Partnering with Industry to Advance Green Fleet Technologies

Northeast and Midwest Joint Equipment Management Meeting
Ron Schoon
June 24, 2013

NREL's Mission

"**NREL develops renewable** energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals."

Dr. Dan Arvizu

NREL R&D Locations

South Table Mountain

"Main Site"

National Wind Technology Center

**"Wind Site"**

Laboratory Snapshot

Only National Laboratory Dedicated Solely to Energy Efficiency and Renewable Energy

- Leading clean-energy innovation for 34 years

- 1740 employees with world-class facilities
  - Another 500 students, contractors, etc
  - Employees from 70 different countries

- Annual budget ~ $312M

- Campus is a living model of sustainable energy

- Owned by the U.S. Department of Energy

- Operated by the Alliance for Sustainable Energy LLC

Scope of NREL's Mission

| Energy Efficiency	Renewable Energy	Electricity Integration	Market Focus
Residential Buildings	Solar	Grid Infrastructure	Private Industry
Commercial Buildings	Wind and Water	Distributed Energy Interconnection	Federal Agencies
Personal and Commercial Vehicles	Biofuels	Battery and Thermal Storage	Defense Dept
	Hydrogen	Electric Transportation	State/Local Govt
	Geothermal		International
	Fuels & Vehicles-Related Technologies		

Underpinned with Basic Science Research

Photoconversion   Computational Science   Systems Biology

Focusing NREL's Roles on "Systems"

Community and Industrial Systems

Integrated and Sustainable

The Built Environment

Highly Efficient • Uses Renewables

Transportation Systems

Highly Efficient • Fuel Flexible

Electricity Generation Systems

Distributed and Utility-Scale Renewable Power

Fuel Production Systems

Use RE Resources

Sustainable Electricity System

Sustainable Transportation System
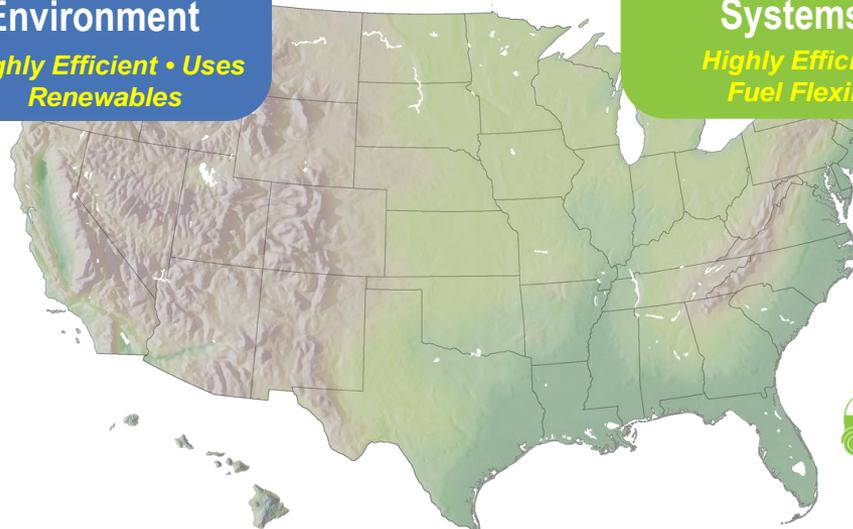
NREL Philosophy → Partnerships

- **NREL has more than 300 active partnering agreements**[*]

- **Roughly 50% our Cooperative R&D Agreements (CRADAs) are with small businesses and 25% with large businesses**

- **More than 40% of our Work for Others (WFO) agreements are with Federal, State or local governments and 25% are with businesses**

* As of 2011 fiscal yearend

NREL's Sites – Leading by Example

- **NREL Onsite Renewable Electricity** -- PV > 4 MW, Wind > 5 MW

Renewable Fuel Heating Plant -- displaces 70% of natural gas use

Science and Technology Facility -- first U.S. Federal LEED Platinum building

**Vehicle Fleet** -- >75% alternatively fueled

Research Support Facility – net-zero energy (1,250 personnel in 330,000 ft^2)

Setting Priorities and Overcoming Challenges

Most Important Challenge for 2013
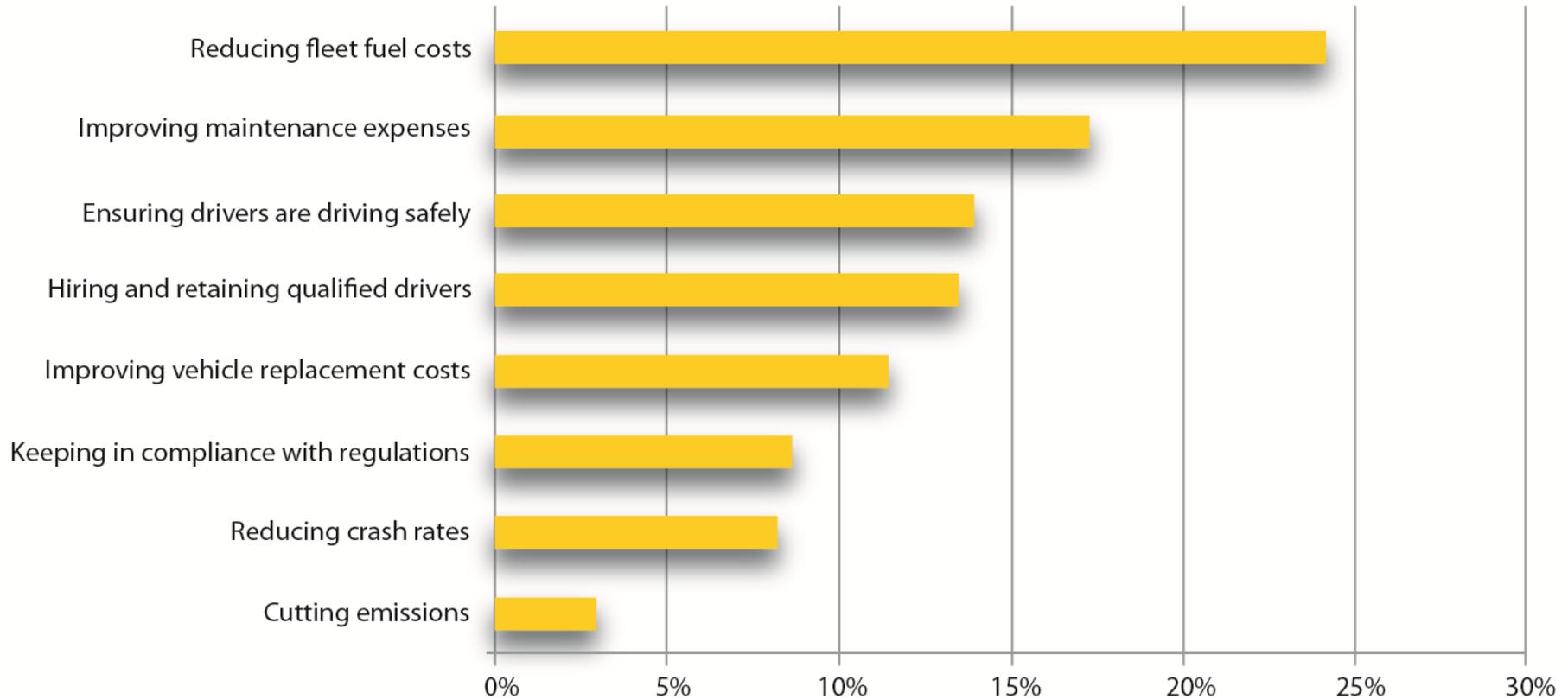
Source: GreenRoad's Fleet Leader 2013 Outlook
Courtesy of Automotive Fleet; December 11, 2012 (www.automotive-fleet.com)

