

APPENDIX A

GSEMODEL OPERATING INSTRUCTIONS

GSEMODEL OPERATING INSTRUCTIONS

Introduction

GSEModel is a personal computer spreadsheet-based analysis tool that has been developed to quantify emission benefits and calculate the cost-effectiveness of converting existing airport ground support equipment (GSE) to cleaner-burning fuels and engine technologies. The model has been developed as a planning tool for use by metropolitan planning organizations (MPOs), airports, and other agencies interested in evaluating potential emission benefits and cost savings resulting from available GSE emission control technologies. It has been designed with a mouse-enabled graphical user interface to make it simple and easy to use.

The GSEModel tool is based upon the “best practice” methodologies and information presented earlier in the body of this report. It has been designed to utilize local (i.e., airport-specific) GSE usage and cost information coupled with best-available emission factor data to perform the following functions using a consistent methodology:

- Estimate current and alternative technology GSE emissions by individual equipment category (e.g., aircraft pushback tractors, baggage tugs, cargo loaders, etc.);
- Compute the emission benefits of the available alternative technologies;
- Quantify the incremental capital, operating, and life-cycle costs of converting GSE units to these alternative technologies; and
- Calculate and compare the cost-effectiveness (cost per unit emissions reduced, e.g., \$/ton) of these alternative technologies for each equipment category under airport-specific operating and usage conditions.

Nevertheless, as with any analysis tool, the results computed by the model retain the inherent uncertainties of the data and estimates upon which they are based. As described in the operating instructions that follow, the model provides “default” values for a number of inputs to enable the user to quickly develop GSE emission reduction and cost-effectiveness estimates associated with alternative technologies. Where actual local data are available, the user is encouraged to utilize them to provide more accurate results.

Following this introduction, the remaining sections of the GSEModel documentation are organized as follows:

- Required Operating Environment - describes the software and hardware needed to run the GSEModel application;
- Quick-Start Installation and Instructions - provides an overview on installing and executing GSEModel to get started quickly; and
- Detailed Operating Instructions and Guidance - contains step-by-step instructions for operating the application and basic guidance for inputting data and interpreting the results.

Required Operating Environment

Software Requirements - GSEModel is a spreadsheet-based application that runs on personal computers using Microsoft's Windows 95 or Windows 98 operating systems.* The model was written in Microsoft Excel Visual Basic for Applications (VBA), an extension of the Visual Basic programming language that allows applications to be designed with a user-friendly interface around a series of Excel spreadsheet calculations. As a result, users must have Microsoft Excel 95 (i.e., Excel 7.0) or Excel 97 installed on their computer in order for the GSEModel application to run.

Hardware Requirements - The minimum hardware requirements listed by Microsoft to run Windows 95 and Excel 7.0 are sufficient to use the GSEModel program. The application has been satisfactorily tested at 640 x 480, 800 x 600, and 1,024 x 768 display resolutions, at both 256-color and 16-bit (HiColor) depths, and should run at any available video display setting.

The GSEModel program requires 500 KB of disk capacity. Each saved scenario file (described later) occupies 14 KB of disk space.

“Quick-Start” Installation and Operating Instructions

Installation of the application simply consists of downloading or copying the **GSEMODEL.XLS** file to any valid directory chosen by the user. However, it is suggested that a separate, initially empty directory be created for the GSEModel application (e.g., C:\GSEMODEL) and the GSEMODEL.XLS file copied into it. As explained later in more detail, a key ease-of-use feature of the application is its ability to save and re-load “input scenario” files. Thus, it is recommended that a new directory be

* The GSEModel application should theoretically, also be able to run under Windows NT 4.0, but it has not been tested under that operating system.

created to store the GSEMODEL.XLS application and the user-created scenario files (suffixed “.gse”) that it uses in order to separate them from other files on your computer.

