eQUEST Training Module 3

Life Cycle Cost Analysis

INTEGRATED idl DESIGN LAB
BOZEMAN
MONTANA STATE UNIVERSITY
SCHOOL OF ARCHITECTURE

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Tom Wood, Director
Lab Assistants Christopher Hancock, Shelby Hinchliff, Justina Hohmann, Amy Lindgren, Heather Schroeder, Bill Zanoni, Emily Sikorski, and Colleen DeVoe

406-994-4934
twood@montana.edu
www.idlbozeman.com

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The Integrated Design Lab - Bozeman is funded by the Northwest Energy Efficiency Alliance. Our services include energy and lighting analysis for Montana architects and engineers who wish to become more aware of the environmental impacts of energy consumption.

As a member of the BetterBricks Lab Network, Montana State University's Integrated Design Lab- Bozeman is your Montana contact for energy and daylighting information, education and tools for assessing integrated design decisions, including daylighting and effecient electric lighting techniques.

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WHAT IS eQUEST?

eQUEST is a building energy simulation tool based on the older and more widely known energy analysis program, DOE-2, from the Lawrence Berkeley National Laboratory and James J. Hirsch and Associates. While DOE-2 was a powerful tool, it was too complicated to be useful to the entire design team and too time-consuming for it to fit into the budget of most projects.

eQUEST took the brains of DOE-2 and added a graphic user interface, wizards, and industry-standard defaults. Now eQUEST can be used for anything from basic energy strategizing to detailed life-cycle costing by anyone from new users to experienced energy modelers.

This training module series focuses on the intuitive side of eQUEST, understanding that not everyone has the time for or need to create highly detailed building simulations. Some of the benefits of simple energy modeling include:

- Gain an intuitive understanding of the effects that basic energy-saving variables can have on a design.
- Study relative cost analysis (i.e. cost #1 vs. cost #2 if x, y, z changes are made) in a short amount of time.
- Propose new and innovative energy design ideas to skeptical critics.

The Integrated Design Lab—Bozeman has created a series of four modules that teach the basics and some advanced features of eQUEST. Designed for architects, this module series explains everything from simple to more complex features, and gives users more tools for the building profession.

The modules will first walk you through the use of the Schematic Design Wizard, a wizard designed to be used in the earliest stages of design when little detailed information is known about the systems of the building. The Energy Efficiency Measure Wizard, a tool for analyzing multiple options for a model at once, is also covered. An introduction to the Design Development Wizard follows for when you are prepared for more specific modeling control. Then eQUEST's Life-Cycle Cost Analysis features are demonstrated. Finally, an in-depth explanation of how to perform Parametric Runs and use the Detail Data Edit mode is presented, providing the user with access to the more advanced features of eQUEST.

For more information concerning eQUEST and a free download, visit: http://www.doe2.com/equest/.

THE TRAINING MODULES

Since eQUEST is a powerful vast computer program, four training modules have been created for the purposes of teaching eQUEST to the interested user. Each module builds on the information presented in the previous module and all of the modules include an example at the end that the user can recreate by following step-by-step instructions. Each module is explained in more detail below:

- **Module 1: Basic Energy Modeling and Comparative Runs**
  This module gives an overview of some of the very basic functions of eQUEST and teaches the user how to set up a simple energy model based on schematic design information. It then explains how to use the EEM Wizard to create multiple scenarios for portions of the model that can be compared in order to provide the user with data as to which scenario is the best for the building.

- **Module 2: Intermediate Energy Modeling**
  This module teaches the user how to navigate the DD Wizard and create a more comprehensive energy model for simulations. The module highlights some of the main features of this wizard and walks the user through creating a model from scratch, as well as updating a previously created SD model.

- **Module 3: Life-Cycle Cost Analysis**
  This module explains what a Life-Cycle Cost Analysis is and how to perform such an analysis using eQUEST.

- **Module 4: Advanced Energy Modeling and Complex Comparative Runs**
  This module shows the user how to modify the properties of an energy model to suit the specific needs of the project. The Detailed Data Edit mode is explored and Parametric Runs are created in order to perform more specific energy analyses.

MODULE 3:
Life Cycle Cost Analysis

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EXECUTIVE SUMMARY

The Integrated Design Lab—Bozeman has created a series of four modules that teach the basics and some advanced features of eQUEST. Designed for architects, this module series explains everything from the simplest to the more complex features, and gives users more tools for the building profession.

Module 3 in the series investigates Life-Cycle Cost Analysis (LCC analysis or LCCA) and explains how to perform such an analysis in eQUEST. The module first discusses the research process for this investigation. Then the findings of the research are reported, including basic information about LCC analysis: what it is, why it should be used, and how it should be performed. Several LCCA programs are analyzed and the LCC analysis function of eQUEST is recommended to perform LCC analysis. A detailed step-by-step explanation of how to use eQUEST's LCC analysis component is also included. A glossary of LCC analysis and related economic acronyms and terms can be found in the Appendix section of this module.

For more information and to download eQUEST, visit: www.doe2.com.

NOTE
This module assumes that the user has a working knowledge of eQUEST and its EEM Wizard.

Some things to ALWAYS keep in mind while working in eQUEST:

- **Work in a linear fashion.** The dynamic defaults in the program automatically change information further in the program. If you are working backwards, this may be information you may have already customized. Working linearly from start to finish and avoiding back stepping can guarantee that your user input stays put!
- **Save frequently.** Like any computer program, some newer versions of eQUEST have a tendency to crash at inconvenient moments. Make sure you are prepared.
- **Keep it simple.** There are some details in your building design that will have little or no impact on energy performance. Leave them out!
- **Analyze the results with caution.** Always check the reports for numbers that seem inappropriate under the circumstances. While the computer is a valuable tool, it does not understand the output it is producing. Use your knowledge to recognize potential inaccuracies!
- **Update your version.** There are several versions of eQUEST, and each have some variations. It is a good idea to update your version of eQUEST to the most current version. For the purposes of this and all subsequent modules, we will be using eQUEST version 3.61.

RESEARCH PROCESS

The course of this research began with some basic internet searches for information about Life-Cycle Cost Analysis. *"User-friendly" Life-Cycle Costing: The BLCC Procedure in an Easy-to-Use Spreadsheet* by Marlin S. Addison was also used as a starting point for research. From these points, several directions were taken for research: websites for The National Institute of Standards and Technology (NIST), The Federal Energy Management Program (FEMP), and other LCC analysis resources were explored; PDFs of LCC analysis training and explanation were perused, and free LCC analysis software was downloaded and tested. Basic economic books were referenced to help gain an understanding of the economic concepts inherent in LCC analysis. A list of these resources is included in the Appendix of this module.

After much research and experimentation with programs, the eQUEST LCC analysis feature was chosen as IDL—Bozeman's preferred LCC analysis software. Further research was conducted to ensure a thorough understanding of all of the functions and related terms in the software. Resources that supply the necessary fuel and discount rates were sought out for future reference.

WHAT IS LIFE-CYCLE COST ANALYSIS AND WHY SHOULD ARCHITECTS USE IT?

Life-Cycle Cost Analysis (LCCA or LCC analysis) is the analysis process that looks at the first construction cost of a building and compares that cost to a building life-cycle cost, a cost that includes the initial, operation, maintenance, and replacement costs inherent in building use over time. This type of analysis is not to be confused with a simplified payback analysis that only looks at the payback period of a single building feature without taking into account the time-value of money or future energy costs and savings. LCC analysis is meant to raise awareness about energy usage and efficiency, construction costs and methods, and other general savings that can be gained when the time and money are invested upfront in a building.

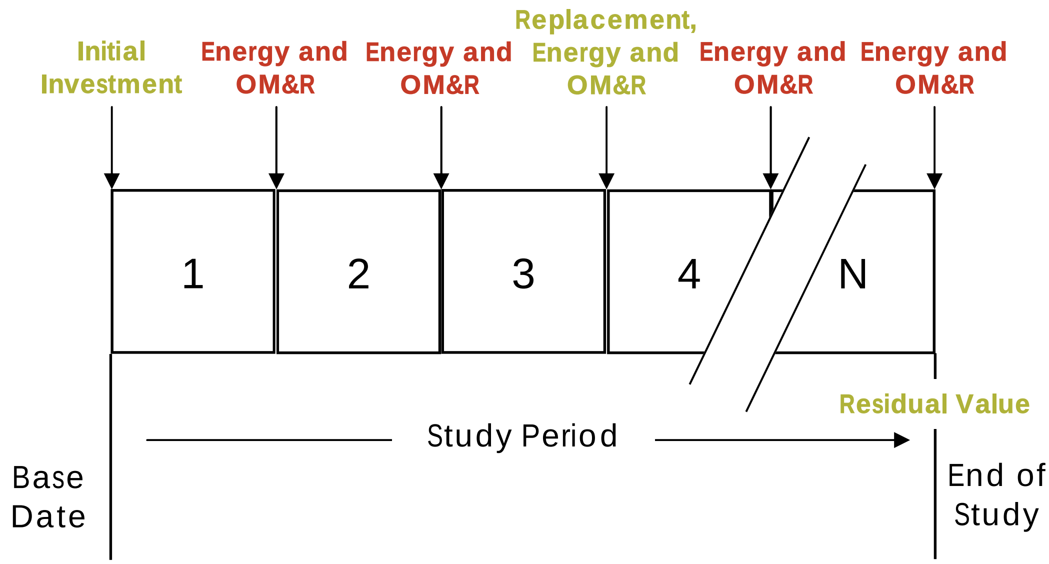
It is important for architects to understand the basic concepts of LCC analysis for several reasons. First, architects need to be able to communicate with a client not just about the initial building costs, but also about the cost of operating and maintaining a building. Most developers looking to sell the building in a short time for a profit will not be interested in this discussion. However, clients that are planning on owning the building for a longer period of time will appreciate a more holistic—and over time money-saving—approach to this part of the design process.

An LCC analysis can be the numerical ammunition an architect needs to prevent detrimental value engineering of project features. Many clients and value engineers do not realize that some of the architectural features of buildings serve multiple purposes, and in some cases save energy and decrease the operational expenses of a building. By simply removing an exterior window overhang or a lightshelf, an owner may save initially in construction costs, but such features are usually included as energy-saving components that are meant to decrease utility bills and increase the comfort and productivity of occupants. An owner should be provided with information that helps them see how certain architectural features that add to the initial cost of the building actually save money and pay for themselves in the future. Often LCC analysis and an awareness of energy-saving options in a design can save money both in the first cost and in the long-term investment. The time spent in the initial design process to perform such an analysis can save thousands of dollars in the future.

LCC ANALYSIS METHODOLOGY

While the theories behind LCC analysis are extensive and at times challenging to comprehend, there are some basic principles that anyone performing an LCC analysis should understand.

- **Start early in the design process.** It is important to begin an LCC analysis early in the design process of a project for several reasons. It helps make the design team and the client aware of the alternatives that can contribute to energy efficiency and occupant productivity early in the project. Since LCC analysis looks at spending more money upfront, it alerts the client to the possible need of raising more initial capital for the project. It ensures that energy- and money-saving alternatives can indeed be implemented in the project. Unless alternatives are considered early in the design process, it becomes unlikely after the architects and engineers have designed the building that changes will be made.
- **LCC analysis is NOT Simple Payback analysis.** As stated before, an LCC analysis is not a Simple Payback analysis (SPB). An SPB analysis only looks at the number of years it would take for a design feature to pay for itself in energy savings. Because different options may have different payback periods and maintenance and repair costs, you cannot use SPB results to compare alternatives. However, an LCC analysis takes all of these things into account by allowing for multiple operations, maintenance, and repair (OMR) inputs for different alternatives, and then setting a standard study period within which all of the alternatives have the opportunity to pay for themselves.
- **LCC analysis requires that you choose a study period.** An LCC analysis is performed for a given study period. A study period is the length of time in years from the date of occupancy for which the energy, operation, maintenance, repair, and replacement costs are added to the first cost of the project. A study period can be of any length. If your project comes under the Federal Energy Management Program (FEMP), then your study period can be up to 25 years from the date of occupancy. If the project is a large building, construction time can be added to the study period. This time is not included in the 25-year maximum. A study period is typically not arbitrary. It can relate to the length of time that an owner will occupy a building or the life-cycle of an HVAC system. For example, if an owner is looking at retrofitting an HVAC system that currently has a predicted life of 10 years and a new system will last 15 years, then the study period for the analysis should be 15 years. If there are no factors dictating the study period, then choose 25 years, as this is eQUEST's maximum study period.
- **Do not overcomplicate the analysis by including costs that will not affect the results.** Due to the economic nature of an LCC analysis, it can quickly become a complicated process. This makes it important to eliminate "sunk costs" in the analysis. Sunk costs are those costs that are the same for every alternative and therefore do not affect the overall totals in the analysis. Only those costs that change for different alternatives should be included.
- **Cash-flow diagrams graphically show the use of money over time.** Several LCC analysis processes encourage the creation and use of a cash-flow diagram. While this type of diagram will not be used in our analysis, it is important to be familiar with it, as you may find that sketching one before you begin will help you. Basically the diagram depicts where the initial, annual, and non-annual costs for the project fall during the study period. What is emphasized with the cash-flow diagram is the importance of keeping the analysis as simple as possible. Costs that affect every alternative or are irrelevant to the study should not be included. The level of detail needed for the analysis should be determined by: the question that needs to be answered, the amount of information available, and the time you have to complete the analysis.



Cash Flow Diagram

- **Maintain cost-reporting consistency throughout the analysis.** Costs in the project need to be recorded at consistent times of the year. Typically annually recurring costs are reported at the end of the year and non-annually recurring costs are reported at the time that they are paid. Some LCC analysis programs have the option of reporting costs in the middle or at the end of the year, and give the option for adding months to the time period. Others simply report annual costs, making the process a little less involved.
- **Do not test an alternative beyond the budget range of the client.** If the first cost of an investment is already too expensive, then it should not be included in the project and LCC analysis.
- **Maintain assumption consistency throughout the analysis.** Assumptions for the project and alternatives need to be maintained throughout the analysis. For example, if multiple types of glazing are being analyzed for energy efficiency in a project and an estimated percentage of windows is assumed, keep that percentage the same throughout the analysis. If it is necessary to analyze the cost and energy efficiency of multiple window percentages, then use this as a variable and keep everything else constant. Otherwise there will be too many variables in the analysis and it will be hard to determine which one saves the most money.
- **On-site energy generation still costs money.** Where on-site energy generation will be used in a project, it is important to incorporate the cost of the generation and distribution in the project. Otherwise the analysis will produce unrealistic results that will be undeliverable to the client.
- **There is more to life than numbers.** Sometimes intangeable factors need to be considered in the analysis. It is best to keep them in mind throughout the analysis because they might dictate a certain alternative choice over another seemingly more cost-efficient choice. For instance, while it may be cost effective to add daylighting windows on the south side of a building, it may not be desirable if the south side of the building faces a graveyard.
- **A significant component in most projects is the productivity of the people using the building.** Some LCC analysis programs incorporate occupancy satisfaction and productivity into the analysis. eQUEST does not do this, but it is important to consider as a nonquantifiable factor along with the analysis numbers.

REAL DISCOUNT RATE VERSUS NOMINAL DISCOUNT RATE ANALYSIS

LCC analysis deals with money and the changing value of the dollar over time due to inflation. Because of this, it is necessary to adjust the monetary amounts analyzed in a project to a consistent value. Discounting is the process of adjusting monetary values to a standard level for a certain year. Typically the results of an LCC analysis, regardless of how the values are inputted, are reported using present value (PV) dollars. Present value dollars incorporate the time-value of money and express results in the current (base year) value of the dollar.

An LCC analysis can be performed using either nominal inflation (discount) rates with current dollar values or real inflation (discount) rates with constant dollar values. The discount rate determines if the values are entered in current dollars or constant dollars. Either way the analysis should produce the same results. Make sure your numbers and rates match. ***REMEMBER: Nominal—Current; Real—Constant***. The following points briefly discuss which rate type should be used based on the project.

- **Constant dollars** require reporting everything in today's prices (the prices of the base year). For example, glazing would be reported at the price that it costs today regardless of the purchase year.
- To use **constant dollars**, which do not include inflation, use **real discount rates**.
- **Current dollars** require reporting everything at the price that it is at the time it is being reported. For example, glazing purchased this year would cost less than glazing purchased ten years from now and should be reported as such.
- To use **current dollars**, which include inflation, use **nominal discount rates**.
- Use nominal discount rates with current dollars if you have major tax considerations or if it is mandated by the project funding (Energy Savings Performance Contracts, etc).
- The annual supplement to Handbook 135 lists real discount fuel rates.
- **If you're not sure what to use, use constant dollars and real discount rates...it's easier. You will report each dollar amount as if you will be paying for it today.**

Note: If you choose to use current dollars with nominal rates, see page A7 of the Appendix of this module for more information and conversion instructions.

Energy inflation rates are different from the general rate of inflation. Typically inflation rates change from month to month and year to year. The National Institute of Standards and Technology (NIST) annually publishes a supplement to Handbook 135 which supports the federal life cycle costing methodology by updating energy price projections and discount factors described, explained and illustrated in NIST's Handbook 135. This supplement provides fuel inflation rates for up to a 30-year period. A copy of the most recent supplement can be found at http://www1.eere.energy.gov/femp/program/lifecycle.html. All non-energy items in the analysis should be adjusted using the general rate of inflation for consistency. ***All of the rates in the annual supplement to Handbook 135 are reported as real discount fuel rates.***

LCC ANALYSIS PROGRAMS

There are many programs that perform LCC analysis, several of which are free to download from the internet. The following is a list of programs investigated for this module with a brief explanation of each and a link to a website where they can be downloaded:

- **BEES 4.0d:** This is a program created by NIST that looks at project materiality. The most recent version was released in July 2007. While it incorporates the embodied energy of materials (how much energy it takes to produce and transport a particular material to a construction site), the options in this program are very limited. The reason for this is companies have to pay to be incorporated into the program listings. This limits the product choices a designer can analyze. Also the user can only choose from a few cities for the analysis. It displays graphs very quickly but the graphical user interface is not entirely intuitive. Overall, the program was not designed to easily perform the type of energy-efficiency LCC analysis we are trying to achieve here. (http://www.bfrl.nist.gov/oae/software/bees/download.html)

- **BLCC5.3:** This program was created by OAE/BFRL/NIST and directly correlates with the Handbook 135 methodologies, as well as other government documents and standards on LCC analysis. It is a straightforward program that allows for many alternatives to be analyzed for a given project. However, the program can become complicated if one tries to explore all of the options it provides. (http://www1.eere.energy.gov/femp/information/download_blcc.html)

- **Energy eVALUator:** This program comes from Energy Design Resources and functions as a simple LCC analysis program. The wizard asks for basic information in a simple format. It allows you to add several alternatives and compare them to the base case. It also quickly performs the analysis and displays results in charts and graphs that are easy to read. One drawback to this program is that it does not include Savings-to-Investment (SIR), Adjusted Internal Rate of Return (AIRR), and Discounted Payback (DPB) analyses. (http://www.energydesignresources.com/resource/131/)

- **User-Friendly BLCC Analysis:** This is an Excel spreadsheet version of the LCC analysis in eQUEST. It was designed to clarify the LCC calculations that eQUEST (see next point) performs in the background. The inputs are basically the same as the information needed for eQUEST and results can be viewed in the form of graphs and charts that are on separate tabs in the spreadsheet. (www.doe2.com)

- **eQUEST:** This program comes from the Department of Energy and is a shell for the DOE-2 energy calculation engine. It is a comprehensive program that performs basic and advanced LCC analysis with minimal user input. It also has clear simple results displayed as charts and graphs for both energy analysis and LCC analysis. (www.doe2.com)

The eQUEST LCC analysis program has been chosen as our analysis engine because it automatically imports the energy usage data and utility costs for a project directly into the LCC calculations. While some of the other programs mentioned here have very good user interfaces, an analyst would have to separately calculate and input all of the utility costs for a project. eQUEST allows us to simplify things and skip this step.

LCC ANALYSIS DECISION TYPES AND LEVELS OF ANALYSIS

Literature on LCC analysis describes five different types of decisions that can be made by using LCC analysis. While a basic LCC analysis will help with most of these decisions, if a more thorough analysis is needed, it is important to know which decision you are trying to make so that you use the appropriate advanced analysis.

As with any project it is important to identify a problem. These decision types will help identify if you need to perform an LCC analysis:

- **Accept/Reject:** LCC analysis can help determine if a potential building design option is cost-effective. This type of decision is a **do or don't do for one option**. For example, a client might be exploring the option of retrofitting light fixtures in an office building. This decision determines whether or not the retrofit will be worth the expense. The retrofit could happen or not—it could be accepted or rejected based on the analysis.
- **Optimal Efficiency Level:** This analysis looks at **several component alternatives** for a building design and **chooses the most long-term cost-effective alternative**. For example, a client is interested in installing the most energy-efficient windows in a new project but has four window companies from which to choose. An LCC analysis would help determine which choice has the optimal efficiency level.
- **Optimal System Selection:** This analysis is similar to the Optimal Efficiency Level, but looks at **building system alternatives as opposed to components**. It determines the most long-tem cost-effective system alternative. For example, an architect who is considering several different HVAC systems for a larger project needs to determine which system is the most efficient based on initial and long-term costs.
- **Optimal Combination of Interdependent Projects:** This analysis looks at several building systems at once and **chooses the most appropriate combination of systems and alternatives** for the best long-term cost-effective combination. For example, if an energy conscious owner wants to build a LEED-certified building, an architect could investigate multiple combinations of systems (such as windows, light fixtures, HVAC systems, etc.) to determine the optimal combination of energy efficient products that will help achieve the LEED rating.
- **Prioritization of Independent Projects:** A basic LCC analysis will not give an answer for this type of decision because it looks at **multiple projects** and **determines which project is the most cost-efficient project to fund**. Most of the time this decision will not be used because it is primarily designed to facilitate the distribution of funding for federal projects. For example, the government has three projects that it wants to fund; however the current budget will only pay for two. LCC analysis can determine which projects are more cost-efficient and help the government decide which ones to fund.

