

Driving R&D for The Next Generation Work Truck



NTEA Green Truck Summit

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Indianapolis, Indiana

March 4, 2015

Today's Discussion

- **NREL's Medium- and Heavy-Duty Truck RD&D**
- **Highlights:**
Improved Energy and Operational Efficiency
- **What's Next?**
- **Ongoing Live Polling**

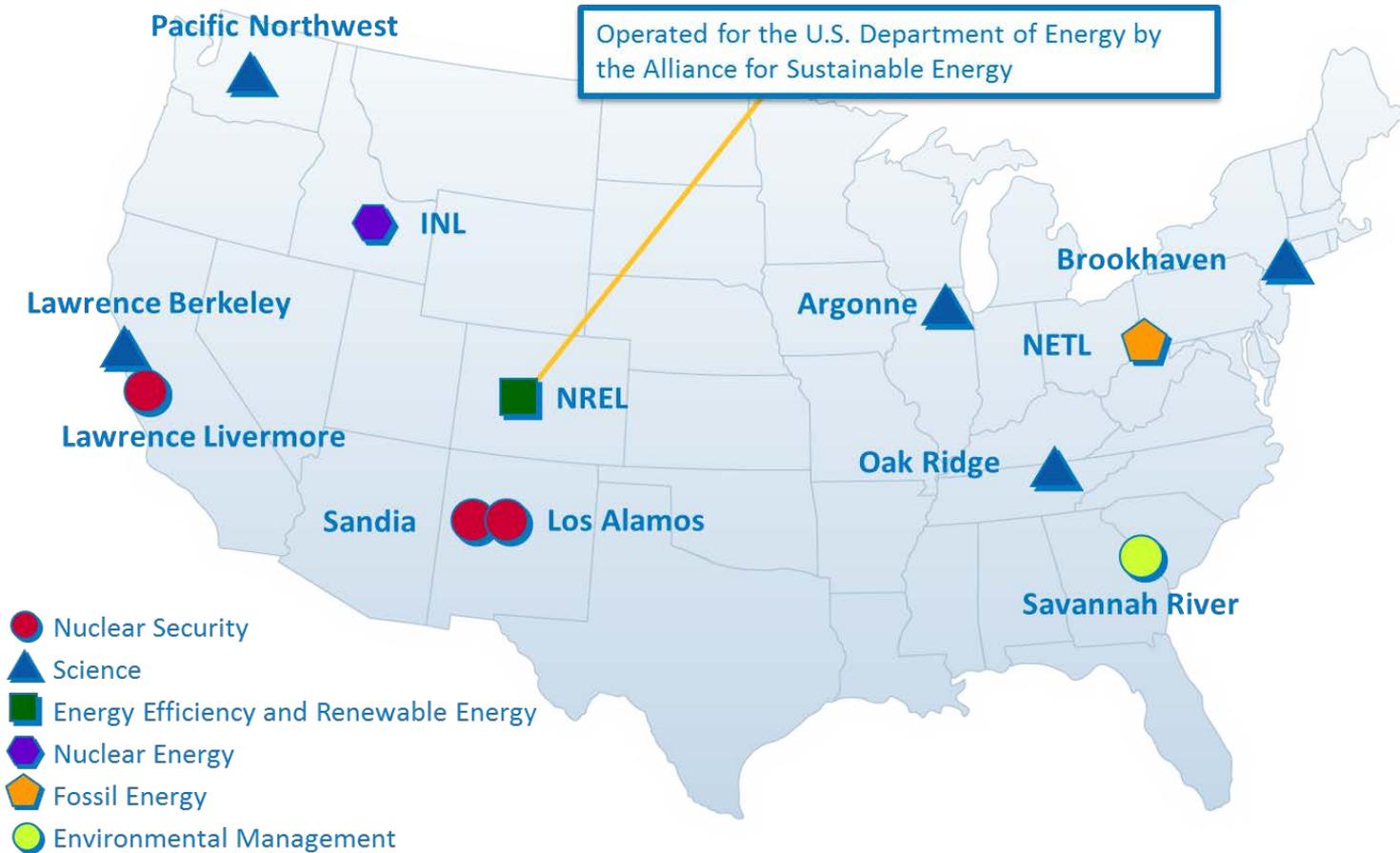
**NREL's
Medium- and Heavy-Duty
Truck RD&D**

Have you ever partnered with NREL or another national lab?

A. Yes

B. No

NREL & the National Lab System



NREL is the only national laboratory dedicated solely to energy efficiency and renewable energy.

Which of the following technology breakthroughs did NREL innovation help bring to market?

