U.S. Department
Of Transportation
Federal Transit
Administration

FTA-WV-26-7006.2008.1

Additional Transit Bus Life Cycle Cost Scenarios Based on Current and Future Fuel Prices

Final Report
Sep 2, 2008

Federal Transit Administration

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE Sep 2008		3. REPORT TYPE AND DATES COVERED Final Report / Sep 2008
4. TITLE AND SUBTITLE Additional Transit Bus Life Cycle Cost Scenarios Based on Current and Future Fuel Prices			5. FUNDING NUMBERS WV-26-7006
6. AUTHOR(S) Nigel N. Clark, Feng Zhen, W. Scott Wayne, and Donald W. Lyons			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Alternative Fuels, Engines & Emissions Dept. of Mechanical & Aerospace Engineering West Virginia University Morgantown, WV 26506 Website URL [cafee.wvu.edu]			8. PERFORMING ORGANIZATION REPORT NUMBER FTA-WV-26-7006.2008.1
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) **Federal Transit Administration** U.S. Department of Transportation Washington, DC 20590 Website URL [www.fta.dot.gov]			10. SPONSORING/MONITORING AGENCY REPORT NUMBER FTA-WV-26-7006.2008.1
11. Supplementary Notes.			
12a. DISTRIBUTION/AVAILABILITY STATEMENT **Available From:** National Technical Information Service/NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. Phone 703.605.6000, Fax 703.605.6900, Email [orders@ntis.fedworld.gov]			12b. DISTRIBUTION CODE
13.ABSTRACT (Maximum 200 words) National average diesel and compressed natural gas fuel price increased to $4.71 per gallon and $14.41 per thousand cubic feet in July 2008. West Virginia University did a life cycle cost analysis for the Federal Transit Administration on diesel hybrid-electric bus technology, conventional diesel bus technology using ultra low sulfur diesel, conventional diesel bus technology using B20 biodiesel fuel, and compressed natural gas bus technology. The fuel price forecast in the previous analysis ($2.67 per gallon for diesel and $13.34 per thousand cubic feet estimated in 2008) was much lower than the current fuel price. The life cycle cost of the four technologies was recalculated according to the high fuel cost. The report addressed how fuel costs were estimated and presented the life cycle cost summary charts for the four different fuel price scenarios.			
14. SUBJECT TERMS Life Cycle Cost, Capital Cost, Operation Cost, Fuel Price, Ultra Low Sulfur Diesel Bus, Bio-diesel Bus, Compressed Natural Gas Bus, Diesel-Electric Hybrid Bus			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

Prescribed by ANSI Std. 239-18298-102

DISCLAIMER NOTICE

Table of Contents

Table of Contents iii

Figures iv

Table v

Acronyms vi

Introduction 7

Fuel Price Forecasts 8

Summary Charts 10

Case 1: Adjusted AEO Forecast 11

Case 2: 25% Higher on Adjusted AEO Forecast 15

Case 3: 50% Higher on Adjusted AEO Forecast 19

Case 4: 100% Higher on Adjusted AEO Forecast 23

Discussion and Conclusions 27

References 29

Figures

Figure 1: 2008 AEO original fuel price forecast and adjusted fuel price forecast (CNG price data were all converted to the base of diesel gallon (energy) equivalent (DGE)). 9

Figure 2: A comparative chart for 100-bus life cycle cost for 12 years based on the adjusted AEO fuel price forecast (Agency pays 20% and 100% (full) of bus price.). 11

Figure 3: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on the adjusted AEO fuel price forecast 12

Figure 4: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on the adjusted AEO fuel price forecast 13

Figure 5: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on the adjusted AEO fuel price forecast 14

Figure 6: A comparative chart for 100-Bus life cycle cost for 12 years based on the 25% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). 15

Figure 7: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 25% higher fuel price forecast 16

Figure 8: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 25% higher fuel price forecast 17

Figure 9: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 25% higher fuel price forecast 18

Figure 10: A comparative chart for 100-bus life cycle cost for 12 years based on the 50% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). 19

Figure 11: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 50% higher fuel price forecast.. 20

Figure 12: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 50% higher fuel price forecast 21

Figure 13: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 50% higher fuel price forecast.. 22

Figure 14: A comparative chart for 100-bus life cycle cost for 12 years based on 100% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). 23

Figure 15: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 100% higher fuel price forecast.. 24

Figure 16: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 100% higher fuel price forecast 25

Figure 17: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 100% higher fuel price forecast.. 26

Figure 18: Four technologies' incremental life cycle cost percentage to diesel technology 28

Table

Table 1: Average fuel price for the four price scenarios 10

Acronyms

AEO	Annual Energy Outlook
B20 Biodiesel	20% Biodiesel and 80% Fossil Diesel
CNG	Compressed Natural Gas
CPI	Consumer Price Index
DGE	Diesel Gallon (Energy) Equivalent
DOE	Department of Energy
EIA	Energy Information Administration
FTA	Federal Transit Administration
LCC	Life Cycle Cost
WVU	West Virginia University

Introduction

West Virginia University did a life cycle cost (LCC) analysis[a] on four types of bus technologies in 2007. The year 2007 analysis estimated and compared total capital and operation costs on purchasing and operating four bus technologies from 2007 to 2019.

1. 100 diesel hybrid-electric buses
2. 100 conventional diesel buses using ultra low sulfur diesel (ULSD) fuel
3. 100 compressed natural gas (CNG) buses
4. 100 conventional diesel buses using B20 biodiesel

In 2008, diesel fuel price rose dramatically. In the 2007 report, the ULSD price was projected to be 2.67 $/gal in 2008 and CNG fuel price was projected to be 13.34 $/MCF[b] in 2008. The Energy Information Administration (EIA) reported the price of ULSD increased from 3.32 $/gal in January 2008 to 4.71 $/gal in July 2008 [1]. Commercial CNG price increased from 11.07 $/MCF in January 2008 to 14.41 $/MCF in June 2008 [2].

Fuel cost is a major concern in bus operation cost. The 2007 LCC were recalculated to reflect the new fuel price in 2008. The recalculated LCC was based on the latest EIA fuel price forecast [3] and calibrated with the current real-world fuel price. Three additional fuel price scenarios assumed that future fuel price would be 25%, 50%, and 100% higher than the projection in the first price scenario.

---

[a] The report is available at FTA website. http://www.fta.dot.gov/documents/WVU_FTA_LCC_Final_Report_07-23-2007.pdf

[b] MCF = Thousand Cubic Feet. The projected prices were presented in 2007 dollars. The latest inflation rate is 1.06 from 2007 to 2008 provided by the Bureau of Labor Statistics.

In the 2007 report, the operation and capital cost factors were literally presented in 2007 dollar. They were converted to 2008 dollars by adjusting with 6% inflation rate according to the latest 2007 to 2008 inflation rate obtained from the inflation calculator[c] provided by the Bureau of Labor Statistics [4], although they were not adjusted for inflation in the 2007 LCC report.

This report first introduced how the four fuel price projections were made. Life cycle cost summary charts were then created for the four scenarios and presented in the following section.

Fuel Price Forecasts

The following task was very similar to the analysis that was included in the 2007 LCC report. In the 2007 report, the fuel prices (CNG and diesel) were adopted from the price forecast from the *2007 Annual Energy Outlook* (AEO) from EIA [3]. By the time of writing, the 2008 AEO was published by EIA [3]. The authors adopted the fuel price forecast from the new AEO. The new AEO predicted the transportation fuel prices in 2006 dollars from 2005 to 2030. The price (CNG and diesel) was converted from 2006 dollars into 2008 dollars by using the rate of inflation 9% from the inflation calculator [4]. As shown in Figure 1a, AEO predicted that the price of fuel (in 2008 dollar) will drop over the next 12 years. In the figure, CNG price data were all converted to the base of diesel gallon (energy) equivalent (DGE).

[c] The inflation calculator uses the average consumer price index (CPI) for a given calendar year.