Running the Program - From Windows 95 or Windows 98, the GSEModel application can be executed in several ways familiar to Windows users:

- Create and launch a shortcut to the application (creating a shortcut is discussed in the next section);
- Double-click* the GSEMODEL.XLS file from within the Windows Explorer or Internet Explorer window (assuming Excel has been installed and associated with .XLS file types);
- Right-click the GSEMODEL.XLS file, then click “Open” from the pop-up menu; or
- Click the Start button at the bottom left of Windows 95 and Windows 98 desktop, select “Documents” from the pop-up menu, and then click the GSEMODEL.XLS file from the pop-up list of documents.

(Note that this latter method works only when the GSEMODEL.XLS file has been recently opened and appears in the “Recent Documents” list.)

Inputting Data - Once the program finishes loading (signaled by a “Ready” indicator at the bottom left of the application window), the user is placed at the top of the first of three data input screens, the SCENARIO INPUTS screen. Using the graphical “point-and-click” interface, much of the input data required by the application can be easily entered by clicking drop-down lists and selecting specific items or clicking various check-boxes to utilize default information supplied by the model. Table A-1 provides a brief summary of the data inputs required by the application.

The buttons near the bottom of each input screen allow the user to navigate from screen to screen.

Viewing Results - After entering all required inputs (or selecting default values), GSEModel automatically performs the alternative technology emission reduction and cost-effectiveness calculations. To view the results, simply click the “View Results” button (the right button at the bottom of each input screen). The user can scroll down the tabular summary to examine the calculated results.

* If the Windows Explorer has been replaced by Internet Explorer (e.g., in Windows 98), Internet Explorer can be configured to launch programs with a single mouse click instead of a double-click.

<p style="text-align: center;">Table A-1 Summary of GSEModel Data Inputs</p>		
Scenario Inputs	IC Technology Activity & Costs Inputs	Electric Technology Inputs
<ul style="list-style-type: none"> • A scenario title (optional) • The GSE equipment category being evaluated • The “base” or current technology used in that type of equipment • The number of units of that type and technology being considered for conversion • The alternative technologies to be assessed 	<ul style="list-style-type: none"> • Annual hours of operation (of the selected equipment type) • Expected equipment and engine life • Purchase, replacement, operating and maintenance costs • Discount rate assumed (for Net Present Value cost analysis) • The weighting scheme (optional) used to combine pollutant emission reductions in calculating cost-effectiveness 	<ul style="list-style-type: none"> • The amount of time (in %) that the current technology GSE equipment being evaluated is operated at idle • Expected electric GSE equipment life and battery life • Electric GSE purchase, replacement, operating and maintenance costs • Power-generation utility emission rates reflective of local conditions

(Note that if complete input data have not been entered, when the View Results button is clicked an “Incomplete Input” message box is displayed that indicates which data must still be entered.)

To return to the input screen after viewing the results calculated by GSEModel, click the “Edit” item on the main menu near the top of the application window. Then click either of the three “Return to ...” items to go back to one of the input entry screens.

IMPORTANT - Other than exiting the program, this is the only way to navigate out of the Results screen!

Printing Inputs and Results - To print both the input data and the tabulated emission reductions and cost-effectiveness results for the current scenario being evaluated, click the “Print” item on the main menu bar, then click the “Print Scenario” item on the drop-down menu. A two-page report is then printed on the current “default” printer selected from Windows. The first page shows a summary of the data inputs; results are displayed on the second page.

Saving and Loading Scenario Files - To make repeated use of the GSEModel tool quicker and easier, the application includes the capability to save a complete set of analysis inputs and re-use them later as a modifiable template for evaluating other GSE scenarios. (This avoids having to type in complete data from scratch for each analysis.) After inputting data for a specific analysis case, the information can be saved to a “scenario file”

(indicated by a “.gse” file extension) by clicking “File” on the main menu and then clicking “Save Scenario.” A dialog box is then displayed, allowing the file to be saved to disk for later use. Click the arrow to the right of the “Save in” box to select the destination directory, then type a file name for the scenario to be saved in the “File name” box, using the .GSE suffix. (It is suggested that the “.gse” scenario files be saved to the same directory where the application program was stored, e.g., C:\GSEMODEL.)