Once you determine which decision you are trying to make with an LCC analysis, you can choose how extensive the analysis needs to be. Basically there are two levels that we will look at for our LCC analysis:

1. A basic LCC analysis—This looks at the basic life-cycle costs of a project and alternatives over the study period.
2. Net Savings (NS), Savings-to-Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR), and Discounted Payback (DPB) analyses—These numbers and ratios provide more insight into some specific cost interpretations of the LCC analysis.

- **Basic LCC Analysis:** This bottom-line analysis simply calculates the life-cycle cost of the base case and all of the alternatives. Some minimal comparative information is provided about the alternatives.
- **Net Savings (NS) Analysis:** This analysis looks at the difference between the alternative case savings relative to the base case. A positive NS value for an alternative is a good investment. This type of analysis can be used for determining which alternative is the most cost-effective overall.
- **Savings-to-Investment Ratio (SIR) Analysis:** Similar to a cost-benefit ratio, this analysis looks at the relationship between costs and savings for each alternative. Sometimes an LCC analysis will show that two alternatives have the same savings. However, this may not be the only consideration. SIR takes the analysis a little farther, creating a ratio that communicates the relative benefit of each alternative. The process results in ratios; alternatives with an SIR greater than 1 are generally cost-effective. Caution must be used with this analysis as only the incremental SIRs incorporate energy efficiency among alternatives.
- **Adjusted Internal Rate of Return (AIRR) Analysis:** This analysis expresses energy efficiency and cost effectiveness as a percentage. The percentage represents the theoretical return rate of an alternative as compared to the base case. Typically a positive alternative is one whose AIRR is greater than the minimum acceptable rate of return (MARR). This analysis automatically redirects savings into an investment and calculates that investment's rate of return. This analysis is different from a standard Internal Rate of Return (IRR) analysis in that an AIRR incorporates the time-value of money into the reinvestment, using a discounted return rate as opposed to the calculated rate that an IRR analysis would use. The AIRR, while still missing some crucial information, looks at the project in a broader sense and allows you to incorporate more variables into the analysis. It is still important to remember such things as risk and project value when looking at this number.
- **Discounted Payback (DPB) Analysis:** Similar to a Simple Payback analysis, which looks at the length of time it would take for an alternative investment to pay for itself, a DPB discounts each cost to equal the present value of money before it calculates the payback period. By incorporating the time-value of money, DPB analysis gives a more realistic picture of the time it would take for an alternative investment to pay for itself in energy savings.

Fortunately the eQUEST LCC analysis module computes all of these for you. However it is up to you to decide how much information you need to include in the analysis. In some cases a minimum amount of information will provide you with the necessary LCC analysis results to help facilitate a decision. At times, a more in-depth study is necessary and may require more input.

HOW TO PERFORM AN LCC ANALYSIS USING eQUEST—OVERVIEW

The following is an overview of the step-by-step process of how to perform an LCC analysis in eQUEST. This analysis will use eQUEST's LCC analysis function. For your convenience, the Integrated Design Lab—Bozeman has created a set of forms for you to fill out to help facilitate your analysis. These forms can be found in the eQUEST Forms section of this module. For this analysis you will need the **EEM & LCC Project Information Form** and the **EEM Runs Form**.

The following pages walk you through each of these steps in detail.

1. Build an energy model of the project in eQUEST. (Refer to Module 1 of this series for instruction on how to do this.)
2. Determine which factors need to be examined in the analysis, and using the **EEM & LCC Project Information Form**, gather the necessary information about the project.
3. Add EEM (Energy Efficiency Measure) runs to the eQUEST model. Use the **EEM Runs Form** to record your inputs. (Refer to Module 1 of this series for instruction on how to do this.)
4. Run the eQUEST building simulation.
5. Analyze the LCC analysis results and make adjustments accordingly.

Keep in mind that since you are performing an eQUEST LCC analysis, most of the information needed for the analysis will be inputted when the energy model of the building is first created. Once you finish inputting data, you will close the EEM Wizard window and go to the Simulation Results area where you will find your LCC results displayed in several forms. This can be confusing at first, especially if you are anticipating inputting number after number and then expecting to watch eQUEST run a hefty slow set of calculations. In most cases, the program runs all of its LCC calculations in the background, leaving you free to continue adjusting your energy models as well as your cost analysis models.

In this tutorial we will use the EEM Wizard to input all of our LCC information. There is another way to input this information in eQUEST. To see this alternative method, look at Appendix A. We will be covering this method more in depth in Module 4 when we discuss parametric runs.

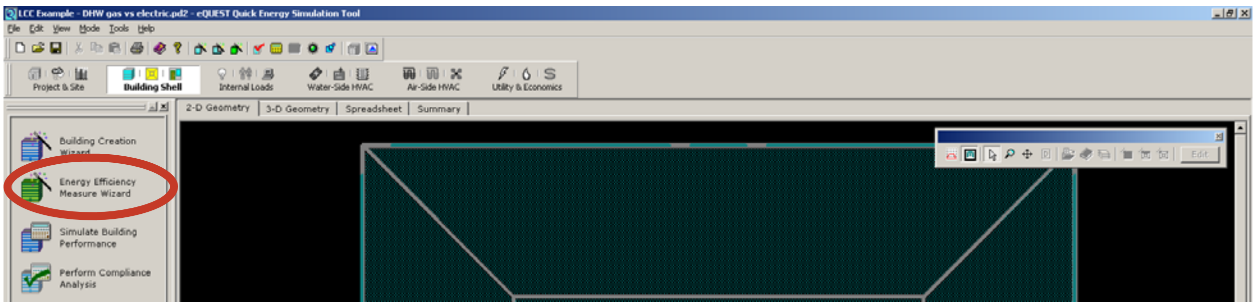
Remember to keep this analysis simple and to only include those costs that are pertinent to the analysis. Including extraneous costs that are the same for every alternative will only complicate the analysis. You can always go back and adjust analysis data, or even create more EEM runs to compare.

HOW TO PERFORM AN LCC ANALYSIS USING eQUEST:

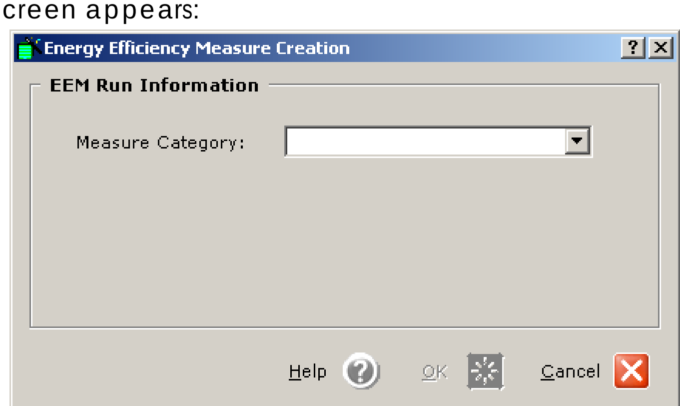
1. Build an energy model of the project in eQUEST. (Refer to Module 1 of this series for instruction on how to do this.)
2. Determine which factors need to be examined in the analysis, and using the **EEM & LCC Project Information Form**, gather the necessary information about the project.
   - The top part of the form allows you to identify the project, architect, and location.
   - Record the design features that need to be analyzed on the middle part of the form. This helps focus your analyses in eQUEST. Examples: window shades, skylights, boiler efficiencies, etc.
   - The bottom portion of the form allows you to record the LCC data that you will use for the project:
     - **Project-wide LCC Data**
       - **DOE/FEMP Fiscal Year**: the year to be analyzed
       - **Number of Analysis Years**: the study period (see page 5 of this report for more information)
       - **Fuel Price Esc Rgn**: the region the project is located in (Montana = WEST)
       - **Analysis Sector**: choose COMMERCIAL or RESIDENTIAL or INDUSTRIAL
       - **Second Fuel Type**: Typically NATURAL GAS (other choices: NONE, LPG, DISTILLATE OIL, COAL)
     - **Uniform Price Escalation Rates**
       - Leave both unchecked to use the DOE estimated fuel escalation rates already incorporated into eQUEST.
       - If you check them you will have to input your own percentage. At times this is valuable, especially if you input 0.0% for both. This will show a Simple Payback analysis (a straight line) in the Life-Cycle Savings Graph Report which will tell you when an alternative will pay for itself.
     - **Marginal Income Tax Rates**
       - Unless you know these, accept the eQUEST defaults for each.
     - **Discount Rate Data**
       - *Unless you are positive that you need Nominal rates, change the eQUEST default to REAL. REAL rates let you input everything in today's dollars, or present value (PV) dollars.*
       - See page 7 for an in-depth discussion of Real vs. Nominal discount rates.
       - To use Nominal rates, see page A7 of the Appendix for more information on how to deal with your monetary inputs.
       - Accept the default of After-Tax unless you have a particular project need.
       - Accept the eQUEST inflation and discount rates if you are unsure of what they are. To find the most recent rates, refer to the Introduction in *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis—April 2008* (Supplement to Handbook 135 of current year) for the General Inflation Rate and the Real/ Nominal Discount Rate. This can be found at the NIST website (http://www1.eere.energy.gov/femp/program/lifecycle.html.)
     - **Baseline Run LCC DATA**
       - **First Cost** is the initial price you will pay for the design feature(s) you are analyzing. For example, if your base case includes clear glazing and you are looking at changing it to tinted glazing for energy efficiency purposes, your first cost in this section would be the clear glazing cost.
       - **Annual Maintenance Cost** is the amount that you need to pay every year to keep up the feature that you are purchasing. For example, a boiler might have an annual maintenance fee.

- **Investment-Related Costs** are those costs that include replacement costs. For example, if you need to replace your baseline boiler after 10 years, you would mark the cost (in present-day dollars if using REAL discount rates) of the boiler as an expense at 10 years.
- **Operations-Related Costs** are those costs that include non-annual maintenance. For example, perhaps a set of filters needs to be changed once every 3 years for an HVAC system. Record this cost (in present-day dollars if using REAL discount rates) as an expense at years 3, 6, 9, 12, etc.

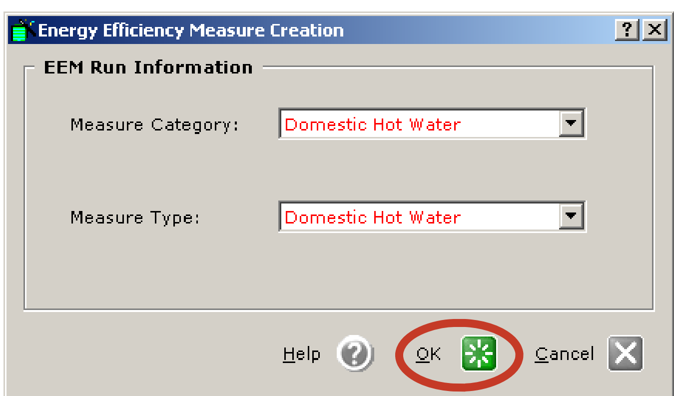
3. Add EEM (Energy Efficiency Measure) runs to the eQUEST model. Use the **EEM Runs Form** to record your inputs.
   - From the main eQUEST screen, click on **Energy Efficiency Measure Wizard**.



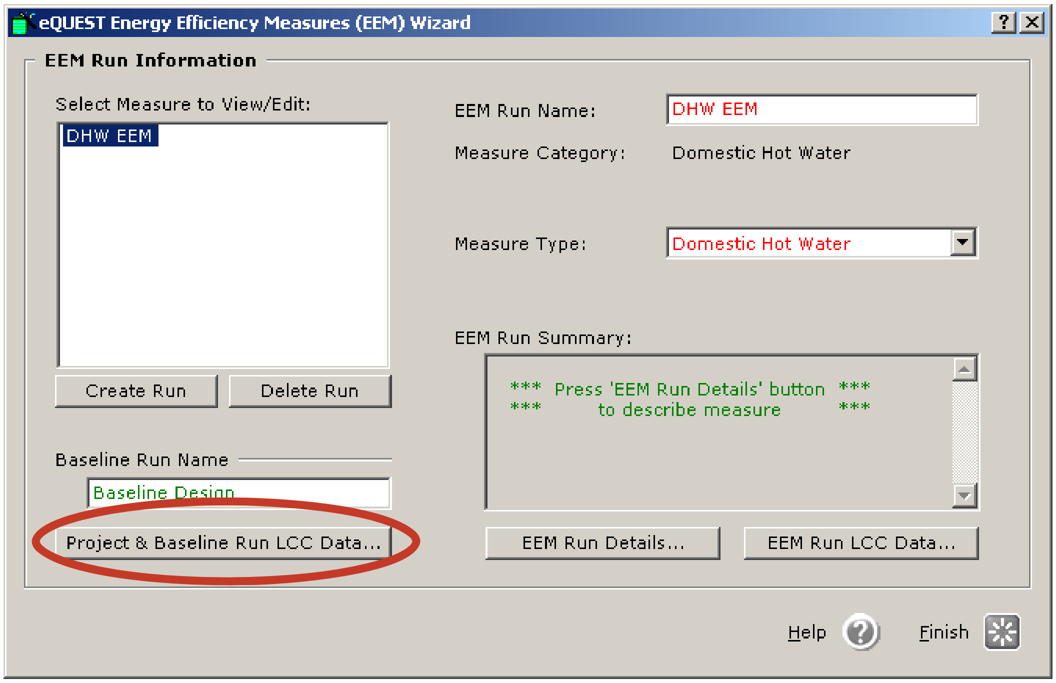
   - The following screen appears:



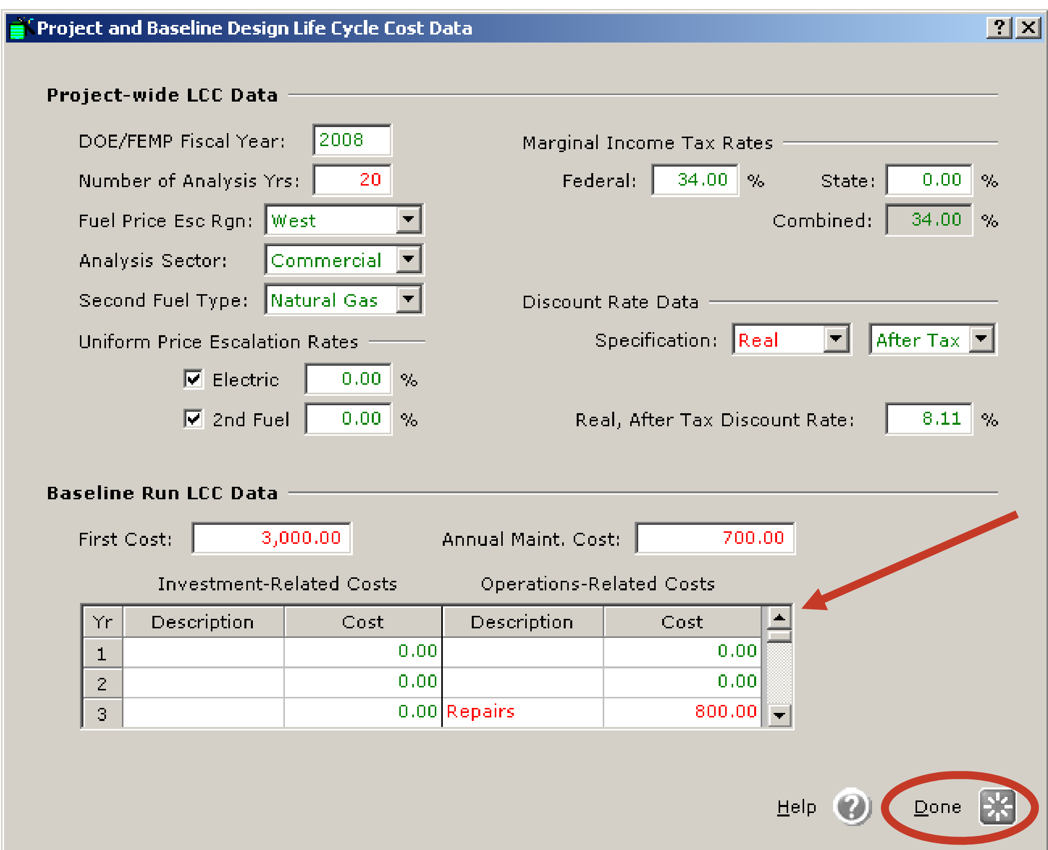
   - Select Domestic Hot Water for both **Measure Type** and **Measure Category** and click **OK**.



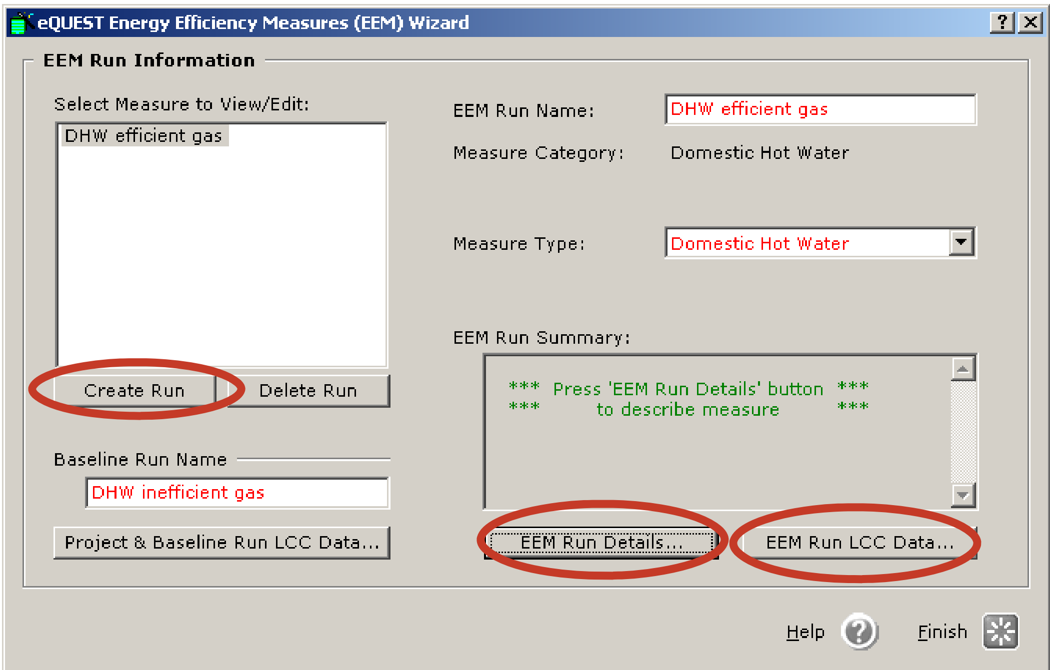
- Click **Project & Baseline Run LCC Data**.



- Input the information you gathered on your **EEM & LCC Project Information Form** and click **Done**.

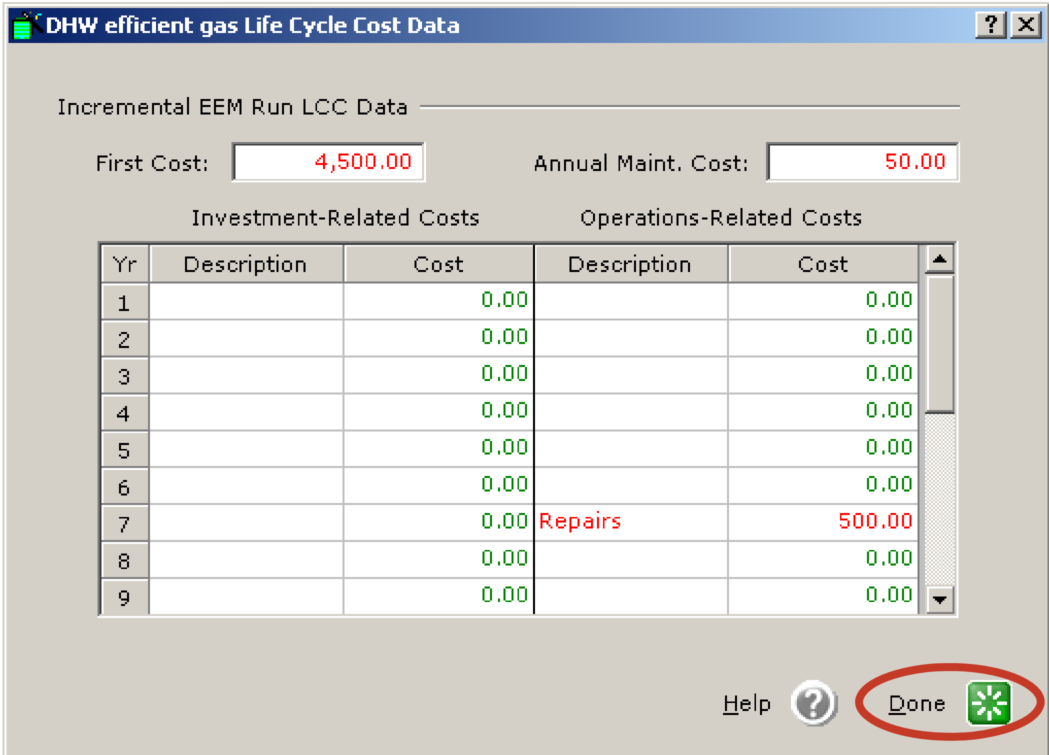


- Next, **create EEM runs**. (For more information on how to set up EEM Runs, see Module 1 of this series.) Use the **EEM & LCC Runs Form** to record your information for each run. Use the **EEM Run Details** button to input the design changes related to the EEM.
- Use the **EEM Run LCC Data** button to input the financial information related to the EEM.



