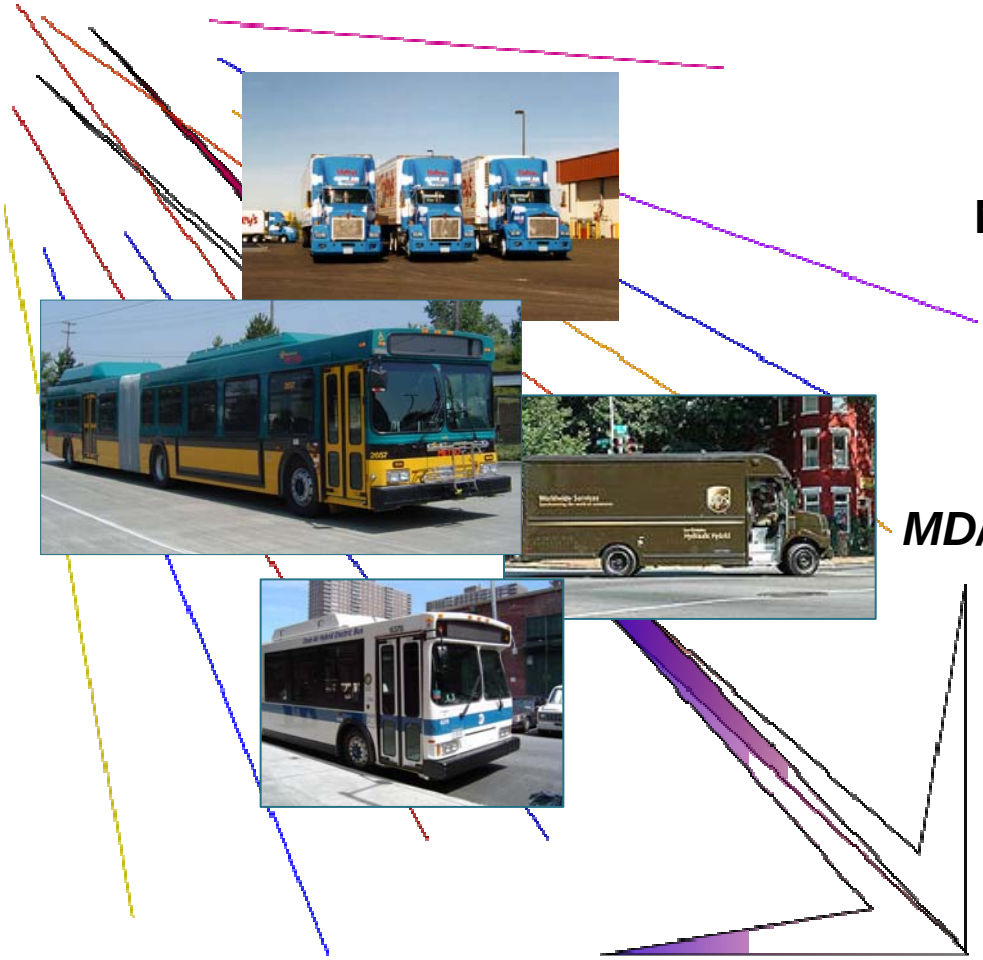
MD/HD Advanced Technology Evaluations



Kevin Walkowicz

National Renewable Energy Laboratory
kevin_walkowicz@nrel.gov
phone: 303.275.4492

DOE Vehicle Technologies Program
Advanced Vehicle Testing Activity
MD/HD Advanced Technology Evaluations