Similarly, to load and re-use a saved scenario file, click “File” on the main menu, then click “Load Scenario.” Select the directory and file to be loaded into the application.

Exiting the Program - To exit the GSEModel application, click “File” on the main menu, then click “Exit GSEModel.” The application will then close and exit. Remember to save the current inputs in a scenario file as described above if you plan to re-use them later.

IMPORTANT - Do not close the GSEModel application using the Close Box in the upper right-hand corner of the application window such as the one  shown.

If this happens inadvertently, you may be prompted as shown below in Figure 1 to save changes to the GSEMODEL.XLS file.

Figure 1



ANSWER “NO” TO THIS PROMPT, OR ELSE YOU MAY CORRUPT THE PROGRAM!

Detailed Operating Instructions and Guidance

This section of the documentation provides step-by-step descriptions and guidance for operating and inputting data to the GSEModel application and understanding the calculated results.

Creating a Shortcut to Launch GSEModel - Prior to running the application for the first time, the user may want to create a shortcut to the application, enabling it to be launched

directly from the Windows desktop with a single mouse click. To do so, perform the following steps:

- Open the Windows Explorer and locate the GSEMODEL.XLS file in the folder/directory it was installed into;
- Right-click the GSEMODEL.XLS file and click “Copy” on the pop-up menu;
- If necessary, size the Explorer window so that part of the desktop is visible, then right-click the mouse on any visible portion of the desktop and click “Paste Shortcut” from the pop-up menu.

Windows then places a shortcut to the application on the desktop called “Shortcut to GSEMODEL.XLS.” To rename the shortcut (e.g., to simply “GSEModel”), select the shortcut icon, right-click and select “Rename” from the pop-up menu. Type in the new name and hit the Enter key on the keyboard when finished.

Inputting Data - Scenario Inputs Screen - After being launched, the GSEModel program takes several seconds to load. When loading is finishing (denoted by a “Ready” indicator in the lower left corner of the application window), the user is placed at the first of three inputs screens, the Scenario screen, shown in Figure 2. The user can navigate from screen to screen using the buttons located toward the bottom of each input screen.

**Figure 2
Scenario Inputs Screen**

SCENARIO INPUTS

ENTER SCENARIO TITLE BELOW (optional)

SELECT EQUIPMENT CATEGORY SELECT CURRENT TECHNOLOGY HOW WILL YOU INPUT NO. OF UNITS TO BE EVALUATED?

Enter it myself
 Have program calculate it from LTO's

SELECT ALTERNATIVE TECHNOLOGIES

Gasoline 4-Stroke
 LPG
 CNG
 Diesel
 Electric
 All Above

Carrier Type	Annual LTO's	GSE Units
Jet, Non-SW - Wide Body		
Jet, Non-SW - Narrow Body		
Jet, SouthWest Regional		
Total GSE Units:		

Ready Sum=0 NUM

On the Scenario screen, basic information about the analysis case being evaluated are entered, including the GSE equipment category and the current and alternative emission control technologies being considered. White-colored areas indicate where user inputs are provided. Each of the inputs on this screen is discussed below.

Scenario Title (optional) - If desired, the user can enter a specific title for the scenario being evaluated.

Equipment Category - Using a drop-down list, accessed by clicking the down arrow to the right of this input box, one of 19 available GSE equipment categories must be selected for analysis. (As stated earlier, the GSEModel application is set up to analyze emission reductions and cost-effectiveness for one category at a time.) Table 2 lists the available GSE equipment categories.

Table 2 GSE Equipment Categories
Aircraft Pushback Tractor
Air Conditioning Unit
Air Start Unit
Baggage Tug
Belt Loader
Bobtail
Cargo Loader
Cart
Deicer
Forklift
Fuel Truck
Ground Power Unit
Lavatory Cart
Lavatory Truck
Lift
Maintenance Truck
Other GSE
Service Truck
Water Truck

Current Technology - A similar drop-down list feature is used to select the technology currently used in the GSE equipment being evaluated. The following choices are available:

- Gas-2 - Two-stroke gasoline engines;
- Gas-4 - Four-stroke gasoline engines;
- LPG - Liquid Petroleum gas-fueled engines;
- CNG - Compressed natural gas-fueled engines;
- Diesel - Diesel-designed and fueled engines; and
- Electric - Electrically powered equipment.

