NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Fuel and Emissions Reduction in Electric Power Take-Off Equipped Utility Vehicles

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Presented by: Arnaud Konan, NREL

Electric Vehicle Symposium & Exhibition (EVS29)
Montréal, Québec, Canada

June 22, 2016
NREL/PR-5400-66737

@EVSymposium29
#EVS29

Electric Vehicle Symposium & Exhibition

June 19-22, 2016 | du 19 au 22 juin 2016

Montréal, Québec, Canada

Organized by: EDTA

Hosted by: EDTA, nea, Electric Mobility Canada

In Collaboration with: AVERE, EVAAP

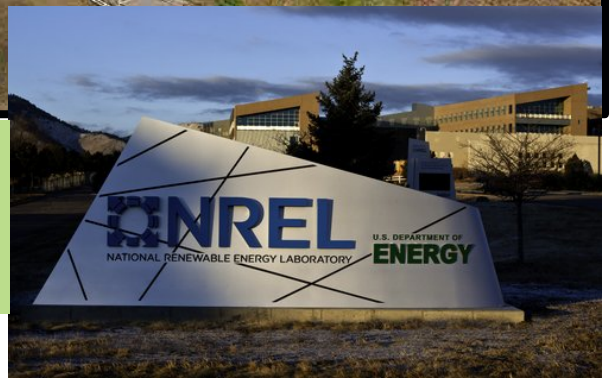
Platinum Sponsors: Québec, Hydro Québec, Investissement Québec

DRIVE ELECTRIC INNOVATION

PROPULSER L'INNOVATION EN MOBILITÉ ÉLECTRIQUE

EVS29.ORG

National Renewable Energy Lab - Campus



National Renewable Energy Laboratory is one of 17 U.S. Department of Energy national labs. It is operated by the Alliance for Sustainable Energy, LLC, in Golden, Colorado.

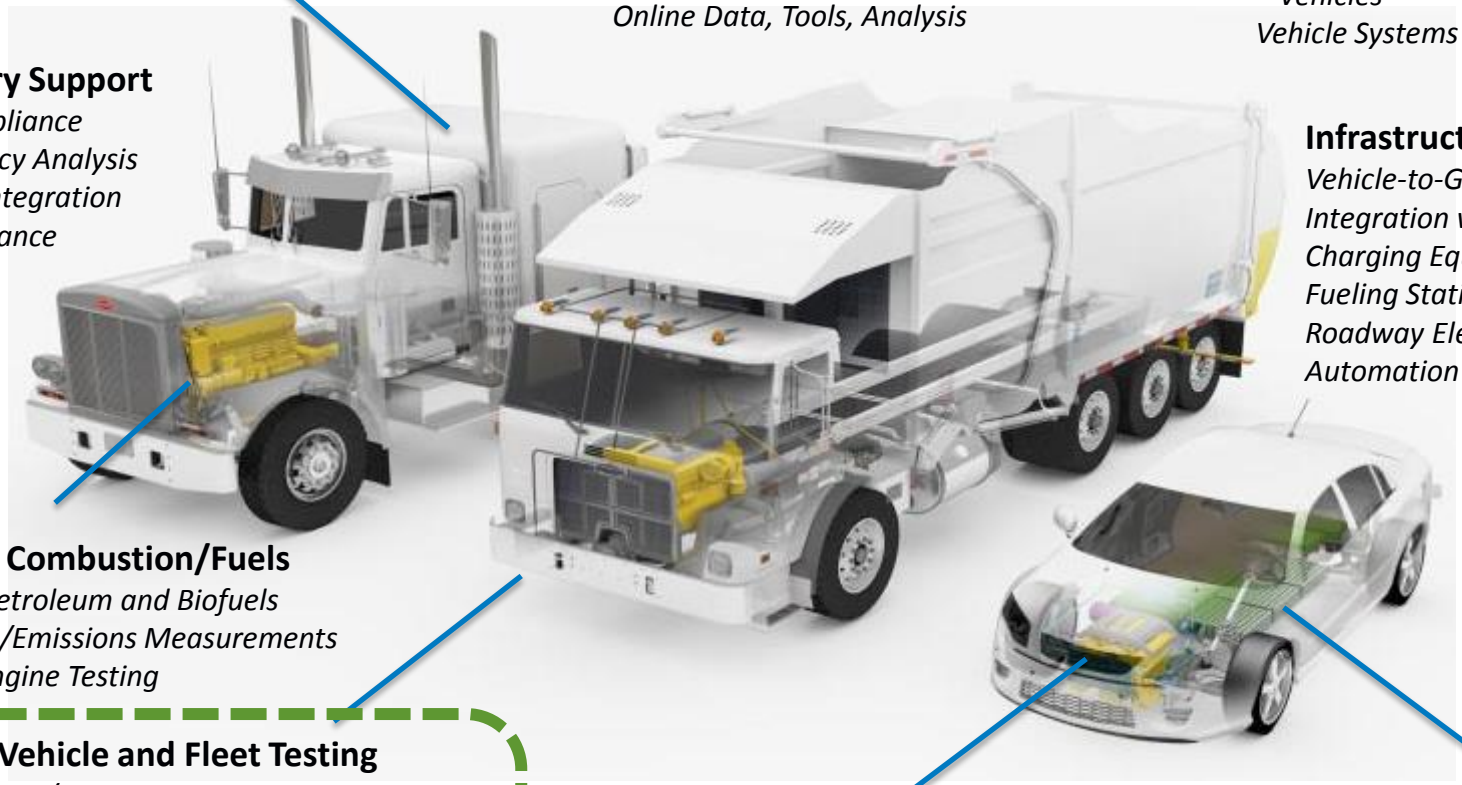
NREL Transportation RD&D Activities & Applications

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

Vehicle Systems Modeling and Simulation
Connected and Automated Vehicles
Vehicle Systems Analysis

Regulatory Support
EPAct Compliance
Data & Policy Analysis
Technical Integration
Fleet Assistance



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

Advanced Combustion/Fuels
Advanced Petroleum and Biofuels
Combustion/Emissions Measurements
Vehicle & Engine Testing

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

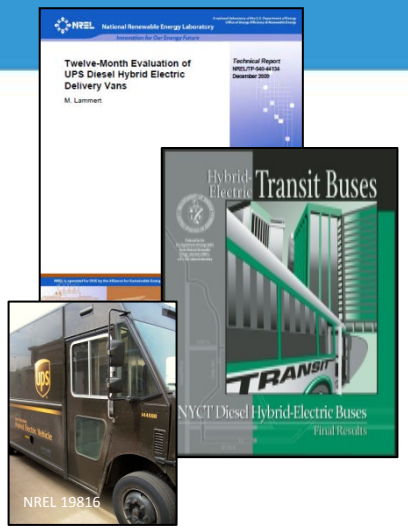
Advanced Power Electronics and Electric Motors
Thermal Management
Thermal Stress and Reliability

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

Illustration by NREL

Providing Unbiased Data and Analysis

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.

- More than 9.5 million miles of advanced technology **MD and HD truck data have been collected, documented, and analyzed** on more than 1,577 different vehicles from more than 50 different providers 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
  - Define intelligent usage of newly developed technology
  - Fleets/users understand all aspects of advanced technology.

Why Electric PTO System?

