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Tracking Costs of Alternatively Fueled Buses in Florida – Phase II

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Summary

- **Client:** Florida Department of Transportation (FDOT)
- **Duration:** 18 Months
- **Budget:** $90K
- **Objective:**
  - Continue recoding and reporting performance and costs of alternative fuel public transit vehicles in Florida using previously established reporting tool
  - Research modification requirements for transit maintenance facilities to make them suitable for alternative fuel buses. Particular attention to CNG.

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Background

- Many transit agencies introduced AFV into their fleets
  - to reduce fuel consumption => save $
  - to reduce GHG emissions => environmental benefits
- TIGGER grants and regular transit capital funds help with AVF acquisitions
- FDOT funds 50% of non-federal share of bus capital
- AFVs do not always provide desired efficiency gains and benefits to agencies

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FDOT Initiatives & Efforts

- Bus Fuels Fleet Evaluation Tool (BuFFeT model) developed by CUTR - 2007
- 2009 NCTR Project – Tracking Costs of Alterative Fuel Buses
  - Establish a process for on-going assessment of benefits and costs of advanced transit technologies
  - Investigate costs of modifying transit maintenance facilities to accommodate AFV

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Project Goals

- Continue collecting & reporting data on performance and costs of AF transit vehicles in Florida
- Update BuFFeT cost model
- Investigate code requirements for modifying transit maintenance facilities to accommodate AFV
- Particular attention to codes related to CNG

Research Approach

- Approached all fixed-route transit agencies with data request
- Standard data submission template provided but would accept data in ANY format
- Quarterly reporting
- Regular reminders over e-mail/phone
- Review national and international codes applicable to gaseous fuels
- Discuss facility modification experience with local fleets that switched to AFV

Type of Data Requested

- Vehicle length
- Power plant
- Fuel type
- Date placed in service
- Vehicle acquisition cost
- Life-to-date mileage
- Life-to-date fuel usage
- Life-to-date labor costs
- Life-to-date parts costs
- Etc.

Early Challenges

- Low Response rate:
  - Nine fixed-route agencies provided meaningful data during calendar 2012
  - Paratransit data is vey limited
- Difficulty with on-going reporting
  - Few agencies provide regular quarterly reporting
- Despite low response rate, the data collected covers the majority of Florida fixed-route fleet (over 2,000 vehicles)

Cost Analysis - Fixed Route Buses

- Nine agencies provided cost data in 2012:
  1. PalmTran
  2. StarMetro
  3. MDT
  4. Votran
  5. Lee County Transit
  6. LYNX
  7. Broward County Transit
  8. Pinellas County Transit Authority (PSTA)
  9. Pasco County Public Transit
- Agencies were asked to report on entire fleet (both diesel and AFV)

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Fixed-Route Fleet Summary

1. Diesel Vehicles (89% of fleet)

- Almost 77% of diesel buses are 40-foot buses
- 8% - 35-foot buses
- 1% - 60-foot articulated buses

2. Diesel Hybrids (9% of fleet)

- 25% of diesel hybrids are 40-foot buses
- 25% 60-foot articulated buses

3. Gasoline (2% of fleet)

4. Trolley (4 vehicles)

5. Gasoline Hybrids (1 vehicle)

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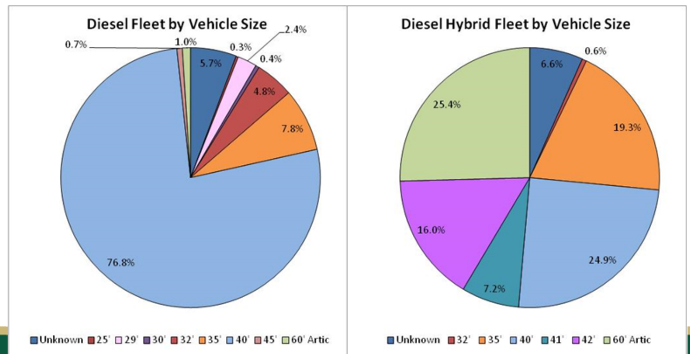
Fleet Summary - Continued

- Most complete data is on diesel and diesel hybrids
- Analysis will focus on these types of vehicles



Performance Comparison Fixed-Route Fleet

- Hybrid vs. Diesel for entire fleet (all-size buses):
  - Hybrid buses demonstrate 14.4% better fuel economy
  - 59.4% lower parts cost per mile
  - 61.3% lower maintenance costs per mile
  - Hybrids cost 67% more than diesel

