E Z SIM

BILLING ANALYSIS TOOL FOR ENERGY ACCOUNTING, AUDITING AND COMMISSIONING

Version 6.0

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APPENDIX A -- Glossary Of Variables And Description Of Model

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About the Tool

The Energy Accounting Tool provides a way to quickly model a building's annual energy consumption and tune it to match the actual billing history.

How to use --

(1). Findings from the tuning process tell the energy auditor what to look for. To assist the audit, we can produce a "Benchmark Report". The tuning process may reveal useful clues to diagnose performance problems within the facility.

(2). The tuned model can be used to estimate energy used for specific end uses or the energy savings from conservation measures. For this purpose, we produce a "Proposal Report", assuming typical weather and occupancy.

(3). With the conservation model, one can predict consumption and compare to actual bills under actual weather and occupancy. For this purpose, we produce a "Commissioning Report".

Installation

The EZ Sim installation will have the following types of files:

- Ezsim.xlt   template file for EZ Sim

- *wx.csv   weather file(s)

We recommend that you install the template file at the appropriate location in your computer for spreadsheet templates. Typically, this is something like "C:\Program Files\Microsoft Office\Templates". However, the directory may have a different path name for your computer. The template location is where Excel looks when you select the "File" "New" command.

Install the weather files in whatever working directory you choose to set up for EZ Sim projects. This working directory is where you will probably want to save EZ Sim project worksheets as they occur. The advantage to template files is that they stay separate and uncorrupted from project files. That way whenever you start a new project, you will always be able to start with a clean template.

1. Getting Around

We assume the reader is familiar with Excel spreadsheets and their layout. Our discussion will be limited to the specifics of the Energy Accounting Tool.

E Z Sim consists of nine stacked spreadsheets. These are labeled as:

- Title Page
- Customer Information
- Tuning Graph
- Demand Graphs

- Detailed Description
- Worksheet
- Benchmark Report
- Proposal Report
- Commissioning Report
- Trend Analysis

Within each sheet, we have tried to consolidate the data fields so that you can move to blocks of text using <PgUp> or <PgDn>.

Note: You can switch between stacked spreadsheets in two ways: (1) Click on the labeled tab at the bottom (2) Press <Ctrl><PgUp> or <Ctrl><PgDn> to move between sheets.

Figure 1 is a flowchart showing how one uses the different worksheets for different tasks within EZ Sim.

Customer Information tab

Tuning Graph tab

Benchmark Report tab

Detailed Description tab

Proposal Report tab

Trend Analysis tab

Commissioning Report tab
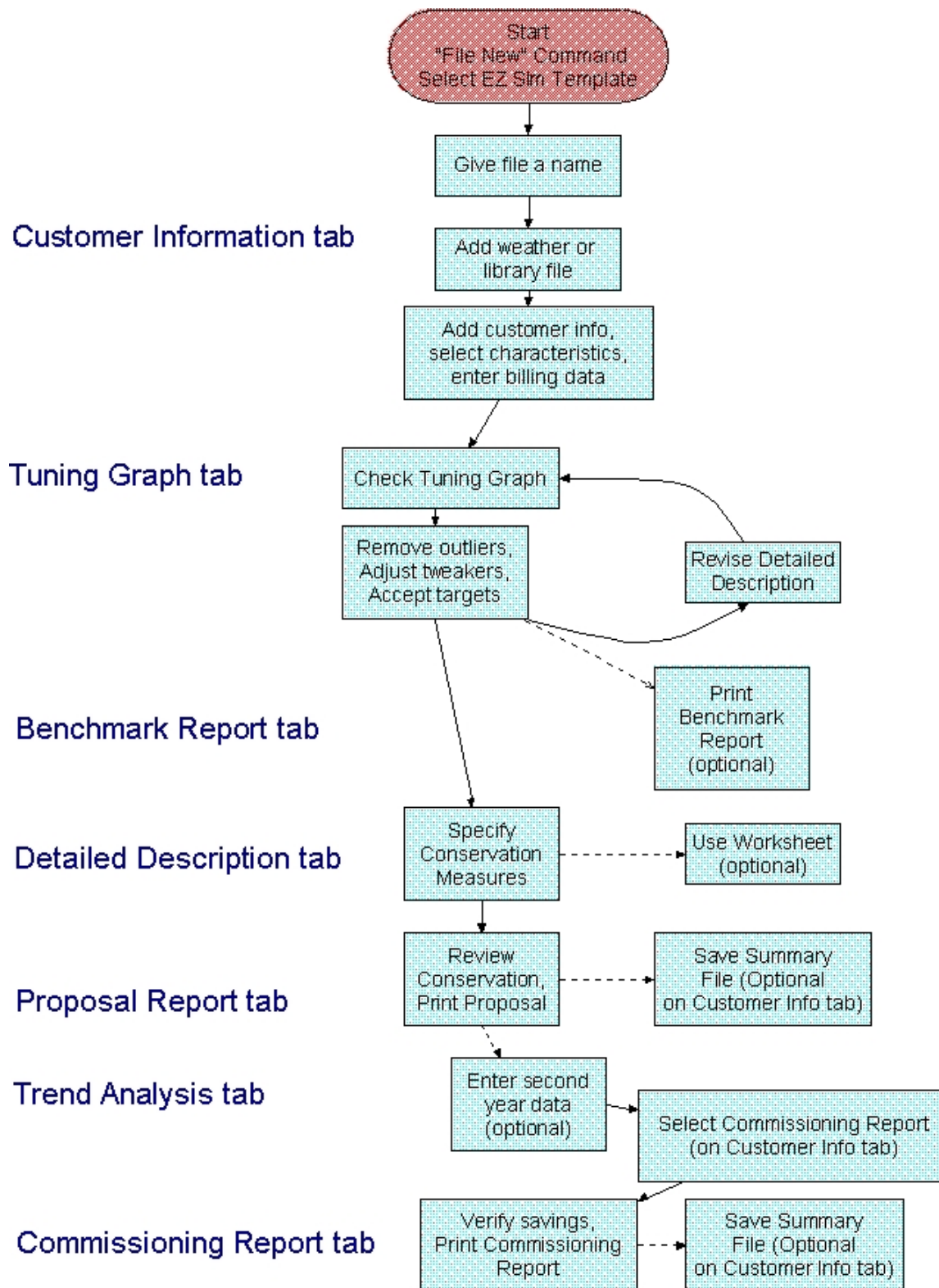
Figure 1. EZ Sim Flowchart

2. Getting Started

You can start your first model of a building with only minimal information. You will need the following:

- Simple Building Description, over phone or quick walk-through
  - ◊ Square footage
  - ◊ Type of building
  - ◊ Type of heating and cooling equipment

- Billing History

The Tool will apply standard assumptions for your type of building. If you have further information about the building, you can update as described in Section 5.

Start Excel and open the template model to the Customer Information Page.

> Note: Set Excel for automatic recalculation to assure that computations are always current. Select under "Tools" "Options" "Calculation".
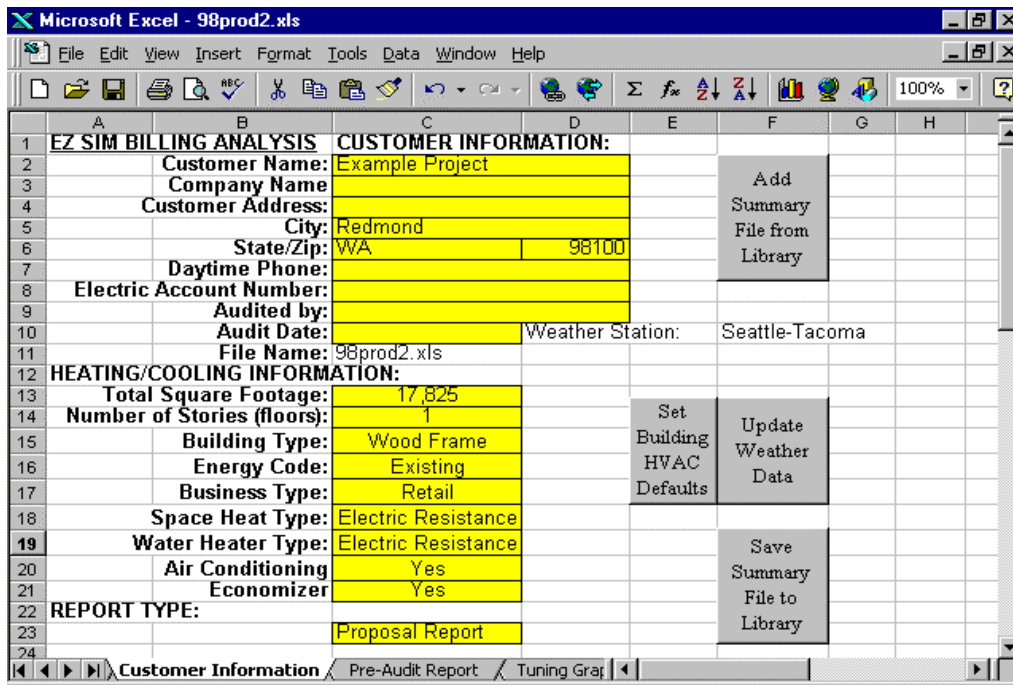
Figure 2. Customer Information Page

Figure 3. Billing Data Area

3. Customer Information Page

The Customer Information page (Figure 2) allows one to input general information about the site. The Customer name, address and contact information provides a record for subsequent output reports.

> **Input areas are highlighted in yellow. Do NOT enter data into other areas!**

Customer Information: Name and address information is for your records. This information is repeated on other sheets to assure consistent record keeping.

Nearest Weather Station lists the site you are using (see Bill Calcs page).

Total Square Footage: input building size. It can be approximate.

Number of Stories: input number of floors

Building Type: choices are
- ◊ Wood Frame
- ◊ Cement Block
- ◊ Masonry
- ◊ High Rise

Energy Code: choices are:
- ◊ Existing
- ◊ New Construction

Business Type: choices are:
- ◊ Food Store
- ◊ Hospital
- ◊ Large Office
- ◊ Lodging
- ◊ Office
- ◊ Residential
- ◊ Retail
- ◊ School
- ◊ Warehouse

Space Heat Type: The choice of heating type also includes the efficiency rating method that will be used to specify a nominal efficiency for the equipment. Choices are:
- ◊ Air Source HP, HSPF
- ◊ Ground HP, COP
- ◊ Electric Resistance
- ◊ Gas or Other Fuel
- ◊ None

Water Heater Type: choices are:
- ◊ Electric Resistance
- ◊ Gas or Other Fuel
- ◊ None

Air Conditioning: choices are Yes or No.

Economizer: choices are Yes or No.

Report Type: choices are Proposal Report or Commissioning Report. Start with the Proposal Report. We will explain these choices later.

The Macro buttons allow for certain operations. (Note: these buttons may not be available on the Excel '95 version due to software limitations.)

Add Summary File From Library

If there is a previously modeled building saved as a summary file, you can bring it in and examine how the modeling was done or use it as a starting point for a new model.

Save Summary File to Library

This button saves a summary file to add to your file folder.

Update Weather Data

If you have downloaded a new weather file, this button will automatically add the weather data to the working file.

Reset Building HVAC Defaults

There are now a variety of more detailed options to select for Duct Configuration and HVAC Controls. At the "Customer Information" page, you may not have sufficient site information to be able to select different options or you may not know what equipment is present. This button sets the HVAC parameters to match the default values considered typical for a building with the construction and business type you have already specified.

Billing Data Area

Lower on the page (Figure 3) is an area for you to input the billing history. Later, we will "tune" the model to match the bills.

The following section is set up to input electric billing data manually. You can also paste in from another worksheet if you have it properly organized.

The first section is organized as:

ELECTRIC BILLING DATA

Read Date: Enter date of the meter reading. The billing interval is computed from the date in adjacent rows.

Billed kW: enter the monthly kW as shown on the bill. If there is more than one meter, add them together and enter the sum.

Billed kWh: enter the monthly kWh as shown on the bill. If there is more than one meter, add them together and enter the sum.

Hint: Check the number of days and temperature columns to the right. If you see strange values, there may be a typo during entry. Note that if meter read dates extent past the data stored in the climate file (see chapter for Advanced Users), you will not be able to use those observations.

Temperature: Normally the program will compute the average temperature during the billing interval. However, if you have your own source of temperature data, you can enter these into the yellow cells. Then the program will use your data instead of the computed values.

Accept Code: If you know that some of the months are atypical, you may not want to use them in the billing analysis. Examples might be months during which the tenants moved in or out. For such months enter zero (0) in this column and the data points will be ignored during the calculations.

The spreadsheet looks at the meter reading dates, calculates the time between meter readings and computes an average daily temperature for the period between dates. It also computes average rate of energy use (Watts per square foot) using the time period between meter reading dates. This is important because "monthly" energy bills are rarely read exactly on the month.

GAS or FUEL BILLING DATA

Enter billing data in the same way. Include at least the meter read date and the therms used for each month. The billing records will likely show the amount of therms used for each period. Calculation from the meter readings may not be appropriate because the therms per cubic foot can vary slightly.

The tool assumes that you are putting in fuel usage as therms. If the customer uses No. 1 heating oil, convert by the factor of 1.34 therm per gallon.

CHANGE TEMPERATURE RANGE

Figure 4 shows the next area below the gas bill input table. EZ Sim is configured with a range of temperatures typical for looking at a building in a temperate climate. That is, we look at operations with an average temperature ranging from 20 degrees to 80 degrees F. You may want to change this range for more extreme climates. For tropical climates, the range of climate extremes may be much less. We suggest a range of 68 degrees to 92 degrees F. Although not required to be evenly distributed, it is a good idea to select an evenly distribution of seven temperature points for graphing. Input these points into the yellow cells. Click on the "Update Temperature Ranges" button to setup the subsequent graphs.

4. Tuning To The Bills

At this point you have a model of the building based on average or typical characteristics. (To change to more detailed specifications, see the "Detailed Description" page discussed in section 5.) Obviously, the model will not be an exact match to your particular facility. So out first step is to check the model against the billing data and adjust the model so it agrees with actual consumption.

The "Tuning Graph" page has several graphs. At the top, Figure 5 shows monthly average energy use compared to the model's predictions. We will use this graph to check and see which month, if any, exhibit atypical behavior.