One Size Does NOT Fit All

NREL's Role in Making Calculated Decisions

People

Advanced Fuels

Advanced Vehicles

Fleet Operations
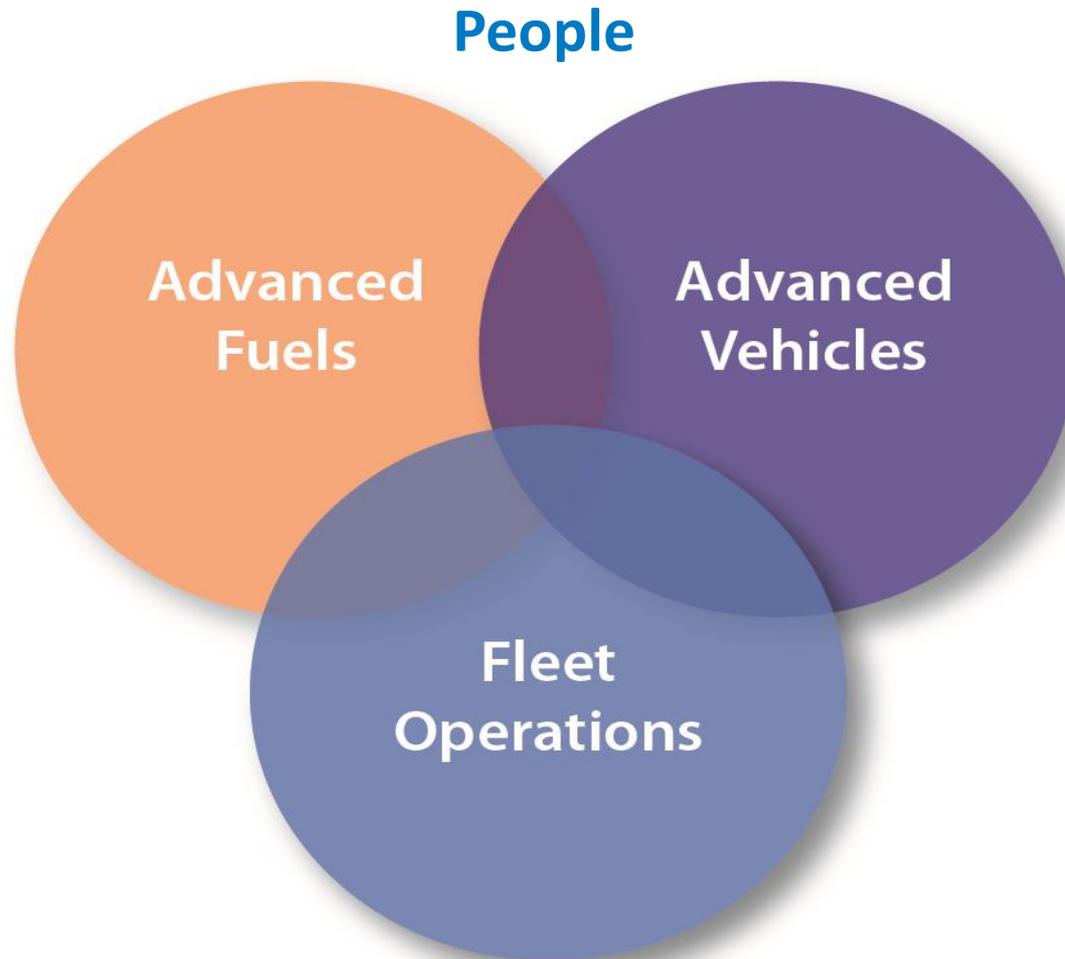
Compliance & Regulations

Intersection of Gasoline and Diesel Demand

Demand for Gasoline and Diesel (2004 - 2011)
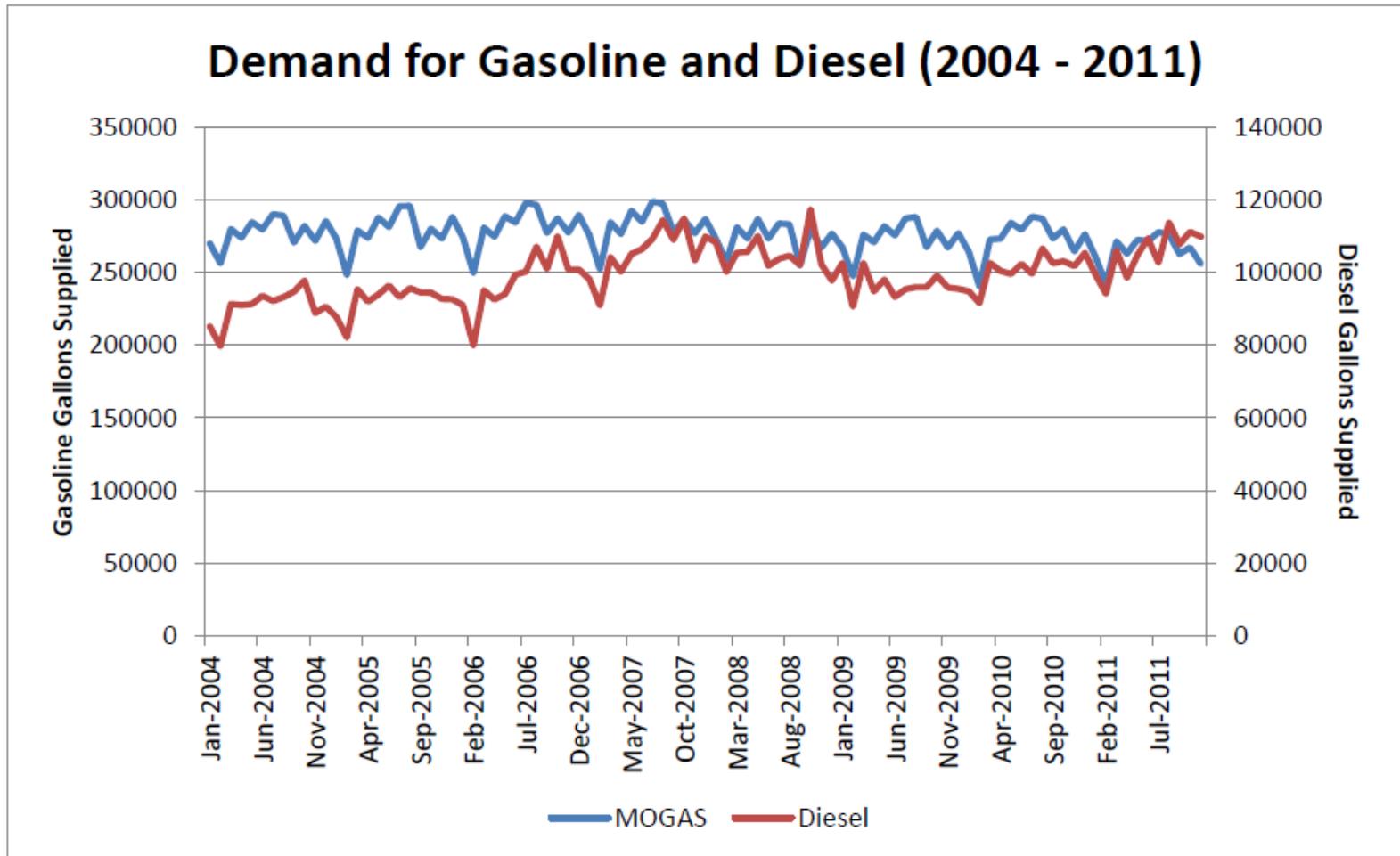
Source: NACS Retail Fuels Report 2012

Diesel Retail Prices Outpace Gasoline

Retail diesel price minus retail gasoline price

$ per gallon
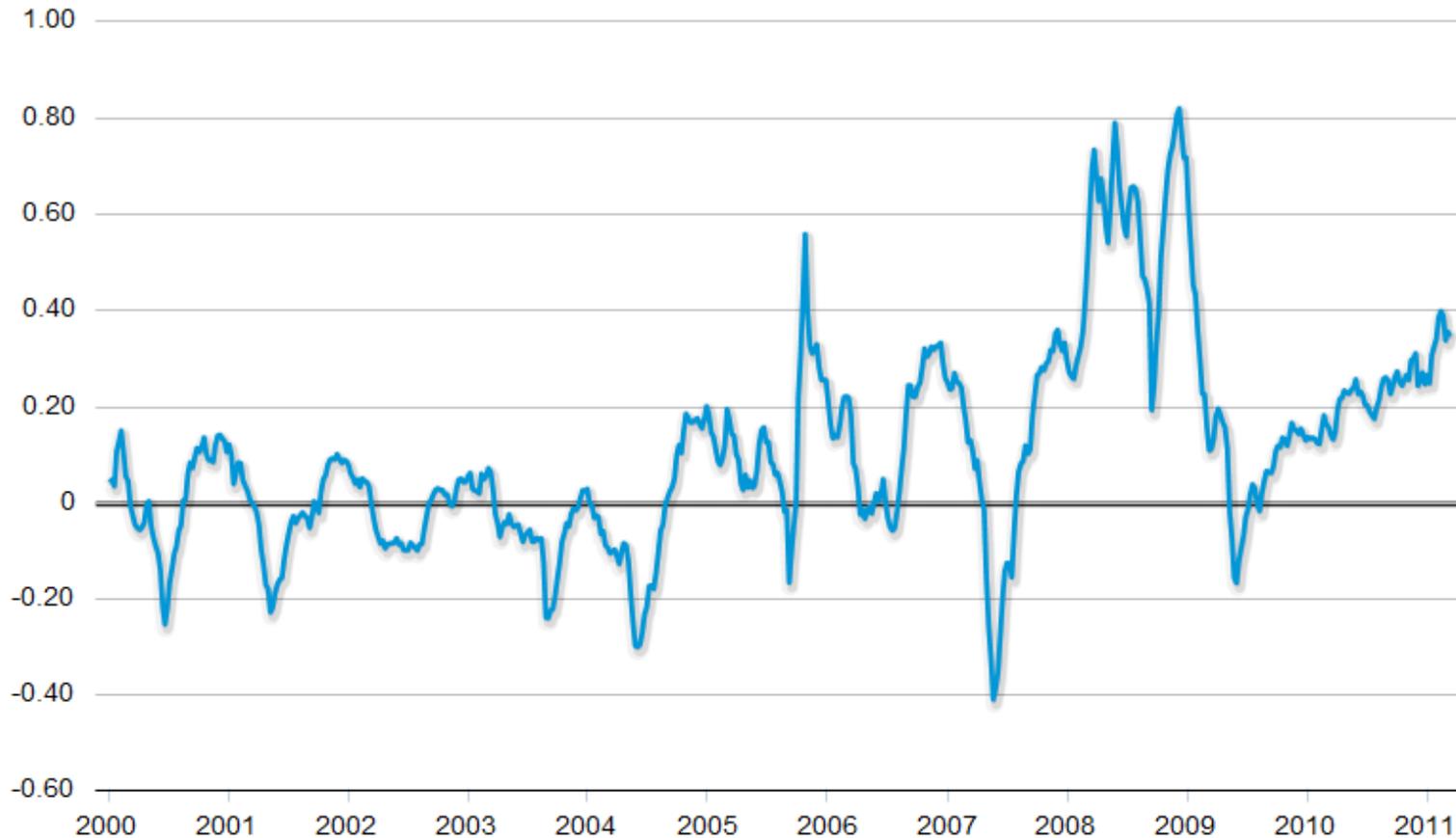
Source: U.S. Energy Information Administration, Weekly Retail Gasoline and Diesel Prices