North Marriott Hotel and Conference Center
Bethesda, Maryland

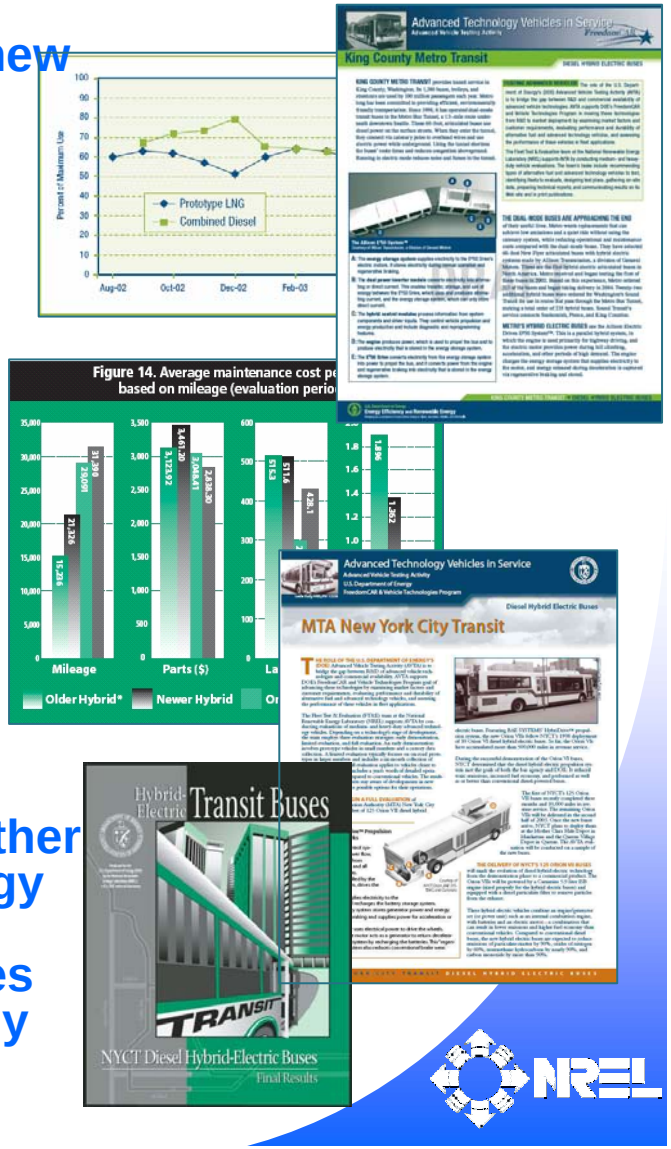
February 28, 2008

This presentation does not contain any proprietary or confidential information

Purpose/Benefits of Work:

Evaluates the in-use performance of advanced vehicle technologies in high fuel usage classes of MD/HD vehicles (Class 3-8, 10,000 lbs GVW and up)

- **Provide real world feedback on performance of new technology vs conventional**
- **6-12 month, on-road evaluations**
- **Obtain and analyze data such as:**
  - **Operating cost/mile**
  - **Fuel economy**
  - **Unscheduled maintenance**
  - **Scheduled maintenance**
  - **Warranty issues**
  - **Reliability (miles between failure)**
  - **Implementation issues from a fleet's perspective**
  - **Duty cycle analysis**
  - **Subsystem performance**
- **Provide data to help fleets, manufacturers and other R&D organizations considering similar technology**
  - **Publish data**
  - **Acquire for vehicle modeling activities**
  - **Identifies additional barriers to energy efficient vehicles**



Accomplishments to Date / Background:

Project began as part of the DOE Alternative Fuel Truck and Bus Evaluation Project:

- Over 10 years and 15 vehicle evaluation sites to date.
- As part of the Advanced Vehicle Testing Activity, project has evolved into on-road evaluations of any technology with potential to save substantial fuel – not just alternative fuel. New fuel efficient technologies considered each year for new evaluation.
- NREL has established a proven protocol and analytical tools for acquiring and analyzing fleet provided and on-vehicle data. Also developed common format for reporting results to industry and R&D community for commercialization of advanced technology
- Latest interests are focused on renewable fuels, HEV and plug-in HEV for the MD/HD industry
- Work is focused on obtaining and reporting operational data (mpg, maintenance and reliability), but will provide in-depth analysis on subsystems and other areas which become of interest