- A. Solar Cells
- B. HEVs
- C. LED Lighting
- D. All of the Above

NREL Snapshot

- Clean-energy innovation for 35 years
- ~1,700 employees
- World-class facilities
- Living model of sustainable energy
- Owned by the Department of Energy
- Operated by the Alliance for Sustainable Energy

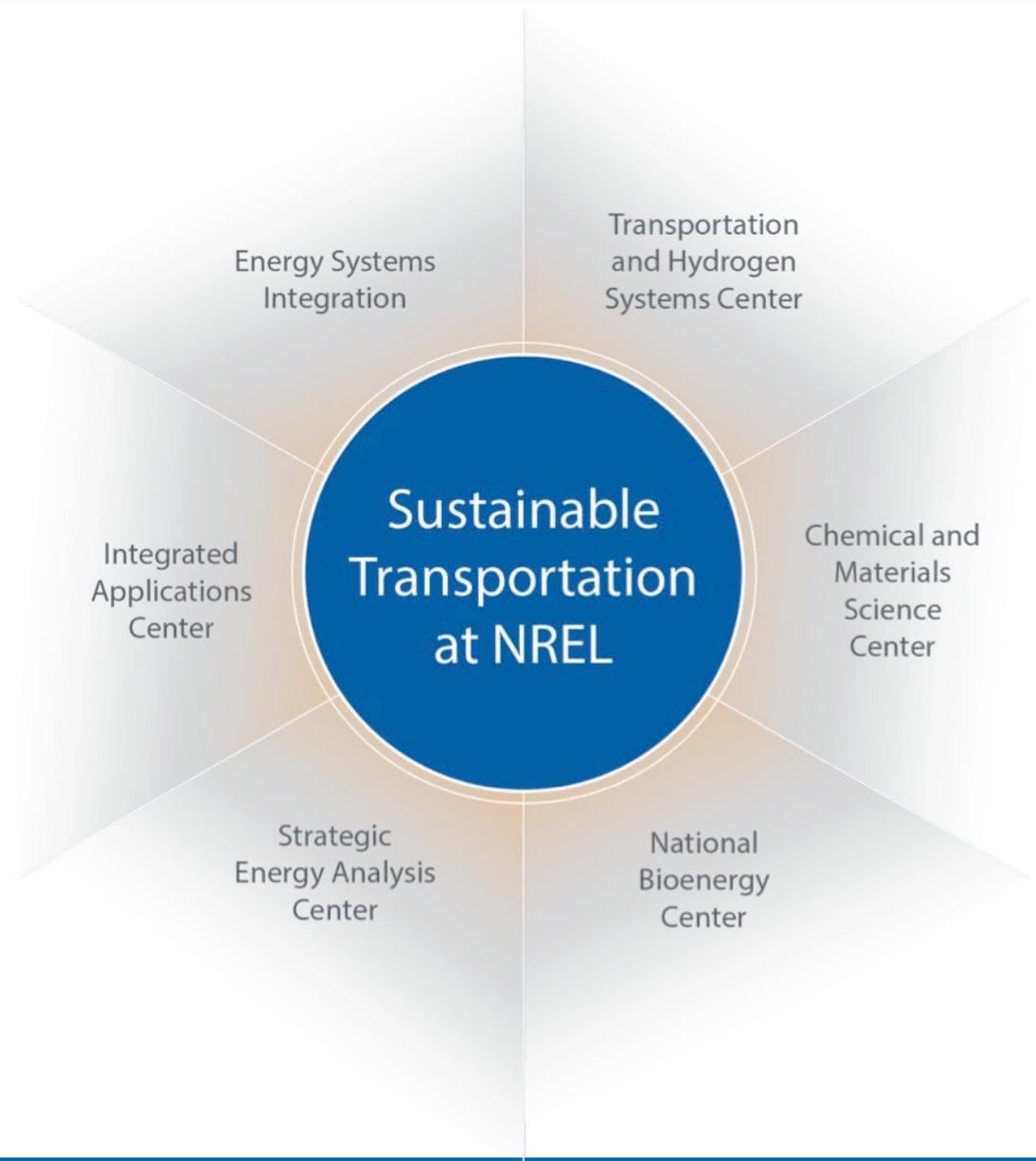


Photos by Dennis Schroeder, NREL

NREL Transportation Research



Photos by Dennis Schroeder, NREL



Flagship Transportation Capabilities

Vehicle Thermal Management

*Integrated Thermal Management
Climate Control / Idle Reduction
Advanced HVAC*

Vehicle Deployment / Clean Cities

*Guidance & Information for Fleet Decision
Makers & Policy Makers
Technical Assistance
Online Data, Tools, Analysis*

