

Model Guide and User Instructions

General Instructions

The model lets the user compare the total lifecycle costs across several cost categories for up to 6 different "purchase scenarios." These scenarios let the user decide when the purchases will be made, the types of buses to be compared, the work load of the buses, and many other cost inputs, all on the User Input page. The user should follow all instructions where noted, and can consult the yellow help comment cells to the left of each of the cost categories. Make a backup copy of the model before using in the case that somehow a change impairs the operations of the model. A good way to approach using the model would be to print the user input page and pre-select the scenarios you wish to run and the corresponding inputs values (green and orange fields). After the values have been entered, the user should evaluate the default values and override any for which they have better information.

Guide to Worksheets in this Model

<i>User Inputs</i>	This is the main interaction page. Here the user will enter data, view default values and be able to override them.
<i>Output Charts</i>	Bar chart of main lifecycle cost subtotals and totals.
<i>Output Table</i>	Table of results by cost item, subtotals, and totals.

Detailed User Instructions

Introduction

This User Guide provides you with the instructions needed to operate the Life Cycle Costing (LCC) Model. It also provides examples and explanations to help you understand the various costing assumptions used throughout the model.

The LCC Model is a tool with a very specific purpose: to compare the various upfront and recurring ("life-cycle") costs of owning and operating diesel, hybrid (both diesel and gasoline) and CNG buses, in nominal 40-foot and 60-foot configurations. Like other tools, the model can be used in a variety of ways and offers a great deal of application flexibility. Unlike most other models, however, data inputs that drive bottom line results can be changed by you to suit individual operational experiences and needs, local costs and special financing situations, and to accommodate future changes as all four of the propulsion technologies evolve and more definitive costing information becomes available.

It is important to note that the data inputs used to create the model were obtained from research conducted during 2005-2007. While diesel and CNG bus experiences were relatively mature and established, hybrid bus experiences were limited and difficult to quantify because of the technology's relative newness. In fact, given the constant pressure to continually reduce emissions and optimize energy consumption, all bus propulsion technologies will evolve as they become more efficient. For example, CNG bus engines will move from lean burn to stoichiometric burn in the future, and diesel engines will be fitted with new equipment to further reduce NOx emissions.

Understanding this, the LCC model is designed to allow you to go beyond the established values based on what was known in 2005-2007, which will already be slightly outdated when this report is first published, and insert values based on current information and each agency's own unique operating conditions.

Spreadsheet Format

The model is based on an Excel® spreadsheet, but you can easily operate this tool without being knowledgeable about the inner workings of the program itself. You will, however, need basic computer skills such as knowing how to open, close and save files. Begin by opening the original Excel® file and click on the “User Input” tab located across the bottom of the page to get started. This tab is where you make all inputs to the model. You'll note that each row of the LCC model is numbered in the left margin. References to specific row numbers are used throughout these instructions to assist you in locating specific model sections. As noted in the Tabs section below, there are abbreviated instructions for using the model contained in the yellow tab in the “User Input” tab and this detail instruction in the “Guide & User Instruction” Tab to assist you.

When working with the model, it is best to save the original LCC Model document in a directory on your computer's hard drive and then change the file name as appropriate when running various comparative scenarios (i.e., when comparing CNG to diesel with and without applying incentives).

Press F9 to Update Model after Changing Inputs

Before we get into the specifics of entering inputs and changing value in the model, we begin with one reminder that you must always remember to hit the F9 key on the keyboard before viewing the results. Doing so refreshes the model by registering all of the inputs that you've made, thereby producing valid output charts and tables. You can hit F9 and review bottom line results after making specific inputs as you continue to work with the model, or wait until you have entered all inputs. In all cases, failure to press F9 after making input changes will result in output charts and tables that may not reflect those inputs. You can make as many or few changes as needed – just remember to hit F9 before viewing the results.

Saving the Original File

Before making any changes to the LCC model copy the Excel® spreadsheet file into its own folder on your computer's hard drive under its original file name. Doing so allows you to retain the original file as a base from which to make as many propulsion comparisons as needed. To save the original document under another file name left click on “file” located across the top right section of the screen, left click on “save as,” type in the new file name (e.g. LCC_Model_V1.0, etc.) and then click on “save.” The original file will be retained along with as many LCC versions that you choose to create from it. If you make changes to the model and should try “save as” the file under its original name, a window will pop out requiring you to confirm replacing the existing original file. Click on “No” and type in the new file name in “File name:” box, and then click on “Save.”

Tabs

When opening the file you will see tabs across the bottom. Each tab opens a new window depending on your needs.

- *“Guide & User Instruction” Tab:* Includes a summary of how to use the model and this instruction
- *“User Inputs” Tab:* Main user page where you enter information needed to run the program

- “*Output Table*” *Tab*: Displays results of user inputs in more detailed text format (after pressing F9)
- “*Output Chart (OC) 1*” *Tab*: Displays results of user inputs in basic graphic format (after pressing F9)
- “*OC 2*” *Tab*: Presents comparison results of the life cycle default costs plus upper and lower error bars (after pressing F9)
- “*OC 3*” *Tab*: Presents comparison results of the life cycle default costs per bus plus upper and lower error bars (after pressing F9)
- “*OC 4*” *Tab*: Presents comparison results of the life cycle default costs per bus mile plus upper and lower error bars (after pressing F9)
- “*OC 1-4 (Small Size)*” *Tab*: Displays output charts 1 to 4 together in small size. It is easier to insert them into Word or other

The User Input tab is the place where the user directs the model to make the comparisons. As you make inputs in this tab, there is “invisible” background programming taking place. Although this programming is suppressed, the various worksheets used as the basis for the programming are presented in the C-15 final report Appendix G. Final report Section 3.3 also provides more detail on the origin of data used to build this spreadsheet, and on the logic behind the calculations.