Note that for a given GSE equipment category, any one of these options can be selected. The GSEModel program does not include logic to identify “valid” choices for each individual equipment category. That responsibility is left up to the user.

Input Units Method/Number of Units - By clicking either of the two radio buttons, the user indicates which of two methods will be used to input the number of GSE units (for the selected category and current technology) to be evaluated:

1. Direct Entry - The user simply enters the number of units being considered in the cell below (e.g., 30 baggage tractors); or

2. Calculate from LTOs - If the number of units of a particular equipment category is unknown, annual LTO (landing and takeoff operation) information can be entered and the GSEModel program will estimate the number of units of the equipment type and current technology selected.

If option 2 is selected, annual LTO data for four commercial air carrier categories are required:*

- Wide-body jets from all carriers except Southwest Airlines;
- Narrow-body jets from all carriers except Southwest Airlines;
- Southwest Airlines jets; and
- Non-jet regional/commuter aircraft (e.g., turboprops).

Alternative Technologies - Using a group of check-boxes, the user can select alternative technology categories to be evaluated by the program as indicated. (Depending upon the current technology selected earlier, one of the alternative technology check-boxes may be disabled and shaded out.) The “All Above” check-box can be used to select or de-select all available technologies.

Inputting Data - I-C Technology Activity & Cost Inputs Screen - Figure 3 shows the layout of the I-C Technology Activity & Cost Inputs screen.

* The GSE Information Series 1 (Basis for GSE Population Estimates) document also prepared under this EPA Work Assignment provides a detailed discussion of how GSE equipment unit counts can be derived from air carrier LTO data.

Figure 3
I-C Technology Activity & Cost Inputs Screen

I-C TECHNOLOGY ACTIVITY & COST INPUTS

CHECK TO USE DEFAULT VALUES

ANNUAL USAGE (hrs/year)

EQUIPMENT LIFE (years)

ENGINE LIFE (years)

	CURRENT	ALTERNATIVE I-C TECHNOLOGIES			
ACTIVITY INPUTS					
ANNUAL USAGE (hrs/year)					
EQUIPMENT LIFE (years)					
ENGINE LIFE (years)					

	CURRENT	ALTERNATIVE I-C TECHNOLOGIES			
COST INPUTS					
PURCHASE PRICE (\$)					
REPLACEMENT/REBUILD COST (\$)					
FUEL USE (GGE gal/hr)					
UNIT FUEL COST (\$/gal)					
UNIT MAINTENANCE COST (\$/hr in use)					

DISCOUNT RATE (%)

POLLUTANT COST-EFFECTIVENESS WEIGHTING SCENARIO
 (produces multi-pollutant CE estimate, optional) (none)

SCENARIO INPUTS ELECTRIC TECH. INPUTS VIEW RESULTS

Ready Sum=0 NUM

This screen is used to enter activity and cost data for the current and alternative technologies for the GSE equipment category selected earlier. (Information for all internal combustion (I-C) technologies is entered on this screen. Electric technology-specific data are entered on the next screen.) Each input area is discussed below.

Activity Inputs - Three “activity”-related data elements are entered in this table for both the current and alternative technologies being modeled:

- Annual Usage - the number of hours per year that the equipment is operated (for I-C engines, this consists of the entire time the engine is on and running, including idling);
- Equipment Life - the expected useful life, in years, of the GSE equipment (typically 16 years); and
- Engine Life - the estimated interval, in years, before an engine replacement or rebuild is needed.

As Figure 3 shows, check-boxes at the left of each of these activity data inputs can be clicked to have the program supply default values for each element. However, the user is encouraged to utilize actual data for the specific airport being modeled, especially for the annual usage inputs.