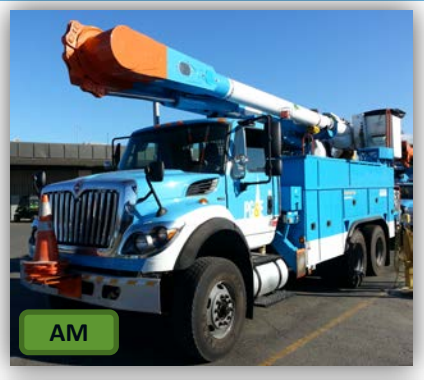
- **The accessibility to an alternative energy source provided by the e-PTO system allows for idle and fuel reduction through running auxiliary loads from the battery.**
- **Emissions benefits are implied and can be calculated using emissions standards.**
- **Others benefits are harder to quantify.**

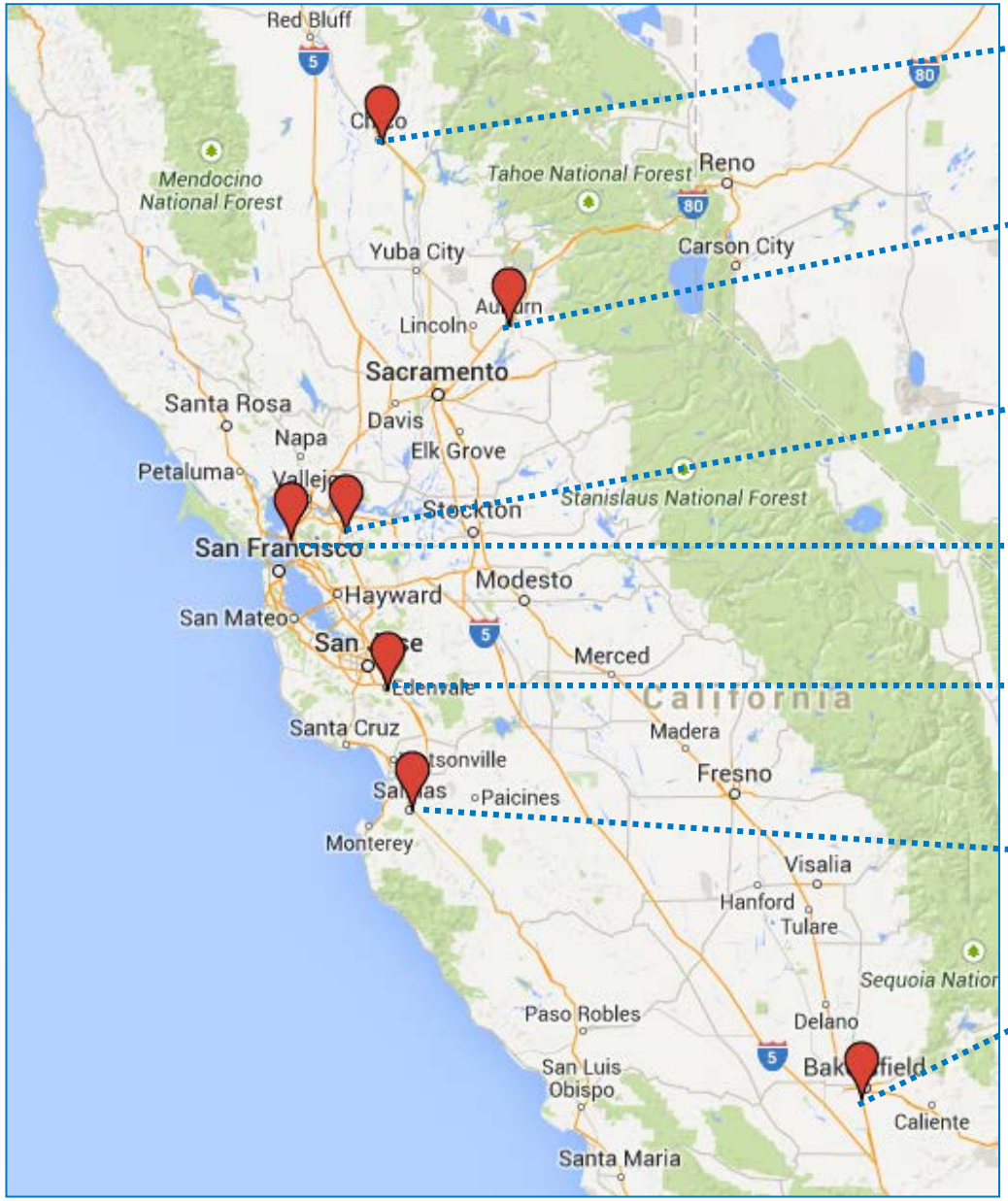
PG&E Fleet Test Project

PHEV Utility Truck Study

- Instrumented 20 PG&E Altec utility trucks
  - 10 “Trouble Trucks” AT (5 w/ ePTO / 5 w/o)
  - 10 “Material Handlers” AM (5 JEMS + 5 AM Diesel)
- 8 weeks of data collection at 7 sites
- Collecting data on:
  - Drive cycle/duty cycle
  - J1939 CAN (including fuel use and NOx sensor)
  - Battery charge/discharge power
  - Electric AC
  - Electric hydraulics
  - Electric auxiliaries.

Fleet Data Collection Locations





Chico

Logger	config	Unit
28	ePTO OFF	B27959
1	ePTO ON	B27961
30	AM Conv	B28082

Auburn

Logger	config	Unit
29	ePTO OFF	B27950
9	ePTO ON	B27956
11	AM JEMS	B26135

Concord

Logger	config	Unit
24	AM JEMS	B26152
15	ePTO ON	B27944

Richmond

Logger	config	Unit
27	ePTO OFF	B27946
26	AM Conv.	B26155

Edenvale

Logger	config	Unit
7	ePTO OFF	B27958
5	AM Conv.	B26143
3	AM JEMS	B26140

Salinas

Logger	config	Unit
13	AM JEMS	B26131

Bakersfield

Logger	config	Unit
8	ePTO OFF	B27948
10	ePTO ON	B27954
25	AM Conv.	B28493
14	ePTO ON	B27953
17	AM JEMS	B25956
12	AM Conv.	B25959

PG&E - AM JEMS (Material Handlers)

Altec's JEMS system (Jobsite Energy Management System), a smart plug-in hybrid system that manages energy use at the jobsite. The hybrid system is designed to power the unit through a typical work day without running the chassis engine

HVAC Control

Data Logger

PG&E – AT- “Trouble Trucks”

Specifications of the Vehicles

Ford F-550 Altec (AT)	
GVWR	19,500 lbs
Engine	Ford Powerstroke 6.7L
Horsepower	300 hp @ 2,800 rpm
Torque	660lb-ft @ 1600 rpm
Battery Capacity	8 kWh
Battery Voltage	~ 12 V
Charging Standards	-
Transmission	6 speed Auto
Drive	4x4