- The following are a few tips to help with the LCC Data portion of the form:
  - Name your runs clearly. This will help when analyzing the results.
  - **<u>LCC Data</u>**:
    - This is just like the Project Baseline LCC Data information, just for each individual EEM Run.
    - **First Cost**: the cost of the EEM change
    - **Annual Maintenance Cost**: the yearly cost to maintain the EEM change
    - **Investment-Related Costs**: the non-annual costs not related to operations and maintenance (for example: replacements)
    - **Operations-Related Costs**: the non-annual operation, maintenance, and repair costs

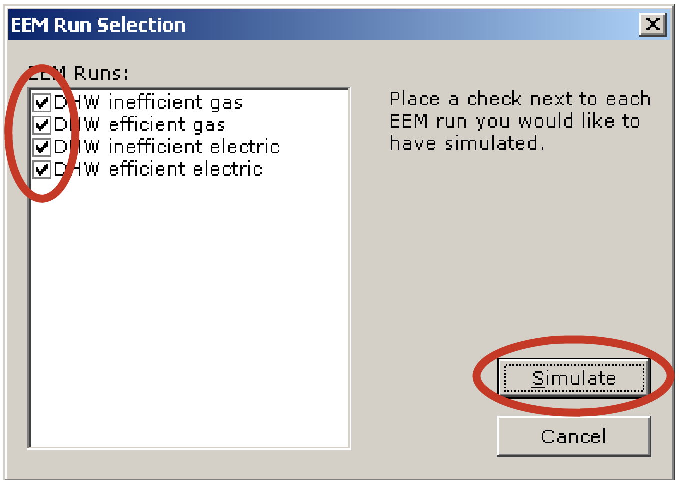
- The following is an image of what the **EEM LCC Data** screen looks like:



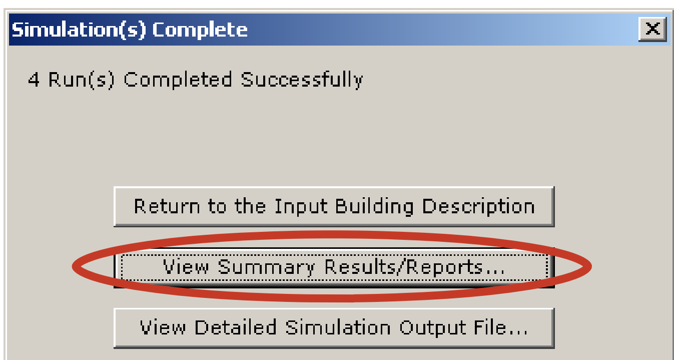
- When finished, click **Done** to exit the screen, and **Finish** to exit the EEM Wizard.

4. Run the eQUEST building simulation by clicking **Simulate Building Performance** on the left side of the screen.

- The following dialogue box will appear:

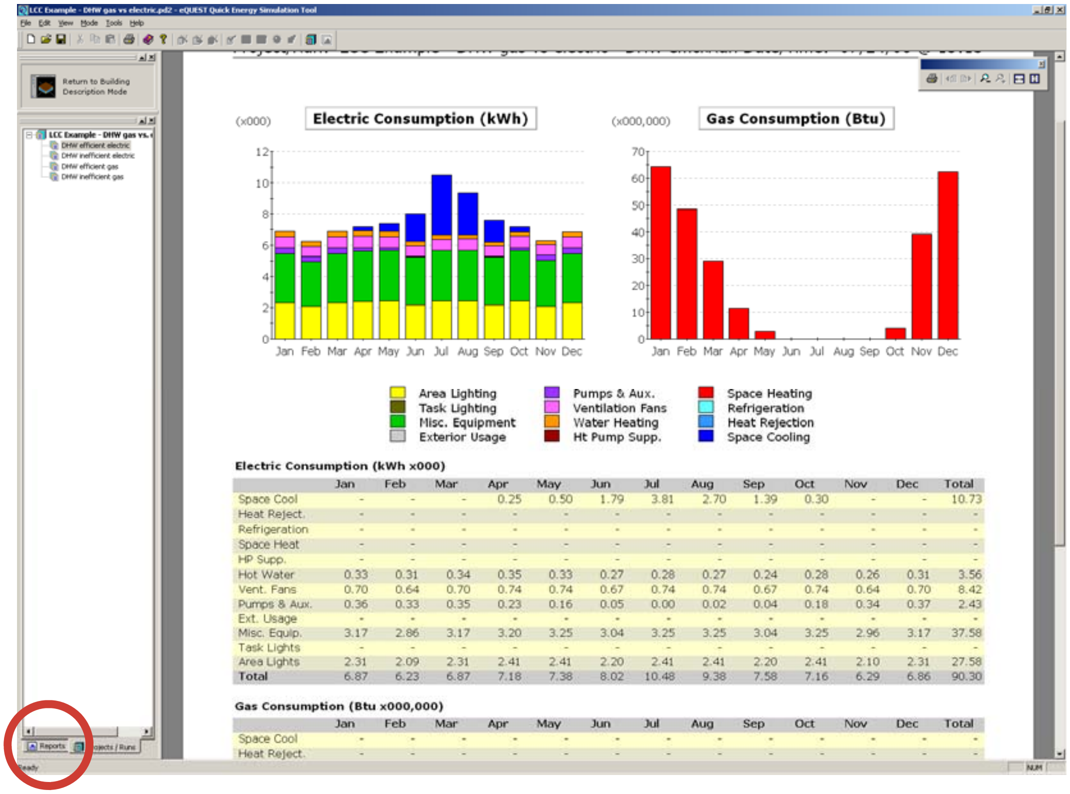


- Select the EEM runs that you would like to include in the LCC analysis by checking/un-checking the appropriate boxes.
- Click **Simulate**.
  - Sometimes eQUEST will ask you to save the file before you simulate the building performance because it cannot run an unsaved simulation file. Just click the **Save** option.
- When eQUEST is finished with the simulation, the following dialog box will appear:

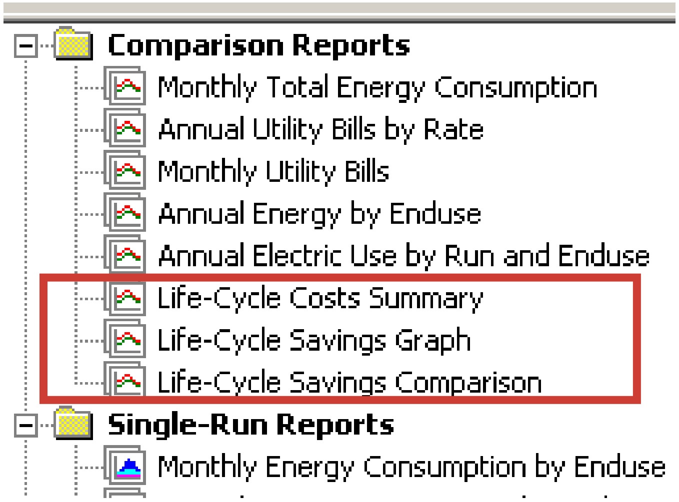


- Click **View Summary Results/Reports...**

5. Analyze the LCC Results and make adjustments accordingly.
   - The following screen will appear:



- Click the **Reports** tab in the bottom left part of the screen.
- The following list of reports will appear:



- We are concerned with the three Life-Cycle reports in the Comparison Reports folder.
- The next few pages discuss the information that you will find on the Life-Cycle reports.
- You can always go back to the EEM Wizard and adjust the LCC data, as well as create new EEM runs to use in the analysis.

WHAT THE eQUEST RESULTS TELL YOU

It is important when looking at the LCC analysis that you keep in mind the things that we have discussed in the beginning pages of this report. This is because LCC analysis is more of an art than a science. It requires being aware of many more factors than those that are incorporated into the quantitative data of the analysis (occupant satisfaction, risk, value, etc.) Simply looking at the numbers will not give you an accurate picture of the true nature of the analysis. As with any eQUEST analysis, be cautious and make sure the results make sense before you accept them. Sometimes simple mistakes can completely change the data.

The following pages discuss the LCC analysis reports that eQUEST generates. When reviewed together, they give a basic picture of the LCC analysis.

Life-Cycle COSTS Summary

This is the most important of all of the LCC reports. It shows the total LCC for each alternative as compared to the base case. Keep in mind that each monetary amount is reported in present value dollars. In other words, each total is given the current time-value of money (assuming that the base date of the analysis is the current year.) Up to eleven runs, including the base case, can be shown here.

The page is broken into three sections. The top section labeled **Life-Cycle COSTS Summary** shows the breakdown of the life-cycle costs for each alternative. The base case is displayed as the starting point of the analysis. The one-time, utility, and maintenance expenses for the first year and the overall study period are also shown.

The middle portion of the chart, titled **Incremental Life-Cycle SAVINGS**, compares each alternative to the previous run. The first alternative is compared to the base case. This is useful when comparing alternatives to each other individually. The order of the alternatives can be changed on the Projects/Runs tab (bottom left-hand corner of the screen—see eQUEST Module 1 for more information). Note that EEM runs that are defined as stacked will still be stacked in this report regardless of project run order. The LCC analysis results are compared to the base case on a run-by-run basis.

The bottom section, **Cumulative Life-Cycle SAVINGS**, reports the cumulative savings when EEM runs are stacked on top of each other. This information is useful when many different factors are being analyzed (window glazings, overhangs, HVAC systems, etc.) and it is important to determine which factor or set of factors is most cost-effective for the project. Keep in mind that any EEM runs that are set up as cascading runs will be calculated as such regardless of the order in which they appear here. However the LCC analysis results of each run are compared to the accumulation of all of the previous runs in this portion of the chart. The order of the runs can be changed on the Projects / Runs tab.

The most important set of values for the analysis can be found in the top right-hand part of the chart under **Total LCC PV$** as these values express the overall LCC costs for each alternative. The lowest alternative is most likely the optimal choice for the project. The graphs on the following pages present supplemental information about the analysis.

Life-Cycle COSTS Summary

Life-Cycle Costs Summary

Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Total LCC PV$
Life-Cycle COSTS								
Base	DHW inefficient gas	$3000	$5684	$11383	$83528	$700	$5137	$83285
Alt #1	DHW efficient gas	$4500	$5166	$11377	$83484	$50	$367	$79306
Alt #2	DHW inefficient electric	$0	$0	$11472	$84181	$0	$0	$73744
Alt #3	DHW efficient electric	$0	$0	$11464	$84123	$0	$0	$73693

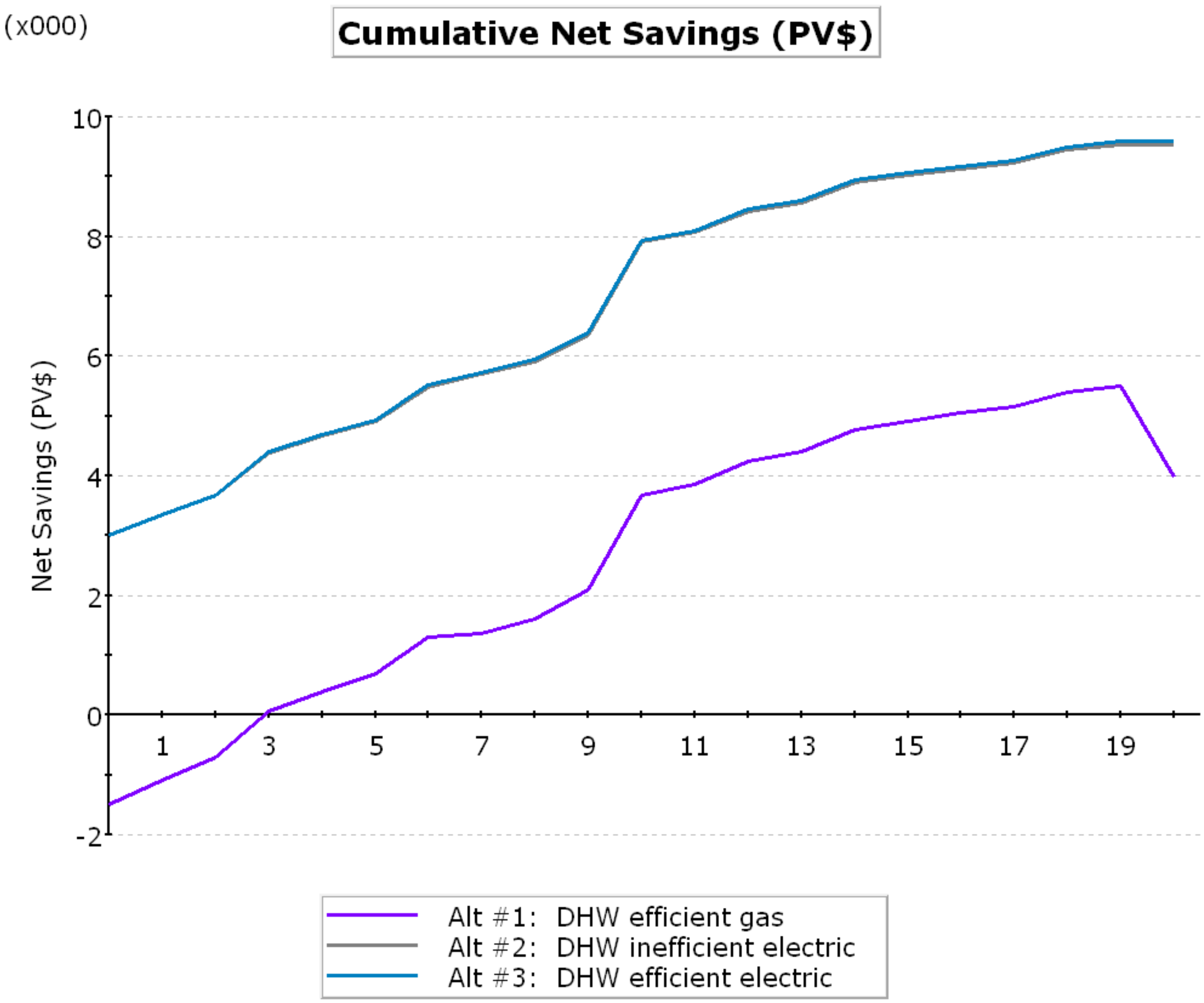
Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Net Savings NS	Simple Payback yrs	Discnt'd Payback yrs	Saving -to- Invest Ratio SIR	Adjusted Internal Rate-of-Return AIRR
Incremental Life-Cycle SAVINGS (negative entries indicate increased costs)												
Alt #1	DHW efficient gas	($-1500)	$518	$6	$44	$650	$4770	$3980	250.0	2.9	6.3	18.6%
Alt #2	DHW inefficient electric	$4500	$5166	($-95)	($-697)	$50	$367	$5562	47.4	0.0	n/a	n/a
Alt #3	DHW efficient electric	$0	$0	$8	$59	$0	$0	$51	n/a	0.0	n/a	n/a
Cumulative Life-Cycle SAVINGS (negative entries indicate increased costs)												
Alt #1	DHW efficient gas	($-1500)	$518	$6	$44	$650	$4770	$3980	250.0	2.9	6.3	18.6%
Alt #2	DHW inefficient electric	$3000	$5684	($-89)	($-653)	$700	$5137	$9541	33.7	0.0	n/a	n/a
Alt #3	DHW efficient electric	$3000	$5684	($-81)	($-594)	$700	$5137	$9593	37.0	0.0	n/a	n/a

Life-Cycle Savings Graph

This graph compares the overall net savings in present value dollars for up to ten alternatives. The graph also shows the breakeven point for each alternative as the place where each line crosses the x-axis. The number of years in the study period is displayed across the x-axis so the breakeven point is easily readable for every alternative. Looking at this graph is the fastest way of determining which alternative has the greatest life-cycle cost savings when compared to the base case.

If in your initial set-up of the analysis, you defined the Uniform Price Escalation Rates to both be 0.0%, this graph will appear as a set of straight lines and clearly tell you the SPB for each EEM run.

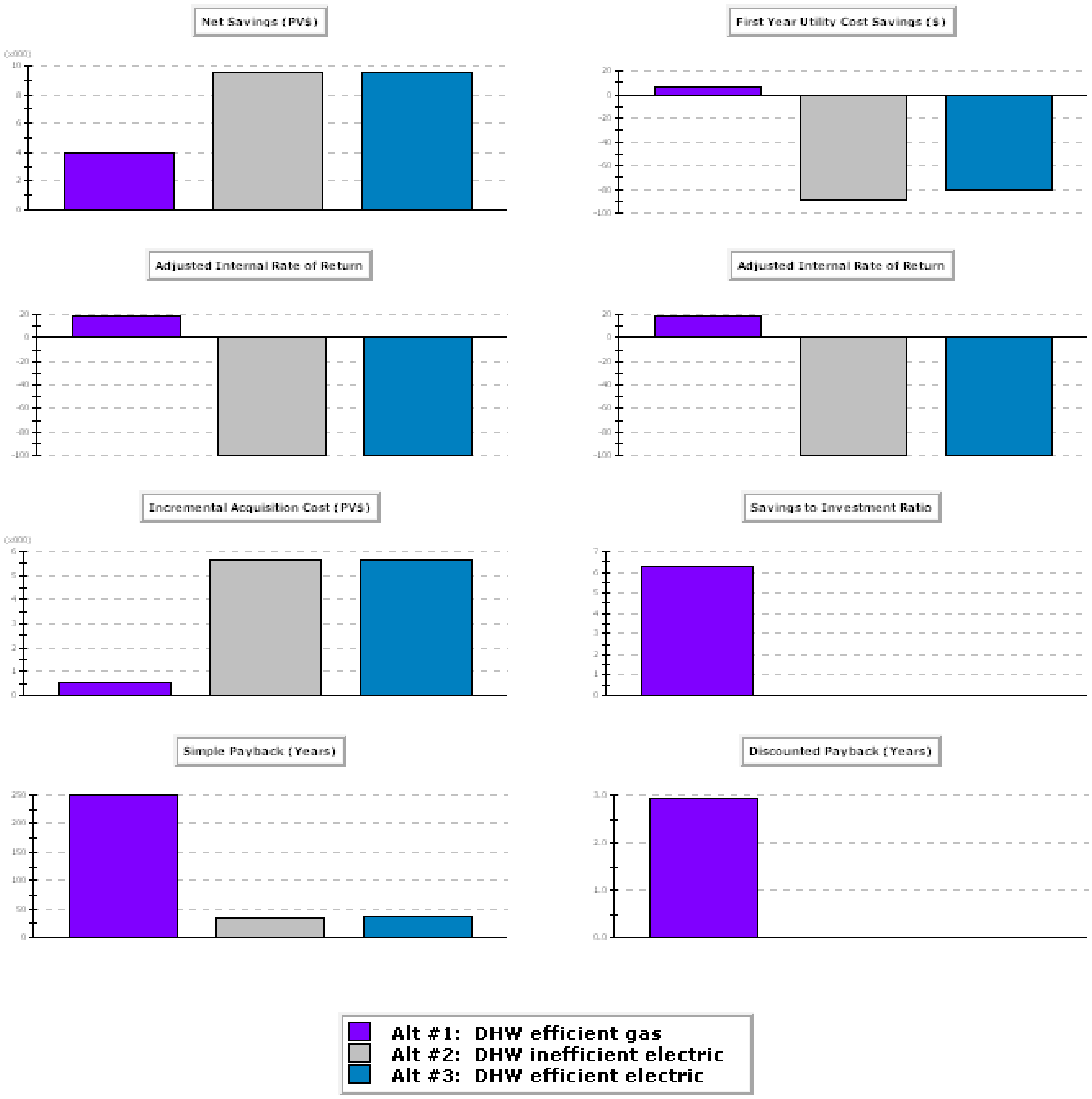
Note: Runs labeled 2 through 11 in the Projects / Runs tab will appear here. The base case (labeled run 1 in the Projects / Runs tab) will not appear in this chart. Also in this chart it is difficult to see that Alternative #2 is actually underneath Alternative #3. Subtle displays such as this are easier to see in the program.



Life-Cycle Savings Comparison

This set of graphs breaks down the LCC analysis into some specifics. This information comes from the Cumulative Life-Cycle Savings portion of the Life-Cycle Costs Summary Report. If your project analyzes multiple alternatives that are not dependent upon cumulative savings, then this report will most likely be meaningless to your analysis. If you are looking at stacking alternatives, then this report will give you some valuable information. It is also useful when analyzing multiple projects at once. eQUEST will leave some graphs blank if it has no information to display. In the two charts below where alternatives are missing, it is implied that there is no payback.

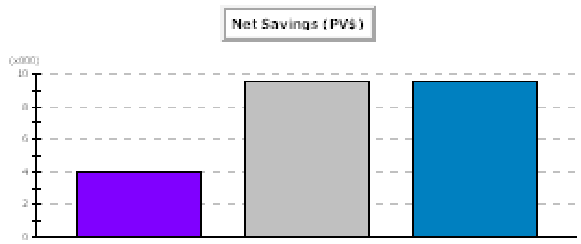
Note that once again only the EEM runs defined as 2 through 11 will appear here since every run is compared to the base case (run 1). The following pages discuss these graphs in depth.



