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Washington Metropolitan Area Transit Authority: Compressed Natural Gas Transit Bus Evaluation

K. Chandler and E. Eberts
Battelle

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National Renewable Energy Laboratory

Technical Report
NREL/TP-540-37626
April 2006

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Prepared under Task No. FC05.9000

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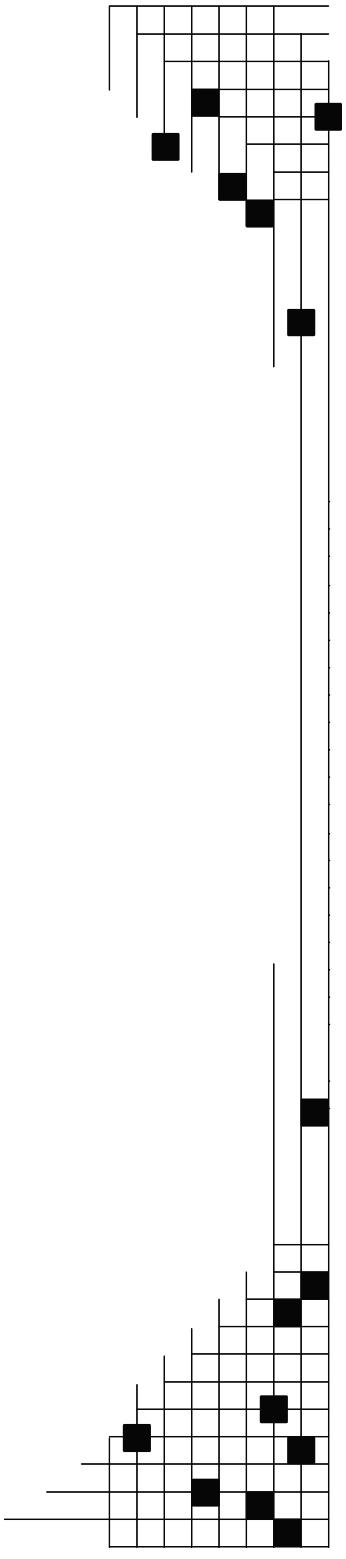

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Foreword

This evaluation would not have been possible without the support and guidance from staff at Washington Metropolitan Area Transit Authority, including the following:

- Jack Requa
- Phillip Wallace
- Robert Golden
- Sebastian Silvani (contractor from Booz Allen Hamilton)
- Barry Goldman
- John Smith.

The authors wish to acknowledge the leadership and input from Dennis Smith at the U.S. Department of Energy, and the contributions to this evaluation from New Flyer, Cummins Westport, Inc., John Deere, and Hanover.

This report is available from the National Renewable Energy Laboratory in PDF at www.nrel.gov/docs/fy06osti/37626.pdf.

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Acronyms and Abbreviations

APTA	America Public Transportation Association
CO	carbon monoxide
CNG	compressed natural gas
CWI	Cummins Westport, Inc.
DDC	Detroit Diesel Corporation
DGE	diesel gallon equivalent
DOE	U.S. Department of Energy
DPF	diesel particulate filter
EGR	exhaust gas recirculation
g/bhp-hr	grams per brake horsepower hour
hp	horsepower
HVAC	heating, ventilation, and air conditioning
MBRC	miles between roadcall
mpDGE	miles per diesel gallon equivalent
mpg	miles per gallon
mph	miles per hour
NGVTF	Natural Gas Vehicle Technology Forum
NMHC	non-methane hydrocarbon
NO_X	nitrogen oxide/oxides of nitrogen
NREL	National Renewable Energy Laboratory
PM	particulate matter
PMI	preventive maintenance inspection
ppm	parts per million
rpm	revolutions per minute
scf	standard cubic feet
THC	total hydrocarbon
TUG	Natural Gas Transit User's Group
ULSD	ultra-low sulfur diesel
WMATA	Washington Metropolitan Transit Authority

Executive Summary

This evaluation of compressed natural gas (CNG) powered transit buses at Washington Metropolitan Area Transit Authority (WMATA) was funded and supported by the U.S. Department of Energy's (DOE) FreedomCAR and Vehicle Technologies Program. The evaluation was completed using a documented data collection and evaluation protocol developed specifically for the assessment of these transportation technologies in operation [1].

The objective of this report is to provide a reasonable comparison between currently available CNG and standard diesel transit buses. The report includes operational, maintenance, and performance data for each study fleet operating from the same depot. Transit agencies considering use of alternative fuel and advanced propulsion technology transit buses are the primary intended audience for this information.

WMATA has been operating 164 CNG buses since 2002 at its Bladensburg depot. Another 250 CNG buses and another CNG depot (Four Mile Run) began operation in 2005. The evaluation in this report focuses on the first order of CNG buses operating at the Bladensburg depot. Two CNG bus propulsion systems were evaluated: the Cummins Westport, Inc. (CWI) C Gas Plus and the John Deere 6081H.

The results presented focus on the evaluation periods for each study group of buses: diesel buses, 12 months (9/2001-8/2002); CWI CNG buses, 12 months (6/2003-5/2004); Deere CNG buses, 6 months (4/2004-9/2004). The Deere CNG buses had a limited evaluation of 6 months because the implementation was a field test confirmation of the technology, which will be a full market introduction with the next Deere CNG bus order from WMATA. The CWI CNG bus propulsion technology was considered a fully implemented commercial product and had a full 12-month evaluation. Diesel propulsion technology was used as the baseline for this evaluation.

Implementation Experience. WMATA staff were dedicated to a positive implementation of CNG buses and appeared to implement the CNG buses into its operation with ease. Work was done early to ensure the equipment (vehicles and facilities) was well matched to WMATA's operation. Management was reported to have been supportive while allowing depot staff to make their own implementation decisions. Because of all the work done before the buses and equipment were brought to the depot, the overall implementation experience was better than expected. WMATA also received good technical support from manufacturers and others.

Routes and Bus Use. The CNG and diesel buses at the Bladensburg depot were used randomly on routes with only 40-foot buses. The CNG buses did not have restrictions due to range or power. The diesel buses (without diesel particulate filters) used in the evaluation operated from Bladensburg depot from 2001–2002 (before the use of the CNG buses). The CNG buses operated from Bladensburg depot starting in 2002.

Fuel Economy and Cost. The CNG buses had fuel economies 16%–18% lower than the diesel buses: 2.3–2.4 mpDGE (miles per diesel gallon equivalent) for the CNG buses versus 2.8 mpg for the diesel buses. This fuel economy difference is better than the 20%–25% fuel economy penalty for CNG shown in previous DOE/National Renewable Energy Laboratory transit bus studies.

The CNG fuel cost averaged $1.19/DGE (diesel energy gallon equivalents) during the evaluation period. Adding the electricity cost for the CNG compressor station ($0.14/DGE), the total CNG fuel cost was $1.33/DGE. The ultra-low sulfur diesel (ULSD) fuel cost during the evaluation period for the diesel bus operation at Bladensburg (2002) averaged $0.75/gal. However, during the CNG bus evaluation period, the ULSD fuel cost averaged $1.33/gal.

Total Maintenance Costs. For the evaluation periods, the CWI CNG buses had 12% lower total maintenance costs than the diesel buses, and the Deere CNG buses had 2% lower total maintenance costs than the diesel buses.

Engine- and Fuel-Related Maintenance Costs. The engine- and fuel-related systems are the air intake, cooling, exhaust, fuel, engine, and non-lighting electrical (cranking, charging, and ignition) systems. These vehicle systems are the most relevant when comparing the differences in diesel and CNG transit bus propulsion technologies. The CWI CNG buses had costs 11% higher than the diesel buses, and the Deere CNG buses had costs 3% higher than the diesel buses. The higher maintenance cost for the CNG buses versus the diesel buses for these systems was expected because of higher-cost engine oil, fuel filters, and the addition of the spark plugs and ignition systems for the CNG buses.

Roadcalls. A roadcall is defined in this report as an on-road failure of an in-service bus requiring the bus to be taken out of service or replaced on route. Both CNG bus groups had better miles between roadcall (MBRC) rates than the diesel buses. The CWI CNG buses had an all roadcall MBRC 44% higher and engine- and fuel-related roadcall MBRC 41% higher than the diesel buses. The Deere CNG buses had an all roadcall MBRC 58% higher and engine- and fuel-related roadcall MBRC 16% higher than the diesel buses.

Total Operating Costs. The total operating costs for the study buses were similar. The fuel costs for CNG and diesel during the CNG bus evaluation periods were the same at $1.33/DGE. The total operating costs were as follows: diesel, $1.06/mile; CWI CNG, $1.09/mile; and Deere CNG, $1.14/mile. The major contributing factors are the fuel costs and fuel economy. Significant changes in the fuel cost or fuel economy would change total operating costs significantly.

Future Bus Orders at WMATA. A subsequent CNG bus order consisted of 250 CNG buses from Orion (model VII, low floor), delivered in 2005. Another CNG bus facility came online in 2005. After this 250 CNG bus order, the next bus order is planned to be diesel and diesel hybrid buses. These diesel buses are required at WMATA to lower the average diesel bus age at the eight depots not currently operating CNG buses.

Status of the CNG Bus Propulsion Technologies. The CWI CNG bus propulsion technology appears from the evaluation to be a mature technology, and is similar in operation and cost to the diesel bus technology. The Deere CNG bus propulsion technology was a field test confirmation during this project and only underwent a limited evaluation. However, by the end of the evaluation, the results indicated that this propulsion technology was maturing. WMATA and Deere have agreed to implement another 100 Deere CNG buses as part of WMATA's 250 CNG bus order in 2005; this will be the first full market introduction of the Deere CNG bus propulsion technology. The order indicates WMATA's confidence in the Deere technology.

Introduction

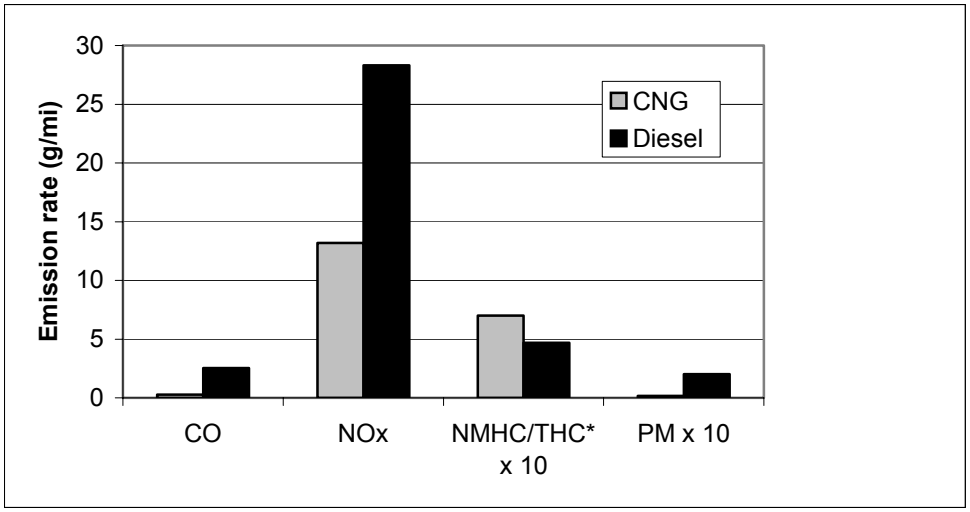
This evaluation of compressed natural gas (CNG) transit buses at Washington Metropolitan Area Transit Authority (WMATA) was supported by the U.S. Department of Energy's (DOE) FreedomCAR and Vehicle Technologies Program. The National Renewable Energy Laboratory (NREL) managed the evaluation as part of DOE's Natural Gas Vehicle Technology Forum (NGVTF)[1]. DOE and NREL have supported the development and deployment of advanced propulsion and alternative fuel vehicles in the United States for many years. The evaluation presented in this report was completed using a documented data collection and evaluation protocol developed specifically for the assessment of advanced propulsion and alternative fuel transportation technologies in operation [1].

This evaluation, conducted in 2004, follows a previous study of WMATA transit buses. In 2002, NREL, West Virginia University, and WMATA conducted a short test program comparing the emissions of WMATA's Cummins Westport, Inc. (CWI) CNG buses and Detroit Diesel Corporation (DDC) Series 50 diesel buses. Table 1 and Figure 1 summarize the vehicle specifications and results that were published [2]. These buses had the same configuration as the CWI and DDC buses examined in the present evaluation but were not the identical buses.

Table 1. WMATA Vehicles Tested in 2002

	CNG Buses	Diesel Buses
Manufacturer	New Flyer	Orion
Model year	2001	2000
GVWR (lb)	40,600	42,540
Odometer (mi)	1,900 2,400 2,500 2,600 2,600	2,290 5,000 105,000 112,900
Engine	CWI C Gas Plus	DDC Series 50
Displacement (L)	8.3	8.5
Rated power (hp)	280	275

[1] See the NGVTF Web site at www.nrel.gov/vehiclesandfuels/ngvtf.



*NMHC for CNG buses, THC for diesel buses.

Figure 1. Results of 2002 WMATA Emission Testing, Central Business District Cycle

The 2004 evaluation described in this report was designed to provide a more complete picture of WMATA's CNG (Figure 2) and diesel buses, comparing in-service operation of the vehicles. The objective was to provide a reasonable comparison between currently available CNG and diesel transit buses. WMATA was chosen for participation in the project based on the agency's dedication to making the CNG technology work in transit service, its commitment to future CNG transit bus orders, and its conversion of another depot to CNG transit bus operations.

The evaluation includes data collected on the operational, maintenance, and performance characteristics of each study fleet operating from the same depot. Additional (to the 2002 testing) emissions testing of similar WMATA CNG and diesel buses were also evaluated; those results are published in another report [3]. Transit agencies considering the use of alternative fuel and advanced propulsion transit buses are the primary intended audience for this information.

Figure 2. WMATA CNG Transit Bus

Fleet Profile: Washington Metropolitan Transit Authority

The American Public Transportation Association (APTA) ranks WMATA as the fourth largest transit system in the United States for combined rail and bus transit, based on passenger miles in fiscal year 2002 [4]. The WMATA service area includes 3.5 million people within a 1,500 square mile area spanning Washington, DC, and parts of Maryland and Virginia (Figure 3). WMATA's 1,460 buses are housed and maintained in 10 depots:

District of Columbia
- Bladensburg
- Northern
- Southeastern
- Western

Maryland
- Landover
- Montgomery
- Southern Ave

Virginia
- Arlington
- Four Mile Run
- Royal

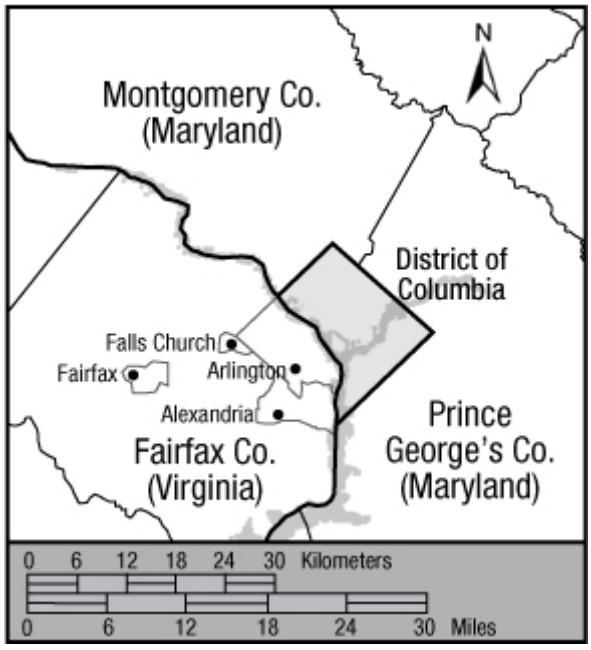


Figure 3. WMATA's Service Area

Emission Reduction Programs

WMATA is aggressively reducing emissions from its bus fleet. Its strategies include purchasing CNG buses as well as deploying passive regenerative diesel particulate filters (DPFs) on diesel buses and using ultra-low sulfur diesel (ULSD) fuel. As of October 2001, WMATA changed its diesel fuel supply to 100% ULSD (approximately 15 ppm sulfur), which enables more effective catalysts to be used in conjunction with the DPFs.

WMATA has been up-fitting 515 of its diesel buses with DPFs, which require use of ULSD to most effectively reduce emissions of particulate matter (PM) and hydrocarbons. WMATA replaced the 2-cycle diesel engines in another 59 diesel buses with new 4-cycle diesel engines equipped with exhaust gas recirculation (EGR) to demonstrate current low-emission diesel

engine technology. WMATA also has supported chassis dynamometer emissions testing to document the emissions of different bus technologies [2,3].

Compressed Natural Gas Bus Program

WMATA is planning to operate 414 CNG buses by 2006, complete modification of two bus divisions to accommodate CNG buses, and modify the Bladensburg Heavy Maintenance Shop to support CNG bus maintenance. The introduction of CNG buses and facility capabilities at WMATA at the time of the completion of this report was as follows:

CNG Buses

- Received 100 CNG buses from New Flyer, September 21, 2001
- Put first CNG buses into service, February 2002
- Received 64 CNG buses from New Flyer, mid-2002
- Ordered 250 CNG buses from Orion started delivery in 2005.

CNG Fueling and Maintenance Facilities

- Completed Bladensburg Bus Division CNG fueling and maintenance facility modifications, September 2002
- Completed Bladensburg Heavy Maintenance Shop modifications, September 2002
- Four Mile Run Bus Division fueling and maintenance facility modifications, completed in 2005.

WMATA intends the Bladensburg and Four Mile Run Bus Divisions to operate only CNG buses, except possibly a few diesel buses for special applications. Both divisions will have a full complement of CNG buses by 2006 with receipt of the 250 Orion VII CNG buses. WMATA determined that two other depots could be considered for CNG conversion; however, capital funding has not been made available. The other six depots are not candidates because of age of the buildings and availability of necessary real estate surrounding the depots.

Future Bus Orders

Beyond the order of 250 CNG buses, WMATA's next planned acquisitions are "clean diesel" buses (diesel buses with advanced emission control technologies fueled with ULSD) and diesel hybrid electric buses. This diesel bus procurement is being pursued because WMATA needs to infuse new buses into its eight non-CNG bus depots.

CNG Propulsion Technology

This section provides general information about the CNG propulsion technologies included in this evaluation at WMATA. As mentioned above, WMATA has 164 full-size CNG transit buses in operation at the Bladensburg bus depot and began receiving 250 more full-size CNG transit buses in 2005. Of the 164 CNG buses, 159 have the CWI C Gas Plus natural gas engine, and five have the John Deere Power Systems 6081H natural gas engine. Originally, all 164 CNG buses had the CWI engine; however, the CWI engine was removed from five of the buses and replaced with the Deere engine before the buses were delivered to the Bladensburg depot. The extra five CWI engines were placed into parts inventory at Bladensburg for later use.

The five buses with Deere natural gas engines were a field test confirmation project at WMATA. The testing resulted in WMATA's next order of 250 CNG buses, including 100 buses with the Deere engine. The other 150 CNG buses will have the CWI engine.

Cummins Westport, Inc.

CWI is a 50-50 joint venture between Cummins, Inc. and Westport Innovations, Inc. Cummins, headquartered in Columbus, Indiana, is a large manufacturer of diesel engines for all types of applications, including on- and off-road heavy trucks and power generation. Westport Innovations, based in Vancouver, British Columbia, is working to develop new commercial engine products by converting petroleum-based technologies to gaseous fuels. CWI engine products are sold and serviced by the Cummins distributor and dealer network.

Four CWI gaseous fuel engines are currently available in several horsepower settings (latest upgrade introduction shown in parentheses) as follows:

- B Gas Plus, 5.9 liter, natural gas, up to 230 hp (introduced 2002)
- B LPG Plus, 5.9 liter, propane, up to 195 hp (introduced 2003)
- C Gas Plus, 8.3 liter, natural gas, up to 280 hp (introduced 2001)
- L Gas Plus, 8.9 liter, natural gas, up to 320 hp (introduced 2003).

The C Gas Plus (Figure 4) was developed for trucks and buses, and has been a commercial product since 2001. It is used by a number of transit agencies in their buses. Development of the "Plus" version of the engine was supported by DOE and NREL [5,6]. Specifications and available power ratings are shown in Table 2.

Figure 4. CWI C Gas Plus Engine

Table 2. CWI C Gas Plus Engine Specifications and Ratings

Specifications		
Advertised Power	250–280 hp	
Governed Speed	2,400 rpm	
Displacement	8.3 L	
Number of Cylinders	6	
Compression Ratio	10:1	
Oil System Capacity	6.3 U.S. gal	
Combustion System	Spark Ignited	
Aspiration	Turbocharged	
Net Weight Dry	1,330 lb	
Fuel Types	CNG/LNG, methane number 65 or greater	
Ratings		
CG-280	280 hp @ 2,400 rpm	850 lb-ft @ 1,400 rpm
CG-275	275 hp @ 2,400 rpm	750 lb-ft @ 1,400 rpm
CG-250	250 hp @ 2,400 rpm	750 lb-ft @ 1,400 rpm
CG-250	250 hp @ 2,400 rpm	660 lb-ft @ 1,400 rpm

Source: CWI Web site, www.cumminswestport.com

John Deere Power Systems

John Deere Power Systems, based in Waterloo, Iowa, is a manufacturing division of Deere & Company. John Deere is well known for farming and off-road equipment; however, their products are used in many applications, including an on-highway natural gas engine, model 6081H (Figure 5). This engine is advertised for use in school buses, shuttle/transit buses, and other on-highway applications. DOE and NREL supported the development and deployment of the 6081H engine [7]. Specifications and available power ratings are shown in Table 3.

Figure 5. John Deere Power Systems 6081H Natural Gas Engine

Table 3. Specifications and Ratings for Deere 6081H Natural Gas Engine

Specifications		
Model	6081H	
Advertised Horsepower	250–280 hp	
Number of Cylinders	6	
Displacement	8.1 L	
Compression Ratio	11:1	
Combustion System	Spark Ignited	
Aspiration	Turbocharged	
Weight	1,660 lb	
Fuel Types	CNG/LNG	
Ratings		
6081H 280 hp	280 hp @ 2200 rpm	900 ft-lb @ 1500 rpm
6081H 275 hp	275 hp @ 2200 rpm	800 ft-lb @ 1400 rpm
6081H 250 hp	250 hp @ 2200 rpm	800 ft-lb @ 1400 rpm
6081H 250 hp	250 hp @ 2200 rpm	735 ft-lb @ 1300 rpm

Source: John Deere Web site, www.deere.com

Deere has been working to introduce this natural gas engine into the transit bus market. Table 4 shows transit agencies where the engine is being demonstrated. WMATA's order of 100 Deere engines represents the engine's transition beyond the demonstration phase.