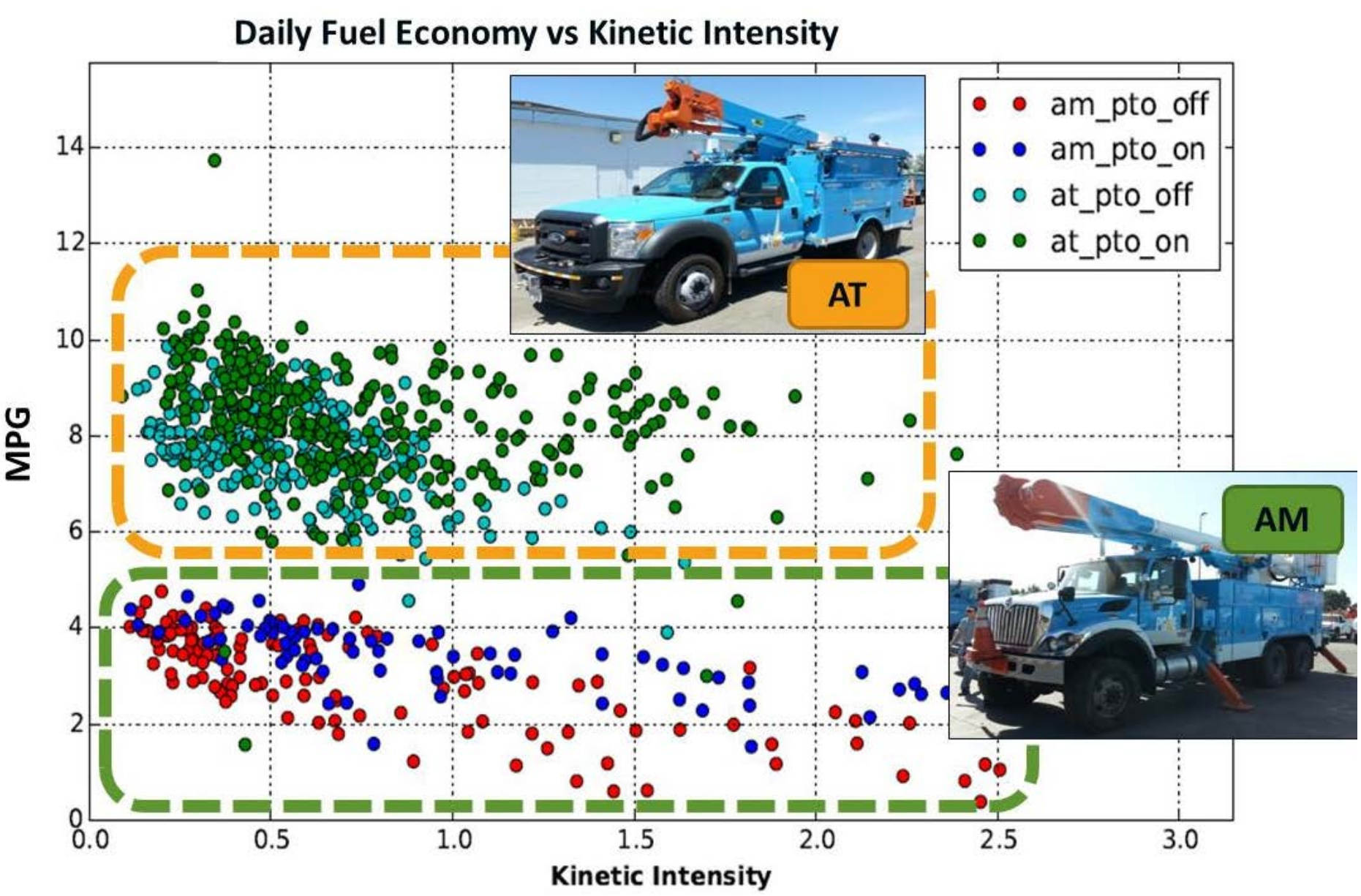
International WorkStar 7500 (AM)	
Curb Weight	56,000 lbs
Engine	International MaxxForce 7.6L
Horsepower	300 hp @ 2,200 rpm
Torque	860lb-ft @ 1300 rpm
Battery Capacity	18 kWh
Battery Voltage	~ 48 V
Charging Standards	SAE J1772
Transmission	Allison 3500 RDS 5-speed
Drive	6x6

Summary Statistics on Vehicles

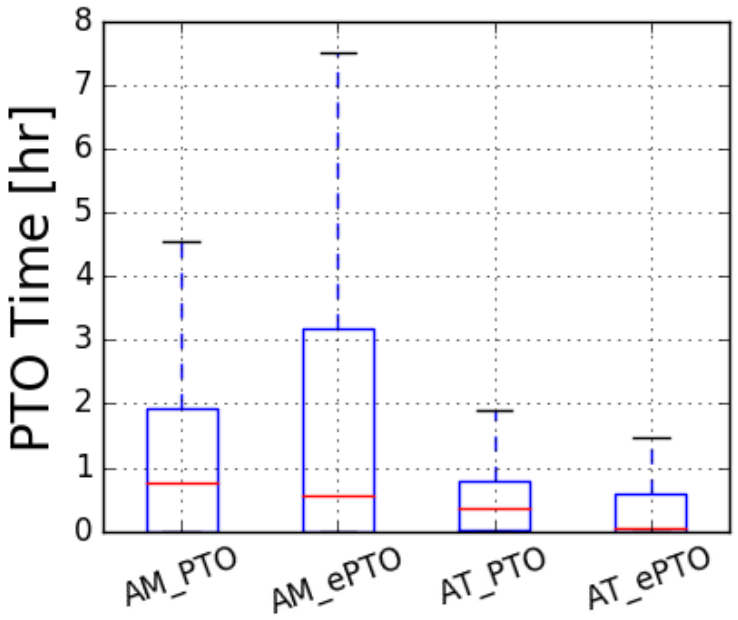
AT Vehicles	10
Total Time [hr]	3,742
Total Distance [mi]	60,800
Fuel [Gallons]	7,543
Driving Fuel Econ. [mpg]	9.11
Driving Time [hr]	1,964
Number of Days	604

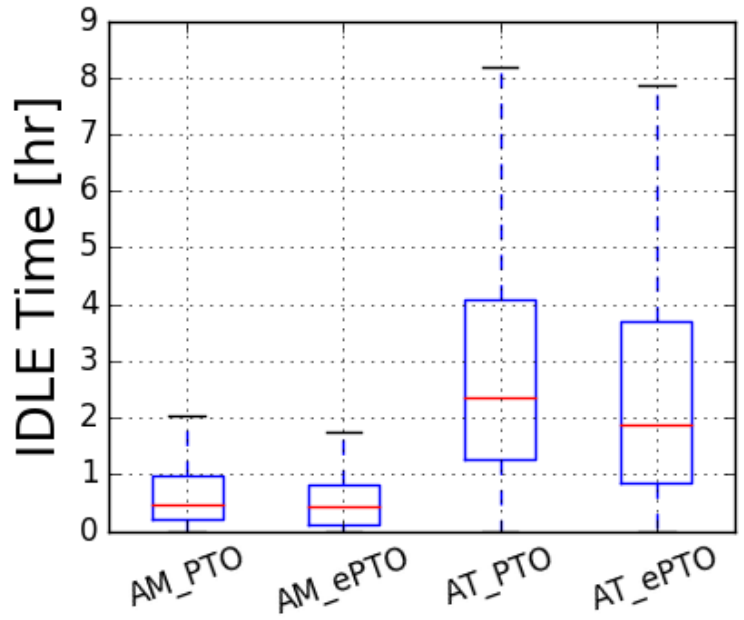
AM Vehicles	10
Total Time [hr]	688
Total Distance [mi]	8,574
Fuel [Gallons]	2,533
Driving Fuel Econ. [mpg]	4.11
Driving Time [hr]	280
Number of Days	284