The Rise of Natural Gas Use in Transportation

*Looking Forward: Natural gas will grow from 1% of today's global vehicle fuel mix to 4% by 2040.*

- *Compressed Natural Gas*
- *Liquid Natural Gas*
- *Gas-to-Liquid*
- *More R&D Underway*

U.S. Natural Gas Vehicle Fuel Consumption
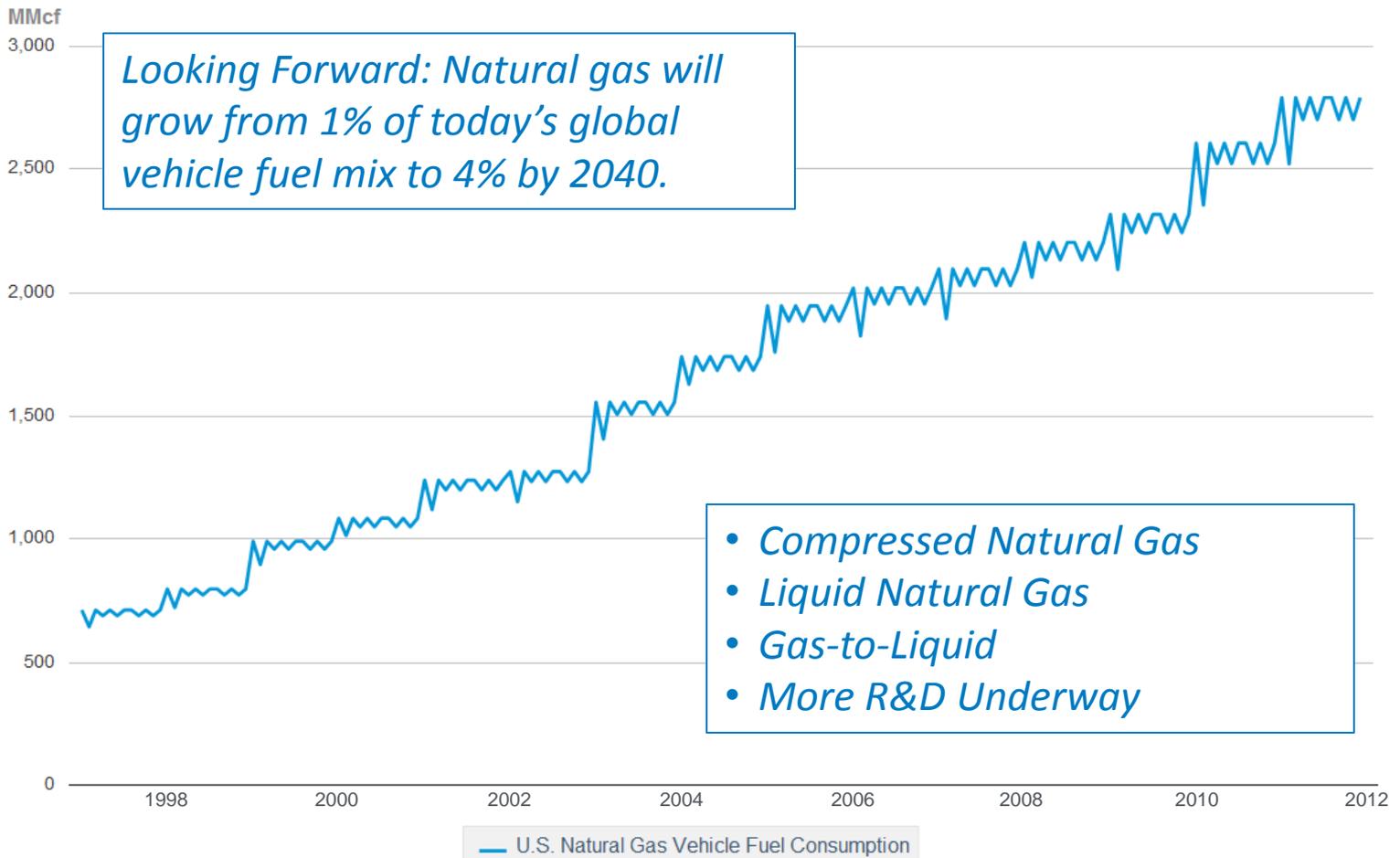
Source: U.S. Energy Information Administration

Natural Gas Price Volatility vs. Petroleum

NATIONWIDE FUEL PRICES — 13-Jan-11

Legend: Gasoline, w/o Tax; Diesel Fuel, w/o Tax; Commercial NG, $/100 cf
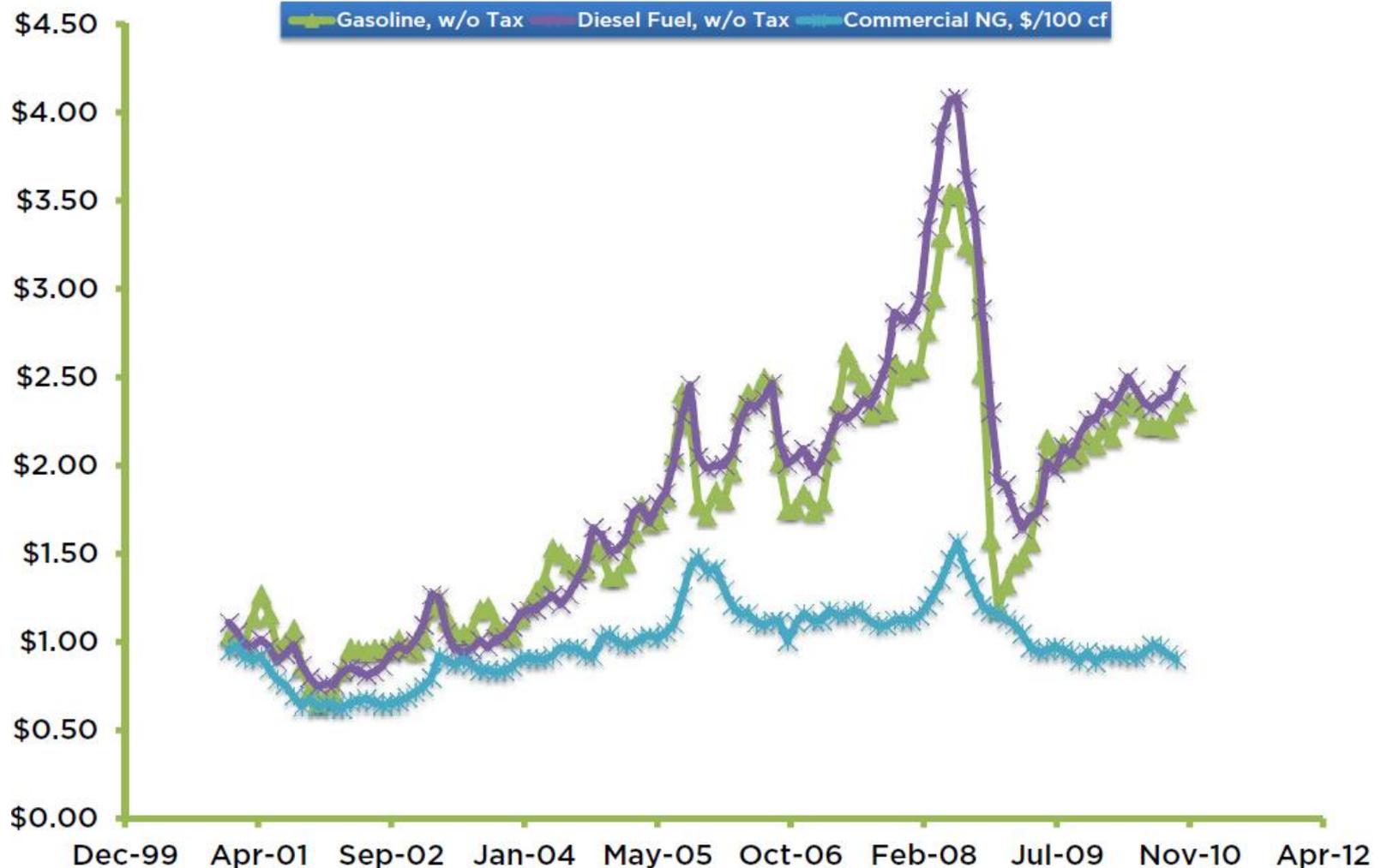
Source: U.S. Department of Energy