User Inputs Page

This page is where you interact with the model by entering agency specific information and changing inputs from the default values when needed. Each value (low, default, or high) is listed in a cell (box). Simply click on the Pink cell (see in Color Coding below) and type in the desired value so that the original or default value will be replaced by the user specified value. Each cell is color coded, as described below.

Color Coding

The various colors used in the model make it easier to use:

- *Green*: These represent critical cells that you must complete to reflect the agency’s bus purchasing plans and basic operating conditions such as expected bus life in years (Row 11), number of buses to be purchased (Row 27), and the average mileage (Row 36) each bus in the fleet will accumulate annually. Make these entries first, or the model will run with the pre-set default values for these cells. The default values used here are 12 years for expected bus life (required when using FTA funds), 100 for the number of buses to be purchased, 2007 for the purchase year, and 37,000 for the average number of miles accumulate annually (based on 2005 and 2006 national averages).
- *Orange*: These cells also reflect agency-specific conditions such as average speed or duty cycle (Row 42 and Row 41), air conditioning loadings (Row 56) and bus heating estimates (Row 60), number of operators (Row 109) and number of mechanics (Row 111) to train, incentive values (below Row 183), and other such entries. Make these entries second, although the model will run with default values.
- *White*: These cells are pre-set with low, medium and high values for each of the costing categories. The model will run with the medium value as the default unless you enter another value to replace the default (see Pink below). Note: You are not able to edit the white cells; always use the pink cells when overriding default values as well as low and high values.
- *Pink*: These cells are where you override the default values listed in the white cells. To override the default setting you can enter a value listed in the high or low cells, or enter another value as appropriate. Once a value is placed into the pink cell the default is automatically overridden.

- *Yellow*: To the left of each costing category is a small yellow box. Drag your cursor over any one to open a dialog window that provides abbreviated instructions and information about each input category.
- *Blue Hyperlink*: Each cost category title is also a hyperlink. Clicking on it will link you to this instruction in “Guide and User Instruction” Tab. The same link exists in the “User Instruction” Tab, which is used to get you back to the “User Input” Tab.

Overall Parameters

The first category found on the User Inputs Page consists of Overall Parameters. Here you enter vital information such as expected bus lifetime, base year, and bus length (40 or 60 foot). Click on the symbol and scroll down to select the desired entry.

All costs are presented in base year dollars. The inflation index will adjust all prices, which are default in 2007 dollars to the appropriate values in the base year. The index inflates costs by 2.918 percent per year, and is based on a composite of producer price indexes in the heavy vehicle and transportation industries. When the base year N is selected, the model will automatically calculate an inflation rate (Cell S10) as the result of $(1.2918^{(N-2007)})$. You can also change the inflation index, if you find the factor to be inaccurate based on more current data. A new index factor can be typed directly into the orange cell (Cell S12). For example, if base year is 2012, the inflation rate in Cell S10 is 1.15. Typing 1.23 in Cell S12 will cause the model use the inflation rate of 1.23 to replace 1.15 for all cost value adjustments.

Purchase Scenario

This model section is divided into sixteen subsections that define the type of buses to be compared (e.g., diesel, hybrid-diesel, hybrid-gasoline, CNG) and the factors that affect cost (e.g., duty cycle, annual mileage, training requirements). To begin comparing bus propulsion types, click the “activate” box in any one of six columns, thereby allowing up to six different bus type comparisons to be made side by side.

1 – Technology (Below Row 21)

For each column activated, select the type of buses to be compared from the pull down menu(). Choices include:

- Pre-2007 diesel
- Diesel (2007 and newer)
- Hybrid - diesel
- Hybrid - gasoline
- CNG

The LCC model will make the required calculations for each of the columns activated and the type of bus selected in each column. Note that pre-2007 diesel is the baseline from which costing calculations for diesel buses (2007 and newer) were made. While pre-2007 comparisons with other buses may be of interest, it is assumed that as a purchasing tool using pre-2007 diesel buses would not be of benefit since these buses are no longer available as new.

2 – Number of Vehicles in Purchase (Below Row 25):

For each column activated, enter the number of buses to be purchased. Entering a “zero” will turn off the scenario for analysis.

3 – Purchase Year (Below Row 29):

For each column activated, use the pull down menu (↓) to select the year you plan to make the bus purchase. The purchase year can be the same as the base (current) year, or any year in the future. The model will make all of the necessary inflation calculations and other (technology based) calculations based on specific purchase years. For example, in 2010 for diesel powered buses the model will include cost increases needed to meet applicable EPA regulations.

4 – Annual Mileage per Vehicle (Below Row 34):

For each column activated, enter the expected mileage that each vehicle type will travel annually.