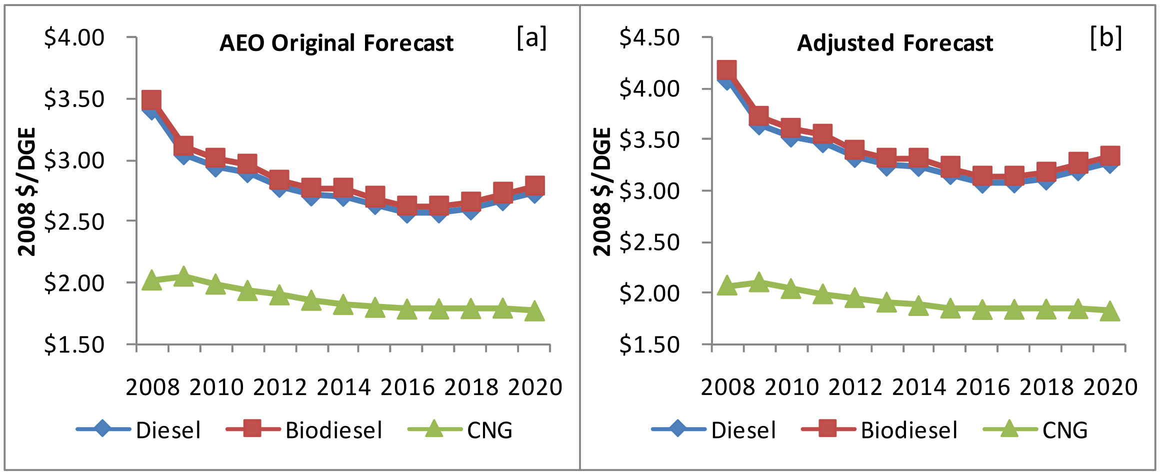


Figure 1: 2008 AEO original fuel price forecast and adjusted fuel price forecast (CNG price data were all converted to the base of diesel gallon (energy) equivalent (DGE)).

The AEO predicted that the diesel price will be 3.50 $/gal and CNG price will be 2.00 $/DGE in year 2008. The average 2008 diesel price was 4.07 $/gal calculated from 2008 ULSD monthly prices reported by EIA (from January 2008 to July 2008) [1, 2]. The authors assumed that the average diesel price will not change for year 2008. The original AEO forecast curve was raised and aligned to the 2008 average price (4.07 $/gal) as shown in Figure 1b. The same procedure was done to the CNG price forecast by aligning the CNG price curve to $2.01 $/DGE in 2008.

The B20 biodiesel price was projected in the following way. The year 2008 B100 price was taken as the base, and this was an average annual B100 price from available *Clean Cities Alternative Fuel Price Reports* (four quarterly reports from October 2007 to July 2008) [5]. The average fossil diesel price (from August 2007 to July 2008) was from the EIA real-world report [1, 2]. The B20 biodiesel price ($4.16) was calculated by adding 20% of the B100 biodiesel price ($4.07) and 80% of the fossil diesel price ($3.68). The price was 2% higher than the fossil diesel price (it was 4.3% in the previous LCC report). It was assumed that the B20 biodiesel price would remain in the same ratio to the fossil diesel price during the 12 year period, as shown in Figure 1b.

Three additional higher price cases were considered in this report. Three cases considered that future fuel price could be 25%, 50%, and 100% higher than the projected prices. Table 1 shows and compares their average 12-years fuel prices.

Table 1: Average fuel price for the four price scenarios

Fuels	Case 1	Case 2	Case 3	Case 4
	Adjusted AEO Forecast	25% Higher to Case 1	50% Higher to Case 1	100% Higher to Case 1
Diesel (per gallon)	$3.33	$4.16	$5.00	$6.66
B20 (per gallon)	$3.40	$4.25	$5.10	$6.80
CNG (per DGE)	$1.91	$2.39	$2.87	$3.82

Summary Charts

As mentioned in the introduction section, LCC was recalculated by introducing the new fuel price forecasts and adjusting other cost factors with 2007 to 2008 inflation. The summary charts were created and shown in this report.

Case 1: Adjusted AEO Forecast

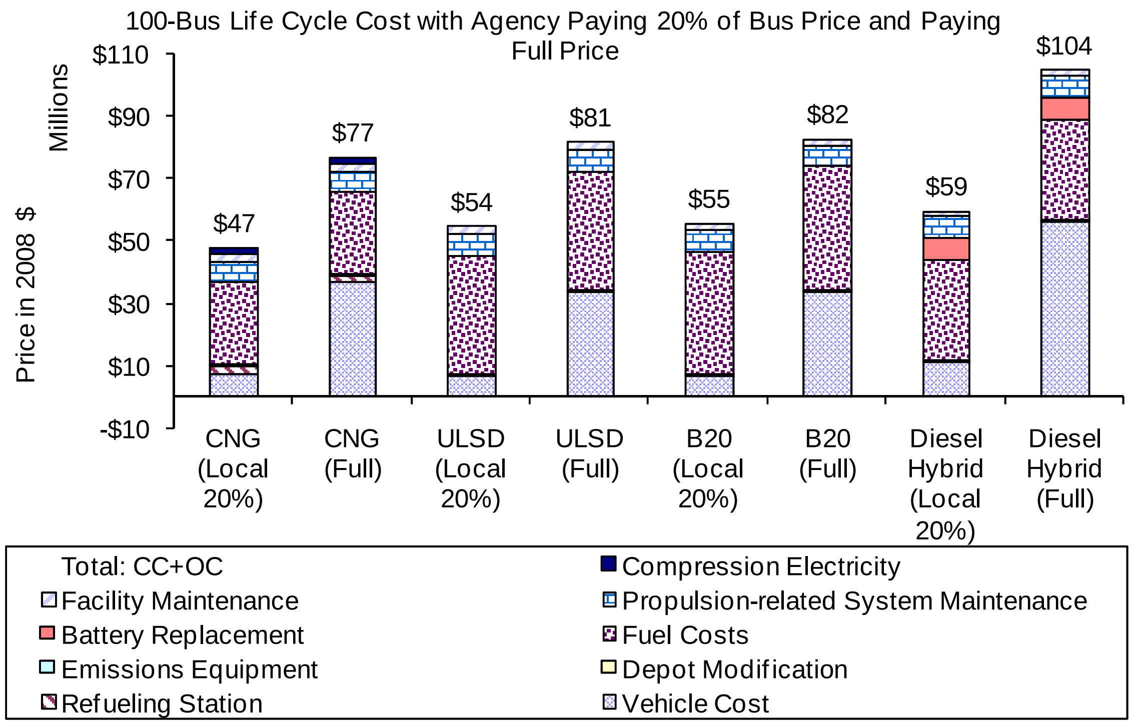
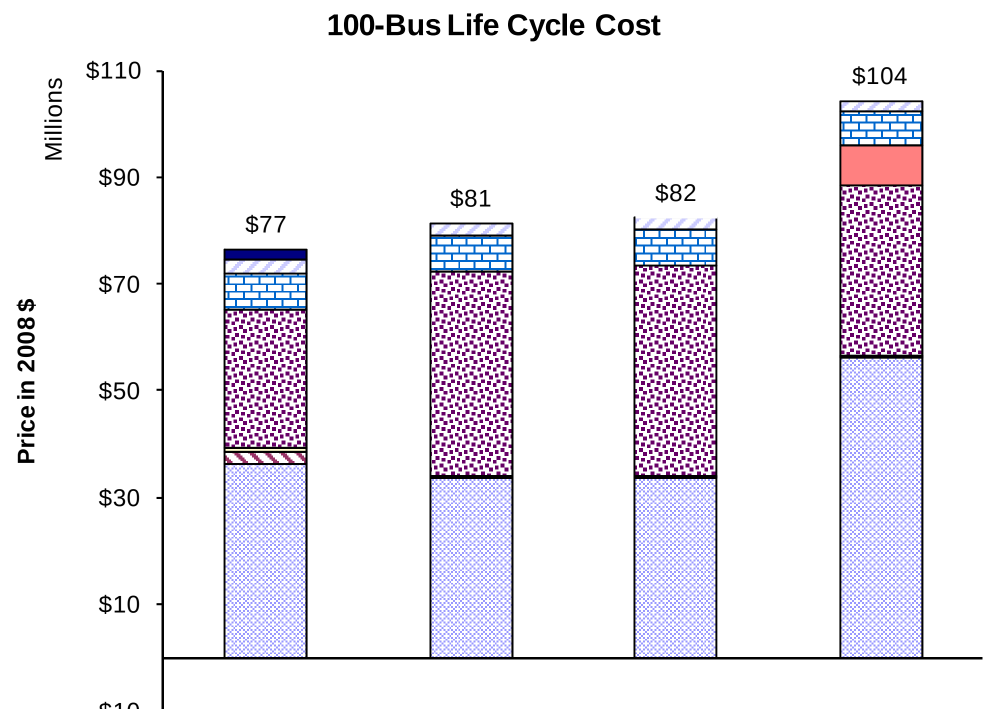
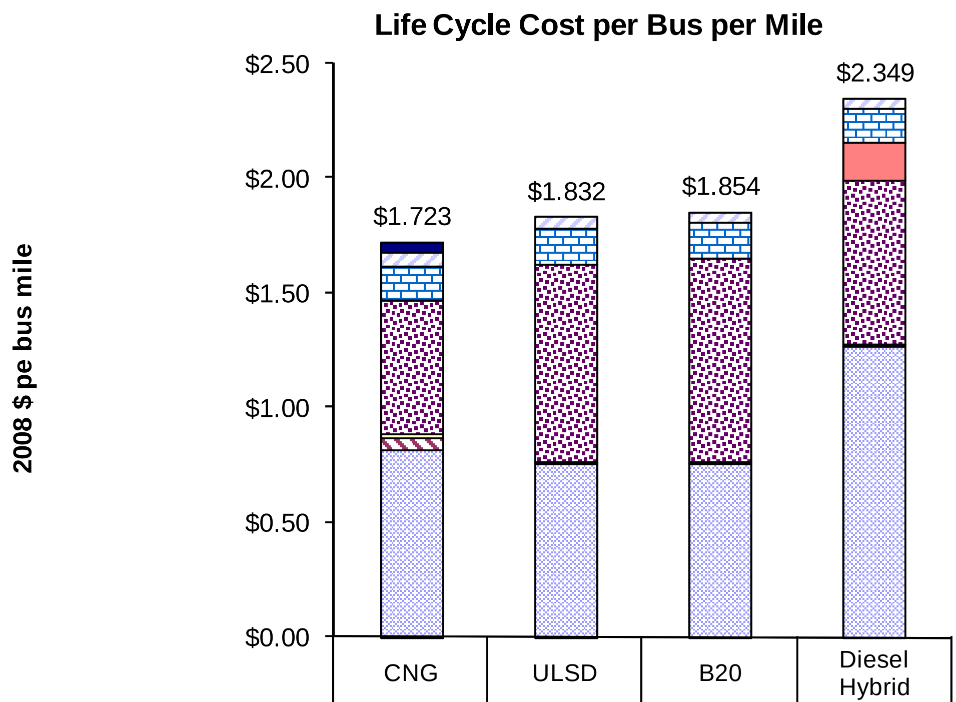