Also note that depending upon which current and alternative technologies have been selected earlier, one or more of the columns in this table (and the Cost Inputs table discussed below) will be disabled and shaded out.*

Cost Inputs - A similarly displayed table is used to enter required cost information as follows:

- Purchase Price - the initial purchase cost of that equipment category and technology, in dollars;
- Replacement/Rebuild Cost - the cost of rebuilding or replacing the engine of the equipment category and technology being evaluated at each interval specified above in the Engine Life inputs, in dollars;
- Fuel Use - the estimated amount of fuel used for each specific technology, in Gasoline Gallon Equivalent (GGE) gallons per hour of operation;
- Unit Fuel Cost - the cost of each technology-specific fuel, in dollars per gallon; and
- Unit Maintenance Cost - the maintenance-related costs of each equipment/technology combination, in dollars per hour of equipment use.**

Reliable, verified data for these costs are not currently available. Therefore, no defaults have been set up within GSEModel for these inputs. The GSE Information Series documents¹²³⁴⁵⁶ also compiled under this Work Assignment provide rough estimates for these inputs.

Discount Rate - Below these tables is a cell to enter the discount rate (in percent) to be used in the Net Present Value (NPV) cost calculations (discussed in detail later). A typical discount rate used in NPV analysis is 6%.

* This is normal. The GSEModel program uses logic that fixes the columns in these tables to specific technologies. Depending on which technology has been selected as the current technology and the alternative technologies chosen, the columns in these tables corresponding to non-selected technologies will be deactivated.

** Most maintenance cost data are reported in these units. If only annual costs are available for a number of GSE units, simply divide these costs by the product of the number of units and their annual usage level, i.e., Unit Maint. Cost (\$/hr) = Annual Maint. Cost for Multiple GSE Units / [# Units x Usage (hrs/year)].

Pollutant Cost-Effectiveness Weighting Scenario (optional) - Finally, using a drop-down list, the user can optionally select a weighting scheme to calculate combined-pollutant cost-effectiveness in addition to the simple, individual pollutant cost-effectiveness estimates always produced by the program. For example, for ozone-related control-strategy analysis, planning agencies often calculate cost-effectiveness by combining HC, NO_x, and CO reductions, where CO is discounted relative to the ozone-formation potential of HC and NO_x.^{*} In addition to ozone, default weighting schemes have been set up for PM₁₀ and CO-only control strategy cost-effectiveness calculations. (To bypass this option, simply leave the “(none)” item selected in the drop-down list.)

Inputting Data - Electric Technology Inputs Screen - If the electrically powered GSE alternative technology was selected for evaluation in the Scenario Screen described earlier, additional electric technology-specific inputs must be entered on this screen, shown in Figure 4. The inputs required in this screen are defined below.

Activity Inputs - The activity-related data required for electric technology is similar but not identical to IC engine inputs. These input distinctions are as follows:

- Base Tech. Operation at Idle - the frequency at which the “base” or current technology engine being modeled operates at idle when turned on^{**}, in percent;
- Battery Life - the expected life of the battery as regularly charged and used to power electric GSE, in years.

The model provides default battery life estimates by GSE category if the check-box to the left of the table is clicked.

Cost Inputs - As with the activity data, electric GSE cost inputs required by the model are similar to their IC engine counterparts, with the following differences:

- Electric Use - the power consumption rate of the electric GSE equipment, in kilowatts per operating hour; and
- Unit Electricity Cost - the energy rate charged by the local electric utility, in dollars per kilowatt-hour (airports are typically charged an industrial rate that is cheaper than residential rates).

^{*} The California Air Resources Board typically uses a HC-NO_x-CO weighting scheme of 1-1-¹/₇, respectively to assess ozone-related control strategies for which multi-pollutant reductions are anticipated.

^{**} This input is used by the model to account for the fact that many I-C engine-powered GSE are left on for prolonged periods and continue to idle without being used. Conversely, it assumes that electric GSE are shut off when not actually in use.