Note: The base case will not appear in these charts.

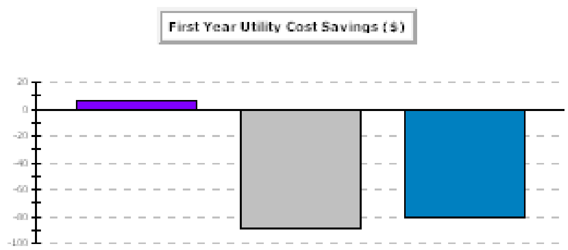
- **Net Savings (PV$)**

This graph shows what the overall savings for each alternative in the LCC analysis will be. It takes into account the time-value of money as well as the overall costs for each alternative. Basically it graphically depicts how much money you would save (or lose) compared to the base case ($0 net savings) if you chose one of the alternatives. It is reported in present value dollars which means that the amounts given are directly related to the current value of the dollar.



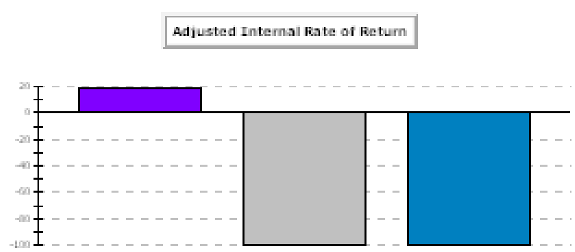
- **First Year Utility Cost Savings ($)**

This graph displays how much each alternative would save in utility costs during the first year as compared to the base case.



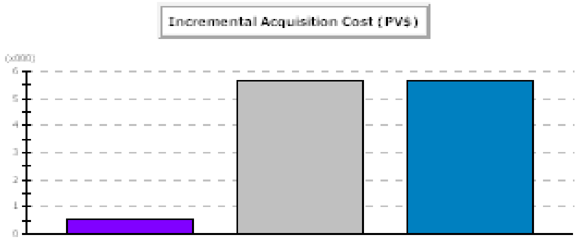
- **Adjusted Internal Rate of Return**

This graph comparatively shows each alternative’s rate of return as a percentage based on discounting. Keep in mind that this information does not incorporate such factors as risk and value. A –100% AIRR simply means that the AIRR could not be calculated.



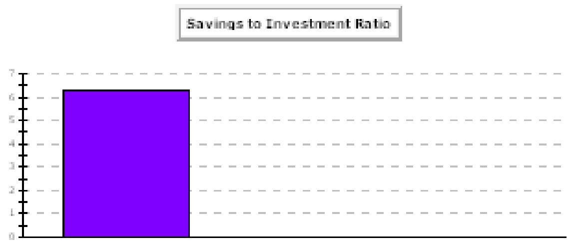
- **Incremental Acquisition Cost (PV$)**

This graph simply displays the information entered initially that pertains to the first cost of each alternative or project as compared to the base case.



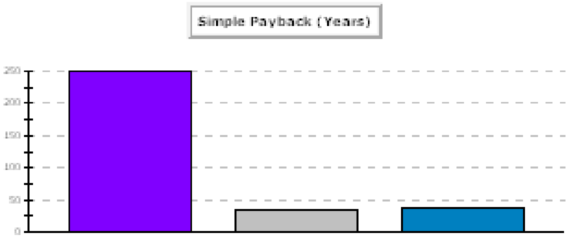
- **Savings to Investment Ratio**

This graph highlights the relative benefit of each alternative or project being analyzed. It makes more sense to use this graph when you are comparing multiple projects because of the type of cost-benefit savings that it shows. An SIR greater than one implies savings for the project. The larger the SIR, the greater the relative savings.



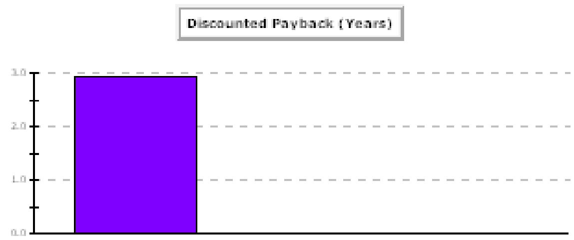
- **Simple Payback (Years)**

Simple Payback (SPB) is the most common economic analysis performed for projects today. It represents the ratio of the initial cost over the first year annual savings. It is typically not considered part of an LCC analysis because it does not take into account the costs of operation, maintenance, repair, energy usage, and the time-value of money. Not only that, in an analysis where diminishing returns are present, SPB will typically favor the minimum cost alternative which may not necessarily be the optimal LCC alternative. It can however be a good additional component in an LCC analysis.



- **Discounted Payback (Years)**

The discounted payback graph represents the Simple Payback of each alternative adjusted for the time-value of money. It gives a more realistic picture of the amount of time it will take for an alternative to pay for itself in energy savings.



APPENDIX

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HOW TO RECORD ALL OF YOUR COSTS FOR A NOMINAL DISCOUNT RATE

Nominal discount rates require that all costs are reported using current dollars, meaning that they must be adjusted for inflation according to the year in which they are reported. For example, glazing purchased in 2007 will cost less than glazing purchased in 2017. The cost of the glazing must be adjusted to take into account the general inflation rate.

A simple Excel spreadsheet, called **Present-Value Converter**, changes today's dollars into a future year's current dollars. It looks like this:

	A	B
1	**Present-Value Converter**	
2	The spreadsheet converts today's prices into future prices for nominal discount rate LCC analysis using current dollars.	
3		
4	**Variables:**	
5	Present Value (today's dollars)	$ 100.00
6	Year of future costs	5
7	General Rate of Inflation	5%
8	**Future Value =**	**$ 127.63**
9		

Simply enter today's dollar amount of the cost, the year that you want the cost to be converted to, and the general rate of inflation (found in the yearly Supplement to Handbook 135) and the Future Value will be calculated.

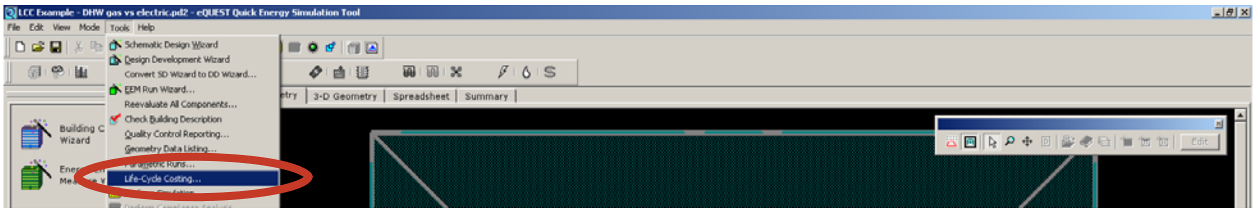
Make sure that you use this converter for all non-annual Investment-Related and Operations-Related Costs to ensure consistency between rates and dollar values.

<u>LCCA ALTERNATIVE METHOD IN eQUEST:</u>

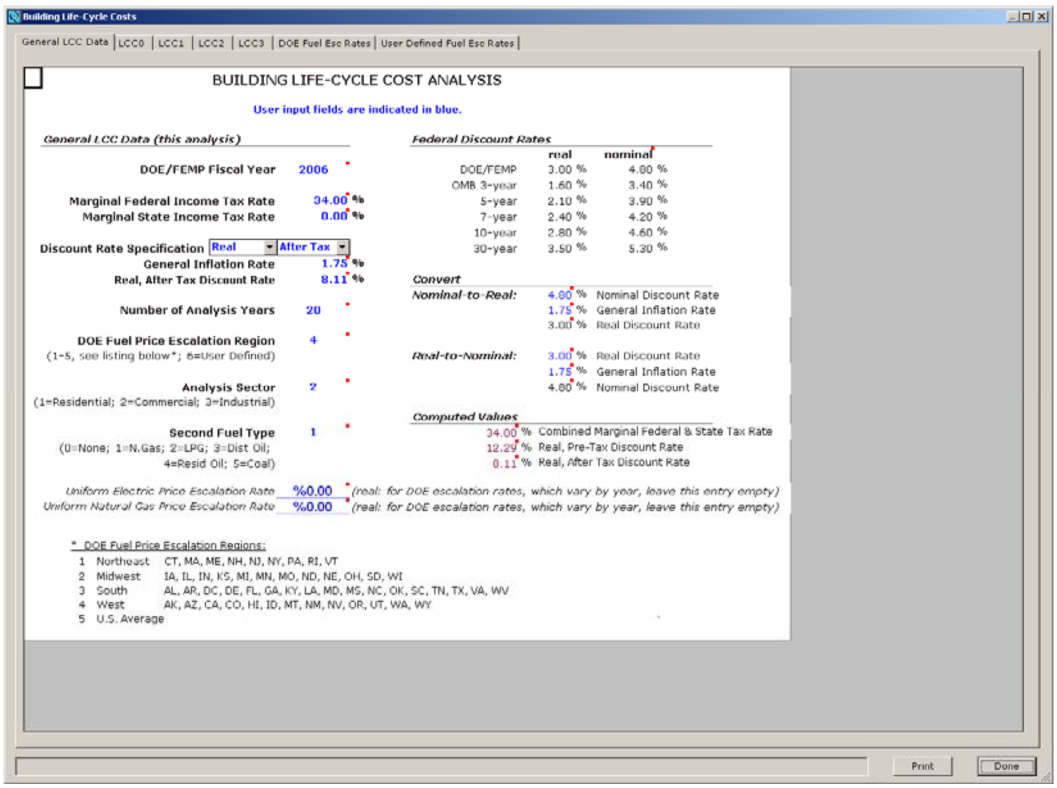
There is an alternative way to enter data for an LCC analysis in eQUEST using a spreadsheet view. This is an excellent way to quickly view all of the inputted LCC information and make adjustments without going back into the EEM Wizard. Follow the steps below to access the spreadsheet view and make information adjustments.

On the **Tools** menu, go to **Life-Cycle Costing.**

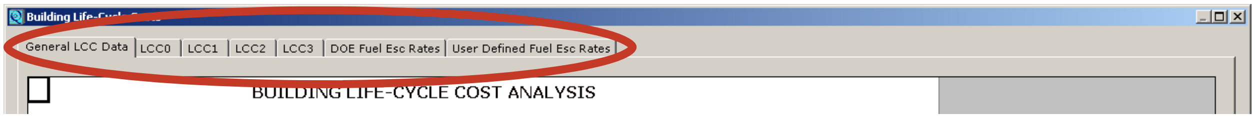
- If you have trouble accessing the Life-Cycle Costing option, make sure that you are in Building Description Mode.



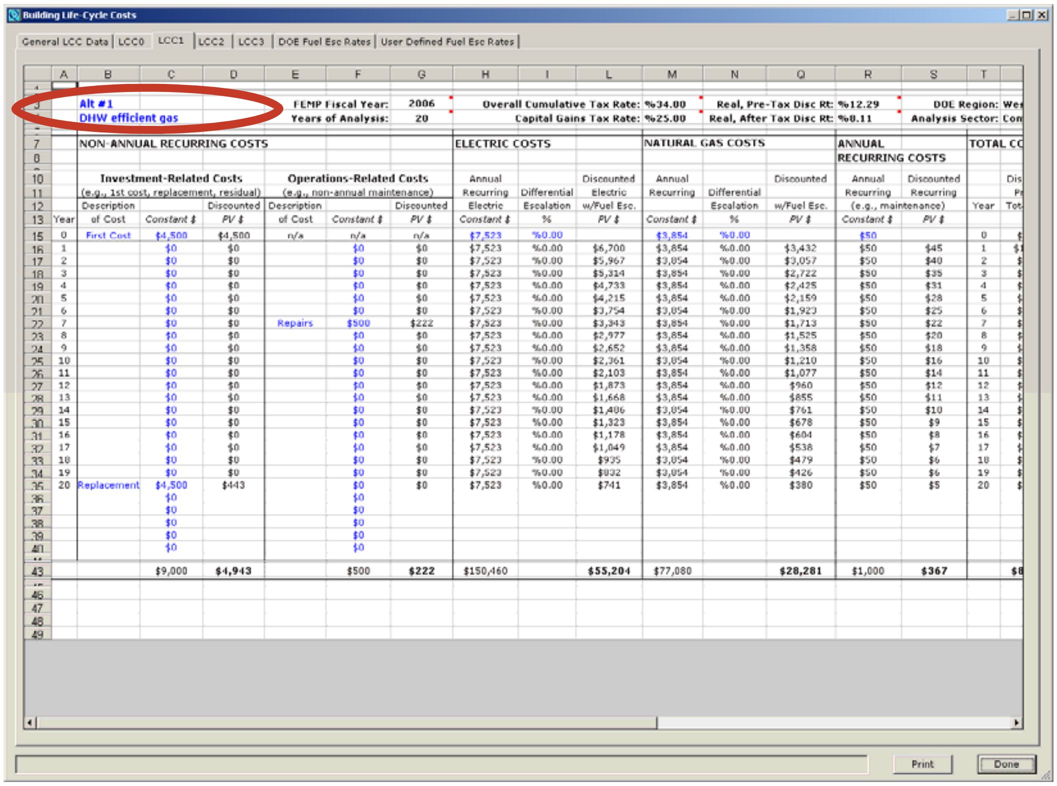
- The following screen appears:



- The tabs in the upper part of the screen allow you to toggle between different EEM Runs and general information for the analysis.
  - General LCC Data contains the information that you recorded on the **Life-Cycle Cost Analysis Project Information Form**.
  - LCC0 is the base case, or the original baseline scenario that was modeled.

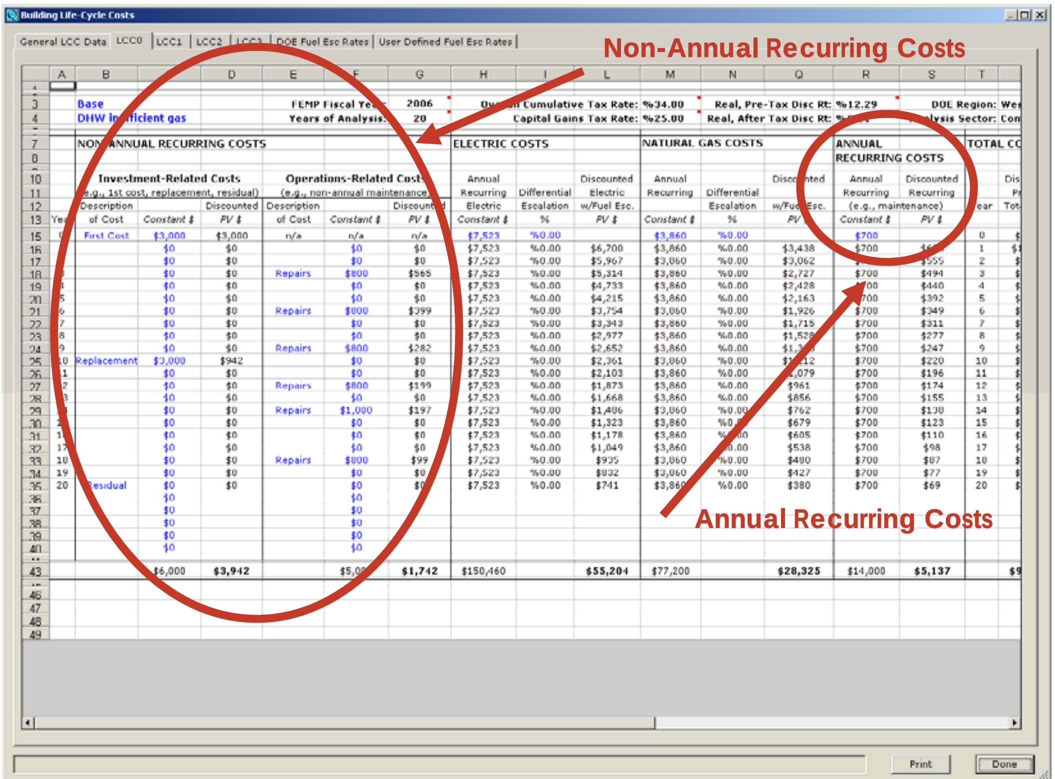


  - The rest of the numbers (LCC1, LCC2, etc.) correspond to the EEM Runs that you created. When you click on a tab, you can see in the upper left-hand corner the name you gave the EEM Run. This is why it is helpful to name the EEM Runs careful when you first create them. If you haven't done this and you aren't sure which run is which, go back to the EEM Wizard and rename the runs with clear logical names that you will recognize in the spreadsheet.



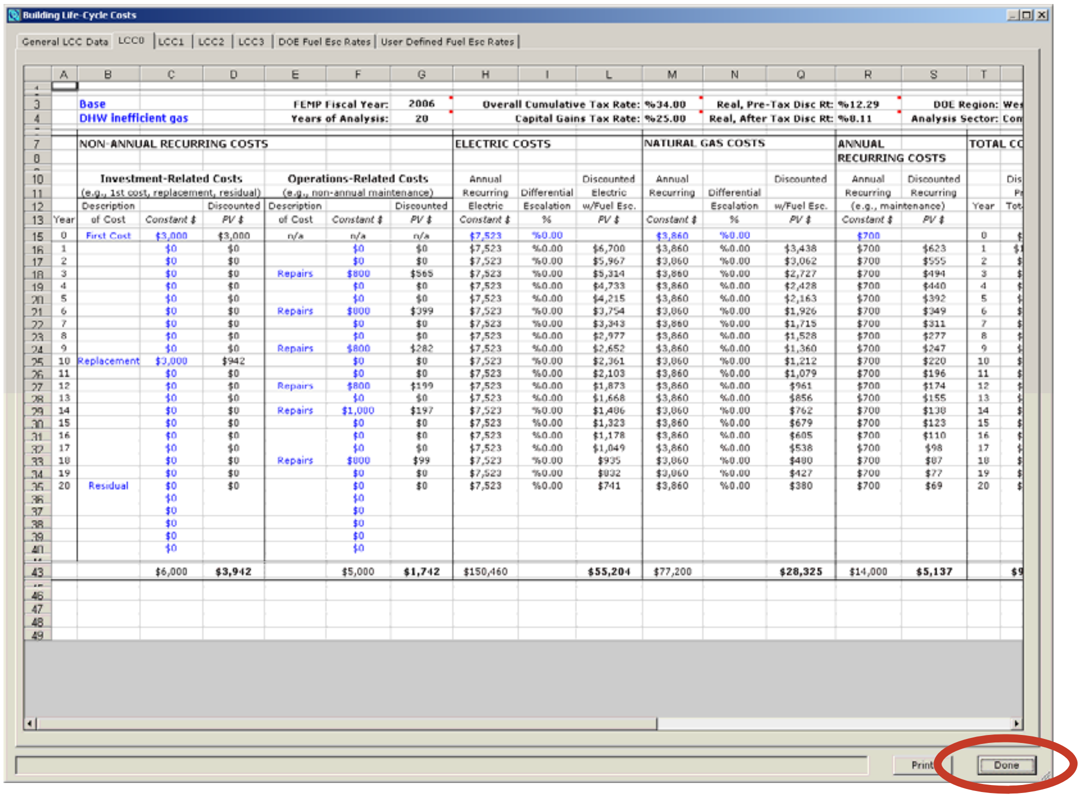
APPENDIX

- When you click on LCC0 or one of the alternatives, the following screen appears:



- This screen allows you to edit:
  - Non-annual Recurring Costs—either investment or operations costs
  - Annual Recurring Costs

- When you are finished adjusting data, click the **Done** button at the bottom right part of the screen.