Figure 2: A comparative chart for 100-bus life cycle cost for 12 years based on the adjusted AEO fuel price forecast (Agency pays 20% and 100% (full) of bus price.). CC = Capital Cost, OC = Operation Cost



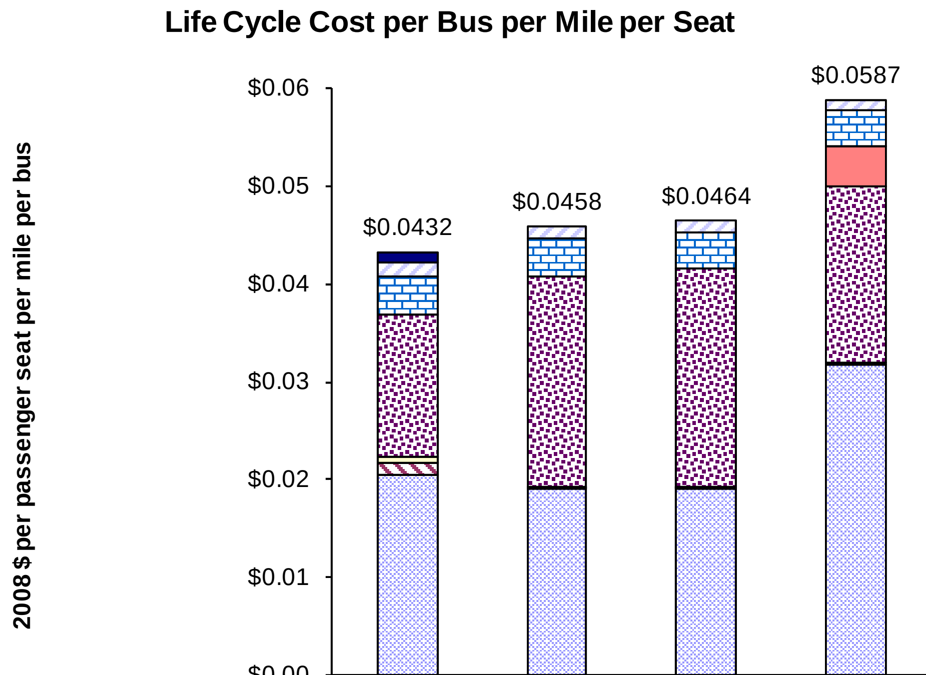
	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$76,523,289	$81,340,149	$82,359,664	$104,334,870
Compression Electricity	$2,014,342	$0	$0	$0
Facility Maintenance	$2,589,869	$2,196,633	$2,230,084	$1,851,806
Propulsion-related System Maintenance	$6,634,346	$7,037,786	$6,646,798	$6,740,415
Battery Replacement	$0	$0	$0	$7,155,000
Fuel Costs	$25,946,468	$38,064,523	$39,441,575	$32,089,157
Emissions Equipment	$0	$152,014	$152,014	$0
Depot Modification	$927,500	$0	$0	$148,400
Refueling Station	$2,120,000	$0	$0	$0
Vehicle Cost	$36,290,764	$33,889,193	$33,889,193	$56,350,093

Figure 3: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on the adjusted AEO fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$1.723	$1.832	$1.854	$2.349
Compression Electricity	$0.045	$0.000	$0.000	$0.000
Facility Maintenance	$0.058	$0.049	$0.050	$0.042
Propulsion-related System Maintenance	$0.149	$0.158	$0.150	$0.152
Battery Replacement	$0.000	$0.000	$0.000	$0.161
Fuel Costs	$0.584	$0.857	$0.888	$0.723
Emissions Equipment	$0.000	$0.003	$0.003	$0.000
Depot Modification	$0.021	$0.000	$0.000	$0.003
Refueling Station	$0.048	$0.000	$0.000	$0.000
Vehicle Cost	$0.817	$0.763	$0.763	$1.269

Figure 4: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on the adjusted AEO fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$0.0432	$0.0458	$0.0464	$0.0587
Compression Electricity	$0.0011	$0.0000	$0.0000	$0.0000
Facility Maintenance	$0.0015	$0.0012	$0.0013	$0.0010
Propulsion-related System Maintenance	$0.0037	$0.0040	$0.0037	$0.0038
Battery Replacement	$0.0000	$0.0000	$0.0000	$0.0040
Fuel Costs	$0.0146	$0.0214	$0.0222	$0.0181
Emissions Equipment	$0.0000	$0.0001	$0.0001	$0.0000
Depot Modification	$0.0005	$0.0000	$0.0000	$0.0001
Refueling Station	$0.0012	$0.0000	$0.0000	$0.0000
Vehicle Cost	$0.0205	$0.0191	$0.0191	$0.0317