U.S. Natural Gas End Consumption

Mcf: November 2012

Category	Value (Mcf)
Commercial & Residential	1,974,999
Lease & Plant Fuel	116,249
Pipeline & Distribution Use	60,406
Transportation Fuel	2,700

Axis: 0 — 500,000 — 1,000,000 — 1,500,000 — 2,000,000 — 2,500,000
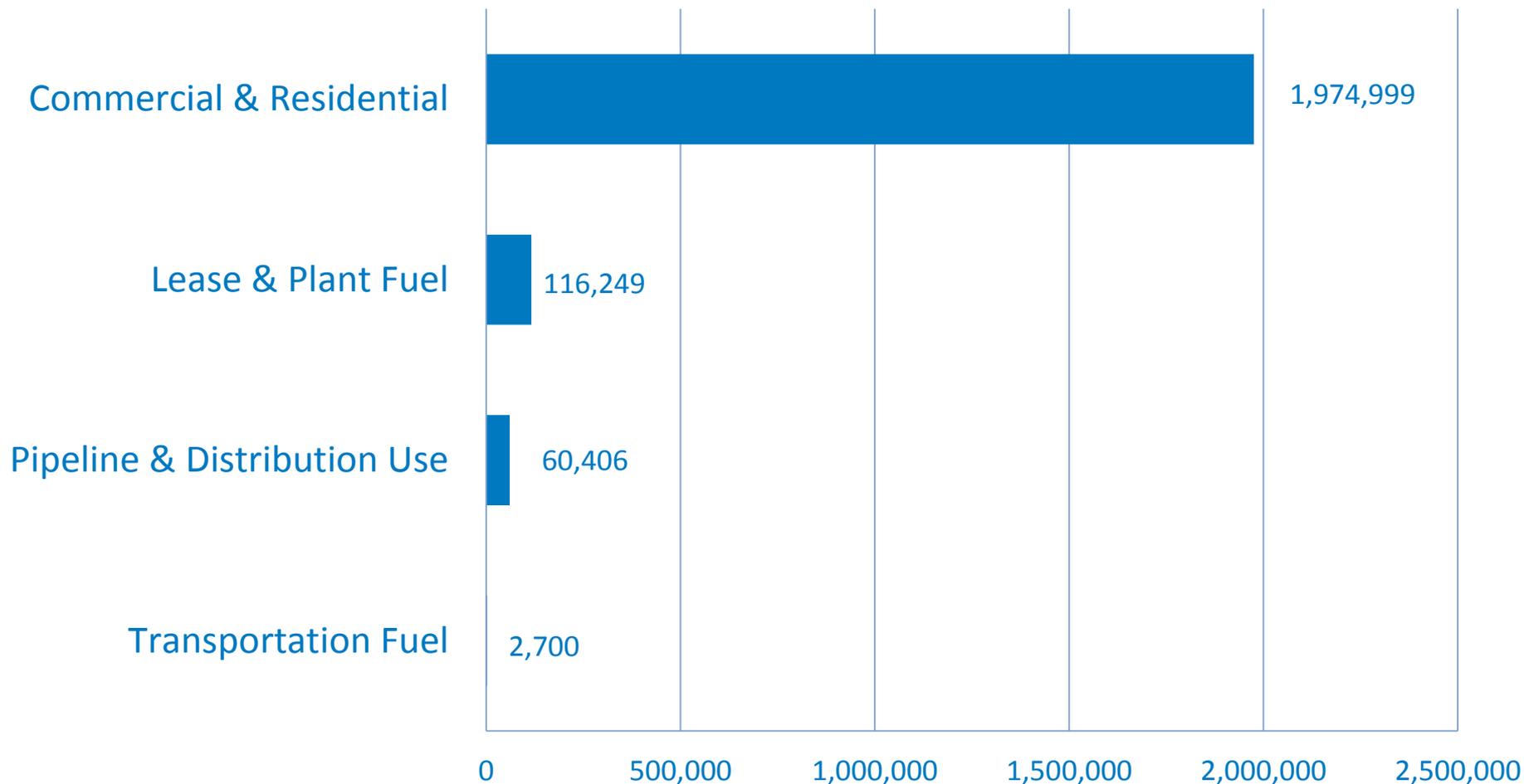
World Transportation Fuel Demand by Type

Millions of oil equivalent barrels per day
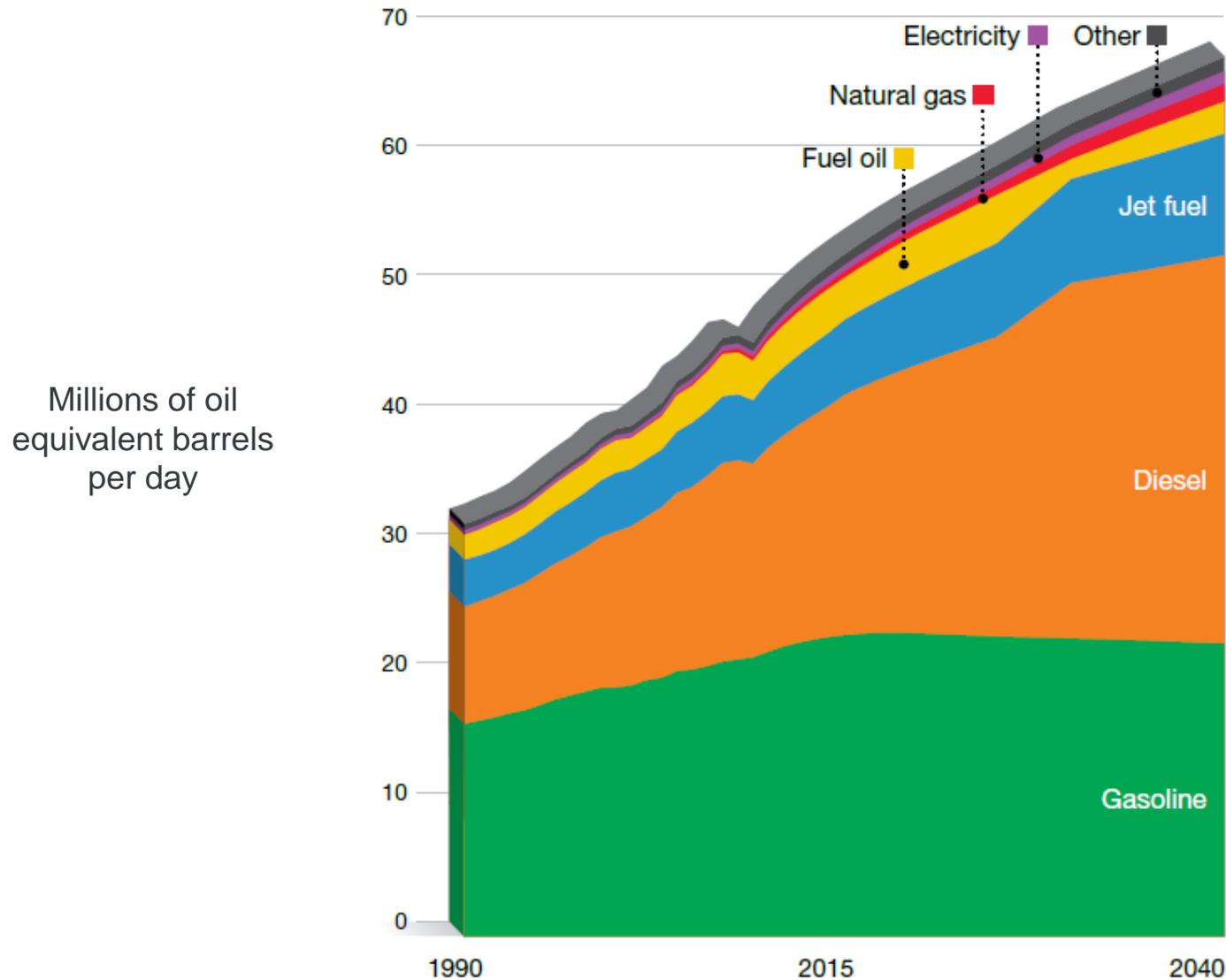
Source: Exxon Outlook for Energy 2012: A View to 2040

Spectrum of Advanced Biofuel Technologies

Near Term

Long Term

Ethanol: Grain or cellulosic material

Biodiesel: Transesterified vegetable and seed oils

Green Diesel: Hydrogenated fats, waste oils, or virgin oils

Other Fermentation Products: Butanol, acetates, lactates, etc.

