Background

The attached memorandum is an analysis showing emissions benefit that could be realized from replacing older buses with newer buses operating on different fuels. It was prepared in response to a request from the Metropolitan Washington Air Quality Technical Advisory Committee (MWAQC TAC). The Travel Management Subcommittee (TMS) which deals with air quality issues reviewed the memorandum at its October 21, 2008 meeting and requested that staff present it to the Bus Planning Subcommittee and the TPB Technical Committee. When this was discussed at the MWAQC-TAC some members expressed interest in holding a workshop on this subject. However, TMS members were not interested in hosting a workshop and wanted input from bus planners to the idea.

National Capital Region Transportation Planning Board

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Memorandum

September 23, 2008
Revised October 15, 2008

To: Travel Management Subcommittee

From: Daivamani Sivasailam
Principal Transportation Engineer

Subject: Transit Buses and Greenhouse Gas (GHG) Emissions, Costs and Cost-Effectiveness

Introduction

At the May 2008 MWAQC Technical Advisory Committee (TAC) meeting there was an agenda item called "Potential for Clean Buses", by Edgar Gonzalez of Montgomery County, who discussed the County's analysis comparing clean diesel and hybrid diesel-electric buses and their decision to buy a combination of the two. Mr. Sebastian Silvani, a consultant for WMATA, on the same agenda item spoke about the different technologies represented in the WMATA bus fleet. The committee requested DTP staff to look into the cost-effectiveness of the various technologies in reducing Greenhouse Gases and consider convening a special meeting of interested parties if necessary.

Staff has obtained the spread sheet prepared by Montgomery County (Attachment A) and emission rates from different WMATA buses provided by Sebastian Silvani (Attachment B).

Montgomery County Experience

As shown in Attachment A, the Montgomery County spread sheet has cost information, followed by emissions estimation and finally cost-effectiveness. Upon review of the spread sheet staff noticed some areas that needed clarification from the analyst. The per mile CO_2 emissions rate from a 2002 bus is lower than the CO_2 emissions rate of either the 2007 clean diesel bus or hybrid diesel-electric bus. The explanation for the higher fuel efficiency for these buses is that the older buses referenced are smaller in size than the 2007 buses which has since been confirmed by Montgomery County staff.

WMATA Experience

WMATA tested a sample of their buses using West Virginia University's heavy duty emissions test facility (mobile) and obtained emissions rates for various technologies based on the WMATA drive cycle. These results are shown in Attachment B.

Analysis

The following Table 1 was prepared by DTP staff using the annual miles driven, fuel economy in miles per gallon, cost of fuel, and cost of maintenance from Montgomery County, and using the WMATA provided emissions rate of CO_2 for hybrid electric buses, new diesel buses, and compressed natural gas (CNG) buses. Staff prepared CO_2 emissions, and cost-effectiveness. As shown in Table 1, hybrid diesel-electric buses produce the lowest CO_2 emissions, followed by CNG and diesel. For cost-effectiveness CNG buses are the most cost-effective followed by diesel, and finally hybrid diesel-electric buses. It should be noted that the CNG costs did not include capital cost of a CNG refueling facility since Montgomery County has existing facilities.

Attachments

Table 1

DTP Staff Analysis of Hybrid Diesel-Electric Buses, CNG and Diesel								
Draft (8/23/08)								
	Existing Diesel		Diesel		Hybrids		CNG	
	Data	Annualized	Data	Annualized	Data	Annualized	Data	Annualized
Procurement Cost (12 year life span)	0		$323,000	$26,917	$497,000	$41,417	$383,000	$31,917
Annual Miles driven per Bus (Montgomery County)		38,340		38,340		38,340		38,340
Miles per Gallon	2.9		2.9		4.0		2.9	
Gallons Used per Year		13,221		13,221	9,585		13221	
Cost for Fuel	$3.60	$47,594	$3.60	$47,594	$3.60	$34,506	$2.30	$30,408
Miles between Rear Brake Jobs	20,000		20,000		80,000		20000	
Brake Jobs per Year	1.92		1.92		0.48			1.92
Cost of Brake Job	$1,400	$2,684	$1,400	$2,684	$2,000	$958	$1,400	$2,684
Cost of Replacing Battery Pack	0	0	0	0	$50,000	$4,167		0
Summary Cost of both Acquisition and Maintenance		$50,278		$77,195		$81,048		$65,008
Incremental cost compared to existing operation				$26,917		$30,770		$14,730
CO2 Annual Emissions in tons (using WMATA rates)		149.14		105.74		85.12		92.98
Cost-effectiveness of CO2 ($'s/ton)				**$255**		**$362**		**$158**

Note:

Cost and operational information provided by Montgomery County
CNG Cost numbers based on the Maryland ATV project
CNG analysis assumes refuelling stations are existing
Existing Diesel Cost includes only operating cost

Attachment A

Montgomery County Bus Analysis

Siva,
As requested, here is the analysis performed by our staff on the cost comparison between Hybrid and Clean Diesel buses. The spreadsheet also has estimates for the cost effectiveness of reducing CO2 emissions for our specific fleet.
Edgar