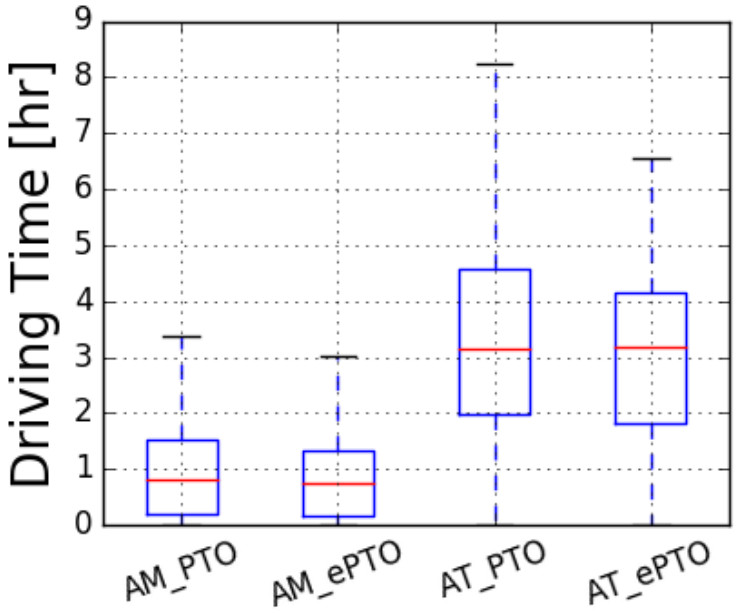
Fuel Economy vs Kinetic Intensity

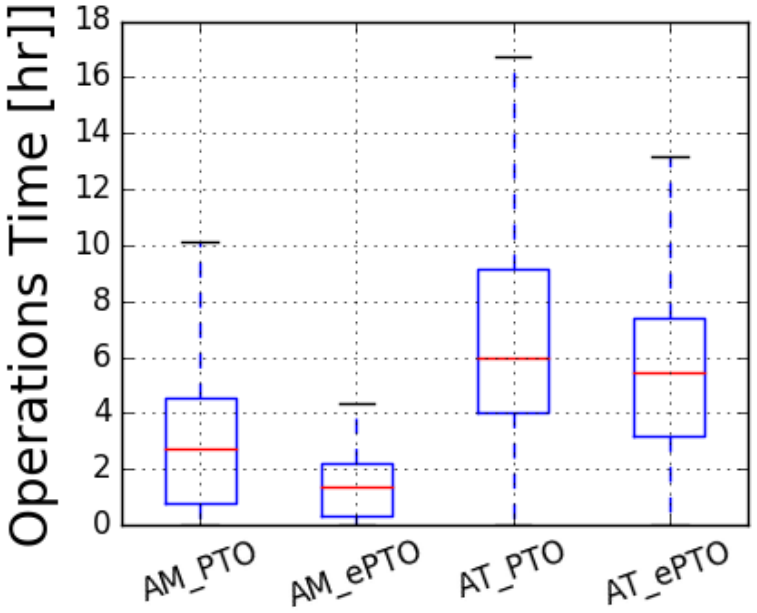


Daily Operations Time Breakdown

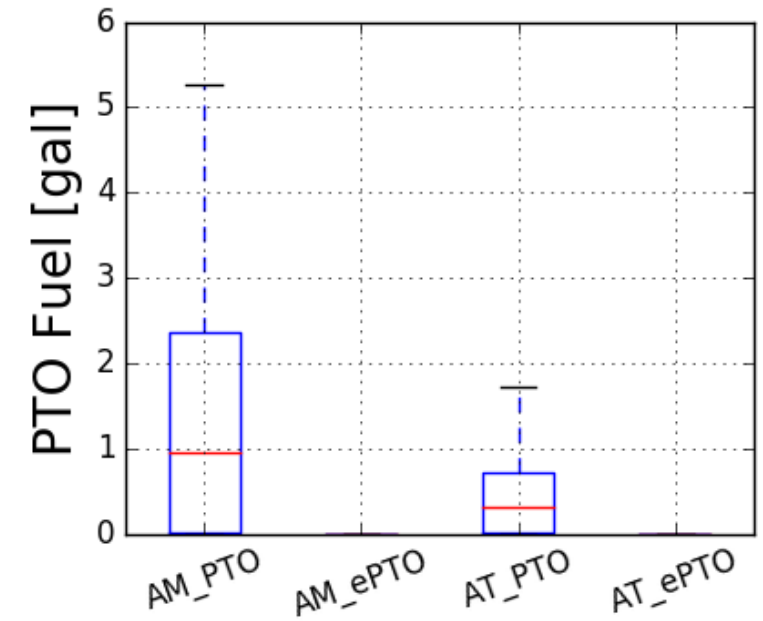


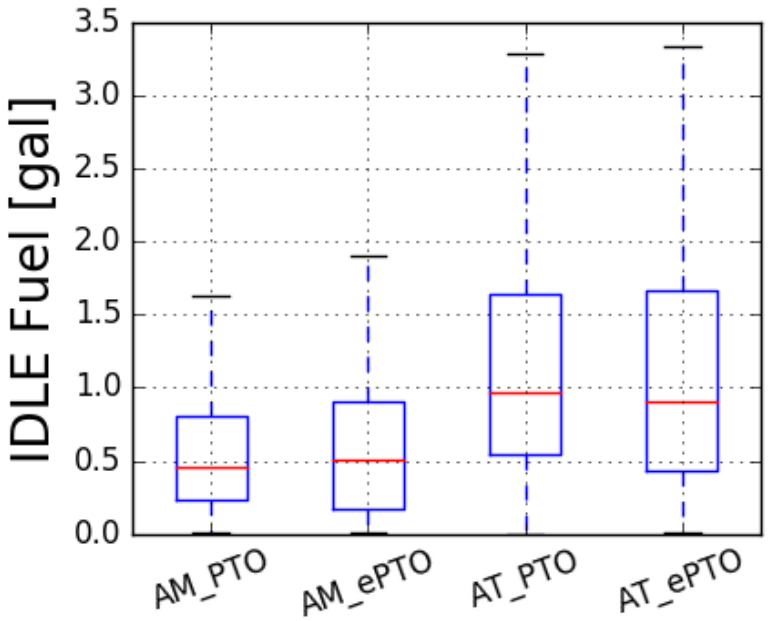


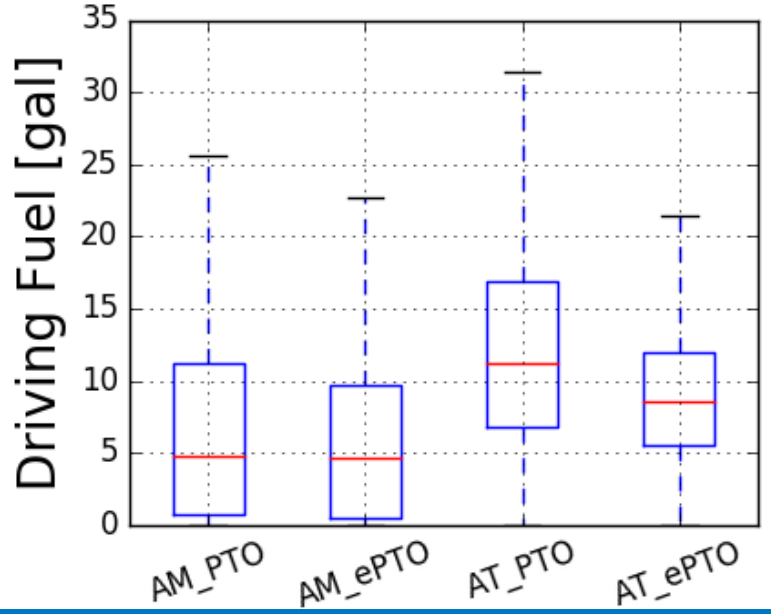


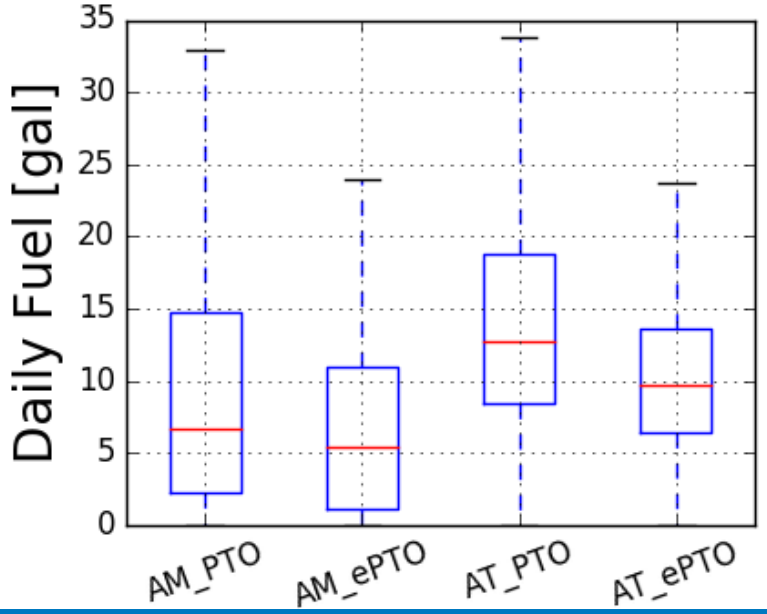


Daily Operations Fuel Breakdown



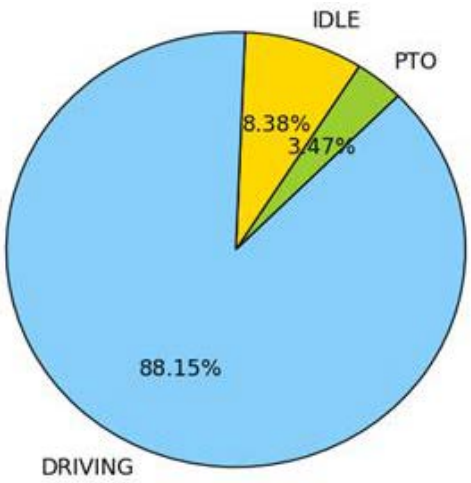






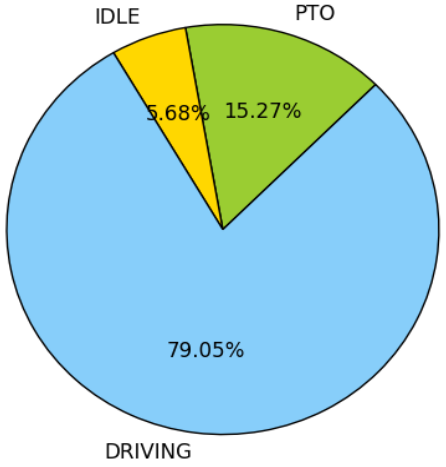
Fuel Consumption Breakdown – All conventional Vehicles