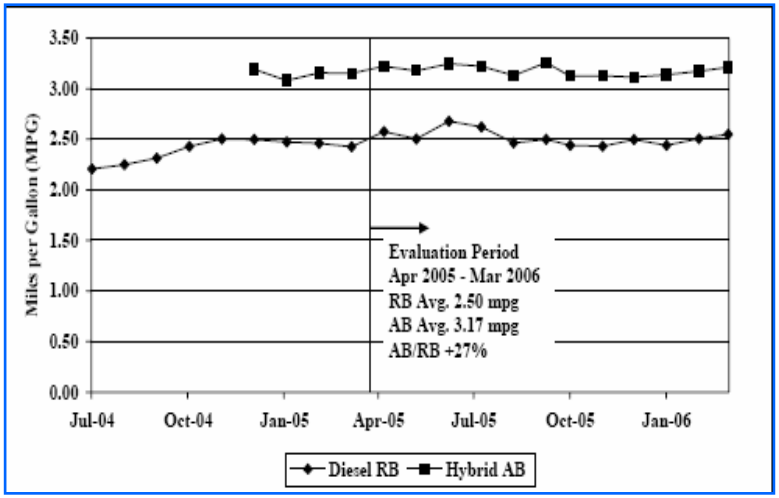
Recent Accomplishments to Date:

Technology	Completion Date
United Parcel Service (UPS) CNG Delivery Vans	2002
Ralphs Grocery EC-Diesel Class 8 Delivery trucks	2003
City of LA Dual Fuel LNG/Diesel Refuse trucks	2004
Norcal LNG CI / diesel pilot ignition Waster Haul Truck	2005
Capstone Charge Depleting Microturbine HEV	2006
Capstone Charge Depleting LPG C Microturbine HEV	2006
King County – GM Allison 'dual mode' HEV transit bus	2006
NYCT – 2002 BAE Series HEV transit bus	2006
NYCT – 2004 BAE EGR equipped Series HEV transit bus	2007
Long Beach – ISE Gasoline Fueled HEV transit bus	2007

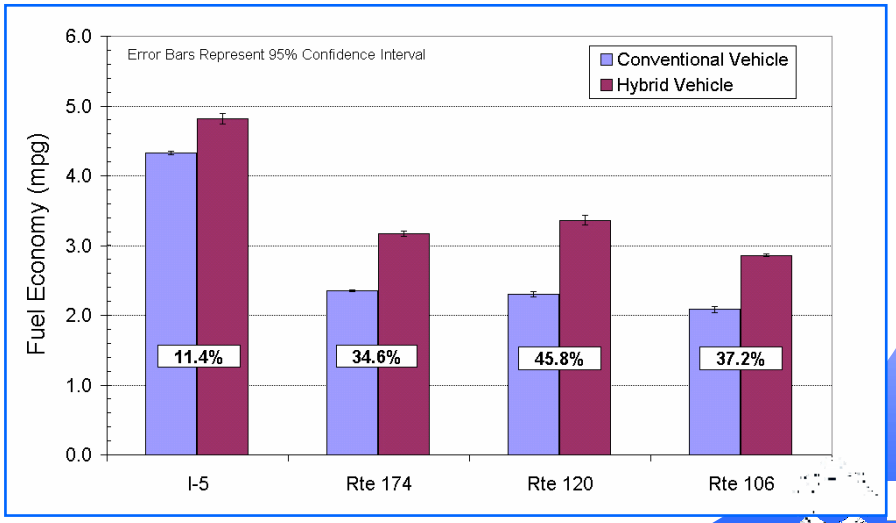
Relevant Outcomes from Recent Work:

FY07 - King County – Evaluated GM Allison parallel HEV transit bus

- **Mapped in-use duty cycle and documented on-road vs in-lab fuel economy – shows importance of duty cycle**



- Documented on-road performance: 27% improvement vs diesels
- Captured duty cycle route and created new composite cycle
- Tested (in-house) 30-75% improvement on dyno on standard cycles (depending on cycle)