**Figure 4
Electric Technology Inputs Screen**

ELECTRIC TECHNOLOGY INPUTS

CHECK TO USE DEFAULT VALUES

ACTIVITY INPUTS	
	BASE TECH. OPERATION AT IDLE (%)
	EQUIPMENT LIFE (years)
<input type="checkbox"/>	BATTERY LIFE (years)

COST INPUTS	
	PURCHASE PRICE (\$)
	REPLACEMENT/REBUILD COST (\$)
<input type="checkbox"/>	ELECTRIC USE (kw/operating hr)
<input type="checkbox"/>	UNIT ELECTRICITY COST (\$/kw-hr)
	UNIT MAINTENANCE COST (\$/hr in use)

SELECT UTILITY EMISSION RATES SCENARIO [Dropdown]

SCENARIO INPUTS ACTIVITY & COST INPUTS VIEW RESULTS

Ready Sum=0 NUM

The program contains default values for both of these inputs based on data contained in the GSE Information Series 4 - Electric GSE guidance cited earlier. That guidance also includes estimates for the other electric technology cost data required by the program for selected equipment categories.

Utility Emission Rates Scenario - Finally, using a drop-down list, the user must select one of three utility emission rate scenarios contained in the program. This input is used to account for the emissions generated at the utility power plant due to the incremental power demand that results from converting IC engine GSE to electric technology. Table 3 lists these scenarios and shows the utility emission rates assumed by the model.

Once all of the inputs required in each of the screens described above are entered (or default values are selected), the GSEModel program automatically performs emission reductions and cost-effectiveness calculations. The “View Results” button located at the bottom of each of these screen can then be clicked to examine the results, or the “Print” item on the main menu can be clicked to print them.

Table 3				
Electric Utility Emission Rate Scenarios and Power Plant Emission Factors (g/hp-hr)				
Scenario	HC	CO	NO _x	PM
Minimum	0.008	0.035	0.080	0.004
Typical	0.037	0.109	0.403	0.023
Maximum	0.124	0.185	2.534	1.371

Output Results - Emissions and Cost-Effectiveness Calculations - This final sub-section of the GSEModel documentation briefly discusses how the emission reduction and cost calculations are performed and presents results from a sample calculation. The methodologies (and default data) used by the program are based entirely upon the GSE Information Series guidance that is summarized in the body of the report to which this documentation is appended.

Using equipment category-specific “average life” emission factors contained in that guidance multiplied by the annual usage inputs described in the preceding sub-sections, GSE emissions (in tons/day) are estimated for current and alternative technologies selected.

Emission reductions (from the current technology emission levels) are then computed on both an absolute (tons/day) and relative (%) basis.

Lifetime costs (based on the equipment useful life, not the engine replacement interval) are then forecasted for engine/battery replacement, operation (i.e., fuel or electricity use), and maintenance by combining the various cost inputs with the equipment usage inputs, and the initial capital cost.

A Net Present Value (NPV) calculation is then performed on these cash flows, using the input discount rate, to compute NPV life-cycle costs for each cost component (initial, replacement, operating and maintenance), and in total under each technology evaluated. The NPV methodology provides a basis to compare a series of uneven future cash flows for difference scenarios (i.e., GSE technologies as used in this application) on an equivalent present value basis, given an assumed discount rate.

Once the NPV costs are computed, individual pollutant cost-effectiveness (\$/ton) is computed by dividing incremental NPV costs (alternative technology costs relative to the current technology) by incremental emission reductions for each alternative technology, where the emission reductions are also expressed on an NPV basis. If selected by the user, combined pollutant cost-effectiveness is similarly calculated by dividing incremental NPV costs by the summed weighted-pollutant reductions.

A sample GSEModel Results report showing these outputs is provided in Figure 5.