Trouble Truck - AT



	Idle	PTO
Mean	0.43 [gal/hr]	0.88[gal/hr]
Median	0.38 [gal/hr]	0.86[gal/hr]

Material Handlers - AM



	Idle	Low RPM PTO	High RPM PTO
Mean	0.82[gal/hr]	0.86[gal/hr]	1.59[gal/hr]
Median	0.66[gal/hr]	0.86[gal/hr]	1.48[gal/hr]

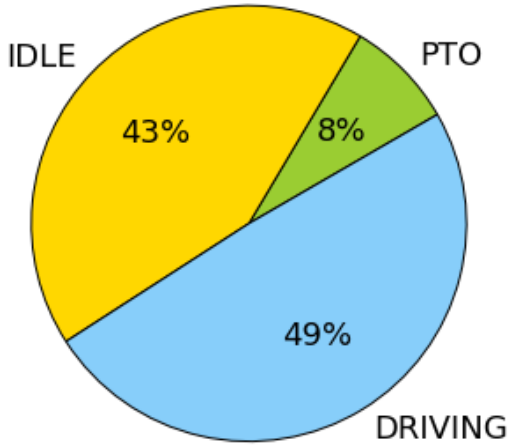
Comparison of Operational Time by Vehicle Type

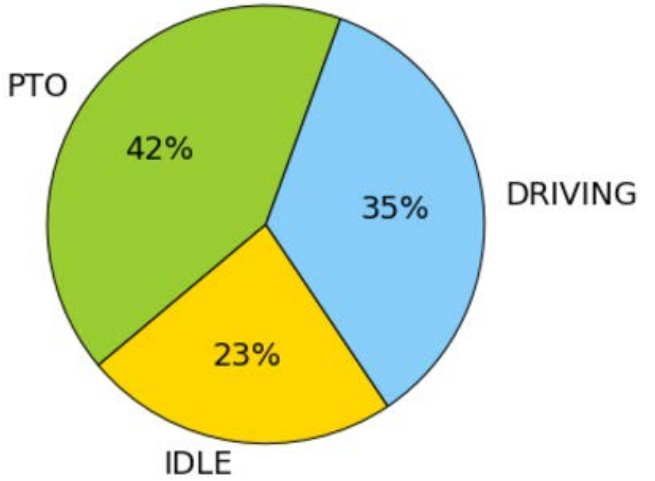
Comparing all groups

AT

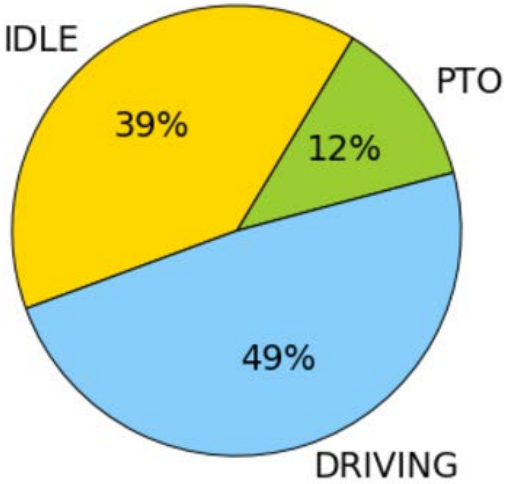
AM

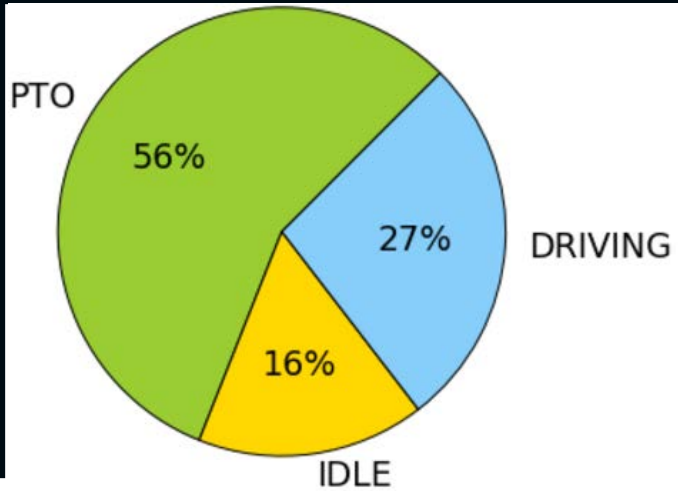
Conventional Trucks





Hybrid Trucks





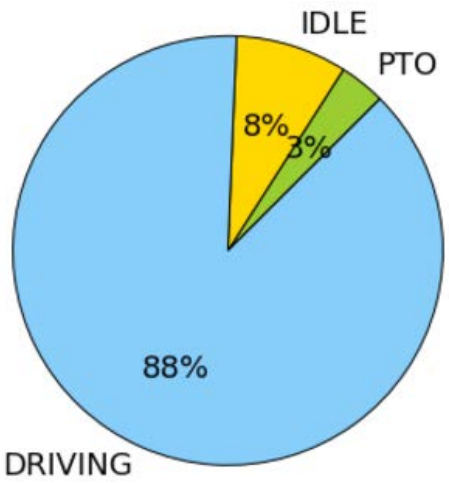
Comparison of Operational Fuel by Vehicle Type