	A	B	C	D	E	F	G	H	I	L	M	N	Q	R	S	T
3		Base			FEMP Fiscal Year:		2006	Overall Cumulative Tax Rate:			%34.00	Real, Pre-Tax Disc Rt:		%12.29	DOE Region:	
4		DHW inefficient gas			Years of Analysis:		20	Capital Gains Tax Rate:			%25.00	Real, After Tax Disc Rt:		%8.11	Analysis Sector:	
7		NON-ANNUAL RECURRING COSTS						ELECTRIC COSTS			NATURAL GAS COSTS			ANNUAL RECURRING COSTS		TOTAL CO
10		Investment-Related Costs			Operations-Related Costs			Annual		Discounted	Annual		Discounted	Annual	Discounted	
11		(e.g., 1st cost, replacement, residual)			(e.g., non-annual maintenance)			Recurring	Differential	Electric	Recurring	Differential		Recurring	Recurring	
12		Description		Discounted	Description		Discounted	Electric	Escalation	w/Fuel Esc.		Escalation	w/Fuel Esc.	(e.g., maintenance)		Year
13	Year	of Cost	Constant $	PV $	of Cost	Constant $	PV $	Constant $	%	PV $	Constant $	%	PV $	Constant $	PV $	
15	0	First Cost	$3,000	$3,000	n/a	n/a	n/a	$7,523	%0.00		$3,860	%0.00		$700		0
16	1		$0	$0		$0	$0	$7,523	%0.00	$6,700	$3,860	%0.00	$3,438	$700	$623	1
17	2		$0	$0		$0	$0	$7,523	%0.00	$5,967	$3,860	%0.00	$3,062	$700	$555	2
18	3		$0	$0	Repairs	$800	$565	$7,523	%0.00	$5,314	$3,860	%0.00	$2,727	$700	$494	3
19	4		$0	$0		$0	$0	$7,523	%0.00	$4,733	$3,860	%0.00	$2,428	$700	$440	4
20	5		$0	$0		$0	$0	$7,523	%0.00	$4,215	$3,860	%0.00	$2,163	$700	$392	5
21	6		$0	$0	Repairs	$800	$399	$7,523	%0.00	$3,754	$3,860	%0.00	$1,926	$700	$349	6
22	7		$0	$0		$0	$0	$7,523	%0.00	$3,343	$3,860	%0.00	$1,715	$700	$311	7
23	8		$0	$0		$0	$0	$7,523	%0.00	$2,977	$3,860	%0.00	$1,528	$700	$277	8
24	9		$0	$0	Repairs	$800	$282	$7,523	%0.00	$2,652	$3,860	%0.00	$1,360	$700	$247	9
25	10	Replacement	$3,000	$942		$0	$0	$7,523	%0.00	$2,361	$3,860	%0.00	$1,212	$700	$220	10
26	11		$0	$0		$0	$0	$7,523	%0.00	$2,103	$3,860	%0.00	$1,079	$700	$196	11
27	12		$0	$0	Repairs	$800	$199	$7,523	%0.00	$1,873	$3,860	%0.00	$961	$700	$174	12
28	13		$0	$0		$0	$0	$7,523	%0.00	$1,668	$3,860	%0.00	$856	$700	$155	13
29	14		$0	$0	Repairs	$1,000	$197	$7,523	%0.00	$1,486	$3,860	%0.00	$762	$700	$138	14
30	15		$0	$0		$0	$0	$7,523	%0.00	$1,323	$3,860	%0.00	$679	$700	$123	15
31	16		$0	$0		$0	$0	$7,523	%0.00	$1,178	$3,860	%0.00	$605	$700	$110	16
32	17		$0	$0		$0	$0	$7,523	%0.00	$1,049	$3,860	%0.00	$538	$700	$98	17
33	18		$0	$0	Repairs	$800	$99	$7,523	%0.00	$935	$3,860	%0.00	$480	$700	$87	18
34	19		$0	$0		$0	$0	$7,523	%0.00	$832	$3,860	%0.00	$427	$700	$77	19
35	20	Residual	$0	$0		$0	$0	$7,523	%0.00	$741	$3,860	%0.00	$380	$700	$69	20
36			$0			$0										
37			$0			$0										
38			$0			$0										
39			$0			$0										
40			$0			$0										
43			$6,000	$3,942		$5,000	$1,742	$150,460		$55,204	$77,200		$28,325	$14,000	$5,137	

APPENDIX

LCC VOCABULARY

There are many terms and acronyms that are used in Life-Cycle Cost analysis that may be unfamiliar to an architect. The following is a list of acronyms and terms that are common in LCC discussions. These lists are meant to be used as a reference for this and other LCC analysis documents. Some of these words appear and are defined in other parts of this report.

It should be noted that while some of these terms were researched independently, many of the terms and acronyms were compiled from resources containing similar lists of acronyms and definitions. This glossary was compiled from *Circular A-94 Revised: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* and the *Project-Oriented Life-Cycle Costing Workshop* (see the Bibliography on page A19 for source information.)

ACRONYMS

- A: Annual amount
- A_o: Annual amount at base-date prices
- AEO2007: Annual Energy Outlook 2007 (DOE-EIA publication)
- AFUE: Annual Fuel Utilization Efficiency
- AIRR: Adjusted Internal Rate of Return
- ASTM: American Society of Testing and Materials
- BOA: Basic Ordering Agreement
- BLCC: NIST Building Life Cycle Cost computer program
- Btu: British Thermal Units
- COAL: Coal
- COP: Coefficient of Performance
- d: Discount rate
- DIST: Distillate Oil
- DoD: Department of Defense
- DOE: Department of Energy
- DPB: Discounted Payback
- e: price escalation rate (annual rate of price change)
- EIA: Energy Information Administration (DOE)
- ECM: Energy Conservation Measure
- EER: Energy Efficiency Ratio
- ELEC: Electricity
- ESCO: Energy Services Company
- ESPC: Energy Savings Performance Contract
- FEMP: Federal Energy Management Program
- FY: Fiscal Year
- GASLN: Gasoline
- GJ: Gigajoule (10^9 joules)
- HVAC: Heating, Ventilation, and Air Conditioning
- kWh: Kilowatt Hours
- LCC: Life-Cycle Cost or Life-Cycle Costing
- LCCA: Life-Cycle Costing Analysis
- LPG: Liquefied petroleum gas
- MARR: Minimum Required Rate of Return
- MBtu: 10^6 x Btu
- MILCON: Military Construction
- N: Number of discount periods (in years)
- NEMS: National Energy Modeling System
- NIST: National Institute of Standards and Technology
- NTGAS: Natural Gas
- NS: Net Savings
- OMB: Office of Management and Budget
- OM&R: Operation, Maintenance, and (Routine) Repairs
- PB: Payback period
- P/C/I: Planning/Constructions or Installation Period
- PV: present value
- RESID: Residual Oil
- SEER: Seasonal Energy Efficiency Ratio
- SIR: Savings-to-Investment Ratio
- SPB: Simple Payback

- SPV: Single Present Value (factor)
- TLCC: Total Life-Cycle Costs
- UC: Utility Contract
- UESC: Utility Energy Service Contract
- UPV: Uniform Present Value (factor)
- UPV*: Modified Uniform Present Value (factor)

GLOSSARY

Adjusted Internal Rate of Return (AIRR): Annual yield from a project over the Study Period, taking into account investment of interim amounts.

Alternative Building System: An installation or modification of an installation in a building intended primarily to reduce energy or water consumption or allow the use of renewable energy sources, or a primarily energy- or water-saving building system, including a renewable energy system, for consideration as part of the design for a new federal building.

Annually Recurring Costs: Those costs incurred each year in an equal, constant dollar amount throughout the Study Period, or that change from year to year at a known rate.

Annual Value (Annual Worth): The time-equivalent value of past, present, or future cash flows expressed as an Annually Recurring Uniform amount over the Study Period.

Annual Value (Annual Worth or Uniform Capital Recovery) Factor: A discount factor by which a present dollar amount may be multiplied to find its equivalent Annual Value, based on a given Discount Rate and a given period of time.

Base Case: The situation against which an Alternative Building System is compared.

Base Date/Base Year: The beginning of the first year of the Study Period, generally the date on which the Life-Cycle Cost analysis is conducted; typically the year in which the analysis is conducted

Base-Year Energy Costs: The quantity of energy delivered to the boundary of a Federal Building in the Base Year, multiplied by the Base-Year Price of fuel.

Base-Year Price: The price of a good or service as of the Base Date.

Benefit-Cost Analysis: A systematic quantitative method of assessing the desirability of government projects or policies when it is important to take along view of future effects and a broad view of possible side-effects.

Capital Asset: Tangible property, including durable goods, equipment, buildings, installations, and land.

Cash Flow: The stream of costs and benefits (expressed for the purpose of this requirement in Constant Dollars) resulting from a project investment.

Certainty-Equivalent: A certain (i.e., nonrandom) outcome that an individual values equally to an uncertain outcome. For a risk averse individual, the certainty-equivalent for an uncertain set of benefits may be less than the mathematical expectation of the outcome; for example, an individual may value a50-50 chance of winning $100 or $0 as only $45. Analogously, a risk-averse individual may have a certainty-equivalent for an uncertain set of costs that is larger in magnitude than the mathematical expectation of costs.

Compound Interest Factors or Formulas: See Discount Factors or Formulas.

Constant Dollars: Dollars of uniform purchasing power tied to a reference year (usually the Base Year) and exclusive of general price inflation or deflation.

Consumer Surplus: The maximum sum of money a consumer would be willing to pay to consume a given amount of a good, less the amount actually paid. It is represented graphically by the area between the demand curve and the price line in a diagram representing the consumer's demand for the good as a function of its price.

Cost Adjustment Factor: The average annual rate at which the phased-in cost of a capital component is adjusted to its value in any year of the Planning/Construction/Installation Period. The Cost Adjustment Factor can, for example, be a contractual rate (sometimes equal to zero) or a rate determined by the agency.

Cost Effective: The condition whereby an Alternative Building System saves more than it costs over the Study Period, where all Cash Flows are assessed in Constant Dollars and discounted to reflect the Time Value of Money.

Current Dollars: Dollars of non-uniform purchasing power, including general price inflation or deflation, in which actual prices are stated. (With zero inflation or deflation, current dollars are identical to constant dollars.) Use with nominal discount rates.

Debt Service: The sum of interest payments and principal payments which comprise or are part of the Contract Payment to an ESCO or UC.

Demand Charge: That portion of the charge for electric service based on the plant and equipment costs associated with supplying the electricity consumed.

Differential Cost: The difference in the costs of an Alternative Building System and the Base Case.

Differential Energy Price Escalation Rate: The difference between a projected general rate of Inflation and the projected rate of price increase assumed for energy.

Discount Factors: Multiplicative numbers used to convert Cash Flows occurring at different times to their equivalent amount at a common time. Discount factors are obtained by solving Discount Formulas based upon one dollar of value and an assumed Discount Rate and time.

Discount Formula: An expression of a mathematical relationship which enables the conversion of dollars at a given point in time to their equivalent amount at some other point in time.

Discount Rate: The rate of interest, reflecting the investor's Time Value of Money (or opportunity cost), that is used in Discount Formulas or to select Discount Factors which in turn are used to convert ("discount") Cash Flows to a common time. Real Discount Rates reflect Time Value of Money apart from changes in the purchasing power of the dollar and are used to discount Constant Dollar Cash Flows; Nominal Discount Rates include changes in the purchasing power of the dollar and are used to discount Current Dollar Cash Flows.

Discounted Payback Period: The time required for the cumulative savings from an investment to pay back the Investment Costs and other accrued costs, taking into account the Time Value of Money.

Discounting: A technique for converting Cash Flows occurring over time to time-equivalent values, at a common point in time, adjusting for the Time Value of Money.

Disposal Cost: See Residual Value.

Economic Life: That period of time over which a Building or Building System is considered to be the lowest cost alternative for satisfying a particular need.

Energy Conservation Measure (ECM): Defined as the installation of new equipment/facilities, modification, or alteration of existing government equipment/facilities, or revised operations and maintenance procedures to reduce energy consumption of facilities/energy systems.

Energy Cost: The annual cost of fuel or energy used to operate a building or building system, as billed by the utility or supplier (including Demand Charges, if any). Energy Costs are incurred during the Service Period only. Energy consumed in the construction or installation of a new building or building system is not included in this cost.

Energy Savings Performance Contracts: Contracts authorized by the Energy Policy Act of 1992 (EPACT), which offer alternative financing of energy and water efficiency improvements in federal buildings and allow the Federal Government to retain a portion of the energy savings and all equipment installed.

Energy Savings Performance Period (ESPC): The period (typically in years) from the date an ECM is operational and accepted by the Government agency to the end of the Contract Period. The Energy Savings Performance Period may also be referred to as the "service period."

Excess Burden: Unless a tax is imposed in the form of a lump sum unrelated to economic activity, such as a head tax, it will affect economic decisions on the margin. Departures from economic efficiency resulting from the distorting effect of taxes are called excess burdens because they disadvantage society without adding to Treasury receipts. This concept is also sometimes referred to as deadweight loss.

External Economy or Diseconomy: A direct effect, either positive or negative, on someone's profit or welfare arising as a byproduct of some other person's or firm's activity. Also referred to as neighborhood or spillover effects, or externalities for short.

Financing Procurement Costs: May be added to Implementation Costs to comprise the total amount financed by an ESCO or UC.

Future Value: The time-equivalent value of past, present, or future Cash Flows expressed as of some future point in time.

Implementation Costs: May include survey costs, feasibility study costs, design expenses, and construction costs, which may be paid by an agency or included in the Contract Payment proposed by ESCO or UC.

Incidence: The ultimate distributional effect of a tax, expenditure, or regulatory program.

Initial Investment Costs: The initial costs of design, engineering, purchase, and installation, exclusive of "Sunk Costs," all of which are assumed to occur as a lump sum at the beginning of the Base Year or during the Planning/Construction/Installation Period for purposes of making the life-cycle cost analysis.

Inflation: The proportionate rate of change in the general price level, as opposed to the proportionate increase in a specific price. Inflation is usually measured by a broad-based price index, such as the implicit deflator for Gross Domestic Product or the Consumer Price Index; a decline in the general purchasing power of the dollar.

Installation Period: The period from the date of contract award to the date all contracted energy conservation measures are operational and accepted by the agency. Installation period may also be referred to as "construction period."

Internal Rate of Return: Annual yield from a project over the Study Period, i.e., the compound rate of interest which, when used to discount Cash Flows of an Alternative Building System, will result in zero Net Savings (Net Benefits).

Life Cycle Cost: The overall estimated cost for a particular program alternative over the time period corresponding to the life of the program, including direct and indirect initial costs plus any periodic or continuing costs of operation and maintenance.

Life-Cycle Cost Analysis (LCCA): A method of economic evaluation that sums discounted dollar costs of initial investment (less Resale, Retention, or Salvage Value), replacements, operations (including energy and water usage), and maintenance and repair of a building or building system over the Study Period (see Life-Cycle Cost). Also, as used in this program, LCCA is a general approach to economic evaluation encompassing several related economic evaluation measures, including Life-Cycle Cost (LCC), Net Benefits (NB) or Net Savings (NS), Savings-to-Investment Ratio (SIR), and Adjusted Internal Rate of Return (AIRR), all of which take into account long-term dollar impacts of a project.

Liquid Petroleum Gas (LPG): Propane, butane, ethane, pentane, or natural gasoline.

Market Interest Rate: The nominal loan interest rate (including inflation) applied by the ESCO or UC to the Amount Financed to compute annual Contract Payments.

Measures of Economic Evaluation: The various ways in which project cash flows can be combined and presented to describe a measure of project cost effectiveness. The measures used to evaluate FEMP projects are Life-Cycle Cost (LCC), Net Savings (NS), Savings-to-Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR). Discounted Payback (DPB) and Simple Payback (SPB) are measures of evaluation not fully consistent with the LCC method but are used as supplementary measures in some federal programs.

Modified Uniform Present Value (Worth) (UPV* or UPW*) Factor: A discount factor used to convert an annual amount escalating at a constant rate to a time equivalent Present Value. The FEMP UPV* Factor indicates a discount factor from a special set published by the U.S. Department of Energy, Federal Energy Management Program, for computing present value energy costs based on variable energy price projections.

Multiplier: The ratio between the direct effect on output or employment and the full effect, including the effects of second order rounds or spending. Multiplier effects greater than 1.0 require the existence of involuntary unemployment.

Mutually Exclusive Projects: Projects where the acceptance of one precludes acceptance of the others. Examples are whether to use single-glazing, double-glazing or triple-glazing for a window; or R11, R19, or R30 levels of insulation in an attic.

Net Present Value: The difference between the discounted present value of benefits and the discounted present value of costs.

Net Savings (Net Benefits): Time-adjusted savings (or benefits) less time-adjusted differential costs taken over the Study Period for an Alternative Building System relative to the base case.

Nominal Discount Rate: The rate of interest (market interest rate) reflecting the time value of money stemming from both inflation and the real earning power of money over time.

Nominal Interest Rate: An interest rate that is not adjusted to remove the effects of actual or expected inflation. Market interest rates are generally nominal interest rates.

Nominal Values: Economic units measured in terms of purchasing power of the date in question. A nominal value reflects the effects of general price inflation.

Nonmutually Exclusive Projects: Projects where the acceptance of one alternative does not preclude the acceptance of the others. Examples are wall insulation and ceiling insulation. (For contrast, see Mutually Exclusive.)

Nonrecurring Costs: Costs that are not uniformly incurred annually over the Study Period.

Nonfuel Operation, Maintenance, and Repair (OM&R) Costs: Labor and material costs required for routine upkeep, repair, and operation, exclusive of energy costs.

Opportunity Cost: The maximum worth of a good or input among possible alternative uses.

Performance Period Expenses: May include management/administration costs, operation and maintenance costs, repair and replacement costs, measurement and verification costs, permits and licenses costs, insurance costs, property taxes, and other costs (e.g., "margin"), which may be paid by agency or included in the Contract Payment proposed by ESCO or UC.

Planning/Construction Period: The period beginning with the Base Date and continuing up to the Service Date, during which only Initial Investment Costs are incurred.

Post-Contract Period: The period between the end of the Contract Period (Contract Term) and the end of the Study Period.

Present Value (Present Worth): The time-equivalent value of past, present or future Cash Flows as of the beginning of the Base Year.

Present Value (Present Worth) Factor: A discount factor by which a future dollar amount may be multiplied to find its equivalent Present Value as of the Base Date. Single Present Value Factors are used to convert single future amounts to Present Values. Uniform Present Value Factors and Modified Present Value Factors are used to convert Annually Recurring amounts to Present Values.

Real or Constant Dollar Values: Economic units measured in terms of constant purchasing power. A real value is not affected by general price inflation. Real values can be estimated by deflating nominal values with a general price index, such as the implicit deflator for Gross Domestic Product or the Consumer Price Index.

Real Discount Rate: The rate of interest reflecting the portion of the time value of money attributable to the real earning power of money over time and not to general price inflation.

Real Interest Rate: An interest rate that has been adjusted to remove the effect of expected or actual inflation. Real interest rates can be approximated by subtracting the expected or actual inflation rate from a nominal interest rate. (A precise estimate can be obtained by dividing one plus the nominal interest rate by one plus the expected or actual inflation rate, and subtracting one from the resulting quotient.)

Relative Price: A price ratio between two goods as, for example, the ratio of the price of energy to the price of equipment.

Renewable Energy: Energy obtained from sources that are essentially inexhaustible (unlike, for instance, fossil fuels of which there is a limited supply). Renewable sources of energy include wind energy, geothermal energy, hydroelectric energy, photovoltaic and solar energy, biomass, and waste.

Replacement Costs: Future costs included in the capital budget to replace a building system during the Study Period.

Resale Value: See Residual Value.

Residual Value: The estimated value, net of any Disposal Costs, of any building or building system removed or replaced during the Study Period; or remaining at the end of the Study Period; or recovered through resale or reuse at the end of the Study Period (also called Resale Value or Salvage Value, or Retention Value).

Retention Value: See Residual Value.

Retrofit: The installation of an Alternative Building System in an Existing Building.

Risk Attitude: The willingness of decision makers to take chances or to gamble on investments of uncertain outcome. Risk attitudes are generally classified as risk-averse, risk-neutral, or risk-taking.

APPENDIX

Risk Exposure: The probability of investing in a project whose economic outcome is less favorable than what is economically acceptable.

Salvage Value: See Residual Value.

Savings-to-Investment Ratio (SIR): A ratio computed from a numerator of discounted energy and/or water savings, plus (less) savings (increases) in Nonfuel Operation and Maintenance Costs, and a denominator of increased Investment Costs plus (less) increased (decreased) Replacement Costs, net of Residual Value (all in present-value terms), for an Alternative Building System as compared with a Base Case.

Sensitivity Analysis: Testing the outcome of an evaluation to changes in the values of one or more system parameters from the initially assumed values.

Service Date: The point in time during the Study Period when a building or building system is put into use, and operating, maintenance, and repair costs (including energy and water costs) begin to be incurred.

Service Period: The period of time starting with the Service Date and continuing through the end of the Study Period.

Shadow Price: An estimate of what the price of a good or input would be in the absence of market distortions, such as externalities or taxes. For example, the shadow price of capital is the present value of the social returns to capital (before corporate income taxes) measured in units of consumption.

Simple Payback Period (SPB): A measure of the length of time required for cumulative savings from a project to recover the Investment Cost and other accrued costs, without taking into account the Time Value of Money.

Single Present Value (Worth) (SPV or SPW) Factor: The discount factor used to convert single future benefit and cost amounts to Present Value.

Study Period: The length of the time period covered by the economic evaluation. This includes both the Planning/Construction Period and the Service Period.

Sunk Cost: A cost incurred in the past that will not be affected by any present or future decision. Sunk costs should be ignored in determining whether a new investment is worthwhile.

Time-of-Use Rate: The charge for service during periods of the day based on the cost of supplying the service at that particular time of the day.

Time Value of Money: The time-dependent value of money. If project Cash Flows are stated in Constant Dollars, their adjustment to a common time basis is necessary to take into account the real earning potential of investments over time. If project cash flows are stated in Current Dollars, their adjustment to a common time basis is necessary to take into account not only the real earning potential over time, but also price inflation or deflation.

APPENDIX

Transfer Payment: A payment of money or goods. A pure transfer is unrelated to the provision of any goods or services in exchange. Such payments alter the distribution of income, but do not directly affect the allocation of resources on the margin.

Treasury Rates: Rates of interest on marketable Treasury debt. Such debt is issued in maturities ranging from 91 days to 30 years.

Uniform Present Value (Worth) (UPV or UPW) Factor: The discount factor used to convert uniform annual values to a time-equivalent Present Value.

Useful Life: The period of time over which a Building or Building System continues to generate benefits or savings.

Utility Contracts (UC) or Utility Energy Services Contracts (UESC): Contracts (Area-Wide Contracts or Basic Ordering Agreements) between a government agency and a utility company, which allow the Federal Government to implement energy and water conservation measures through financing provided by the utility.

Willingness to Pay: The maximum amount an individual would be willing to give up in order to secure a change in the provision of a good or service.

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Special thanks goes to Marlin S. Addison and Jeff Cole for answering my questions about Life-Cycle Cost Analysis and eQUEST’s LCCA component.

APPENDIX

EXAMPLE

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The following set of instructions directs the reader to create a simple energy model in eQUEST and then use a Life-Cycle Cost analysis to compare gas and electric domestic hot water (DHW) heaters. The results of the analysis are then discussed. For more information about any of these steps, please refer to the text of this training module.