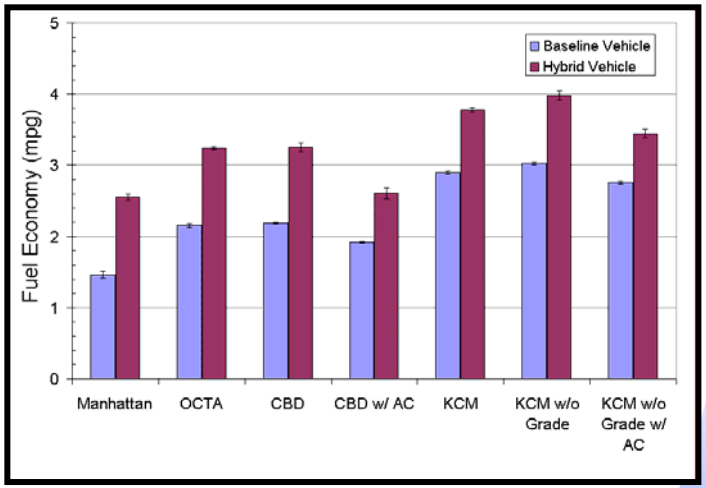
Relevant Outcomes from Recent Work:

FY07 - King County – Evaluated GM Allison parallel HEV transit bus

- **Obtained field data on A/C use and grade and documented effect of on mpg**

- **Documented durability of NiMH battery packs and hybrid system**

Category	Diesel Ryerson Base	Hybrid Atlantic Base	Hybrid Difference	Hybrid South Base
Monthly Average Mileage per Bus	2,949	3,096	+5%	3,957
Fuel Economy (mpg)	2.50	3.17	+27%	3.75
Fuel Cost per Mile ($) (@$1.98/gal)	0.79	0.62	-22%	0.53
Total Maintenance Cost per Mile ($)	0.46	0.44	-4%	0.41
Propulsion-Only Maintenance Cost per Mile ($)	0.12	0.13	+8%	0.13
Total Operating Cost per Mile ($)	1.25	1.06	-15%	0.94
Miles Between All Road calls	5,896	4,954	-16%	4,696
Miles Between Propulsion Road calls	12,199	10,616	-13%	8,547

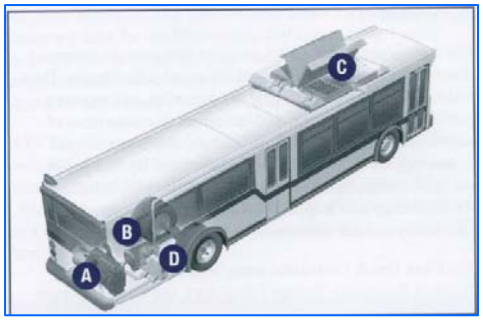


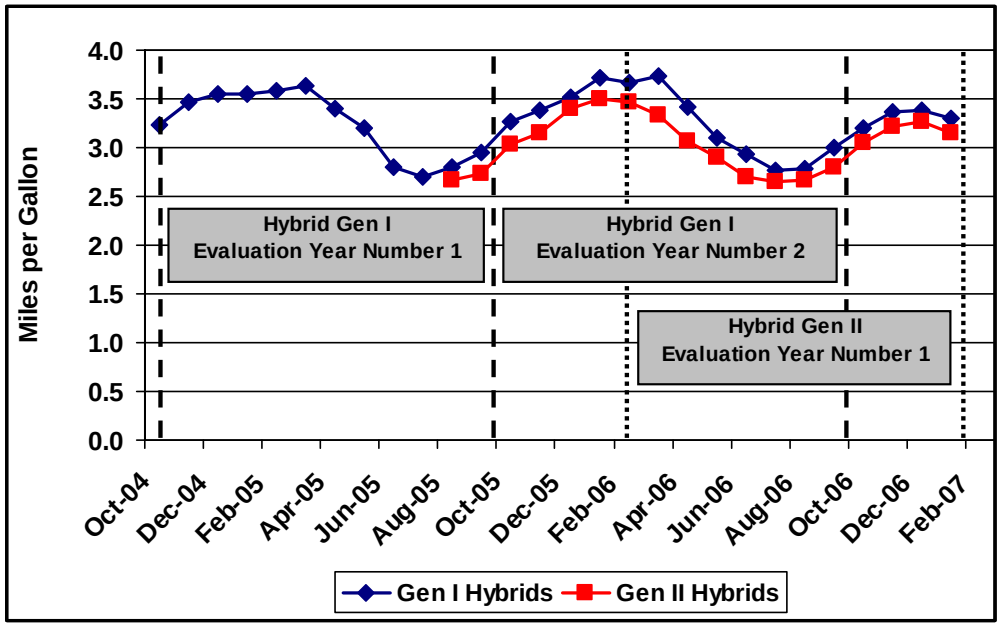
- **Project helped document and publicize overall performance of GM dual mode HEV buses to help with future deployment – many more orders placed**