Figure 5: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on the adjusted AEO fuel price forecast. CC = Capital Cost, OC = Operation Cost

Case 2: 25% Higher on Adjusted AEO Forecast

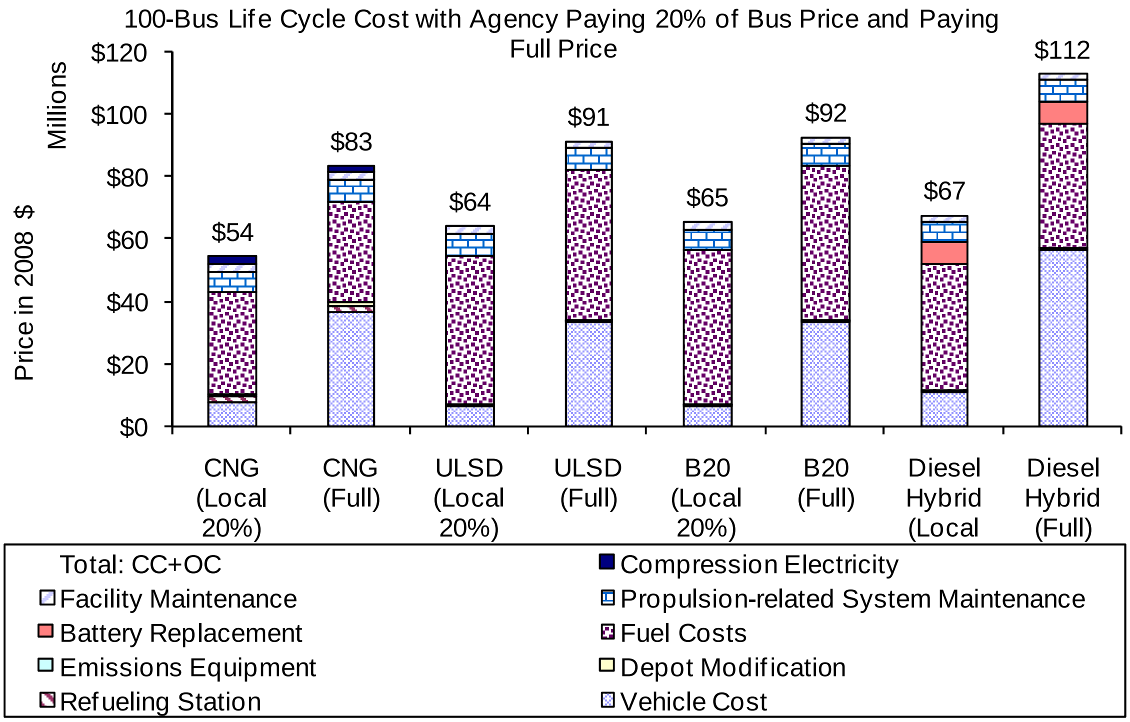
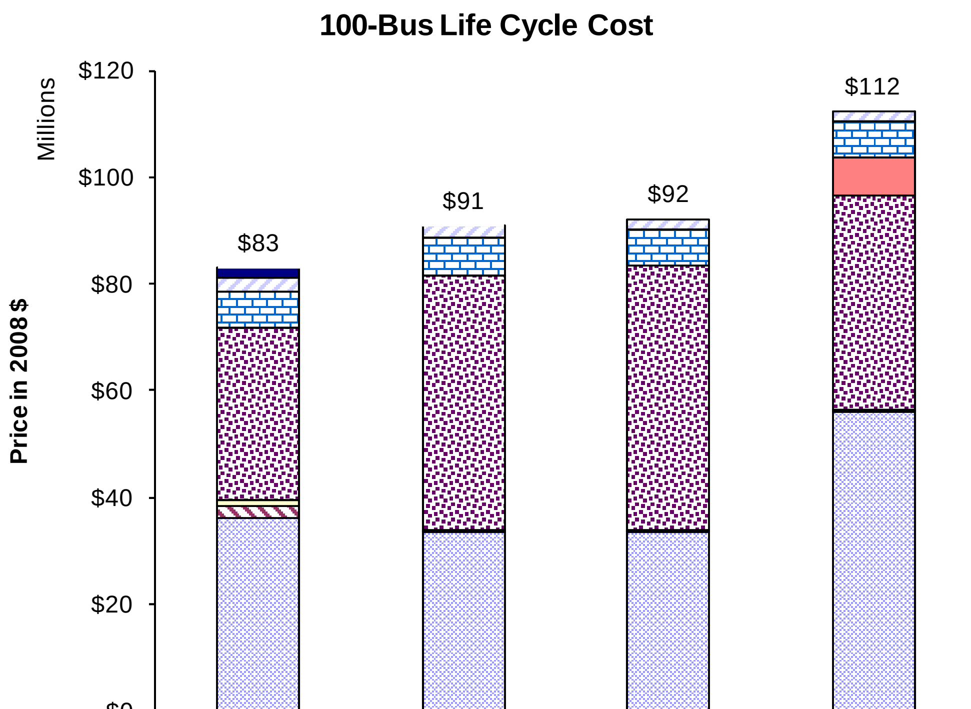
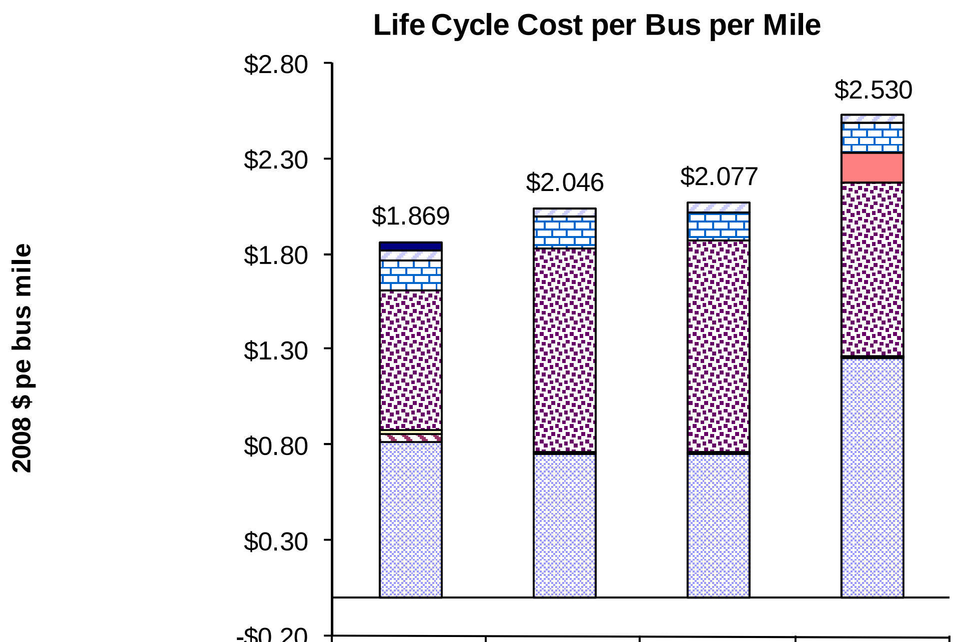


Figure 6: A comparative chart for 100-Bus life cycle cost for 12 years based on the 25% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). CC = Capital Cost, OC = Operation Cost