Regulatory Support

*EPAct Compliance
Data & Policy Analysis
Technical Integration
Fleet Assistance*



Combustion / Fuels

*Advanced Petroleum and Biofuels
Combustion / Emissions Measurements
Vehicle and Engine Testing*

Infrastructure

*Vehicle-to-Grid Integration
Integration with Renewables
Charging Equipment & Controls
Fueling Stations & Equipment
Roadway Electrification
Automation*

Vehicle and Fleet Testing

*MD/HD Dynamometer Testing
MDV and HDV Testing / Analysis
Drive Cycle Analysis / Field Evaluations
Technology Performance Comparisons
Data Collection, Storage, & Analysis
Analysis & Optimization Tools*

Power Electronics and Electric Motors

*Thermal Management
Thermal Stress and Reliability*

Battery & Fuel Cell Energy Storage

*Development, Testing, Analysis
Thermal Characterization/Management
Life/Abuse Testing/Modeling
Computer-Aided Engineering
Electrode Material Development*

Illustration by Josh Bauer, NREL

Many Partners in Wide Range of Sectors



CaFCP - California Fuel Cell Partnership
 CaSFCC - California Stationary Fuel Cell Collaborative
 CARB - California Air Resources Board
 CCSE - California Center for Sustainable Energy
 CEC - California Energy Commission
 CRC - Coordinating Research Council
 DOT - Department of Transportation

EDTA - Electric Drive Transportation Association
 EIC - EIC Laboratories
 EMA - Engine Manufacturers Association
 EPRI - Electric Power Research Institute
 GTI - Gas Technology Institute
 MECA - Manufacturers of Emissions Controls Association
 MTNW - Measurement Tools Northwest

NASEO - National Association of State Energy Offices
 NBB - National Biodiesel Board
 NGA - National Governors Association
 NGVA - Natural Gas Vehicles for America
 NIST - National Institute of Standards and Technology
 NTCNA - Nissan Technical Center North America
 NTEA - National Truck Equipment Association

PERC - Propane Education Research Council
 PPG - Pittsburgh Plate and Glass
 RFA - Renewable Fuels Association
 SCAQMD - South Coast Air Quality Management District
 SDG&E - San Diego Gas and Electric
 SwRI - Southwest Research Institute
 UTRC - United Technologies Research Center

Partners not included on this map:

- CellEra
- Tanaka Kikinokogyo
- Toyota Central R&D
- Israel
- Japan
- Japan

Illustration by Josh Bauer, NREL

**Highlights:
Improved Energy and
Operational Efficiency
for Medium- and
Heavy-Duty Trucks**

NREL Medium- & Heavy-Duty Vehicle RD&D

NREL provides core RD&D for medium- and heavy-duty fleets through:

- MDV and HDV analysis and testing
- Field evaluations
- Performance data collection and analysis
- Experimental evaluation and virtual modeling and simulation
- Guidance and information for fleet decision makers and policy makers
- Stimulation and expansion of markets
- Forums for collaboration
- Technical expertise
- Online tools and data
- Regulatory guidance.



Top photo courtesy of UPS
Bottom photo by Trish Cozart, NREL

At what distance did NREL find the most fuel savings between two trucks traveling at 65 mph?

- A. 20 feet
- B. 40 feet
- C. 50 feet
- D. 75 feet

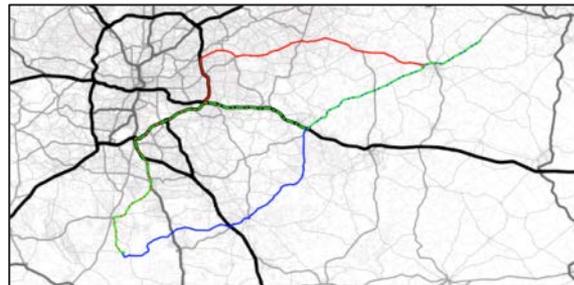
Validating Fuel Savings from Connected Vehicles



Class 8 Truck Platooning

- On-track testing and evaluation of platooning impact on fuel efficiency and emissions
- Class 8 line-haul trucks
- Combined “team” fuel savings from 3.7% to 6.4%.

Partners: Intertek , Peloton



Connected Vehicle Technology for Trucks

Vehicle platooning

Driving analysis and behavior

“Green” routing and adaptive control

Photo by Ganymed Stanek/Peloton (top), image and figure by NREL (bottom)

What percentage of long-haul truck fuel is used for rest-period idling?