The next graph, Figure 6, is our primary workhorse. Graphing average energy usage against average temperature allows us to understand how different end uses interact to affect consumption. That is because the different uses vary by season. So we can describe building operations as a line. Although the data points may be in different locations depending on weather, they can be compared to the line that represents expected operations. And it's easy to tell if the points are on or off the line.
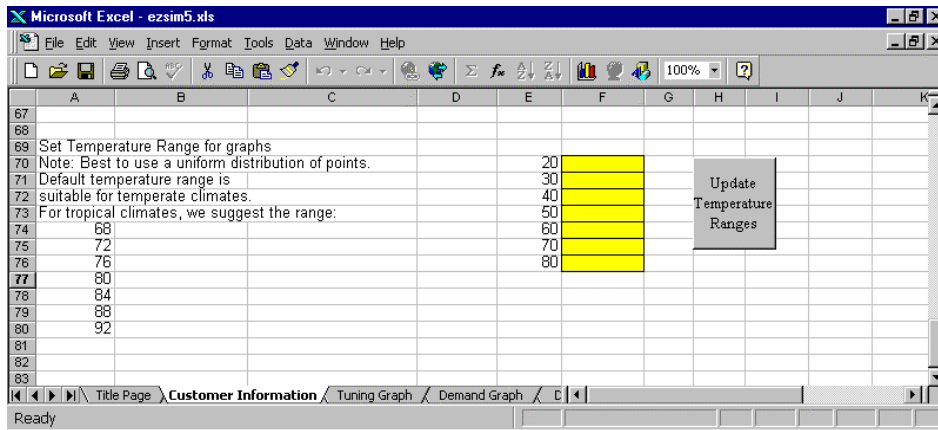
Figure 4. Change Temperature Range
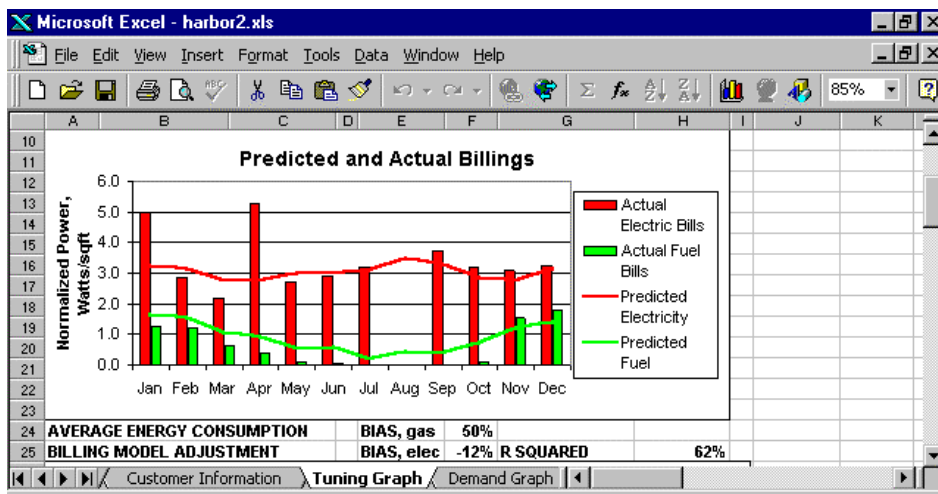
Figure 5. Review Model Graph
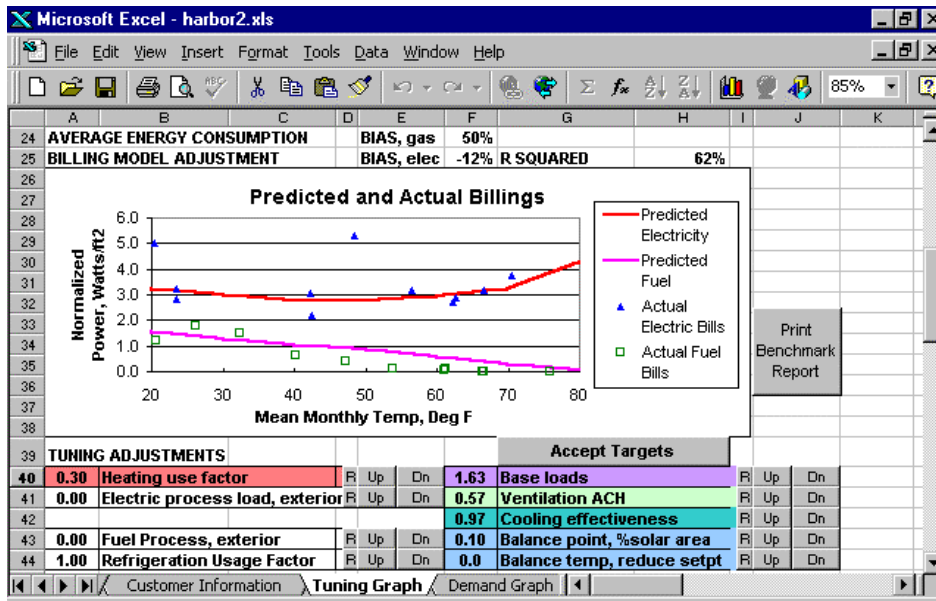
Figure 6. Operations Plot or Tuning Graph

Here is how to understand the operations or "tuning" plot. When we graph the average monthly energy use against the average temperature, we see the following general sort of graph. For electrically heated buildings, the electricity usage has a U-shaped plot. The bottom of the plot is mostly usage that is the same regardless of season -- that is, the lights and plug loads. The portion of the electricity that increases with hot weather represents air conditioning. The portion that increases with cold weather represents space heating. Of course, all of these uses are present at the same time and the model serves to help us keep track of them.

For gas heated facilities, the plot is similar except the space heating usage shows up as gas consumption rather than electricity. The graph below shows a building that uses both.

Notice how the graph is arranged. The lines show how the model is computing energy usage. The data points show the actual billings. You want to adjust the lines so that they fit the points. A good fit is indicated by an R2 (upper right corner) that is as close to 100% as possible and bias indicators as close to zero as possible.

Hint: If the R Squared does not have a value, it may be because the worksheet is trying to compute for fuel use when there is none. For an all-electric building, make sure the fuel bill observations have the reject code set to 0.

Tuning a model is somewhat of an art. The tuning factors can react in different ways that all provide reasonable fit to data points. Steps for a tuning process follow. These steps are the same as those followed by an engineer using a sophisticated computer model. The steps can be applied in any order but generally the first steps will have the greatest effect.

To simplify tuning, we apply a two step process. First, we tune using quick adjustment factors as described below. Later, we will arrange the building parameter so that these adjustment factors are no longer needed.

The quick adjustment factors are in the table labeled "TUNING ADJUSTMENTS" in the graph above. For each adjustment, there is first a number showing the current value being used by the model. Then there is the name of the adjustment; then a reset button labeled "R". And finally the "Up" or "Down" buttons will move the modeled line as indicated.

HINT: If you don't like the changes, you can always restore the factor to its original value by clicking on the "R" button.

The colors for each of the adjustment factors will be used to help us remember which factors affect which specific end uses.

Step 1: *Base loads,* (Purple box)

Look at the bottom of the electric line. Does it look like the whole electric line needs to go up or down? If so, we need to adjust the fixed portion of annual consumption that represents lights and plug loads. You can adjust by changing this factor to adjust the internal loads within the building.

Step 2:   *Cool Effectiveness*, (Aqua box)

Does it look like the modeled line matches the electricity use during hot weather? To change the amount of cooling during hot weather, adjust this factor.

Step 3.   *Heating Use Factor,* (red box)

Does it look like the energy usage matches during cold weather? To change the amount of heating during cold weather, adjust this factor.

Step 4:   *Ventilation ACH,* (Light Green box)

Check the fuel or heating line. If that line needs to curve up at hot or cold weather extremes, change this factor. This factor changes the number of ventilation air changes per hour or ACH. Increasing ACH will increase the curvature for both the heating and cooling portions of the lines.

Step 5:   Balance point and temperature adjustments (Light Blue boxes)

Solar gain area, To change the balance temperature or point of inflection (where the line begins to show heating), adjust this factor. Increasing the solar gain area means that the building needs less space heating. So the balance temperature (where heating begins) is moved to colder temperatures. Alternatively, decreasing the solar gain area moves heating toward hotter weather and also requires less cooling. This factor has a relatively small effect. If a larger change is needed, consider changing the *Reduce Setpoint* adjustment.

Step 6:   Adjust baseloads and other process loads (White boxes).

 Sometimes there is a constant amount of energy usage for equipment that is not usually part of the building. For example, there could be parking lot lights that show up on the electric bill. Or there could be gas used for cooking or laundry facilities. If we think there is some constant usage of this type, we can include it as a process load. There are two categories -- either it is inside the building and contributes to internal gains or it is outside the building and has not effect on other end uses.

Electric Process Load, This is electricity used outside. An example might be parking lot lights. If the use occurs inside the building, adjust the *Base loads* instead.

Fuel Process, This is gas used outside the building as a constant baseload or in a way that does not affect internal gains. An example might be cooking where all the heat is ventilated out.

Refrigeration Usage Factor, This factor only applies if you have specified some amount of refrigeration consumption. That can be done on the "Customer Information" page by specifying "Air Conditioning and Refrigeration" for cooling. Or it can be done on the "Detailed Description" page to be described later. If you have some refrigeration, this factor moves it up or down. Refrigeration is similar to a baseload but increases somewhat with hot weather.

Step 7.   *Accept Targets*

Does it look like the model matches the bills? If so, click the "Accept Targets" button. This transfers our choices of "quick" tuning factors over to the "Detailed Description" page where we will be able to code these factors as engineering parameters.

What Have We Learned?

The adjustment process above is only the first step in tuning a model. It tells us where our initial guesses about the building are correct and where they need to be refined. All of these insights are hypotheses we can test in the field when we visit the building or when we talk to the facility operator. Here is what the tuning adjustments tell us:

Base loads: If we had to change this factor, then internal gains need to be adjusted. These include the product of lighting installed density and lighting use factor times operating hours. The same is true for plug loads. Thus, any or all of these variables could be adjusted to provide a more accurate model.

Cooling effectiveness: If we had to change this factor, it could be because the cooling equipment has a different efficiency, there could be losses in distribution or the cooling loads of the building could be different.

Heating effectiveness: If we had to change this factor, then it could be because the equipment has a different efficiency, there could be losses in distribution or the insulation level of the building could be different.

Ventilation ACH: Increasing has the effect of making the heating and cooling lines curve. The building becomes more sensitive to temperature.

Balance temperature adjustments: If we had to apply these factors, the most likely change is the assumed setpoints for heating and cooling. We should also check the assumptions about internal gains and the building UA.

Fuel Process: If these factors were used, then there is an additional use of fuel within the building.

Figure 7 presents a flowchart of the tuning process. Remember that the "tweakers" cover only the most common adjustments and only an aggregated level. Adjustments for the less common parameters or separation of multiple parameters takes place on the "Detailed Description" page because it offers more detailed choices.

Start

Enter Customer and Billing Data

Are Temperatures Computed?

No → Upate Weather Data

Yes

Review Tuning Graph

Need to Tune?

No → Review Detailed Description

Yes

Repeat Tuning Process

CheckFuel Line, Add Process Load? → Fuel Process Tweaker

CheckSpace Heat → Ventilation or Heating Use Tweaker

Check Electricity, Increase/Decrease All? → Baseload Tweaker, HVAC Type on Detailed Description

Check Calendar Plot → Change Hours on Detailed Description

Check Cooling → Cooling Tweaker, Change HVAC Type on Detailed Description

Check Balance Temp → Change Setpoints, Solar Gains

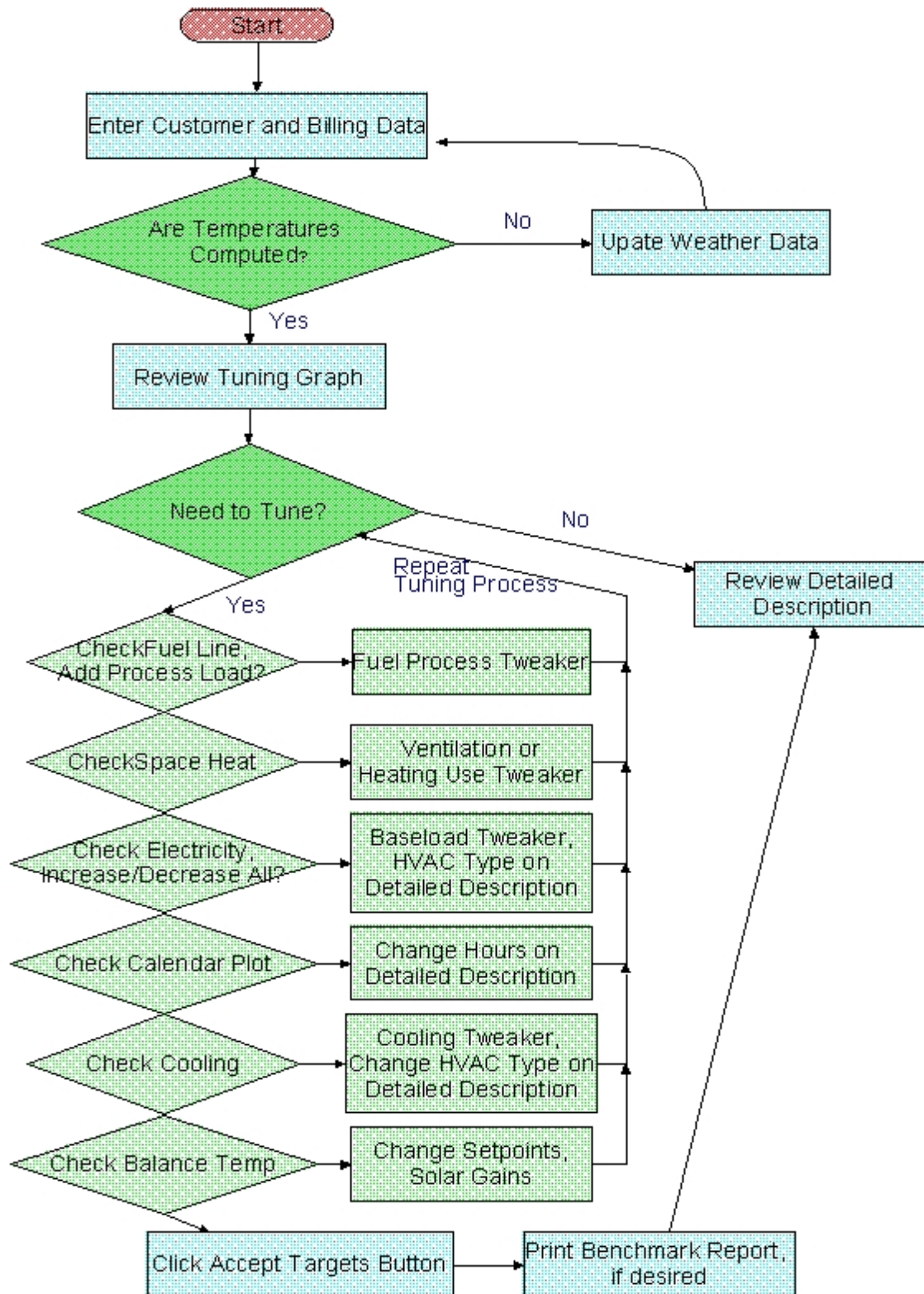Click Accept Targets Button → Print Benchmark Report, if desired

Figure 7. Tuning Flowchart

Checking the Results

Seasonal End Uses

Further down on the page are graphs that show how our choices have informed the model. There is a chart showing electricity end uses as a function of temperature. Look at the chart to see if the end use consumption seems reasonable. Below that is another similar chart showing fuel consumption.

These charts show a line for the "Comparison Case". This represents a similar building that has conservation measures installed. But before we make comparisons, we need to define the comparison case on the "Detailed Description" page. So don't utilize this line until we have completed that step in Section 5.

Electrical Demand

On the page "Demand Graphs" are similar charts showing demand or kW consumption. Figure 8 shows what the model assumes for demand as a function of temperature. The model estimates a typical demand for summer and winter. Then it extrapolates between these levels for shoulder months. Note that demand is defined in a conservative fashion -- as the 15-minute usage spike that appears on a customer's bill. This is an important distinction because the opportunities for demand savings are limited. Although conservation measures may improve overall energy consumption, there are still occasions when the HVAC system operates at its maximum capacity. Thus, the same 15-minute spike can occur, even though we hope it will be less frequent after conservation measures. For this reason, we make only conservative estimates for potential demand savings. Reducing lighting or other internal loads will reduce demand. But HVAC improvements likely will not. This issue is discussed in the section on conservation measures.