Pyrolysis Liquids: Alternative feedstock to refinery

Synthesis Gas: Fischer-Tropsch liquids, methanol, dimethyl ether, or mixed alcohols.

Algae-Derived Fuels: Source of triglycerides and carbohydrates

Hydrocarbon Fuels: From hydrogenation or produced in-situ.

Looking Beyond Liquid Fuels

Vehicle technologies are advancing beyond liquid fuels, like these electric hybrids.

Electric vehicles, however, come with their own challenges.

Let's Talk Operations

NREL Approach to Support Fleet Operations

1 **Analyze Your Fleet:** Obtain data to deeply understand your fleet. How are you using your fleet now; What do you really need your fleet to do?

2 **Analyze Your Options:** Simulate potential fuel and vehicle technology applications against captured duty cycles.

3 **Select Your Solution Portfolio:** Understand what is right for entire fleet, depot, or route.

Background:
Lots of Work by the DOE and National Labs to Collect, Analyze and Report on Newly Deployed Advanced Technology

Buy it, then try it: Evaluations of newly deployed technology are very useful, but is a backward looking approach

Try it before you buy it. Simulate: Evaluations could also be forward looking ….but good data is needed for accurate assessment.

Refined Data to Make Informed Decisions

Drive Cycle Data & Analysis · Vocational Fleet Database · Modeling & Simulation Tools · Online Resources and Tools
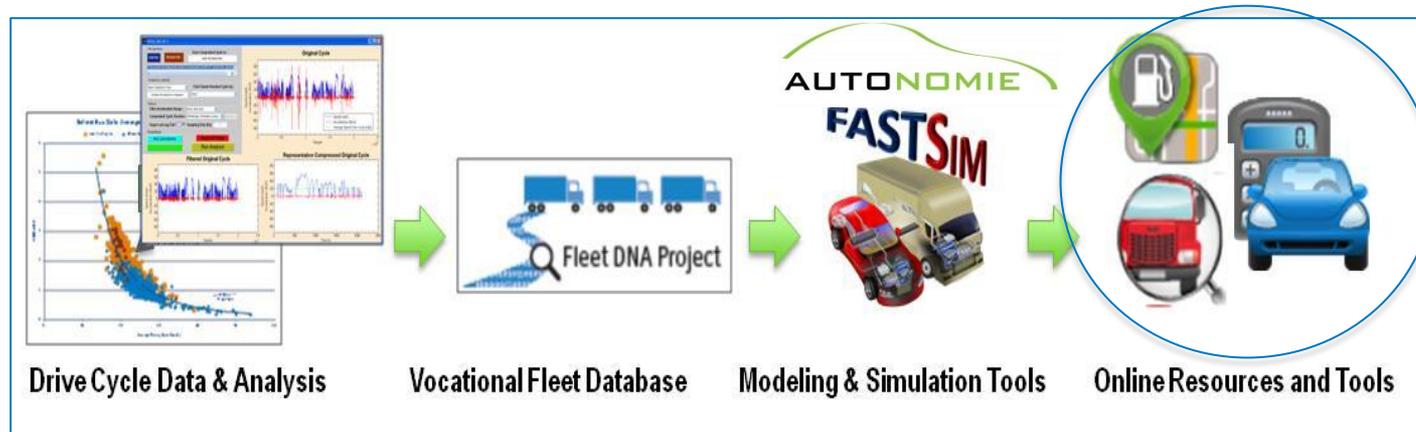
- **Drive Cycle / Duty Cycle Data**
  - speed
  - acceleration
  - grade
  - miles, hours driven
  - power take off / aux loads

- **Operating Condition Data**
  - temp, humidity, etc.
  - payload
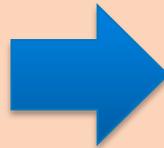
- **Vocational Analysis**
  - route / fleet averages

- **Situational Modeling & Simulation**
  - sensitivity studies
  - placement optimization
  - expected performance

- **On-Line Tools**
  - Clean Cities
  - Alternative Fuels Data Center

An Approach to Assess New Technology

Collect In-Use Data:

- Acquire Field Data

- Process Data:
    - **DRIVE™**
    - FAT (Fleet Analysis Tool)

- Compile & Summarize:
    - **(Fleet DNA**
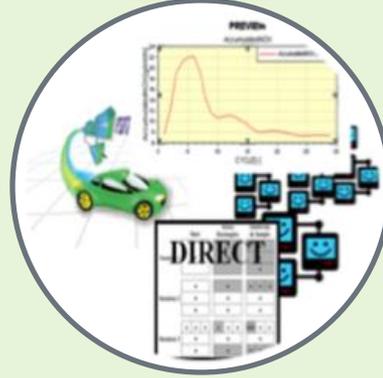
Analyze and Simulate:

- Utilize User Specific Field Data

- Vehicle Simulation:
    - **FASTSim**
    - Autonomie
- Benefit Analysis:
   - best technology for specific application

Validate in Laboratory:

- Validate field data in a controlled setting

- Quantify emissions and fuel consumption

- Explore limits, assess changes to system

Effects of Variable Duty Cycle:

1. **Fuel economy variation**

2. **Component life variation**

3. **Life cycle costs/payback**

4. **Placement of vehicles for maximum ROI**

Understand duty cycle = Understand right technology for application
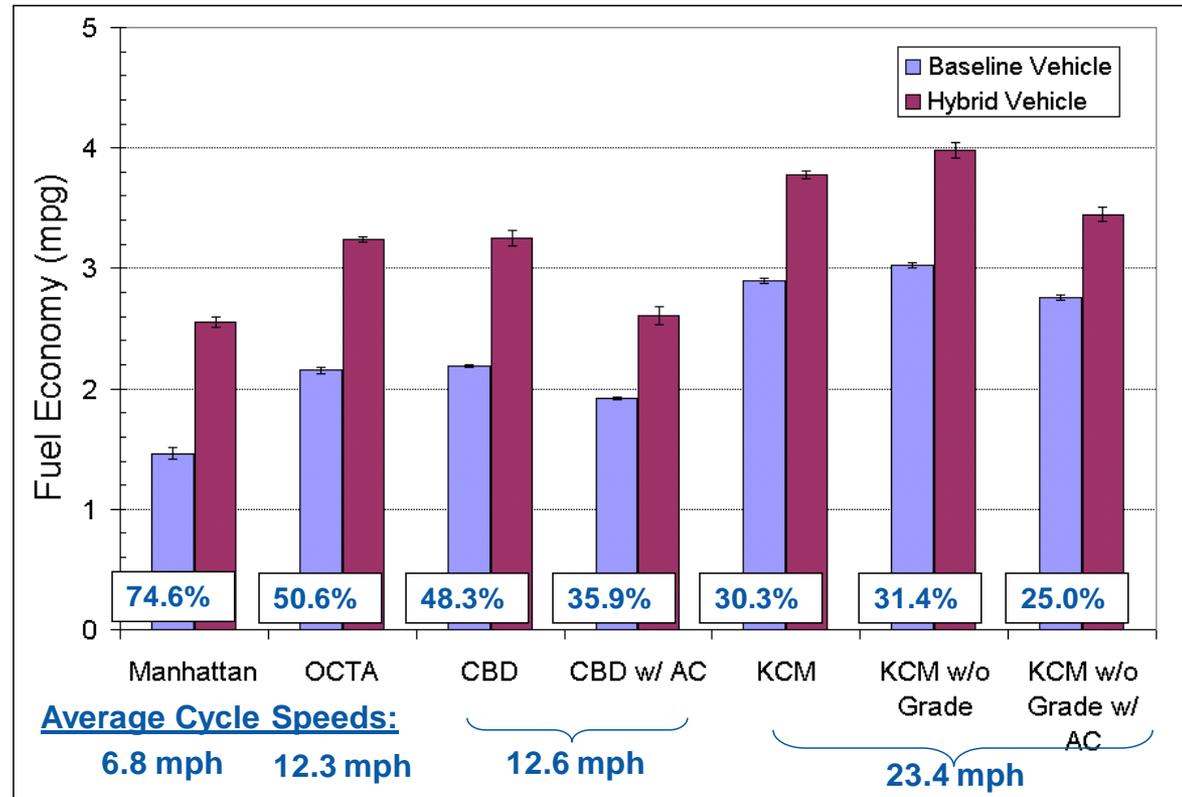
Example: HEV Bus Fuel Economy Improvements

Drive cycle important to assess technologies such as: aero devices, low rolling resistance tires, engine sizing, transmission options, light-weighting, battery usage, driver feedback, etc.