Table 4. Current Transit Demonstration Sites for the Deere 6081H Natural Gas Engine

Demonstration Site	Location	Number of Buses
Omnitrans	San Bernardino, CA	2
MetroLink	Rock Island, IL	21
WMATA	Washington, DC	5
Metropolitan Atlanta Rapid Transit Authority (MARTA)	Atlanta, GA	2
Queens Surface Transit	New York City, NY	2
Utah Transit Authority (UTA)	Salt Lake City, UT	2
	Total	**34**

Evaluation Results

This section shows the results of the evaluation of CNG buses and diesel buses operating from WMATA's Bladensburg depot. The CNG buses with CWI engines were evaluated for 12 months. The CNG buses with Deere engines were not in operation for a full 12 months during the evaluation at WMATA and were evaluated for only 6 months. The study buses and evaluation periods are shown in Table 5.

Table 5. Evaluation Buses and Data Periods

Group	Bus Number	Start Date of Operation	Fuel Data Period	Maintenance Data Period
Diesel	2070	8/4/2000	9/01 – 8/02	11/01 – 8/02
	2071	8/8/2000	9/01 – 8/02	11/01 – 8/02
	2072	8/2/2000	9/01 – 8/02	11/01 – 8/02
	2073	8/4/2000	9/01 – 8/02	11/01 – 8/02
	2074	8/22/2000	9/01 – 8/02	11/01 – 8/02
CNG CWI	2302	8/21/2002	6/03 – 5/04	6/03 – 5/04
	2303	8/14/2002	6/03 – 5/04	6/03 – 5/04
	2304	8/27/2002	6/03 – 5/04	6/03 – 5/04
	2307	8/27/2002	6/03 – 5/04	6/03 – 5/04
	2309	8/20/2002	6/03 – 5/04	6/03 – 5/04
CNG Deere	2460	2/12/2003	4/04 – 9/04	4/04 – 9/04
	2461	2/12/2003	4/04 – 9/04	4/04 – 9/04
	2462	2/6/2003	4/04 – 9/04	4/04 – 9/04
	2463	1/30/2003	4/04 – 9/04	4/04 – 9/04
	2464	2/5/2003	4/04 – 9/04	4/04 – 9/04

The diesel buses were in operation at the Bladensburg depot just before the arrival and start of operation of the CNG buses. After the CNG buses started operation, the diesel buses were moved to other WMATA depots for operation. The evaluation period for the diesel buses was chosen to match a year's worth of operation at the Bladensburg depot so that the comparison to the CNG buses would be while operating in a similar duty cycle. Data from the Deere CNG buses originally matched the CWI CNG bus data period, but was extended six months of data beyond a software update for emissions and performance in March 2004, and only those six months were provided in the evaluation period as discussed earlier.

Evaluation results in this section are focused on the data periods indicated. In several cases, data from the start of operation for the buses is used to explore maturation level of the propulsion technologies. When this has been done, the charts indicate where the evaluation data periods are located within the data set. All data presented in this report have been collected from a time frame when the buses were operating from the Bladensburg depot.

Vehicle System Descriptions

Table 6 shows summary system descriptions for the evaluation buses. Appendix A gives more detailed vehicle system descriptions. The diesel buses were approximately 1 year older than the CNG buses and built by a different manufacturer. These differences are expected to affect the evaluation and are discussed in the data evaluation section of this report.

Table 7 shows emissions certification levels for the engines studied in this evaluation. Both groups of buses with CNG engines used oxidation catalysts for emissions control. The oxidation catalysts on the Deere engines were upgraded in March 2004; chassis dynamometer emission testing took place in April 2004, after which the 6-month evaluation of the Deere CNG buses began. The CWI CNG buses had the same oxidation catalyst configuration during the evaluation period and emission testing as they had since beginning operation at WMATA. The diesel buses did not have aftertreatment during the evaluation but had DPFs during the emission testing.

Table 6. WMATA Diesel and CNG Bus System Description Summary

Vehicle Information	Diesel	CNG – CWI	CNG – Deere
Number of Buses in Study	5	5	5
Chassis Manufacturer/Model	Orion VI Low Floor (06.501)	New Flyer C40 Low Floor	New Flyer C40 Low Floor
Chassis Model Year	2000	2001	2002
Engine Manufacturer/Model	DDC Series 50	CWI C Gas Plus	Deere 6081H
Engine Model Year	2000	2001	2002/2004*
Aftertreatment	None	Fleetguard-Nelson oxidation catalyst	Johnson Matthey oxidation catalyst
Maximum Power Maximum Torque	275 hp @ 2,100 rpm 890 lb-ft @ 1,200 rpm	280 hp @ 2,400 rpm 850 lb-ft @ 1,400 rpm	280 hp @ 2,200 rpm 900 lb-ft @ 1,500 rpm
Fuel System Capacity	125 gal	21,161 scf @ 3,600 psi	21,161 scf @ 3,600 psi
Transmission Manufacturer/Model	Allison/B400R	Allison/B400R	Allison/B400R
Curb Weight	29,300 lb	30,080 lb	30,080 lb
Gross Vehicle Weight	42,540 lb	40,600 lb	40,600 lb
Bus Cost	$300,000	$340,000	$340,000

*MY 2002 engines modified to MY 2004 specifications.

Table 7. Emissions Certification Levels (g/bhp-hr)

Model Year	Fuel	THC	NMHC	NO_x	CO	PM	Engine Family
1998/2001	Certification Levels	1.3	1.2	4.0	15.5	0.05	All
2000 Series 50	Diesel	0.11		3.9	0.9	0.05	YDDXH08.5FJN
2001/2 C Gas Plus	Natural Gas		0.2	1.5	1.3	0.01	2CEXH0505CBH
2004	Certification Levels	1.3	2.4, 2.5		15.5	0.05	All
2004 6081H	Natural Gas		0.2	1.5	0.9	0.01	4JDXH08.1066

Implementation Experience

As WMATA was planning to purchase new buses to be delivered in 2000 and 2001, the WMATA Board of Directors expressed a desire to proactively minimize bus emissions in the Washington, DC, metropolitan area. Nitrogen oxide (NO_x) was considered the most important emission, followed by PM. The Board requested that WMATA hold a workshop to review available bus technologies so that an informed purchasing decision could be made. WMATA held an alternative fuels workshop in July 2000. Topics included air pollution, asthma, methods of reducing diesel emissions, experience with hybrid electric and CNG buses, and development of fuel cells. WMATA wanted to reduce emissions as much as possible while using only proven and reliable technology.

One of the conclusions from the workshop was that several technologies could reduce NO_x well below current diesel emissions levels. Fuel cell technology was preferred for the future but was not expected to be available in the near term. Hybrid electric vehicles were in the testing phase and were not yet proven. Diesel buses with advanced emissions control required ULSD and were expected to reduce most pollutants significantly. CNG buses were the proven technology that produced the lowest NO_x emissions.

Following the workshop, the Board approved a request for proposal for CNG buses in December 2000, and then approved purchase of 164 low-floor CNG buses from New Flyer in August 2001. To execute the purchase as quickly as possible, WMATA used an existing option on a Pierce Transit (Tacoma, Washington) contract with New Flyer. At about the same time, WMATA reviewed its 10 bus-operating divisions to determine which locations would best accommodate CNG bus operations. Only four of the 10 divisions were candidates for conversion based on age of the buildings and property available for CNG equipment. The depot chosen to be first to operate CNG buses was Bladensburg. The second depot chosen for CNG operation was Four Mile Run. CNG operations started at Four Mile Run depot in 2005.

Operations at Bladensburg were scheduled to commence in January 2002. This required that a CNG fueling station be constructed, and a 40-year-old maintenance and operating facility be modified. Initial costs included a $40,000 incremental increase for the CNG buses, an additional $15.6 million for the fueling facility (~$4 million), and modifications to the Bladensburg facility (~$11.6 million).

The CNG fueling station at Bladensburg was completed in late 2001 (Figure 6 and Figure 7). CNG fueling, which is provided by three compressors, is located alongside diesel fueling. WMATA pays a contractor approximately $360,000 per year for operations and maintenance of the CNG fueling facility and equipment.

The maintenance facility was modified to accommodate CNG operation inside the facility, including additional ventilation (4 air changes per hour), methane detection, and alarm systems. Upgrades were required for the lighting and electrical systems. A new heating system was added so there were no open flames. Structural modifications were made for fireproofing and to isolate occupied building areas (office space). These modifications required asbestos disposal from the facility, which was unexpected and added nearly $1 million to the cost. Modifications were completed in late 2001. Figure 8 shows the maintenance facility, which is adjacent to the CNG fueling area.

Figure 6. CNG Fueling Area at Bladensburg

Figure 7. CNG Fueling Dispenser at WMATA

Complete awareness training was a key to successful introduction of the CNG buses, according to WMATA. Management and key staff visited several other transit agencies that had CNG buses in service. Pierce Transit provided training for mechanics and management personnel. WMATA staff also received training from New Flyer and received familiarization training sponsored by DOE and DOE's Clean Cities Program. WMATA participated in the Natural Gas Transit User's Group (TUG)[2] and hosted one of its meetings. The TUG brings natural gas transit bus operators together to share successes and important natural gas vehicle related information [8].

[2] See the NGVTF Web site at www.nrel.gov/vehiclesandfuels/ngvtf/tug.html for more information about TUG.

Figure 8. Maintenance Facility at Bladensburg

Many partners contributed to the implementation of CNG buses at WMATA. The following are summarized comments from WMATA staff about the major partners:

- The **natural gas company** was helpful and responsive to fuel supply and safety issues.
- The **fire department** became involved early in the process. This was considered a lesson learned, i.e., it is a good idea to involve the fire department early and regularly.
- The **permitting process** was challenging. There were issues getting all of the parties that needed to sign-off involved.
- **WMATA management** was supportive and hands-off except when necessary, as reported by staff at Bladensburg. Management was patient with problems that arose.
- **DOE/NREL** provided technical advice and Clean Cities Tiger Team consultants for advice in technology selection, procurement specifications, and training materials.
- **New Flyer, CWI, and Deere** were extremely supportive and available to ensure that bus issues were resolved quickly.

WMATA introduced CNG buses starting in February 2002 with 10 buses. All 164 CNG buses were phased into operation by the end of 2003. Comments from WMATA personnel on the implementation process for the fueling station, maintenance and operations facility upgrades; and bus operations were generally positive. The following are summarized comments from WMATA staff about each part of the implementation:

General Comments

- Lots of work was done well before the buses arrived onsite.
- There were some fears at the beginning, but the training and familiarization information was helpful.
- The slow introduction of the CNG buses into service was a good thing; buses performed better than expected, and reliability was feared to be a much bigger issue than it was.
- Use of CNG was ultimately a good thing: emissions are better, smell is much better, buses are quieter, and the shop is cleaner. The only issue is the fuel economy, but buses have plenty of power.
- The CNG buses were well received by the public. Drivers and mechanics generally like the buses.

- It was extremely important that WMATA management gave Bladensburg staff the power to make decisions, and that management was patient and supportive.
- It was important to stay on top of the CNG program and be proactive to ensure success.
- Care must be taken not to give in to the temptation to cut corners on the cost of the project and the equipment needed to be successful.

CNG Fueling Station

- There are no other CNG fueling stations around Bladensburg, so it is extremely important that the fueling station is operational.
- During the blackout in the Northeast, it became clear that Bladensburg should have backup generators for the fueling station, so that fueling can continue even without grid power. (Note: addition of backup power at WMATA is complete.)

Maintenance Facility

- There were general issues with the methane detection system, specifically false positives; this has been a problem with the fueling station as well. (Note: repair of this system is complete.)
- The need for welding outlets was an issue in the maintenance facility.

Routes and Bus Use

Currently, the 164 CNG buses are operated from the Bladensburg depot, located at 2250 26th Street, NE in Washington, DC. The Bladensburg depot operates 232 buses total. All buses of each type/size are randomly dispatched on the routes of that type/size serviced from the depot. The CNG buses do not have restrictions due to range or power requirements. The CNG and diesel buses are interchangeable on all routes that use 40-foot buses. As WMATA receives its next CNG bus order, Bladensburg is expected to receive 38 more CNG buses, for a total of 202 CNG buses out of 232 buses at the depot. The remaining 30 buses at Bladensburg will include articulated buses and buses less than 40-feet long.

Table 8 shows total mileage and operating hours for CNG buses at Bladensburg; Appendix B gives more detail. The mileage and operating hours include revenue and non-revenue operation. These statistics were calculated to understand the average speed of CNG bus operation as an indicator of duty cycle. The "Total" line in the table includes the weekday numbers multiplied by five, and added to the Saturday and Sunday numbers to give a result for the entire week's operation. The average speed by route ranges from 8–16 mph and is an overall average of 11.6 mph.

Table 8. Summary of CNG Bus Operation at Bladensburg

Day of Week	Miles/Day	Operating Hours	Average Speed (mph)
Weekday	16,613.88	1,448.43	11.5
Saturday	7,224.11	581.73	12.4
Sunday	5,770.27	438.40	13.2
Total	**96,063.78**	**8,262.30**	**11.6**

Table 9 shows average monthly mileage for the study buses. The diesel buses averaged 25% higher monthly mileage than the CNG buses. The primary reason for this difference between diesel and CNG bus mileage is the way the buses were scheduled during their evaluation periods. The maximum pullout for Bladensburg is 206 buses for the morning peak and 183 buses for the afternoon peak. Only 82 Bladensburg buses pull out in the morning and run all day, and it is these all-day buses that accumulate the highest mileage. When the diesel bus evaluation period began in September 2001, there were no CNG buses at Bladensburg, and the evaluation diesel buses were among the newest diesel buses at the depot. WMATA chose to put the newest diesel buses (including the evaluation buses) on the all-day routes more often than older diesel buses. When the CNG buses began operation at Bladensburg they were more randomly assigned to the all-day routes, i.e., unlike the diesel evaluation buses, the CNG evaluation buses were not preferentially used on all-day routes. Thus, the CNG evaluation buses averaged less monthly and yearly mileage than the diesel evaluation buses. WMATA indicated that the difference in mileage per vehicle was not because of a problem with the CNG buses.

Only 6 months of data for the Deere CNG buses are included in this analysis (Table 5). Deere was still having maintenance and operating issues with bus number 2464 (discussed later) during the evaluation, which kept that bus from reaching a monthly average mileage close to the other buses.

Table 9. Average Monthly Bus Use (Evaluation Period)

Vehicle	Total Mileage	Months	Monthly Average
2070	34,399	12	2,867
2071	39,361	12	3,280
2072	45,252	12	3,771
2073	34,894	12	2,908
2074	31,539	11	2,867
Diesel Buses	**185,445**	**59**	**3,143**
2302	23,842	11	2,167
2303	36,951	12	3,079
2304	29,710	12	2,476
2307	29,436	12	2,453
2309	23,769	10	2,377
CNG Buses - CWI	**143,708**	**57**	**2,521**
2460	14,773	6	2,462
2461	16,162	6	2,694
2462	16,914	6	2,819
2463	16,619	6	2,770
2464	9,035	6	1,506
CNG Buses - Deere	**73,503**	**30**	**2,450**

Fuel Consumption, Economy, and Cost

Data for fuel consumption included each fuel fill (amount of fuel, hubodometer reading, and date), and fuel prices were collected from WMATA monthly. Fuel consumption and economy by vehicle and study group are detailed in Appendix C. WMATA used #2 diesel until it switched to ULSD in October 2001.

The CNG fuel consumption data were collected at the CNG dispenser with a readout in diesel energy gallon equivalents (DGE). The dispenser actually measures CNG in pounds mass with a Coriolis meter. The dispenser computer converts the pounds mass to DGE at 6.4 lb CNG/DGE.

Table 10 shows fuel consumption and economy for each study vehicle and study group. The diesel bus fuel consumption and economy were calculated from operation during September 2001 through August 2002. The CNG bus fuel consumption and economy for the CWI buses were calculated from operation during June 2003 through May 2004, and for the Deere buses from operation during April 2004 through September 2004.

Table 10. Fuel Consumption and Economy by Vehicle (Evaluation Period)

Vehicle	Mileage (Fuel Base)	Gallons Consumed	MPG*
2070	32,861	11,969	2.75
2071	36,670	12,157	3.02
2072	44,515	15,076	2.95
2073	32,875	11,791	2.79
2074	31,440	11,919	2.64
Total – Diesel	**178,361**	**62,912**	**2.84**
2302	23,842	9,932	2.40
2303	34,650	13,593	2.55
2304	29,472	13,363	2.21
2307	29,096	12,794	2.27
2309	23,769	11,140	2.13
Total – CNG CWI	**140,829**	**60,822**	**2.32**
2460	14,773	6,389	2.31
2461	16,162	7,208	2.24
2462	16,514	6,404	2.58
2463	15,541	6,470	2.40
2464	8,803	3,628	2.43
Total – CNG Deere	**71,793**	**30,099**	**2.39**

*Miles per diesel gallon for diesel buses, miles per DGE for CNG buses.

The mileage shown in Table 10 is not the entire mileage that each vehicle accumulated during the evaluation period. It is only the mileage used in the fuel economy calculation. Some data have been removed from the fuel economy calculation based on fuel consumption data that was missing from WMATA's data recording system.

One issue with the fuel economy data is that when the hubodometer reading from WMATA's buses is not available or appears to be incorrect, the computer system inserts a hubodometer reading calculated to match a 3.00-mpg fuel economy. In most cases, this is corrected in the next fuel record in the database. However, in some cases, these incorrect hubodometer readings continue to be recorded for several days or weeks. This causes some of the fuel economy calculations to be artificially high until the hubodometer is corrected in the system.

The energy equivalent fuel economy of the CWI CNG buses was 18% lower, and the energy equivalent fuel economy of the Deere CNG buses was 16% lower compared with the diesel buses. This fuel economy difference is better than previous DOE/NREL studies of CNG and LNG transit buses, which showed natural gas bus fuel economy to be 20%–30% lower than diesel bus fuel economy [9,10]. Figure 9 and Figure 10 show fuel economy by study group and month for the diesel and CNG buses during their entire operation at Bladensburg. The diesel buses operated at Bladensburg for more than 2 years and consistently averaged around 2.8 mpg. The CNG buses operated since August 2002 and consistently averaged around 2.3–2.4 mpDGE (miles per diesel gallon equivalent).

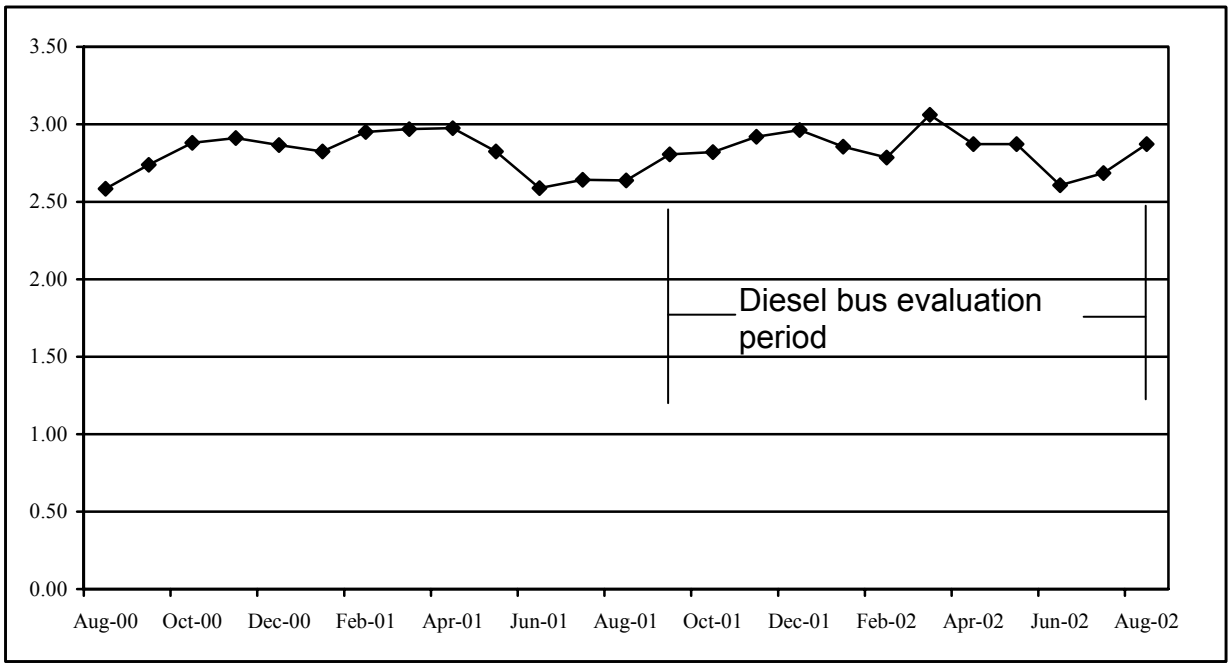


Figure 9. Fuel Economy (mpg) of Diesel Buses at Bladensburg (All Data)

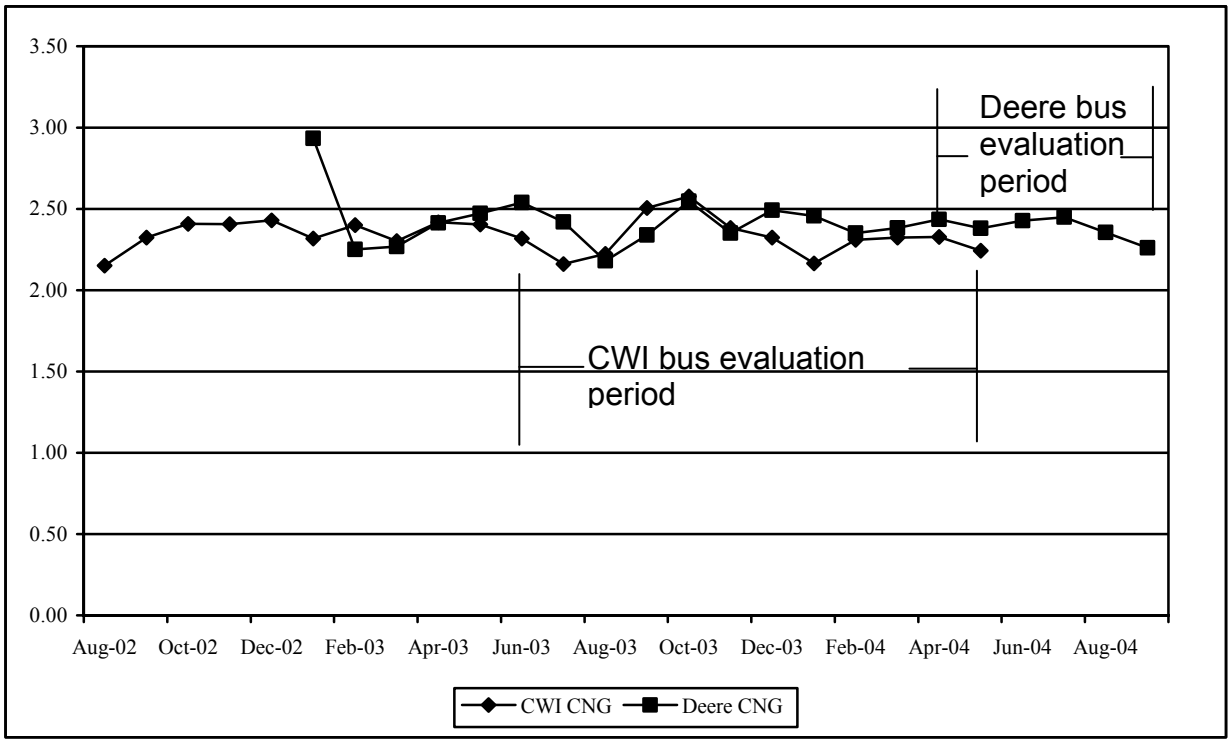


Figure 10. Monthly Fuel Economy (mpDGE) of CNG Buses at Bladensburg (All Data)

Since this evaluation, the WMATA diesel buses as a fleet have been modified to reduce emissions with DPFs, and some of the diesel buses have been repowered with newer EGR-equipped engines. These modifications may have affected the fuel economy of the diesel buses.