Figure 8 shows how the model is assuming a summer maximum and a winter maximum. Sometimes the model has difficult deciding on the maxima because it is not clear which months are heating and which are cooling months. The user can select a "seasonal break point", that is the temperature point to distinguish the seasons. One makes this selection by clicking on the "Change" button located just below Figure 8. The break point should be between 40 and 80 degrees. There is no particular rationale for these extrema -- they just serve to catch typographical errors in entering the value.
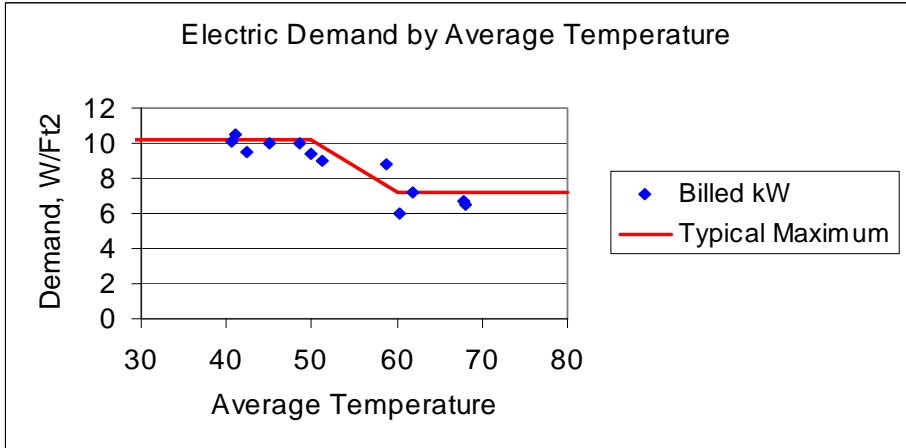
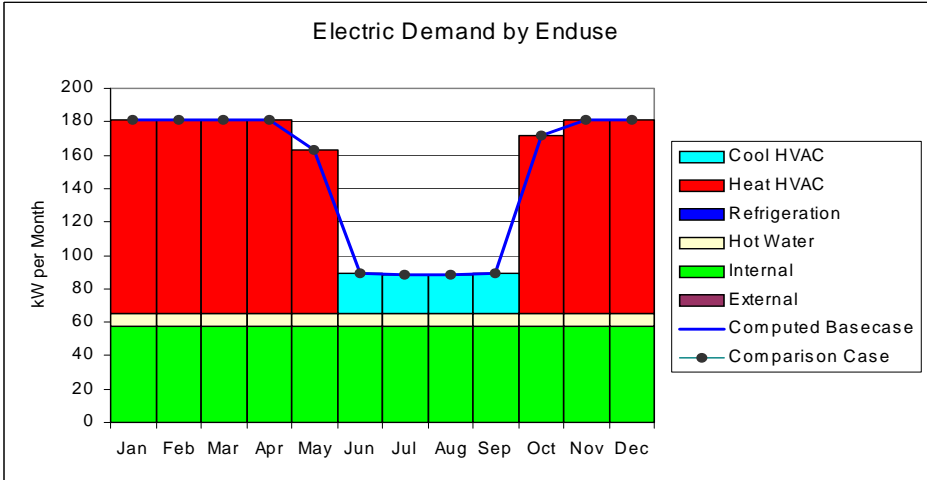**Figure 8. Actual and Modeled Demand**
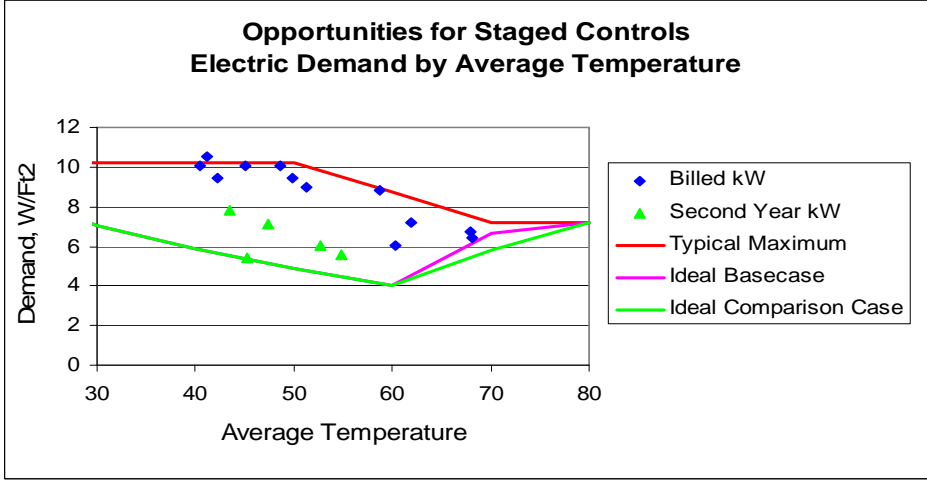

Figure 9. Monthly Demand by End Use

Figure 10. Opportunity for Staged Controls

Figure 9 shows how the model is allocating demand to different end uses. Remember that the demand represents peak consumption during one time of the day --whatever time requires the highest electricity use. In the example, we see that the load for lighting and other uses is assumed to be constant. Then, depending on the season, we have a demand component associated with either heating or cooling. In the example, the heating demand dominates the demand bills. After we have defined the comparison case, we will be able to see how conservation measures might affect demand.

Figure 10 shows how current kW usage compares to an ideal or well-operated building. The red line shows current kW consumption computed with the winter and summer demand maximums. The green line shows the basecase facility but with the ability to stage or modulate loads. In this example, where there are differences, it suggests that staging controls should be considered as a possible conservation options. The pink line shows an ideally modulated demand schedule derived from the comparison case. These lines indicate the opportunity for conservation savings that might reduce demand, if applied properly.

5. Refining the Tuned Model

Now we have a tuned model. But the tuning was done by applying the adjustment factors. Ideally, we would like to fix our assumptions about the building as engineering parameters and remove the adjustment factors. We do that by reviewing the page titled "Detailed Description".

This page allows one to change the standard assumptions about the building. One uses this page (1) to update the base case building when you have additional information (2) to match parameters derived from the tuning to bills (3) to specify energy conservation measures.

This page shows two columns for building parameters -- the base case building and the comparison building.

Input areas are highlighted in yellow. Do NOT enter data into other areas!

If you change the parameters in the yellow areas, you will see the default values change.

Detailed Description Page

Adjust Solar Gains and Envelope Description (Blue Block)

The first part of the Detailed Description page is shown in Figure 11. For explanations of the variables, consult the glossary in the Appendix.

Figure 11. Envelope and Glazing Description

Notice how the columns are filled in with default assumptions. If you know additional information about the building, you can put it in the appropriate cell. Enter the data in the yellow box and the column will update. For example, if you know that the building is well insulated, you can change the U-value of the building components. Definitions of the variables are off to the right of this screen.

This page shows a value called the "Effective Glazing Product" in the blue outlined box. If you have applied the Balance temperature, solar gains adjustment factor, here is where the effects show up. A red warning message will pop up to with a target value for the gains. The areas marked in blue are alternative ways to change the Effective Glazing Product. You can adjust the window parameters until the glazing product matches the target value.

Adjust Baseloads (Purple Block)

Now let's look at the next part of the Detailed Description Page in Figure 12. Here we see the same way of entering data for the Connected Loads Description. In this case, the page shows the "Average Internal Gain" that is used by the model. This average is a function of the amount of lights and plug loads as well as the number of occupied hours. If you are using the "baseload up/down" adjustment factor, a reminder message in red will pop up.

In the example shown, a message pops up to say that internal gains should be adjusted to total 1.68 W/sqft. And the current value is 1.40 W/sqft. We would like to set up the model to match the target. You can modify several variables to accomplish that result. These are shown in purple to match the Average Internal Gain box. Usually the

"Connected Lighting" or "Connected Plug Loads" are ones to modify. Enter appropriate values in the right or Comparison Case column until the Average Internal Gains agree with the target. In the example above, values of 2.00 W/sqft for lights and 1.00 W/sqft plug loads were entered in the right column. One or both of these values could be increased depending on what you think best suits this particular building.

Alternatively, you might adjust the operating hours as described later. Or you could adjust the Lighting or Plug Usage Factor. (The usage factors refer to the fact that not all the installed lights or appliances are on at one time. Usually, we assume about 85% are on. However, it could well be less of buildings with partial occupancy. Or even more for buildings that are highly used.)

Notice that when you change one column a red "X" pops up on the left. This message is a reminder that you have specified something different between the two buildings. It serves as a reminder if conservation measures have been specified.

You may have specific information to enter. For example, if an energy audit was done, the auditor should provide a specific number for the Connected Lighting. In this case, enter the specific number in the right column. Then you can still adjust the "Light Usage Factor". Alternatively, you may adjust the number of occupied hours. Occupied hours are located two pages down and are also outlined in purple.

Follow the same process of modifying the right column until the Average Internal Gains match the target. Then make sure the values in the right column are the same. Later, we can change the Comparison Case to include conservation measures. But first, it's a good idea to make sure that all values between the two columns match. To remove the pop-up message, go back to the Billing Data page and click the "Accept Targets" button again. The tuning graph should not change.

Adjust Ventilation (Green Block)

In Figure 13, we do a similar adjustment for the Occupancy Description. Here we can adjust the amount of ventilation so that it matches that assumed during the initial bill tuning process. In the example shown, a ventilation rate of 2.00 ACH is entered during occupied hours. But to match the bills, requires a target of 5.00 ACH. (This building was experiencing runaway economizers!) So we need to increase the ventilation rate until we match the target. Note the red "X" in column A to remind us that we have something different between the two columns.

Figure 14 details hours of operation. Operating Schedules have already been discussed in the context of Internal Loads. Note that this data block is part of the "purple" block associated with the Baseloads.

Operating schedules for Exterior Lights, such as parking lots or security lighting, are shown in Figure 15. If you decide to change this schedule, you may need to review the Bill Tuning chart to assure that the fit of curves to data is still good.

Figure 12. Internal Loads Description

Figure 13. Occupied/Unoccupied Description
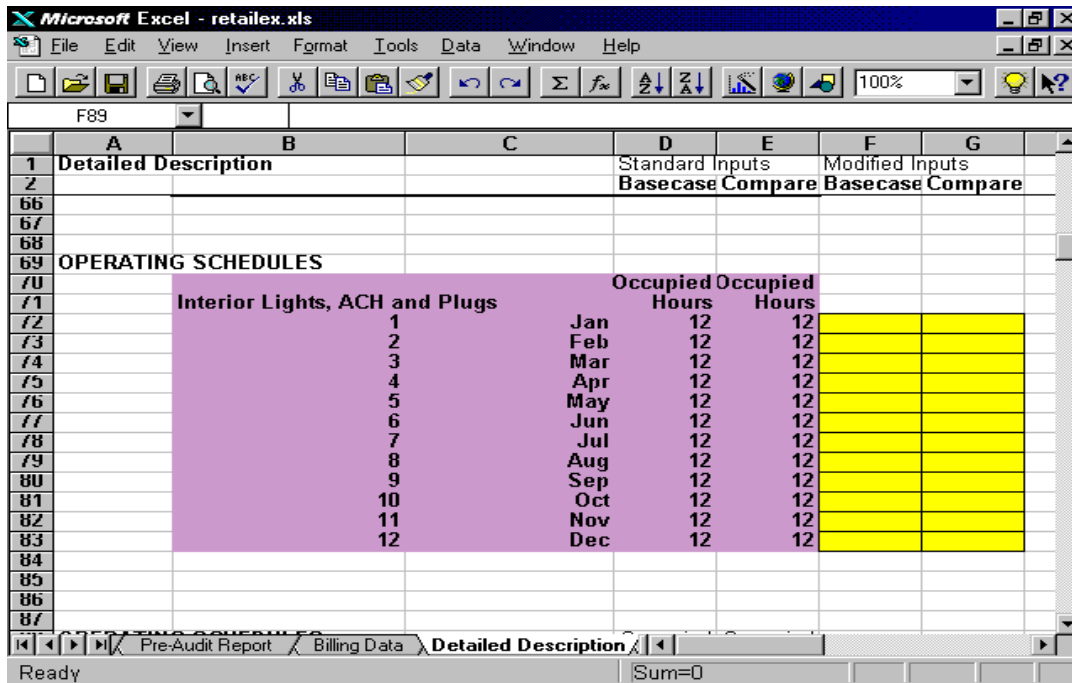
Figure 14. Operating Schedules
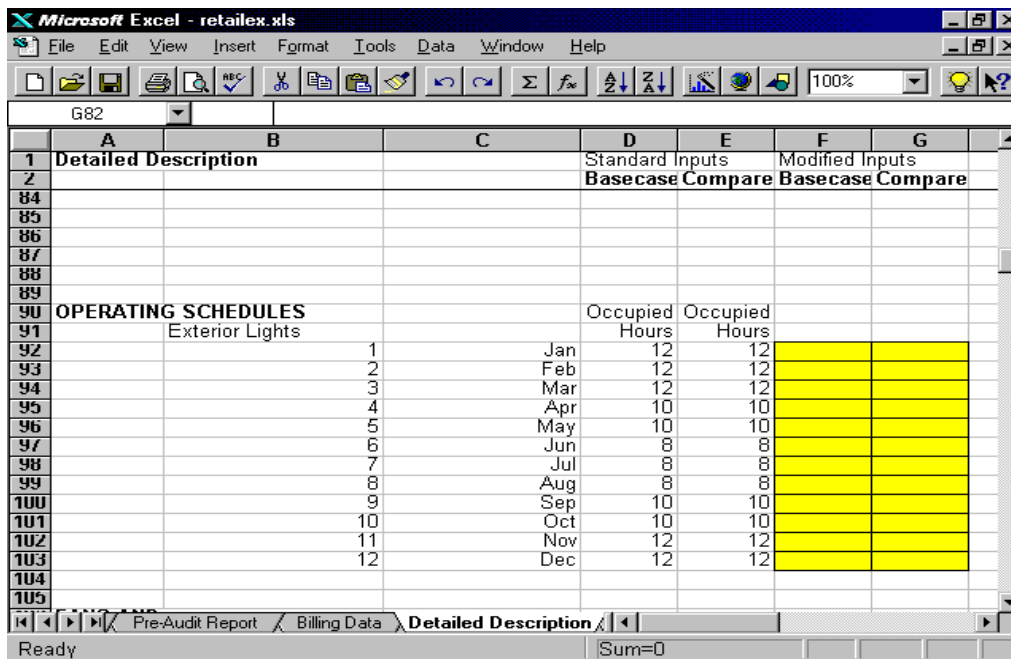
Figure 15. External Light Operating Schedule

Figure 16. Ventilation and Fan Description

Ventilation and Fan Controls

Figure 16 describes fans and ventilation. For details of these variables refer to the Glossary in the Appendix.

The first choice box is for the duct configuration -- choices are single and dual duct systems. Table 1 shows examples of how to define some common duct configurations.

The next choice box is for type of ventilation -- usually either air coming in with the HVAC or with mechanical ventilation.

Fan resizing is a conservation measure that may be applied to the comparison case. It will be discussed under conservation options.

The fan control choice box is an important energy specification. On/Off are the simplest controls -- typical of packaged rooftop units. Often these units operate with Constant Volume (CV). More advanced and efficient central control systems include Variable Air Volume (VAV). Older VAV systems may rely on inefficient vanes to modify the airflow. More modern systems may use Variable Speed Drive (VSD) to regulate airflow. Advanced systems with digital controls may use a Terminal Regulated Air Volume (TRAV) approach. The advantage of TRAV systems is due to controls that allow for

airflow reset based on duct pressures. This is indicated a Pressure control factor close to 100%. A poor VAV system may be indicated by excessively high minimum box flow rates. This also indicates leaky dampers that may cause seriously affect energy consumption. A poor HVAC system in general may be indicated by high static pressure.

Table 1. Duct Configuration/ HVAC Control Options

Duct Type	Definition	Control Strategy, Multi-Zoned HVAC	Control Strategy, Single Zone per HVAC unit
Dual Duct	Both heating and cooling distributed by separate ducts	CV with Time Control, VAV	Not applicable
Single Cool	Cooling distributed by ducts, heating by terminal resistance, radiator or coil	CV with Time Control, VAV	On/off with typical packaged AC units
Single Heat	Heating distributed by ducts, cooling (if any) by fan coil	No central distribution of cooled air, could have chilled water loop	On/off with typical packaged heater or heat pump
Single Both	Heating and cooling alternately distributed by duct or fan coil	Typical of Heat Pump Loop, utilizes central distribution with individual fan coils fan heat/cool in each zone	On/off with typical packaged heating/AC units, PTACs

HVAC controls influence choices for related parameters are shown in Table 2.

Table 2. HVAC and Fan Control Options

HVAC Fan Control Options	Typical Conditions	Related Variables
Constant Volume, Time Control	Heating/cooling distributed from central plant and mixed at terminals, fan runs constantly, boxes forced to accept minimum flows whether needed or not. Highly inefficient, potential terminal reheat problems.	Minimum box flows are high with consequent damper leakage and terminal reheat problems, high static pressure
On/Off	Packaged units or other systems with simple on/off thermostat, constant volume fan controlled by thermal loads	
On/Off with Constant Volume Fan	Heating/cooling controlled with on/off thermostat but fan timed for ventilation, typical of Heat Pump Loop Systems	Occupied ventilation rate Heat Recovery, Heat Pump Loop
VAV with Damper	Variable Air Volume, but flow controlled by dampers, most inefficient. Degenerative mode of a failed Vane system.	Minimum box flows are high with consequent damper leakage and terminal reheat problems, high static pressure
VAV with Vanes	VAV with poor modulation at low flow rates	Minimum box flows are high
VAV with VSD	VAV with fan speed controlled by total duct pressure or flow	Reduced minimum box flows, reduced static pressure, Pressure control factor is 0.5 to 0.7
VAV with Pressure Reset	VAV with multi-speed fan controlled by changing duct pressure settings	Reduced minimum box flows, reduced static pressure, Pressure control factor between 0.4 to 0.6
TRAV	VAV with flow controlled by flow measured at terminals	Low minimum box flows, low static pressure, Pressure control factor is 0.9 to 1.0

Figure 17. Heating System Description

Figure 18. Cooling System Description

Adjust Heating Effectiveness (Red Block)

Figure 17 describes the Heating System. There are three possible types. First, the system can use recovered heat if it is appropriate. Examples include a circulating loop heat pump system of heat recovery from grocery store refrigeration. For ordinary buildings, these options are not likely. For details on specifying a thermal loop or other heat recovery system, se the Appendix.