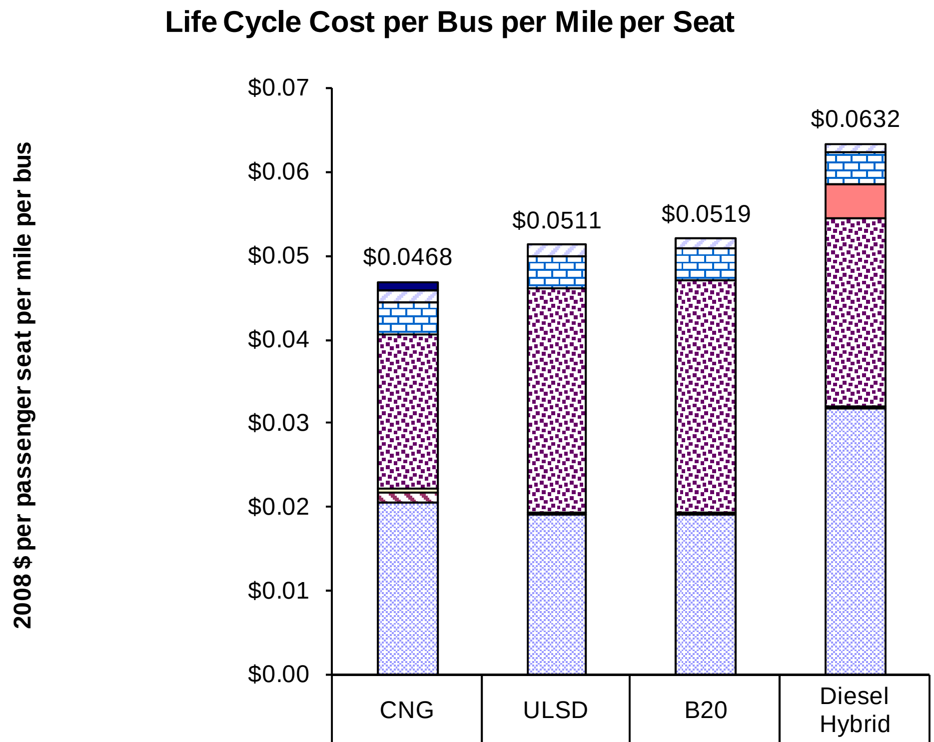
	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$83,009,906	$90,856,280	$92,220,058	$112,357,160
Compression Electricity	$2,014,342	$0	$0	$0
Facility Maintenance	$2,589,869	$2,196,633	$2,230,084	$1,851,806
Propulsion-related System Maintenance	$6,634,346	$7,037,786	$6,646,798	$6,740,415
Battery Replacement	$0	$0	$0	$7,155,000
Fuel Costs	$32,433,085	$47,580,654	$49,301,969	$40,111,446
Emissions Equipment	$0	$152,014	$152,014	$0
Depot Modification	$927,500	$0	$0	$148,400
Refueling Station	$2,120,000	$0	$0	$0
Vehicle Cost	$36,290,764	$33,889,193	$33,889,193	$56,350,093

Figure 7: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 25% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$1.869	$2.046	$2.077	$2.530
Compression Electricity	$0.045	$0.000	$0.000	$0.000
Facility Maintenance	$0.058	$0.049	$0.050	$0.042
Propulsion-related System Maintenance	$0.149	$0.158	$0.150	$0.152
Battery Replacement	$0.000	$0.000	$0.000	$0.161
Fuel Costs	$0.730	$1.071	$1.110	$0.903
Emissions Equipment	$0.000	$0.003	$0.003	$0.000
Depot Modification	$0.021	$0.000	$0.000	$0.003
Refueling Station	$0.048	$0.000	$0.000	$0.000
Vehicle Cost	$0.817	$0.763	$0.763	$1.269

Figure 8: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 25% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$0.0468	$0.0511	$0.0519	$0.0632
Compression Electricity	$0.0011	$0.0000	$0.0000	$0.0000
Facility Maintenance	$0.0015	$0.0012	$0.0013	$0.0010
Propulsion-related System Maintenance	$0.0037	$0.0040	$0.0037	$0.0038
Battery Replacement	$0.0000	$0.0000	$0.0000	$0.0040
Fuel Costs	$0.0183	$0.0268	$0.0278	$0.0226
Emissions Equipment	$0.0000	$0.0001	$0.0001	$0.0000
Depot Modification	$0.0005	$0.0000	$0.0000	$0.0001
Refueling Station	$0.0012	$0.0000	$0.0000	$0.0000
Vehicle Cost	$0.0205	$0.0191	$0.0191	$0.0317

Figure 9: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 25% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost

Case 3: 50% Higher on Adjusted AEO Forecast

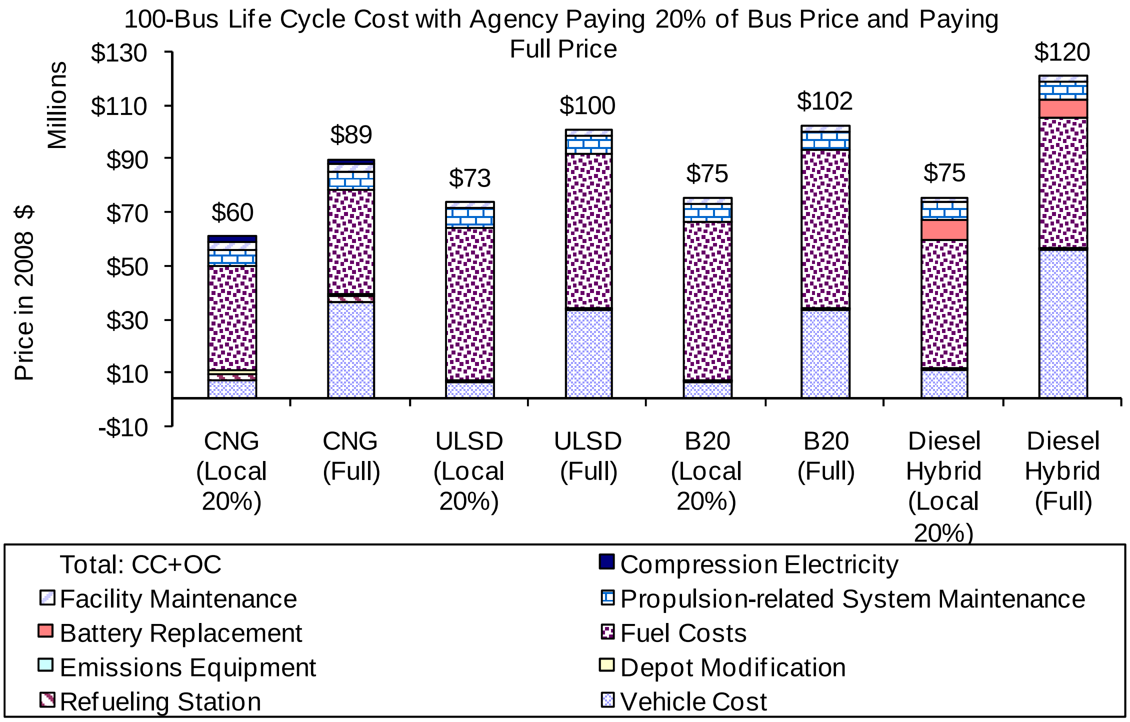
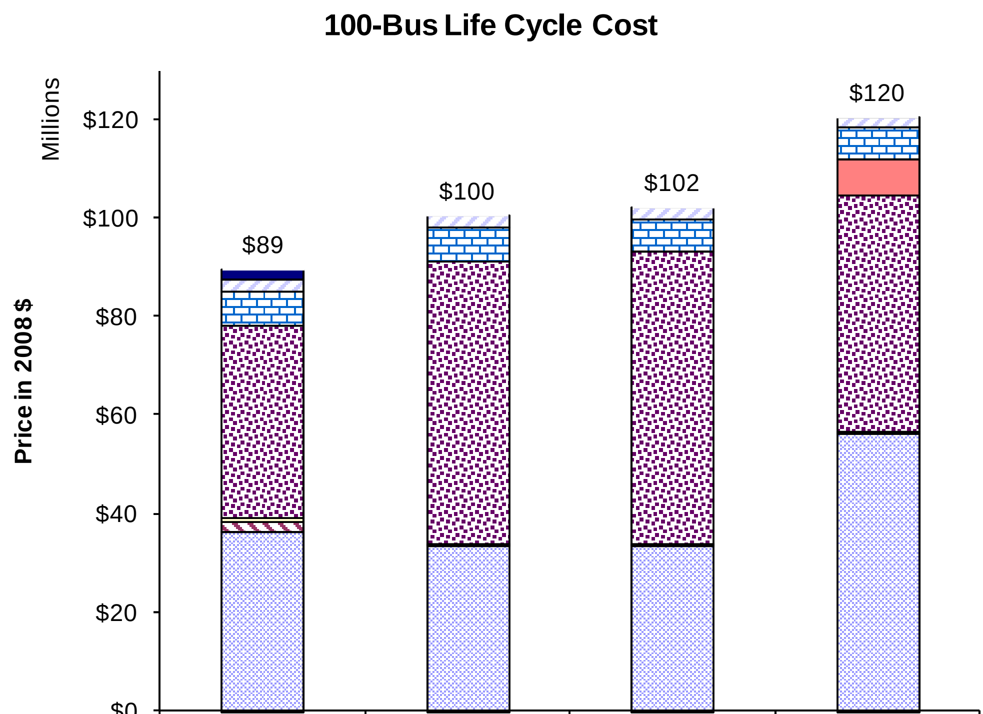
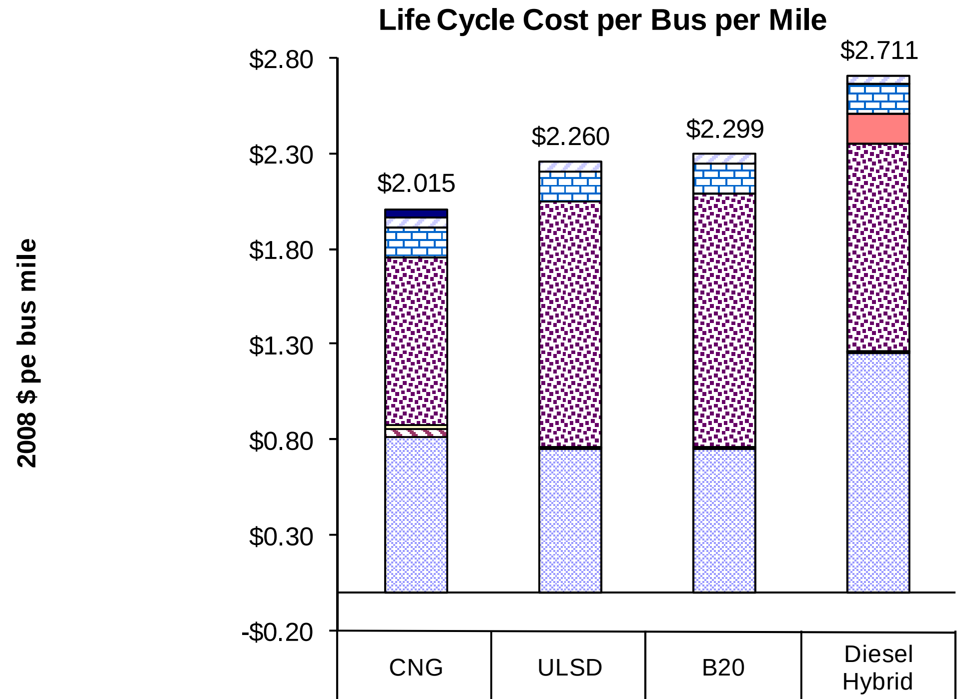