Relevant Outcomes from Recent Work:

FY2006 and FY2007: Evaluated NYCT – 2002 BAE HEV (series) transit bus vs 2004 EGR equipped HEV (series) transit bus

- **Examined 2 generations of HEV's over 3 years**
  - **documented fuel economy w/seasonal variation and overall improvements in operation**
  - **Documented lower fuel economy from Gen II buses: likely due to EGR, battery calibration.**



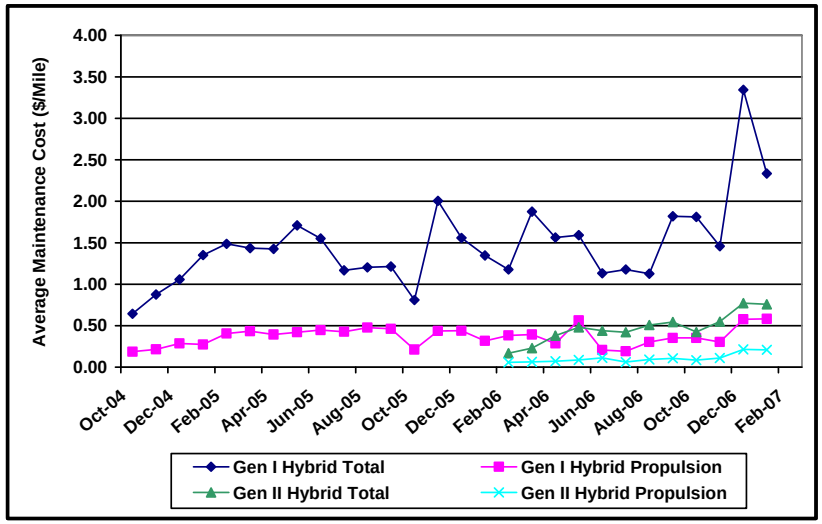


Relevant Outcomes from Recent Work:

FY2006 and FY2007: Evaluated NYCT – 2002 BAE HEV (series) transit bus vs 2004 EGR equipped HEV (series) transit bus

- **Documented durability of Lead Acid battery packs and hybrid system**
  - **battery failure rate at 0 for Gen II vs 4.8% for Gen I**
- **Documented cost savings from reduced brake maintenance**

Bus Number	Date	Reline Type	Odometer Reading
	Gen I Hybrid Buses		
6367	02/21/2006	4-wheel	50,807
6368	07/25/2006	2-wheel	66,455
6368	12/28/2006	2-wheel	74,523
6369	05/04/2005	2-wheel	57,073
6375	04/11/2006	4-wheel	54,685
6378	09/26/2006	4-wheel	68,444
6379	03/13/2006	4-wheel	49,272
6380	01/26/2006	2-wheel	48,685
6381	02/28/2006	4-wheel	50,267
6382	11/02/2005	4-wheel	45,217
6387	07/07/2006	4-wheel	59,769
	Average	First reline	55,067
	CNG Buses		
7657	07/08/2004	4-wheel	20,288
7662	09/22/2004	2-wheel	20,043
7666	01/01/2005	4-wheel	28,759
7670	10/08/2004	2-wheel	25,924
7677	01/14/2005	2-wheel	24,730
7688	06/22/2005	4-wheel	33,581
	Average	First reline	25,554