Second, the system can use electricity, either resistance heating or a heat pump. This is the most likely option. Third, the system can use gas or other fuel. In this case, the gas is used first whenever temperatures fall below the "Fuel Heat Threshold Temperature". In the example, this temperature is set to 100 degrees so gas will always be used for space heating. It is possible to have a heat pump with gas backup, in which case the threshold temperature would be specified as something like 40 degrees. In that case, gas would be used below 40 degrees and the heat pump at higher temperatures.

Heating equipment comes in a wide range of efficiencies. You may want to consider a high efficiency unit as a possible conservation measure. For that reason, you can specify a nominal rating for the equipment. The rating units (HSPF, COP or AFUE) are selected when you pick the type of heating system. In the example above, selecting a heat pump gives us a default HSPF of 5. If you know what the rating of the equipment is, put that value into the right column.

Refining the adjustment follows a similar procedure. You could adjust the Efficiency Rating. However, since that is a standard rating, it is better to leave that as the nominal equipment rating. Instead, change the Efficiency Modifier until the Modeled Heating Effectiveness agrees with the target.

Then make sure the values are consistent in the right column.

Adjust Cooling Effectiveness (Aqua Block)

Figure 18 shows how we specify the cooling system. You can input an efficiency rating for the air conditioning equipment. You can also change the Efficiency Modifier until the Modeled Cooling Effectiveness matches the target. This efficiency modifier is an empirical adjustment that frequently needs to be changed to match the observed consumption. One point should be mentioned -- the option for selecting a chiller plant usually assumes a chiller/ cooling tower combination. For a chiller with an air-cooled condenser, select an air cooled system as chiller/air.

Supermarket Refrigeration

The spreadsheet allows one to estimate the consumption due to supermarket refrigeration. The key is to inventory the types of refrigeration loads by the case temperature. We have set up the worksheet in Figure 19 for that operation.

Figure 19. Refrigerated Case Description

	A/B	C	D Basecase Lineal Ft	E Compare Lineal Ft	F Condu Btu/ft	G Auxillary W/ft	H	I
1	Detailed Description		Standard Inputs		Modified Inputs			
2	Grocery7		Basecase	Compare	Baseca	Compare		
163	REFRIGERATION		Basecase	Compare	Condu	Auxillary		
164	Cooler Case Types		Lineal Ft	Lineal Ft	Btu/ft	W/ft		
165	39 degrees, open		30	30	25	45		
166	39 degrees, closed				10	90		
167	30 degrees, open		30	30	25	45		
168	30 degrees, closed				10	90		
169	-10 degrees, closed		30	30	15	80		
170	-10 degrees, open				15	35		
171	-10 degrees, closed				15	80		
172	walk-in, 30 degrees				20	35		
173		Adjust Refrigeration Usage		1.10				
174	Total linear feet		90	90				
175	Mean Conduction		22	22				
176	Mean Auxillary		57	57				
177	Average Temperature		20	20				
178	Refrigeration Thermal Export, W/sqft		0.9	0.9				

Figure 19. Refrigerated Case Description

Figure 20. Refrigeration System Description

	A/B	C	D Basecase	E Compare	F Baseca	G Compare	H/I
1	Detailed Description		Standard Inputs		Modified Inputs		
2	Grocery7		Basecase	Compare	Baseca	Compare	
179	Refrigeratio Load Factor		0.7	0.7			
180	Refrigeration Usage Factor		1	1			
181	Resistance defrost, fraction served		0	0			
182	Compressor code						
183	Basecase	Compare					
184	Piston	Piston	1	1			
185	Compressor Efficiency modifier		1	1			>1 more effic than nomin:
186	Compressor Distribution Efficiency		0.9	0.9			
187	Compressor Control code						
188	Basecase	Compare					
189	Heat Recovery	Heat Recovery	3	3			
190	Condenser Code						
191	Basecase	Compare					
192	Air Cooled	Air Cooled	1	1			
193	Condenser Efficiency modifier		1	1			>1 more effic than nomin:
194	Condenser Fan Fraction		0.1	0.1			
195							

Figure 20. Refrigeration System Description

Typically, the refrigeration cases are described as:

Dairy and vegetable cases	Medium Temperature	39 degrees
Deli and Meat cases	Low Temperature	30 degrees
All frozen foods	Freezer	-10 degrees

In addition, cases are described as open (chest type freezers or open deli cases) or closed (with glass doors). For each, we inventory the lineal feet of each case.

Notice we are only counting cases connected through refrigeration lines. We do not include self-contained coolers since these would be included under plug loads. Check carefully when there are beverage coolers and deli cases. If there is a grill with warm air coming out, these are self-contained units and DO NOT COUNT. You can check the line titled "Refrigeration Thermal Export" to get an idea of how much the refrigeration load turns out to be. Typically, a grocery store will have 3-5 W/sqft. If values are extremely high, that is an indication that too many cases have been counted.

For walk-in beverage and dairy coolers, count the length of the glass door area as the length. There may also be walk-in storage coolers for frozen foods, meats or produce. These are better insulated than the retail cases so the actual size is less important. Merely inventory the length of these walk-in rooms regardless of the width.

The lineal parameters can be changed using the yellow cells. The parameters are the conductivity (Btu/ft-deg) and auxiliary power (W/ft) for each type of case. Conservation measures can be specified by changing the lineal parameters and then also changing length specified by case type. In the example above, suppose that you were reducing the auxiliary power by installing T8 lights in a closed low-temperature case. That could be shown as follows:

First, specify the lineal feet for the basecase unit. The default is auxiliary usage of 90 W/ft.

Next, specify on another line the same lineal feet but only for the comparison unit. Change the auxiliary to reflect the more efficient unit.

We also want to specify overall system parameters for the refrigeration plant.

One of the possible Control options is Heat Recovery. THIS MEANS RECOVERY FOR SPACE HEATING, NOT WATER HEATING. Recovery for space heating is fairly common on older systems. Modern systems utilizing floating head do not produce as much waste heat during cold weather and are not expected to provide for heat recovery.

The refrigeration parameters are defined in more detail in the Appendix:

Refrigeration Load Factor	Adjusts refrigeration demand on Demand Graph page. A load factor of 1.0 reduces peak demand. A load factor of less than 1 increases the demand during peak.
Refrigeration Usage Factor	Adjusted amount of refrigeration load (Thermal Export value). The target comes from the Tuning Graph page
Hot Gas Defrost Fraction	Usually a 1 or a 0, may be a fraction
Compressor, Control or Condenser Code	Select type in box
Compressor or Condenser Efficiency Modifier	Usually 1, may increase for efficient unit, such as water-cooled
Compressor Distribution Efficiency	Usually 0.9, may increase for better insulation on refrigerant lines
Condenser Fan Fraction	Usually 0.1, may increase for poor fans

Fuel Load Adjustments

The only other tuning adjustment factors are additive values for possible fuel loads inside or outside the building. You can review these factors under the Connected Building Loads Description. If you wish, you can update the assumptions and remove these factors.

Changes in Occupancy

Sometimes the billing data reflects unusual patterns of occupancy. For example, motels or country clubs might have an occupancy rate that varies by season. You will need to make some decisions about how this variable should be handled. We can adjust the tuned model to match the variation in occupancy.

But then it will be necessary to decide if the variation is "normal" or if the occupancy should be based on an average level. Here is how to proceed.

First, you will need to collect information about what the level of occupancy should be. This might come from occupancy records, say for a motel. Or it might come from interviews with the customer. Ask if there were months with partial occupancy and, if so, can the level be estimated.

Next, tune the model to monthly level of occupancy by adjusting the occupied hours for each month. Follow the usual steps to develop the best model fit using the R2 criterion.

Now you have to decide how to handle "typical" occupancy. In general, we would recommend changing all the monthly operating hours to reflect an average occupancy. However, there may be reasons to keep a seasonal pattern in the occupancy. Change the hours to match the "typical" hours and save this file as the tuned model. The

Proposal And Commissioning Reports will be based on whatever occupancy pattern you have included.

Detailed Description of the Variables

See the Glossary section in the Appendix.

Typical Worksheet

In specifying the building variables, on often must calculate average values. A sample worksheet is included to help with this process. This worksheet is essentially a scratch pad. It is not linked to any other parts of the program. You add other calculations or customize the scratch pad to assist whatever calculations are needed. However, results must then be entered into the appropriate place on the "Detailed Description" page.

Equipment Sizing

At the bottom of the "Detailed Description" page is a table showing the equipment sizes computed by EZ Sim under design conditions. EZ Sim uses this information to size the HVAC equipment. It is presented for the user so that one can see the potential for possible downsizing due to conservation measures. We do NOT recommend using this information for design sizing -- it is for informational purposes only.

6. Specify Conservation Measures

At this point, you should have a tuned model where (1) the adjustment factors have been set back to their neutral value and appropriate changes made to the Detailed Description page (2) both the Basecase and Comparison Case columns agree. We do this to make sure that we have an accurate comparison between the two cases. Now it is possible to enter changes for conservation measures into the Comparison Case column. The resulting changes will be a good representation of the savings that can be expected for the specific facility. Table 3 shows typical conservation measures and where to change the Comparison Case model.

Modeling Demand Measures

The model performs a conservative calculation of demand-saving measures. Demand is assumed to be the customer's one-time consumption spike during the billing interval. In general, reduction in lighting or process loads can be expected to occur on peak so they result in a demand decrease. However, HVAC measures, even though they save energy, may not affect the 15-minute maximum demand. So HVAC measures usually are not counted for demand savings. This conservative assumption may overlook some demand improvements, such as fixing a heating or cooling spike. However, it is more likely that the HVAC system will still run at full design capacity sometime during the month, so that no change in demand will appear.

There are a few measures that are specifically demand related. One is Fan Resizing under the "Fan Control" area. We assume that it is possible to re-pully or otherwise

adjust fan speed if we can reduce the thermal loads of the building. When the Fan Resize option is selected, the model will resize the fan based on design conditions.

The most significant demand saving is to specify Demand Limiting Controls. In this case, one programs the energy management system for a specific kW limit. That limit is entered in the worksheet in units of W/sqft.

Table 3. Conservation Measure Specifications

Conservation Measure	Model Variable to Change	Typical Baseline Values	Typical Conservation Values
Wall Insulation	ENVELOPE Wall U	.25-.10	.05
Roof Insulation	ENVELOPE Roof U	.05-.50	.03
Efficient Glazing	GLAZING Glass U, GLAZING transmission	Single 1.1 0.85	Double 0.50 0.15-0.80
Efficient Interior Lighting	INTERIOR LOADS Connected Lighting	Office 1 - 2 Retail 2 - 4	Office 1.2, Retail 2
Exit Signs	Light Usage Factor	Use worksheet	
Occupancy Sensors	Light Usage Factor	.85	Reduce
Dimming Controls	Light Usage Factor	.85	.50-.75
Efficient Exterior Lights	EXTERIOR LOADS, Exterior Lighting	Security 0.1, Parking 0.5	Reduce
Energy Management Controls	OPERATING SCHED, Operating Hours FAN CONTROLS	10-12 hours Specify VAV or TRAV	Subtract 1-2 hr, Specify VAV or TRAV
High Efficiency Heat Pump or Other Equipment	HEATING PLANT, Efficiency Rating COOLING, Efficiency Rating	HSPF 5-6, AFUE .5-.6 EER 8-10	HSPF 7-8, AFUE .7-.9 EER 10
High Efficiency Refrigeration Cases	REFRIGERATION, Cooler Cases	Conduct. 15-25 Aux. 45-90 W	Reduce 20% , Reduce10-20 W
Duct Sealing	HEATING PLANT, Usage Modifier	As tuned, 0.7-1.0	Divide by 0.83 for typical retrofit duct sealing

Residential Building Type

In general, EZ Sim was developed with the idea of a tool for commercial buildings. However, some users requested that we include a residential building as well. The

simulation methodology works just as well on residential buildings -- however, tuning may be more difficult. That is because residential buildings are more affected by consumer behavior. In particular, use of wood heating can affect the tuning process -- closely examine the tuning plot and reject outlier points that may include wood heating.

Another consideration is consumption for residential hot water. We have included a standard default value but you may wish to adjust for family size and/or conservation measures. The table below lists some typical values for hot water consumption. However, individual families can easily differ by a factor of two! Once again, closely examine the tuning plot and check for reasonableness of assumptions. If you use the table below, the consumption estimate must still be divided by square footage and entered on the "Detailed Description" page.

Table 4. Residential Hot Water Consumption

Family Size	Typical Consumption Rate, Watts	Consumption with Low Flow Devices, Watts
1 - 2	200	100
3	400	285
4	500	300
5 plus	600	350

7. Producing Reports

Type of Report

Table 5. Output Reports

Report Type	Weather Used	Bills Used	Output Reports
Benchmark Report	Actual Weather (in this case pre-retrofit)	Customer Information page (pre-retrofit), compare basecase "typical" parameters	Recommendations from tuning process, informed audit
Proposal	Typical Weather (TMY or Long Term Average)	Customer Information page (pre-retrofit), compare basecase to comparison with conservation	Base-Comparison Conservation Savings
Commissioning	Actual Weather (in this case post-retrofit)	Trend Analysis page (post-retrofit), compare basecase to comparison with conservation	Predicted/Actual Savings = Effectiveness Rate

Print macros are available on each page for the reports. Of course, all the standard Excel print commands are also possible. You use these commands to print specific graphs or to customize outputs. You can also cut-and-past into other applications. Table 5 shows the differences between the types of report:

Benchmarking or Informing the Energy Audit

With this initial information, we know something about the building's energy use and what it takes to get a tuned model. This information tells us what to look for at the site during the energy audit. Figure 21 shows what the average consumption looks like by month. This information may be useful to an auditor trying to ascertain if certain months that were atypical. Figure 22 shows a comparison of the actual bills and "tuned" model against the comparison case. For benchmarking purposes, the comparison case would be set up to represent what we think is typical for a building of this type.

Figure 23 shows what the next section of the report looks like. The Energy Usage Index (EUI) includes both electricity and fuel consumption in one number. The EUI line graph shows where this building falls in comparison to what is typical for buildings of this sort. (Typical building usage comes from Bonneville's ELCAP project).