Figure 10: A comparative chart for 100-bus life cycle cost for 12 years based on the 50% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). CC = Capital Cost, OC = Operation Cost



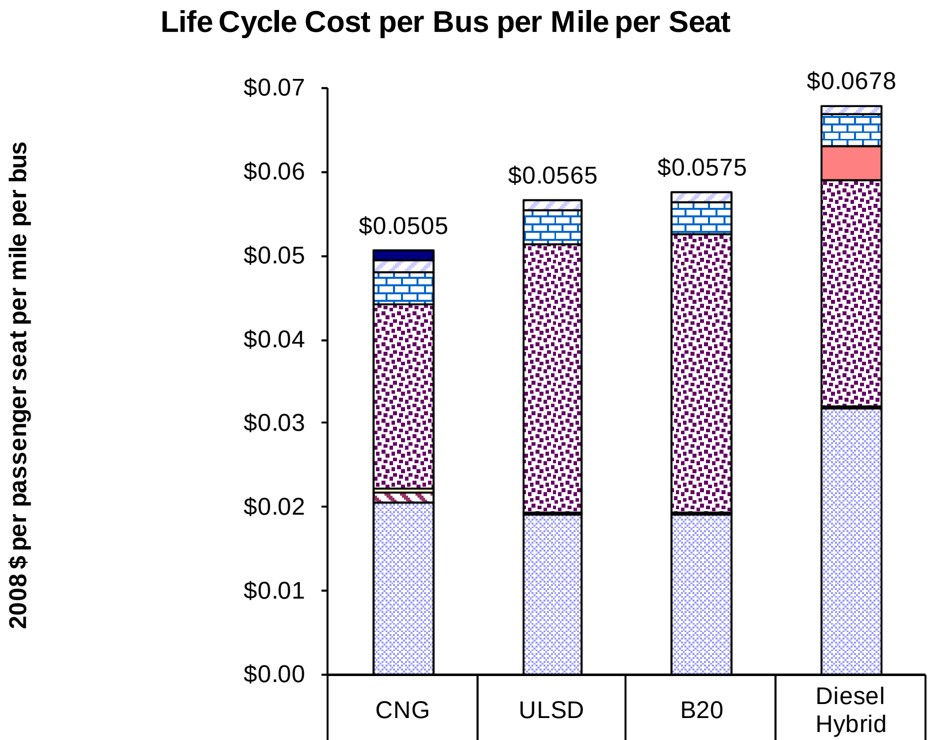
	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$89,496,523	$100,372,410	$102,080,452	$120,379,449
Compression Electricity	$2,014,342	$0	$0	$0
Facility Maintenance	$2,589,869	$2,196,633	$2,230,084	$1,851,806
Propulsion-related System Maintenance	$6,634,346	$7,037,786	$6,646,798	$6,740,415
Battery Replacement	$0	$0	$0	$7,155,000
Fuel Costs	$38,919,702	$57,096,785	$59,162,363	$48,133,735
Emissions Equipment	$0	$152,014	$152,014	$0
Depot Modification	$927,500	$0	$0	$148,400
Refueling Station	$2,120,000	$0	$0	$0
Vehicle Cost	$36,290,764	$33,889,193	$33,889,193	$56,350,093

Figure 11: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 50% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$2.015	$2.260	$2.299	$2.711
Compression Electricity	$0.045	$0.000	$0.000	$0.000
Facility Maintenance	$0.058	$0.049	$0.050	$0.042
Propulsion-related System Maintenance	$0.149	$0.158	$0.150	$0.152
Battery Replacement	$0.000	$0.000	$0.000	$0.161
Fuel Costs	$0.876	$1.286	$1.332	$1.084
Emissions Equipment	$0.000	$0.003	$0.003	$0.000
Depot Modification	$0.021	$0.000	$0.000	$0.003
Refueling Station	$0.048	$0.000	$0.000	$0.000
Vehicle Cost	$0.817	$0.763	$0.763	$1.269

Figure 12: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 50% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$0.0505	$0.0565	$0.0575	$0.0678
Compression Electricity	$0.0011	$0.0000	$0.0000	$0.0000
Facility Maintenance	$0.0015	$0.0012	$0.0013	$0.0010
Propulsion-related System Maintenance	$0.0037	$0.0040	$0.0037	$0.0038
Battery Replacement	$0.0000	$0.0000	$0.0000	$0.0040
Fuel Costs	$0.0220	$0.0321	$0.0333	$0.0271
Emissions Equipment	$0.0000	$0.0001	$0.0001	$0.0000
Depot Modification	$0.0005	$0.0000	$0.0000	$0.0001
Refueling Station	$0.0012	$0.0000	$0.0000	$0.0000
Vehicle Cost	$0.0205	$0.0191	$0.0191	$0.0317

Figure 13: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 50% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost

