Program</td>
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<tr>
<td>BYD</td>
<td>OEM Support</td>
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<td>US Environmental Protection Agency</td>
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<td>Gov’t Collaboration</td>
<td>Outside</td>
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<td>Gov’t Collaboration</td>
<td>Outside</td>
<td>Providing funding for fleet evaluation</td>
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<tr>
<td>California Air Resource Board</td>
<td>Funding Partner</td>
<td>Gov’t Collaboration</td>
<td>Outside</td>
<td>Providing funding for fleet evaluation</td>
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<tr>
<td>South Coast Air Quality Management District</td>
<td>Funding Partner</td>
<td>Gov’t Collaboration</td>
<td>Outside</td>
<td>Providing funding for fleet evaluation, assistance with access to fleets, coordination with</td>
</tr>
<tr>
<td>DOE Clean Cities</td>
<td>Coordination</td>
<td>Gov’t Collaboration</td>
<td>VT Program</td>
<td>Providing funding to assess fleet-specific technology options for National Clean Fleets Partnerships (Verizon, City of Indianapolis, PG&amp;E)</td>
</tr>
</tbody>
</table>

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1. **Continuing need for unbiased information, data, and analysis**
   - Fleets are faced with a long menu of alternatives, including propane, natural gas, electric, fuel cells, aerodynamics devices, connected and autonomous vehicles, low rolling-resistance tires, etc.
   - Fleets are also faced with changing economic drivers and technology implementation issues such as demand charges, charge management, wireless charging, green routing, etc.
   - Fleets need objective information on the performance of these technologies within the context of their operations
   - Technology developers need detailed duty cycle and performance information to optimize energy efficiency solutions that meet vocational requirements

2. **Availability of technology solutions that are reliable and cost effective for economically viable commercial applications**
   - Limited rollout of EVs, HEVs, 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 potential regulatory/process requirements;
   - New EPA HD GHG rules likely to cause demand for new cost-effective energy saving technologies, and better unbiased data on technology- and application-specific efficiency performance.
Summary

• MD and HD vehicle technology evaluations provide test results, detailed on-road performance data, analysis, and published reports that help drive design improvements, guide deployment decisions, inform regulatory processes, and provide field data for researchers.

• Key technical accomplishments in FY16/FY17 include:
  o Published 16 technical papers/presentations from fleet evaluation activities, including at key forums such as SAE Commercial Vehicle Engineering Congress, SAE World Congress, SAE Range Extenders Symposium, IEEE Transportation Electrification Conference, Electric Vehicle Symposium & Exhibition EVS29, Automate Vehicles Symposium and NTEA Green Truck Summit
  o Published final technical report on Frito-Lay EV evaluation – and completed data collection and analysis activities on Foothill Transit EV bus, Miami-Dade HHV refuse hauler evaluations;
  o Kicked-off three new fleet evaluations including: Duke Energy fleet evaluation of Odyne PHEV utility trucks, UPS / Workhorse extended range EVs, and Long Beach Transit BYD EV transit bus with wireless power transfer
  o Applied results of fleet evaluations and Fleet DNA to DOE RD&D programs, including Energy Storage, Hydrogen and Fuel Cells, Power Electronics, National Clean Fleet Partnership, Clean Cities National Parks, Super Truck II, and EV Everywhere
  o Fleet evaluation data and analysis are contributing to seven industry-led FOA vehicle electrification, Super Truck II awards, and an ARPAe NEXTCAR award
  o Fleet evaluation data and analysis used by other Federal and State agencies, including EPA, U.S. Department of Transportation (DOT), National Park Service, CARB, CEC, SCAQMD
Acknowledgements and Contacts

Thank you to:

Lee Sleza and David Anderson
Vehicle Technologies Office – U.S. Department of Energy

Additional thanks to all the fleet and industry partners without whom this work would not be possible

For more information contact:

Kenneth Kelly
National Renewable Energy Laboratory
kenneth.kelly@nrel.gov
phone: 303.275.4465
Technical Backup Slides
Drive Cycle Analysis Tool — DriveCAT

How It Works
1. Select a drive cycle from the table below.
2. View drive cycle description, data, and charts.
3. Download drive cycle data, charts, and/or related publications.

Select a Drive Cycle

Drive Cycle Description
A dynamic chassis dynamometer test cycle for a heavy-duty HDOG (HDDG) developed by the California Air Resources Board (CARB) with the Virginia Commonwealth University

NREL Miami-Dade Refuse

Drive Cycle Comparison

Related NREL Resources
- Project Startup: Evaluating the Performance of Hydraulic Hybrid Refuse Vehicles
- NREL Evaluates Performance of Hydraulic Hybrid Refuse Vehicles
- Miami-Dade County Hydraulic Hybrid Refuse Truck Testing

https://www.nrel.gov/transportation/drive-cycle-tool/
Collaboration and Coordination with Other Institutions

This project **absolutely requires** industry collaboration required for successful studies.

Past industry partners included:


<table>
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<tr>
<th>FY15/16 Collaborations &amp; Coordination with Others</th>
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<tr>
<td><strong>Partner</strong></td>
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<td>FedEx Corporation</td>
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<td>UPS</td>
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<td>S. Coast Air Quality Mgt. District / CARB</td>
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<td>Clean Cities Program</td>
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<td>NTEA/GTA</td>
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<td>Oak Ridge National Laboratory</td>
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And More....
Data and Information Exchange

DOE FT&E Evaluation Projects

Fleet DNA
DRIVE
FASTSim
DriveCAT

DOE Programs

Energy Storage
Power Electronics
Hydrogen and Fuel Cells
21st Century Truck
National Clean Fleet Partners
EV Everywhere
INTEGRATE

Industry Partners

Extensive fleet and industry partners

Other Agencies

U.S. EPA
National Park Service
DOT - Volpe
TARDEC
SCAQMD
CARB / CEC

Research Orgs

ORNL, INL, LLNL, ANL
Clemson, Ohio State, U of Michigan, Georgia Tech...

Collaborations, Data and Information Sharing