5 – Fuel Economy (Below Row 38):

For each column activated, Sections 5A-5D will calculate fuel economy in miles per gallon.

5A (Below Row 40)

Select either “duty cycle” or “average speed” as one of the variables when calculating fuel economy. Click on one or the other to highlight your selection. If you select the average speed method you simply enter the average operation speed as expressed in mph (Row 45). Here you could use either route average speed or fleet average speed (revenue plus non-revenue mileages divided by total hours) to estimate fuel economy performance.

If you select the duty cycle method you insert the percentage of mileage traveled (Row 47) in slow city speed (4-8 mph), fast city speed (8-15 mph), suburb speed (15-25 mph), and freeway speed (25-50 mph). In all cases, the percentages must add up to 100% or you’ll be asked to revise the inputs.

In both cases (duty cycle or average speed) the program will automatically make the necessary miles per gallon (mpg) calculations, which will be shown in Section 5D (Row 62) after all Section 5 inputs have been made. The basic calculations do not account for air conditioning or heating use, but can be adjusted for as described below.

5B (Below Row 54)

Air Conditioning Loading: Here the model allows you to take into consideration the effect air conditioning (AC) has on fuel economy by selecting a numeric value from 0 to 10. To change the settings, toggle the ← or → symbol to select the desired numeric value.

Zero (0) indicates there is no AC load (frigid climate, buses not equipped with AC), 10 indicates that the AC is always on and heavily loaded due to humidity and temperature effects (tropical climate), and five (5) indicates that the bus is operated in a temperate zone. Other numeric values between 0-10 can also be entered. Scale 5 is the default setting for the model, and represents moderate AC usage applicable for most US agencies. Below scale 5 (cooler climates), buses will gain a fuel economy benefit because of reduced AC operation. Likewise, for any scale over 5, fuel economy will be reduced due to increased AC usage.

The program will automatically make the necessary miles per gallon (mpg) adjustments, which will be shown in Section 5D (Below Row 62) for your review after all Section 5 inputs have been made.

5C (Below Row 58)

Heater Loads: This subsection takes into account the fuel economy penalty resulting from the use of fuel-fed auxiliary heating units typically used in cold climates by selecting a numeric value from 5 to 10. Again, you can change the settings by toggling the ← or → symbol to select the desired numeric value.

Default value five (5) indicates the bus is not equipped with an auxiliary heater (or it is not used); 10 indicates that the auxiliary heater is always used (frigid climate). Numeric values in-between 5 and 10 can also be manually entered to indicate partial auxiliary heater use. The program will automatically make the necessary miles per gallon (mpg) adjustments, which will be shown in Section 5D (Below Row 58) after all Section 5 inputs have been made. As with AC, the model will calculate a higher fuel economy penalty for higher auxiliary heater use.

5D (Below Row 62)

Review Resulting Fuel Economies - For each column activated, this section will allow you to review the fuel economy calculations expressed in mpg based on the inputs you made in Subsections 5A through 5C. Results are expressed in low, medium and high values. As always, the model will automatically select the medium input as the default. To select another value (i.e., either the high or low value, or any other value), you will need to manually input that value into the pink cell. This “pink cell” (Row 66) option may also be used in cases where you have reliable information on actual fuel economy to insert instead of the values provided for in the model.

6- Purchase Cost (Below Row 68)

The purchase price of each bus type, expressed in 1,000 dollars per bus (i.e., \$290.5 equals \$290,500), is a one-time cost. Unless you enter another value in the pink cell, the model will select the medium value as the default.

Per-bus prices included in the model are for base buses minimally equipped with basic onboard equipment such as air conditioning, multiplexing and basic electric destination signs, and standard warranty coverage (one year for the entire vehicle and two years of powertrain coverage; the cost of extended powertrain warranty is accounted for separately in Section 7 of the LCC model). Bus costs provided in the model do not include Intelligent Transportation System (ITS) features such as automatic vehicle location (AVL), next stop annunciators, security cameras, automatic passenger counters, radio and data communications, and various other onboard electronic systems that add significantly to the overall price of each bus. Due to the wide range of optional equipment available for buses today, agencies may need to enter the appropriate value manually in the pink cells.

7 – Extended Powertrain Warranty Costs (Below Row 75)

Also expressed in units of 1,000 dollars per bus, warranty costs for the vehicle propulsion system are one-time costs accounted for at time of bus purchase. The cost depends on how long the warranty is purchased. Unless you enter another value in the pink cell, the model will select three years as the default and calculate the costs. For hybrid buses the LCC model will automatically reduce extended powertrain warranty costs over time because of anticipated improvements in reliability.

For diesel and CNG buses, extended powertrain warranty coverage applies to the internal combustion engine (ICE) and conventional automatic transmission. For hybrid buses, extended warranty coverage applies to the entire hybrid propulsion system including the ICE.

8 – Engine Rebuild/Replacement Costs for Bus Lifetime (Below Row 83)

For all bus types these costs apply to rebuilding the ICE, and are based on replacing the original engine with a rebuilt unit obtained from an OEM authorized rebuilding facility. Labor is calculated at \$50 per hour, and rebuild costs include removal and replacement (R&R) labor along with miscellaneous supplies needed during the R&R process.