Case 4: 100% Higher on Adjusted AEO Forecast

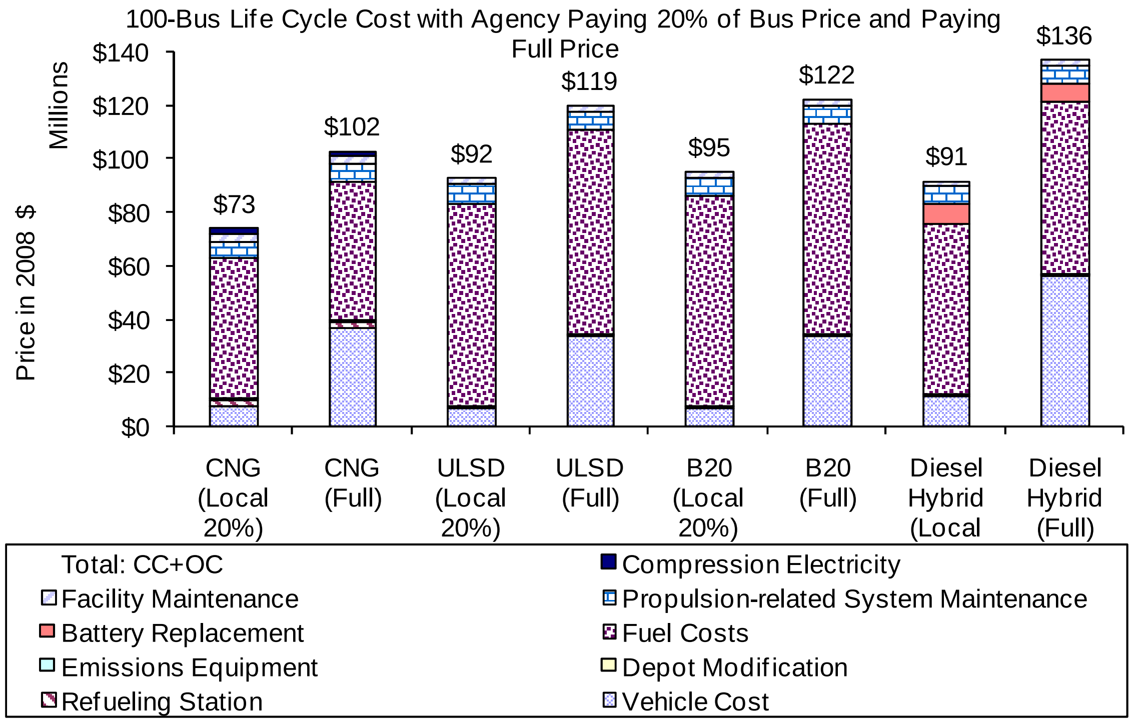
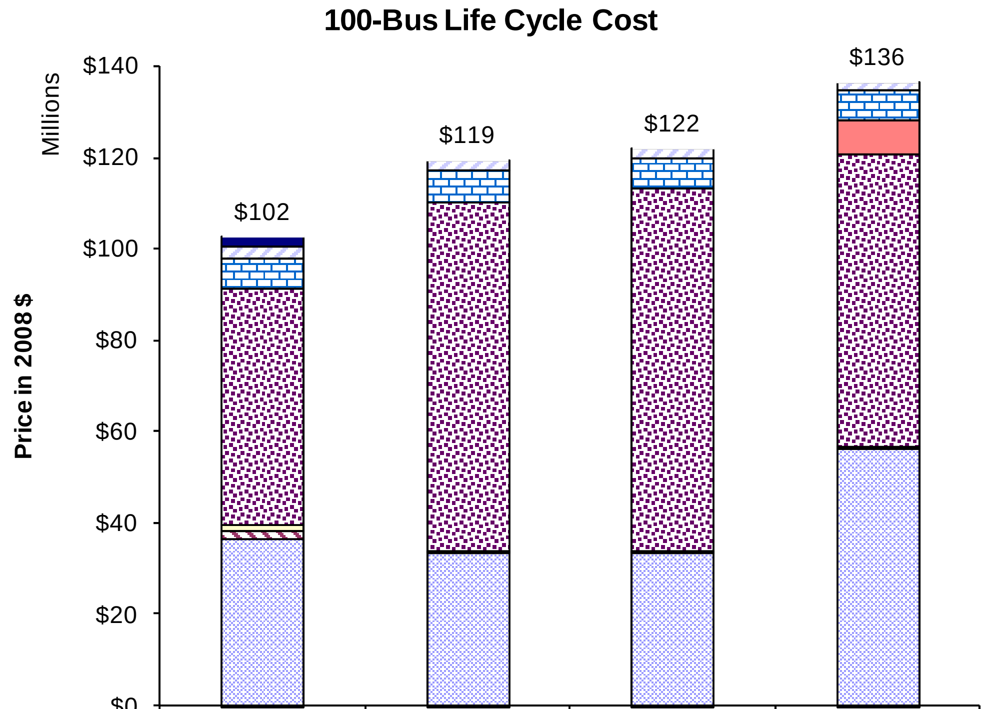
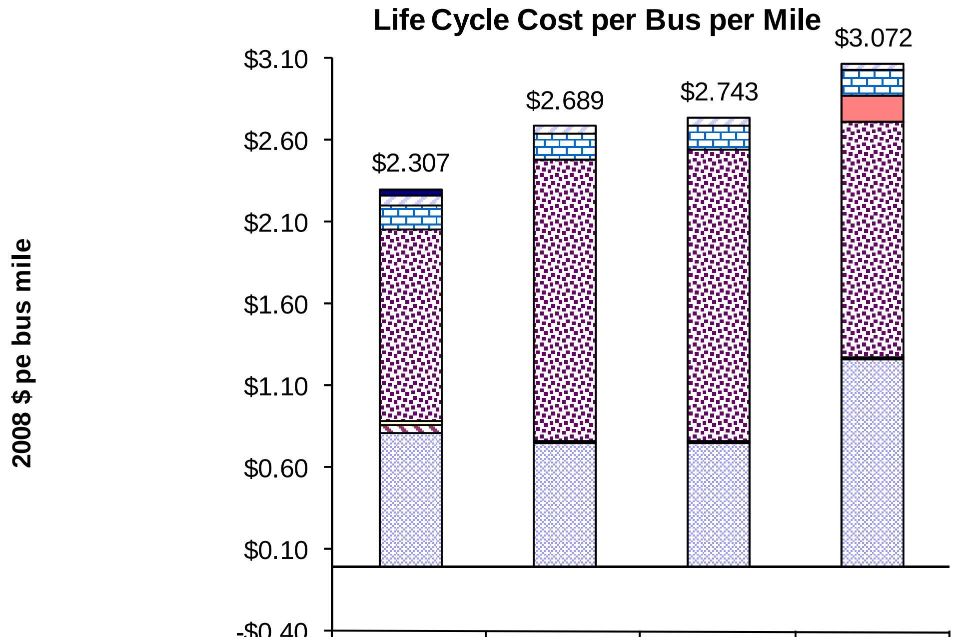


Figure 14: A comparative chart for 100-bus life cycle cost for 12 years based on 100% higher fuel price forecast (Agency pays 20% and 100% (full) of bus price.). CC = Capital Cost, OC = Operation Cost