The next block tells you what to look for based on the "tweakers" that were found to be necessary. The example above shows how these look in one specific case. Table 6. Recommendations for Energy Auditors lists these directions for specific observations.
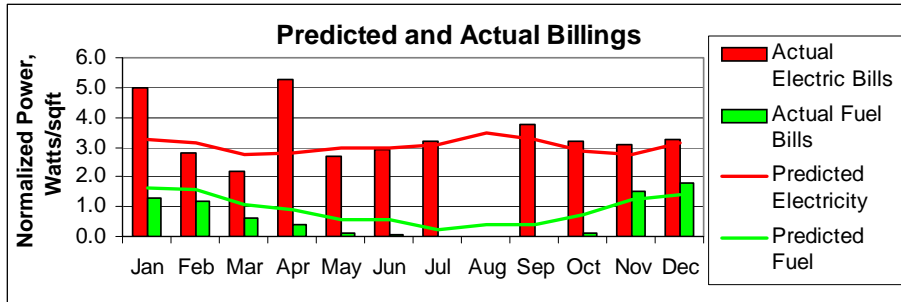
Figure 21. Benchmark by Month
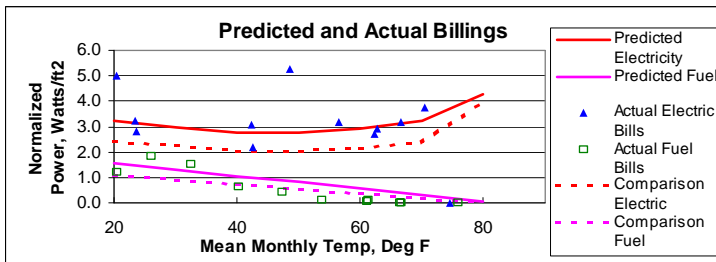
Figure 22. Benchmark Models
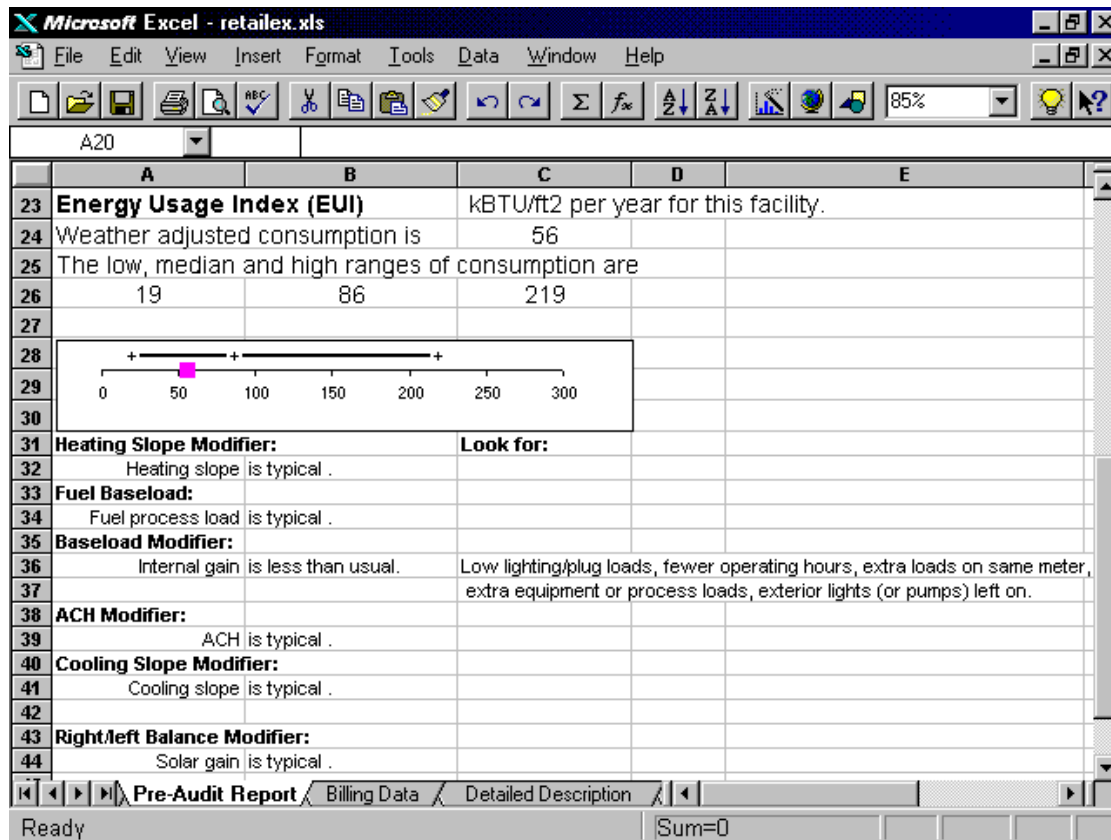
Figure 23. Benchmark Report

Table 6. Recommendations for Energy Auditors

Adjustment Factor	Value	Conclusions
Heating effectiveness	High	Poor insulation levels, heating efficiency, or distribution losses.
	Low	High insulation levels, heating efficiency, partial occupancy or unused areas.
Base loads	High	High lighting/plug loads, extra equipment, extended operating hours, missing meters.
	Low	Low lighting/plug loads, fewer operating hours, extra loads on same meter, partial occupancy or unused areas, extra equipment or process loads, exterior lights (or pumps) left on.
Ventilation ACH	High	Doors open, locked vent dampers, faulty economizer.
	Low	Inadequate ventilation blocked vent dampers.
Cooling Effectiveness	High	Low roof insulation, poor glazing, different solar orientation, poor cooling or distribution efficiency, dueling controls.
	Low	High roof insulation, good glazing, solar shading, high cooling eff, partial occupancy or unused areas.
Balance Temperature, Solar Gains	High	Low insulation values, partial occupancy, decrease heating/ increase cooling setpoints.
	Low	Extreme solar orientation or exposure, increase heating/ decrease cooling setpoints.
Fuel Process Load	>0	Additional energy uses

Produce the Proposal Report

Customer information at the top of the page is a repeat of the previous page, just so you have a clear record of the project.
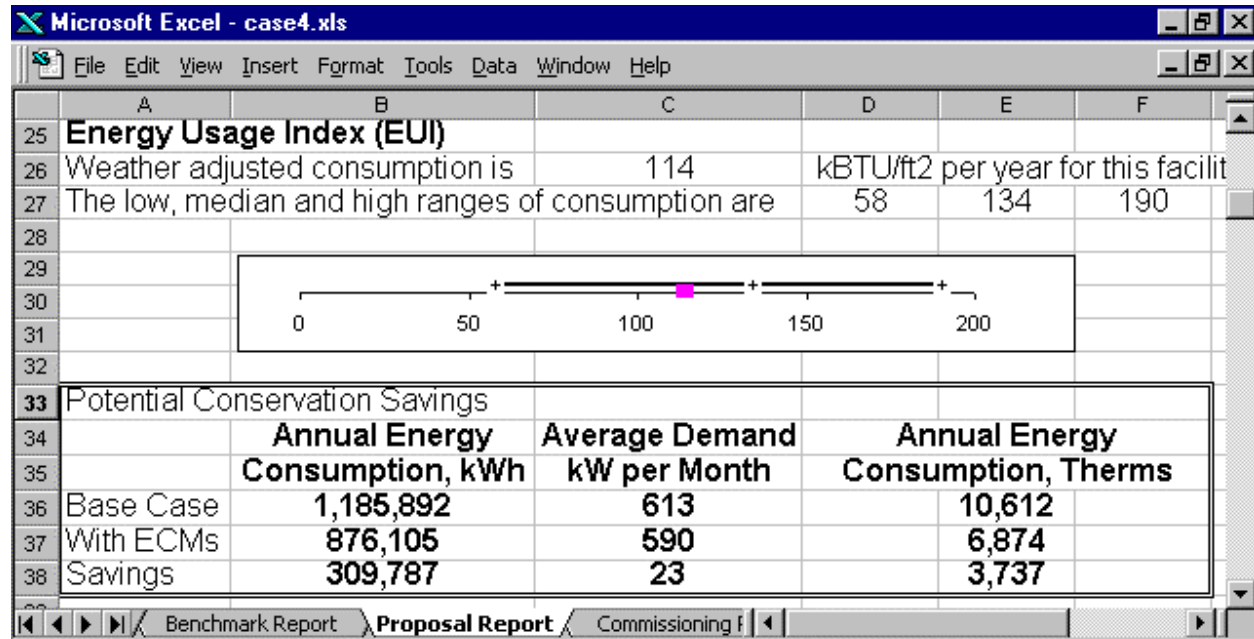
Figure 24. Proposal Report

Summary of usage is shown in Figure 24. The line graph shows where this building falls in comparison to what is typical for buildings of this sort. (Typical building usage comes from Bonneville's ELCAP project). The Energy Usage Index (EUI) includes both electricity and fuel consumption in one number.

The Potential Savings box compares the basecase building to one with conservation measures. If no measures have been specified, this box will show no savings. Measures are specified on the Detailed Description page.

Breakdown of end uses within the building is shown in Figure 25. Each of the end uses is specified in the legend. This chart utilizes the building with conservation measures for the end uses. The "Base Case" line shows total energy consumption of the base case building with no energy conservation measures. It is included for comparison so that one can see the effect of conservation. Notice the energy units are Watts per square foot. This chart is useful primarily to compare the relative sizes of different end uses.

Or Figure 26 shows annual consumption (combined for all fuels) by end use for both the basecase and comparison case. The proposal report page contains a numeric table detailing the consumption used in this figure.
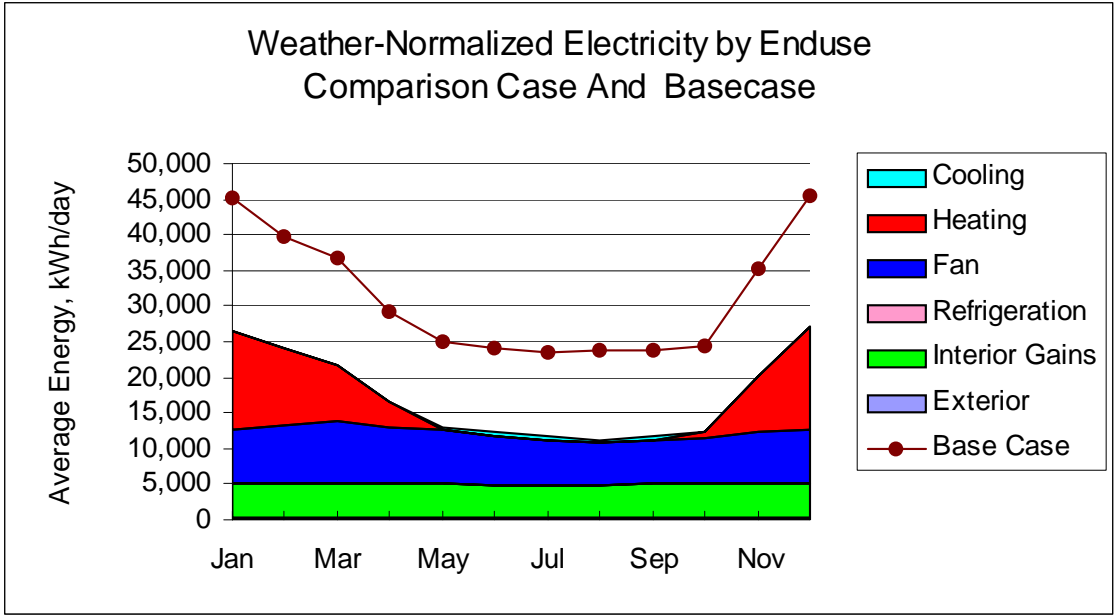
Figure 25. Proposed End Use Consumption
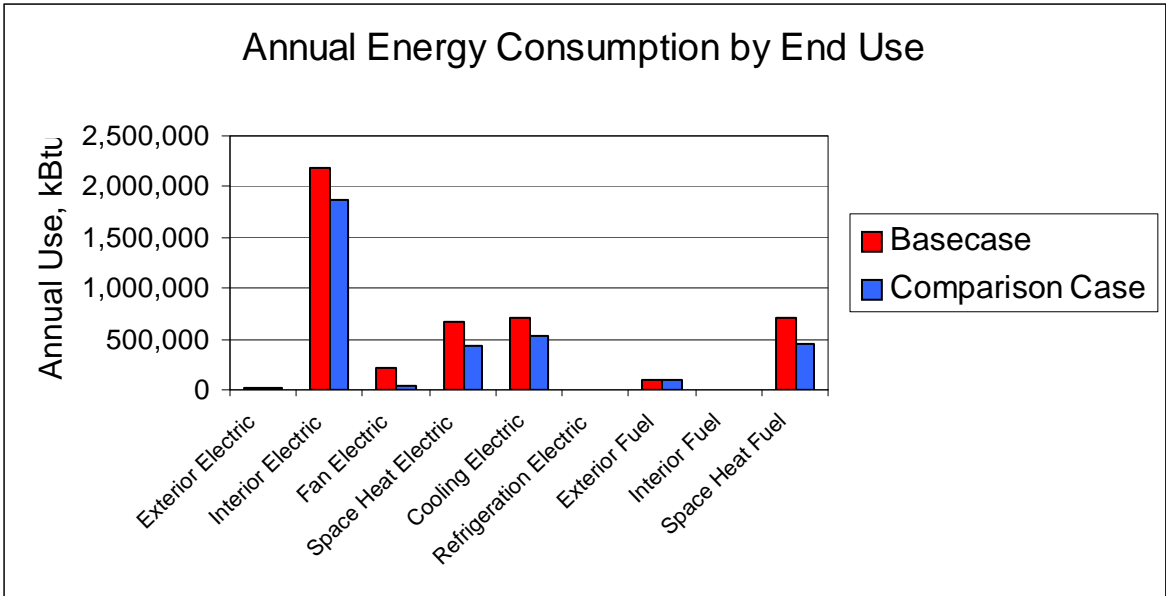
Figure 26. Annual End Use Consumption

If one is interested in the monthly bills, Figure 27 is more useful. This chart shows the weather-normalized monthly bills, with and without energy conservation measures.
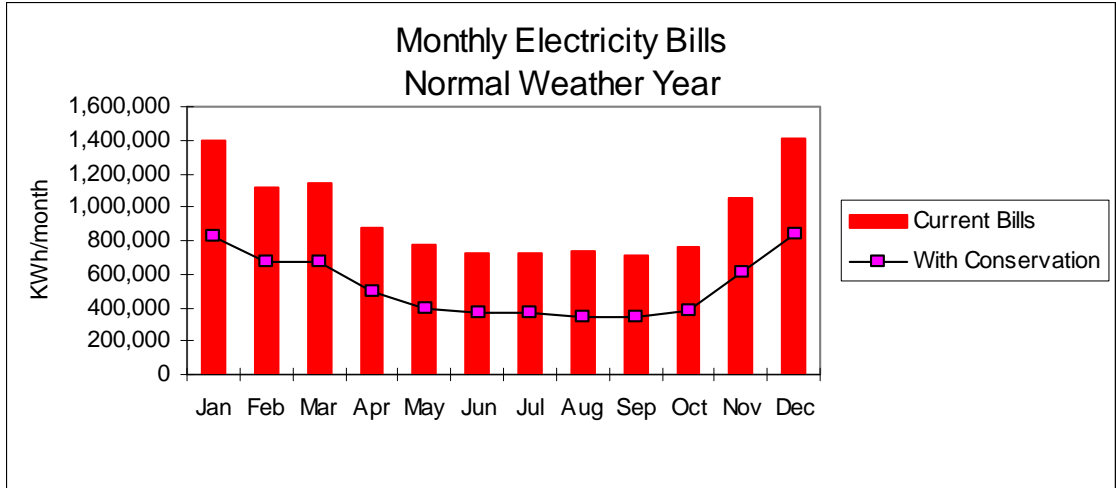
Figure 27. Proposed Monthly Bills

The same information for electrical demand is shown in Figure 28.
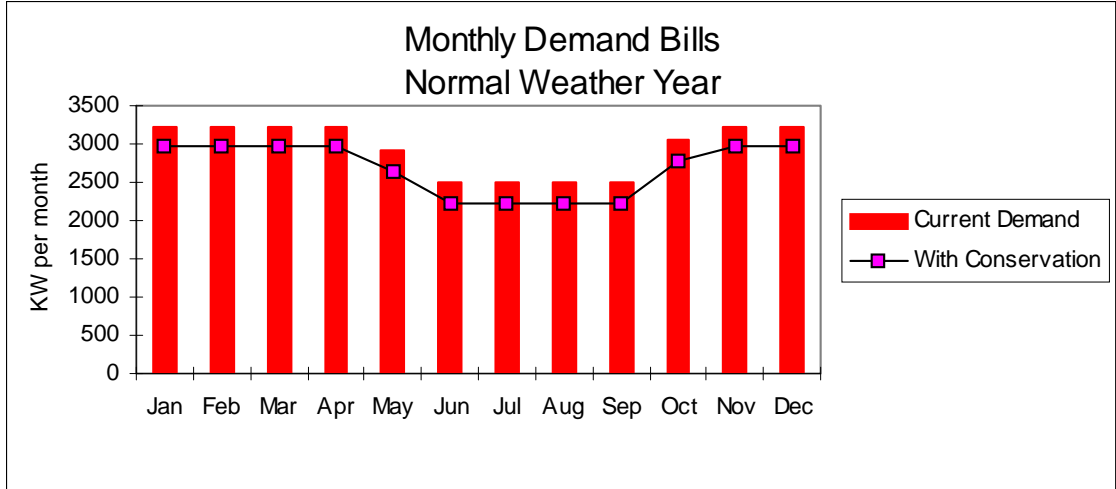
Figure 28. Proposed Monthly Demand Bills

Similar charts present the end use consumption and monthly bills for fuel. In case you want to compute the dollar value of the savings, there is a table at the bottom of the report that lists monthly kWh, kW and therms. Since utility rates vary widely, it up to the user to compute the monthly dollar value using the appropriate rates.