Use the pull down menu (↓) (Row 87) to select the engine rebuild schedule. For each propulsion type the model assumes the original engine will last a specified amount of years before requiring its first rebuild with subsequent rebuilds occurring at different intervals to denote high, mid and low cost values. A selection of the "6,4,4..." schedule, for example, means the first rebuild takes place at year 6 with subsequent rebuilds occurring every four years thereafter until the bus reaches its useful life.

Unless you enter another value in the pink cell, the model will select the medium value as the default. Costs are again expressed in units of 1,000 dollars per bus. For diesel and CNG buses, the model will automatically select the default of "6,4,4..." unless you select another choice from the drop-down menu or enter another value in the pink (user input) cell. Costs will be calculated throughout the entire bus life.

In the case of hybrid buses where a variety of diesel engines are used and rebuild/replacement data are sparse, costs are based on "throw-away" replacement engines (i.e., engines are replaced and not rebuilt). For hybrid buses the model will automatically select the mid cost schedule of "7,6,6..." as the default unless you select another choice from the drop-down menu. Or you can select "7,5,5..." as the high cost schedule, "7,7,7..." as the low cost value, or enter another value in the pink cell.

Vendor rebuilds are used here as a way of capturing overhead costs in a consistent manner. Agencies that rebuild their own engines can insert their actual parts and labor costs with or without accounting for overhead (i.e., facility costs, employee benefits, warranty, etc.). Rebuild/replacement cost assumptions for the various internal combustion engines are shown in the table below.

Internal Combustion Engine Rebuild/Replacement Costs (Per Replacement)		
Diesel	CNG	Hybrid
Low – \$15,000	Low – \$15,000	Low – \$10,000
Mid – 20,000	Mid – 20,000	Mid – 15,000
High – 25,000	High – 25,000	High – 20,000
Notes:		
· Assumes diesel and CNG engines will be rebuilt with factory remanufactured unit (i.e., no in-chassis rebuilds); includes labor cost to remove and replace R&R engine		
· Cost based on rebuilds conducted by an outside vendor to capture all overhead costs associated with the rebuilds/replacements.		
· In the case of hybrids where a variety of diesel engines can be used and rebuild/replacement data is sparse, costs are based on "throw-away" replacement engines (i.e., engines are replaced and not rebuilt). In addition, the model assumes a longer interval between engine replacements.		

9 – Transmission Rebuild/Replacement Costs for Bus Lifetime (Below Row 94)

For diesel and CNG buses these costs are based on replacing the original automatic transmission with a rebuilt unit obtained from an OEM authorized rebuilding facility. For hybrid buses costs are based on removing the original hybrid drive system and replacing it with a factory remanufactured unit. Again, labor is calculated at \$50 per hour and costs include R&R labor and the cost of miscellaneous supplies needed during the R&R process.

Like the engine section above, use the pull down menu (Row 93) to select the transmission rebuild schedule. These costs are also expressed in units of 1,000 dollars per bus. The transmissions rebuild schedule follows the same one used for engine rebuilds.

For diesel and CNG buses, the model will automatically select the mid cost schedule of “6,4,4,4...” as the default for transmission rebuilds unless you select another choice from the drop-down menu or enter another value in the pink cell. Costs will be calculated throughout the bus life.

For hybrid buses, the model will automatically select the mid cost schedule of “7,6,6,6...” as the default unless you select another choice from the drop-down menu. Or you can select “7,5,5,5...” as the high cost schedule, “7,7,7,7...” as the low cost schedule, or enter another value in the pink user input cell. Given the relative newness of hybrid drive systems, and that rebuild intervals were provided as estimates by vendors, you will need to keep abreast of actual rebuild schedules to ensure inputs used here reflect actual field experiences.

Again, vendor rebuild costs are used to capture related overhead costs. In the case of the hybrid drive system it is expected that factory rebuilds done on an exchange basis will be the only available option, at least until use of this equipment becomes more widespread and agencies gain the knowledge and tools needed to perform the rebuilding themselves. In the case of diesel and CNG buses, agencies who rebuild their own automatic transmissions can insert their actual parts and labor cost (with or without accounting for overhead). Likewise, as more information becomes available on the rebuilding of hybrid drive systems, agencies can override the default setting by entering another value.

Transmission rebuild cost assumptions for diesel and CNG buses are identical in that the low, mid and high values are \$10,500, \$11,750, and \$13,000 respectively. Again for diesel and CNG buses the model assumes:

- Transmissions will be rebuilt with factory remanufactured unit and includes labor cost to R&R transmission; and
- Rebuilds will be conducted by an outside vendor to capture all overhead costs associated with the rebuilds.

For hybrid buses, transmissions rebuild cost assumptions are \$31,300 (low), \$35,850 (mid) and \$40,400 (high). Costs are based on removal of original hybrid propulsion system and replacement with a factory remanufactured unit.

Costs associated with rebuilding the internal combustion engine (ICE) are included separately under “Internal Combustion Engine Rebuild.”

10 – Training Costs (Below Row 105)

In this category, the costs of training operators and mechanics on new hybrid and CNG diesel buses are incremental to (above and beyond) training costs associated with diesel buses. For hybrid and CNG buses users, enter the number of operators and mechanics that require training based on the number of these two bus types being procured. Labor for both operators and mechanics is based on a default rate of \$50 per hour and includes safety training; you can manually input another hourly rate for each type of work as appropriate.