The diesel fuel cost during the diesel bus evaluation period averaged $0.75 per gallon. Diesel fuel cost during the CNG bus evaluation period averaged $1.33 per gallon. CNG fuel costs during the CNG bus evaluation period averaged $1.19 per DGE. These average costs were calculated based on monthly average costs and are shown in Appendix D.

Electricity required for operation of the fuel station added to the cost of the CNG fuel. WMATA estimated this cost to be approximately $300,000 per year or $25,000 per month. The approximate CNG use at this station has been 182,000 DGE per month. This translates into an increase of $0.14 per DGE for electricity. Thus, the real cost of CNG averaged $1.33 per DGE, the same as the recent average diesel fuel cost.

Total Maintenance Costs

Maintenance work orders for each bus in this study were collected as far back as they were available from WMATA. For the diesel buses, this included the last 10 months of operation at Bladensburg before the CNG buses started operation. Once the CNG buses started full operation at Bladensburg, the diesel buses were sent to another depot. For both sets of CNG buses, all of the maintenance work orders were collected back to start of operation for each vehicle. For the CWI CNG buses, the last 12 months of operation are the evaluation focus, and for the Deere CNG buses the last 6 months of operation are the evaluation focus. Appendix E provides detailed maintenance cost information by vehicle and study group.

The evaluation periods were chosen to attempt to match the same operation and maintenance activities by only collecting data from the Bladensburg depot and using data from similar vehicle ages, based on hubodometer readings. However, there are slight differences. At the end of the evaluation period for the study group buses, the hubodometer readings were generally as follows: diesel buses, had accumulated 60,000–70,000 miles; CWI CNG buses, 50,000–60,000 miles; and Deere CNG buses, approximately 40,000 miles. There was one exception for the Deere buses: bus 2464 had approximately 20,000 miles at the end of the evaluation period. These relative ages are important because maintenance costs tend to go up slightly over time as buses age. Thus, the Deere buses should have measurably lower maintenance costs than the diesel buses. The CWI buses most likely do not have enough of an age difference to have measurably different maintenance costs compared with the diesel buses.

Warranty costs are generally not included in this analysis of maintenance costs. Warranty has been paid as a premium for the CNG buses in the purchase price and is not included in this operations analysis. Some parts were provided to WMATA at no cost, and some labor from CWI and Deere mechanics helped WMATA introduce the CNG buses and keep them operating. Any cost incurred by WMATA for the CNG buses that was not covered by warranty has been included in this analysis.

For DOE/NREL evaluations, accident repairs are typically removed because of their random nature, high cost, and potential to skew analysis results when they have no direct impact on the comparison being drawn in the evaluation. Accidents are only relevant if they indicate safety issues. Only one minor accident occurred during the WMATA study—to one of the diesel buses—and there were no costs reported associated with the repair. No significant safety issues were reported during the WMATA evaluation.

Tire costs at WMATA are part of a lease program and have not been included in this maintenance cost analysis. However, labor hours for tire work or parts associated with tire work have been included. Only costs for the tires themselves have not been included.

Labor costs for this evaluation have been kept constant at $50/hour for all maintenance activities. Labor hours have been reported so this number can be adjusted to reflect another average mechanic rate as desired. Parts costs were taken from recent costs for those parts, and these costs were held constant for the evaluation.

Table 11 shows total maintenance costs for each study group for all data and for the evaluation periods. For the evaluation periods, the CWI CNG buses had total maintenance costs 12% lower than for the diesel buses, and the Deere CNG buses had total maintenance costs 2% lower than for the diesel buses.

Table 11. Total Maintenance Costs

Vehicle	All Data (10 Months)				Evaluation Period (10 Months)			
	Mileage	Parts ($)	Labor Hours	Cost ($) per Mile	Mileage	Parts ($)	Labor Hours	Cost ($) per Mile
2070	27,301	2,465.63	315.6	0.668	27,301	2,465.63	315.6	0.668
2071	33,309	3,741.82	297.2	0.558	33,309	3,741.82	297.2	0.558
2072	38,292	1,992.55	262.8	0.395	38,292	1,992.55	262.8	0.395
2073	29,169	2,840.31	342.9	0.685	29,169	2,840.31	342.9	0.685
2074	24,475	2,015.62	321.5	0.739	24,475	2,015.62	321.5	0.739
Total Diesel	**152,546**	**13,055.93**	**1,540.0**		**152,546**	**13,055.93**	**1,540.0**	
Average per Bus	**30,509**	**2,611.19**	**308.0**	**0.590**	**30,509**	**2,611.19**	**308.0**	**0.590**
Vehicle	**All Data**				**Evaluation Period (12 Months)**			
	Mileage	**Parts ($)**	**Labor Hours**	**Cost ($) per Mile**	**Mileage**	**Parts ($)**	**Labor Hours**	**Cost ($) per Mile**
2302	44,531	4,428.23	411.2	0.561	23,842	2,166.81	234.5	0.583
2303	58,147	2,922.35	421.7	0.413	36,951	1,949.87	261.2	0.406
2304	52,180	3,089.44	433.3	0.474	29,710	1,662.35	237.2	0.455
2307	49,367	3,967.37	441.7	0.528	29,436	2,110.01	235.2	0.471
2309	45,516	3,254.37	480.2	0.621	23,769	3,254.37	310.7	0.790
Total CWI CNG	**249,741**	**18,678.74**	**2,188.1**		**143,708**	**11,143.41**	**1,278.8**	
Average per Bus	**49,948**	**3,735.75**	**437.6**	**0.513**	**28,742**	**2,228.68**	**255.8**	**0.522**
Vehicle	**All Data**				**Evaluation Period (6 Months)**			
	Mileage	**Parts ($)**	**Labor Hours**	**Cost ($) per Mile**	**Mileage**	**Parts ($)**	**Labor Hours**	**Cost ($) per Mile**
2460	41,636	4,091.98	503.4	0.703	14,773	1,902.11	175.3	0.722
2461	39,875	3,058.65	503.6	0.708	16,162	598.32	106.5	0.366
2462	42,490	3,471.63	496.8	0.666	16,914	961.96	145.1	0.486
2463	42,692	4,255.34	541.9	0.734	16,619	1,410.27	162.8	0.575
2464	17,865	1,759.75	428.4	1.297	9,053	568.83	147.7	0.880
Total Deere CNG	**184,558**	**16,637.35**	**2,474.1**		**73,503**	**5,441.49**	**737.4**	
Average per Bus	**36,912**	**3,327.47**	**494.8**	**0.760**	**14,701**	**1,088.30**	**147.5**	**0.576**

"All Data" for the CWI CNG buses were generally from 8/02–5/04 and for the Deere CNG buses were generally from 2/03–9/04. The "Evaluation Period" was the final 12 months of data for the CWI CNG buses and the final 6 months for the Deere CNG buses. The longer "All Data" period is included to study how the maintenance costs have changed over a longer period.

One diesel bus had significantly lower maintenance costs than the other diesel buses. This was because of low frequency of unscheduled maintenance for this one bus. The other diesel buses had issues with brakes, hydraulics, air conditioning, transmission, and the engine. The CWI CNG buses had two high-cost buses—2302 and 2309—caused by brake, transmission, engine, and cooling system repairs. The Deere CNG buses also had two high-cost buses: 2460 and 2464. For bus 2460, the cost was due to brake repairs and engine issues. Bus 2464 had significantly lower

use owing to engine problems and damage to the destination sign and body of the bus that had to be repaired.

Figure 11, Figure 12, and Figure 13 show cumulative average maintenance cost for each of the study bus groups for the entire data collection. Diesel bus maintenance costs were generally above $0.500/mile, with a slight increase at the end of the data period (Figure 11). CWI CNG bus maintenance costs averaged about $0.500/mile for nearly the entire operating period (Figure 12). The Deere CNG buses had high maintenance costs at the beginning of operation, but these costs came down significantly as the buses started full operation around March–April 2004 (Figure 13). The early high maintenance costs for the Deere CNG buses were caused by work done to resolve issues of repowering these buses from the CWI engine to the Deere engine.

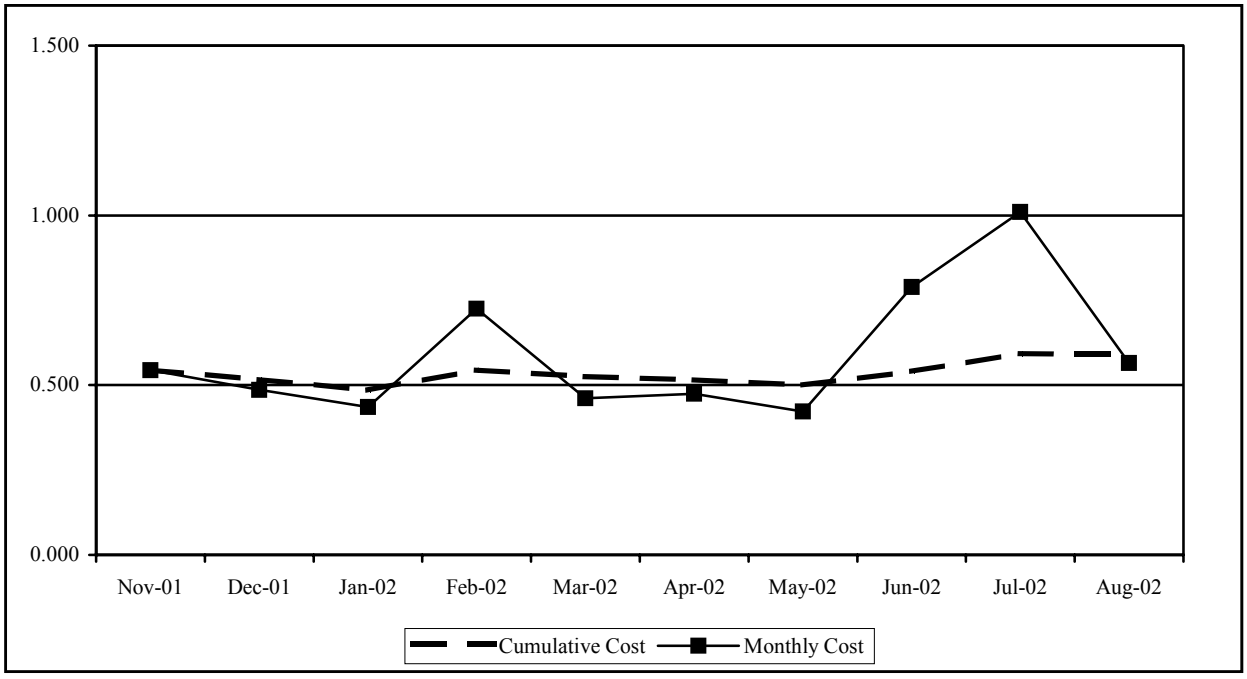


Figure 11. Monthly and Cumulative Maintenance Cost for Diesel Buses ($/Mile, All Data) (for diesel buses, All Data = Evaluation Period)

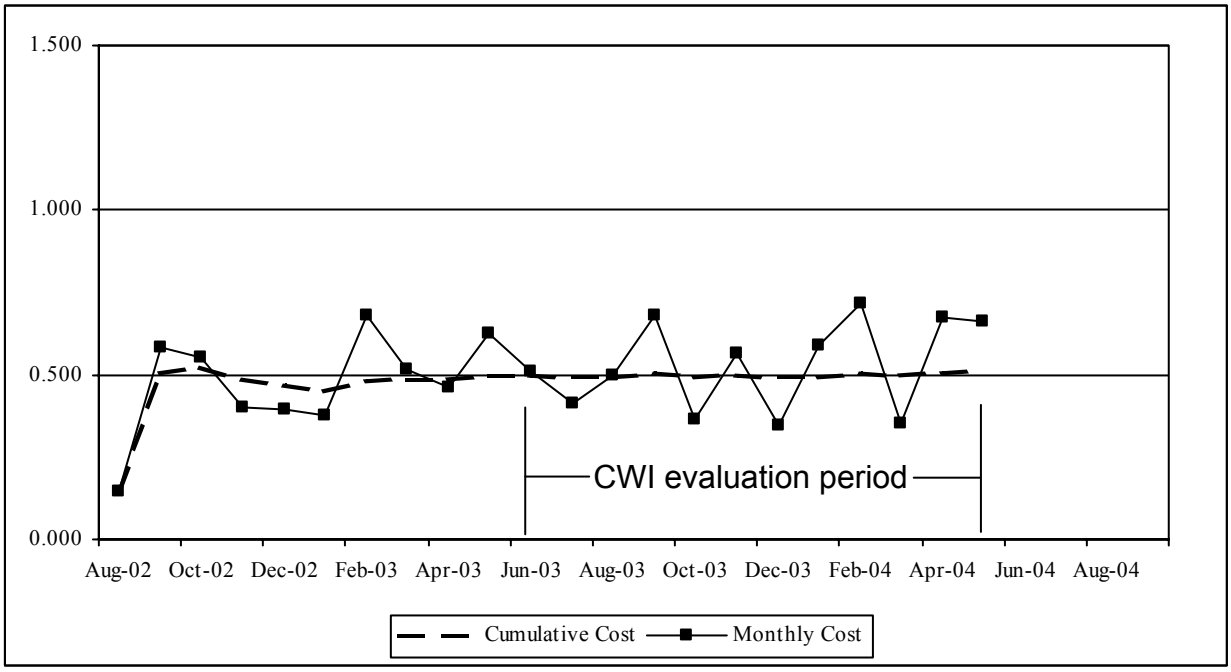


Figure 12. Monthly and Cumulative Maintenance Cost for CWI CNG Buses ($/Mile, All Data)

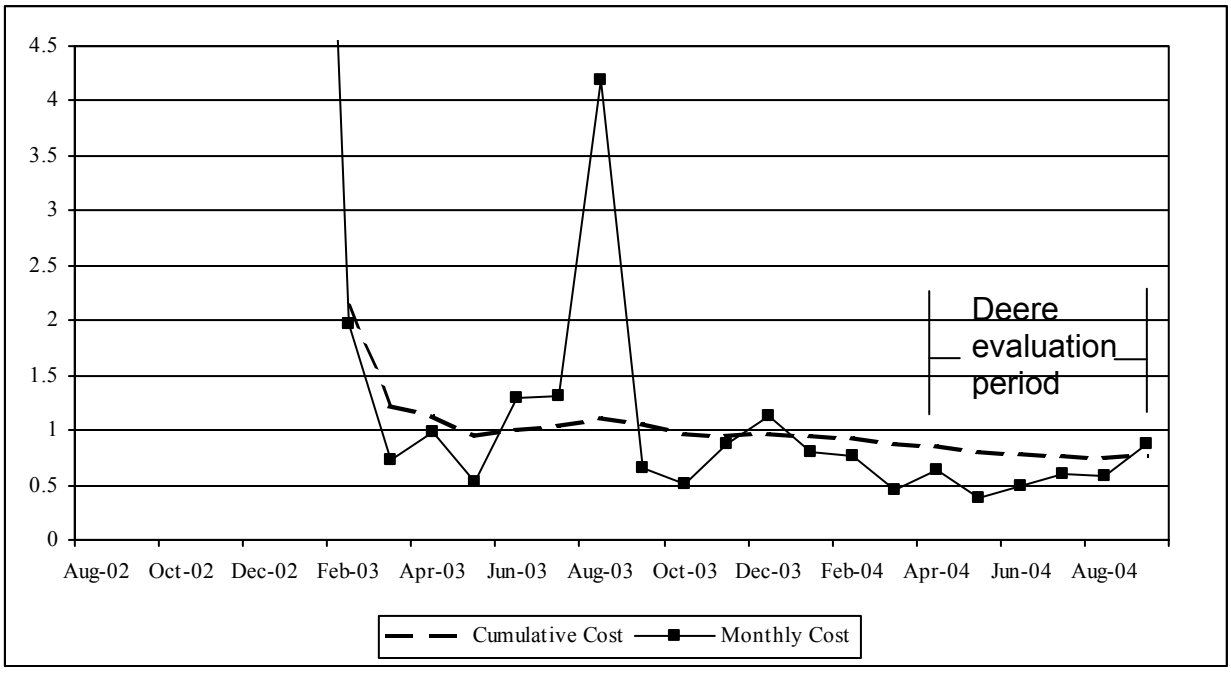


Figure 13. Monthly and Cumulative Maintenance Cost for Deere CNG Buses ($/Mile, All Data)

Maintenance Costs by Vehicle System

Table 12 shows maintenance costs by vehicle system and study group of buses. The vehicle system maintenance costs shown in the table include the following:

- Preventive maintenance inspections (PMI): only labor for inspections during preventive maintenance
- Engine- and fuel-related: exhaust, fuel, engine, non-lighting electrical, air intake, and cooling
- Cab, body, accessories, and hydraulics: includes body repairs, glass, and painting; cab and sheet metal repairs including seats and doors; accessory repairs such as radios and destination signs; and hydraulics for systems such as the wheelchair lift
- Brakes
- Heating, ventilation, and air conditioning (HVAC)
- Transmission
- Air, general: buses have significant need for compressed air to control brakes, throttle, door systems, and suspension; this category is for repairs of a general nature for the air system and not specifically associated with one of the systems listed in this category
- Tires: WMATA has a tire lease program, so only the mechanic time and parts other than the tires themselves are included in this category
- Lighting
- Frame, steering, and suspension
- Axles, wheels, and drive shaft.

Appendix F has detailed maintenance costs broken down by system for each study group. The top five vehicle systems based on maintenance costs are the same for each of the study groups for the evaluation period; however, the order is slightly different for each. Those five systems are PMI; engine/fuel-related; cab, body, accessories, and hydraulics; brakes; and HVAC.

Table 12. Breakdown of Vehicle System Maintenance Costs (Evaluation Periods Only)

System	Diesel		CWI CNG		Deere CNG	
	Cost/mi ($)	Percent of Total (%)	Cost/mi ($)	Percent of Total (%)	Cost/mi ($)	Percent of Total (%)
PMI	0.170	29	0.121	23	0.139	24
Engine/Fuel-Related	0.122	20	0.135	26	0.126	22
Cab, Body, Accessories, and Hydraulics	0.104	17	0.109	21	0.170	29
Brakes	0.067	11	0.034	6	0.066	11
HVAC	0.039	7	0.034	6	0.030	5
Transmission	0.035	6	0.030	6	0.005	1
Air, General	0.016	3	0.003	1	0.003	1
Frame, Steering, and Suspension	0.015	3	0.026	5	0.006	1
Tires	0.013	2	0.010	2	0.010	2
Lighting	0.006	1	0.017	3	0.006	1
Axles, Wheels, and Drive Shaft	0.004	1	0.003	1	0.015	3
Total	**0.590**	**100**	**0.522**	**100**	**0.576**	**100**

The following discussion of maintenance costs by vehicle system focuses on the evaluation periods:

- **Total engine/fuel-related**—The CWI CNG buses had costs 11% higher, and the Deere CNG buses had costs 3% higher than the diesel buses. These higher costs are expected for the CNG buses because of higher engine oil and fuel filter costs as well as costs for spark plugs, which are not required for the diesel buses. The following are descriptions of each of the system groups that constitute this category.

    - **Exhaust**—The exhaust system maintenance was nearly the same for the CWI CNG and the diesel buses. The Deere CNG buses had 67% higher maintenance costs than the diesel buses; the higher cost was due to repairs for the exhaust pipes and issues related to the turbocharger.

    - **Fuel**—Both groups of CNG buses had higher fuel system maintenance costs (2.3 times higher for CWI CNG and 51% higher for Deere CNG) than the diesel buses. This was due to more expensive fuel filters and troubleshooting. Some problems with the natural gas sensors were experienced.

    - **Engine**—Engine maintenance was nearly the same for the CWI CNG (6% higher) and diesel buses. The Deere CNG buses had 74% higher maintenance costs compared with the diesel buses. The Deere CNG buses had troubleshooting costs and problems with the engine sensors such as the oxygen sensor.

    - **Non-lighting electrical**—Both groups of CNG buses had higher maintenance costs for these systems (2.3 times higher for CWI CNG and 41% higher for Deere CNG).

High troubleshooting costs were attributed to this category related to spark plugs, batteries, and alternator repairs.

- **Air intake**—Both groups of CNG buses had higher maintenance costs for the air-intake system (21 times higher for CWI CNG and 8.5 times higher for Deere CNG). This was due to the diesel buses having very low maintenance costs for air intake repairs and the CNG buses having their air filters replaced on a more regular basis. The diesel buses only had air-intake filter repairs with no troubleshooting labor reported.

- **Cooling**—Both groups of CNG buses had lower maintenance costs for the cooling system (64% lower for CWI CNG and 69% lower for Deere CNG). The diesel buses had problems with the radiator and main cooling fan. Significant labor was expended to troubleshoot and repair these problems, including several roadcalls.

- **Cab, body, accessories, and hydraulics**—The CWI CNG buses had 5% higher maintenance costs for these systems than the diesel buses. The Deere CNG buses had 63% higher maintenance costs than the diesel buses. The Deere CNG buses had a few significant repairs for one of the rear doors and one of the destination signs.

- **Frame, steering, and suspension**—The CWI CNG buses had maintenance costs 73% higher than the diesel buses. Most of these repairs were for the suspension system, including shocks and leveling valves. There was one significant repair for the steering system. The Deere CNG buses had maintenance costs 60% lower than the diesel buses.

- **Axles, wheels, and drive shaft**—The CWI CNG buses had maintenance costs 25% lower than the diesel buses. The Deere CNG buses had maintenance costs 3.8 times higher than the diesel buses. The diesel bus maintenance costs for these systems were low, and the Deere CNG buses had a few significant repairs for the wheels and drive shaft.