Power Plant	Number of Buses	Average Age (years)	Average Acquisition Cost	Gas Mileage (MPG)	Parts Cost per Mile	Maintenance Cost per Mile	Total Cost per Mile
Diesel	1,787	7.4	$351,597	3.93	$0.337	$0.773	$1.059
Diesel Hybrid	181	2.3	$587,070	4.50	$0.137	$0.299	$0.441
Gasoline	38			16.95			$0.204
Gasoline Hybrid	1			3.77			$0.880
Trolley	4	11.3		5.45	$0.245	$0.147	$0.393
Total Fleet:	***2,011***	***6.9***	**$364,234**	**4.16**	**$0.323**	**$0.736**	**$1.002**

- Difference in performance can be partially explained by difference in average age of diesel and hybrid buses

Performance Comparison
Fixed-Route Fleet

- Diesel hybrid buses typically have better gas mileage, lower costs per mile, but higher acquisition cost
- Average hybrid bus is much younger than diesel bus, still under warranty
- Vehicle size plays an important role in how diesel buses compare to diesel hybrids
- Differential in fuel mileage between diesel and hybrid is greater for larger buses

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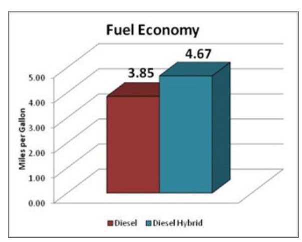
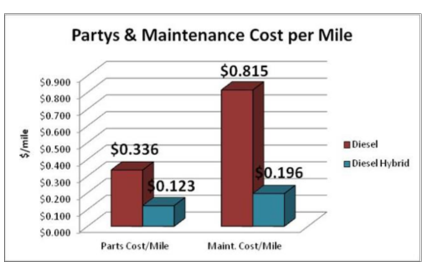
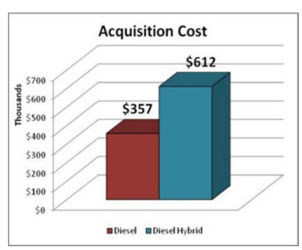
Diesel vs. Hybrid Comparison:
40-foot Buses

- 40' Hybrid vs. 40' Diesel:
  - 21.2% better gas mileage
  - 63.3% lower parts cost/mile
  - 76.0% lower maintenance costs/mile
  - 71.1% **more** expensive







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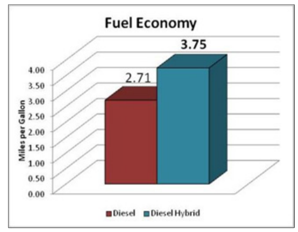
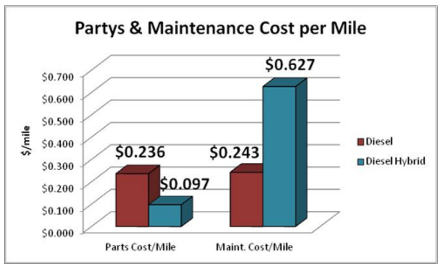
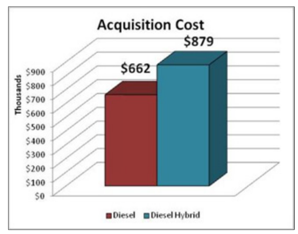
Diesel vs. Hybrid Comparison: 60-foot Articulated Buses

- 60’ Hybrid vs. 60’ Diesel:
  - 38.5% better gas mileage
  - 58.9% lower parts cost/mile
  - 157.9% **higher** maint. costs/mile
  - 32.8% **more** expensive







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Proper Comparison – Account for Miles Driven

- Potential flaw in methodology: use of simple averages to calculate MPG and costs/mile
- Simple averages ignore the difference in miles driven
- Data show that different categories of buses vary greatly in terms of the amount of miles they drive
- The use of weighted averages to calculate MPG and costs/mile is warranted
- Weighted approach: parameters that are based on higher mileage will have higher influence on final estimate

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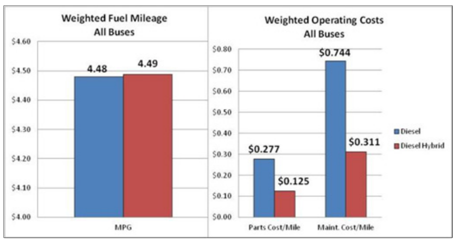
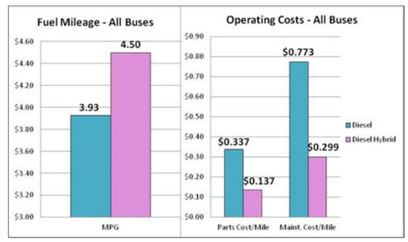
Weighted Comparison: Diesel vs. Diesel Hybrid of Any Size

- Accounting for miles driven reduces comparative advantage of diesel hybrid technology over diesel
- Hybrid buses and diesel buses of **any size** have comparable weighted average gas mileage