Except for CNG, all training costs are one-time expenses required only when buses first arrive. Refresher training costs based on 0.5 hour per operator annually are automatically calculated throughout the bus life only for CNG buses because of safety implications.

Based on the number of operators and maintenance personnel entered and their respective hourly wage per hour, the model automatically calculates costs based on mid-level assumptions (default) made for the number of incremental training hours estimated for each propulsion type. These assumptions are shown in the table below.

Incremental Training (per affected employee)		
	Hybrid	CNG
Operator	Low - 1 hour	Low - 0.5 hour + 0.5 hour/year
	Mid - 2 hours	Mid - 1.0 hour + 0.5 hour/year
	High - 4 hours	High - 1.5 hours + 0.5 hour/year
Maintenance	Low - 16 hours	Low - 8 hours
	Mid - 18 hours	Mid - 10 hours
	High - 20 hours	High - 12 hours
Notes:		
<ul style="list-style-type: none"> • Assumes no additional training required for diesel buses; training costs for hybrid and CNG are above any beyond what would be considered typical training for diesel buses • All costs include safety training • Except for CNG, all training costs are one-time costs needed when buses first arrive; refresher training costs based on 0.5 hour per operator annually are automatically calculated throughout the bus life only for CNG buses because of safety implications. 		

As with all other cost inputs, you can override the default settings by inserting another cost value in the pink cell (expressed in multiples of \$1,000). If the default hours are not appropriate for your operation you could use the low and high assumptions provided in the above table as the basis for your calculations. Manually entering another value into the pink cell will override the default.

11 – Unscheduled Maintenance Costs (Below Row 119)

Bus maintenance costs are divided under scheduled and unscheduled events. An unscheduled event is one where maintenance is unplanned such as that resulting from a road call or a repair made to correct a defect noted by the operator during a pre-trip inspection. Scheduled maintenance consists of planned events such as preventive maintenance inspections (PMIs) and scheduled campaigns to repair similar defects on a range of buses.

Unscheduled maintenance costs are listed in dollars/cents per mile. The LCC model automatically selects the medium range as the default unless you manually enter an amount from the high or low range for each bus type, or manually enter a per mile cost based on your own experience or updated information.

Scheduled and unscheduled maintenance costing data used in the model were obtained from the test sites (discussed in final report Section 3.3) based on pre-2007 buses and adjusted with extended warranty and bus operation speed. Maintenance costs for different technologies are not absolute average costs found in test sites. Instead, baseline diesel bus costs were defined, and the costs for hybrid and CNG buses are referenced to the baseline. Detail is discussed in Section 3.3 in the final report. The table below presents the maintenance cost for four technologies in dollar per mile.

	Pre-2007 Diesel			Diesel			Hybrid-Diesel		
	Low	Mid	High	Low	Mid	High	Low	Mid	High
Scheduled	0.08	0.17	0.27	0.15	0.21	0.27	0.08	0.18	0.28
Unscheduled	0.3	0.36	0.43	0.32	0.38	0.45	0.13	0.41	0.95
Total	0.38	0.53	0.7	0.47	0.59	0.72	0.21	0.59	1.23
Propulsion Portion	0.12	0.15	0.18	0.13	0.16	0.19	0.13	0.19	0.37
Brake Portion	0.04	0.07	0.16	0.04	0.07	0.16	0.02	0.05	0.12

	Hybrid-Gasoline			CNG		
	Low	Mid	High	Low	Mid	High
Scheduled	0.08	0.18	0.28	0.14	0.28	0.3
Unscheduled	0.13	0.41	0.95	0.27	0.4	1.01
Total	0.21	0.59	1.23	0.41	0.68	1.31
Propulsion Portion	0.13	0.19	0.37	0.14	0.18	0.35
Brake Portion	0.02	0.05	0.12	0.04	0.07	0.16

The data were assumed to be equal to the maintenance cost under NO warranty and in average 15 mph speed operation. It was evident that warranty cost would not be reflected in the agency's scheduled or unscheduled maintenance costs. Slow speed operation would end up with less mileage, which might increase per-mile maintenance cost. The model simply reduces maintenance costs by half during the warranty period including standard warranty (two years) and extended warranty (user defined in Row 75). A speed correction function is used in the model to reflect the role of speed in maintenance cost. The function increases maintenance cost when buses are operated in slower speed and vice versa. The function

is correction factor = $0.5 + 7.5 / (\text{average speed})$. Final maintenance costs are calculated in the following equation.

$$\text{Costs} = \text{CorrectionFactor} \times \left(\frac{\text{WarrantyYears}}{\text{BusLifeYears}} \times \frac{1}{2} + \frac{\text{NonWarrantyYears}}{\text{BusLifeYears}} \right) \times \text{OriginalCosts}$$

12 - Scheduled Maintenance Costs (Below Row 126)

Costs for scheduled maintenance are accounted for separately in the model similar to unscheduled maintenance; see Unscheduled Maintenance Costs above for instructions and notes. Remember, the LCC model automatically selects the medium range as the default unless you manually enter another amount into the pink cell.