- **Brakes**—The CWI CNG buses had brake maintenance costs 49% lower than the diesel buses. The Deere CNG buses had costs about the same as the diesel buses, which was not expected because the Deere CNG buses had lower mileage.

- **Tires**—Both groups of CNG buses had tire repair costs 23% lower than the diesel buses. Repair costs for tires were low for all three groups of buses.

- **HVAC**—Both groups of CNG buses had HVAC repair costs lower than the diesel buses (13% lower for CWI CNG and 23% lower for Deere CNG).

- **PMI**—Both groups of CNG buses had PMI costs lower than the diesel buses (29% lower for CWI CNG and 18% lower for Deere CNG). There was a difference in time for the evaluation period used for the diesel buses as compared to the CNG buses. There appears to have been a change in the standard number of hours of mechanic labor used for the inspection of buses between when the diesel bus evaluation period occurred and when the CNG bus evaluation period occurred.

- **Lighting**—The CWI CNG buses had maintenance costs 2.8 times higher than the diesel buses. However, all three bus groups had low lighting costs. The CWI CNG buses had a few significant repairs, which required troubleshooting the wiring. The Deere CNG buses had essentially the same maintenance costs for lighting repairs as the diesel buses.

Roadcalls

A roadcall is defined in this report as an on-road failure of an in-service bus that required the bus be taken out of service or replaced on route. Roadcalls are a direct indicator of reliability for transit buses. Figure 14 and Figure 15 show miles between roadcalls (MBRC) for all roadcalls and for only engine- and fuel-related (exhaust, fuel, engine, non-lighting electrical, air intake, and cooling) roadcalls. A higher MBRC means higher reliability.

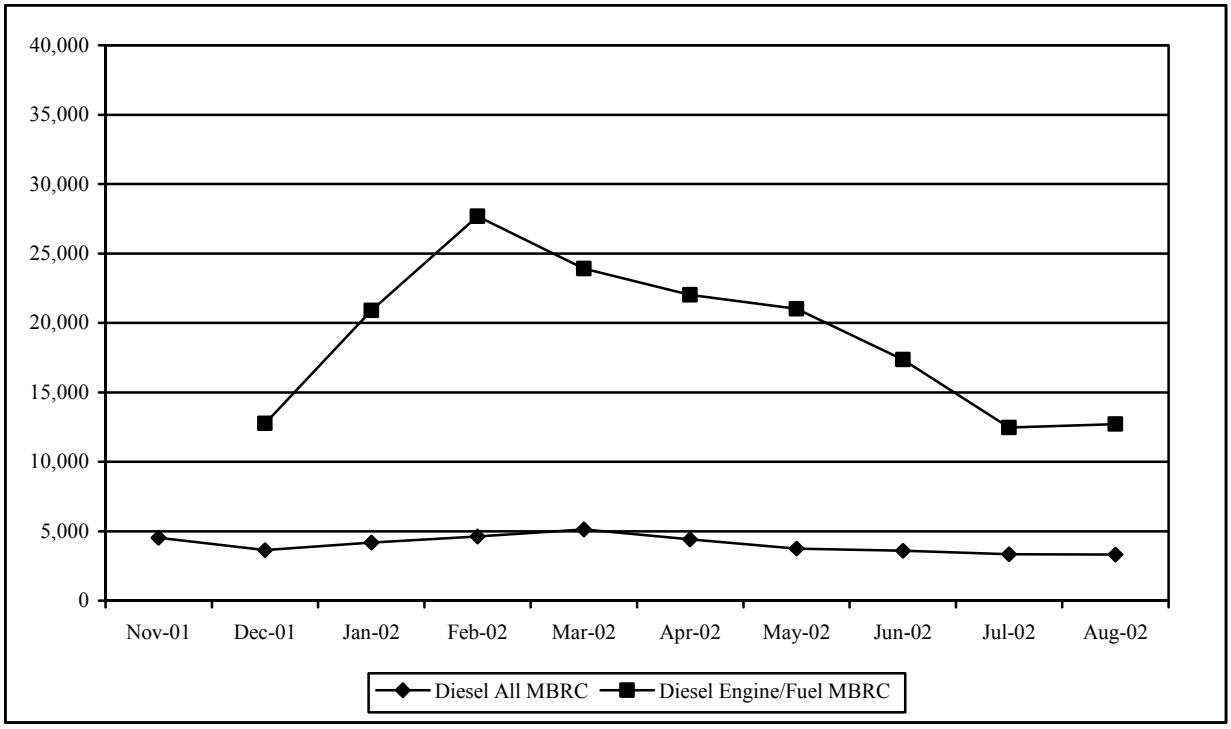


Figure 14. Cumulative MBRC for Diesel Buses (All Data)
(for diesel buses, All Data = Evaluation Period)

Figure 14 shows MBRC for the diesel buses. The MBRC for all roadcalls is below 5,000 miles for the entire data period shown. The MBRC for the engine- and fuel-related roadcalls was as high as about 27,000 miles and then dipped down below 15,000 miles. The lower MBRC for engine- and fuel-related roadcalls was due to engine and cooling system problems.

Figure 15 shows MBRC for both groups of CNG buses. The CWI CNG buses had MBRC for all roadcalls above 5,000 miles for all of the data collected. The MBRC for engine- and fuel-related roadcalls for CWI CNG buses was as high as 35,000 miles and ended around 23,000 miles. The drop from 35,000 miles during June–August 2003 was caused by five roadcalls: one for charging, one for exhaust, and three for the engine system. The CWI CNG buses had an MBRC for all roadcalls and for engine- and fuel-related roadcalls above the MBRC for the diesel buses.

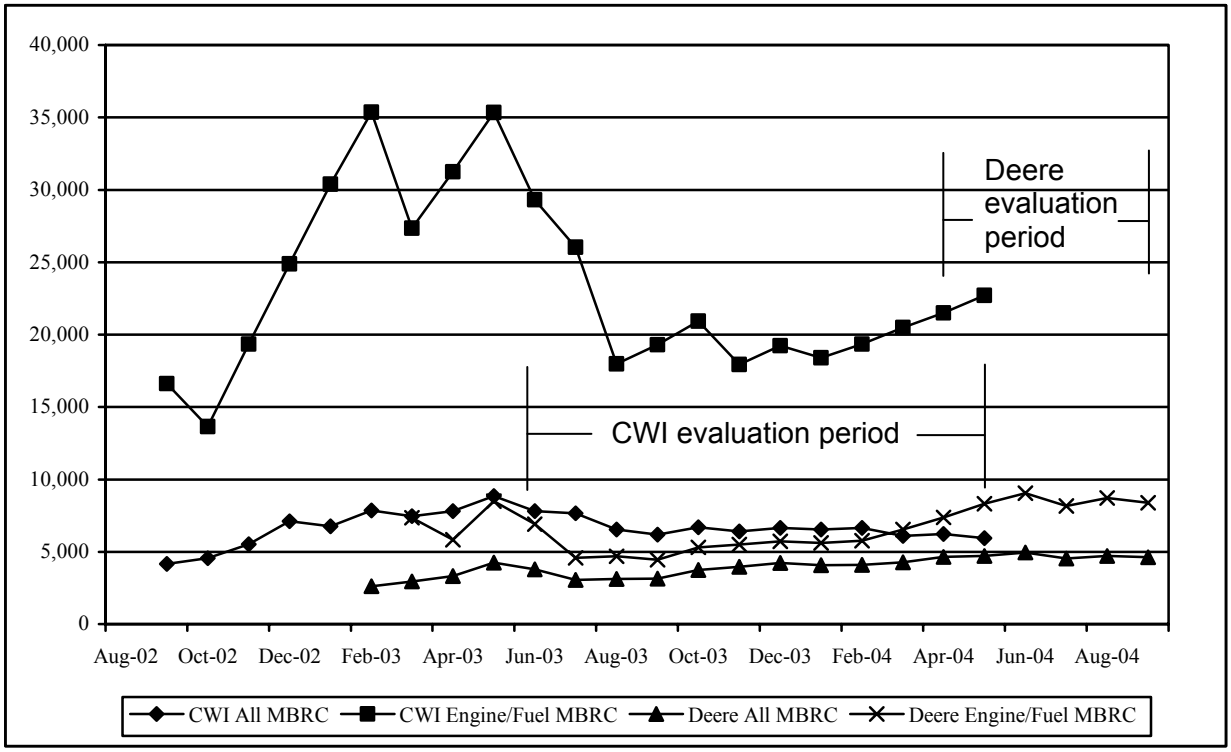


Figure 15. Cumulative MBRC for CNG Buses (All Data)

For the Deere CNG buses, the MBRC for all roadcalls ended at just under 5,000 miles. The MBRC for engine- and fuel-related roadcalls rose significantly during the last 6 months shown and ended at around 8,000 miles. Problems causing roadcalls for the engine- and fuel-related roadcalls included engine, exhaust, and cooling system issues. The last 6 months of operation showed the highest MBRC for both types of roadcalls for the Deere CNG buses.

Table 13 shows all roadcalls broken down by system for the evaluation period. For the diesel buses, the systems with the highest number of roadcalls were brakes, transmission, cooling, and farebox. For the CWI CNG buses, the systems with the highest number of roadcalls were farebox, doors and interlock, engine, and transmission. For the Deere CNG buses, the systems with the highest number of roadcalls were farebox, engine, and body exterior.

Table 13. Summary of Roadcalls by System (Evaluation Periods)

System	Diesel		CWI – CNG		Deere – CNG	
	Roadcalls	Percent (%)	Roadcalls	Percent (%)	Roadcalls	Percent (%)
HVAC	2	4	0	0	0	0
Doors and Interlock	2	4	4	14	0	0
Wipers and Washer	0	0	0	0	1	7
Windows	0	0	2	8	0	0
Body Exterior	1	2	1	3	0	0
Body Interior	1	2	1	3	2	14
Brakes	8	18	1	3	0	0
Steering	0	0	1	3	0	0
Suspension	2	4	0	0	0	0
Tires	1	2	0	0	0	0
Rear Axle	0	0	0	0	1	7
Transmission	7	15	3	10	0	0
Non-Lighting Electrical	1	2	1	3	1	7
Lighting	1	2	0	0	0	0
Cooling	7	15	1	3	0	0
Exhaust	0	0	1	3	0	0
Fuel	2	4	1	3	0	0
Engine	2	4	4	14	3	22
Wheelchair Lift/Ramp	1	2	0	0	0	0
Farebox	7	15	9	30	6	43
Horn	1	2	0	0	0	0
Destination Sign	1	2	0	0	0	0
Total	**47**	**100**	**30**	**100**	**14**	**100**

Summary of Operating Costs

Table 14 shows a summary of operating costs for the study groups, including fuel and total maintenance costs per mile. The diesel study group has two rows in the table: one with the diesel fuel cost average from the evaluation period and another calculated with an average diesel fuel cost from the same period as the CNG bus evaluation period. The average diesel cost per gallon was $0.75 for the evaluation period and $1.33 for the representative or recent evaluation period (the same period as the CWI CNG bus evaluation period). The CNG fuel costs were averaged over the evaluation period, and $0.14 per gallon was added for electricity costs for operating the CNG compression and dispensing station (based on a $300,000 per year cost for electricity). This CNG fuel cost does not include the operations and maintenance contract for the station ($360,000 per year) because the diesel fuel station operation and maintenance costs were unknown for the evaluation periods.

The maintenance costs shown are for the evaluation period and include all maintenance actions. The total maintenance costs are similar for the three study groups, with the diesel group being slightly higher than the two CNG groups. For total operating costs, the representative diesel group was only 3% lower compared with the CWI CNG group and 7% lower compared with the

Deere CNG group. The general conclusion is that the operating costs accounted for in this evaluation for the diesel and CNG buses are similar, and are most influenced by fuel cost and fuel economy.

Table 14. Total Operating Cost ($/Mile, Evaluation Periods)

Study Group	Fuel Cost	Maintenance Cost	Total Cost
Diesel (Evaluation Period)	0.26	0.59	**0.85**
Diesel (Representative)*	0.47	0.59	**1.06**
CNG – CWI	0.57	0.52	**1.09**
CNG – Deere	0.56	0.58	**1.14**

*The difference between diesel (evaluation period) and diesel (representative) is the fuel cost. Diesel (evaluation period) uses the actual diesel fuel cost during the evaluation period of the diesel buses, September 2001 to August 2002 ($0.75/gal). Diesel (representative) uses the diesel fuel cost during the evaluation period of the CNG buses ($1.33/gal).

Summary of Results

The presented results focus on the evaluation period for each study group of buses: diesel buses, 12 months (9/2001-8/2002); CWI CNG buses, 12 months (6/2003-5/2004); Deere CNG buses, 6 months (4/2004-9/2004). The Deere CNG buses had a limited evaluation of 6 months because the implementation was a field test confirmation of the technology, which will be a full market introduction with the next Deere CNG bus order from WMATA. The CWI CNG bus propulsion technology was considered a fully implemented commercial product and had a full 12-month evaluation as did the CWI CNG technology. Diesel propulsion technology was used as the baseline for this evaluation.

Implementation Experience. WMATA was dedicated to a positive implementation of CNG buses and appeared to implement the CNG buses into its operation with ease. Work was done early to ensure the equipment (vehicles and facilities) was well matched to WMATA's operation. Management was reported to have been supportive while allowing depot staff to make their own implementation decisions. Because of all the work done before the buses and equipment were brought to the depot, the overall implementation experience was better than expected. WMATA also received good technical support from manufacturers and others.

Routes and Bus Use. The CNG and diesel buses at the Bladensburg depot were used randomly on 40-foot bus routes. The CNG buses did not have restrictions due to range or power. The diesel buses used in the evaluation operated from Bladensburg depot from 2001–2002 (before the use of the CNG buses). The CNG buses operated from Bladensburg depot starting in 2002.

Fuel Economy and Cost. The CNG buses had fuel economies 16%–18% lower than the diesel buses: 2.3–2.4 mpDGE for the CNG buses versus 2.8 mpg for the diesel buses. This fuel economy difference is better than the 20%–25% fuel economy penalty for CNG shown in previous DOE/NREL transit bus studies and may be due to emission control hardware now required on diesel engines.

The CNG fuel cost averaged $1.19/DGE during the evaluation period. Adding the electricity cost for the CNG compressor station ($0.14/DGE), the total CNG fuel cost was $1.33/DGE. The

ULSD fuel cost during the evaluation period for the diesel bus operation at Bladensburg (2002) averaged $0.75/gal. However, during the CNG bus evaluation period, the ULSD fuel cost averaged $1.33/gal.

Total Maintenance Costs. For the evaluation periods, the CWI CNG buses had 12% lower total maintenance costs than the diesel buses, and the Deere CNG buses had 2% lower total maintenance costs than the diesel buses.

Engine- and Fuel-Related Maintenance Costs. The engine- and fuel-related systems are the air intake, cooling, exhaust, fuel, engine, and non-lighting electrical (cranking, charging, and ignition) systems. These vehicle systems are the most relevant when comparing the differences in diesel and CNG transit bus propulsion technologies. The CWI CNG buses had costs 11% higher than the diesel buses, and the Deere CNG buses had costs 3% higher than the diesel buses. The higher maintenance cost for the CNG buses versus the diesel buses for these systems was expected because of higher-cost engine oil, fuel filters, and the addition of the spark plugs and ignition systems for the CNG buses.

Roadcalls. A roadcall is defined in this report as an on-road failure of an in-service bus requiring the bus to be taken out of service or replaced on route. Both CNG bus groups had better MBRC rates than the diesel buses. The CWI CNG buses had an all roadcall MBRC 44% higher and engine- and fuel-related roadcall MBRC 41% higher than the diesel buses. The Deere CNG buses had an all roadcall MBRC 58% higher and engine- and fuel-related roadcall MBRC 16% higher than the diesel buses.

Total Operating Costs. The total operating costs for the study buses were similar. The fuel costs for CNG and diesel during the CNG bus evaluation periods were the same at $1.33/DGE. The total operating costs were as follows: diesel, $1.06/mile; CWI CNG, $1.09/mile; and Deere CNG, $1.14/mile. The major contributing factors are the fuel costs and fuel economy. Significant changes in the fuel cost or fuel economy would change total operating costs significantly.

Future Bus Orders at WMATA. A subsequent CNG bus order consisted of 250 CNG buses from Orion (model VII, low floor), which started delivery in 2005. Another CNG bus facility came online in 2005. After this CNG bus order, the next bus order is planned to be diesel and diesel hybrid buses. These diesel buses are required at WMATA to lower the average diesel bus age at the eight depots not currently operating CNG buses.

Status of the CNG Bus Propulsion Technologies. The CWI CNG bus propulsion technology appears from the evaluation to be a mature technology and is similar in operation and cost to the diesel bus technology. The Deere CNG bus propulsion technology was a field test confirmation during this project and only underwent a limited evaluation. However, by the end of the evaluation, the results indicated that this propulsion technology was maturing. WMATA and Deere have agreed to implement another 100 Deere CNG buses as part of WMATA's 250 CNG bus order, with delivery in 2005; this will be the first full market introduction of the Deere CNG bus propulsion technology. The order indicates WMATA's confidence in the Deere technology, even with higher engine maintenance costs.

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Appendix A

Vehicle System Descriptions

Bus Company	Vehicle Number	Start Date	Start Odometer	Test Fuel or Technology	Bus Manufacturer	Bus Model	Bus ear of Manufacture	Vehicle Identification Number (VIN)	Engine Manufacturer	Engine ear of Manufacture	Engine Model	Engine Serial Number (ESN)
Washington	2302	8/21/2002	3,841	CNG	New Flyer	C40LF	2001	5FYC2LP181U023236	Cummins Westport	2001	C8.3G+	46164278
Metropolitan Area	2303	8/14/2002	3,734	CNG	New Flyer	C40LF	2001	5FYC2LP1X1U023237	Cummins Westport	2001	C8.3G+	46149447
Transit Authority	2304	8/27/2002	3,966	CNG	New Flyer	C40LF	2001	5FYC2LP111U023238	Cummins Westport	2001	C8.3G+	46155233
WMATA	2307	8/27/2002	3,288	CNG	New Flyer	C40LF	2001	5FYC2LP111U023241	Cummins Westport	2001	C8.3G+	46154856
	2309	8/20/2002	3,876	CNG	New Flyer	C40LF	2001	5FYC2LP151U023243	Cummins Westport	2001	C8.3G+	46154843
	2460	2/12/2003	1,981	CNG	New Flyer	C40LF	2002	5FYC2LP172U023665	John Deere	2001	6081H	G6081H209814
	2461	2/12/2003	2,366	CNG	New Flyer	C40LF	2002	5FYC2LP192U023666	John Deere	2001	6081H	G6081H210481
	2462	2/6/2003	1,711	CNG	New Flyer	C40LF	2002	5FYC2LP102U023667	John Deere	2001	6081H	G6081H210480
	2463	1/30/2003	1,769	CNG	New Flyer	C40LF	2002	5FYC2LP122U023668	John Deere	2001	6081H	G6081H210482
	2464	2/5/2003	1,862	CNG	New Flyer	C40LF	2002	5FYC2LP142U023669	John Deere	2001	6081H	G6081H210479
	2070	8/4/2000	662	Diesel	Orion Bus Ind.	06.501	2000	1VH6H2A28Y6600308	Detroit Diesel	2000	S50	04R0031725
	2071	8/8/2000	591	Diesel	Orion Bus Ind.	06.501	2000	1VH6H2A2XY6600309	Detroit Diesel	2000	S50	04R0031729
	2072	8/2/2000	621	Diesel	Orion Bus Ind.	06.501	2000	1VH6H2A26Y6600310	Detroit Diesel	2000	S50	04R0031766
	2073	8/4/2000	582	Diesel	Orion Bus Ind.	06.501	2000	1VH6H2A28Y6600311	Detroit Diesel	2000	S50	04R0031730
	2074	8/22/2000	625	Diesel	Orion Bus Ind.	06.501	2000	1VH6H2A2XY6600312	Detroit Diesel	2000	S50	04R0031798

Transit Agency: **Washington Metropolitan Area Transit Authority (Washington, DC)**

Vehicle System	Diesel	CNG (CWI)	CNG (Deere)
General Bus Specifications			
Bus Number	2070-4	2302-4, 7, 9	2460-4
Bus Manufacturer/Model	Orion/VI	New Flyer/C40LF	New Flyer/C40LF
Bus Length, Ft.	40	40	40
Bus Width & Height, In.	102, 121	102, 126	102, 126
Wheel Base, In.	278		
Gross Vehicle Wt. Rating Total, lb.	42,540	40,600	40,600
Curb Weight Total, lb.	29,300	31,500	31,500
Number of Passenger Seats with no Wheelchairs on Board	38	40	40
Number of Wheelchair Positions	2	2	2
Maximum Number of Standees	50	20	20
Air Conditioning? (Yes/No)	Yes	Yes	Yes
Wheelchair Lift/Ramp? (Yes/No)	Yes	Yes	Yes
Engine/Fuel System			
Fuel Type(s)/Additives	ULSD/None	CNG/None	CNG/None
Engine Manufacturer	Detroit Diesel Corp.	Cummins Westport	Deere Power Systems
Engine Model Number	Series 50, DDEC IV	C Gas Plus	6081HFN04
Year of Manufacture	2000	2001	2001
EPA Engine Family Name	YDDXH08.5FJN	2CEXH0505CBI	2JDXH08.1001
Compression Ratio of engine	15.0:1	10.1:1	11:1
Type of Ignition Aid used in engine	None	Spark Plugs	Spark Plugs
EPA certified? (Yes/No)	Yes	Yes	Yes
CARB Certified? (Yes/No)	Yes	Yes	Yes
BHP Maximum and rpm	275 bhp at 2,100 rpm	280 bhp at 2,400 rpm	280 bhp at 2,200 rpm
Torque Maximum and rpm	890 ft-lbs at 1,200 rpm	850 ft-lbs at 1,400 rpm	900 ft-lbs at 1,500 rpm
Displacement (L)	8.5	8.3	8.1
Blower? (Yes/No)	No	No	No
Turbocharger? (Yes/No)	Yes	Yes	Yes
Mechanical or Electronic Fuel Inj.?	Electronic	N/A	N/A
Direct Injection or Fumigation?	Injection	Fumigation	Fumigation
Throttle for Intake Air? (Yes/No)	No	Yes	Yes
Number of Fuel Storage Tanks	1	7	7
Total Useful Amount of Fuel Storage	125 gal	21,161 scf	21,161 scf
Transmission			
Manufacturer and Model Number	Allison/B400R	Allison/B400R	Allison/B400R
Torque Conversion Ratio			
Drive Axle Ratio	5.24:1		
Retarder? (Yes/No)	Yes	Yes	Yes
Safety E uipment			
Fire Detection (Yes/No)	Yes	Yes	Yes
Fire Suppression (Yes/No)	Yes	Yes	Yes
Vapor Detection (Yes/No)	No	Yes	Yes
Emissions E uipment			
Catalytic Converter (Yes/No)	No	Yes	Yes
Diesel Particulate Trap (Yes/No)	No	No	No