Analysis of Hybrid Buses vs. Diesel

	Hybrids	Diesel	Difference
Procurement Cost	$ 497,000	$ 323,000	
Annualized - 12 years	$ 41,417	$ 26,917	$14,500
Est Miles per Year per Bus	38,340	38,340	
Miles per Gallon	4.0	2.9	
Gallons Used per Year	9,585	13,221	
Est Cost/Gallon (based on FY 09 budgeted cost per gallon)	$ 3.60	$ 3.60	
Cost for Fuel per year	$ 34,506	$ 47,594	$ (13,088)
Miles between Rear Brake Jobs	80,000	20,000	
Brake Jobs per Year	0.48	1.92	
Cost of Brake Job	$ 2,000	$ 1,400	
Cost per Year for Brake Jobs	$ 958	$ 2,684	$ (1,725)
Cost of Replacing Battery Pack	$ 50,000		
Annualized - 12 years	$ 4,167	$	$ 4,167
Summary of Annual Cost of both Acquisition and Maintenance	$ 81,048	$ 77,195	$ 3,853
Savings per year in fuel and maintenance			$ 10,647
Savings over 12 year life			$ 127,764

Analysis of Pollutant Impacts of FY 08 Supplemental & 09 CE Recommendation versus Hybrids

	(NOx + PM) Grams/Mile	Avg Miles/Bus	Pollution per Year Grams Per Bus	Pollution per Year Tons/Year
1995/96 Diesels	23.80	38,340	912,486	1.0
2002 Diesels	18.50	38,340	709,285	0.8
New Clean Diesel	5.65	38,340	216,620	0.2
New Hybrid	3.90	38,340	149,525	0.2

	NOx + PM		
	CE REC	Hybrids (same $'s)	T&E REC
*Old Diesels being replaced	(67.6)	(42.1)	(67.6)
Clean Diesels (81)	17.5	-	8.4
Hybrids (53)	-	7.9	-
Hybrids (81)	-	-	5.8
Total Tons per Year	(50.1)	(34.1)	(53.3)

**Cost	$ 25,339,000	$ 25,339,000	$ 27,142,195
Cost per ton of pollution reduction	$ 506,112	$ 742,258	$ 508,924

Difference in Cost from CE REC to purchase all Hybrids $ 1,803,195

Difference in Pollution Reduction from CE REC to all Hybrids (3.3)

**Acquistion Cost per Ton to Reduce Pollution from CE REC to all Hybrids $ (552,019)

CE REC (FY 08 & 09) - purchase 81 clean diesels to replace 81 model year 1995-96 diesel buses

All Hybrids - requires add'l $13,908,000 to CE REC to purchase 81 hybrid buses to replace old diesel buses

* Assumes 81 old diesels replaced in CE REC and All Hybrids, but only 53 if all hybrids with no add'l $'s

** Assumes costs as follows:

	FY 08	FY 09
40' Diesel (incl farebox in FY 08)	$ 327,000	$ 323,000
30' Diesel	$ 295,000	N/A
40' Hybrid (incl farebox in FY 08)	$ 501,000	$ 497,000
30' Hybrid	$ 463,000	N/A

** 5.4 tons reduced at an additional cost of $13,908,000 = $2,559,130 per ton

Analysis of Pollutant Impacts of FY 08 Supplemental & 09 CE Recommendation versus Hybrids

Per Bus	Gallons of Diesel/Year	CO_2 Tons/Year	CO_2 Pounds/Mile
95/96 Diesels	12,368	138.4	7.2
2002 Diesels	6,285	70.3	3.7
Clean Diesels	13,221	148.0	7.7
Hybrids	9,585	107.3	5.6

	CO_2 CE REC	Hybrids (same $'s)	T&E REC
*Old Diesels being replaced	(9,101.6)	(5,225.9)	(9,101.6)
Clean Diesels (81)	11,985.2	-	6,214.5
Hybrids (53)		5,685.6	-
Hybrids (81)			4,183.7
Total Tons per Year	2,883.6	459.7	1,296.6

Cost (CE REC vs T&E REC)	$	1,803,195
Change in Tons of CO_2		1,586.9
Cost per Ton	$	1,136.28

Attachment B

WMATA Bus Emission Rates

Siva,

As discussed, below is a sample of the CO2 emission data gathered by WVU on WMATA buses. Unless otherwise noted, the results are averages of 2 or more 40 ft. transit buses under the WMATA drive cycle we discussed. Please remember that although the average data is probably sufficient for most analyses, I do have individual results if required.

Bus Model, Engine Model, CO2 (g/mi)
2000 Orion V, DDC S50, 3529 g/mi
1996 Orion V, 2002 DDC S50, 3343 g/mi (repowered bus)
2006 New Flyer, Cummins ISL-Allison Hybrid, 2014 g/mi
2006 New Flyer, Cummins ISM EGR, 2502 g/mi
2005 Orion VII, Cummins CG CNG, 2286 g/mi
2005 Orion VII, John Deere 6081 CNG, 2089 g/mi

If you need any clarification of the data, please let me know.

Sebastian