Produce the Commissioning Report

This report provides you with a prediction for energy consumption based on the actual weather and occupancy history. It differs from the consumption listed in the Proposal Report because that report is based on average weather. Using these predictions, you can compare the actual performance of the building to see if it agrees with expectations.

Note: This process assumes that you have already developed and saved a tuned model of the basecase building with conservation measures for comparison

Note: This report assumes that you have selected the "Commissioning Report" on the first page. If not, a red message pops up to inform you that the calculations have been set up for the proposal report.

To utilize this feature, follow these steps:

1. Develop a tuned building model for the basecase building using historical billings.

2. Specify the conservation measures.

3. Save this file.

4. After the conservation retrofit, collect billing information for another year. Input these data on the "Trend Analysis" page.

5. Select the "Commissioning Report" option on the first page. Without further tuning, look at the commissioning report. This will illustrate the results of the previously tuned model compared with the most recent billing information.

6. The Commissioning Report includes an estimate of the conservation effectiveness. This is the ratio of predicted to actual savings. If actual savings exceed predictions, the ratio will be greater than one. These savings are based on the actual post-retrofit weather and operating conditions. Thus, the actual billings can be compared to predicted consumption to see if targets are met. The effectiveness of the conservation measures is expected to be similar during an average weather year.

Reviewing the Output Table

Figure 29 shows a table of electricity usage by month. This table permits comparison of actual to predicted total consumption and savings. Columns in the table are defined as:

Billed KWh	From post-retrofit bills and actual weather
Predicted kWh	Using post-retrofit weather and the comparison model with conservation measures
Baseline kWh	Using post-retrofit weather and the base model without conservation measures
Actual Savings	Difference between Billed and Baseline kWh
Predicted Savings	Difference between Predicted and Baseline kWh

Figure 29. Commissioning Output Table

The spreadsheet shows:

Comparison of Actual and Projected Utility Bills

ELECTRIC BILLING DATA

	Read	Billed KWh	Predicted kWh	Baseline kWh	Actual Savings	Predicted Savings
Jan-97	02/05/97	74,880	64,131	103,440	28,560	39,309
Feb-97	03/06/97	80,320	64,341	103,472	23,152	39,132
Mar-97	04/08/97	77,480	69,718	110,487	33,007	40,770
Apr-97	05/09/97	70,480	63,510	96,895	26,415	33,385
May-97	06/06/97	61,480	61,170	85,313	23,833	24,143
Jun-97	07/08/97	68,680	71,822	98,887	30,207	27,065
Jul-97	08/07/97	76,040	74,427	95,488	19,448	21,061
Aug-97	09/09/97	82,440	81,693	105,326	22,886	23,633
Sep-97	10/08/97	62,960	63,685	90,668	27,708	26,983
Oct-97	11/05/97	64,040	57,523	90,335	26,295	32,812
Nov-97	12/08/97	86,920	72,026	114,426	27,506	42,400
Dec-96	01/08/97	73,880	77,333	126,435	52,555	49,102
Annual Total		879,600	821,377	1,221,172	341,572	399,795

Effective Savings Fraction
85%

Tabs: Proposal Report / Commissioning Report / Trend Analy

Figure 30. Commissioning Graph
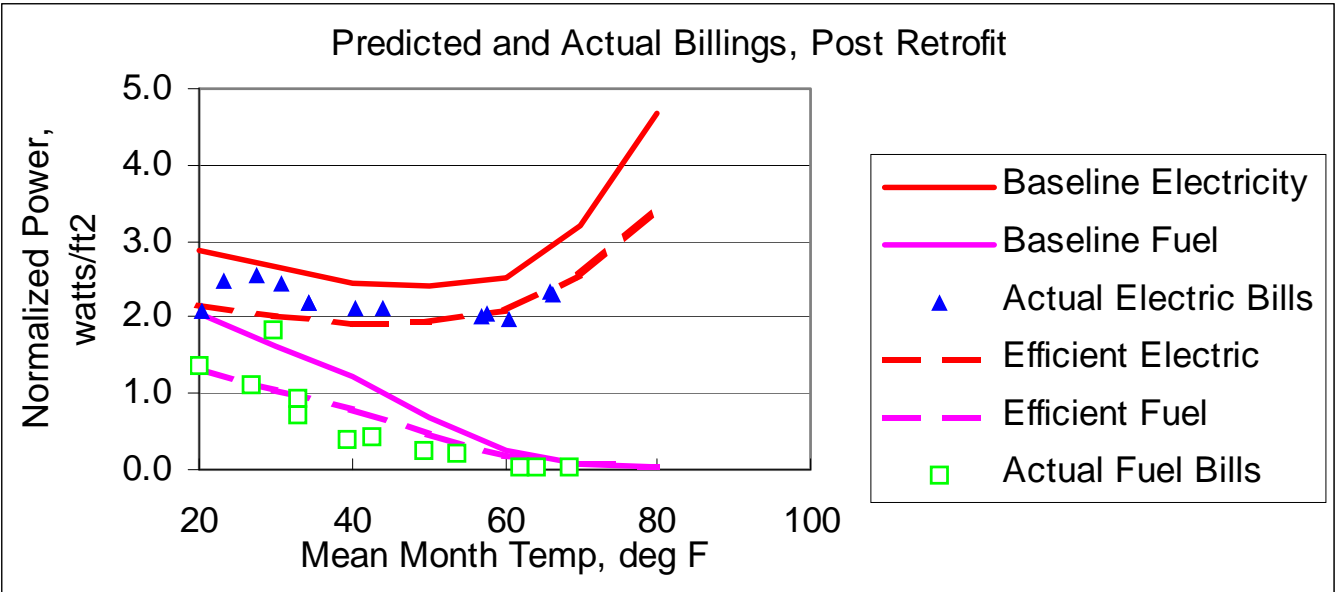
Figure 31. Pre/Post Models Compared

One useful check on the pre/post modeling is to compare how the models align with the post-retrofit bills. This is presented in Figure 31.
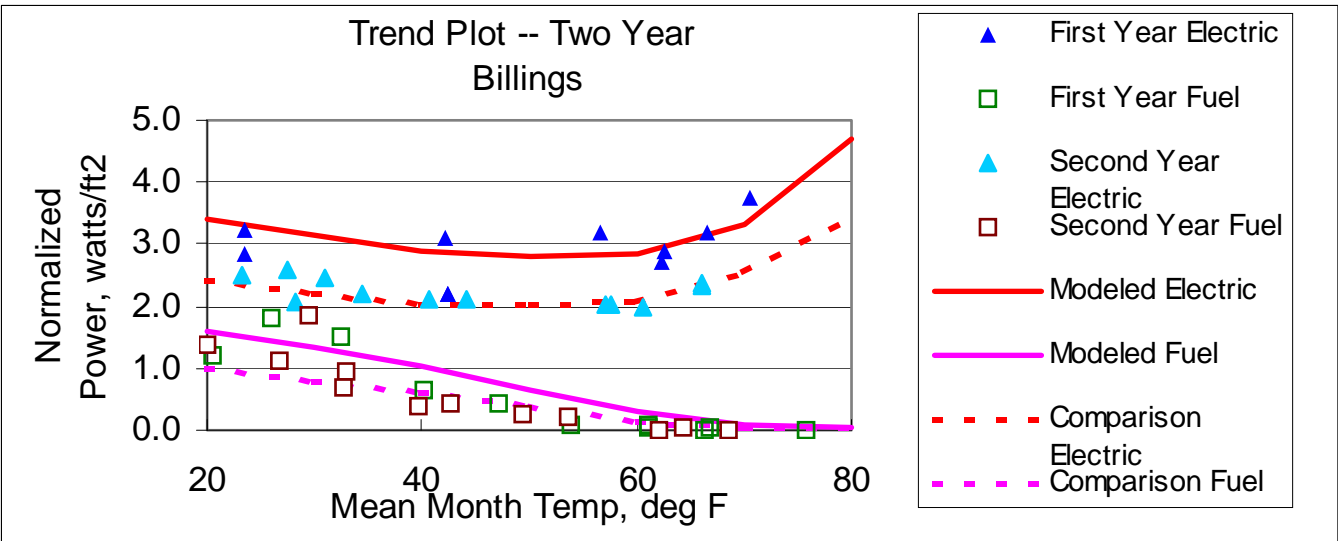
Figure 32. Trend Plot

From the ratio of the two savings calculations, we compute an Effective Savings Fraction. Thus, if the actual savings are 85% of the predictions, we say that the measures are 85% effective. Total consumption is also shown as a chart in Figure 30 for comparison.

Similar tables and charts supplied for gas consumption and kW demand.

Printing Reports

All of the reports and worksheets can be printed using the usual Excel print commands or using push button macros on each report page.

8. Trend Analysis

One useful technique to look at buildings is to observe energy consumption over time and determine if there has been a trend. To accomplish trend analysis, there is another worksheet for entering additional billing data. These data may represent extra pre- or post-retrofit years. They are entered as described previously. The difference is that, if you intend to produce a Commissioning comparison, you can only do that with second-year data. In that case, select the "Commissioning Report" on the "Customer Information" page. The trend analysis graph is shown in Figure 32. Notice that lines from both the basecase and comparison case models are included. This way you can check to see if the tuning parameters seem to be appropriate for both cases. The first-year triangles (electric), and boxes (gas) and modeled lines are from the "Tuning Graph". The additional points from this page are graphed labeled as belonging to the second year.

9. Save Summary File

In many cases, you will save the entire working file, complete with all the calculation worksheets, weather files and other hidden details. These files are large and sometimes you may wish to save a smaller summary file. The summary file is easier to send by email. Another user can then paste the building details from the summary into a template and have a working file. There is a macro for this operation on the "Customer Information" page. The File Save menu prompts for a file name.

10. For Advanced Users

For those familiar with spreadsheets, there are additional worksheets which are normally "hidden" to prevent novice users from tampering with formulae. These sheets can be unhidden and modified, but the users must beware. Do not change parts of the spreadsheets that contain working formulae!

The remaining worksheets are:

- CompCase Calc   Models for Comparison building
- BaseCase Calc   Models for Basecase building
- Demand Calc   Computes kW demand
- Bill Calc   Matches entered billing data to weather file, computes average temperature during metering interval

Updating or Changing Weather Sites

The most frequent change is likely to be updating or changing the weather data. A push-button macro to add weather files is on the "Customer Information" page. Weather

files can be purchased and downloaded from our website at www.ezsim.com. Files for over 250 sites in the U.S. and Canada are on-line. Weather availability is limited by what government agencies have available. We hope to update the weather files every month or so depending on when weather data is released.

Adding Additional Weather Information

You can update your own weather files easily. This consists simply of adding new values of daily average temperature to the bottom of the data columns.

The weather data represent one of the largest program "chunks". In order to keep the program to manageable size, we suggest keeping the columns of weather data to a modest size. There are two tricks. First, numbers use less memory than formulae. So if you calculate the Julian date with a formula, change it to a value before saving the file. The second approach is to minimize the column length to an appropriate time interval, say three years.

To update weather, we suggest the following:

1. Use an existing weather file as a template. Move the cursor to the bottom of columns A through E. Key in additional values for the Julian date, year, month, day, and daily average temperature in subsequent rows.

2. Column A is the Julian date. You can compute using a formula but if you do, we recommend changing to a value when done. This can be done using "Edit" "Copy" "Paste Special" "Values".

3. If you want to use the file for a different city, you will need to update the long-term table in columns J-L. Information includes the name of the city, latitude and source of data (for documentation, not actually used in computations). The mean monthly temperatures represent long term averages and are available from a variety of sources. Solar Irradiation is a measure of the relative "sunniness". Solar irradiation and humidity ratio are available from NREL. Neither is a critical variable and they maybe entered for a nearby site with similar climate if not available for the specific site. To change the weather site, update these data as needed.

4. Save the file as a new template for the appropriate city.

Sources for Weather Data

Recently many weather sites have become available over the Internet. Unfortunately there is not yet a standard format or nomenclature used by the different weather agencies. Generally, one should look for historical climate data and a table showing the mean temperature for each day. To locate an appropriate website, look at the Oregon Climate Service (http://www.ocs.orst.edu) or the National Weather Service (http://www.nws.mbay.net/nws.html). National Ocean and Atmospheric Administration is the national repository for weather data. Useful information is available online from their Climvis service starting at http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=climvisgsod.html.

Precision of the Savings Estimates

Federal agencies and other institutions ask that savings be verified according to the International Measurement and Performance Verification Protocol (IMPVP). The protocol is not difficult to follow but it does suggest that any estimate of savings should include an estimate of the probable error. EZ Sim is well suited to providing an estimate of the error associated with fitting the model to the billing data points. A table of the precision results has been included at the bottom of the Proposal Report page. An example is shown below.

Accuracy of Estimates

	Annual Energy	Average Demand	Fuel
	kWh/year	kW per month	Therm/yr
Basecase	2,019,550	273	15,483
Relative SE	4%	13%	na
Compcase	1,734,332	266	4,362
Relative SE	1%	4%	na
Savings	285,218	7	11,121
SE/Annual	4%	5%	na
SE Savings	31%	171%	na
PE, +/-	59,010	8	na
SE, +/-	87,423	12	na
90% CL, +/-	171,349	24	na

This example shows the amount of consumption for the Basecase and the relative error associated with that estimate. In this case, typical consumption is 2,019,550 kWh/yr with a Standard Error of 4% in fitting the modeled consumption to the actual. In the Comparison Case, the consumption is 1,734,332 kWh/yr and the Standard Error is 1% relative to the typical Basecase consumption. Savings are the difference between the two consumption figures. The Standard Error of the savings estimate is 4% of the Basecase consumption, 31% of the savings estimate or 87,423 kWh/yr. One may also be interested in the 90% Confidence Limit as representing an error band around the estimate. Sometimes one is also interested in the Probable Error (PE) or the 50% Confidence Limit. This figure represents the most likely amount of error since it is equally likely that the error is either higher or lower than the PE.

For the accuracy table, both the Basecase and Compcase models should be tuned to match the pre- and post-retrofit data respectively. If that is so, no problem. But in some cases, a hypothetical baseline is used. That is, the models are fit with operating parameters that are different than the "tuned" values. For example, operating hours may

have been extended in the second year. We want to compare the second year with the operating hours to what the original facility would have used under the same extended hours. In that case, save the accuracy results (that is, the +/- values in the table) for the models tuned to match the pre and post cases. But compute the savings values using the hypothetical case.

Example:

A school installed efficient lights, but increased operating hours at the same time, canceling out the savings. The tuned models show SE of 4% but savings of only 26,000 kWh.

Use the "Paste Special Values" command to save the accuracy results into the Save Area.

If we change the basecase to include the extended hours with the old lighting, savings would be 623,000 kWh, but accuracy is 8% because the old billings depart from what we are assuming as the revised basecase.

Best solution: list the savings at 623,000 kWh but with accuracy of 4% and +/-CL values coming from the fitted models.

TECHNICAL APPENDIX -- GLOSSARY of VARIABLES and DESCRIPTION of MODEL

Table of Contents

Introduction

GENERAL - This glossary is intended to define the operation of the input variables used to describe a building and its operation. The variables all operate in the context of a building model. In order to use these variables properly, it is necessary to have a brief understanding of the model that uses the variables. Therefore, this glossary includes a limited discussion of the building model as it relates to a group of variables being defined. Note that the variables are not grouped alphabetically, but are grouped by function and in the same order as on the input sheet.

The input variables have units that are common to the trade and where possible they are normalized to a per/ft2 basis. In this way the input variables have values which fall within limited ranges. A good guess within the prescribed range is an adequate input in most cases.