Appendix B

Routes from Bladensburg

Route Summary for Bladensburg
Effective Date 12/28/2003

LGRP	Route	Line Name	Day of Week	No. of Buses			Revenue			Non-Revenue			Total			Vehicle Type
				AM	PM	Base	Miles	Time	Avg Speed	Miles	Time	Avg Speed	Miles	Time	Avg Speed	
14	X2	Benning Rd-H St	Weekday	12	16	10	1403.03	149.05	9.41	209.79	15.63	13.42	1612.82	164.68	9.79	
			Saturday	9	10		1097.56	105.73	10.38	119.78	8.33	14.37	1217.34	114.07	10.67	
			Sunday	6	6		847.55	75.53	11.22	62.58	4.33	14.44	910.13	79.87	11.40	
			Total	**75**	**96**	**50**	**8960.26**	**926.52**	**9.67**	**1231.31**	**90.83**	**13.56**	**10191.57**	**1017.35**	**10.02**	K/A
18	96, 97	East Cap-Cardozo	Weekday	6	3	0	208.85	20.77	10.06	80.79	4.53	17.82	289.64	25.30	11.45	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**30**	**15**	**0**	**1044.25**	**103.83**	**10.06**	**403.95**	**22.67**	**17.82**	**1448.20**	**126.50**	**11.45**	NG
25	X8	Maryland Avenue	Weekday	2	2	1	162.00	19.12	8.47	13.62	0.90	15.13	175.62	20.02	8.77	
			Saturday	1	1		103.50	11.50	9.00	3.85	0.27	14.44	107.35	11.77	9.12	
			Sunday	1	1		103.50	11.50	9.00	3.85	0.27	14.44	107.35	11.77	9.12	
			Total	**12**	**12**	**5**	**1017.00**	**118.58**	**8.58**	**75.80**	**5.03**	**15.06**	**1092.80**	**123.62**	**8.84**	NG
34	H6	Brookland-Ft Linc	Weekday	4	5	3	698.21	50.22	13.90	59.92	4.17	14.38	758.13	54.38	13.94	
			Saturday	2	2		429.95	27.47	15.65	14.92	1.03	14.44	444.87	28.50	15.61	
			Sunday	1	1		288.80	17.73	16.29	21.22	1.47	14.47	310.02	19.20	16.15	
			Total	**23**	**28**	**15**	**4209.80**	**296.28**	**14.21**	**335.74**	**23.33**	**14.39**	**4545.54**	**319.62**	**14.22**	S
35	H2,3,4	Crosstown	Weekday	17	12	7	1278.04	123.92	10.31	207.49	13.88	14.95	1485.53	137.80	10.78	
			Saturday	5	5		869.30	74.58	11.66	47.90	3.33	14.37	917.20	77.92	11.77	
			Sunday	5	5		651.40	52.68	12.36	95.80	6.67	14.37	747.20	59.35	12.59	
			Total	**95**	**70**	**35**	**7910.90**	**746.85**	**10.59**	**1181.15**	**79.42**	**14.87**	**9092.05**	**826.27**	**11.00**	NG
37	D5	Mac Blvd-Geotown	Weekday	1	1	0	40.80	3.33	12.24	37.87	2.18	17.35	78.67	5.52	14.26	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**5**	**5**	**0**	**204.00**	**16.67**	**12.24**	**189.35**	**10.92**	**17.35**	**393.35**	**27.58**	**14.26**	NG
44	U8	Cap Hts-Benn Hts	Weekday	7	7	4	912.84	80.30	11.37	99.50	6.30	15.79	1012.34	86.60	11.69	
			Saturday	2	3		600.60	47.30	12.70	46.31	2.93	15.79	646.91	50.23	12.88	
			Sunday	2	2		423.29	30.77	13.76	42.07	2.53	16.61	465.36	33.30	13.97	
			Total	**39**	**40**	**20**	**5588.09**	**479.57**	**11.65**	**585.88**	**36.97**	**15.85**	**6173.97**	**516.53**	**11.95**	NG
45	D8	Hospital Center	Weekday	7	11	5	946.16	94.45	10.02	112.22	7.32	15.34	1058.38	101.77	10.40	
			Saturday	5	6		712.40	64.05	11.12	93.85	5.92	15.86	806.25	69.97	11.52	
			Sunday	3	3		417.64	36.27	11.52	33.99	2.13	15.93	451.63	38.40	11.76	
			Total	**43**	**64**	**25**	**5860.84**	**572.57**	**10.24**	**688.94**	**44.63**	**15.44**	**6549.78**	**617.20**	**10.61**	M
49	B8,9	Ft Lincoln Shuttle	Weekday	4	3	1	217.25	18.70	11.62	14.57	1.23	11.81	231.82	19.93	11.63	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**20**	**15**	**5**	**1086.25**	**93.50**	**11.62**	**72.85**	**6.17**	**11.81**	**1159.10**	**99.67**	**11.63**	S
55	D1,3,6	Sibley-Stad Arm	Weekday	22	11	8	1552.54	156.57	9.92	281.08	19.52	14.40	1833.62	176.08	10.41	
			Saturday	5	5		937.26	77.30	12.12	77.57	5.50	14.10	1014.83	82.80	12.26	
			Sunday	5	5		691.13	55.05	12.55	139.72	10.48	13.33	830.85	65.53	12.68	
			Total	**120**	**65**	**40**	**9391.09**	**915.18**	**10.26**	**1622.69**	**113.57**	**14.29**	**11013.78**	**1028.75**	**10.71**	NG

LGRP	Route	Line Name	Day of Week	No. of Buses			Revenue			Non-Revenue			Total			Vehicle Type
				AM	PM	Base	Miles	Time	Avg Speed	Miles	Time	Avg Speed	Miles	Time	Avg Speed	
56	D4	Ivy City-Un Stat	Weekday	3	3	2	423.80	39.82	10.64	14.44	0.95	15.20	438.24	40.77	10.75	
			Saturday	2	2		326.75	29.90	10.93	24.64	2.17	11.37	351.39	32.07	10.96	
			Sunday	2	2		219.98	18.30	12.02	44.98	2.98	15.08	264.96	21.28	12.45	
			Total	**19**	**19**	**10**	**2665.73**	**247.28**	**10.78**	**141.82**	**9.90**	**14.33**	**2807.55**	**257.18**	**10.92**	S
57	V5	Fx Vill-Lenf Plaz	Weekday	3	0	0	28.20	2.13	13.22	23.25	1.62	14.38	51.45	3.75	13.72	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**15**	**0**	**0**	**141.00**	**10.67**	**13.22**	**116.25**	**8.08**	**14.38**	**257.25**	**18.75**	**13.72**	NG
62	H1	Brookland-Pot Pk	Weekday	4	4	0	89.19	10.92	8.17	92.14	6.55	14.07	181.33	17.47	10.38	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**20**	**20**	**0**	**445.95**	**54.58**	**8.17**	**460.70**	**32.75**	**14.07**	**906.65**	**87.33**	**10.38**	NG
74	81,82,83,86	Maryland	Weekday	12	13	7	1816.49	131.00	13.87	321.65	12.30	26.15	2138.14	143.30	14.92	
			Saturday	6	6		788.78	52.98	14.89	147.09	6.43	22.86	935.87	59.42	15.75	
			Sunday	6	6		653.73	42.15	15.51	141.45	5.77	24.53	795.18	47.92	16.60	
			Total	**72**	**77**	**35**	**10524.96**	**750.13**	**14.03**	**1896.79**	**73.70**	**25.74**	**12421.75**	**823.83**	**15.08**	NG
78	U4	Sher Rd-Riv Terr	Weekday	3	3	1	367.10	28.37	12.94	68.40	5.00	13.68	435.50	33.37	13.05	
			Saturday	1	1		196.00	15.03	13.04	34.20	2.33	14.66	230.20	17.37	13.26	
			Sunday	1	1		190.40	14.17	13.44	41.04	2.80	14.66	231.44	16.97	13.64	
			Total	**17**	**17**	**5**	**2221.90**	**171.03**	**12.99**	**417.24**	**30.13**	**13.85**	**2639.14**	**201.17**	**13.12**	S
81	42	Mount Pleasant	Weekday	1	4	0	96.89	15.37	6.31	92.33	6.82	13.54	189.22	22.18	8.53	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**5**	**20**	**0**	**484.45**	**76.83**	**6.31**	**461.65**	**34.08**	**13.54**	**946.10**	**110.92**	**8.53**	NG
86	80	North Capitol St	Weekday	13	14	10	1333.17	160.03	8.33	158.65	10.30	15.40	1491.82	170.33	8.76	
			Saturday	5	5		834.15	86.88	9.60	79.17	5.07	15.63	913.32	91.95	9.93	
			Sunday	4	5		640.07	61.42	10.42	65.81	4.30	15.30	705.88	65.72	10.74	
			Total	**74**	**80**	**50**	**8140.07**	**948.47**	**8.58**	**938.23**	**60.87**	**15.41**	**9078.30**	**1009.33**	**8.99**	NG
93	30,32,34,35,36	Pennsylvania Ave	Weekday	13	5	0	331.75	37.63	8.82	251.43	15.90	15.81	583.18	53.53	10.89	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**65**	**25**	**0**	**1658.75**	**188.17**	**8.82**	**1257.15**	**79.50**	**15.81**	**2915.90**	**267.67**	**10.89**	NG
95	W4	Deanwood-Alab Ave	Weekday	0	2	0	79.25	6.78	11.68	31.40	1.43	21.91	110.65	8.22	13.47	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**0**	**10**	**0**	**396.25**	**33.92**	**11.68**	**157.00**	**7.17**	**21.91**	**553.25**	**41.08**	**13.47**	NG
101	G8	Rhode Island Ave	Weekday	11	10	4	929.36	94.37	9.85	134.04	9.55	14.04	1063.40	103.92	10.23	
			Saturday	3	3		617.09	50.52	12.22	39.37	2.73	14.40	656.46	53.25	12.33	
			Sunday	3	4		505.58	38.85	13.01	26.30	1.83	14.35	531.88	40.68	13.07	
			Total	**61**	**57**	**20**	**5769.47**	**561.20**	**10.28**	**735.87**	**52.32**	**14.07**	**6505.34**	**613.52**	**10.60**	NG
134	U2	Minn Ave-Anac	Weekday	3	3	2	272.70	32.33	8.43	82.69	5.75	14.38	355.39	38.08	9.33	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**15**	**15**	**10**	**1363.50**	**161.67**	**8.43**	**413.45**	**28.75**	**14.38**	**1776.95**	**190.42**	**9.33**	NG

LGRP	Route	Line Name	Day of Week	No. of Buses			Revenue			Non-Revenue			Total			Vehicle Type
				AM	PM	Base	Miles	Time	Avg Speed	Miles	Time	Avg Speed	Miles	Time	Avg Speed	
135	U5,6	Mayfair-Mars Hgts	Weekday	4	5	3	685.02	66.22	10.35	95.67	6.80	14.07	780.69	73.02	10.69	
			Saturday	3	3		576.33	49.27	11.70	43.48	2.80	15.53	619.81	52.07	11.90	
			Sunday	2	2		379.00	32.57	11.64	28.58	1.87	15.31	407.58	34.43	11.84	
			Total	**25**	**30**	**15**	**4380.43**	**412.92**	**10.61**	**550.41**	**38.67**	**14.23**	**4930.84**	**451.58**	**10.92**	NG
150	B2	Blad Rd-Anacostia	Weekday	15	14	7	1634.17	147.08	11.11	137.26	9.72	14.13	1771.43	156.80	11.30	
			Saturday	5	6		1060.91	79.92	13.28	30.45	2.23	13.63	1091.36	82.15	13.28	
			Sunday	4	5		863.24	60.58	14.25	19.72	1.43	13.76	882.96	62.02	14.24	
			Total	**84**	**81**	**35**	**10095.00**	**875.92**	**11.53**	**736.47**	**52.25**	**14.10**	**10831.47**	**928.17**	**11.67**	NG
151	X1,3	Benning Road	Weekday	10	7	0	191.87	20.20	9.50	213.95	13.95	15.34	405.82	34.15	11.88	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**50**	**35**	**0**	**959.35**	**101.00**	**9.50**	**1069.75**	**69.75**	**15.34**	**2029.10**	**170.75**	**11.88**	NG
514	B99	Bus Operator Shuttle	Weekday	1	1	1	134.40	14.40	9.33	0.28	0.07	4.20	134.68	14.47	9.31	
			Saturday	1	1		109.20	11.70	9.33	0.28	0.07	4.20	109.48	11.77	9.30	
			Sunday	1	1		109.20	11.70	9.33	0.28	0.07	4.20	109.48	11.77	9.30	
			Total	**7**	**7**	**5**	**890.40**	**95.40**	**9.33**	**1.96**	**0.47**	**4.20**	**892.36**	**95.87**	**9.31**	M
544	P1,2,6	Anac-Eckington	Weekday	1	3	0	106.30	11.40	9.32	43.01	3.03	14.18	149.31	14.43	10.34	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**5**	**15**	**0**	**531.50**	**57.00**	**9.32**	**215.05**	**15.17**	**14.18**	**746.55**	**72.17**	**10.34**	NG
583	K2	Takoma-Ft Totten	Weekday	3	3	0	148.40	15.33	9.68	53.68	3.35	16.02	202.08	18.68	10.82	
			Saturday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	0	0		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**15**	**15**	**0**	**742.00**	**76.67**	**9.68**	**268.40**	**16.75**	**16.02**	**1010.40**	**93.42**	**10.82**	S/M
800	R1,2,5	Riggs Road	Weekday	8	7	3	1002.68	65.15	15.39	200.38	10.08	19.87	1203.06	75.23	15.99	
			Saturday	2	2		0.00	0.00		0.00	0.00		0.00	0.00		
			Sunday	2	3		0.00	0.00		0.00	0.00		0.00	0.00		
			Total	**44**	**40**	**15**	**5013.40**	**325.75**	**15.39**	**1001.90**	**50.42**	**19.87**	**6015.30**	**376.17**	**15.99**	NG
801	R3	Gblt-Fort Totten	Weekday	4	4	2	702.95	42.05	16.72	133.78	5.32	25.16	836.73	47.37	17.66	
			Saturday	1	2		165.60	8.92	18.57	19.46	1.17	16.68	185.06	10.08	18.35	
			Sunday	1	1		165.60	8.47	19.56	13.16	0.80	16.45	178.76	9.27	19.29	
			Total	**22**	**23**	**10**	**3845.95**	**227.63**	**16.90**	**701.52**	**28.55**	**24.57**	**4547.47**	**256.18**	**17.75**	NG
802	R4	Queens Chapel Rd	Weekday	3	4	1	358.02	30.97	11.56	68.82	4.37	15.76	426.84	35.33	12.08	
			Saturday	1	1		126.36	9.43	13.40	9.58	0.67	14.37	135.94	10.10	13.46	
			Sunday	1	1		110.69	7.88	14.04	6.58	0.53	12.34	117.27	8.42	13.93	
			Total	**17**	**22**	**5**	**2027.15**	**172.15**	**11.78**	**360.26**	**23.03**	**15.64**	**2387.41**	**195.18**	**12.23**	NG
		All Natural Gas Buses	Weekday	160	135	59	13813.08	1277.63	10.81	2800.80	170.80	16.40	16613.88	1448.43	11.47	
			Saturday	39	42		6679.88	548.60	12.18	544.23	33.13	16.43	7224.11	581.73	12.42	
			Sunday	36	40		5187.23	401.92	12.91	583.04	36.48	15.98	5770.27	438.40	13.16	
			Total	**875**	**757**	**295**	**80932.51**	**7338.68**	**11.03**	**15131.27**	**923.62**	**16.38**	**96063.78**	**8262.30**	**11.63**	NG

Appendix C

Fuel Consumption and Economy

WMATA Diesel Buses
Fuel Analysis

Diesel Buses

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	9955	10389	10337	11273	15250	14226	14106	15037	16125	13785	13192	17019	12586	15895	17004	13597	11908	16273	13586	16365	16384	16912	16536	15527	15458	358725	185445
Mileage sed in Calc	9955	10389	10166	10725	14430	13721	13693	15037	14417	13142	12847	16139	12145	15591	17004	12291	11822	15510	13187	15434	14966	16078	15685	15527	15266	345167	178361
Total Fuel Reported	3853	3794	3557	3773	5219	4959	4686	5066	5165	4710	4981	6210	4665	5710	6029	4404	4003	5629	4823	5089	5332	5773	6164	5781	5332	124707	64069
Fuel sed in Calculation	3853	3794	3528	3683	5034	4857	4642	5066	4844	4651	4964	6109	4605	5554	6029	4210	3991	5432	4734	5042	5210	5596	6017	5781	5316	122542	62912
Fuel Economy (Mile/Gal)	2.58	2.74	2.88	2.91	2.87	2.82	2.95	2.97	2.98	2.83	2.59	2.64	2.64	2.81	2.82	2.92	2.96	2.86	2.79	3.06	2.87	2.87	2.61	2.69	2.87	2.82	2.84
Min Odometer	1316	3111	3915	4794	8032	11219	13919	16748	21046	24883	26000	28572	32373	34960	38098	40574	43623	46377	48813	52624	56026	58763	61676	64017	65855		
Max Odometer	3323	6373	9586	12834	15724	17926	20958	23523	25862	28810	31798	35530	38004	40907	45102	47942	50266	54331	57759	61699	65236	68735	72094	76567	80959		

Diesel Bus 2070

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	2109	2980	2675	3050	3042	3134	2692	3271	2241	3046	2988	3732	2474	2903	4195	2840	1504	2491	2325	1238	3327	3354	4002	2977	3243	71833	34399
Mileage sed in Calc	2109	2980	2675	3050	3042	3134	2692	3271	2241	3046	2988	3732	2474	2903	4195	2635	1504	2487	2325	648	2588	3354	4002	2977	3243	70295	32861
Total Fuel Reported	821	1082	945	1035	1042	1136	882	1053	775	1044	1148	1482	953	1037	1473	923	546	1023	836	217	923	1209	1594	1123	1187	25489	12091
Fuel sed in Calculation	821	1082	945	1035	1042	1136	882	1053	775	1044	1148	1482	953	1037	1473	905	546	919	836	217	923	1209	1594	1123	1187	25367	11969
Fuel Economy (Mile/Gal)	2.57	2.75	2.83	2.95	2.92	2.76	3.05	3.11	2.89	2.92	2.60	2.52	2.60	2.80	2.85	2.91	2.75	2.71	2.78	2.99	2.80	2.77	2.51	2.65	2.73	2.77	2.75
Odometer	2679	5659	8334	11384	14426	17560	20252	23523	25764	28810	31798	35530	38004	40907	45102	47942	49446	51937	54262	55500	58827	62181	66183	69160	72403	72403	72403

Diesel Bus 2071

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	2321	1559	1413	879	2884	2854	2856	3979	3944	3629	3329	3684	1805	2674	3378	2504	3064	3593	3416	3660	3005	4427	2931	2967	3742	74497	39361
Mileage sed in Calc	2321	1559	1389	879	2578	2854	2856	3979	3944	3629	3329	3389	1805	2469	3378	2104	3064	3469	3017	3319	2617	3593	2931	2967	3742	71181	36670
Total Fuel Reported	920	555	474	302	964	990	943	1229	1220	1243	1227	1250	639	885	1146	756	1027	1178	1101	1104	955	1307	994	1030	1204	24643	12687
Fuel sed in Calculation	920	555	474	302	906	990	943	1229	1220	1243	1227	1207	639	859	1146	678	1027	1155	1012	1057	865	1130	994	1030	1204	24012	12157
Fuel Economy (Mile/Gal)	2.52	2.81	2.93	2.91	2.85	2.88	3.03	3.24	3.23	2.92	2.71	2.81	2.82	2.87	2.95	3.10	2.98	3.00	2.98	3.14	3.03	3.18	2.95	2.88	3.11	2.96	3.02
Odometer	2881	4440	5853	6732	9616	12470	15326	19305	23249	26878	30207	33891	35696	38370	41748	44252	47316	50909	54325	57985	60990	65417	68348	71315	75057	75057	75057

Diesel Bus 2072

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	2033	539	804	879	3238	3187	2700	2829	4298	3837	3676	3997	3151	3982	2978	3770	3829	4065	3428	3940	3537	3499	3359	4473	4392	80420	45252
Mileage sed in Calc	2033	539	804	879	3238	3187	2700	2829	3660	3332	3452	3640	2984	3982	2978	3410	3743	4065	3428	3940	3246	3499	3359	4473	4392	77792	44515
Total Fuel Reported	785	215	264	293	1124	1079	943	1061	1294	1216	1296	1413	1169	1352	1025	1100	1274	1354	1256	1353	1154	1176	1195	1497	1445	27333	15181
Fuel sed in Calculation	785	215	264	293	1124	1079	943	1061	1231	1157	1282	1355	1157	1352	1025	1039	1262	1354	1256	1353	1122	1176	1195	1497	1445	27022	15076
Fuel Economy (Mile/Gal)	2.59	2.51	3.05	3.00	2.88	2.95	2.86	2.67	2.97	2.88	2.69	2.69	2.58	2.95	2.91	3.28	2.97	3.00	2.73	2.91	2.89	2.98	2.81	2.99	3.04	2.88	2.95
Odometer	2572	3111	3915	4794	8032	11219	13919	16748	21046	24883	28559	32556	35707	39689	42667	46437	50266	54331	57759	61699	65236	68735	72094	76567	80959	80959	80959

Diesel Bus 2073

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	2776	3050	3213	3248	2890	2202	3032	2437	2467	138	0	2572	3801	2587	3138	2476	3275	3370	1981	3716	3110	2737	2913	2341	3250	66720	34894
Mileage sed in Calc	2776	3050	3213	2700	2376	2202	2619	2437	2155	0	0	2344	3527	2587	3138	2135	3275	2735	1981	3716	3110	2737	2062	2341	3058	62274	32875
Total Fuel Reported	1037	1096	1105	1045	988	812	965	847	732	0	0	837	1357	895	1084	802	1044	1033	779	1233	1063	1086	964	924	1154	22882	12061
Fuel sed in Calculation	1037	1096	1105	955	861	812	921	847	685	0	0	837	1309	895	1084	765	1044	963	779	1233	1063	1086	817	924	1138	22256	11791
Fuel Economy (Mile/Gal)	2.68	2.78	2.91	2.83	2.76	2.71	2.84	2.88	3.15			2.80	2.69	2.89	2.89	2.79	3.14	2.84	2.54	3.01	2.93	2.52	2.52	2.53	2.69	2.80	2.79
Odometer	3323	6373	9586	12834	15724	17926	20958	23395	25862	26000	26000	28572	32373	34960	38098	40574	43849	47219	49200	52916	56026	58763	61676	64017	67267	67267	67267