Understanding Vocational Behavior: Fleet DNA

Fleet DNA Project

A vocational data base of vehicle use information: Phase 1 and Phase 2

- Phase 1: Pre-Sorted data sets

- Phase 2: Sortable Data Sets


User can custom sort and graph:

- Class

- Vocation

- Fuel Type (or drivetrain)

- Region (4)

- Sub-region (based on census map)

Understanding the Big Picture: Fleet DNA

- **DOE funded, NREL in partnership with ORNL**

- **20+ high value metrics / data products available for each vocation**

- **Provides reference data for industry drive-cycle development**

- **OEMs: better understanding of customer use profiles**

- **Fleets: information on how to achieve the maximum ROI from technology investment**

- **Funding Agencies: optimize impact of financial incentive offers**

- **R&D Activities: data source for modeling and simulation.**

Fleet DNA Project

School Bus Data Average Driving Speed vs. Kinetic Intensity
■ School District 1 ◆ School District 2 ▲ School District 3 — Power (Aggregate Data)

$y = 2182.6x^{-2.324}$
$R^2 = 0.7533$

KI (1/mile) vs. Average Driving Speed (mph)

Data subsets represent multiple fleet sources and locations
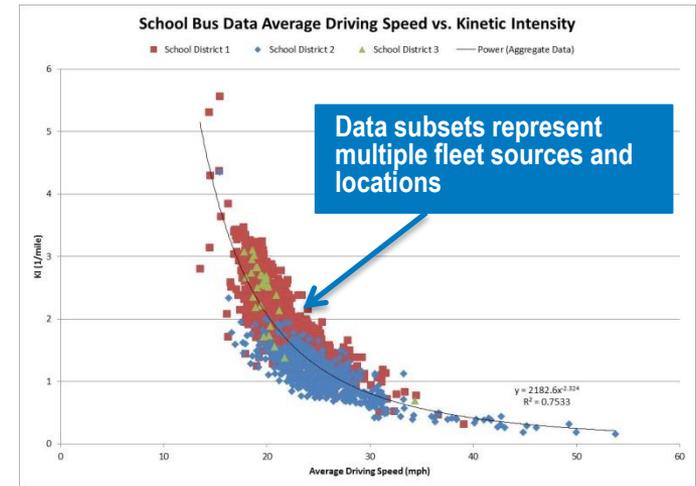
Data: Aggregated and Anonymous Fleets Not Identified!

Preliminary Participation:

- **NTEA / GTA**
- **DOE**
- **SCAQMD**
- **CARB**
- **ORNL**

- **Calstart**
- **Zonar**
- **Many, Many Fleets and OEMS**

Example Data Output of Fleet DNA: Phase I
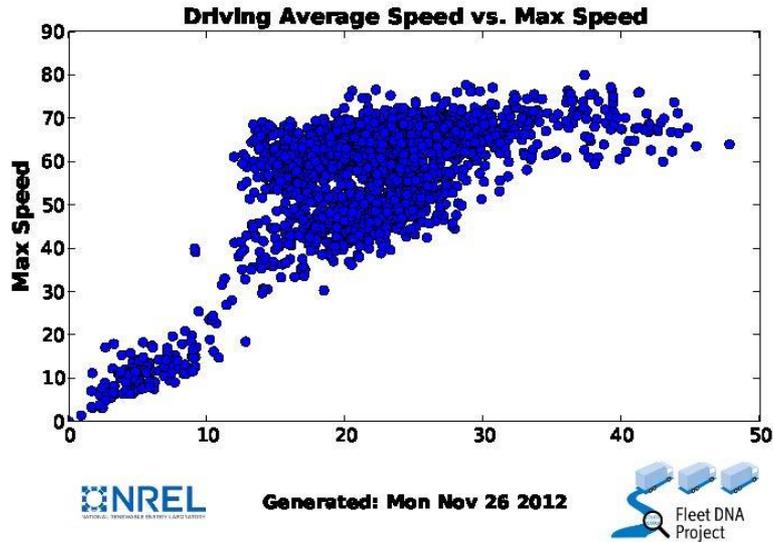
Data Products to visualize and calculate vehicle use patterns

Visualizations show data variability

Data analysis enables calculated decision making
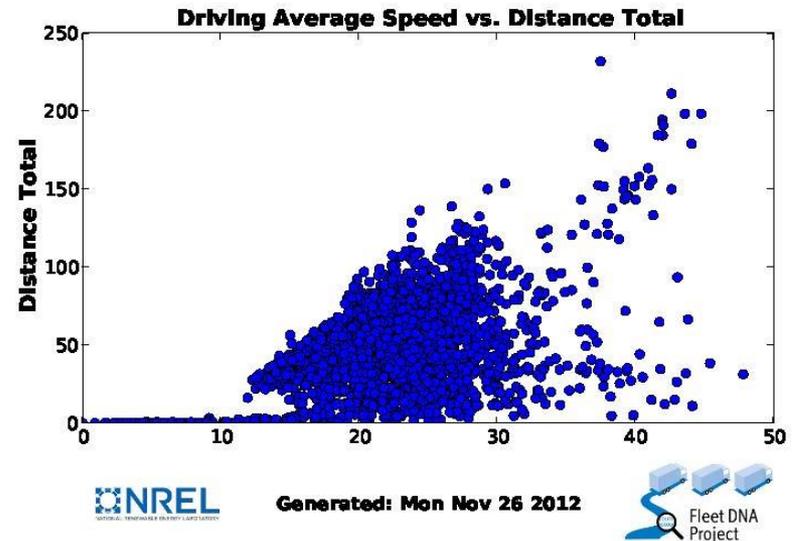
Data Sets

Available

- Class 4-6 Delivery Vans (parcel, food, uniform)

- Class 3-4 Light Aerials (telecom service)

- Class 5-6 Aerial (utilities)

- Class 3 Service Vans (telecom)

- Class 8 Tractor / Trailer (beverage delivery)

- Class 6 Box Trucks (in-city delivery)

- EV MD Delivery Vans (multiple uses)

Acquired, Coming Soon

- Class 8 OTR Tractor Trailers

- Transit Buses

- Shuttle Buses (airport, specialty)

- Refuse Trucks (multiple types)

- Tow Trucks

Pursuing

- Class 8 OTR Tractor Trailers

- Transit Buses

- Shuttle Buses

- Refuse Trucks

- Tow Trucks

- High PTO Use Work Trucks

DOE Data Priorities:
1) National Fuel Consumption
2) Payback / ROI Success
3) Scalable or Transferable technology

Required Data

Parameter	Frequency	Source	Required	Desired
Time	1 hz	CAN / J1939	x	
Date	1 hz	CAN / J1940	x	
Vehicle ID	1 / day	CAN / J1941	x	
Vehicle Speed (MPH)	1 hz	CAN / J1942		x
Engine Speed (RPM)	1 hz	CAN / J1943		x
Engine Mode (on/off)	1 hz	CAN / J1944		x
Instantaneous Fuel Usage (gram)	1 hz	CAN / J1945		x
Cumulative Fuel Usage (litre)	1 hz	CAN / J1946		x
PTO Engage (y or n) if applicable	1 hz	CAN / J1947		x
PTO % (if applicable)	1 hz	CAN / J1948		x
Elevation	1 hz	CAN / J1949	x	
GPS Latitude	1 hz	GPS	x	
GPS Longitude	1 hz	GPS	x	
GPS HDOP	1 hz	GPS	x	

Typical data required from fleets for inclusion into Fleet DNA

- may vary by application / situation
- other data can be useful if available and needed: torque demands, ambient temp, gear, etc....

Hardware Requirements / Utilized

NREL hardware:

- gathers basic drive cycle data + additional if desired

- TSI 747 Pro - GPS only units

Other Options:

- Use Existing Telematics – leverage large scale, long term tracking efforts

- Fleet Analysis + Telematics providers for in depth and specialized short term data capture

Data Analysis: Drive Cycle Data

## **D**rive-cycle **R**apid **I**nvestigation, **V**isualization **and E**valuation **Tool (DRIVE)**

- Created to help fleets and OEMs understand vehicle usage for proper vehicle placement, design and testing

- Combines large amounts (days or weeks of usage) of user data, filters, creates new cycles