13 – Infrastructure Specific Costs (Below Row 133)

This section of the LCC model accounts for those costs to construct a fueling facility and modify other bus facilities along with costs associated with operating and maintaining the fueling facility. Default costs are unique to CNG buses and assume zero costs for the other technologies (CNG, diesel). Hence, if there are infrastructure costs associated with diesel or gasoline fuels, you must enter them in the pink cells (Row 142) to have them considered in the model.

Much of CNG infrastructure cost can vary to a great degree depending on the overall site layout, the costs of other facility modifications that are cited along with CNG facility costs, the type of CNG fueling selected, the amount of modification required to bring storage and workshop facilities up to code, and other factors that may or may not apply to your particular site and operation. Despite these great variables, a process based on agency experiences and other information was developed to reflect CNG specific costs. That process is described in the instructions that follow and in the Data Collection section (final report 3.3.2). As with any input, you can manually insert your own costs based on actual facility costs or estimates.

13A – New or Additional Infrastructure Costs (Below Row 133)

In this subsection you enter the number of CNG buses that the new infrastructure (fueling, maintenance and storage facilities) will need to service, which may or may not be the same as the number of buses being planned for purchase. New facilities will be needed in cases where the agency:

- Currently has no CNG facilities
- Existing facilities are under-sized (not large enough to handle additional CNG buses planned)
- Desire to over-size CNG facilities (purposely size them larger to accommodate future CNG bus procurements)

In this subsection it is important to note that you ONLY input the number of CNG buses that the new facility will be required to service as a result of the anticipated procurement. For example, if your agency currently does not have a CNG facility, plans to purchase 50 CNG buses, and will size the CNG facility for only 50 buses, you would enter 50 buses in Row 137 because all 50 buses would require infrastructure. If your agency plans to purchase 50 CNG buses but will over-size the CNG facility to handle 100 buses to accommodate a second (later) bus purchase, you would enter 100 buses. In this later case the model will inflate costs for the CNG buses because infrastructure costs for the larger infrastructure investment are spread over a smaller number of buses.

In another example let's assume your agency plans to add 50 CNG buses to its existing CNG fleet and already has an infrastructure that can accommodate 25 of them. In this case you would enter 25 buses in

Row 137, which will trigger costs for a new facility to account for the remaining 25 buses that the existing facility cannot accommodate. Likewise, if you plan to add 50 more CNG buses to your existing fleet and the CNG facility has been sized to accommodate all 50 of them, you would enter 0 buses in Row 132. Here, no infrastructure costs are included for CNG.

If you should fail to enter the specific number of CNG buses to be serviced by the CNG facility the LCC model will automatically use the number of buses planned to be purchased as the default. Enter zero if no facility investment will be included in this purchase scenario.

The LCC model favors CNG from a costing perspective when infrastructure investments have already been made and the existing CNG facility is sufficiently sized to accommodate additional CNG bus purchases. In this case investments already made in CNG infrastructure are not accounted for in the cost, and calculated costs are lower than average, affecting comparisons with other propulsion types. Conversely, the higher cost scenario for CNG is one where the agency plans to over-size its new CNG facilities in relationship to the initial number of CNG buses purchased (see below for how CNG infrastructure costs are allocated).

It is not possible to configure this LCC model as a total accounting tool for a bus operation, so the simplified approach described here must be used. Assuming that new facilities will be needed to service the CNG buses being considered for purchase, the default (medium range) CNG infrastructure costs are assigned by the model as one million dollars plus \$15,000 for each CNG bus indicated in Row 137. The low range is 20 percent lower than that amount; the high range is 20 percent higher than that amount. As with all default values, you can override them by manually inputting a high, low or any other appropriate value into the pink cell.

Low, high and default (mid) examples for various CNG infrastructure costs based on the cost assignments described above are provided in following table.

Number of CNG Buses Requiring Facility Infrastructure	Default (Mid) Calculation	Low Estimate - 20%	High Estimate +20%
25	\$1,375,000 (\$1 Million + \$15,000 x 25)	\$1,100,000	\$1,650,000
50	\$1,750,000 (\$1 Million + \$15,000 x 50)	\$1,400,000	\$2,100,000
100	\$2,500,000 (\$1 Million + \$15,000 x 100)	\$2,000,000	\$3,000,000
200	\$4,000,000 (\$1 Million + \$15,000 x 200)	\$3,200,000	\$4,800,000

13B – Operating and Maintenance (O&M) Costs for Facilities (Below Row 144)

These costs represent costs needed to maintain the CNG fueling infrastructure on an annual basis and include costs associated with powering the CNG fueling compressors, rebuilding them, and maintaining the overall CNG infrastructure. Based on the infrastructure costs in Section 13A above, the model will calculate O&M costs based on six percent of the CNG infrastructure costs. Examples of annual O&M costs for CNG facilities are shown in the table below. Six percent is not applied to the user define value (Row 142) if you override the default value and manually enter another value in the pink cells in Section 13A. To override the default costs for annual CNG infrastructure O&M manually enter the high, low or any other appropriate value into the pink cell. These costs will continue for the life of the CNG buses.