A. 6.8%

B. 2.3%

C. 15.1%

D. 0.8%

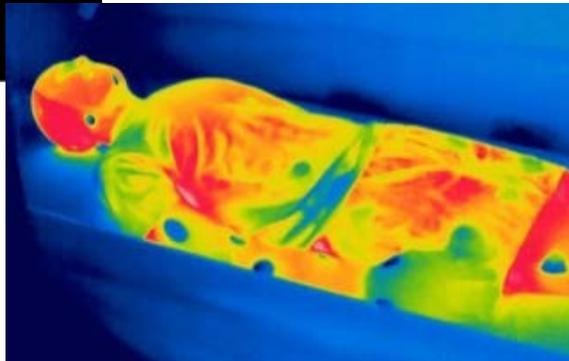
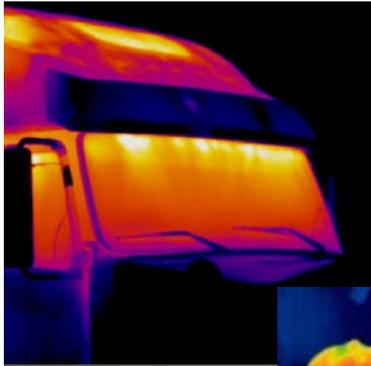
Assessing Impact of Heavy-Duty Vehicle Thermal Management



High Efficiency Configurations Lower AC Demands by >36%

- 667 million gallons of diesel fuel used annually for long-haul truck rest period idling
- More than a 36% reduction in A/C loads using high efficiency configuration included ultra-white paint, advanced insulation, advanced curtains
- More than a 20% reduction in A/C load going from black to white paint.

Partners: Volvo Trucks, PPG, Aearo Technologies



Heavy-Duty Vehicle Thermal Management

Experimental evaluation
CoolCalc rapid HVAC analysis
A/C model development

Top and far right photos by Dennis Schroeder, NREL
Figure and infrared image by NREL

What is the most fuel-efficient technology option for medium-duty package delivery trucks?

- A. Downsize High-Efficiency Diesel
- B. Hydraulic Hybrid
- C. Electric Hybrid
- D. It Depends

Quantifying Fuel Savings Benefits of Advanced Technologies

UPS Hydraulic Hybrid Testing

- Field Study of 20 hydraulic hybrid delivery vans vs. gasoline and diesel non-hybrid vans
- Chassis dynamometer testing using drive cycles developed from field measurements
- 19-56% improvement over non-hybrid – specific benefit depends on use and comparison.

Partner: UPS, Parker Hannifin



Photo by Dennis Schroeder, NREL

Fleet Testing and Evaluation Capabilities

Drive cycle/duty cycle analysis

Field data collection (operations, fuel, cost, etc.)

Vehicle & engine performance data (baseline vs. new)

On-road emissions measurement

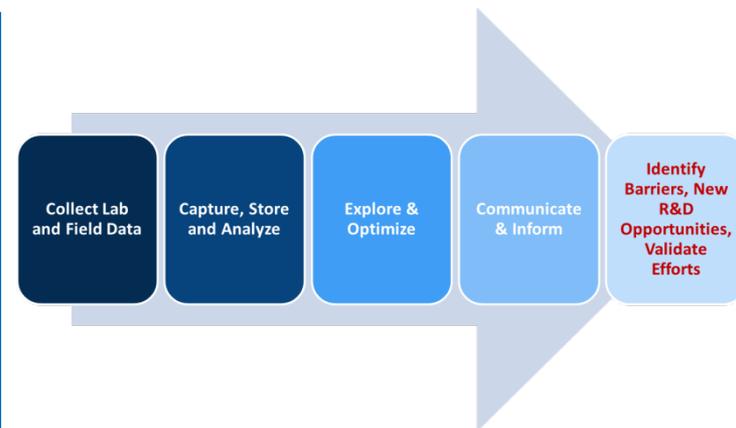
Analysis of options – identify best use of technology

Renewable Fuels and Lubricants Laboratory

Vehicle and engine testing

Emissions and fuel consumption measurement

Heavy-duty chassis and engine dynamometers



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

On an average day of operation, how many hours does a typical package delivery truck idle?

- A. 2 hours
- B. 3 hours
- C. 5 hours
- D. 6 hours

Capturing and Analyzing Medium- and Heavy-Duty Truck Data

Medium-Duty Electric Vehicle Data Collection

- Collected 25 channels of 1-Hz propulsion system operation, use, and performance data
- Amassed data on more than 162,000 vehicle days and 4 million miles of EV operation
- Processing routines capable of handling multiple vehicles simultaneously, saving time and computing resources.