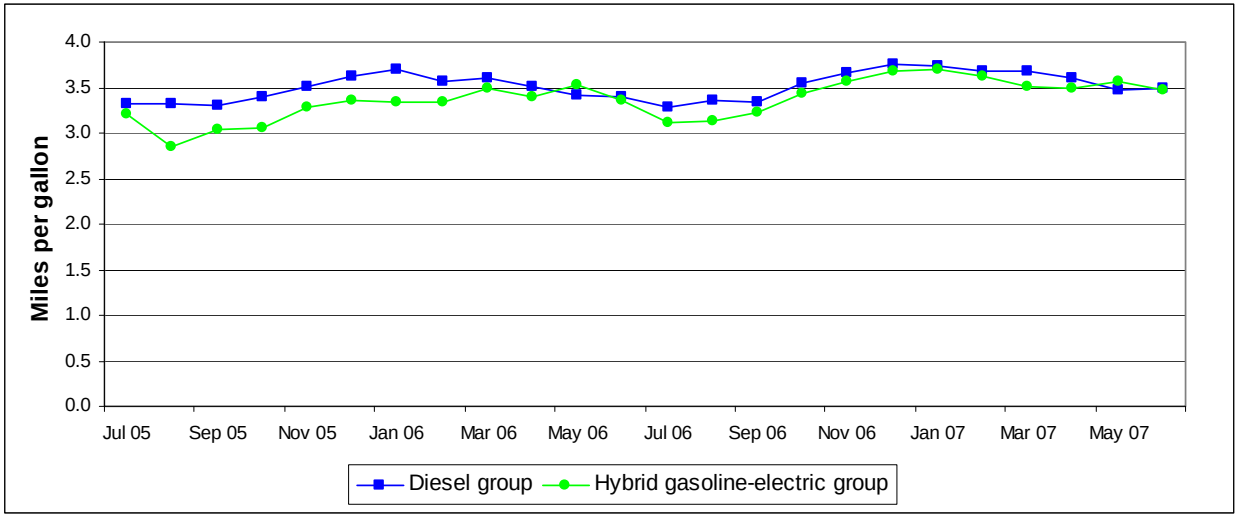


- **Project helped document and publicize overall performance of BAE HEV buses to help with future deployment – many more orders placed from NYCT and other agencies**

Relevant Outcomes from Recent Work:

FY07: Evaluated Long Beach – ISE Gasoline Fueled HEV transit bus

- **Obtained and analyzed in-use fuel economy on 10 gasoline fueled HEV's versus 10 conventional diesels**
  - **found a 4.3% lower fuel economy for hybrids (volumetric)**
  - **found a 8.5% higher fuel economy for hybrids (energy equivalent)**
  - **Found seasonal variation 10-12%**
    - **provides another look at air conditioning energy consumption**



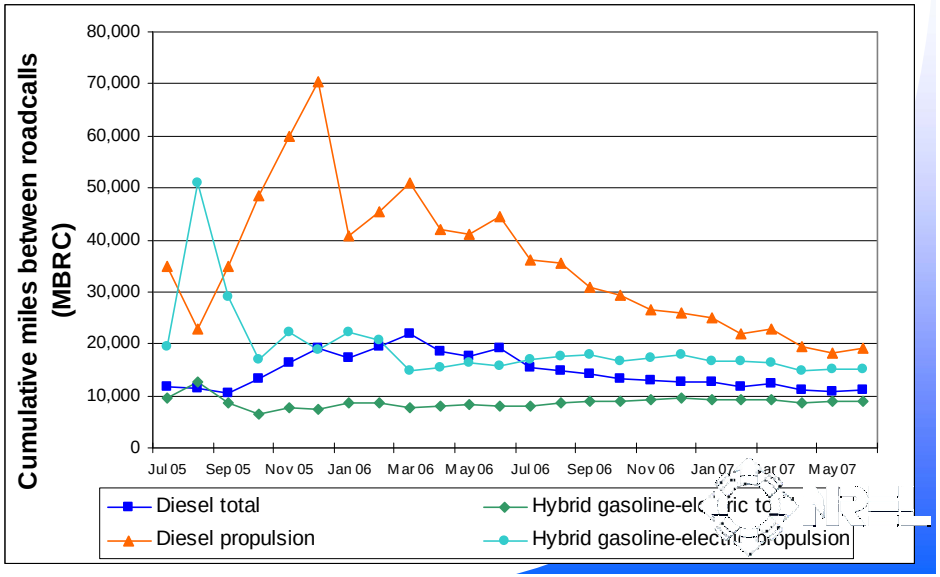
Relevant Outcomes from Recent Work:

FY07: Long Beach – ISE Gasoline Fueled HEV transit bus

- **Documented durability of first use in industry of Maxwell Ultracapacitor packs and hybrid system**
  - **No energy storage system failures during evaluation**

- **Documented improvement in brake life due to hybridization**
  - **cost savings for operator**
  - **usually 40k miles on a set of brakes**
  - **Hybrids at 70k+ miles and no replacement yet**

- **Overall reliability of buses documented**



FY08 Work Plan:

Task 1: UPS Hybrid Delivery Vehicle Evaluation

- Evaluates an order of 50 Eaton Hybrid Delivery Vans with Li Ion battery technology (hybrid system developed in part by DOE under Heavy Hybrid Program)
- Helps obtain data on advanced battery technology and latest MD hybrid system in commercial fleet

Task 2: PHEV School Bus Evaluation

- Evaluates 1st deployment of Plug-in Hybrid School Bus in the U.S. Partners include IC Corporation, Enova and Advanced Energy
- Help analyze data on 'Post-Transmission' hybrid with charge depletion strategy in public school fleets
- Coordinates evaluation with Vehicle Systems Activity to optimize control strategy and conduct detailed dynamometer testing for subsystem analysis

FY08 Work Plan:

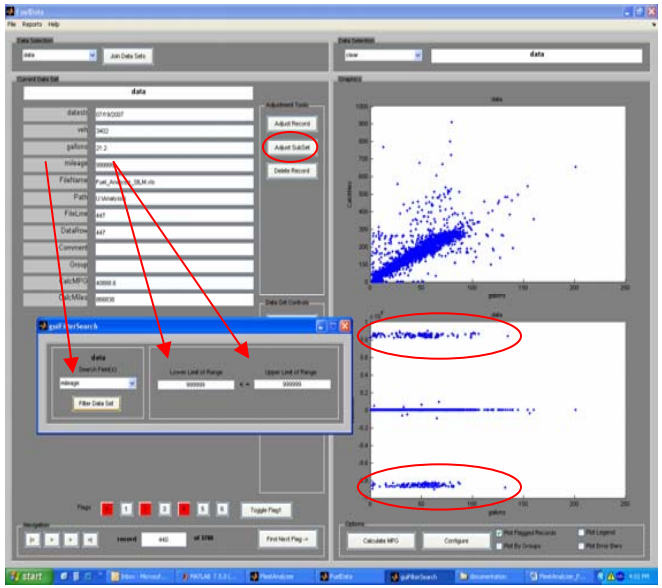
Task 3: GTL / BTL Class 8 Evaluation

- Evaluate the operational performance, emissions implications and fuel system & aftertreatment durability utilizing F-T diesel fuel with 2007 diesel technology.
- Helps understand issues to utilize a potential renewable fuel option for HD fleets (bio-to-liquid using Fischer-Tropsch process) – syngas created from fossil fuel or biomass

Task 4: Electric Accessories in Fleet Study

- Evaluates use of electric accessories in HD market
- Includes data collection from transit bus fleet using electric cooling fans
- Coordinates work with Vehicle Systems Activity to validate modeling efforts.
- Goal is to understand best use of electric accessories for specific applications in MD/HD market

FY08 Work Plan:



Task 5: Fleet Evaluation Tools

- Refinement of maintenance and fuel economy data tool already in use by NREL
- Matlab based tool to allow fleets to easily capture drive cycle data and analyze for internal analysis