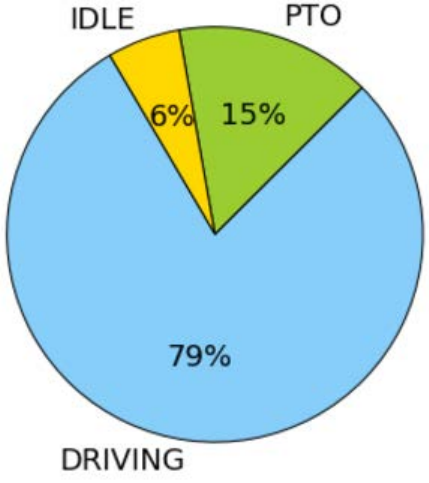
Comparing all groups

AT

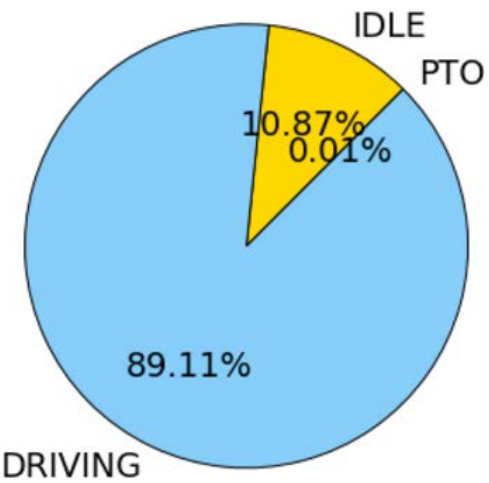
AM

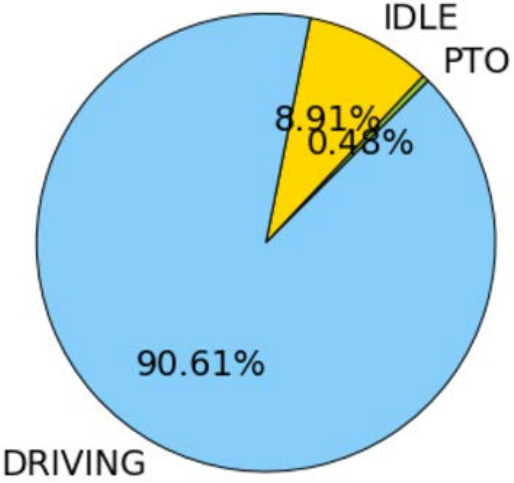
Conventional Trucks



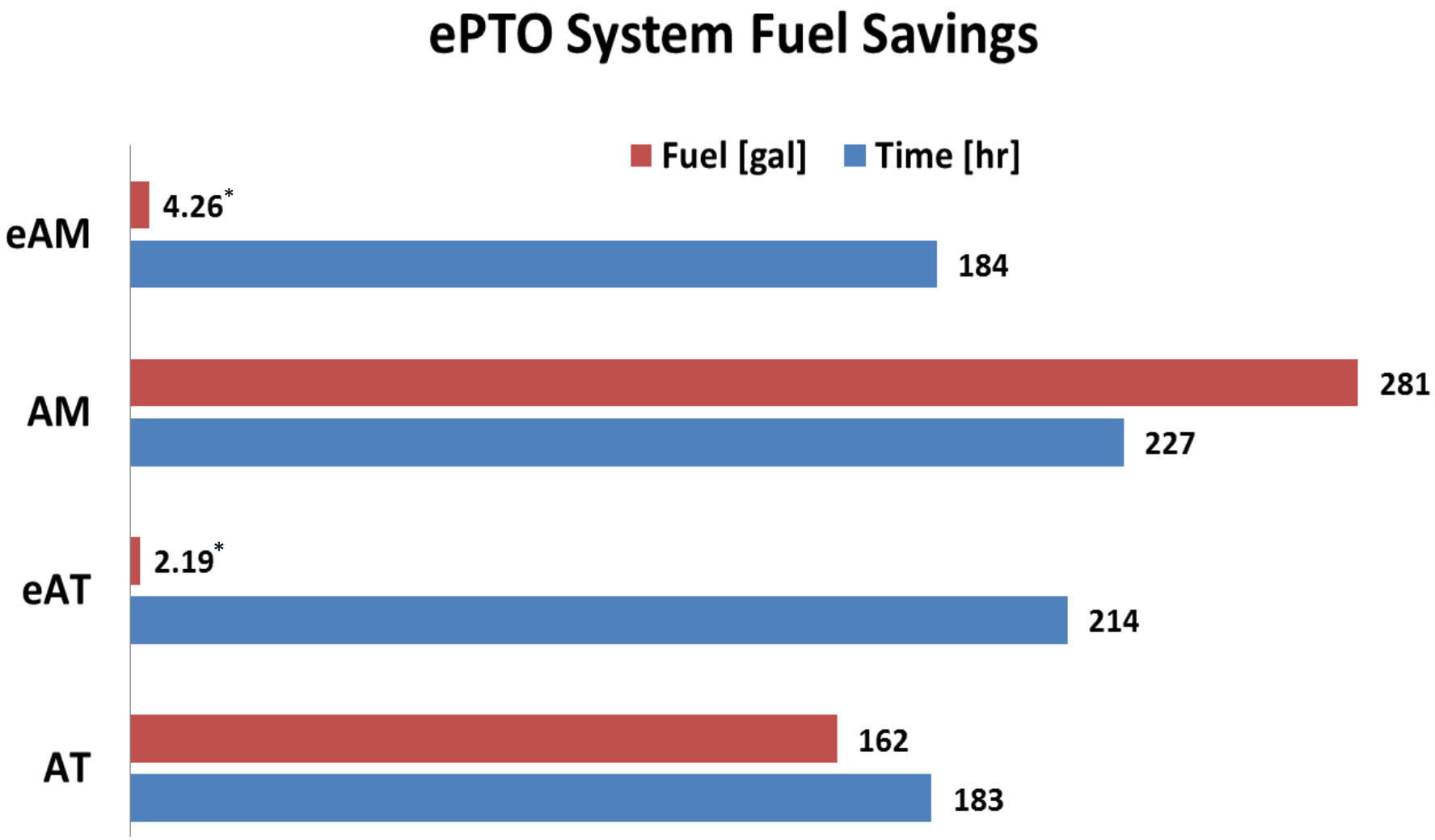


Hybrid Trucks





Fuel Savings



* 1 gallon of Diesel Fuel is equivalent to 37.6 kWh

Fuel Savings

- PTO operation requires relatively low levels of energy compared to idling of large displacement diesel engines
- Showed significant emission and fuel savings benefits from engine idle reduction at the jobsite
- Additional benefits:
  - Low noise enables longer work hours in residential neighborhoods
  - Low noise enables elevated jobsite safety
  - Auxiliary HVAC and 120 VAC outlets offer comfort and convenience for power tool use and battery charging
  - Plug-in charging can be used to maintain batteries and offset fuel use from charging

Thank You!

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Special Thanks:

DOE Vehicle Technologies Office

Vehicle Systems Program

Lee Slezak and David Anderson

National Clean Fleet Partnership

Mark Smith

INDUSTRY PARTNERS

PG&E

ALTEC INC.

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Appendix

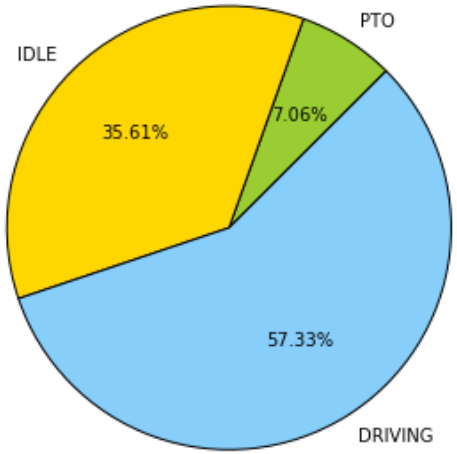
Comparison of Operational Time by Vehicle Type