NOTE

This module assumes that the user has a working knowledge of eQUEST and its EEM Wizard. For more information about how to use eQUEST, please refer to the previous training modules, as well as the DOE-2 website, www.doe2.com.

Some things to ALWAYS keep in mind while working in eQUEST:

- **Work in a linear fashion.** The dynamic defaults in the program automatically change information further in the program. If you are working backwards, this may be information you may have already customized. Working linearly from start to finish and avoiding back stepping can guarantee that your user input stays put!
- **Save frequently.** Like any computer program, some newer versions of eQUEST have a tendency to crash at inconvenient moments. Make sure you are prepared.
- **Keep it simple.** There are some details in your building design that will have little or no impact on energy performance. Leave them out!
- **Analyze the results with caution.** Always check the reports for numbers that seem inappropriate under the circumstances. While the computer is a valuable tool, it does not understand the output it is producing. Use your knowledge to recognize potential inaccuracies!
- **Update your version.** There are several versions of eQUEST, and each have some variations. It is a good idea to update your version of eQUEST to the most current version. For the purposes of this and all subsequent modules, we will be using eQUEST version 3.61.

PERFORMING AN LCC ANALYSIS USING eQUEST

The following list of steps was taken directly from the eQUEST Module 3 on Life-Cycle Cost Analysis. This example will walk the user through these steps in order to create an energy model in eQUEST and then use the EEM Wizard to perform an LCC analysis in eQUEST. The next several pages will go through the following steps in detail:

1. Build an energy model of the project in eQUEST. (Refer to Module 1 in this series for instruction on how to do this.)
2. Determine which factors need to be examined in the analysis, and using the **EEM & LCC Project Information Form**, gather the necessary information about the project.
3. Add EEM (Energy Efficiency Measure) runs to the eQUEST model. Use the **EEM Runs Form** to record your inputs. (Refer to Module 1 of this series for instruction on how to do this.)
4. Run the eQUEST building simulation.
5. Analyze the LCC Results and make adjustments accordingly.

Keep in mind that because you are performing an eQUEST LCC analysis, most of the information needed for the analysis will be inputted when the energy model of the building is first created. Once you finish inputting data, you will close the EEM Wizard window and go to the Simulation Results area where you will find your LCC results displayed in several forms. This can be confusing at first, especially if you are anticipating inputting number after number and then expecting to watch eQUEST slowly run a set of calculations. In most cases, the program runs all of its LCC calculations in the background, leaving you free to continue adjusting your energy models as well as your cost analysis models.

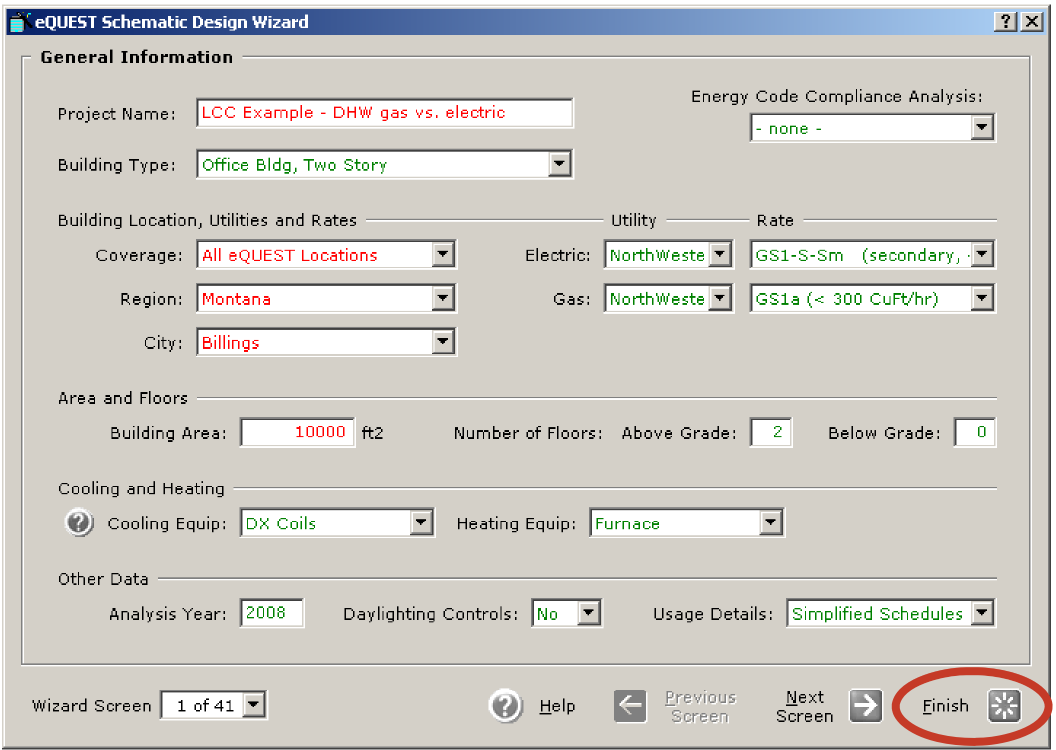
In this example we will use the EEM Wizard to input all of our LCC information. We will construct a simple two-story office building and then build some EEMs related to the Domestic Hot Water (DHW). After adding some LCC data to the EEM runs, the results will be discussed. At the end of this example, we have included the results from another LCC analysis that we created in eQUEST to help further explain some of the eQUEST reports.

We will be keeping this analysis very simple in order to demonstrate how the LCC analysis features work in eQUEST. You may notice that some of the numbers seem unrealistic and inflated for the analysis. This is to make it easier to explain the analysis and results, especially because we are looking at a very small component of the overall building.

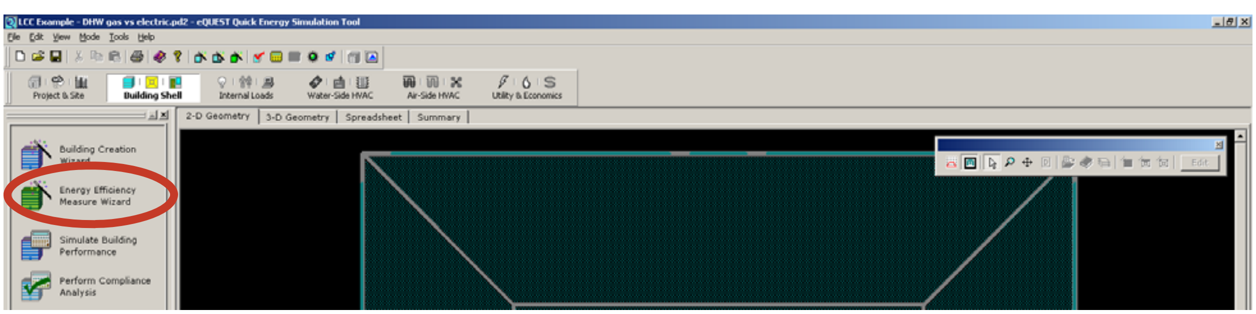
As you go through the EEM Wizard, you will want to fill out a EEM forms which can be found at the end of this module. This will help you gather all of your information in one place and allow someone else to understand how the basic energy model was built. Completed forms a shown throughout the exercise.

LCC ANALYSIS IN eQUEST: DHW GAS VS. ELECTRIC

1. Build an energy model in eQUEST.
   - Open an new project in eQUEST and choose the **Schematic Design Wizard**.
   - On Screen 1 of 41 make the following changes (shown in **red**). We will accept all other defaults for this model.
   - Click **Finish** in the bottom right-hand corner.

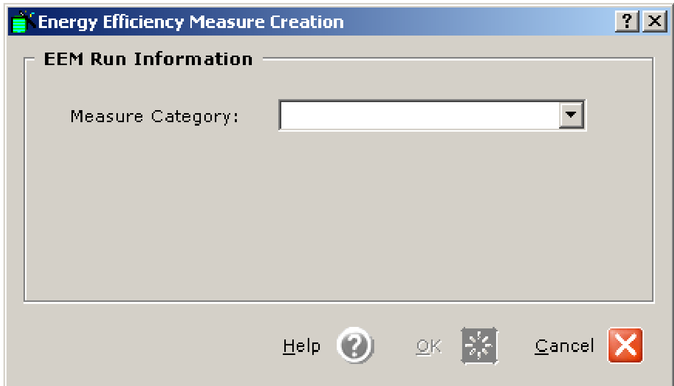


   - If you need further assistance using the Schematic Design Wizard, please refer to Module 1 of this series.
2. Determine which factors need to be examined in the analysis and using the **EEM & LCC Project Information Form**, gather the necessary information about the project.
   - A completed form for this example is located on page E8.
   - To input this information, open the **EEM Wizard**. (Note: If you have trouble navigating this wizard, please refer to Module 1.)

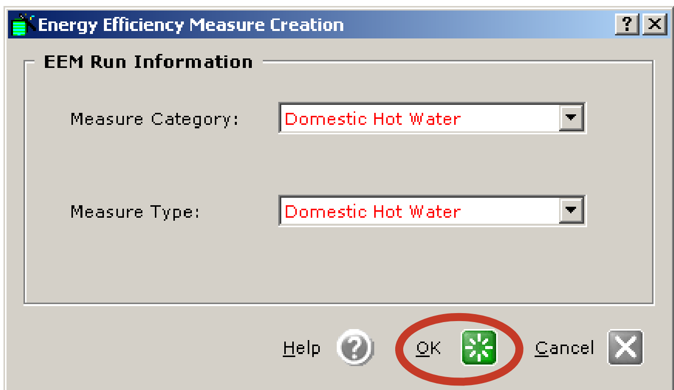


EXAMPLE

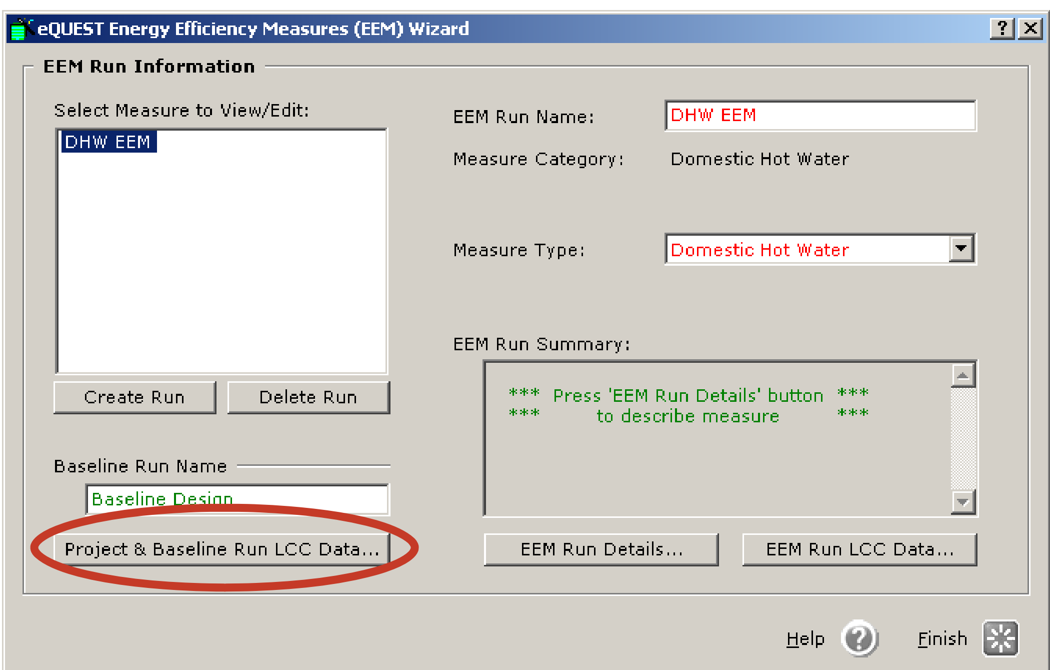
- The following screen will appear:



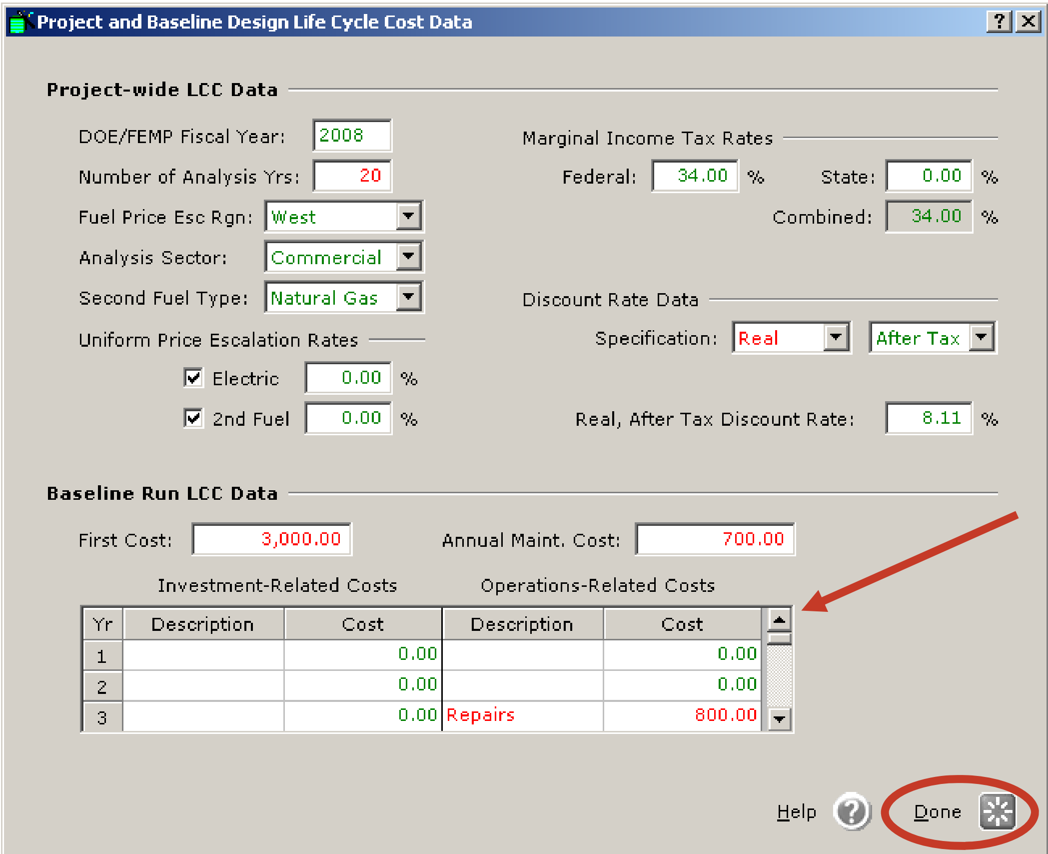
- Select **Domestic Hot Water** for Measure Category and Measure Type. Click **OK**.



- On the next screen, select **Project & Baseline Run LCC Data…**



- The following screen will appear:



- Fill in all of the information on the next page (**EEM & LCC Project Information Form**). The screen above shows the changes that were made in **red**. Remember to scroll down in the LCC costs section to add **repairs and replacements**.
- Click **Done**.

EXAMPLE

EXAMPLE

EEM & LCC Project Information Form

Project:	LCC Example - DHW gas vs. electric
Architect:	Integrated Design Lab - Bozeman
Location:	Billings, MT
Design Features to be analyzed:	DHW - gas vs. electric - inefficient vs. efficient
Baseline Run/LCC0:	DHW inefficient gas
EEM Run #1/LCC1:	DHW efficient gas
EEM Run #2/LCC2:	DHW inefficient electric
EEM Run #3/LCC3:	DHW efficient electric
EEM Run #4/LCC4:	
EEM Run #5/LCC5:	
EEM Run #6/LCC6:	

Project-wide LCC Data		**Marginal Income Tax Rates**	
DOE/FEMP Fiscal Year:	2008	Federal:	[eQUEST default]
Number of Analysis Yrs:	20	State:	[eQUEST default]
Fuel Price Esc Rgn:	West	Combined:	[eQUEST default]
Analysis Sector:	Commercial	**Discount Rate Data**	
Second Fuel Type:	Natural Gas	Specification:	Real ◉ Nominal ○
Uniform Price Escalation Rates			Pre ○ After Tax ◉
Electric ☒	0.00%	Inflation Rate:	[eQUEST default]
2nd Fuel ☒	0.00%	Discount Rate:	[eQUEST default]

Baseline Run LCC DATA	First Cost: $3000		Annual Maint. Cost: $700	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS
3, 6, 9			Repairs	$800
10	Replacement	$3000		
12, 18			Repairs	$800
14			Repairs	$1000

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT: LCC Example - DHW gas vs. electric

EEM RUN:	DHW efficient gas
Measure Type:	Domestic Hot Water
Apply Measure To:	- baseline run -

Describe EEM Changes Made:

- increase R-value of tank to R-20
- increase cost to compensate for efficiency
- decrease maintenance costs

LCC DATA	First Cost: $4500		Annual Maint. Cost: $50	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS
7			Repairs	$500
20	Replacement	$4500		

EEM Run:	DHW inefficient electric
Measure Type:	Domestic Hot Water
Apply Measure To:	- baseline run -

Describe EEM Changes Made:

- change DHW to electric

LCC DATA	First Cost: $2500		Annual Maint. Cost: $400	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS
3, 7			Repairs	$600
10	Replacement	$2500		
13, 17			Repairs	$600
20	Replacement	$2500		

Created by Integrated Design Lab—Bozeman

EXAMPLE

EXAMPLE

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT: LCC Example - DHW gas vs. electric

EEM RUN:	DHW efficient electric
Measure Type:	Domestic Hot Water
Apply Measure To:	- baseline run -
Describe EEM Changes Made:	

- increase R-value of tank to R-20
- increase cost to compensate for efficiency
- decrease maintenance costs

LCC DATA	First Cost: $3500		Annual Maint. Cost: $300	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS
5, 10, 15			Repairs	$400
20	Replacement	$3500		

EEM Run:	
Measure Type:	
Apply Measure To:	
Describe EEM Changes Made:	

LCC DATA	First Cost:		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

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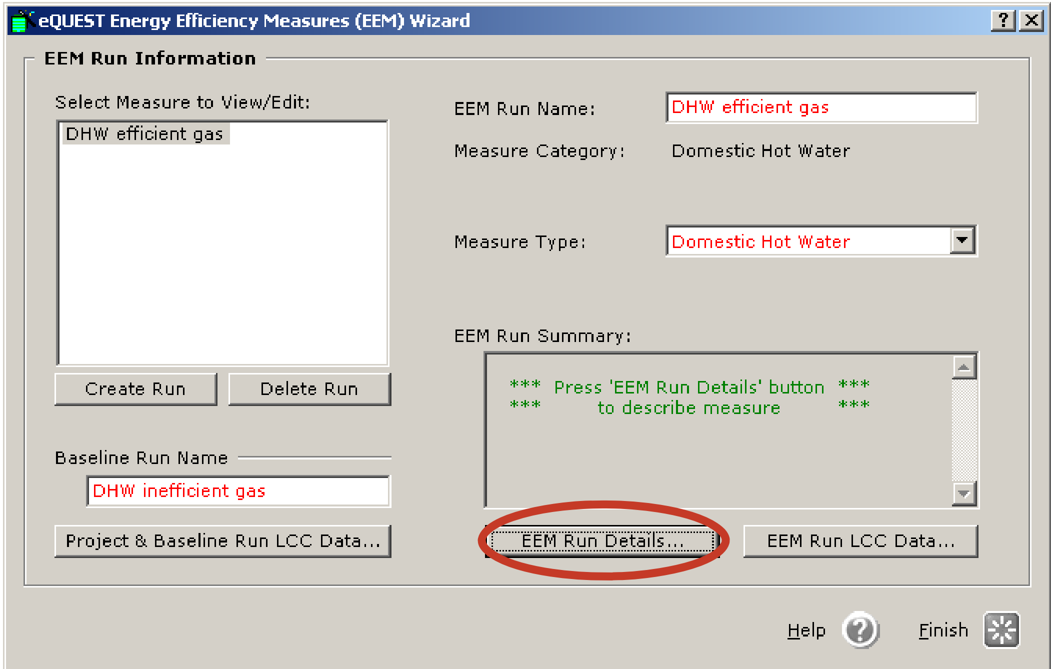
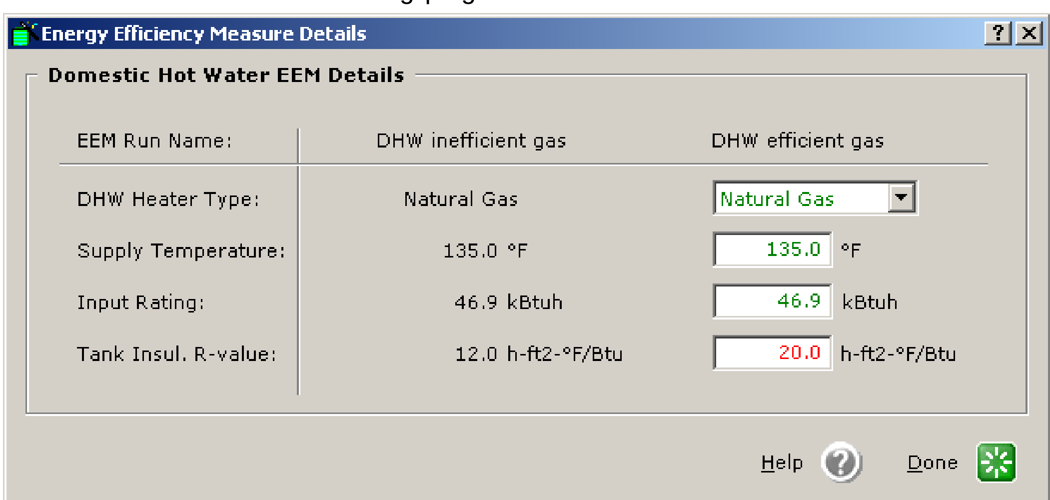
3. Add another EEM (Energy Efficiency Measure) run to the eQUEST model. Use the **EEM & LCC Runs Form** to record your inputs.
   - Pages E11-E12 show the completed **EEM & LCC Runs Forms** for this example.
   - Input this information into the EEM Wizard.
   - Create a new run, change its name, and select **EEM Run Details…**