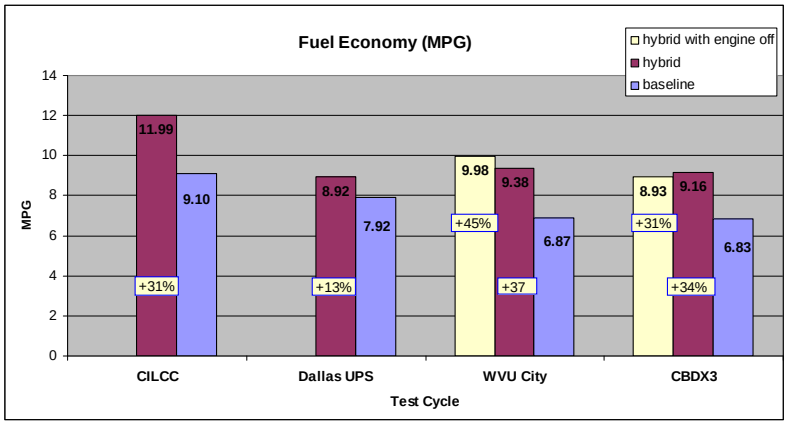
Task 6: Fed Ex Evaluation

- Evaluates deployment of gasoline electric HEV delivery vehicles in southern California fleet
- First of 20 vehicles delivered to Fed Ex by Azure Corporation
- Evaluates a clean, efficient technology
- Coordinates work with PHEV simulation and analysis to look at options for MD PHEV applications

FY08 Accomplishments:

Task 1: UPS Hybrid Delivery Vehicle Evaluation

- Completed dyno testing of baseline vehicle and hybrid vehicle
- Initiated data collection effort in Dallas
- Further efforts for remainder of FY08 will include full data set analysis and possible Lithium battery degradation testing



Task 2: PHEV School Bus Evaluation

- Obtained initial data from Advanced Energy on various locations for further analysis
- Multiple sites to be considered and further analyzed in remainder FY08
- Further efforts for remainder of FY08 will provide more detailed analysis on maintenance and operation of buses for 12 month period

FY08 Accomplishments:

Task 3: GTL / BTL Class 8 Evaluation

- In discussions with major fuel provider and engine OEM for project initiation - both of which have interest in FT derived fuel for future transportation
- Further efforts in FY08 will provide further exploration of biomass to liquid opportunities in the US and begin data collection (to end in FY09)

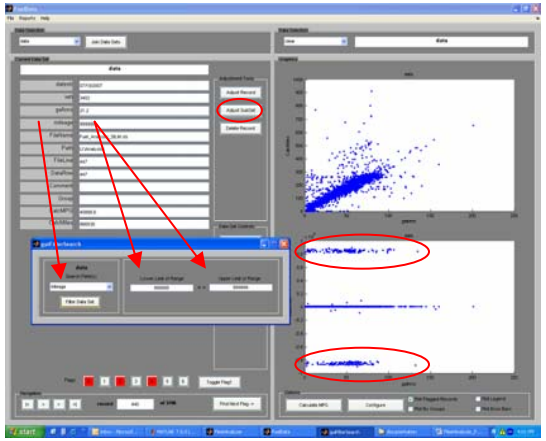
Task 4: Electric Accessories in Fleet Study

- Preliminary data obtained from bus fleet utilizing electric fans
- Data being used for modeling (being performed by ANL) to assess use of electric accessories in various applications
- Future work in FY08 will include additional data to be collected from additional sites and systems and validated against model

FY08 Accomplishments:

Task 5: Fleet Evaluation Tools

- Maintenance and Fuel Economy analysis tool validated against traditional manual method with ~1% variation observed
- Plan for remainder of FY08 will be to begin validation of automated duty cycle analysis tool currently under development



Task 6: Fed Ex Evaluation

- SOW and data collection plan finalized
- Vehicles to be delivered in May
- Remainder of FY08 will include initial data analysis and vehicle dynamometer testing (paid for by SCAQMD)
- Project will wrap up in FY2009 with final analysis

Justification of Project & Future Plans:

Justification:

- **Project provides in-depth analysis of newly emerging technology as it performs in commercial use**
- **Provides Vehicle Technologies Office and Vehicle Systems areas with in-use data for analysis and identifies areas for further investigation opportunities**
- **NREL has developed and utilized in-use evaluations of commercial MD and HD technology for over 10 years**

Future Plans:

- **FY2009 will continue to work with Vehicle Technologies Office to identify areas of interest and implement new projects to evaluate new technologies**
- **Continue to improve process to obtain relevant data:**
  - **new tools**
  - **new test methods**
  - **better communication of data both internal to DOE and external to industry**

Thanks to:

Lee Slezak
Vehicle Technology Analysis & Evaluation
Vehicle Technologies Program

For More information:

Kevin Walkowicz
National Renewable Energy Laboratory
kevin_walkowicz@nrel.gov
phone: 303.275.4492