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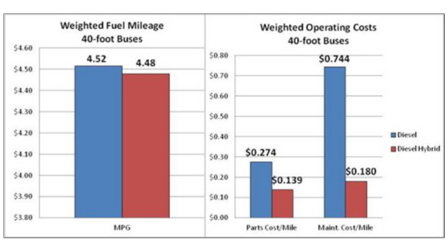
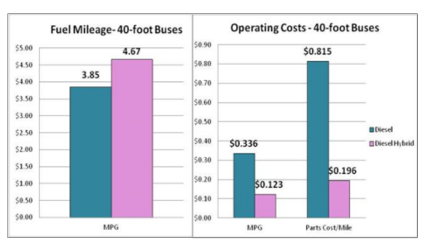
Weighted Comparison: 40-foot Diesel vs. 40-foot Hybrid

- For 40-foot buses, diesel hybrids show slightly **lower** weighted average MPG than diesel buses
- Costs/mile still favor diesel hybrid technology but differential between hybrid and diesel is smaller when accounting for miles driven





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Explanation of Results

- Observed results do not necessarily mean that diesel hybrid power plant performs worse than diesel
- Potential explanation:
  - Small number of older generation hybrids, with lower fuel efficiency, which have logged a lot of miles
  - Large number of older high-mileage diesel buses that perform exceptionally well
- As newer-generation hybrids are driven more miles, weighted average fuel efficiency of hybrid buses will improve

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Life Cycle Impact of AFVs

- Extrapolating differential in fuel efficiency and operating costs to the life of the vehicle provides estimate of benefits of AFV (diesel hybrid)
- Over 12-year life of the vehicles, diesel hybrid bus of any size is projected to:
  - Provide $33,084 saving to transit agency in terms of reduction in fuel and operating costs, compared to diesel bus
  - Reduce tailpipe emissions (compared to diesel bus):
    - NOx – by 0.9 tons
    - CO_2 – by 38.1 tons

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Life Cycle Impact - 40-foot Hybrid Bus

- Replacing one diesel bus with diesel hybrid is projected to
  - Provide $107,014 saving (fuel + operating cost) to the agency over life of the vehicle
  - Reduce tailpipe emission
    - NOx – by 1.2 tons
    - CO_2 – by 53.9 tons
- This projection takes into account costly battery replacement ($67,500) and diesel price of $4/gallon
- As battery technology improves and/or fuel price increases potential savings will increase

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Paratransit Fleet

- Data on only 95 demand response vehicles could be collected:
  - No AFVs
  - 40% - Diesel vehicles
  - 20% - Gasoline
  - 20% - Unknown power plant (was not reported)
- Paratransit data have significant gaps (many parameters are missing)
- Data indicate that diesel demand response vehicles typically perform better than gasoline:
  - 34.2% better fuel economy
  - 19.1% lower total cost per mile

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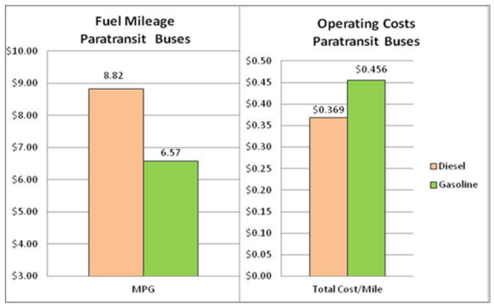
Paratransit Fleet – Comparison Between Power Plants

- Diesel-powered vs. Gasoline-powered demand response vehicles



- Due to data limitations little meaningful analysis & comparison could be performed

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Guidelines for Maintenance Facility Modifications

- Review code requirements for transit maintenance facilities
- Identify particular requirements for CNG and LNG (gaining popularity lately)
- Look at relevant national and international standards
- Summarize and provide common guidelines for modifying maintenance facilities to accommodate AFVs fueled by gaseous fuels (CNG/LNG)
- Guidelines for CNG/LNG modifications developed by Clean Vehicle Education Foundation (8/2012)

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Code Requirements

- Codes that regulate maintenance facilities:
  - International Fire Code (IFC 2012)
  - International Mechanical Code (IMC 2012)
  - International Building Code (IBC 2012)
  - National Fire Protection Association's NFPA 30A (2012) - Code for Motor Fuel Dispensing Facilities and Repair Garages
  - NFPA 52 (2010) – Vehicular Gaseous Fuel Systems Code
  - NFPA 88A (2007) – Standards for Parking Structures
- These codes deal with both traditional liquid fuels and alternative fuels

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Codes Applicability

- Codes were written as performance requirements and not design standards
- Actual standards are often set by local authorities interpreting the codes
- Codes apply **only** to major repair garages (NFPA 30A and IFC exempt minor garages from code requirements specific to CNG/LNG)
- Major repair activity = work involving engine overhauls, painting, body work, and any repairs requiring drawing vehicle fuel (NFPA 30A)
- Big cost savings can be realized if facility can be divided into separate major/minor repair areas