- Integrated with Fleet DNA for public use

- Quickly processes and analyzes data :
  - over 150 metrics
  - histograms
  - scatter plots
  - Creates custom cycle
  - Recommends standard cycles
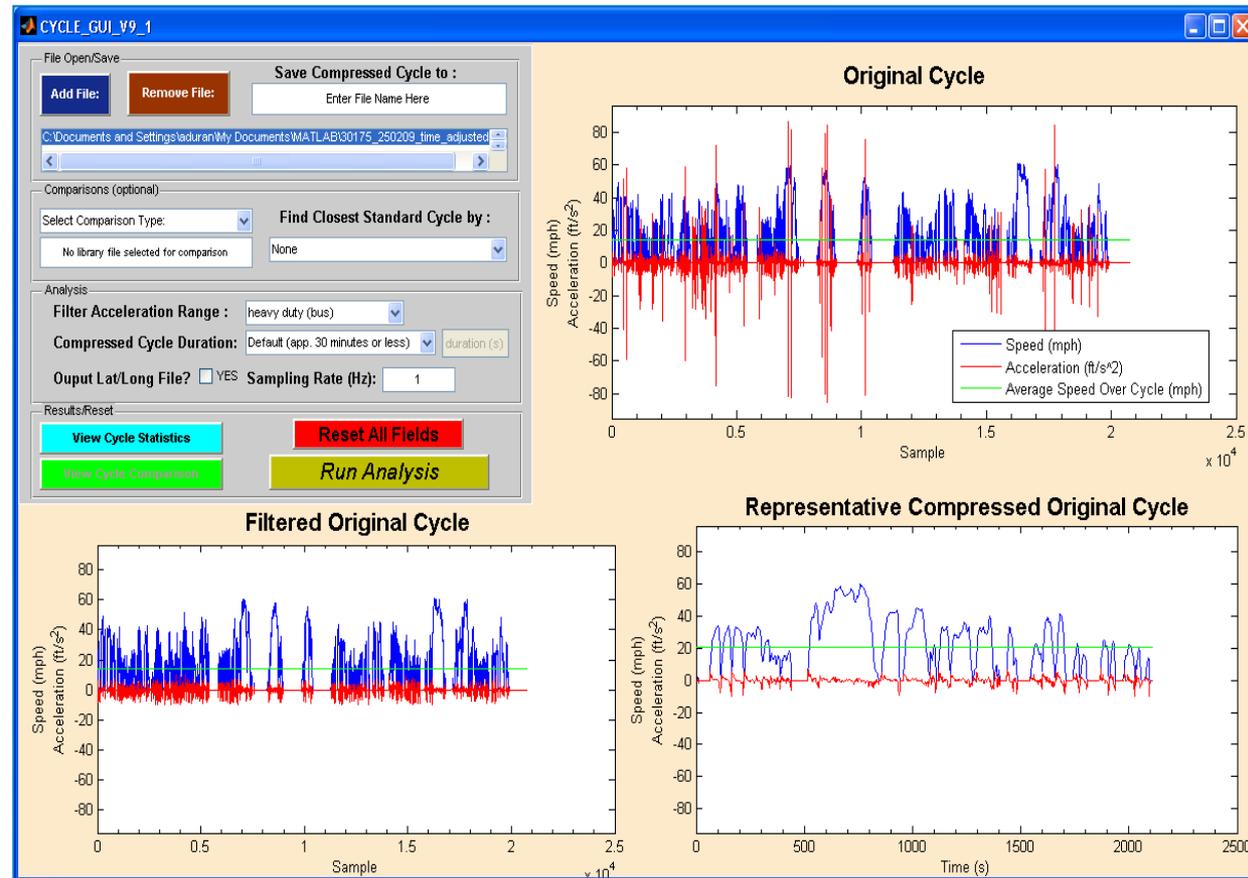
Data Analysis: Simulation

Future **A**utomotive **S**ystems **T**echnology **Sim**ulator **(FASTSim)**

- Vehicle modeling tool to similar to Autonomie

- FastSim is well suited for conducting large data sweeps

  - short run time in accessible Excel environment

  - Validated performance output: fuel economy and cost results

PEV Fuel Cost per Mile Relative to Baseline Diesel
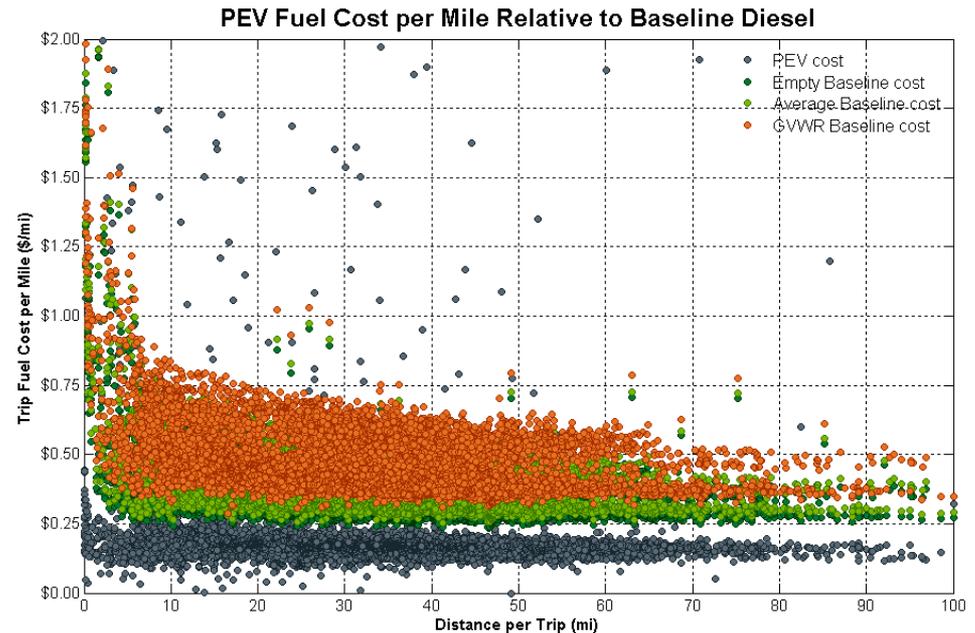
Example Use: Fleet DNA & the GTA

GTA: membership with interest in improving vehicle efficiency

+

Fleet DNA: DOE supported database and analysis of technology

- **GTA identifies & recruits interested fleet /technology for data analysis**

- **Fleet DNA provides drive cycle analysis back to data provider**

- **Fleet DNA performs simulation of vocational data set to assess benefit of technology for the specific usage patterns:**
  - Aero improvement
  - Rolling Resistance
  - Engine sizing
  - Transmission options
  - Mass reduction
  - Driving behavior
  - HEV, EV options
  - Anti-Idle options
  - Natural Gas and Biofuel options
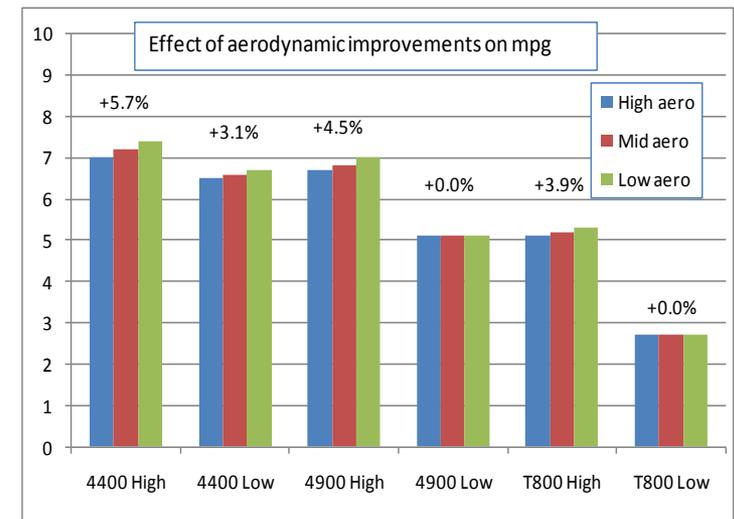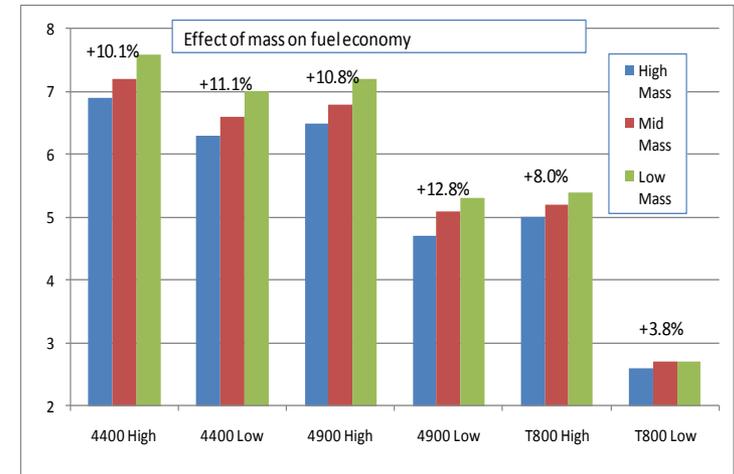
Summary: Calculated Decision Making

Capture Baseline Data
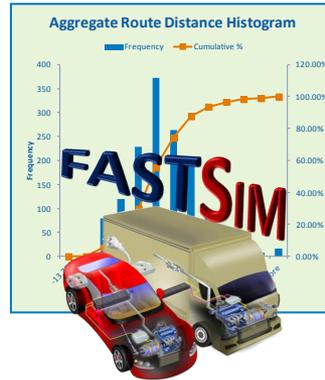
**Analyze Data &
Simulate Performance**
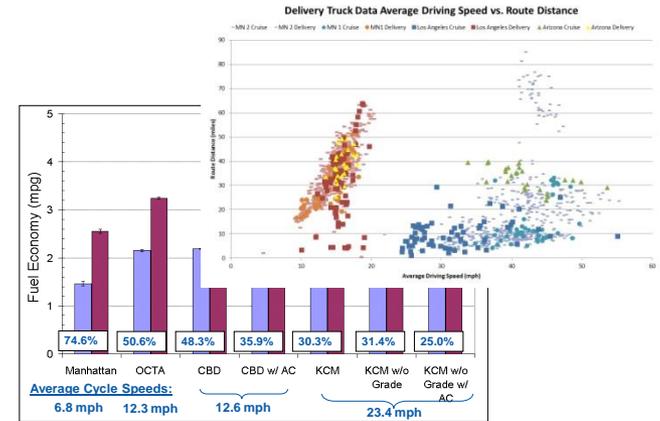
**Identify best application for
technology**