Diesel Bus 2074

Item	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	an-01	Feb-01	Mar-01	Apr-01	May-01	un-01	ul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total	Last ear Total
Total Mileage	716	2261	2232	3217	3196	2849	2826	2521	3175	3135	3199	3034	1355	3749	3315	2007	236	2754	2436	3811	3405	2895	3331	2769	831	65255	31539
Mileage sed in Calc	716	2261	2085	3217	3196	2344	2826	2521	2417	3135	3078	3034	1355	3650	3315	2007	236	2754	2436	3811	3405	2895	3331	2769	831	63625	31440
Total Fuel Reported	290	846	769	1098	1101	942	953	876	1144	1207	1310	1228	547	1541	1301	823	112	1041	851	1182	1237	995	1417	1207	342	24360	12049
Fuel sed in Calculation	290	846	740	1098	1101	840	953	876	933	1207	1307	1228	547	1411	1301	823	112	1041	851	1182	1237	995	1417	1207	342	23885	11919
Fuel Economy (Mile/Gal)	2.47	2.67	2.82	2.93	2.90	2.79	2.97	2.88	2.59	2.60	2.36	2.47	2.48	2.59	2.55	2.44	2.11	2.65	2.86	3.22	2.75	2.91	2.35	2.29	2.43	2.66	2.64
Odometer	1316	3577	5809	9026	12222	15071	17897	20418	23593	26728	29927	32961	34316	38065	41380	43387	43623	46377	48813	52624	56029	58924	62255	65024	65855	65855	65855

WMATA CNG Buses
Fuel Analysis

CNG/Cummins Buses — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	3063	13542	10662	11433	11089	10971	9952	11314	11731	12276	11189	12955	13584	10664	12891	12001	13082	9942	10376	12634	11177	13213	249741	143708
Mileage sed in Calc	3063	13175	9375	10723	10948	10971	8949	11314	10583	12054	11189	12955	13584	10015	12891	11241	12816	8738	10376	12634	11177	13213	241984	140829
Total Fuel Reported	1424	5706	4042	4623	4505	4732	3951	4964	4600	5034	4827	5995	6109	4112	5002	4770	5515	4637	4493	5436	4804	5890	105171	61590
Fuel sed in Calculation	1424	5668	3893	4456	4505	4732	3728	4917	4378	5016	4827	5995	6109	3998	5002	4718	5515	4035	4493	5436	4804	5890	103539	60822
Fuel Economy (Mile/Gal)	2.15	2.32	2.41	2.41	2.43	2.32	2.40	2.30	2.42	2.40	2.32	2.16	2.22	2.51	2.58	2.38	2.32	2.17	2.31	2.32	2.33	2.24	2.34	2.32
Min Odometer	3546	6230	8063	9574	11532	13330	15894	18113	20955	23219	25426	27962	30400	32060	32229	33863	36473	38977	41190	44160	46248	48372		
Max Odometer	4822	8058	10202	12430	14653	16750	19109	21452	23850	26436	28638	31271	34014	37346	40883	43999	46029	47778	50798	54238	56875	60639		

CNG/Cummins Bus 2302 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	981	3236	2144	2228	1884	2062	852	2605	2260	2437	2392	2773	2312	2434	2805	2441	2537		1210	726	2088	2124	44531	23842
Mileage sed in Calc	981	3057	1571	2228	1743	2062	852	2605	1965	2437	2392	2773	2312	2434	2805	2441	2537		1210	726	2088	2124	43343	23842
Total Fuel Reported	448	1241	705	1055	687	872	389	1102	812	983	939	1218	994	997	1089	975	1003		601	339	840	937	18226	9932
Fuel sed in Calculation	448	1203	659	1055	687	872	389	1102	760	983	939	1218	994	997	1089	975	1003		601	339	840	937	18090	9932
Fuel Economy (Mile/Gal)	2.19	2.54	2.38	2.11	2.54	2.36	2.19	2.36	2.59	2.48	2.55	2.28	2.33	2.44	2.58	2.50	2.53		2.01	2.14	2.49	2.27	2.40	2.40
Odometer	4822	8058	10202	12430	14314	16376	17228	19833	22093	24530	26922	29695	32007	34441	37246	39687	42224		43434	44160	46248	48372	48372	48372

CNG/Cummins Bus 2303 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	705	2616	2348	2694	2195	2282	1887	2233	2177	2059	2588	2796	3615	3417	3537	3116	2296	2725	3020	3440	2637	3764	58147	36951
Mileage sed in Calc	705	2616	2348	1984	2195	2282	1454	2233	2177	2059	2588	2796	3615	3006	3537	2696	2030	1521	3020	3440	2637	3764	54703	34650
Total Fuel Reported	360	1128	964	947	922	937	677	1004	885	867	1159	1324	1539	1085	1199	1038	961	1152	1008	1237	1077	1505	22975	14284
Fuel sed in Calculation	360	1128	964	780	922	937	592	1004	885	867	1159	1324	1539	1024	1199	1010	961	550	1008	1237	1077	1505	22032	13593
Fuel Economy (Mile/Gal)	1.96	2.32	2.44	2.54	2.38	2.44	2.46	2.22	2.46	2.37	2.23	2.11	2.35	2.94	2.95	2.67	2.11	2.77	3.00	2.78	2.45	2.50	2.48	2.55
Odometer	4439	7055	9403	12097	14292	16574	18461	20694	22871	24930	27518	30314	33929	37346	40883	43999	46029	47778	50798	54238	56875	60639	60639	60639

CNG/Cummins Bus 2304 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	556	2722	2362	2451	2596	2097	2359	2343	2398	2586	2202	2633	2743	2396	3365	2264	2909	2237	1694	2658	2056	2553	52180	29710
Mileage sed in Calc	556	2722	2066	2451	2596	2097	1789	2343	1946	2364	2202	2633	2743	2158	3365	2264	2909	2237	1694	2658	2056	2553	50402	29472
Total Fuel Reported	221	1235	953	1020	1089	1046	843	1072	902	982	955	1219	1331	1058	1342	956	1207	1128	913	1202	888	1217	22779	13416
Fuel sed in Calculation	221	1235	887	1020	1089	1046	705	1025	851	964	955	1219	1331	1005	1342	956	1207	1128	913	1202	888	1217	22406	13363
Fuel Economy (Mile/Gal)	2.52	2.20	2.33	2.40	2.38	2.00	2.54	2.29	2.29	2.45	2.31	2.16	2.06	2.15	2.51	2.37	2.41	1.98	1.86	2.21	2.32	2.10	2.25	2.21
Odometer	4522	7244	9606	12057	14653	16750	19109	21452	23850	26436	28638	31271	34014	36410	39775	42039	44948	47185	48879	51537	53593	56146	56146	56146

CNG/Cummins Bus 2307 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	258	2684	1833	1511	1958	1798	2564	2219	2842	2264	2207	2536	2438	2375	3015	2546	2730	2476	2239	2814	1452	2608	49367	29436
Mileage sed in Calc	258	2496	1415	1511	1958	1798	2564	2219	2842	2264	2207	2536	2438	2375	3015	2206	2730	2476	2239	2814	1452	2608	48421	29096
Total Fuel Reported	124	1061	605	571	793	801	1090	945	1153	910	970	1174	1118	949	1274	1038	1162	1118	899	1293	662	1161	20871	12818
Fuel sed in Calculation	124	1061	568	571	793	801	1090	945	1153	910	970	1174	1118	949	1274	1014	1162	1118	899	1293	662	1161	20810	12794
Fuel Economy (Mile/Gal)	2.08	2.35	2.49	2.65	2.47	2.24	2.35	2.35	2.46	2.49	2.28	2.16	2.18	2.50	2.37	2.18	2.35	2.21	2.49	2.18	2.19	2.25	2.33	2.27
Odometer	3546	6230	8063	9574	11532	13330	15894	18113	20955	23219	25426	27962	30400	32775	35790	38336	41066	43542	45781	48595	50047	52655	52655	52655

CNG/Cummins Bus 2309 **Last ear**

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	563	2284	1975	2549	2456	2732	2290	1914	2054	2930	1800	2217	2476	42	169	1634	2610	2504	2213	2996	2944	2164	45516	23769
Mileage sed in Calc	563	2284	1975	2549	2456	2732	2290	1914	1653	2930	1800	2217	2476	42	169	1634	2610	2504	2213	2996	2944	2164	45115	23769
Total Fuel Reported	271	1041	815	1030	1014	1076	952	841	848	1292	804	1060	1127	23	98	763	1182	1239	1072	1365	1337	1070	20320	11140
Fuel sed in Calculation	271	1041	815	1030	1014	1076	952	841	729	1292	804	1060	1127	23	98	763	1182	1239	1072	1365	1337	1070	20201	11140
Fuel Economy (Mile/Gal)	2.08	2.19	2.42	2.47	2.42	2.54	2.41	2.28	2.27	2.27	2.24	2.09	2.20	1.83	1.72	2.14	2.21	2.02	2.06	2.19	2.20	2.02	2.23	2.13
Odometer	4341	6625	8600	11149	13605	16337	18627	20541	22595	25525	27325	29542	32018	32060	32229	33863	36473	38977	41190	44186	47130	49294	49294	49294

WMATA CNG Buses
Fuel Analysis

CNG/Deere Buses — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage	88	5153	9461	8604	10637	7568	4253	1034	6516	10194	7909	8668	9625	8434	12911	14193	16031	12277	9616	11069	10317	184558	73503
Mileage sed in Calc	88	4771	9461	8604	10637	7568	4061	859	6360	10194	7072	8668	9625	8434	12911	14193	16031	11331	9084	11069	10085	181106	71793
Total Fuel Reported	30	2180	4172	3566	4301	2980	1678	414	2719	4002	3187	3477	3919	3586	5420	5830	6734	4795	3805	4700	4468	75963	30332
Fuel sed in Calculation	30	2120	4172	3566	4301	2980	1678	394	2719	4002	3007	3477	3919	3586	5420	5830	6734	4667	3709	4700	4459	75470	30099
Fuel Economy (Mile/Gal)	2.93	2.25	2.27	2.41	2.47	2.54	2.42	2.18	2.34	2.55	2.35	2.49	2.46	2.35	2.38	2.43	2.38	2.43	2.45	2.36	2.26	2.40	2.39
Min Odometer	1659	2212	3027	3556	4563	5905	6436	6801	7268	7722	8053	8355	8893	9163	10631	13679	16384	17963	18590	19127	19666		
Max Odometer	2366	3559	6051	7781	10546	11852	13166	13333	15305	17765	20138	22598	24788	26246	28844	31956	35616	38042	40179	42315	44461		

CNG/Deere Bus 2460 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		231	2621	1646	2329	2442	1661	156	2238	2460	2373	2460	2190	1458	2598	3112	3660	2426	2137	2136	1302	41636	14773
Mileage sed in Calc		231	2621	1646	2329	2442	1469	156	2082	2460	1536	2460	2190	1458	2598	3112	3660	2426	2137	2136	1302	40451	14773
Total Fuel Reported		140	1082	685	967	814	463	52	852	857	695	954	897	674	1252	1236	1499	1045	955	910	744	16773	6389
Fuel sed in Calculation		140	1082	685	967	814	463	52	852	857	515	954	897	674	1252	1236	1499	1045	955	910	744	16593	6389
Fuel Economy (Mile/Gal)		1.65	2.42	2.40	2.41	3.00	3.17	3.00	2.44	2.87	2.98	2.58	2.44	2.16	2.08	2.52	2.44	2.32	2.24	2.35	1.75	2.44	2.31
Odometer		2212	4833	6479	8808	11250	12911	13067	15305	17765	20138	22598	24788	26246	28844	31956	35616	38042	40179	42315	43617	43617	43617

CNG/Deere Bus 2461 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		1173	1788	2307	2399	1424	0	235	482	2606	2501	1747	1866	2493	2692	2594	3296	3001	1971	2358	2942	39875	16162
Mileage sed in Calc		1173	1788	2307	2399	1424	0	60	482	2606	2501	1747	1866	2493	2692	2594	3296	3001	1971	2358	2942	39700	16162
Total Fuel Reported		493	785	981	1009	663	0	63	222	1030	963	669	798	979	1127	1048	1413	1354	829	1319	1245	16990	7208
Fuel sed in Calculation		493	785	981	1009	663	0	43	222	1030	963	669	798	979	1127	1048	1413	1354	829	1319	1245	16970	7208
Fuel Economy (Mile/Gal)		2.38	2.28	2.35	2.38	2.15		1.40	2.17	2.53	2.60	2.61	2.34	2.55	2.39	2.48	2.33	2.22	2.38	1.79	2.36	2.34	2.24
Odometer	2366	3539	5327	7634	10033	11457	11457	11692	12174	14780	17281	19028	20894	23387	26079	28673	31969	34970	36941	39299	42241	42241	42241

CNG/Deere Bus 2462 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		892	2489	2392	2137	1054	747	111	1638	2587	1069	2324	3014	2205	2917	2537	2871	3521	2211	3142	2632	42490	16914
Mileage sed in Calc		892	2489	2392	2137	1054	747	111	1638	2587	1069	2324	3014	2205	2917	2537	2871	3121	2211	3142	2632	42090	15868
Total Fuel Reported		405	1071	1002	837	477	299	37	721	1019	750	888	1041	735	1095	1061	1340	1115	767	1086	1063	16809	6160
Fuel sed in Calculation		405	1071	1002	837	477	299	37	721	1019	750	888	1041	735	1095	1061	1340	1087	767	1086	1063	16781	6160
Fuel Economy (Mile/Gal)		2.20	2.32	2.39	2.55	2.21	2.50	3.00	2.27	2.54	1.43	2.62	2.90	3.00	2.66	2.39	2.14	2.87	2.88	2.89	2.48	2.51	2.58
Odometer	1659	2551	5040	7432	9569	10623	11370	11481	13119	15706	16775	19099	22113	24318	27235	29772	32643	36164	38375	41517	44149	44149	44149

CNG/Deere Bus 2463 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage	88	1702	2492	1730	2765	1306	1314	167	1691	2087	1635	1835	2017	2008	3236	2902	3499	1750	2670	2896	2902	42692	16619
Mileage sed in Calc	88	1702	2492	1730	2765	1306	1314	167	1691	2087	1635	1835	2017	2008	3236	2902	3499	1204	2138	2896	2902	41614	15497
Total Fuel Reported	30	745	1035	701	1118	604	604	91	743	892	614	815	852	985	1321	1113	1424	621	1009	1207	1292	17816	6510
Fuel sed in Calculation	30	745	1035	701	1118	604	604	91	743	892	614	815	852	985	1321	1113	1424	521	913	1207	1292	17620	6510
Fuel Economy (Mile/Gal)	2.93	2.28	2.41	2.47	2.47	2.16	2.18	1.84	2.28	2.34	2.66	2.25	2.37	2.04	2.45	2.61	2.46	2.31	2.34	2.40	2.25	2.36	2.38
Odometer	1857	3559	6051	7781	10546	11852	13166	13333	15024	17111	18746	20581	22598	24606	27842	30744	34243	35993	38663	41559	44461	44461	44461

CNG/Deere Bus 2464 **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		1155	71	529	1007	1342	531	365	467	454	331	302	538	270	1468	3048	2705	1579	627	537	539	17865	9035
Mileage sed in Calc		773	71	529	1007	1342	531	365	467	454	331	302	538	270	1468	3048	2705	1579	627	537	307	17251	8331
Total Fuel Reported		397	199	197	370	422	312	171	181	204	165	151	331	213	625	1372	1058	660	245	178	124	7575	3750
Fuel sed in Calculation		337	199	197	370	422	312	171	181	204	165	151	331	213	625	1372	1058	660	245	178	115	7506	3750
Fuel Economy (Mile/Gal)		2.29	0.36	2.69	2.72	3.18	1.70	2.13	2.58	2.23	2.01	2.00	1.63	1.27	2.35	2.22	2.56	2.39	2.56	3.02	2.67	2.30	2.22
Odometer	1801	2956	3027	3556	4563	5905	6436	6801	7268	7722	8053	8355	8893	9163	10631	13679	16384	17963	18590	19127	19666	19666	19666

Appendix D

Diesel and CNG Fuel Costs

Average Diesel Fuel Costs at WMATA

Period	ear	Cost/Gal
Sep 1st	2001	0.8751
Sep 2nd	2001	0.9434
Oct 1st	2001	0.7654
Oct 2nd	2001	0.7451
Nov 1st	2001	0.6917
Nov 2nd	2001	0.6417
Dec 1st	2001	0.5963
Dec 2nd	2001	0.5517
Jan 1st	2002	0.6293
Jan 2nd	2002	0.5936
Feb 1st	2002	0.5813
Feb 2nd	2002	0.6143
Mar 1st	2002	0.7166
Mar 2nd	2002	0.8006
Apr 1st	2002	0.8189
Apr 2nd	2002	0.8399
May 1st	2002	0.8291
May 2nd	2002	0.8333
Jun 1st	2002	0.8136
Jun 2nd	2002	0.7849
Jul 1st	2002	0.8334
Jul 2nd	2002	0.8516
Aug 1st	2002	0.8452
Aug 2nd	2002	0.8768
Average		**0.75**

CNG Costs at WMATA by Month

Month	Dry Therm	Wet Therm	Total Cost	/gal	DGE
Jul-03	251363	237853	177,210.86	1.03	172,049.4
Aug-03	269830	255328	190,226.07	1.03	184,685.5
Sep-03	251573	238052	177,491.03	1.03	172,321.4
Oct-03	230708	218308	160,908.88	1.02	157,753.8
Nov-03	327241	309653	281,519.11	1.26	223,427.9
Dec-03	162850	154097	140,124.37	1.26	111,209.8
Jan-04	514797	487128	439,377.74	1.25	351,502.2
Feb-04	255532	241797	0.00	1.25	
Mar-04	318142	301043	261,367.18	1.25	209,093.7
Apr-04	261640	247578	220,395.59	1.23	179,183.4
May-04	186422	176403	157,050.71	1.23	127,683.5
Jun-04	269768	255269	230,385.71	1.25	184,308.6
Jul-04	282020	266863	240,846.74	1.25	192,677.4
Aug-04	267806	253412	228,710.62	1.25	182,968.5
Sep-04	269688	255193	230,317.55	1.25	184,254.0
Total/Average			**3,135,932.16**	**1.19**	**2,633,119.1**

Appendix E

Total Maintenance Costs

WMATA CNG Buses
Repairs Analysis

Diesel Buses

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		13597	11908	16273	13586	16365	16384	16912	16536	15527	15458	152546
Roadcalls - All		3	4	3	2	2	6	8	6	7	5	46
Roadcalls - Engine/Fuel		0	2	0	0	1	1	1	2	4	1	12
Parts Costs		1188.34	389.35	1067.03	1430.51	848.57	1187.51	1055.90	2417.63	2574.76	896.33	13055.93
Labor Hours		124.20	107.90	120.40	168.40	133.90	131.90	121.80	212.60	262.10	156.80	1540.00
Total Cost per Mile ( )		0.544	0.486	0.436	0.725	0.461	0.475	0.423	0.789	1.010	0.565	0.590
Min Odometer	38098	40574	43623	46377	48813	52624	56026	58763	61676	64017	65855	
Max Odometer	45102	47942	50266	54331	57759	61699	65236	68735	72094	76567	80959	

Diesel Bus 2070

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		2840	1504	2491	2325	1238	3327	3354	4002	2977	3243	27301
Roadcalls - All		0	0	1	1	1	2	1	2	1	2	11
Roadcalls - Engine/Fuel		0	0	0	0	1	1	0	0	0	1	3
Parts Costs		305.67	0.00	47.50	639.24	78.44	449.96	429.17	100.96	331.08	83.61	2465.63
Labor Hours		27.0	16.0	21.4	38.5	20.9	29.1	25.2	40.0	38.3	59.2	315.6
Total Cost per Mile ( )		0.583	0.532	0.449	1.103	0.907	0.573	0.504	0.525	0.754	0.939	0.668
Odometer	45102	47942	49446	51937	54262	55500	58827	62181	66183	69160	72403	72403

Diesel Bus 2071

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		2504	3064	3593	3416	3660	3005	4427	2931	2967	3742	33309
Roadcalls - All		0	0	1	0	0	2	2	2	0	0	7
Roadcalls - Engine/Fuel		0	0	0	0	0	0	0	1	0	0	1
Parts Costs		231.25	35.99	515.15	34.62	394.49	232.20	0.00	1350.67	807.83	139.62	3741.82
Labor Hours		19.5	30.0	28.2	15.2	37.0	29.5	17.8	54.0	46.0	20.0	297.2
Total Cost per Mile ( )		0.482	0.501	0.536	0.233	0.613	0.568	0.201	1.382	1.047	0.305	0.558
Odometer	41748	44252	47316	50909	54325	57985	60990	65417	68348	71315	75057	75057

Diesel Bus 2072

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		3770	3829	4065	3428	3940	3537	3499	3359	4473	4392	38292
Roadcalls - All		1	2	0	0	0	1	1	0	3	1	9
Roadcalls - Engine/Fuel		0	1	0	0	0	0	1	0	2	0	4
Parts Costs		345.55	104.62	4.38	225.14	254.88	186.42	86.68	312.46	376.43	95.99	1992.55
Labor Hours		20.0	27.1	19.5	26.7	19.2	20.8	27.2	43.5	41.5	17.3	262.8
Total Cost per Mile ( )		0.357	0.381	0.241	0.455	0.308	0.347	0.413	0.741	0.548	0.219	0.395
Odometer	42667	46437	50266	54331	57759	61699	65236	68735	72094	76567	80959	80959

Diesel Bus 2073

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		2476	3275	3370	1981	3716	3110	2737	2913	2341	3250	29169
Roadcalls - All		2	1	1	1	0	0	2	2	2	0	11
Roadcalls - Engine/Fuel		0	1	0	0	0	0	0	1	1	0	3
Parts Costs		0.00	248.74	500.00	272.43	90.76	126.60	540.05	548.92	215.81	297.00	2840.31
Labor Hours		21.5	32.1	38.5	28.0	36.5	34.0	30.9	59.1	46.3	16.0	342.9
Total Cost per Mile ( )		0.434	0.566	0.720	0.844	0.516	0.587	0.762	1.203	1.081	0.338	0.685
Odometer	38098	40574	43849	47219	49200	52916	56026	58763	61676	64017	67267	67267