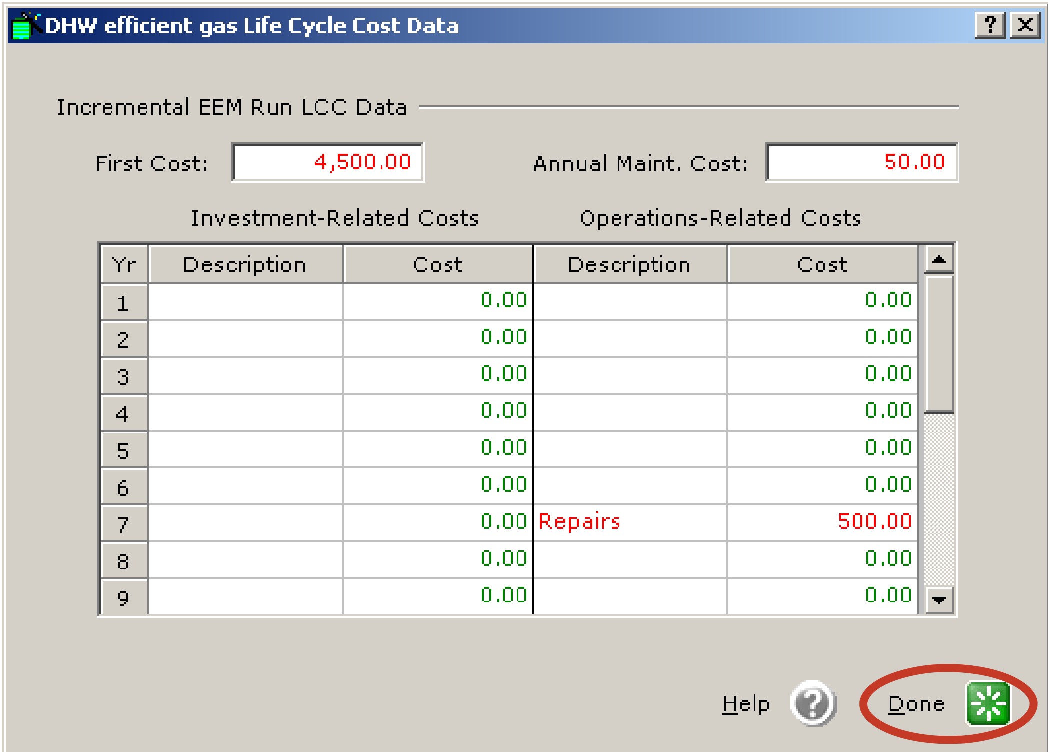
   - The following screen appears. Make the EEM changes necessary according to the **EEM & LCC Runs Forms** on the following pages.



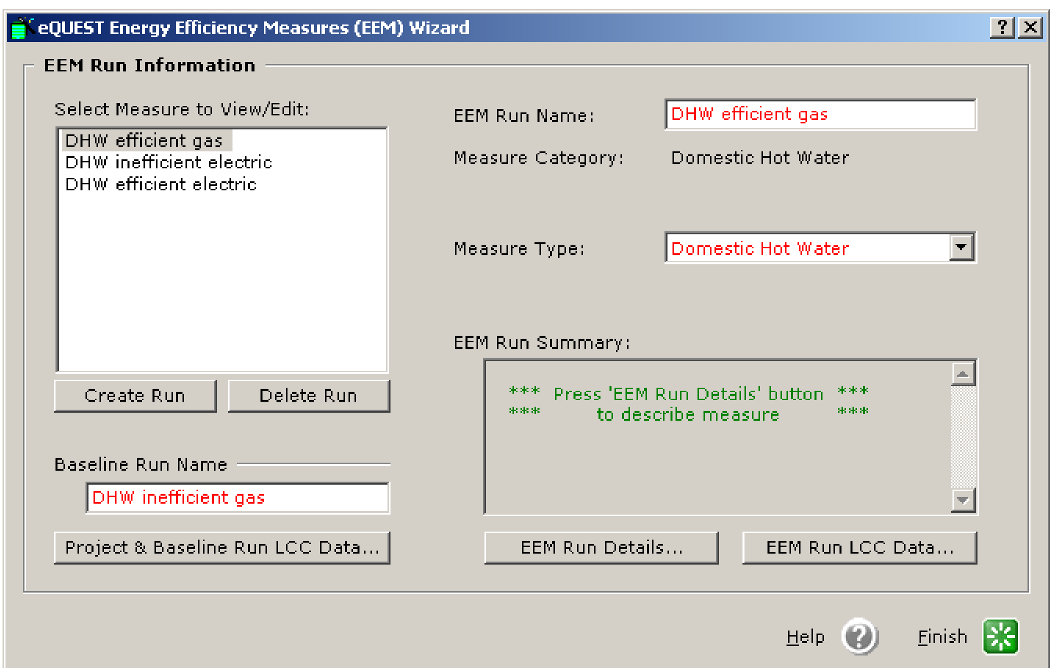
EXAMPLE

EXAMPLE

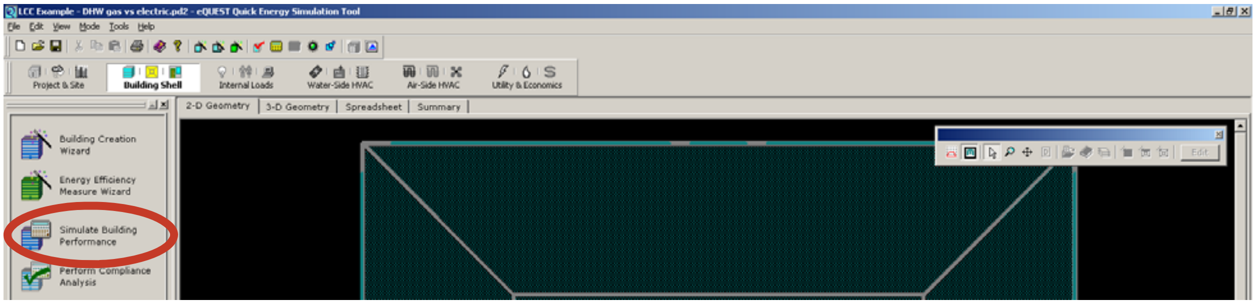
- Return to the EEM Wizard main screen and select **EEM Run LCC Data…**
- The following screen appears. Input the **EEM & LCC Run Forms** data in the appropriate places. Click **Done** when you are finished.



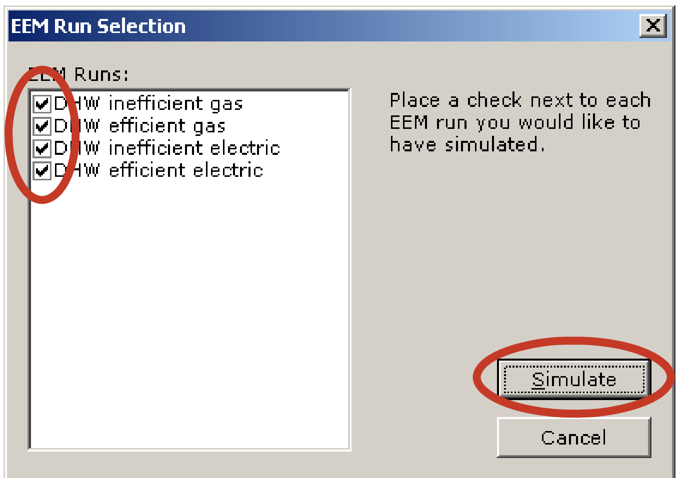
- Input all of the EEM and LCC information for all of the alternative EEM runs shown on the following two pages. Your screen should look like this before you exit the EEM Wizard:



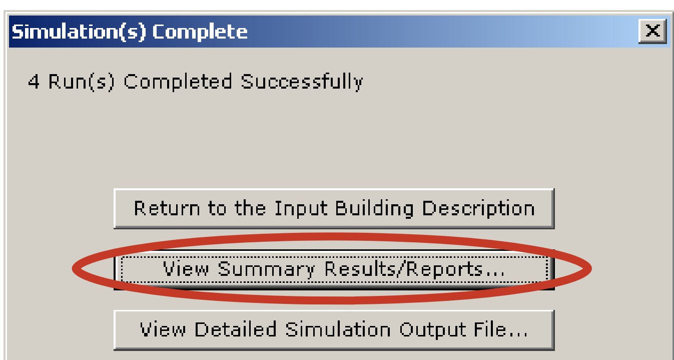
4. Run the eQUEST building simulation by clicking **Simulate Building Performance** on the left side of the screen.



- Select the EEM runs that you would like to include in the LCC analysis by checking/un-checking the appropriate boxes. Click **Simulate**.



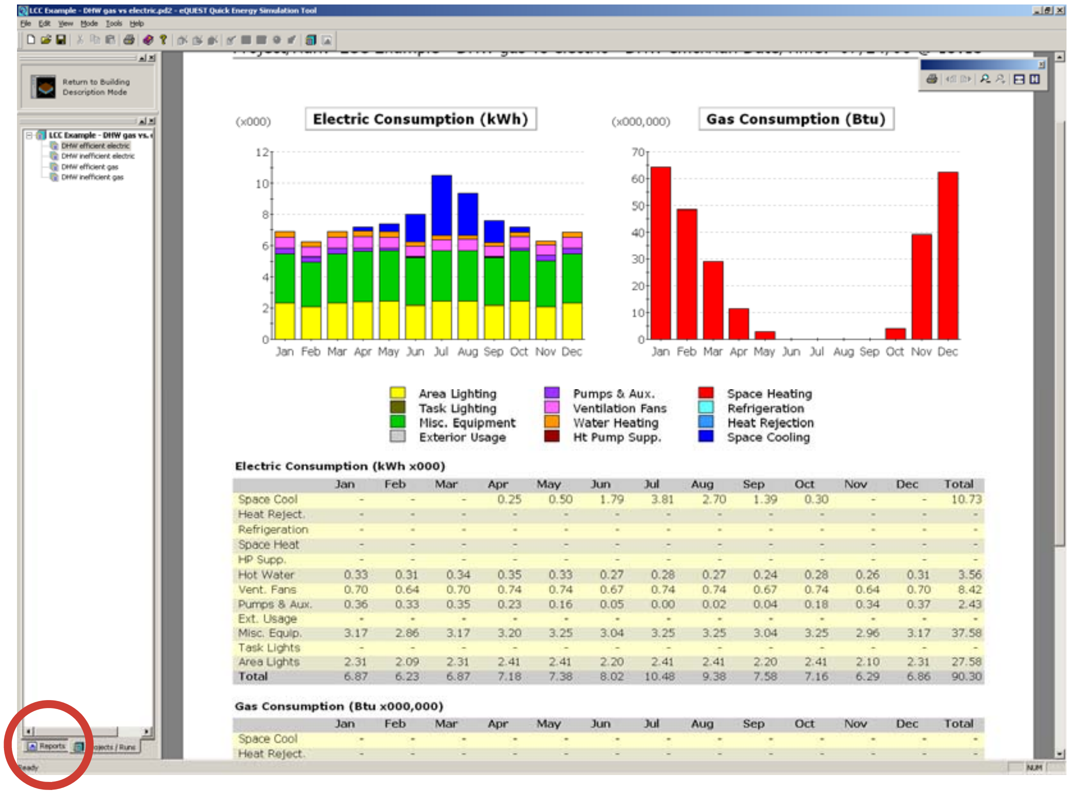
- When eQUEST is finished with the simulation, click **View Summary Results/Reports...**



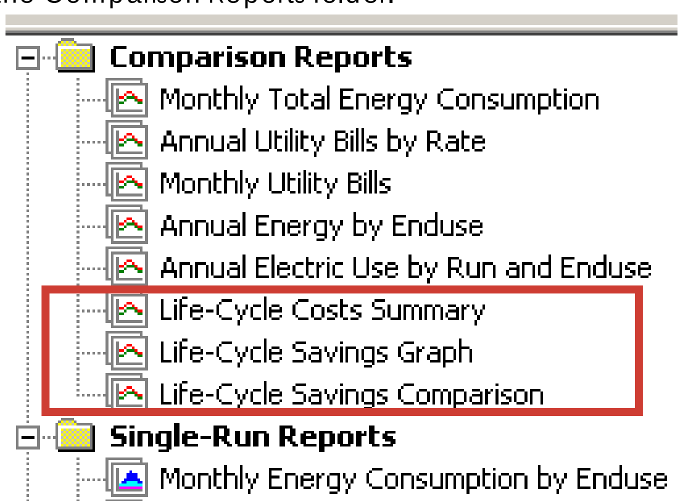
EXAMPLE

EXAMPLE

- The following screen will appear. Click the **Reports** tab in the bottom left part of the screen.



- The following list of reports will appear: We are concerned with the three Life-Cycle reports under the Comparison Reports folder.



5. Analyze the LCC Results and make adjustments accordingly.
   - The next few pages show examples of the LCC analysis reports and give a brief analysis of this example.
   - For information on analyzing the data, refer to pages 16-22 of the text of this module.
   - Remember, you can always go back to the EEM Wizard and adjust the LCC data, as well as create new EEM runs to use in the analysis.

EXAMPLE 1 RESULTS SUMMARY

The Life-Cycle Costs Summary (page E16) displays numerical data for the analysis. It is a good way to quantitatively identify which alternative will have the smallest total life-cycle cost. This information can be found in the last column of the top section of the report. In this example, Alternative #1—DHW efficient gas—has the least total LCC cost: $79306. This amount is in present value dollars, or the value of money today (or the starting date of the analysis). The reason that the difference between this value and the greatest value (the base case) is only about $4000 is that DHW is not a large portion of the energy consumption of a building. If this example had analyzed HVAC systems for a larger building or had combined HVAC with different alternatives such as high-performance window glazing, overhangs, or building orientation, a much greater difference would probably be seen.

Due to the type of analysis we are doing, the bottom section is not relevant. This is because it looks at the cumulative savings if all of the alternatives were combined with each previous one in the list. Since we are doing an either/or analysis, this is not useful information to us.

The middle section, however, compares individual alternative to individual alternative. In this example, the cumulative analysis does not give us any information since this example focused on an A, B, C, or D choice. Situations that could combine multiple alternatives, such as high-performance glazing plus overhangs, would benefit from the information in the cumulative section.

Both the Cumulative Net Savings chart and the Life-Cycle Savings Comparison charts are based on the Cumulative Life-Cycle Savings portion of the first report. Because this information is not relevant to this example, the following pages (E17—E25) provide you with the information used to create another example followed by the results and an analysis of them.

EXAMPLE

Life-Cycle Costs Summary

Life-Cycle COSTS

Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Total LCC PV$
Base	DHW inefficient gas	$3000	$5684	$11383	$83528	$700	$5137	$83285
Alt #1	DHW efficient gas	$4500	$5166	$11377	$83484	$50	$367	$79306
Alt #2	DHW inefficient electric	$2500	$4438	$11472	$84181	$400	$2935	$81398
Alt #3	DHW efficient electric	$3500	$4265	$11464	$84123	$300	$2201	$80405

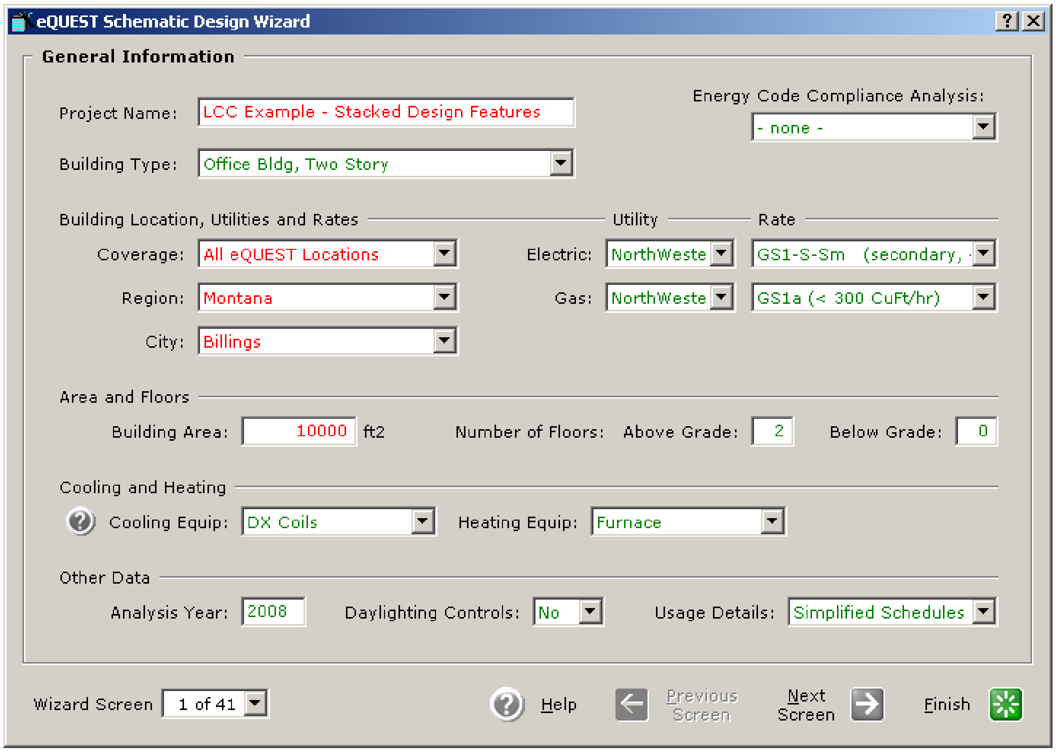
Incremental Life-Cycle SAVINGS (negative entries indicate increased costs)

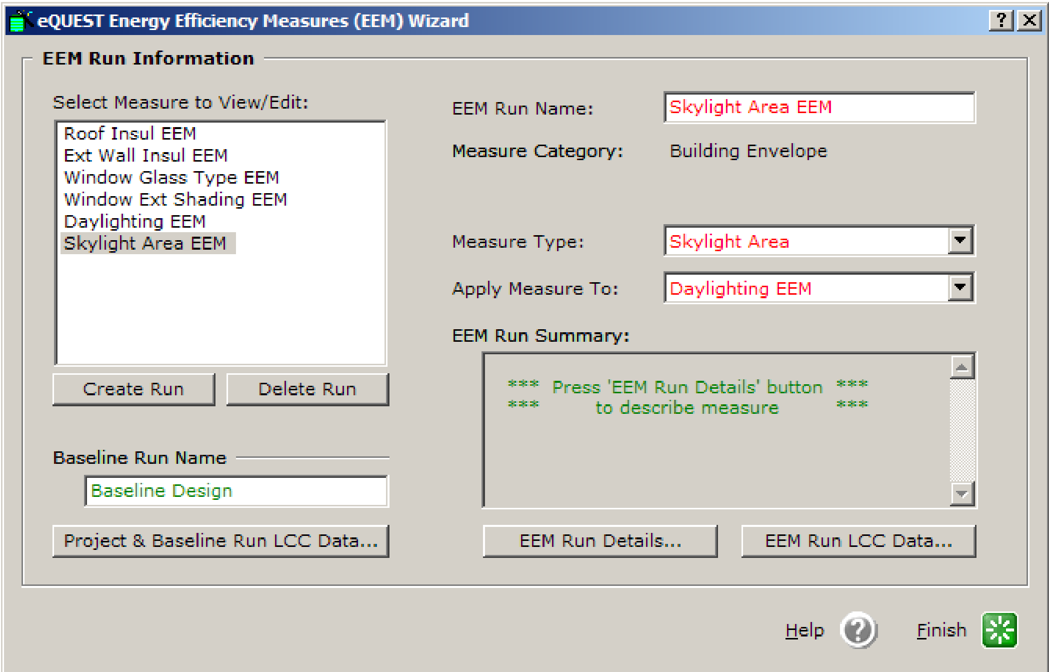
Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Net Savings NS	Simple Payback yrs	Discnt'd Payback yrs	Saving -to- Invest Ratio SIR	Adjusted Internal Rate-of-Return AIRR
Alt #1	DHW efficient gas	($-1500)	$518	$6	$44	$650	$4770	$3980	250.0	2.9	6.3	18.6%
Alt #2	DHW inefficient electric	$2000	$727	($-95)	($-697)	($-350)	($-2568)	($-2092)	21.1	0.0	n/a	n/a
Alt #3	DHW efficient electric	($-1000)	$173	$8	$59	$100	$734	$993	125.0	9.1	4.1	16.0%

Cumulative Life-Cycle SAVINGS (negative entries indicate increased costs)

Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Net Savings NS	Simple Payback yrs	Discnt'd Payback yrs	Saving -to- Invest Ratio SIR	Adjusted Internal Rate-of-Return AIRR
Alt #1	DHW efficient gas	($-1500)	$518	$6	$44	$650	$4770	$3980	250.0	2.9	6.3	18.6%
Alt #2	DHW inefficient electric	$500	$1246	($-89)	($-653)	$300	$2201	$1888	5.6	0.0	n/a	n/a
Alt #3	DHW efficient electric	($-500)	$1419	($-81)	($-594)	$400	$2935	$2881	n/a	2.2	n/a	n/a

EXAMPLE 2: LCC EXAMPLE—STACKED DESIGN FEATURES





EXAMPLE

EXAMPLE

EEM & LCC Project Information Form

Project:	LCC Example - Stacked Design Features
Architect:	Integrated Design Lab - Bozeman
Location:	Billings, MT
Design Features to be analyzed:	- insulation - window glazing, shading, skylights - daylighting
Baseline Run/LCC0:	Baseline
EEM Run #1/LCC1:	Roof Insulation
EEM Run #2/LCC2:	Wall Insulation
EEM Run #3/LCC3:	Glazing Type
EEM Run #4/LCC4:	Window Shading
EEM Run #5/LCC5:	Daylighting
EEM Run #6/LCC6:	Skylights

Project-wide LCC Data		**Marginal Income Tax Rates**	
DOE/FEMP Fiscal Year:	2008	Federal:	[eQUEST default]
Number of Analysis Yrs:	25	State:	[eQUEST default]
Fuel Price Esc Rgn:	West	Combined:	[eQUEST default]
Analysis Sector:	Commercial	**Discount Rate Data**	
Second Fuel Type:	Gas	Specification:	Real ◉ Nominal ○
Uniform Price Escalation Rates			Pre ○ After Tax ◉
Electric ☒	0.00%	Inflation Rate:	[eQUEST default]
2nd Fuel ☒	0.00%	Discount Rate:	[eQUEST default]

Baseline Run LCC DATA	First Cost: $1,800,000		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT: LCC Example - Stacked Design Features

EEM RUN:	Roof Insul EEM
Measure Type:	Roof Insulation
Apply Measure To:	n/a
Describe EEM Changes Made:	
Improve roof insulation from R-18 to R-36	

LCC DATA	First Cost: $1,808,000		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EEM Run:	Ext Wall Insul EEM
Measure Type:	Exterior Wall Insulation
Apply Measure To:	Roof Insul EEM
Describe EEM Changes Made:	
Improve wall insulation from R-19 to R-21 + R-7	

LCC DATA	First Cost: $1,810,000		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EXAMPLE

EXAMPLE

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT: LCC Example - Stacked Design Features

EEM RUN:	Window Glass Type EEM
Measure Type:	Window Glass Type
Apply Measure To:	Ext Wall Insul EEM
Describe EEM Changes Made:	

Change from default to Double low-E with 1/2" Argon

LCC DATA	First Cost: $1,837,500		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EEM Run:	Window Ext Shading EEM
Measure Type:	Window Exterior Shading
Apply Measure To:	Window Glass Type EEM
Describe EEM Changes Made:	

South: 3ft deep
East and West: 1 ft deep

LCC DATA	First Cost: $1,821,000		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT: LCC Example - Stacked Design Features

EEM RUN:	Daylighting EEM
Measure Type:	Daylighting
Apply Measure To:	Window Ext Shading EEM

Describe EEM Changes Made:

Ground: Side lit
Top Floor: All

*Both: Switched 2/3 - 1/3 - off

LCC DATA	First Cost: $1,816,500		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EEM Run:	Skylight Area EEM
Measure Type:	Skylight Area
Apply Measure To:	Daylighting EEM

Describe EEM Changes Made:

Add skylights to 5% of ALL of roof

LCC DATA	First Cost: $1,825,500		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EXAMPLE

EXAMPLE 2 RESULTS

Looking first to the Life-Cycle Costs Summary report, you can see that the lowest Total LCC alternative is #5, Daylighting EEM ($1,687,077). Since this analysis was performed using stacked EEMs of different variables we can use the other two LCC reports to confirm this alternative to be our best option.

The Cumulative Net Savings (PV$) Report displays the net savings over the study period of 25 years for each alternative. Remember that everything is being compared to the base case, so it is not shown here. As you can see on this report (page E24), the only alternative that breaks even is alternative #5 at about 16 years. This means that in 16 years all of the modifications made to the baseline design (alternatives 1-5 because we stacked the EEM runs) will pay for themselves in savings. Considering that the life of the building extends well beyond the 25-year study period, this could potentially be a valid investment if the client is willing and able to pay the cash upfront.

The final report, the Life-Cycle Savings Comparison, further verifies that alternative #5 is the best option based on this LCC analysis. It is the only alternative with a positive net savings. It also has the highest first year utility savings and adjusted internal rate of return, implying a strong payback for the project. While normally the savings to investment ratio is only used for comparing different projects, you can see here that alternative #5 also has the highest ratio. This implies that this alternative will bring the most money for the investment. Finally, the discounted payback verifies that alternative #5 will bring a return on the investment after 16 years. Notice how alternative #5 is the lowest value in the simple payback graph. This is because, unlike discounted payback, simple payback does not incorporate the time-value of money. The Incremental Acquisition Cost Graph shows the amount above and beyond the initial project cost of each alternative. Notice that even though the EEM runs were stacked, eQUEST looked at the cost of each alternative individually instead of adding them cumulatively.

Overall the reports verify our initial conclusion that alternative #5 is the best LCC option for this project. However, keep in mind that this is a basic analysis and that there are many more variables at stake than those that eQUEST requires—occupant satisfaction and productivity, risk, value, etc. These should also be considered when examining the results for an LCC analysis.

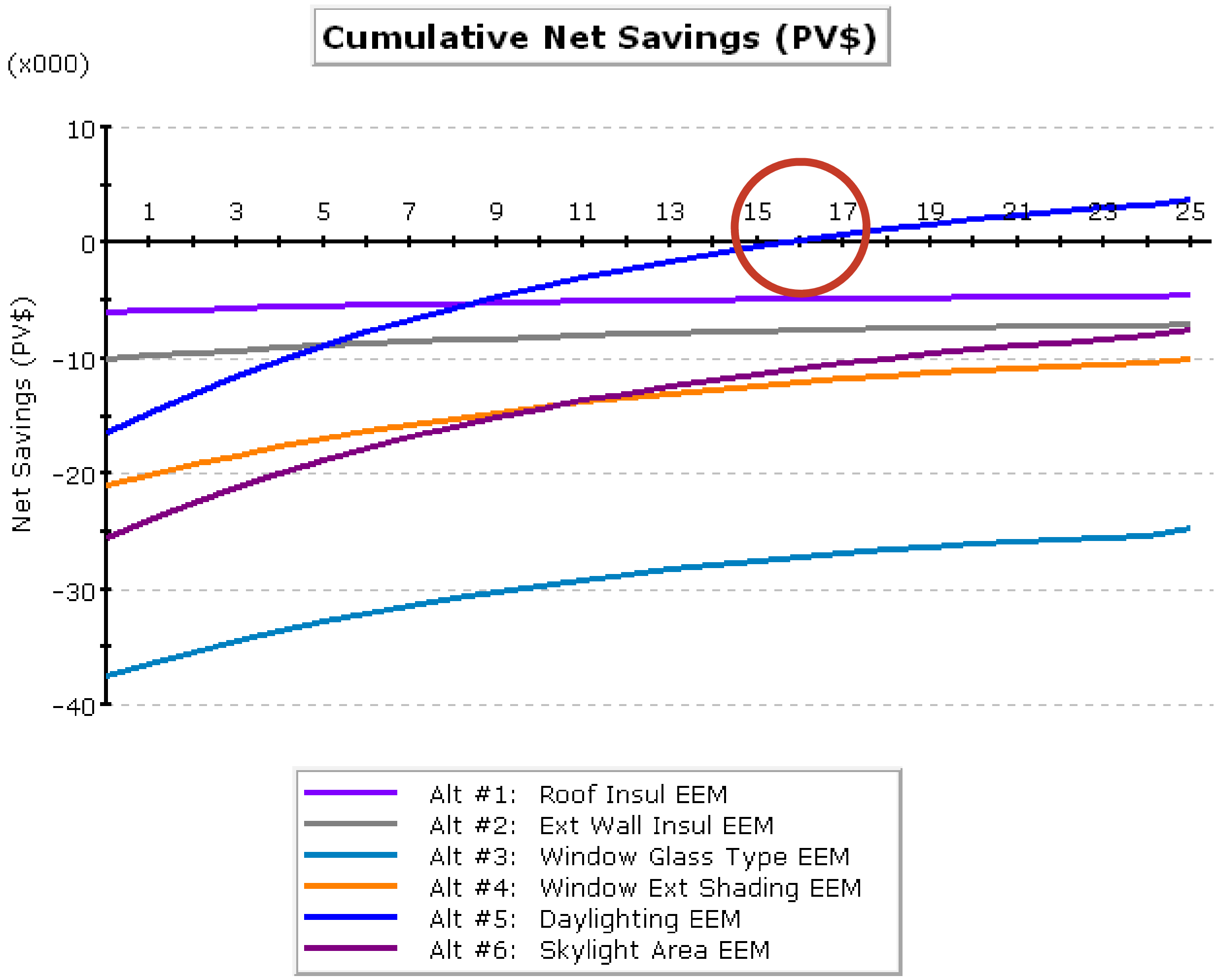
Life-Cycle Costs Summary

Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Total LCC PV$
Life-Cycle COSTS								
Base	Baseline Design	$1800000	$1800000	$11383	$87543	$0	$0	$1690903
Alt #1	Roof Insul EEM	$1806000	$1806000	$11261	$86604	$0	$0	$1695422
Alt #2	Ext Wall Insul EEM	$1810000	$1810000	$11092	$85305	$0	$0	$1697824
Alt #3	Window Glass Type EEM	$1837500	$1837500	$10101	$77683	$0	$0	$1715525
Alt #4	Window Ext Shading EEM	$1821000	$1821000	$10116	$77799	$0	$0	$1700858
Alt #5	Daylighting EEM	$1816500	$1816500	$8719	$67055	$0	$0	$1687077
Alt #6	Skylight Area EEM	$1825500	$1825500	$9189	$70669	$0	$0	$1698415

Case	Description	One-Time Costs 1st year $	One-Time Costs LCC PV$	Total Utility 1st year $	Total Utility LCC PV$	Maintenance 1st year $	Maintenance LCC PV$	Net Savings NS	Simple Payback yrs	Discnt'd Payback yrs	Saving-to-Invest Ratio SIR	Adjusted Internal Rate-of-Return AIRR
Incremental Life-Cycle SAVINGS (negative entries indicate increased costs)												
Alt #1	Roof Insul EEM	($-6000)	($-6000)	$122	$938	$0	$0	($-4520)	49.2	n/a	0.2	2.1%
Alt #2	Ext Wall Insul EEM	($-4000)	($-4000)	$169	$1300	$0	$0	($-2401)	23.7	n/a	0.3	5.2%
Alt #3	Window Glass Type EEM	($-27500)	($-27500)	$991	$7621	$0	$0	($-17701)	27.7	n/a	0.3	4.5%
Alt #4	Window Ext Shading EEM	$16500	$16500	($-15)	($-115)	$0	$0	$14667	1100.0	0.0	n/a	n/a
Alt #5	Daylighting EEM	$4500	$4500	$1397	$10744	$0	$0	$13781	n/a	0.0	n/a	n/a
Alt #6	Skylight Area EEM	($-9000)	($-9000)	($-470)	($-3615)	$0	$0	($-11338)	n/a	n/a	n/a	n/a
Cumulative Life-Cycle SAVINGS (negative entries indicate increased costs)												
Alt #1	Roof Insul EEM	($-6000)	($-6000)	$122	$938	$0	$0	($-4520)	49.2	0.0	0.2	2.1%
Alt #2	Ext Wall Insul EEM	($-10000)	($-10000)	$291	$2238	$0	$0	($-6921)	34.4	0.0	0.2	3.6%
Alt #3	Window Glass Type EEM	($-37500)	($-37500)	$1282	$9859	$0	$0	($-24622)	29.3	0.0	0.3	4.3%
Alt #4	Window Ext Shading EEM	($-21000)	($-21000)	$1267	$9744	$0	$0	($-9956)	16.6	0.0	0.5	6.7%
Alt #5	Daylighting EEM	($-16500)	($-16500)	$2664	$20488	$0	$0	$3825	6.2	15.6	1.2	11.0%
Alt #6	Skylight Area EEM	($-25500)	($-25500)	$2194	$16873	$0	$0	($-7513)	11.6	0.0	0.7	8.2%

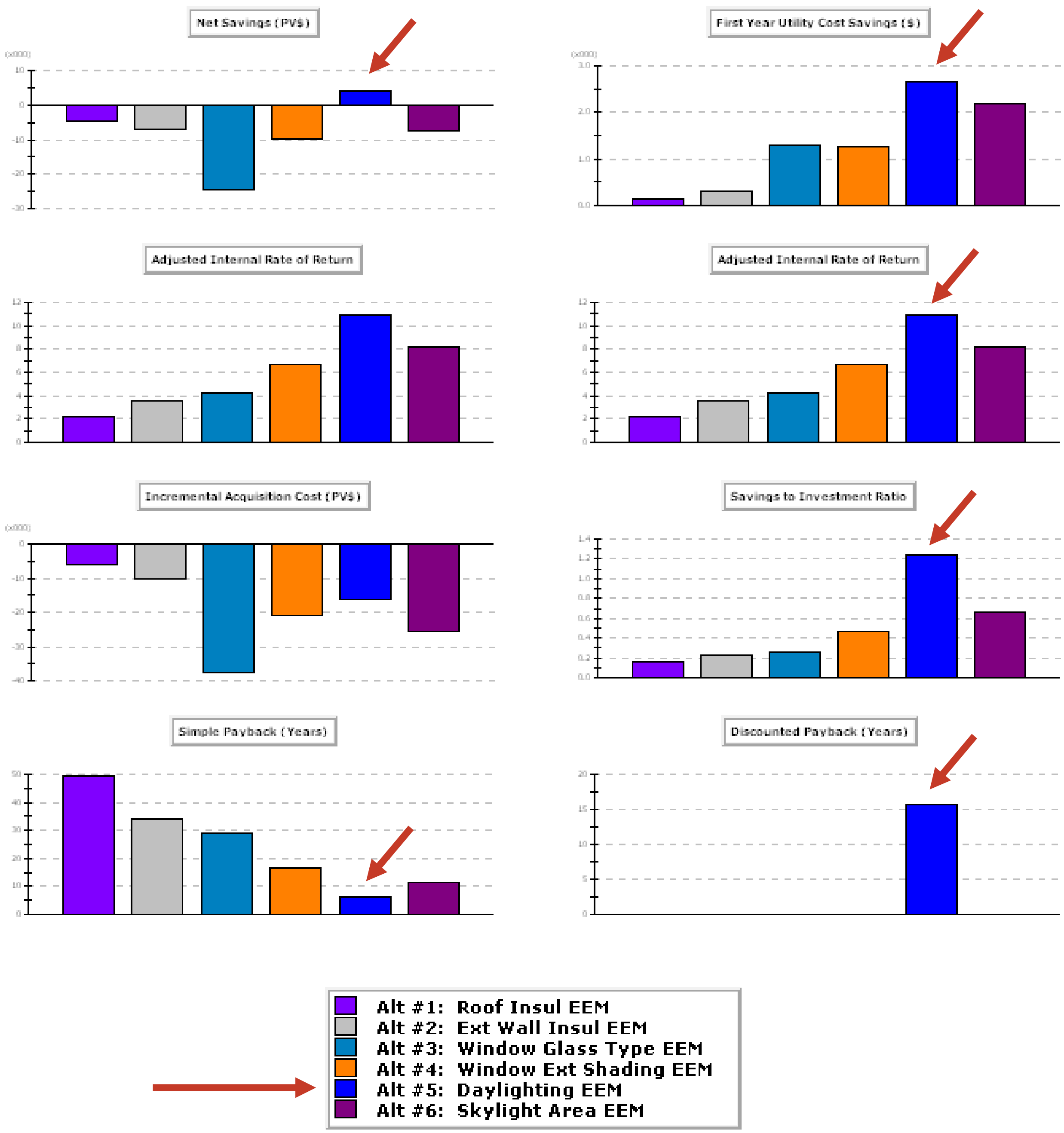
EXAMPLE

Cumulative Net Savings (PV$)



EXAMPLE

Life-Cycle Savings Comparison



EXAMPLE

FINISHING THE EXERCISE

At this point, you can continue working with either example, or simply save and close out of eQUEST. If at any time you have questions, please refer to the module text for more in-depth instructions.

eQUEST FORMS

PROJECT:
DATE:

Schematic Design Wizard Form

Screen 1	General Information
Project Name:	
Building Type:	
Location:	
Utility Information:	
Areas and Floors:	
Cooling and Heating:	
Other Data:	

Screen 3	Building Footprint
Footprint Shape and Notes:	
Zoning Pattern & Notes	
Floor Heights:	

PROJECT:
DATE:

Screen 4	**Building Envelope Constructions**
Roof Surfaces:	
Above Grade Walls:	
Ground Floor:	
Infiltration:	

Screen 5	**Building Interior Constructions**
Ceilings:	
Vertical Walls:	
Floors:	

Screen 6	**Exterior Doors**
Door Types:	
Door Construction:	

PROJECT:
DATE:

Screen 7	Exterior Windows
Specification:	
Window Types:	
Window Construction:	
Gross % / Net %	

Screen 8	Exterior Window Shades and Blinds
Overhangs:	
Fins:	
Blinds:	

Screen 9	Roof Skylights
Zones:	
Amount:	
Dimensions:	
Glazing Type:	
Light Well:	
Custom Zones: (from image)	

PROJECT:
DATE:

Screen 10	Ground Floor Daylight Zoning
Daylit From:	
Photosensors:	
Lighting control Method:	
Custom Zones: (from image)	

Screen 11	Typical (Middle) Floor Daylight Zoning
Daylit From:	
Photosensors:	
Lighting Control Method:	
Custom Zones: (from image)	

Screen 12	Top Floor Daylighting Zone
Daylit From:	
Photosensors:	
Lighting Control Method:	
Custom Zones: (from image)	

PROJECT:
DATE:

Screen 13	Activity Areas Allocation
Describe Settings:	

Screen 14	Occupied Loads by Activity Area
Describe Settings:	

Screen 16	Unoccupied Loads by Activity Area
Describe Settings:	

Screen 17	Main Schedule Information
Describe Settings:	

Screen 18	Interior Lighting Loads and Profiles
Describe Settings:	

PROJECT:
DATE:

Screen 19	**HVAC System Definitions**
System 1:	
System 2:	
System 1 Serves:	

Screen 20	**HVAC Zones: Temperature and Air Flows**
Thermostats:	
Temperatures:	
Air Flows:	

Screen 21	**Packaged HVAC Equipment**
Describe Settings:	

Screen 22	**HVAC System Fans**
Describe Settings:	

Screen 23	**HVAC System #1 Fan Schedules**
Describe Settings:	

Screen 24	**HVAC System #2 Fan Schedules**
Describe Settings:	

Screen 25	**HVAC Zone Heating, Vent and Economizers**
Describe Settings:	

PROJECT:
DATE:

Screen 26	HVAC System Hot/Cold Deck Resets
Describe Settings:	

Screen 29	Cooling Primary Equipment / Primary Equipment Heat Rejection
Describe Settings:	

Screen 30	Chilled Water System Control
Describe Settings:	

Screen 31	Heating Primary Equipment
Describe Settings:	

Screen 32	Hot Water System Control
Describe Settings:	

Screen 33	Domestic Hot Water Heating Equipment
Describe Settings:	

Screen 35	Electric Utility Charges / Utility Block Charges / Utility Time-of-Use Charges
Describe Settings:	

Screen 36	Electric Utility Time-of-Use Periods
Describe Settings:	

Screen 37	Fuel Utility Charges
Describe Settings:	

PROJECT:
DATE:

Screen 41	Project Information
Building Location:	
Building Owner:	
Component Names:	

[Screens]	Other Notes

PROJECT:
DATE:

EEM & LCC Project Information Form

Project:	
Architect:	
Location:	
Design Features to be analyzed:	
Baseline Run/LCC0:	
EEM Run #1/LCC1:	
EEM Run #2/LCC2:	
EEM Run #3/LCC3:	
EEM Run #4/LCC4:	
EEM Run #5/LCC5:	
EEM Run #6/LCC6:	

Project-wide LCC Data		**Marginal Income Tax Rates**			
DOE/FEMP Fiscal Year:		Federal:			
Number of Analysis Yrs:		State:			
Fuel Price Esc Rgn:	U.S. Average	Combined:			
Analysis Sector:		**Discount Rate Data**			
Second Fuel Type:		Specification:	Real ○	Nominal ○	
Uniform Price Escalation Rates			Pre ○	After Tax ○	
Electric ☐		Inflation Rate:			
2nd Fuel ☐		Discount Rate:			

Baseline Run LCC DATA	First Cost:		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

eQUEST EEM Runs and Life-Cycle Cost Analysis Forms

PROJECT:

EEM RUN:	
Measure Type:	
Apply Measure To:	
Describe EEM Changes Made:	

LCC DATA	First Cost:		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS

EEM Run:	
Measure Type:	
Apply Measure To:	
Describe EEM Changes Made:	

LCC DATA	First Cost:		Annual Maint. Cost:	
	INVESTMENT-RELATED COSTS		OPERATIONS-RELATED COSTS	
YEAR	DESCRIPTION	COSTS	DESCRIPTION	COSTS