Overall the building model consists of seven sub models all acting interactively; the sub models are:

> ENVELOPE/SOLAR MODEL
>
> BUILDING CONNECTED LOADS MODEL
>
> OCCUPANCY MODEL
>
> FAN MODEL
>
> HEATING PLANT MODEL
>
> COOLING PLANT MODEL
>
> REFRIGERATION PLANT MODEL

A description of each of these sub models and its associated variables is given below:

Description of Envelope/Solar Model And Variables

Basic Model Operation

The envelope/solar model calculates the envelope thermal losses/gains and the envelope solar gains. A key feature of this model is that it does not require a detailed inventory of walls and glazing. Instead the model creates an analog building with the same floor area, the same number of floors and the same shape factor. For most buildings this internally generated model is equivalent from and energy standpoint and vastly simpler to set up. This analog model relies on broadly averaged inputs such as mean wall U, and mean glazing U or transmission. If desired these averaged inputs can be rigorously derived from detailed audit observations through the use of prepared worksheets, but it is not necessary to operate the model.

The solar gains in this model are based on an internal model of the solar gains on surfaces facing each cardinal direction and skyward. The solar model depends on the average monthly temperature and a constant factor unique to each month. No other solar inputs are required. Monthly solar gain through windows is calculated from minimal glazing

specifications consisting of the percentage of glazing facing north, south, and in skylights. Mean glazing light transmission and external shading are also included in the window gain calculation.

Definitions of Envelope/Solar Variables And Typical Settings

TOTAL FLOOR AREA - This is a key variable in this model because all energy use is referenced to it. This variable is intended to specify the total floor area of the conditioned envelope.

NUMBER OF FLOORS - This variable specifies the number of floors in the conditioned envelope

HEIGHT PER FLOOR - This variable specifies the exterior height per floor in feet. The height is assumed to be constant for all floors. Typical heights per floor are about 10 feet.

MASS - This variable specifies the mass of the building envelope and structure. This variable is used in calculating the effect of temperature set backs, and categorizes the building mass at one of three levels: 1) low mass, a wood frame structure, 2) medium mass, a cement block or masonry building, or 3) high mass, a heavy masonry building.

CORE FACTOR - This variable specifies the portion of the building that is isolated from the building envelope gains and losses. It is only used in large buildings with a core that must always be cooled. Most small buildings will have a low core factor of 0.1.

PASSIVE INFILTRATION - This variable specifies the infiltration of the building due to cracks and the thermal stack effect of heated air. This variable does not include the infiltration due to operation of HVAC fans. Typical values for this variable vary from a low of 0.1 ACH for a very tight building to a high of 1 or 2 ACH corresponding to a drafty building.

SHAPE FACTOR - This variable specifies the ratio of the perimeter of the building compared to the perimeter of an equivalent square building. For example, if this variable is 1 the building is square. For rectangular buildings, shape factor is 1.1-1.3. For complex buildings, it may be up to 2.

MEAN WALL U/ft2 - This variable specifies the mean heat loss rate of the walls. The units for this variable are BTU/wall ft2/degF/hr. The units used are relative to the area of the wall, so the mean wall U is the weighted mean wall U, weighted on the basis of the wall areas. The worksheet calculates the mean wall U from a U value specified for each of the building walls. The worksheet also documents the weighted mean calculation method and the assumed wall U for each of the individual building walls. Typical values for the mean wall U would range from a low of.05 for an R19 wall meeting the current code, to a high of .25 for a cement block wall.

MEAN ROOF ABSORBTIVITY - This variable specifies the capability of the roof to absorb solar gain. The absorbtivity varies from a low of 0.1 for a highly reflective or white wall to a high of 1 for a perfectly black wall.

MEAN ROOF/FLOOR U - This variable specifies the heat loss rate of the roof or the roof and floor. It is expressed as a U value per foot of roof. Typical values for this variable vary from a low of .03 for a highly insulated roof to a high of .5 for an uninsulated roof.

PERIMETER LOSS/ft - This variable specifies building floor loss through the perimeter of the ground floor. This variable is used only when there is a known perimeter loss, otherwise it is 0. Note that the units for this variable are BTU/ft perimeter/hr/deg.

MEAN GLASS U/ft2 - This variable specifies the glazing heat loss rate. The units for this variable are BTU/glazing ft2/degF/hr. This is a weighted mean, weighted on the basis of the area of each glazing area. The MEAN GLASS U/ft2 and other glazing variables are calculated in the worksheet from the specifics for each of the glazing orientations. The worksheet also documents the weighted mean calculation and the specifics assumed for each individual glazing orientation. Typical values for this variable range from a low of .4 for low E double glazing to a high of 1.1 for common single glazing.

GLASS ft2/ft2 WALL - This variable specifies the portion of the walls that are glazed. Values for this variable range from a low of 0 for a windowless wall to a high of 1 for walls consisting entirely of glazing. Note here that the individual glazing areas need not be used, only the ratio of the glazed area to the wall area is necessary.

SOLAR TRANSMISSION - This variable specifies the weighted mean solar transmission of the glazing, weighted on the basis of the areas of each of the individual glazing areas. The mean solar transmission is calculated in the worksheet from the transmission associated with each individual glazing orientation. It is usually listed on cut sheets as the Shading Coefficient. Typical values for SOLAR TRANSMISSION range from a low of .15 for shaded glass used on heavily glazed large buildings to a high of .85 for clear single glazing.

EXTERNAL SOLAR SHADE - This variable specifies the weighted mean external solar shade weighted on the basis of the areas of each of the individual glazing areas. The MEAN EXTERNAL SHADE is calculated in the worksheet from the external shade assigned to each of the individual glazing orientations. Typical values for this variable range from a low of 0 for a building completely shaded from all directions, to a high of 1 for a building with all glazing surfaces unshaded.

% NORTH GLASS - This variable specifies the fraction of the total glazing area facing north. For example, a building with equal glazing in each cardinal direction would have % NORTH GLASS = .25.

% SOUTH GLASS - This variable specifies the fraction of the total glazing area facing south.

% SKY GLASS - This variable specifies the fraction of the total glazing area in skylights.

Description of the Connected Loads Model And Variables

Basic Model Operation

The connected loads model classifies all electrical and fuel loads as either interior or exterior building loads. Interior loads occur within the conditioned space. These loads contribute to internal gain and will influence the need for heating and/or cooling. Exterior loads such as exterior lighting or irrigation may have no effect on internal gain and will not influence the building HVAC but the loads must be accounted for in order to simulate actual utility bills. Some loads such as DHW or interior cooking may contribute only partially to internal gain because a major portion of the load is going down the drain or being vented.

All electrical loads internal and external are described in terms of the connected watts. This description of the load in terms of connected watts is done to facilitate the simulation of lighting and other measures that may vary with occupancy duration. The connected load alone does not fully describe the energy use of the load because it does not indicate the duration of the load. Load duration is described in the occupancy model.

Fuel loads are not described in terms of connected watts, but are described in terms of average energy use. However, the average energy use of fuel loads is described in terms of watts in order to use common energy units so that the gains of both fuel and electrical loads can be aggregated.

For the sake of simplicity, the description of all interior building loads classifies a load as one of three fundamental load types: 1) lighting, 2) plugs, or 3) fuel process. All interior electric loads are assumed to contribute fully to internal gain; internal fuel loads are assumed to contribute partially to internal gain as specified by an interior gain factor.

Exterior loads are classified as one of four fundamental types of load: 1) exterior lighting, 2) exterior electric process, 3) exterior fuel process, and 4) DHW electric and fuel. DHW loads are classified as exterior loads because most of these loads do not contribute to internal gains but are discharged down the drain. The model assumes that only 15% of DHW loads are internal gain.

Definitions of Load Variables And Typical Settings

CONNECTED LIGHT - This variable describes the average building connected lighting load. Note that the average connected lighting load is described in terms of watts/ft2 of building. The worksheet can be used to calculate of this average load and other lighting variables from a description of several types of individual building lighting loads. The worksheet also documents the calculation of the average lighting load and documents the individual lighting loads used in the calculation of the overall average connected lighting load. The variable CONNECTED LIGHT is used to simulate the effects of a lighting retrofit measure where lighting fixture wattage is changed. Typical values for this variable will vary from a low of 1 watt/ft2 for current code office buildings to 2 watts/ft2 in older office buildings and up to 4 watts/ft2 in retail usages.

LIGHT USAGE FACTOR - This variable specifies the fraction of the connected light load that is on in the occupied and unoccupied periods. The normal range for this variable is from 0 to 1. For example if the entire connected light load is on during occupied hours, then the OCCUPIED LIGHTING USAGE FACTOR would be 1. In practice the usage factor is

not 1 because some lights IN LOCATIONS such as closets, unused rooms, and storerooms etc. are not on all the time. The occupied LIGHTING USAGE FACTOR is a weighted mean of the usage factors for all the different types of lighting used during the occupied period weighted by the connected load for each type of lighting. The worksheet calculates the mean weighted lighting usage factors from several light loads. This Lighting Loads Worksheet also documents the calculation of the usage factors as well as documenting the loads and assumed usage factors for each of the constituent light loads. The LIGHTING USAGE FACTOR can be used to simulate the effect of daylight dimming controls because these dimming controls effectively lower the amount of time that a given lighting circuit is on during use. Monitored lighting usage factors for lighting within 12 feet of a window wall show a long term lighting usage factor of .5 to .75. Situations with unused offices or infrequently used storage rooms would have low lighting usage factors of the order of .1 to .25.

CONNECTED PLUG - This variable describes the average building connected plug load. The connected plug load is described in terms of watts/ft2 building floor area. A Plug Loads Worksheet can be used to calculate this average plug load and other plug variables from a description of several types of individual building plug loads. The Plug Loads Worksheet also documents the calculation of the overall average connected plug load and documents the individual plug loads (or load types) used in the calculation of the overall average connected plug load. The CONNECTED PLUG load can be quite high, 4-8 watts/ft2, in cases where high wattage appliances such as stoves or coffee makers are used. But this high connected load may not manifest as high energy use because the load is infrequently used. The full effect of the connected plug load is determined in concert with the associated variable, PLUG USAGE FACTOR, which is also calculated on the Plug Loads Worksheet. Plug loads can be very diverse loads, and it is usually not worth the effort to describe these loads in detail unless it is the subject of a conservation measure. Monitoring results have showed that the overall average energy use of plugs is in the range of 0.5 to 1.5 watts/ft2. In order to avoid specifying an excessive internal gain, it is important to verify that the CONNECTED PLUG times the average occupied/ unoccupied USAGE FACTOR is in the range of 0.5 to 1.5 watts/ft2.

PLUG USAGE FACTOR - This variable specifies the fraction of the connected plug load that is on during the occupied and unoccupied periods. The normal range for this variable is from 0 to 1. Some plug loads such as computers that are continuously on for the entire occupied period may be close to 1. But most plug loads are for infrequently cycled loads such as copiers, printers refrigerators, and coffee makers. These loads would rarely have PLUG USAGE FACTORS greater than .25. The PLUG USAGE FACTOR is the weighted mean of the plug usage factors for several types of load in the building, weighted by the connected loads. The worksheet calculates the weighted mean plug load factor from several different plug loads and documents the method of calculation as well as the assumptions used to define the basic types of plug loads in the building.

FUEL PROCESS & INTERNAL GAIN FACTOR - These variables describe the energy use of an interior fuel load such as cooking or manufacturing. Note that this type of load is described directly in terms of its average energy use, as opposed to a connected wattage. Also this fuel load is described in terms of watts not gallons/day or therms/day which may

be its native units. A brief units conversion must be made in order to input this variable in terms of watts/ft2. This conversion is done as follows: first convert gallons or therms /day to BTU/day, then,

FUEL PROCESS watts/ft2 = (BTU/day)/ 24 hrs per day/ 3.413/ area of building ft2.

The full internal gain effect of the fuel process load requires the specification of the associated variable INTERNAL GAIN FACTOR, which describes the portion of the internal fuel load that is retained as internal gain.

EXTERIOR LIGHTING - This variable specifies the connected load for the outside lighting. Note that the outside lighting is defined in terms of watts/ft2, where the ft2 area refers to the building floor area, not the exterior lighted area. The energy use by exterior lighting will require the specification on an associated variable, EXTERIOR LIGHTING SCHEDULE, which specifies the daily duration of the exterior lighting load. EXTERIOR LIGHTING SCHEDULE must be specified for each month as the night length changes seasonally.

Typical values for EXTERIOR LIGHTING will vary from 0.1 watts/ft2 for a large building with minimal walkway lighting to 0.5 watts/ft2 for lighting in a large parking lot or garage.

ELECTRIC PROCESS & PROCESS UTILIZATION FACTOR - This variable specifies the connected load for an exterior electric process. Note here that the load is defined in terms of watts/ft2, where the ft2 refers to the building floor area. The energy use by this exterior process load will require the specification of an associated variable, PROCESS UTILIZATION FACTOR, which specifies the fraction of time that the exterior load is active.

PROCESS PEAK FACTOR - This variable designates the fraction of the connected process load that is active during the building peak demand. Currently this model does not estimate peak demands, and this variable will have no effect on the energy calculations. It is arbitrarily set at 0.

FUEL PROCESS - This variable defines an exterior fuel process. Note that the exterior fuel process is defined in terms of average energy in watts/ft2, where ft2 refers to the building floor area. The average fuel process energy is given in terms of watts rather than the native fuel units that may be gallons or therms. The units conversion from fuel units to watts proceeds as follows:

1. first convert the fuel use to BTU/day, then

FUEL PROCESS watts/ft2 = (BTU/day)/ 24 hrs per day/3 .413/ ft2 floor

FUEL DHW and/or ELECTRIC DHW - These variables specify the average energy load for DHW. Note that this load is specified with respect to the ft2 building floor area. Typical values for this variable will vary dramatically with the building size. A good rule of thumb is to assume an average load of 500 watts for a 100gal/day DHW load. This load is then divided by the building floor area. For example for a 1000ft2 building with a 100 gal/day DHW load the ELECTRIC or FUEL DHW would be .5 watts/ft2.

Description of Occupancy Model And Variables

Basic Model Operation

The occupancy model adjusts the building model to account for the behavior of the occupants. The occupants have a profound effect on the energy use of the building through the heating and cooling set points, the ventilation rate, and the internal gains due to lights and plugs and other loads. The model simulates these effects by constructing an average day divided into an occupied and an unoccupied state. The variable (OCCUPIED HOURS) gives the number of hours that the building is in an occupied state; the remainder of the 24 hours in a day the building is considered unoccupied. The variable OCCUPIED HOURS is given for each month in order to simulate seasonal occupancies such as schools. The mechanical ventilation for the occupied and unoccupied states is specified by the variable (ACH). The lighting and plug energy is controlled by the variables (LIGHTING USAGE FACTOR and PLUG USAGE FACTOR) which specify how much of the connected lighting and plug loads are in actual use during the occupied and unoccupied states. The heating and cooling setpoints for the occupied and unoccupied states are specified by the variables (HEAT SET and COOL SET).

Definitions of Occupancy Variables And Typical Settings

HEAT SET - This variable controls the heating set point. It is specified twice, once for the occupied portion of the day, and once for the unoccupied portion of the day. The normal range for this variable is 65 to 75 deg F. This variable is used to simulate the effects of night setback of the heating thermostat. The simulation of a thermostat setback includes the effects of the length of setback and the mass of the building through the related variables MASS and OCCUPIED HOURS which both effect the calculation of setback savings.

COOL SET - This variable controls the cooling set point. It is specified twice, once for the occupied portion of the day, and once for the unoccupied portion of the day. The normal range for this variable is 75 to 85 deg F. This variable can be used to simulate the effects of "night setup" of the cooling thermostat. The simulation of cooling thermostat setup includes the effects of the length of the setup and the mass of the building through the related variables MASS and OCCUPIED HOURS which both effect the calculation of cooling set up savings.

ACH - This variable controls the ventilation caused by the occupants, either by operation of the HVAC system or by manual means, such as operable windows, if there is no ventilation system. The ventilation specified by this variable is in addition to the natural ventilation specified by the variable PASSIVE INFILTRATION. The normal range for this variable is from a low of 0.3 ACH, Air Changes per Hour, to higher values of 1 or 2 ACH for heavily ventilated usages.