Diesel Bus 2074

Item	Oct-01	Nov-01	Dec-01	an-02	Feb-02	Mar-02	Apr-02	May-02	un-02	ul-02	Aug-02	Total
Total Mileage		2007	236	2754	2436	3811	3405	2895	3331	2769	831	24475
Roadcalls - All		0	1	0	0	1	1	2	0	1	2	8
Roadcalls - Engine/Fuel		0	0	0	0	0	0	0	0	1	0	1
Parts Costs		305.87	0.00	0.00	259.08	30.00	192.33	0.00	104.62	843.61	280.11	2015.62
Labor Hours		36.2	2.7	12.8	60.0	20.3	18.5	20.7	16.0	90.0	44.3	321.5
Total Cost per Mile ( )		1.054	0.572	0.232	1.338	0.274	0.328	0.358	0.272	1.930	3.003	0.739
Odometer	41380	43387	43623	46377	48813	52624	56029	58924	62255	65024	65855	65855

WMATA CNG Buses
Repairs Analysis

CNG/Cummins Buses — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	3063	13542	10662	11433	11089	10971	9952	11314	11731	12276	11189	12955	13584	10664	12891	12001	13082	9942	10376	12634	11177	13213	249741	143708
Roadcalls - All	0	4	2	1	0	2	0	2	1	0	3	2	5	3	0	3	1	2	1	5	1	4	42	30
Roadcalls - Engine/Fuel	0	1	1	0	0	0	0	1	0	0	1	1	3	0	0	2	0	1	0	0	0	0	11	8
Parts Costs	229.88	1681.96	1185.26	557.95	292.67	199.53	927.88	432.74	340.68	1686.78	1015.97	487.92	987.29	1080.40	808.53	938.38	743.71	789.42	1222.94	553.02	952.57	1563.26	18678.74	11143.41
Labor Hours	4.50	124.50	93.80	80.10	81.80	78.20	117.10	108.30	101.60	119.40	94.00	96.80	115.60	123.80	78.40	116.10	75.30	101.80	124.50	77.44	131.50	143.60	2188.1	1278.8
Total Cost per Mile ( )	0.149	0.584	0.551	0.399	0.395	0.375	0.682	0.517	0.462	0.624	0.511	0.411	0.498	0.682	0.367	0.562	0.345	0.591	0.718	0.350	0.673	0.662	0.513	0.522
Min Odometer	3546	6230	8063	9574	11532	13330	15894	18113	20955	23219	25426	27962	30400	32060	32229	33863	36473	38977	41190	44160	46248	48372		
Max Odometer	4822	8058	10202	12430	14653	16750	19109	21452	23850	26436	28638	31271	34014	37346	40883	43999	46029	47778	50798	54238	56875	60639		

CNG/Cummins Bus 2302 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	981	3236	2144	2228	1884	2062	852	2605	2260	2437	2392	2773	2312	2434	2805	2441	2537	0	1210	726	2088	2124	44531	23842
Roadcalls - All	0	0	1	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	1	0	1	7	6
Roadcalls - Engine/Fuel	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Parts Costs	0.00	549.14	530.80	214.24	0.00	0.00	75.00	317.59	0.00	574.65	35.00	75.00	715.46	0.00	406.87	25.00	266.15	0.00	35.00	136.98	64.59	406.76	4428.23	2166.81
Labor Hours	0.0	17.0	25.0	22.5	12.5	14.5	22.5	24.5	14.5	23.7	17.3	30.4	28.0	13.3	26.3	1.8	29.9	7.0	19.5	15.9	11.0	34.1	411.2	234.5
Total Cost per Mile ( )	0.000	0.432	0.831	0.601	0.332	0.352	1.408	0.592	0.321	0.722	0.376	0.575	0.915	0.273	0.614	0.047	0.694		0.835	1.286	0.294	0.994	0.561	0.583
Odometer	4822	8058	10202	12430	14314	16376	17228	19833	22093	24530	26922	29695	32007	34441	37246	39687	42224	42224	43434	44160	46248	48372	48372	48372

CNG/Cummins Bus 2303 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	705	2616	2348	2694	2195	2282	1887	2233	2177	2059	2588	2796	3615	3417	3537	3116	2296	2725	3020	3440	2637	3764	58147	36951
Roadcalls - All	0	0	0	0	0	0	0	2	0	0	0	0	2	1	0	0	0	1	0	2	0	0	8	6
Roadcalls - Engine/Fuel	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	3	2
Parts Costs	0.00	277.26	0.00	140.25	97.21	0.00	205.40	31.15	0.00	221.21	0.00	205.46	0.00	323.80	81.80	298.00	33.40	274.67	353.48	31.15	242.46	105.65	2922.35	1949.87
Labor Hours	0.0	22.0	4.0	5.5	20.0	12.0	29.5	16.3	23.0	28.2	12.0	20.5	13.6	25.7	14.5	28.3	14.5	25.0	36.2	13.7	32.2	25.0	421.7	261.2
Total Cost per Mile ( )	0.000	0.526	0.085	0.154	0.500	0.263	0.891	0.379	0.528	0.792	0.232	0.440	0.188	0.471	0.228	0.550	0.330	0.560	0.716	0.208	0.702	0.360	0.413	0.406
Odometer	4439	7055	9403	12097	14292	16574	18461	20694	22871	24930	27518	30314	33929	37346	40883	43999	46029	47778	50798	54238	56875	60639	60639	60639

CNG/Cummins Bus 2304 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	556	2722	2362	2451	2596	2097	2359	2343	2398	2586	2202	2633	2743	2396	3365	2264	2909	2237	1694	2658	2056	2553	52180	29710
Roadcalls - All	0	2	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	7	4
Roadcalls - Engine/Fuel	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	2
Parts Costs	0.00	333.04	424.58	195.46	0.00	0.00	236.55	42.00	0.00	195.46	229.88	207.46	45.22	345.74	0.00	0.00	195.46	53.09	364.29	0.00	0.00	221.21	3089.44	1662.35
Labor Hours	0.0	32.0	30.3	13.5	16.3	9.4	29.3	24.0	22.3	19.0	19.8	16.5	22.5	44.0	5.3	15.3	17.0	11.0	26.8	10.0	24.5	24.5	433.3	237.2
Total Cost per Mile ( )	0.000	0.710	0.821	0.355	0.314	0.224	0.721	0.530	0.465	0.443	0.554	0.392	0.427	1.062	0.079	0.338	0.359	0.270	1.006	0.188	0.596	0.566	0.474	0.455
Odometer	4522	7244	9606	12057	14653	16750	19109	21452	23850	26436	28638	31271	34014	36410	39775	42039	44948	47185	48879	51537	53593	56146	56146	56146

CNG/Cummins Bus 2307 — Last ear

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	258	2684	1833	1511	1958	1798	2564	2219	2842	2264	2207	2536	2438	2375	3015	2546	2730	2476	2239	2814	1452	2608	49367	29436
Roadcalls - All	0	1	1	1	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	0	0	10	6
Roadcalls - Engine/Fuel	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Parts Costs	229.88	277.26	229.88	0.00	0.00	199.53	80.13	0.00	340.68	500.00	195.46	0.00	0.00	329.06	45.78	345.21	0.00	222.38	236.44	90.16	645.52	0.00	3967.37	2110.01
Labor Hours	4.5	27.1	22.5	26.1	10.5	27.3	8.0	17.5	34.0	29.0	20.0	19.6	20.0	21.8	10.6	18.1	2.7	32.8	10.5	15.5	47.6	16.0	441.7	235.2
Total Cost per Mile ( )	0.000	0.608	0.739	0.864	0.268	0.870	0.187	0.394	0.718	0.861	0.542	0.386	0.410	0.597	0.191	0.491	0.049	0.752	0.340	0.307	2.084	0.307	0.528	0.471
Odometer	3546	6230	8063	9574	11532	13330	15894	18113	20955	23219	25426	27962	30400	32775	35790	38336	41066	43542	45781	48595	50047	52655	52655	52655

CNG/Cummins Bus 2309 **Last ear**

Item	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	Total	Total
Total Mileage	563	2284	1975	2549	2456	2732	2290	1914	2054	2930	1800	2217	2476	42	169	1634	2610	2504	2213	2996	2944	2164	45516	23769
Roadcalls - All	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	2	1	0	0	1	0	2	10	8
Roadcalls - Engine/Fuel	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	3	3
Parts Costs	0.00	245.26	0.00	8.00	195.46	0.00	330.80	42.00	0.00	195.46	555.63	0.00	226.61	81.80	274.08	270.17	248.70	239.28	233.73	294.73	0.00	829.64	4271.35	3254.37
Labor Hours	0.0	26.4	12.0	12.5	22.5	15.0	27.8	26.0	7.8	19.5	24.9	9.8	31.5	19.0	21.7	52.6	11.2	26.0	31.5	22.3	16.2	44.0	480.2	310.7
Total Cost per Mile ( )	0.000	0.685	0.304	0.248	0.538	0.275	0.751	0.701	0.190	0.399	1.000	0.221	0.728	24.567	8.042	1.775	0.310	0.615	0.817	0.471	0.275	1.400	0.621	0.790
Odometer	4341	6625	8600	11149	13605	16337	18627	20541	22595	25525	27325	29542	32018	32060	32229	33863	36473	38977	41190	44186	47130	49294	49294	49294

WMATA CNG Buses
Repairs Analysis

CNG/Deere Buses — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage	88	5153	9461	8604	10637	7568	4253	1034	6516	10194	7909	8668	9625	8434	12911	14193	16031	12277	9616	11069	10317	184558	73503
Roadcalls - All	0	2	3	2	1	3	4	0	2	0	1	1	3	2	2	1	3	1	5	1	3	40	14
Roadcalls - Engine/Fuel	0	0	2	2	0	2	4	0	2	0	1	1	2	1	0	0	0	0	3	0	2	22	5
Parts Costs	112.24	925.93	318.42	794.98	106.80	767.10	618.49	1099.44	474.87	965.08	681.16	1926.35	755.97	1448.19	200.84	1484.31	568.84	900.11	834.70	821.02	832.51	16637.35	5441.49
Labor Hours	18.5	183.4	131.5	152.9	112.2	179.8	99.3	64.8	74.9	85.6	124.7	156.0	137.6	100.2	115.3	150.0	108.7	101.2	99.6	112.9	165.0	2474.1	737.4
Total Cost per Mile ( )	11.787	1.959	0.729	0.981	0.537	1.289	1.313	4.197	0.648	0.515	0.874	1.122	0.793	0.766	0.462	0.633	0.375	0.485	0.605	0.584	0.880	0.760	0.576
Min Odometer	1659	2212	3027	3556	4563	5905	6436	6801	7268	7722	8053	8355	8893	9163	10631	13679	16384	17963	18590	19127	19666		
Max Odometer	2366	3559	6051	7781	10546	11852	13166	13333	15305	17765	20138	22598	24788	26246	28844	31956	35616	38042	40179	42315	44461		

CNG/Deere Bus 2460 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		231	2621	1646	2329	2442	1661	156	2238	2460	2373	2460	2190	1458	2598	3112	3660	2426	2137	2136	1302	41636	14773
Roadcalls - All		0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	1	0	3	1	2	11	7
Roadcalls - Engine/Fuel		0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	2	0	1	7	3
Parts Costs		229.88	25.75	161.89	0.00	150.00	136.89	229.88	242.22	118.60	314.75	294.52	285.49	0.00	0.00	823.76	50.00	254.36	68.48	545.00	160.51	4091.98	1902.11
Labor Hours		40.5	16.1	42.8	13.0	26.8	31.8	14.0	16.0	13.9	30.0	10.7	38.5	7.5	26.5	35.7	19.3	32.3	22.8	26.5	38.7	503.4	175.3
Total Cost per Mile ( )		9.761	0.317	1.398	0.279	0.610	1.040	5.961	0.466	0.331	0.765	0.337	1.009	0.257	0.510	0.838	0.277	0.771	0.566	0.875	1.609	0.703	0.722
Odometer		2212	4833	6479	8808	11250	12911	13067	15305	17765	20138	22598	24788	26246	28844	31956	35616	38042	40179	42315	43617	43617	43617

CNG/Deere Bus 2461 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		1173	1788	2307	2399	1424	0	235	482	2606	2501	1747	1866	2493	2692	2594	3296	3001	1971	2358	2942	39875	16162
Roadcalls - All		0	2	1	0	1	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	8	1
Roadcalls - Engine/Fuel		0	2	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	6	0
Parts Costs		320.53	62.79	175.25	0.00	429.56	0.00	231.88	0.00	120.60	2.00	582.35	65.00	269.75	200.62	30.00	164.64	0.00	0.00	226.02	177.66	3058.65	598.32
Labor Hours		41.5	57.9	33.1	18.7	42.8	13.0	7.0	17.5	12.5	22.5	58.2	25.1	10.0	37.3	29.2	18.2	0.0	8.5	12.6	38.0	503.6	106.5
Total Cost per Mile ( )		2.042	1.654	0.793	0.390	1.804	#DIV/0!	2.476	1.815	0.286	0.451	1.999	0.707	0.309	0.767	0.574	0.326	0.000	0.216	0.363	0.706	0.708	0.366
Odometer	2366	3539	5327	7634	10033	11457	11457	11692	12174	14780	17281	19028	20894	23387	26079	28673	31969	34970	36941	39299	42241	42241	42241

CNG/Deere Bus 2462 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		892	2489	2392	2137	1054	747	111	1638	2587	1069	2324	3014	2205	2917	2537	2871	3521	2211	3142	2632	42490	16914
Roadcalls - All		1	0	0	1	1	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	8	3
Roadcalls - Engine/Fuel		0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	5	2
Parts Costs		112.24	0.00	165.25	81.80	47.79	47.79	405.80	207.08	53.94	114.24	673.75	143.60	456.39	0.00	207.58	118.60	267.68	72.96	0.00	295.14	3471.63	961.96
Labor Hours		29.4	17.5	24.0	38.5	40.5	8.5	23.0	14.3	13.2	22.2	56.3	14.6	31.7	18.0	28.3	20.5	31.5	20.5	16.5	27.8	496.8	145.1
Total Cost per Mile ( )		1.774	0.352	0.571	0.939	1.967	0.633	14.016	0.563	0.276	1.145	1.501	0.290	0.926	0.309	0.640	0.398	0.523	0.497	0.263	0.640	0.666	0.486
Odometer	1659	2551	5040	7432	9569	10623	11370	11481	13119	15706	16775	19099	22113	24318	27235	29772	32643	36164	38375	41517	44149	44149	44149

CNG/Deere Bus 2463 — **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage	88	1702	2492	1730	2765	1306	1314	167	1691	2087	1635	1835	2017	2008	3236	2902	3499	1750	2670	2896	2902	42692	16619
Roadcalls - All	0	0	1	0	0	1	0	0	1	0	0	0	1	2	0	0	1	1	1	0	0	9	3
Roadcalls - Engine/Fuel	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2	0
Parts Costs	112.24	33.40	0.00	242.02	25.00	104.75	249.13	231.88	25.57	641.94	250.17	179.92	27.00	722.05	0.00	180.20	133.60	154.01	693.26	50.00	199.20	4255.34	1410.27
Labor Hours	18.5	23.5	18.5	17.0	25.5	56.2	10.5	12.8	18.1	27.2	43.5	18.4	34.4	46.5	8.5	34.0	8.2	14.5	30.8	31.3	44.0	541.9	162.8
Total Cost per Mile ( )	11.787	0.710	0.371	0.631	0.470	2.232	0.589	5.221	0.550	0.959	1.483	0.599	0.866	1.517	0.131	0.648	0.155	0.502	0.836	0.558	0.827	0.734	0.575
Odometer	1857	3559	6051	7781	10546	11852	13166	13333	15024	17111	18746	20581	22598	24606	27842	30744	34243	35993	38663	41559	44461	44461	44461

CNG/Deere Bus 2464 **Last 6 Mos**

Item	an-03	Feb-03	Mar-03	Apr-03	May-03	un-03	ul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	an-04	Feb-04	Mar-04	Apr-04	May-04	un-04	ul-04	Aug-04	Sep-04	Total	Total
Total Mileage		1155	71	529	1007	1342	531	365	467	454	331	302	538	270	1468	3048	2705	1579	627	537	539	17865	9035
Roadcalls - All		1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0
Roadcalls - Engine/Fuel		0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Parts Costs		229.88	229.88	50.57	0.00	35.00	184.68	0.00	0.00	30.00	0.00	195.81	234.88	0.00	0.22	242.77	102.00	224.06	0.00	0.00	0.00	1759.75	568.83
Labor Hours		48.5	21.5	36.0	16.5	13.5	35.5	8.0	9.0	18.8	6.5	12.4	25.0	4.5	25.0	22.8	42.5	22.9	17.0	26.0	16.5	428.4	147.7
Total Cost per Mile ( )		2.299	18.379	3.498	0.819	0.529	3.691	1.096	0.964	2.137	0.982	2.701	2.760	0.833	0.852	0.454	0.823	0.867	1.356	2.421	1.531	1.297	0.880
Odometer	1801	2956	3027	3556	4563	5905	6436	6801	7268	7722	8053	8355	8893	9163	10631	13679	16384	17963	18590	19127	19666	19666	19666

Appendix F

Maintenance Costs Broken Down by Vehicle System

Fleet Summary Statistics 12/13/2004

Washington Metropolitan Area Transit Authority (WMATA)

Diesel Study Group

Fleet Operations and Economics

	Diesel All Data	Diesel Last ear
Number of Vehicles	5	5
Period Used for Fuel and Oil Op Anaysis	8/00-8/02	9/01-8/02
Total Number of Months in Period	25	12
Fuel and Oil Analysis Base Fleet Mileage	345,167	178,361
Period Used for Maintenance Op Analysis	11/01-8/02	11/01-8/02
Total Number of Months in Period	10	10
Maintenance Analysis Base Fleet Mileage	152,546	152,546
Average Monthly Mileage per Vehicle	2,940	3,143
Fleet Diesel Usage in Gal.	122,542	62,912
Representative Fleet MPG (energy equiv)	2.82	2.84
Diesel Cost per gallon	1.33	1.33
Fuel Cost per Mile	**0.472**	**0.469**
Total Scheduled Repair Cost per Mile	0.273	0.273
Total Unscheduled Repair cost per Mile	0.318	0.318
Total Maintenance Cost per Mile	**0.590**	**0.590**
Total Operating Cost per Mile	**1.063**	**1.059**

Maintenance Costs

	Diesel All Data	Diesel Last ear
Fleet Mileage	152,546	152,546
Total Parts Cost	13,055.93	13,055.93
Total Labor Hours	1540.0	1540.0
Average Labor Cost (@ $50.00 per hour)	77,000.00	77,000.00
Total Maintenance Cost	90,055.93	90,055.93
Total Maintenance Cost per Bus	18,011.19	18,011.19
Total Maintenance Cost per Mile	**0.590**	**0.590**

Breakdown of Maintenance Costs by Vehicle System

	Diesel All Data	Diesel Last ear
Fleet Mileage	152,546	152,546
Total Engine/Fuel-Related Systems (ATA VMRS 30, 31, 32, 33, 41, 42, 43, 44, 45)		
Parts Cost	5,114.48	5,114.48
Labor Hours	268.4	268.4
Average Labor Cost	13,420.00	13,420.00
Total Cost (for system)	18,534.48	18,534.48
Total Cost (for system) per Bus	3,706.90	3,706.90
Total Cost (for system) per Mile	**0.1215**	**0.1215**
Exhaust System Repairs (ATA VMRS 43)		
Parts Cost	420.06	420.06
Labor Hours	17.0	17.0
Average Labor Cost	850.00	850.00
Total Cost (for system)	1,270.06	1,270.06
Total Cost (for system) per Bus	254.01	254.01
Total Cost (for system) per Mile	**0.0083**	**0.0083**
Fuel System Repairs (ATA VMRS 44)		
Parts Cost	766.01	766.01
Labor Hours	10.2	10.2
Average Labor Cost	510.00	510.00
Total Cost (for system)	1,276.01	1,276.01
Total Cost (for system) per Bus	255.20	255.20
Total Cost (for system) per Mile	**0.0084**	**0.0084**
Power Plant (Engine) Repairs (ATA VMRS 45)		
Parts Cost	1,301.90	1,301.90
Labor Hours	61.7	61.7
Average Labor Cost	3,085.00	3,085.00
Total Cost (for system)	4,386.90	4,386.90
Total Cost (for system) per Bus	877.38	877.38
Total Cost (for system) per Mile	**0.0288**	**0.0288**
Electrical System Repairs (ATA VMRS 30-Electrical General, 31-Charging, 32-Cranking, 33-Ignition)		
Parts Cost	1,457.83	1,457.83
Labor Hours	22.5	22.5
Average Labor Cost	1,125.00	1,125.00
Total Cost (for system)	2,582.83	2,582.83
Total Cost (for system) per Bus	516.57	516.57
Total Cost (for system) per Mile	**0.0169**	**0.0169**

Breakdown of Maintenance Costs by Vehicle System (continued)

	Diesel All Data	Diesel Last ear
Air Intake System Repairs (ATA VMRS 41)		
Parts Cost	123.15	123.15
Labor Hours	0.0	0.0
Average Labor Cost	0.00	0.00
Total Cost (for system)	123.15	123.15
Total Cost (for system) per Bus	24.63	24.63
Total Cost (for system) per Mile	**0.0008**	**0.0008**
Cooling System Repairs (ATA VMRS 42)		
Parts Cost	1,045.53	1,045.53
Labor Hours	157.0	157.0
Average Labor Cost	7,850.00	7,850.00
Total Cost (for system)	8,895.53	8,895.53
Total Cost (for system) per Bus	1,779.11	1,779.11
Total Cost (for system) per Mile	**0.0583**	**0.0583**
Hydraulic System Repairs (ATA VMRS 65)		
Parts Cost	207.22	207.22
Labor Hours	18.0	18.0
Average Labor Cost	900.00	900.00
Total Cost (for system)	1,107.22	1,107.22
Total Cost (for system) per Bus	221.44	221.44
Total Cost (for system) per Mile	**0.0073**	**0.0073**
General Air System Repairs (ATA VMRS 10)		
Parts Cost	399.63	399.63
Labor Hours	42.1	42.1
Average Labor Cost	2,105.00	2,105.00
Total Cost (for system)	2,504.63	2,504.63
Total Cost (for system) per Bus	500.93	500.93
Total Cost (for system) per Mile	**0.0164**	**0.0164**
Brake System Repairs (ATA VMRS 13)		
Parts Cost	2,523.91	2,523.91
Labor Hours	153.3	153.3
Average Labor Cost	7,665.00	7,665.00
Total Cost (for system)	10,188.91	10,188.91
Total Cost (for system) per Bus	2,037.78	2,037.78
Total Cost (for system) per Mile	**0.0668**	**0.0668**
Transmission Repairs (ATA VMRS 27)		
Parts Cost	1,906.79	1,906.79
Labor Hours	68.6	68.6
Average Labor Cost	3,430.00	3,430.00
Total Cost (for system)	5,336.79	5,336.79
Total Cost (for system) per Bus	1,067.36	1,067.36
Total Cost (for system) per Mile	**0.0350**	**0.0350**

Breakdown of Maintenance Costs by Vehicle System (continued)

	Diesel All Data	Diesel Last ear
Inspections Only - no parts replacements (101)		
Parts Cost	0.00	0.00
Labor Hours	518.0	518.0
Average Labor Cost	25,900.00	25,900.00
Total Cost (for system)	25,900.00	25,900.00
Total Cost (for system) per Bus	5,180.00	5,180.00
Total Cost (for system) per Mile	**0.1698**	**0.1698**
Cab, Body, and Accessories Systems Repairs (ATA VMRS 02-Cab and Sheet Metal, 50-Accessories, 71-Body)		
Parts Cost	797.55	797.55
Labor Hours	278.7	278.7
Average Labor Cost	13,935.00	13,935.00
Total Cost (for system)	14,732.55	14,732.55
Total Cost (for system) per Bus	2,946.51	2,946.51
Total Cost (for system) per Mile	**0.0966**	**0.0966**
HVAC System Repairs (ATA VMRS 01)		
Parts Cost	1,085.21	1,085.21
Labor Hours	98.4	98.4
Average Labor Cost	4,920.00	4,920.00
Total Cost (for system)	6,005.21	6,005.21
Total Cost (for system) per Bus	1,201.04	1,201.04
Total Cost (for system) per Mile	**0.0394**	**0.0394**
Lighting System Repairs (ATA VMRS 34)		
Parts Cost	204.52	204.52
Labor Hours	13.0	13.0
Average Labor Cost	650.00	650.00
Total Cost (for system)	854.52	854.52
Total Cost (for system) per Bus	170.90	170.90
Total Cost (for system) per Mile	**0.0056**	**0.0056**
Frame, Steering, and Suspension Repairs (ATA VMRS 14-Frame, 15-Steering, 16-Suspension)		
Parts Cost	690.12	690.12
Labor Hours	32.5	32.5
Average Labor Cost	1,625.00	1,625.00
Total Cost (for system)	2,315.12	2,315.12
Total Cost (for system) per Bus	463.02	463.02
Total Cost (for system) per Mile	**0.0152**	**0.0152**
Axle, Wheel, and Drive Shaft Repairs (ATA VMRS 11-Front Axle, 18-Wheels, 22-Rear Axle, 24-Drive Shaft)		
Parts Cost	126.00	126.00
Labor Hours	10.5	10.5
Average Labor Cost	525.00	525.00
Total Cost (for system)	651.00	651.00
Total Cost (for system) per Bus	130.20	130.20
Total Cost (for system) per Mile	**0.0043**	**0.0043**

Breakdown of Maintenance Costs by Vehicle System (continued)

	Diesel All Data	Diesel Last ear
Tire Repairs (ATA VMRS 17)		
Parts Cost	0.00	0.00
Labor Hours	38.5	38.5
Average Labor Cost	1,925.00	1,925.00
Total Cost (for system)	1,925.00	1,925.00
Total Cost (for system) per Bus	385.00	385.00
Total Cost (for system) per Mile	**0.0126**	**0.0126**

Notes

1. The engine/fuel-related systems were chosen to include only those systems of the vehicles that could be directly impacted by the selection of a fuel.