Number of CNG Buses Requiring Facility Infrastructure	Default (Mid) Calculation (Annual Cost)	Low Estimate (Annual Cost)	High Estimate (Annual Cost)
25	\$82,500 (\$1,375,000 x 6%)	\$66,000 (\$1,100,000 x 6%)	\$99,000 (\$1,650,000 x 6%)
50	\$105,000 (\$1,750,000 x 6%)	\$84,000 (\$1,400,000 x 6%)	\$126,000 (\$2,100,000 x 6%)
100	\$150,000 (\$2,500,000 x 6%)	\$120,000 (\$2,000,000 x 6%)	\$180,000 (\$3,000,000 x 6%)
200	\$240,000 (\$4,000,000 x 6%)	\$192,000 (\$3,200,000 x 6%)	\$288,000 (\$4,800,000 x 6%)

14 – Hybrid Specific Costs (Below Row 151)

The subsections below account for those costs unique to operating hybrid buses and includes diagnostic equipment costs, energy storage replacement costs, and the costs to keep spare energy storage packs in inventory should they be needed.

14A – Diagnostic Equipment (Below Row 153)

In this subsection the LCC model accounts for diagnostic equipment costs incremental to (above and beyond) considered typical to maintain and repair diesel and CNG buses. Begin by entering the number of hybrid buses to be serviced from a given workshop location. The model assumes that all hybrid buses will be serviced from only one workshop location; note the explanation provided below.

Diagnostic equipment cost calculations are based on one set of diagnostic tools for each group of 50 buses. The default cost for this equipment is \$5,000 per 50 buses, with the low and high set at \$3,000 and \$7,000 respectively for the same 50 buses. The LCC model will automatically add in the cost of diagnostic equipment once multiples of 50 buses are exceeded. Since the model assumes that all hybrid buses will operate from one workshop location, you will need to make a manual entry in the pink cell if multiple locations will service hybrid buses. For example, if 50 buses will be serviced from two workshops enter \$10,000 as the mid-level cost because two sets of diagnostic equipment will be required.

Diagnostic costs for hybrids are based on use of diesel and gasoline engines. However, you should note that the equipment needed to achieve full diagnostic capability for gasoline hybrid engines may be as high as \$20,000.

14B – Energy Storage Replacement (Below Row 162)

Again, this subsection only applies to hybrid buses and assumes that the cost to replace the entire onboard battery pack (energy storage) is \$27,500 including the labor to R&R it. Here the model bases high, low and mid (default) values not on variable costs for the energy storage equipment (it remains fixed at \$27,500 per replacement), but instead bases the values on the expected life of the equipment. The mid cost value (default) assumes that each \$27,500 energy storage pack will last six years, the high cost value assumes a four-year battery pack life, while the low cost value assumes an eight-year life before replacement is required.

In addition, the model does not simply assume that all battery packs will be replaced exactly at the estimated battery life year. Instead, the model assumes that a given battery pack (original or replacement) will have a 50 percent chance of requiring replacement at the expected life year, a 25 percent chance for failure one year earlier, and a 25 percent chance of lasting one year more than expected.

Based on the number of hybrid buses and expected bus years that you selected earlier, the model will automatically make the calculations and display the total costs in the low, medium (default) and high cells. The worksheet showing the algorithm used to make these calculations is shown in section 3.3.2 in the final report.

As mentioned throughout these instructions, the model selects the amount shown in the default cell (mid level) unless you manually enter another value (e.g., low, high or other) in the pink cell. Other than selecting a high or low value, there may be scenarios where a manual entry may be required. For example, those considering hybrid buses with ultra capacitors should insert “0” for a 12-year bus life because this energy storage technology is expected to last that long without requiring replacement. In this case, no costs will be assigned for battery pack replacement. Also, because the model uses a fixed cost of \$27,500 for energy storage pack replacement, you will need to make your own calculations and manually enter the results in the pink cell when battery prices change due to technology advances.

14C – Spare Energy Storage Packs (Below Row 169)

This additional hybrid-only subsection allows you to account for the costs of keeping spare energy storage packs in inventory (as opposed to keeping a bus down until a replacement pack is ordered and arrives). Again using \$27,500 as the fixed average cost for a spare energy pack, the default is set at one spare energy pack per 20 hybrid buses. The calculation is made automatically based on the number of hybrid buses you entered earlier for purchase. One spare energy pack per 30 buses is calculated at the low cost value, while one spare energy pack for every 10 hybrid buses represents the high cost value. Unless you enter the high, low or another value manually, the model will select the default (mid) value.

15 – Projected Average Fuel Costs (Below Row 176)

Given the vast number of uncertainties related to energy, accounting for future fuel costs becomes a challenging task, especially when trying to predict 12 years into the future and beyond. Nevertheless, a rigorous approach incorporating the forecasts of a range of international energy agencies, described in detail in the section 3.3.2 of the final report, has been used to account for future diesel, gasoline and CNG

fuel costs. Diesel and CNG costs are expressed in diesel equivalent gallons (DEG), while gasoline is expressed in gasoline equivalent gallons (GEG). Conversions are made automatically when the appropriate technology (e.g., hybrid-diesel, CNG, etc.) is selected in Section 1 (Row 21) of the model.

Depending on the purchase year, the model will calculate a 12-year average per-gallon fuel price. The price will be used throughout the bus life. Unless the low or high cost value is manually entered in to the pink cell, or you input another fuel price in \$/DGE or \$/GGE into this cell, the model will automatically select the mid value as the default. Fuel cost calculations in this section do NOT include taxes; they are accounted for if applicable in Section 16.