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Areas Regulated by Codes

- There are seven main areas covered by national codes that apply to CNG and LNG:
  - General ventilation
  - Ventilation in pits
  - Gas detection
  - Sources of ignition
  - Electrical classification
  - Preparation of vehicles for maintenance
  - Maintenance and decommissioning of containers
- Before considering modifications, need to verify that garage meets requirements for liquid fuels:
  - Ventilation rate for enclosed parking garages – at least 1 cfm/ft^2 (NFPA 88A 5.3.2)

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Addressing CNG/LNG Hazard

- Requirements vary depending whether the gas is odorized or not
- Maintenance facilities handling non-odorized gases and LNG are subject to more stringent rules
- Code requirements address the hazard of CNG/LNG by setting performance standards to:
  - Reduce presence of flammable mixture
  - Eliminate potential source of ignition

- More detailed description is available in the final report

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Requirements for odorized CNG

Ventilation

- NFPA 30A – no requirement specific to CNG; same ventilation requirement as for liquid fuels
- IFC – continuous mechanical ventilation with rate of 5 air exchanges per hour (1cfm/ft^2 = 5 air exchanges per hour for ceiling height of 12 ft.)
- Mechanical ventilation needs to be continuous except when ventilation system is:
  - Interlocked with gas detection system, or
  - Electrically interlocked with lighting circuit
- NFPA 30A requires ventilation only for fuel dispensing areas; IFC 2011 requires ventilation for all CNG repair areas

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Requirements for odorized CNG

Ventilation in pits

- Ventilation in subfloor work areas is already required for liquid fuels (should be already met by existing maintenance garage)
- IFC requires 1.5 cfm/ft^2
- NFPA requires 1 cfm/ft^2
- Exact rate can be specified by local authority

Gas detection

- No requirements for odorized CNG
- While not required, some repair facilities may chose to install a gas detection system

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Requirements for odorized CNG

- Recommended guidelines for gas detection systems:
  - Should be approved by local authority (fire marshal)
  - Shall activate at 25% of lower flammability limit
  - Upon activation the gas detection system shall:
    - Activate mechanical ventilation
    - Deactivate tall heating systems in major repair garage
    - Initiate audible and visual alarm
  - When natural gas detection system fails it shall:
    - Activate mechanical ventilation
    - Deactivate tall heating systems in major repair garage
    - Initiate audible and visual alarm

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Requirements for odorized CNG

Source of Ignition

- IFC, IBC, IMC, NFPA 70 – provide requirements for liquid fuels restricting ignition sources within 18 inches from the floor (should be already met)
- NFPA 30 has additional requirement for CNG major repair garages – no open flame heating equipment with exposed surface with temperature above 750° F in any area with potential ignitable concentration of natural gas
- Conservative approach – completely eliminate such heating equipment from any area of CNG major repair garage

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Requirements for odorized CNG

Electrical Classification

- NFPA 30A – space within 18 inches of ceiling of major CNG garage needs to be classified as Class 1, Division 2 location => classified electric wiring
- Exception for facilities with ventilation rate of at least 4 air exchanges per hour
- Design of ceiling support structure should be taken into account
- If classified location cannot be easily eliminated by ventilation, all electrical installations must meet Class 1, Division 2 requirements

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Requirements for odorized CNG

Preparation of CNG Vehicles for Maintenance

- IFC – only code that has requirements for preparing CNG vehicles for maintenance
- Code requires to valve off all fuel storage cylinders on CNG vehicle before entering repair garage
- In the event of suspected damage to CNG fuel system, entire system should be inspected for leaks prior to brining vehicle to repair facility

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Requirements for odorized CNG

Maintenance & Decommissioning of Fuel Containers

- NFPA 52 – repair facilities need to have specific written procedures for decommissioning fuel cylinders
- Each repair garages needs to install proper defueling facility, approved by local regulating authority
- Consideration should be given to natural gas recovery system to reduce the amount of gas released in the atmosphere

Challenges and Limitations

- Data availability
- Difficulty with periodic reporting
- Limited number of AFV in Florida fixed-route transit fleet (only 9% are AFV)
- Low variety of AFV in the state fleet (diesel hybrid is the only type of AFVs)
- Sparse and incomplete data on demand response vehicles
- Results of the analysis should be interpreted with caution

Next Steps

- New Project: Investigation, Quantification and Recommendations – Performance of Alternatively Fueled Buses (18 months, FDOT)
- Alternative Fuel Bus Clearinghouse (12 months, Federal)
- Collect and analyze performance & cost data on alternative fuel transit vehicles nationwide
  - Bigger data set
  - More variety of AFV
- As more field data are collected reliability and usefulness of the analysis of advanced transit technologies will improve

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Thank You!

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