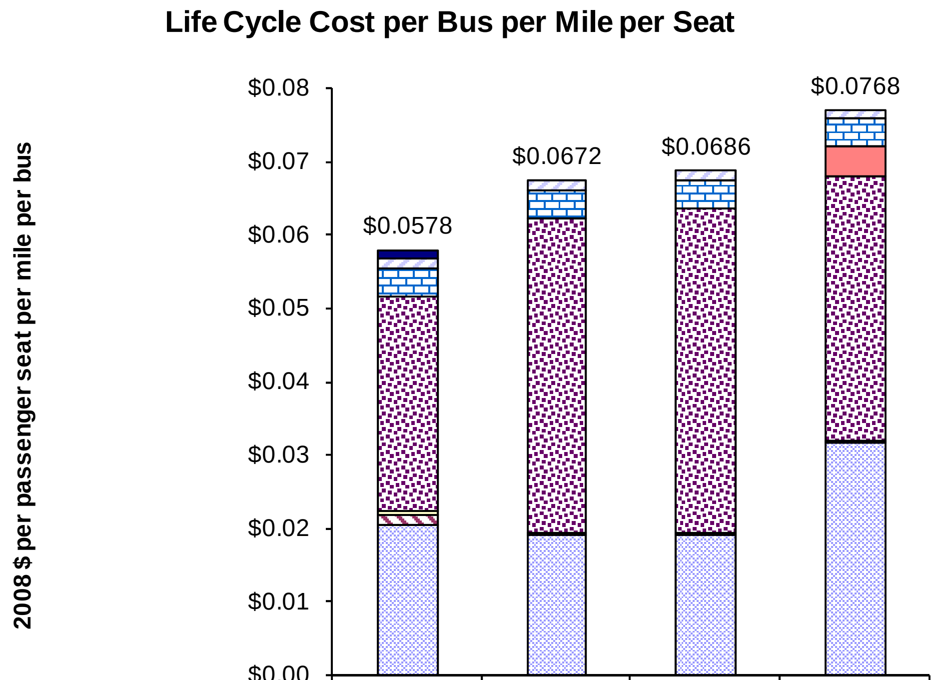
	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$102,469,757	$119,404,672	$121,801,239	$136,424,027
Compression Electricity	$2,014,342	$0	$0	$0
Facility Maintenance	$2,589,869	$2,196,633	$2,230,084	$1,851,806
Propulsion-related System Maintenance	$6,634,346	$7,037,786	$6,646,798	$6,740,415
Battery Replacement	$0	$0	$0	$7,155,000
Fuel Costs	$51,892,936	$76,129,046	$78,883,150	$64,178,314
Emissions Equipment	$0	$152,014	$152,014	$0
Depot Modification	$927,500	$0	$0	$148,400
Refueling Station	$2,120,000	$0	$0	$0
Vehicle Cost	$36,290,764	$33,889,193	$33,889,193	$56,350,093

Figure 15: Total life cycle cost for a 100-bus fleet for 12 years without procurement subsidy based on 100% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$2.307	$2.689	$2.743	$3.072
Compression Electricity	$0.045	$0.000	$0.000	$0.000
Facility Maintenance	$0.058	$0.049	$0.050	$0.042
Propulsion-related System Maintenance	$0.149	$0.158	$0.150	$0.152
Battery Replacement	$0.000	$0.000	$0.000	$0.161
Fuel Costs	$1.168	$1.714	$1.776	$1.445
Emissions Equipment	$0.000	$0.003	$0.003	$0.000
Depot Modification	$0.021	$0.000	$0.000	$0.003
Refueling Station	$0.048	$0.000	$0.000	$0.000
Vehicle Cost	$0.817	$0.763	$0.763	$1.269

Figure 16: Life cycle cost per bus per mile for a 100-bus fleet for 12 years based on 100% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost



	CNG	ULSD	B20	Diesel Hybrid
Total: CC+OC	$0.0578	$0.0672	$0.0686	$0.0768
Compression Electricity	$0.0011	$0.0000	$0.0000	$0.0000
Facility Maintenance	$0.0015	$0.0012	$0.0013	$0.0010
Propulsion-related System Maintenance	$0.0037	$0.0040	$0.0037	$0.0038
Battery Replacement	$0.0000	$0.0000	$0.0000	$0.0040
Fuel Costs	$0.0293	$0.0429	$0.0444	$0.0361
Emissions Equipment	$0.0000	$0.0001	$0.0001	$0.0000
Depot Modification	$0.0005	$0.0000	$0.0000	$0.0001
Refueling Station	$0.0012	$0.0000	$0.0000	$0.0000
Vehicle Cost	$0.0205	$0.0191	$0.0191	$0.0317

Figure 17: Life cycle cost per passenger seat per bus per mile for a 100-bus fleet for 12 years based on 100% higher fuel price forecast. CC = Capital Cost, OC = Operation Cost

Discussion and Conclusions

The LCC analysis was made for a 100-bus fleet purchase and operation. The buses were assumed to be operated at 12.7 mph average speed (national average speed). Annual mileage for each bus was 32,007 miles. When considering or selecting bus technologies, it is important to recognize that fuel economy and emissions depended strongly on bus route and bus operation conditions.

The summary charts revealed that hybrid technology had a higher cost than diesel technology, without considering any hybrid incentives for all four cases. Although hybrid buses offered the best fuel economy, this was offset by the bus purchase price and battery replacement cost. However, hybrid-electric bus technology dropped from 28% to 14% higher cost compared to diesel technology as shown in Figure 18, when average diesel price increased from 3.33 $/gal to 6.66 $/gal. If the 80% federal subsidiary was considered, the two technologies were very similar on cost when diesel fuel price averaged 5.00 $/gal for 12 years (as shown in Figure 10). Hybrid buses operating on B20 were not separately evaluated, but would have similar cost to hybrid buses operating on ULSD.

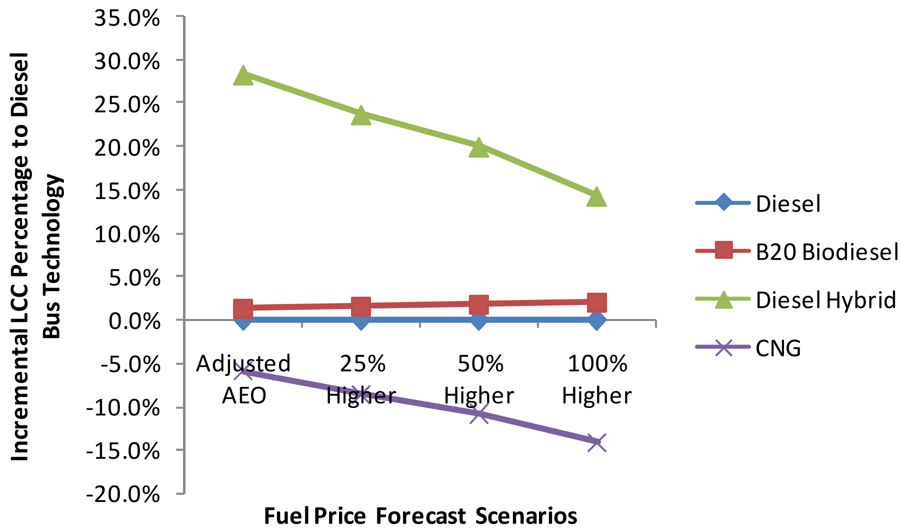


Figure 18: Four technologies' incremental life cycle cost percentage to diesel technology

The LCC summary charts show that CNG buses are the most economic technology in four scenarios. Purchase of 100 buses was big enough to dilute the CNG infrastructure cost in the overall cost, so that the capital cost was slightly higher for CNG buses than for diesel buses. However, CNG price remains much lower than the diesel fuel price in the analysis, compensating for CNG bus throttled engine fuel economy and additional cost of procurement, infrastructure, and compression electricity.

Disadvantaged by increasing fuel price, diesel buses were no longer the most economic technology in this analysis. The diesel buses fueled by B20 biodiesel were only slightly higher in overall cost due to the added expense of the fuel. Again, the nature of bus activity influences the performance of hybrid drive systems, throttled engines, and diesel engines in different ways. Relative cost differences between technologies will change with parameters such as average speed of operation and terrain (grade) of the route.

References

1. Energy Information Administration Weekly Retail Gasoline and Diesel Prices, http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm, Accessed in August, 2008.
2. Energy Information Administration Natural Gas Prices, http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm, Accessed in August, 2008.
3. "Annual Energy Outlook (AEO 2008)," US DOE Energy Information Administration, http://www.eia.doe.gov/oiaf/aeo/index.html, Accessed in February 2007.
4. US Department of Labor Bureau of Labor Statistics Consumer Price Index, http://www.bls.gov/bls/inflation.htm, Accessed in August 2008.
5. "Alternative Fuel Price Report," US DOE Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/afdc/price_report.html, Accessed in August 2008.