Partners: Smith, Navistar, Odyne, Shorepower, Frito-Lay, Staples, FedEx, PG&E, Coke, etc.



Photo courtesy of Frito Lay



Fleet DNA Big Data & Analysis Characterize Real-World Operation

Operational data from over 560 trucks across 14 different vocations and a variety of powertrains currently in Fleet DNA.

- Secure archiving of sensitive fleet data
- Automated quality control and processing of data
- Publically available aggregated data and reports
- Detailed GPS drive cycle analysis
- Spatial mapping/GIS analysis/fueling rates/on-road emissions
- Integration with other databases and modeling tools.

Data and Results for:

Industry, Fleets, Government Agencies, Research Organizations

How many public compressed natural gas stations are there within 100 miles of here?

A. 7

B. 18

C. 29

D. 36

Identifying & Breaking Down Barriers to Natural Gas Technologies



New Natural Gas Engines for Vocational Trucks

- Addressed a critical gap in natural gas engine technology for medium- and heavy-duty vehicles
- Two projects focused on development, certification and commercial production of engines utilizing both compressed natural gas and liquefied natural gas
- First natural gas-powered 11.9-liter engines put into commercial production.

Partners: California Energy Commission, South Coast Air Quality Management District, Cummins Westport, Southwest Research Institute, Doosan Infracore, NGVTF



Outreach & Education

Guidance and information for fleet decision makers and policy makers

Stimulation and expansion of markets

Forums for collaboration

Online tools and data

Photo courtesy of Cummins Westport, Inc.

Next Generation Transportation Systems

Transportation Technologies and Market Fundamentals are Changing Rapidly

NREL is Expanding Efforts in the Following Areas:

- Connected and automated vehicles
- Vehicle-grid integration
- Fuel-vehicle system optimization
- Urban transportation and system planning.



Left & middle photos by Dennis Schroeder, NREL



Top illustration courtesy of U.S. Department of Transportation

Bottom illustration by Josh Bauer, NREL

Working with NREL

DOE AOP – Annual Operating Plan

DOE FOA – Funding Opportunity Announcement

Other FOA – Funding Opportunity Announcement

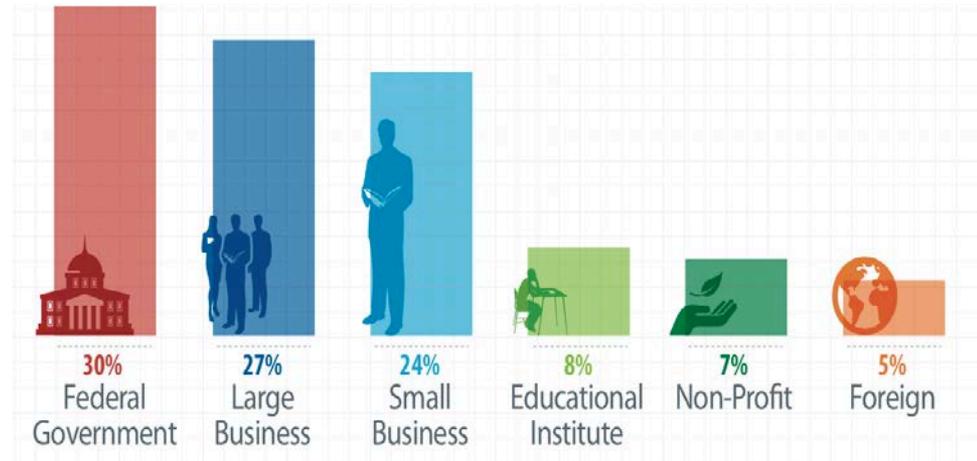
CRADA – Cooperative Research and Development Agreement

WFO – Work for Others

Partnership on DOE & Other Agency Projects

National Laboratories Seek to Partner with Commercial Entities to Increase Market Impact

- NREL has 650+ active partnership agreements and leads the DOE laboratory system in cooperative research agreements.
- NREL has more than 800 patented or patent-pending technologies available for licensing .



NREL 2014 Partnerships

Current and Upcoming Opportunities

- 2015 Vehicle Technologies Office Funding Opportunity Announcements
- ARPA-E OPEN FOA
- SuperTruck II
- Department of Defense .



Photo courtesy of iStock

Call on NREL to :

- Leverage existing technology work portfolios and partnerships
- Provide access to world-class test facilities and capabilities
- Serve as a third-party for technology validation, market acceptance, analysis, and data dissemination
- Provide systems-level energy analysis.

**Learn more at
www.nrel.gov/transportation**

NREL/PR-5400-63855

March 2015

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.