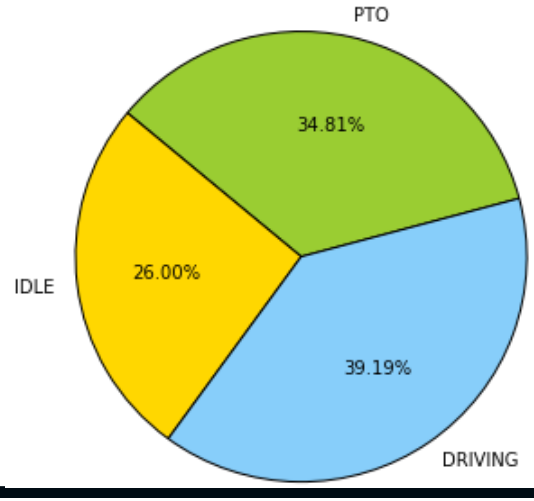
Comparing typical vehicle types

AT

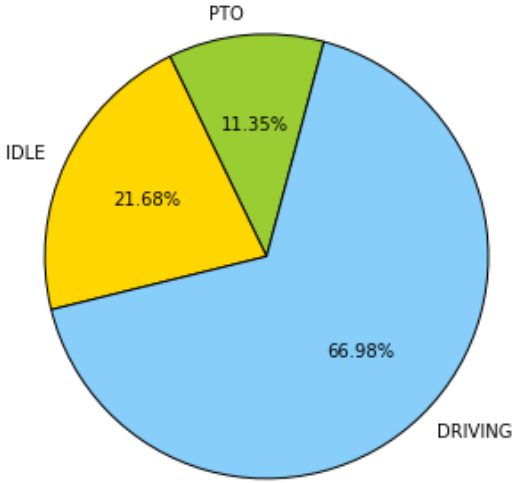
AM

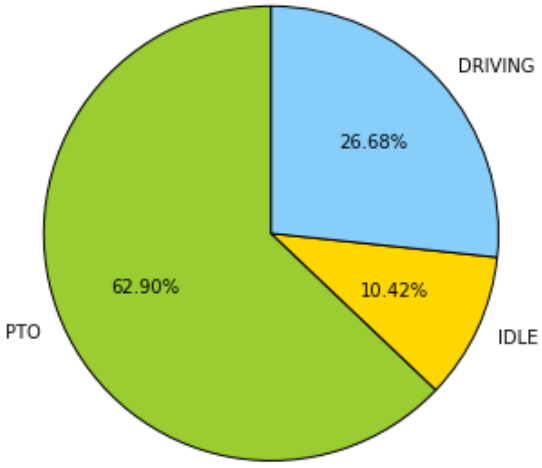
Conventional Trucks





Hybrid Trucks





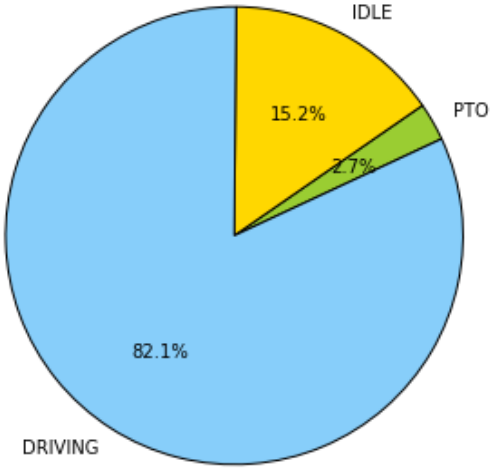
Comparison of Operational Fuel by Vehicle Type

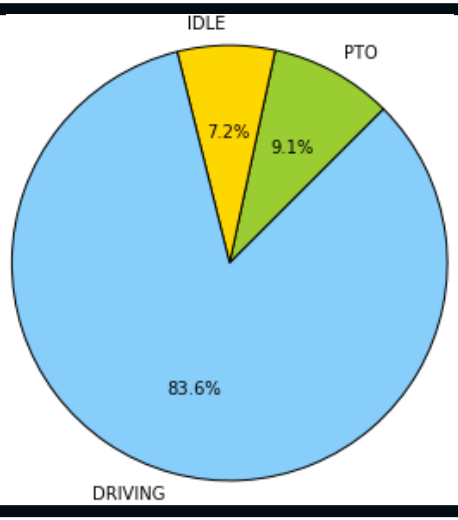
Comparing one typical vehicle type to each other

AT

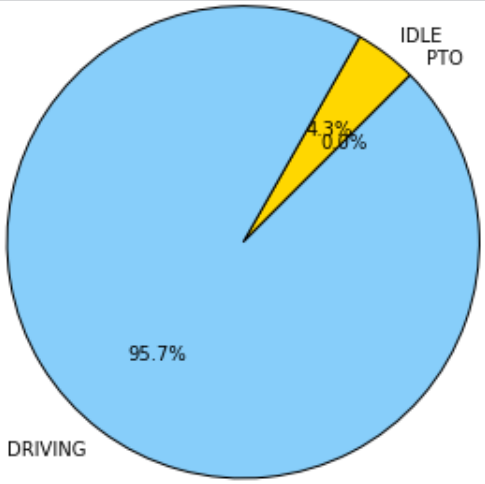
AM

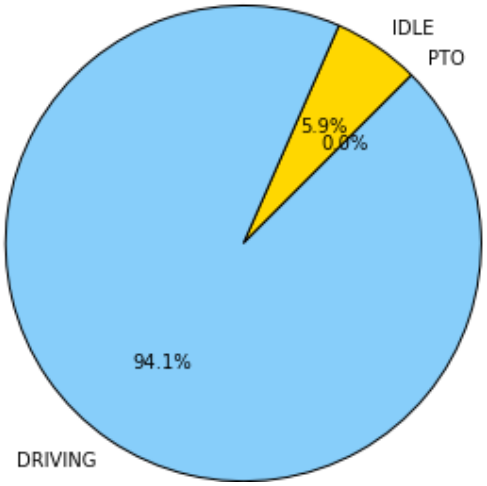
Conventional Trucks





Hybrid Trucks





NREL Fleet DNA

Objectives:

- Capture and quantify drive-cycle and technology variation for the multitude of medium- and heavy-duty vocations
- Provide a common data storage warehouse for medium- and heavy-duty vehicle data across DOE activities and labs – www.nrel.gov/fleetdna
- Integrate existing DOE tools, models, and analyses to provide data-driven decision making capabilities .

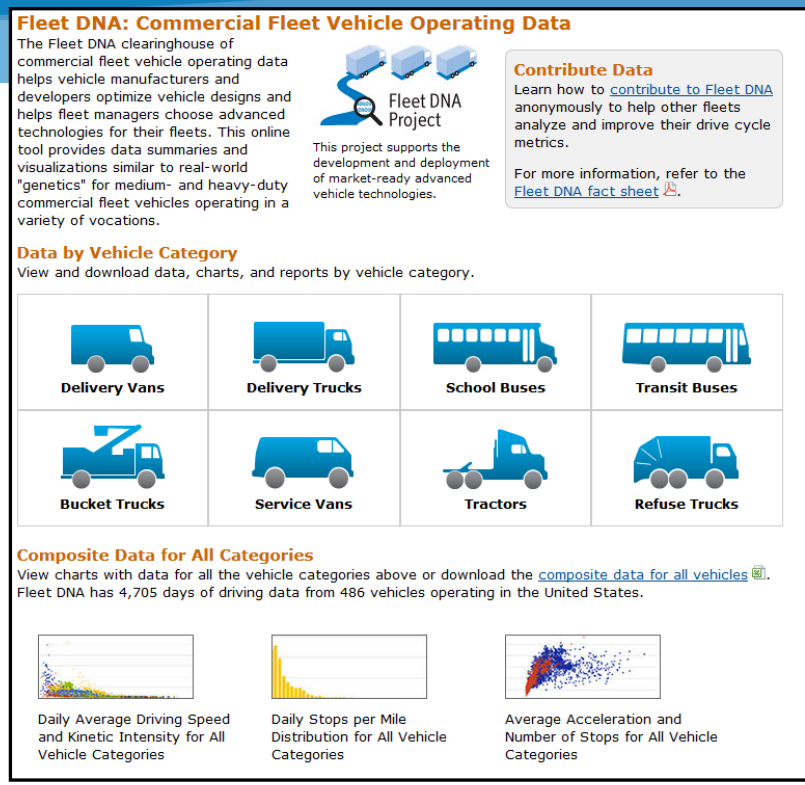
For Government : Provide in-use data for standard drive-cycle development, R&D, tech targets, and rule making

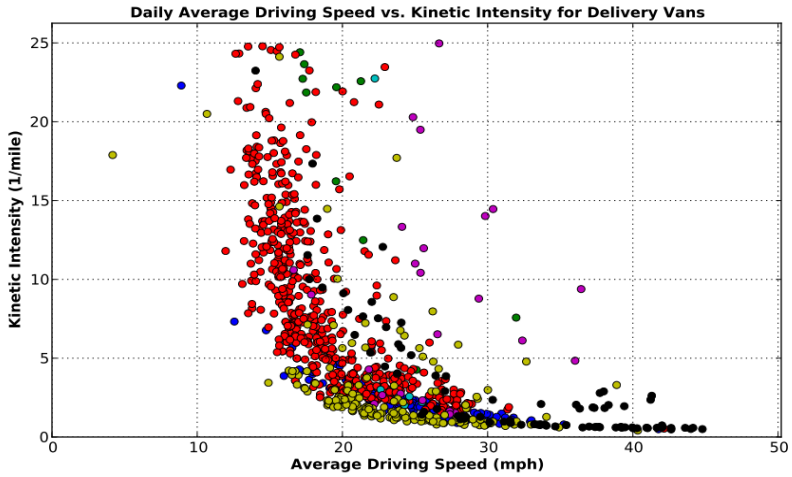
For OEMs: Real-world usage datasets provide concrete examples of customer use profiles