16 – Incentives, Credits & Taxes (Below Row 183)

This section allows you to account for incentives, credits, taxes and other costs for the various propulsion options being considered. In sections 16A (Below Row 185) and 16B (Below Row 200), you can adjust the predicted fuel costs to account for fuel taxes and fuel credits. Other vehicle purchase incentives for the various propulsion options being considered are entered in section 16C (Below Row 215). Section 16D (Below Row 232) allows miscellaneous one-time and yearly recurring credits to be entered. A future one-time cost can be entered in section 16E (Below row 237). Instruction details for each of these subsections follow.

16A – Fuel Taxes (Below Row 185)

This subsection allows you to account for fuel taxes if applicable by inputting specific taxes for your unique operation, which will then be automatically added to the projected average fuel cost calculated in Section 15. Unless a manual entry is made in the pink cell, the model will use the default tax values based on the current federal fuel tax and the low 48-state average fuel tax. The default federal taxes for diesel fuel, gasoline fuel, and CNG are 0.24 (\$/gallon), 0.18 (\$/gallon), and 0.18 (\$/GGE), respectively.

Note: If you do not pay federal or state fuel taxes, you must zero out the amounts or the model will account for them.

GGE represents gasoline gallon equivalent for CNG; one GGE CNG has the same amount of energy as one gallon of gasoline. Internally the model conducts computations in diesel gallon equivalent, or DGE. Also note that a default is not supplied for “other tax,” which you can enter manually to account for a local tax.

16B – Fuel Credits (Below Row 200)

In this subsection you can account for the effects of fuel incentives (credits) on fuel cost. Unlike the other sections, there is no default supplied so unless you make an entry the model will not apply a credit.

If credits do apply, begin by selecting fuel credits in four unit formats available from the dropdown menu (↓). These units correspond to both a percent discount from the base cost, and a certain number of cents per unit of fuel. The cents per unit fuel can be entered in five fuel unit measures available.

- % Credit (0 to 100)
- Cents/MillionBTU (MMBTU)
- Cents/DieselGalEq (DGE)

Cents/GasolineGalEq (GGE)
Cents/ThousandCubicFt (MCF)
Cents/MillionCubicFt (MCF)

Enter the value, in units appropriate to the drop-down menu selection, in the orange cell. You then enter the timeframe for the credit, which allows the model to use the discount over the years it applies. After the time period expires, the model returns to use the full amount calculated in Section 16A. The effective fuel credit (low, medium, high) is then calculated by the model in appropriate units (percent or cents per gallon, etc.) and shown for your review. The effective credits, however, will all be shown in cents/DGE.

The final cost is calculated by subtracting these credits from the fuel prices calculated in Section 16A. If a multiple credit computation is necessary, you can calculate the credits separately by repeating the steps mentioned above and apply them as one value in cents/DGE in the pink cells (Row 209) this subsection.

NOTE: Currently, CNG enjoys a fuel tax credit from Federal Highway Bill equivalent to \$25 cents/GGE, which will last to 2009.

16C – Purchase Credits (Below Row 215)

Like the subsection above, there is no default supplied unless you make an entry. If applicable, this subsection allows you to account for purchase credits available to agencies to encourage the adoption of advanced technologies. These credits may be based on a direct discount (cash or percent) off of the purchase price of an advanced technology bus, or a discount on the difference in price between an advanced technology bus and a conventional diesel bus. The difference is calculated automatically and shown by subtracting the price of one conventional diesel bus from the price of one bus of the technology to be purchased. If default diesel buses are being purchased, this difference value will be zero.

Use the dropdown menu to select the per-bus purchase credit as a:

- Percentage of the whole bus price,
- Percentage of the difference or,
- Straight cash discount per bus.

The purchase credit is then entered in appropriate units (percent or dollars). If the purchase credit computation is more complex, or if multiple credits exist, you must separately calculate the per bus credit, in thousands of dollars, and manually apply it in this section as a cash discount. Again, the default for this subsection is zero; all entries in thousand dollars per bus must be made manually in the pink cells (Row 225) for credits to be applied.

Important! If the purchase price in section 6 (Below Row 68) includes all purchase credits, you should skip the calculations of this subsection. Otherwise you will doubt account credits.

16D- Miscellaneous Credits and Grants (Below Row 232)

In this subsection you manually enter any other credit or grant available that has not already been addressed in Section 16. An entry in the “one time credit” cell is applied only once by the model; yearly operating credits are applied annually over the lifetime of the purchase.

16E – Miscellaneous Future Year One-Time Costs (Below 237)

In some cases the bus purchaser may know of substantial future costs associated with a bus purchase. For example, a purchaser of 2008 diesel buses may have an obligation to meet 2010 emissions standards around the time of the first engine rebuild. This anticipated future cost should be entered on a per bus basis in thousands of dollars. Make sure to adjust costs to anticipated bus life and enter the amount in base year dollars.

Reminder!

After making input changes to the model, remember to hit the F9 on your keyboard to refresh the model and produce representative output values. Failure to press F9 will result in output charts and tables that do not reflect your inputs. You can go back and make as many or few changes as needed – just remember to hit F9 before viewing the results.