2. ATA VMRS coding is based on parts that were replaced. If there was no part replaced in a given repair, then the code was chosen by the system being worked on.

3. In general, inspections (with no part replacements) were only included in the overall totals (not by system). 101 was created to track labor costs for PMA inspections.

4. ATA VMRS 02-Cab and Sheet Metal represents seats, doors, etc.; ATA VMRS 50-Accessories represents things like fire extinguishers, test kits, etc.; ATA VMRS 71-Body represent mostly windows and windshields.

5. Average labor cost is assumed to be $50 per hour.

6. Warranty costs are not included.

Fleet Summary Statistics 2/16/2006
Washington Metropolitan Area Transit Authority (WMATA)
Cummins CNG Study Group

Fleet Operations and Economics

	CNG Cummins C8.3G	
	All Data	**Last ear**
Number of Vehicles	5	5
Period Used for Fuel and Oil Op Anaysis	8/02-5/04	6/03-5/04
Total Number of Months in Period	22	12
Fuel and Oil Analysis Base Fleet Mileage	241,984	140,829
Period Used for Maintenance Op Analysis	8/02-5/04	6/03-5/04
Total Number of Months in Period	22	12
Maintenance Analysis Base Fleet Mileage	249,741	143,708
Average Monthly Mileage per Vehicle	2,378	2,478
Fleet CNG/Diesel Equiv. Usage in Gal.	103,539	60,822
Representative Fleet MPG (energy equiv)	2.34	2.32
Diesel Cost per gallon	1.33	1.33
Fuel Cost per Mile	**0.569**	**0.574**
Total Scheduled Repair Cost per Mile	0.294	0.265
Total Unscheduled Repair cost per Mile	0.219	0.258
Total Maintenance Cost per Mile	**0.513**	**0.522**
Total Operating Cost per Mile	**1.082**	**1.097**

Maintenance Costs

	CNG Cummins C8.3G	
	All Data	**Last ear**
Fleet Mileage	249,741	143,708
Total Parts Cost	18,678.74	11,143.41
Total Labor Hours	2188.1	1278.8
Average Labor Cost	109,407.00	63,942.00
(@ $50.00 per hour)		
Total Maintenance Cost	128,085.74	75,085.41
Total Maintenance Cost per Bus	25,617.15	15,017.08
Total Maintenance Cost per Mile	**0.513**	**0.522**

Breakdown of Maintenance Costs by Vehicle System

	CNG Cummins C8.3G	
	All Data	**Last ear**
Fleet Mileage	249,741	143,708
Total Engine/Fuel-Related Systems (ATA VMRS 30, 31, 32, 33, 41, 42, 43, 44, 45)		
Parts Cost	11,653.75	6,160.62
Labor Hours	433.1	264.8
Average Labor Cost	21,655.00	13,240.00
Total Cost (for system)	33,308.75	19,400.62
Total Cost (for system) per Bus	6,661.75	3,880.12
Total Cost (for system) per Mile	**0.1334**	**0.1350**
Exhaust System Repairs (ATA VMRS 43)		
Parts Cost	75.00	75.00
Labor Hours	23.2	22.2
Average Labor Cost	1,160.00	1,110.00
Total Cost (for system)	1,235.00	1,185.00
Total Cost (for system) per Bus	247.00	237.00
Total Cost (for system) per Mile	**0.0049**	**0.0082**
Fuel System Repairs (ATA VMRS 44)		
Parts Cost	3,065.70	1,509.31
Labor Hours	49.8	25.5
Average Labor Cost	2,490.00	1,275.00
Total Cost (for system)	5,555.70	2,784.31
Total Cost (for system) per Bus	1,111.14	556.86
Total Cost (for system) per Mile	**0.0222**	**0.0194**
Power Plant (Engine) Repairs (ATA VMRS 45)		
Parts Cost	3,254.93	1,828.22
Labor Hours	72.1	51.3
Average Labor Cost	3,605.00	2,565.00
Total Cost (for system)	6,859.93	4,393.22
Total Cost (for system) per Bus	1,371.99	878.64
Total Cost (for system) per Mile	**0.0275**	**0.0306**
Electrical System Repairs (ATA VMRS 30-Electrical General, 31-Charging, 32-Cranking, 33-Ignition)		
Parts Cost	2,973.88	1,285.34
Labor Hours	154.1	85.4
Average Labor Cost	7,705.00	4,270.00
Total Cost (for system)	10,678.88	5,555.34
Total Cost (for system) per Bus	2,135.78	1,111.07
Total Cost (for system) per Mile	**0.0428**	**0.0387**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Cummins C8.3G	
	All Data	Last ear
Air Intake System Repairs (ATA VMRS 41)		
Parts Cost	1,637.81	929.39
Labor Hours	48.0	30.0
Average Labor Cost	2,400.00	1,500.00
Total Cost (for system)	4,037.81	2,429.39
Total Cost (for system) per Bus	807.56	485.88
Total Cost (for system) per Mile	**0.0162**	**0.0169**
Cooling System Repairs (ATA VMRS 42)		
Parts Cost	646.43	533.36
Labor Hours	85.9	50.4
Average Labor Cost	4,295.00	2,520.00
Total Cost (for system)	4,941.43	3,053.36
Total Cost (for system) per Bus	988.29	610.67
Total Cost (for system) per Mile	**0.0198**	**0.0212**
Hydraulic System Repairs (ATA VMRS 65)		
Parts Cost	99.40	49.70
Labor Hours	10.6	6.3
Average Labor Cost	530.00	315.00
Total Cost (for system)	629.40	364.70
Total Cost (for system) per Bus	125.88	72.94
Total Cost (for system) per Mile	**0.0025**	**0.0025**
General Air System Repairs (ATA VMRS 10)		
Parts Cost	323.78	207.50
Labor Hours	14.0	5.5
Average Labor Cost	700.00	275.00
Total Cost (for system)	1,023.78	482.50
Total Cost (for system) per Bus	204.76	96.50
Total Cost (for system) per Mile	**0.0041**	**0.0034**
Brake System Repairs (ATA VMRS 13)		
Parts Cost	1,871.45	1,333.89
Labor Hours	112.0	71.3
Average Labor Cost	5,600.00	3,565.00
Total Cost (for system)	7,471.45	4,898.89
Total Cost (for system) per Bus	1,494.29	979.78
Total Cost (for system) per Mile	**0.0299**	**0.0341**
Transmission Repairs (ATA VMRS 27)		
Parts Cost	876.84	388.62
Labor Hours	89.9	78.6
Average Labor Cost	4,497.00	3,932.00
Total Cost (for system)	5,373.84	4,320.62
Total Cost (for system) per Bus	1,074.77	864.12
Total Cost (for system) per Mile	**0.0215**	**0.0301**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Cummins C8.3G	
	All Data	Last ear
Inspections Only - no parts replacements (101)		
Parts Cost	0.00	0.00
Labor Hours	742.1	347.1
Average Labor Cost	37,105.00	17,355.00
Total Cost (for system)	37,105.00	17,355.00
Total Cost (for system) per Bus	7,421.00	3,471.00
Total Cost (for system) per Mile	**0.1486**	**0.1208**
Cab, Body, and Accessories Systems Repairs (ATA VMRS 02-Cab and Sheet Metal, 50-Accessories, 71-Body)		
Parts Cost	1,483.45	1,446.45
Labor Hours	434.4	275.8
Average Labor Cost	21,720.00	13,790.00
Total Cost (for system)	23,203.45	15,236.45
Total Cost (for system) per Bus	4,640.69	3,047.29
Total Cost (for system) per Mile	**0.0929**	**0.1060**
HVAC System Repairs (ATA VMRS 01)		
Parts Cost	1,317.75	760.38
Labor Hours	154.8	82.5
Average Labor Cost	7,740.00	4,125.00
Total Cost (for system)	9,057.75	4,885.38
Total Cost (for system) per Bus	1,811.55	977.08
Total Cost (for system) per Mile	**0.0363**	**0.0340**
Lighting System Repairs (ATA VMRS 34)		
Parts Cost	380.27	380.27
Labor Hours	43.5	41.0
Average Labor Cost	2,175.00	2,050.00
Total Cost (for system)	2,555.27	2,430.27
Total Cost (for system) per Bus	511.05	486.05
Total Cost (for system) per Mile	**0.0102**	**0.0169**
Frame, Steering, and Suspension Repairs (ATA VMRS 14-Frame, 15-Steering, 16-Suspension)		
Parts Cost	420.05	415.98
Labor Hours	80.0	67.7
Average Labor Cost	4,000.00	3,385.00
Total Cost (for system)	4,420.05	3,800.98
Total Cost (for system) per Bus	884.01	760.20
Total Cost (for system) per Mile	**0.0177**	**0.0264**
Axle, Wheel, and Drive Shaft Repairs (ATA VMRS 11-Front Axle, 18-Wheels, 22-Rear Axle, 24-Drive Shaft)		
Parts Cost	252.00	0.00
Labor Hours	21.8	9.8
Average Labor Cost	1,090.00	490.00
Total Cost (for system)	1,342.00	490.00
Total Cost (for system) per Bus	268.40	98.00
Total Cost (for system) per Mile	**0.0054**	**0.0034**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Cummins C8.3G	
	All Data	**Last ear**
Tire Repairs (ATA VMRS 17)		
Parts Cost	0.00	0.00
Labor Hours	51.9	28.4
Average Labor Cost	2,595.00	1,420.00
Total Cost (for system)	2,595.00	1,420.00
Total Cost (for system) per Bus	519.00	284.00
Total Cost (for system) per Mile	**0.0104**	**0.0099**

Notes

1. The engine/fuel-related systems were chosen to include only those systems of the vehicles that could be directly impacted by the selection of a fuel.

2. ATA VMRS coding is based on parts that were replaced. If there was no part replaced in a given repair, then the code was chosen by the system being worked on.

3. In general, inspections (with no part replacements) were only included in the overall totals (not by system). 101 was created to track labor costs for PMA inspections.

4. ATA VMRS 02-Cab and Sheet Metal represents seats, doors, etc.; ATA VMRS 50-Accessories represents things like fire extinguishers, test kits, etc.; ATA VMRS 71-Body represent mostly windows and windshields.

5. Average labor cost is assumed to be $50 per hour.

6. Warranty costs are not included.

Fleet Summary Statistics 12/13/2004

Washington Metropolitan Area Transit Authority (WMATA)

Deere CNG Study Group

Fleet Operations and Economics

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Number of Vehicles	5	5
Period Used for Fuel and Oil Op Anaysis	2/03-9/04	4/04-9/04
Total Number of Months in Period	20	6
Fuel and Oil Analysis Base Fleet Mileage	181,106	71,793
Period Used for Maintenance Op Analysis	2/03-9/04	4/04-9/04
Total Number of Months in Period	20	6
Maintenance Analysis Base Fleet Mileage	184,558	73,503
Average Monthly Mileage per Vehicle	1,846	2,450
Fleet CNG/Diesel Equiv. Usage in Gal.	75,470	30,099
Representative Fleet MPG (energy equiv)	2.40	2.39
Diesel Cost per gallon	1.33	1.33
Fuel Cost per Mile	**0.554**	**0.558**
Total Scheduled Repair Cost per Mile	0.354	0.303
Total Unscheduled Repair cost per Mile	0.407	0.272
Total Maintenance Cost per Mile	**0.760**	**0.576**
Total Operating Cost per Mile	**1.315**	**1.133**

Maintenance Costs

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Fleet Mileage	184,558	73,503
Total Parts Cost	16,637.35	5,441.49
Total Labor Hours	2474.1	737.4
Average Labor Cost	123,705.00	36,872.00
(@ $50.00 per hour)		
Total Maintenance Cost	140,342.35	42,313.49
Total Maintenance Cost per Bus	28,068.47	8,462.70
Total Maintenance Cost per Mile	**0.760**	**0.576**

Breakdown of Maintenance Costs by Vehicle System

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Fleet Mileage	184,558	73,503
Total Engine/Fuel-Related Systems (ATA VMRS 30, 31, 32, 33, 41, 42, 43, 44, 45)		
Parts Cost	9,328.79	2,205.13
Labor Hours	760.1	140.5
Average Labor Cost	38,005.00	7,025.00
Total Cost (for system)	47,333.79	9,230.13
Total Cost (for system) per Bus	9,466.76	1,846.03
Total Cost (for system) per Mile	**0.2565**	**0.1256**
Exhaust System Repairs (ATA VMRS 43)		
Parts Cost	94.88	49.88
Labor Hours	45.6	19.5
Average Labor Cost	2,280.00	975.00
Total Cost (for system)	2,374.88	1,024.88
Total Cost (for system) per Bus	474.98	204.98
Total Cost (for system) per Mile	**0.0129**	**0.0139**
Fuel System Repairs (ATA VMRS 44)		
Parts Cost	2,193.76	737.12
Labor Hours	59.8	4.0
Average Labor Cost	2,990.00	200.00
Total Cost (for system)	5,183.76	937.12
Total Cost (for system) per Bus	1,036.75	187.42
Total Cost (for system) per Mile	**0.0281**	**0.0127**
Power Plant (Engine) Repairs (ATA VMRS 45)		
Parts Cost	2,087.44	829.92
Labor Hours	346.3	57.2
Average Labor Cost	17,315.00	2,860.00
Total Cost (for system)	19,402.44	3,689.92
Total Cost (for system) per Bus	3,880.49	737.98
Total Cost (for system) per Mile	**0.1051**	**0.0502**
Electrical System Repairs (ATA VMRS 30-Electrical General, 31-Charging, 32-Cranking, 33-Ignition)		
Parts Cost	4,390.99	321.14
Labor Hours	179.7	28.5
Average Labor Cost	8,985.00	1,425.00
Total Cost (for system)	13,375.99	1,746.14
Total Cost (for system) per Bus	2,675.20	349.23
Total Cost (for system) per Mile	**0.0725**	**0.0238**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Air Intake System Repairs (ATA VMRS 41)		
Parts Cost	150.75	103.00
Labor Hours	25.0	8.0
Average Labor Cost	1,250.00	400.00
Total Cost (for system)	1,400.75	503.00
Total Cost (for system) per Bus	280.15	100.60
Total Cost (for system) per Mile	**0.0076**	**0.0068**
Cooling System Repairs (ATA VMRS 42)		
Parts Cost	410.97	164.07
Labor Hours	103.7	23.3
Average Labor Cost	5,185.00	1,165.00
Total Cost (for system)	5,595.97	1,329.07
Total Cost (for system) per Bus	1,119.19	265.81
Total Cost (for system) per Mile	**0.0303**	**0.0181**
Hydraulic System Repairs (ATA VMRS 65)		
Parts Cost	104.46	39.76
Labor Hours	12.0	1.0
Average Labor Cost	600.00	50.00
Total Cost (for system)	704.46	89.76
Total Cost (for system) per Bus	140.89	17.95
Total Cost (for system) per Mile	**0.0038**	**0.0012**
General Air System Repairs (ATA VMRS 10)		
Parts Cost	325.00	195.00
Labor Hours	5.0	0.0
Average Labor Cost	250.00	0.00
Total Cost (for system)	575.00	195.00
Total Cost (for system) per Bus	115.00	39.00
Total Cost (for system) per Mile	**0.0031**	**0.0027**
Brake System Repairs (ATA VMRS 13)		
Parts Cost	1,951.54	1,829.93
Labor Hours	131.2	60.5
Average Labor Cost	6,560.00	3,025.00
Total Cost (for system)	8,511.54	4,854.93
Total Cost (for system) per Bus	1,702.31	970.99
Total Cost (for system) per Mile	**0.0461**	**0.0661**
Transmission Repairs (ATA VMRS 27)		
Parts Cost	240.96	96.00
Labor Hours	38.2	5.7
Average Labor Cost	1,910.00	285.00
Total Cost (for system)	2,150.96	381.00
Total Cost (for system) per Bus	430.19	76.20
Total Cost (for system) per Mile	**0.0117**	**0.0052**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Inspections Only - no parts replacements (101)		
Parts Cost	0.00	0.00
Labor Hours	609.3	204.7
Average Labor Cost	30,467.00	10,237.00
Total Cost (for system)	30,467.00	10,237.00
Total Cost (for system) per Bus	6,093.40	2,047.40
Total Cost (for system) per Mile	**0.1651**	**0.1393**
Cab, Body, and Accessories Systems Repairs (ATA VMRS 02-Cab and Sheet Metal, 50-Accessories, 71-Body)		
Parts Cost	2,559.54	685.50
Labor Hours	590.2	234.0
Average Labor Cost	29,510.00	11,700.00
Total Cost (for system)	32,069.54	12,385.50
Total Cost (for system) per Bus	6,413.91	2,477.10
Total Cost (for system) per Mile	**0.1738**	**0.1685**
HVAC System Repairs (ATA VMRS 01)		
Parts Cost	790.07	156.32
Labor Hours	134.8	40.5
Average Labor Cost	6,740.00	2,025.00
Total Cost (for system)	7,530.07	2,181.32
Total Cost (for system) per Bus	1,506.01	436.26
Total Cost (for system) per Mile	**0.0408**	**0.0297**
Lighting System Repairs (ATA VMRS 34)		
Parts Cost	270.50	50.00
Labor Hours	28.8	8.3
Average Labor Cost	1,440.00	415.00
Total Cost (for system)	1,710.50	465.00
Total Cost (for system) per Bus	342.10	93.00
Total Cost (for system) per Mile	**0.0093**	**0.0063**
Frame, Steering, and Suspension Repairs (ATA VMRS 14-Frame, 15-Steering, 16-Suspension)		
Parts Cost	446.49	63.85
Labor Hours	84.3	7.5
Average Labor Cost	4,215.00	375.00
Total Cost (for system)	4,661.49	438.85
Total Cost (for system) per Bus	932.30	87.77
Total Cost (for system) per Mile	**0.0253**	**0.0060**
Axle, Wheel, and Drive Shaft Repairs (ATA VMRS 11-Front Axle, 18-Wheels, 22-Rear Axle, 24-Drive Shaft)		
Parts Cost	585.00	85.00
Labor Hours	40.7	20.7
Average Labor Cost	2,035.00	1,035.00
Total Cost (for system)	2,620.00	1,120.00
Total Cost (for system) per Bus	524.00	224.00
Total Cost (for system) per Mile	**0.0142**	**0.0152**

Breakdown of Maintenance Costs by Vehicle System (continued)

	CNG Deere 6081	
	All Data	**Last 6 Mos**
Tire Repairs (ATA VMRS 17)		
Parts Cost	35.00	35.00
Labor Hours	39.5	14.0
Average Labor Cost	1,975.00	700.00
Total Cost (for system)	2,010.00	735.00
Total Cost (for system) per Bus	402.00	147.00
Total Cost (for system) per Mile	**0.0109**	**0.0100**

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5. Average labor cost is assumed to be $50 per hour.

6. Warranty costs are not included.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
April 2006	Technical Report	

4. TITLE AND SUBTITLE
Washington Metropolitan Area Transit Authority: Compressed Natural Gas Transit Bus Evaluation

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
K. Chandler, E. Eberts, M. Melendez

5d. PROJECT NUMBER
NREL/TP-540-37626

5e. TASK NUMBER
FC05.9000

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/TP-540-37626

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
Through the evaluation of compressed natural gas (CNG) powered transit buses at Washington Metropolitan Area Transit Authority (WMATA), the report's objective is to provide a reasonable comparison between between currently available CNG and standard diesel transit buses.

15. SUBJECT TERMS
compressed natural gas; CNG; transit buses; Washington Metropolitan Area Transit Authority; WMATA; natural gas vehicles

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (*Include area code*)
Unclassified	Unclassified	Unclassified	UL		

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Prescribed by ANSI Std. Z39.18