Figure 5 Sample GSEModel Results Report

GSE MODEL RESULTS

SCENARIO TITLE: Cost-Effectiveness Calculation Example (Baggage Tug)
EQUIPMENT CATEGORY: Baggage Tug
CURRENT TECHNOLOGY: Gas-4
NUMBER OF UNITS: 1

<u>Emissions (tons/year)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		1.148	-	0.574	0.382	0.217	0.006
CO		57.648	-	36.030	36.030	0.686	0.019
NOx		0.699	-	0.525	0.525	1.842	0.068
PM		0.007	-	0.006	0.006	0.136	0.004
<u>Emission Reductions (tons/year)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		n/a	-	0.57	0.77	0.93	1.14
CO		n/a	-	21.62	21.62	56.96	57.63
NOx		n/a	-	0.17	0.17	-1.14	0.63
PM		n/a	-	0.00	0.00	-0.13	0.00
<u>Emission Reductions (%)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		n/a	-	50.0%	66.7%	81.1%	99.4%
CO		n/a	-	37.5%	37.5%	98.8%	100.0%
NOx		n/a	-	25.0%	25.0%	-163.3%	90.2%
PM		n/a	-	16.3%	16.3%	-1758.9%	46.5%
<u>NPV Lifetime Costs (\$)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
Purchase Cost		\$17,000	-	\$19,000	\$21,000	\$22,000	\$30,000
Replacement Cost		\$2,568	-	\$2,568	\$2,568	\$2,568	\$6,566
Fuel Cost		\$59,481	-	\$49,072	\$65,058	\$27,386	\$5,576
Maintenance Cost		\$47,089	-	\$37,176	\$37,176	\$47,089	\$15,614
Total Cost		\$126,139	-	\$107,816	\$125,802	\$99,044	\$57,756
<u>NPV Lifetime Emissions (tons)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		10.157	-	5.079	3.381	1.924	0.056
CO		510.265	-	318.916	318.916	6.076	0.164
NOx		6.190	-	4.643	4.643	16.302	0.606
PM		0.065	-	0.054	0.054	1.201	0.035
Weighted Total: Ozone		89.243	-	55.281	53.584	19.094	0.685
<u>NPV Incremental Cost Savings (\$)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
Purchase Cost		n/a	-	-\$2,000	-\$4,000	-\$5,000	-\$13,000
Replacement Cost		n/a	-	\$0	\$0	\$0	-\$3,997
Fuel Cost		n/a	-	\$10,409	-\$5,576	\$32,095	\$53,905
Maintenance Cost		n/a	-	\$9,914	\$9,914	\$0	\$31,475
Total Cost		n/a	-	\$18,323	\$337	\$27,095	\$68,383
<u>NPV Emission Reductions (tons)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		n/a	-	5.079	6.776	8.233	10.101
CO		n/a	-	191.349	191.349	504.189	510.101
NOx		n/a	-	1.548	1.548	-10.112	5.584
PM		n/a	-	0.011	0.011	-1.136	0.030
Weighted Total: Ozone		n/a	-	33.962	35.659	70.149	88.557
<u>Incremental Cost-Effectiveness (\$/ton)</u>		Current		Alternative Technologies			
		<u>Gas-4</u>		<u>LPG</u>	<u>CNG</u>	<u>Diesel</u>	<u>Electric</u>
HC		n/a	-	\$3,608	\$50	\$3,291	\$6,770
CO		n/a	-	\$96	\$2	\$54	\$134
NOx		n/a	-	\$11,839	\$218	-\$2,680	\$12,245
PM		n/a	-	\$1,742,065	\$32,057	-\$23,842	\$2,278,120
Weighted Total: Ozone		n/a	-	\$540	\$9	\$386	\$772

4. REFERENCES

1. GSE Information Series 1, "Basis for GSE Population Estimates," Energy and Environmental Analysis, Inc., September 1998.
2. GSE Information Series 2, "GSE Emissions and Activity Estimates," Energy and Environmental Analysis, Inc., September 1998.
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4. A. "GSE Control Strategy Summary," Energy and Environmental Analysis, Inc., September 1998.
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5. GSE Information Series 5, "Emissions Aftertreatment," Energy and Environmental Analysis, Inc., September 1998.
6. GSE Information Series 6, "Fixed Gate Support," Energy and Environmental Analysis, Inc., September 1998.