1. Provide Fleets, OEM's and Researchers with refined data and analysis of options specific to their needs
2. Create and maintain an accessible data base for public use
3. Recommend drive cycles
4. Identify most appropriate technologies for observed drive cycle data

Interested in Participating?

www.nrel.gov/vehiclesandfuels/fleettest/research_fleet_dna.html

FleetDASH Tour

- **Available datasets provide *Actionable* Analytics/Business Intelligence**
- **Economies of scale: Standard platform for all Federal agencies**
- **Track fuel consumption throughout the year (30K ft. view)**

https://federalfleets.energy.gov/FleetDASH/

FleetDASH Tour

Search
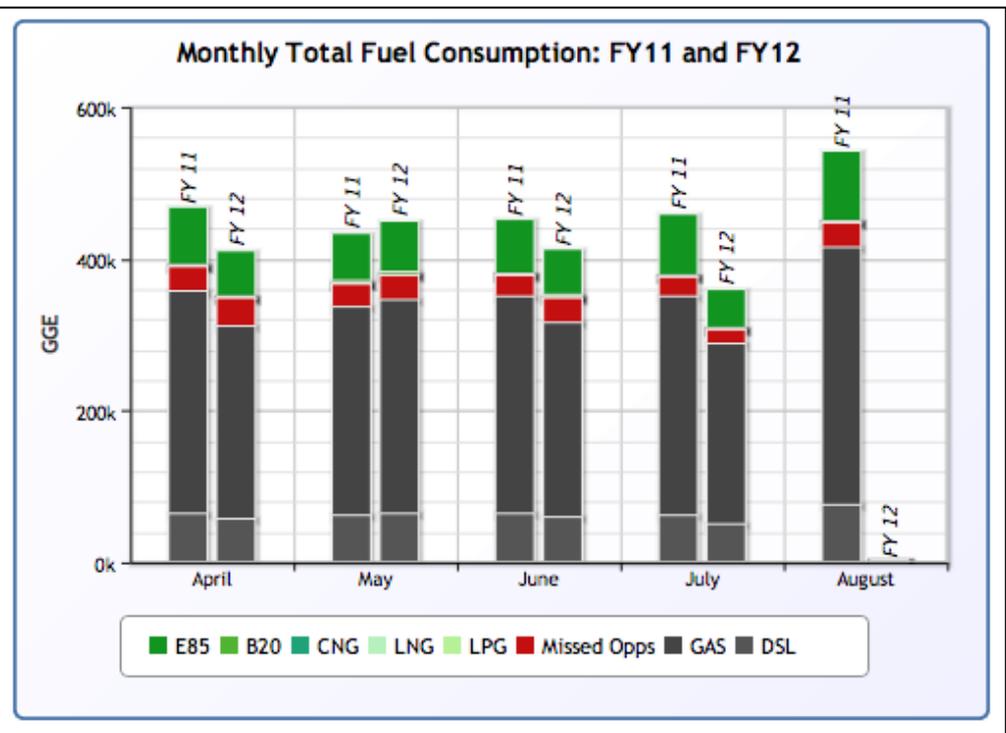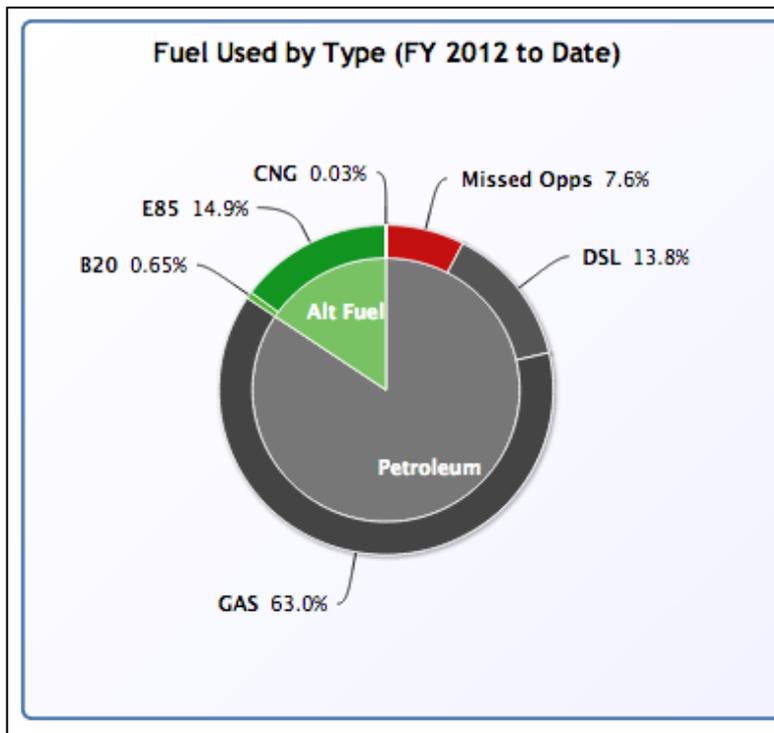
Fleet	Federal Supply Service; All Other ▾	Tag		SEARCH

Missed Opportunity Summary: 8 Missed Opportunities totaling 105 GGEs involving 4 vehicles.

• Vehicle/Transaction level detail reveals precisely WHO and WHERE

Vehicles in the Federal Supply Service; All Other fleet

Tag	Vehicle Fuel Type	Petroleum		Alt Fuels		This Month	Missed Opportunities	
		Total GGE	% of Total Fuel Use	Total GGE	% of Total Fuel Use	Total Fuel Use (GGE)	Total GGE ▾	% of Total Fuel Use
G111377G ⓘ	E85	44	100%	0	0%	44	41	93%
G414581G ⓘ	E85	35	100%	0	0%	35	35	100%
G411680H ⓘ	E85	14	100%	0	0%	14	14	100%
G107115H ⓘ	E85	13	100%	0	0%	13	13	100%
G410651E	DSL	9	100%	0	0%	9	0	0%

Transactions corresponding to Tag# G111377G from the Federal Supply Service; All Other fleet

Station Name	Address	City	State	Zip	Fuel Type Purchased	Date	GGEs Purchased	Missed Opportunity ▾	Alternate Station
Circle K - 01947	5501 E GOLF LINKS RD	Tucson	AZ	85711	GAS	2013-02-01	4.05	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-04	12.81	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-08	14.23	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-14	10.18	Yes	Alternate Station

FleetDASH Tour

Search

Fleet Federal Supply

Missed Opportunity

Vehicles in the

Tag	
G111377G	ⓘ
G414581G	ⓘ
G411680H	ⓘ
G107115H	ⓘ
G410651E	D

Vehicle Details (G11-1377G) ✕

Customer Detail:

RANDAL PATTERSON
Federal Supply Service, All Other
GSA, AREA PROPERTY OFFICE - 12575 NORTH
SKODA DRIVE
MARANA AZ 856530000
RANDAL.PATTERSON@GSA.GOV
(520)4000308 - Ext:

Vehicle Detail:

Tag:	G11-1377G
Make/Model:	CHEVROLET - IMPALA
Fuel Type:	Ethanol / Unleaded Gasoline
Vehicle Type:	Sedan/St Wgn Midsize
BOAC:	479142
SIN:	10B.11GA
Garage Zip:	85653
Date Assigned:	4/28/08
Emergency Response:	No
Law Enforcement:	No
Avg Monthly Mileage:	537.00

Vehicle 1 of 15 on this page >

- Vehicle/Transaction level detail reveals precisely WHO and WHERE

		This Month	Missed Opportunities	
Total Use	Total	Total Fuel Use (GGE)	Total GGE ▼	% of Total Fuel Use
		44	41	93%
		35	35	100%
		14	14	100%
		13	13	100%
		9	0	0%

Transactions corre ... **ply Service; All Other fleet**

Station Name	Address					te	GGEs Purchased	Missed Opportunity ▼	Alternate Station
Circle K - 01947	5501 E GOL LINKS RD					-02-01	4.05	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-04	12.81	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-08	14.23	Yes	Alternate Station
Giant Store 6615	6150 S KOLB RD	Tucson	AZ	85756	GAS	2013-02-14	10.18	Yes	Alternate Station

FleetDASH Tour

- Vehicle/Transaction level detail reveals precisely WHO and WHERE

Alternative Fuels Data Center

To Summarize . . .

o **The Energy and Transportation Sectors** are intersecting and overlapping

-- new frontier for Energy Systems Integration research

-- future diesel fuel prices are likely to be less predictable

o **Additional Complexity to Manage:** Diversified power train technologies

-- more challenging optimization problem

-- new tools are available to help match optimal solution to your application

Thank You!

Northeast and Midwest Joint Equipment Management
Meeting
Ron Schoon
June 24, 2013

Visit us online at www.nrel.gov