For Fleets: Vocational datasets help illustrate how to maximize return on technology investments

For Funding Agencies: Reveal ways to optimize impact of financial incentive offers

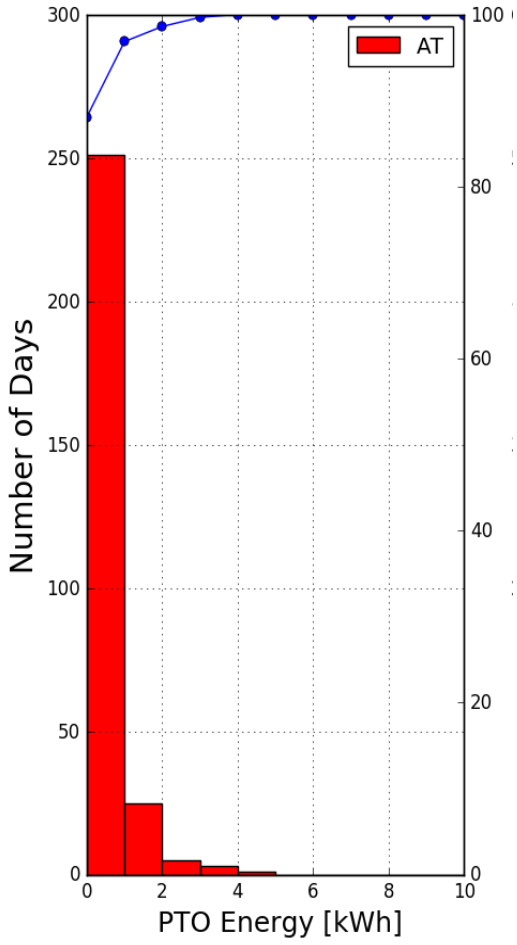
For Researchers: Provide a data source for modeling and simulation.

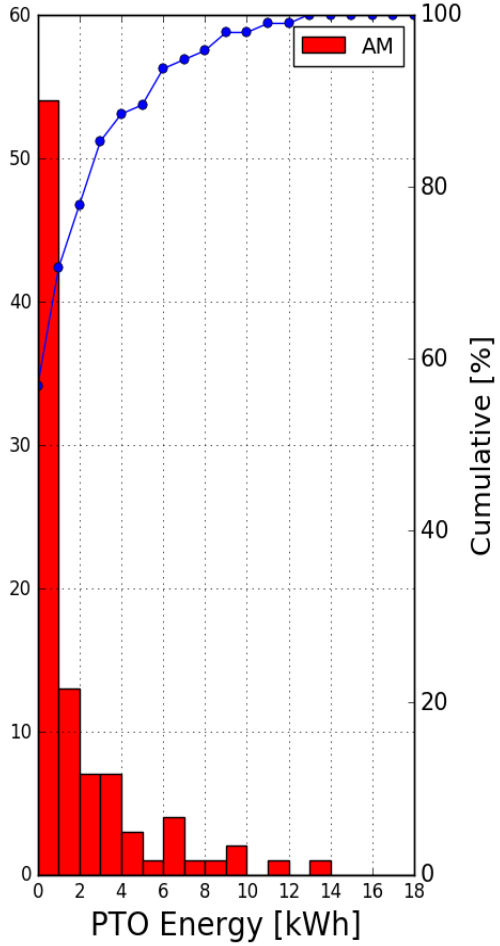




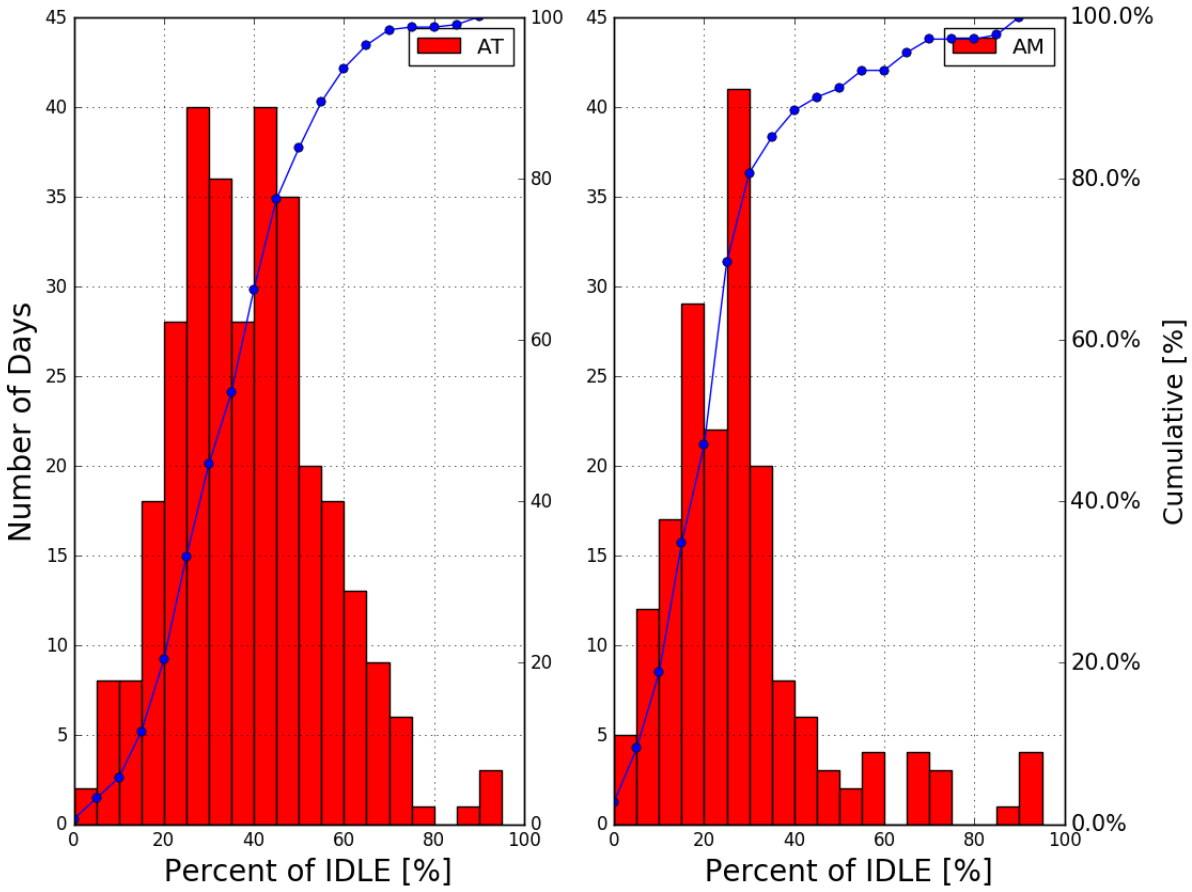
Daily Battery Usage for ePTO Operation

- The batteries on theses trucks were appropriate for the application.





Daily Percent Idle Time



Complete Stats

AT Vehicles	10
Total Engine on Time [hr]	3,742
Total Distance [mi]	60,800
Total Work [kWh]	119,084
Fuel [Gallons]	7,543
Fuel Econ. [mpg]	8.06
Driving Fuel Econ. [mpg]	9.11
Driving Time [hr]	1,964
Zero Speed Time [hr]	1,778
Zero Speed Fuel [Gallons]	866
IDLE Time [hr]	1652.88
PTO Time [hr]	397.5
Grid Energy [kWh]	14.29
Number of Days	604.0
Total Time [hr]	4,059

AM Vehicles	10
Total Engine on Time [hr]	688
Total Distance [mi]	8,574
Total Work [kWh]	29,946
Fuel [Gallons]	2,533
Fuel Econ. [mpg]	3.39
Driving Fuel Econ. [mpg]	4.11
Driving Time [hr]	280
Zero Speed Time [hr]	408
Zero Speed Fuel [Gallons]	448
IDLE Time [hr]	180.85
PTO Time [hr]	411.4
Grid Energy [kWh]	136.81
Number of Days	284.0
Total Time [hr]	871.4