LIGHT PEAK FACTOR - This variable designates the maximum fraction of the connected load that is active during building peak demand. Currently the model does not compute building peak demands, so this variable will have no effect on energy results; it is arbitrarily set to 85%.

PLUG PEAK FACTOR - This variable designates the maximum fraction of the connected plug load that is active during building peak demand. Currently the model does not compute building peak demands, and this variable will have no effect on the energy use calculations; it is arbitrarily set at 85%.

METABOLIC GAIN - This variable specifies the thermal gain from the occupants during occupied hours. It is well known that a sedentary human being emits about 100 watts of thermal energy. This variable is expressed as watts/ft2 of occupied space. It is calculated by:

METABOLIC GAIN = (100*# people)/ft2 building.

For most office and retail situations the METABOLIC GAIN ranges from .5 to 1 watt/ft2. In a dense occupancy situation such as a theater or meeting hall there may be 10 people per 100ft2 and a METABOLIC GAIN of 10 watts/ft2. The full impact of the METABOLIC GAIN depends on the related variable OCCUPIED HOURS that specifies the duration of the gain.

OPERATING SCHEDULES/ OCCUPIED HOURS - This variable specifies the average number of occupied hours in a day. It is calculated as the average number of occupied hours per day for an extended period exceeding a week. Since the OCCUPIED HOURS are the average over a period including low use days, the magnitude of OCCUPIED HOURS will be lower than the number of occupied hours in an active day. For example the OCCUPIED HOURS for an occupancy of 8 hours/day 5 days/week is 40hours/ 7days=5.7 hours/day. OCCUPIED HOURS can vary from month to month in situations with seasonal occupancy such as schools or lodging, and therefore this variable must have an input value for each of the 12 months.

OPERATING SCHEDULES/EXTERIOR LIGHTING - This variable specifies the number of hours per day for exterior lighting. Since the length of night varies seasonally this variable also varies month to month and must have an input value for each of the 12 months. Note that this variable is expressed as hours/day. The full effect of this variable is related to the associated variable EXTERIOR LIGHTING that specifies the connected load of the exterior lighting. This variable can be used to simulate other seasonal exterior loads such as irrigation pumping instead of lighting.

Description of Fan Model And Variables

Basic Model Operation

DUCT CONFIGURATION establishes what type of distribution system is involved. Choices are Dual Duct or variants of Single Duct. The choice of heating, cooling or both allows any application not selected to be ignored from subsequent calculations. DUCT

CONFIGURATION must be consistent with an appropriate choice of Fan Control mode. Some definitions are presented in Table 7.

Table 7. Duct System Definitions

Duct Type	Definition	Control Strategy, Multi-Zoned HVAC	Control Strategy, Single Zone per HVAC unit
Dual Duct	Both heating and cooling distributed by separate ducts	CV with Time Control, VAV	Not applicable
Single Cool	Cooling distributed by ducts, heating by terminal resistance, radiator or coil	CV with Time Control, VAV	On/off with typical packaged AC units
Single Heat	Heating distributed by ducts, cooling (if any) by fan coil	No central distribution of cooled air, could have chilled water loop	On/off with typical packaged heater or heat pump
Single Both	Heating and cooling alternately distributed by duct or fan coil	Typical of Heat Pump Loop, utilizes central distribution with individual fan coils fan heat/cool in each zone	On/off with typical packaged heating/AC units, PTACs

The fan model first establishes the fresh air source with the variable (FRESH AIR SOURCE) The fresh air source is a choice that must be specified as either 1) natural ventilation, 2) with the HVAC system or 3) by a separate fresh air fan. In most cases the fresh air is introduced along with heated and/or cooled air via the HVAC system.

The fan system model has complex interactions with other submodels because energy of the fan system becomes part of the airstream and alters the heating and cooling loads. Under some conditions defined by the variable (MIN BOX FLOW), a fan system will mix heated and cooled air creating a significant system inefficiency. The amount of fan energy can be quite variable, depending on the fan control strategy input in the variable (FAN CONTROL CODE) as well as the motor efficiency (FAN/MOTOR EFFICIENCY) and static pressure (STATIC PRESSURE)

In large and complex fan systems the fan energy will vary with the load on the fan relative to its full design load, the load factor. In order to model the effects of load factor dependent energy use, the model automatically sizes the fan to conditions specified by the variables

(DESIGN HEATING TEMP, and DESIGN COOLING TEMP) and the variables specifying the heating and cooling distribution temperatures, (HEAT DELTA T, and COOL DELTA T).

The FAN CONTROL choice is used to select a part-load efficiency curve for the fans. The Constant Volume (CV) fan is simply turned off/on in step increments to match need for airflow. Thus, its part-load response is completely linear. However, turning the fan off may not be allowable if ventilation rates are to be maintained. An attempt to modulate the airflow by restricting dampers leads to the most inefficient curve, greatly exceeding the CV line. Modulating the fan vanes is more effective but becomes inefficient at low flow rate. TRAV represents a digital control system that allows a Variable Speed Drive (VSD) with fan speed set based on the measured flow at the terminals. This is the most efficient type of control and closely approaches the ideal cube law for fan power. Not all systems have the ability to reset based on pressure -- pneumatic systems, for example, poorly implement pressure reset. The degree to which the VSD system is able to accomplish full pressure reset is specified as the "Pressure Control Factor".
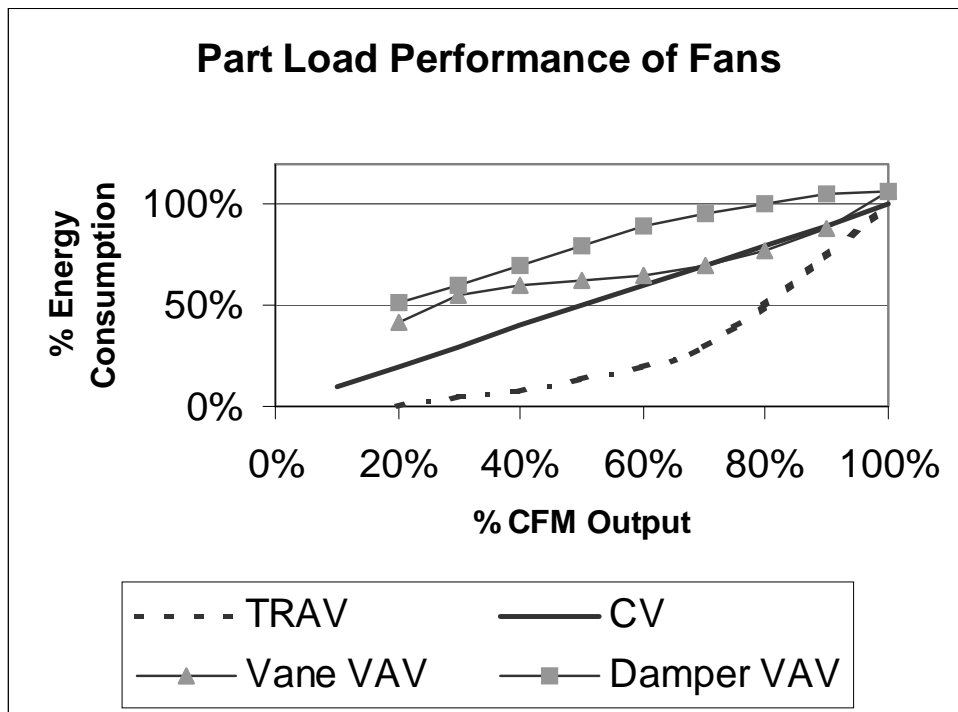
Figure 33. Part Load Fan Performance

Definitions Of Fan Variables And Typical Settings

DUCT CONFIGURATION - This is a choice variable allowing Dual Duct, Single Cool Duct, Single Heat Duct, Single Duct Both or Radiant, No fans.

FRESH AIR SOURCE - This is a choice variable specifying the source of fresh air by a choice of natural infiltration, with HVAC, or separate fresh air system. Very old buildings often have a NATURAL infiltration system with no fans for fresh air, relying on window and

door leakage for fresh air. A building of this type may have no fans at all with heat distributed by radiators or interior unitary gas heaters with small circulating fans. In most modern buildings, fresh air is distributed W/HVAC system as it distributes heated or cooled air. In some unusual occupancies, such as gymnasiums or shops fresh air may be distributed by a dedicated fan system.

FAN/MOTOR EFFICIENCY - This is the overall efficiency of air movement at full load. It is the product of the motor efficiency times the fan efficiency, both at full load. Typically this overall efficiency will range from .65 for large efficient air distribution systems 5 Horsepower and above to .45 for fractional horsepower less efficient systems.

STATIC PRESSURE - This is the duct pressure relative to building pressure at which the air is distributed at design full flow. This pressure has a direct effect on fan energy and can vary widely from 0.5 inches water to 6 inches. Typically rooftop units without ductwork have low static pressures of 0.5; central plants with restricted ductwork can have high static pressure.

CONTROLS REHEAT - This is not strictly a fan variable, but it is associated with the other fan variables. This variable expresses the effect of "fighting thermostats" that lead to simultaneous heating and cooling. The units are Watts/ft2. Usually the variable is 0; a seriously bad control system may have a value of 0.5 - 1 W/ft2.

RESIZE FAN ECM? - This is a yes/no choice variable that only applies to the comparison case. The model uses the design loads to size the fan for the basecase conditions. If you allow conservation measures, it may be possible to resize the fan for the reduced thermal loads. If this measure is selected, the model will resize the fan for design conditions applicable to the comparison case.

HVAC FAN CONTROL - This is a choice variable for the type of fan controls. Choice options are explained in Table 8.

Table 8. HVAC and Fan Control Options

HVAC Fan Control Options	Typical Conditions	Related Variables
Constant Volume, Time Control	Heating/cooling distributed from central plant and mixed at terminals, fan runs constantly, boxes forced to accept minimum flows whether needed or not. Highly inefficient, potential terminal reheat problems.	Minimum box flows are high with consequent damper leakage and terminal reheat problems, high static pressure
On/Off	Packaged units or other systems with simple on/off thermostat, constant volume fan controlled by thermal loads	
On/Off with Constant Volume Fan	Heating/cooling controlled with on/off thermostat but fan timed for ventilation, typical of Heat Pump Loop Systems	Occupied ventilation rate Heat Recovery, Heat Pump Loop
VAV with Damper	Variable Air Volume, but flow controlled by dampers, most inefficient. Degenerative mode of a failed Vane system.	Minimum box flows are high with consequent damper leakage and terminal reheat problems, high static pressure
VAV with Vanes	VAV with poor modulation at low flow rates	Minimum box flows are high
VAV with VSD	VAV with fan speed controlled by total duct pressure or flow	Reduced minimum box flows, reduced static pressure, Pressure control factor is 0.5 to 0.7
VAV with Pressure Reset	VAV with multi-speed fan controlled by changing duct pressure settings	Reduced minimum box flows, reduced static pressure, Pressure control factor between 0.4 to 0.6
TRAV	VAV with flow controlled by flow measured at terminals	Low minimum box flows, low static pressure, Pressure control factor is 0.9 to 1.0

Description Of The Heating Plant Model And Variables

Basic Model Operation

A heating model is used only if the variable (1=HEAT, 0=NO HEAT) is set to 1. The variable (DESIGN HEATING TEMP) specifies the lowest mean monthly temperature for which the heating was designed, and it effects the automatic sizing of fans in the model.

Modeling a real building heating plant can be quite complex if the heating plant includes heat recovery of space or refrigeration heat or if the heat plant is an electric/gas hybrid such as a heat pump with gas backup at low temperatures. This model allows for the specification of such complex heating plants by creating a model heat plant with three stages of heating. The appropriate settings for each stage allow for the modeling of almost any heat plant.

FIRST STAGE - This is the heat recovery stage. In a well-controlled heating system, the heat recovery always precedes the application of other heating. Most heating systems do not have heat recovery and the variables (RECOVERED SPACE COOLING and RECOVERED REFRIG) are normally set to 0. However, if the heating system has space heat recovery such as a heat pump loop or a heat recovery chiller, then the variable (RECOV'D SPACE COOLING) must be set to 1. In this case the available building cooling will be used for heating at the COP noted by the variable (HEAT RECOVERY COP). The amount of heating recoverable will automatically be limited to the amount of cooling required. If only a portion of the building cooling is available, say only a portion of the building has heat recovery, then the variable (RECOVERED SPACE COOLING) is set to the fraction of the building cooling that is available for heating. Any of the methods of heat recovery (heat pump loop, refrigeration or other heat recovery) is set by this variable. For a heat pump loop system, one must also specify the pumping energy.

COOLING PUMPING POWER - This variable specifies the power in W/ft2 for distribution of chilled water. It may apply for chiller systems as well. The variable is interactive because the pumping power increases cooling load.

HEATING PUMPING POWER in W/ft2 specifies the power for heat distribution in a hydronic heating or heat pump loop. It may apply for some Stage Two or Stage Three systems as well. This power is interactive because the pumping energy can apply to the heating load.

SECOND STAGE - This is the electric heating stage. This stage is turned on by the variable (FUEL HEAT THRESHOLD TMP) in stage three. For all mean monthly temperatures above this threshold temp, electric heating will be used. The type of electric heating to be used is designated by the variable (HEAT SOURCE), which allows a choice between resistance and air and ground source heat pumps. If electric heat is only is to be used then the variable (FUEL HEAT THRESHOLD TMP) should be set to a low value, say 0 deg, and electric heat will be turned on at all mean monthly temperatures above that value. If no electric heating is to be used then the variable (FUEL HEAT THRESHOLD TMP) should be set to a high number, say 100deg, so that electric heat is never turned on. If gas heat is to be used only as a backup to a heat pump at below 40 deg F, then the variable (FUEL HEAT THRESHOLD TMP) should be set to 40.

THIRD STAGE - This is the fuel heating stage. Fuel heat is turned on for all mean monthly temperatures below the (FUEL HEAT THRESHOLD TMP). When fuel heat is turned on,

the heating is applied at an n efficiency specified by the variable(FUEL HEAT EFFICIENCY)

Definitions Of Heating Variables And Typical Settings

DESIGN HEATING TEMP - set to the design heating temperature for the building location. If this design temperature is not known then set it to 10 deg F below the mean January temperature. This variable does not have much effect on the modeled outcomes, but it does effect fan sizing. The use of a design heating temperature much too low will to some degree simulate an oversized system.

RECOV'D SPACE COOLING - This variable specifies the fraction of the cooling load that is applicable to heating. This variable should be set to 0 if there is no cooling heat recovery. In a system such as a heat pump loop, covering the whole building the variable should be set to 1. If some but not all of the building cooling load is recovered for heating then the variable should be set to some value between 0 and 1 based on judgment. For an average monthly temperature, the amount of heat recoverable is always limited to the amount of cooling load.

COOL REC'VY COP - This variable specifies the COP at which the cooling load is applied to heating. For a large heat recovery chiller, this value should be set to 5 or more. For a heat pump loop, this value should be set to the value, EER/3.413. A value of 3-6 is usually appropriate for this variable. This variable is only used when the associated variable, RECOV'D SPACE COOLING, is set to a non-zero value between 0 and 1.

RECOV'D REFRIG - This variable specifies the fraction of the refrigeration load that is applicable to space heating. This variable should be set to 0. The variable is only to be used when refrigeration is being modeled which is not current in this particular version of the model.

HEAT SOURCE - This is a choice variable designating the type of electric heat to be used, resistance, air source heat pump or ground source heat pump. This variable only has an effect on those months with mean monthly temperatures above the temperature specified by the associated variable, FUEL HEAT THRESHOLD TMP.

EFFICIENCY RATING - This variable specifies the rated efficiency of the heat source. All electric heat sources specify efficiency as an HSPF (Heating Season Performance Factor). The cut sheets for most electric heat sources will usually specify the HSPF. If HSPF is not specified, then use the steady state COP at 47 deg F. If the COP is available but not the HSPF then use the graphs below to derive the HSPF from the COP. Note the distinction between air source package units and air source split systems. HSPF will have values ranging from 5 for old heat pumps to 8 for new efficient heat pumps. A reasonable value for a ground source heat pump is 10.
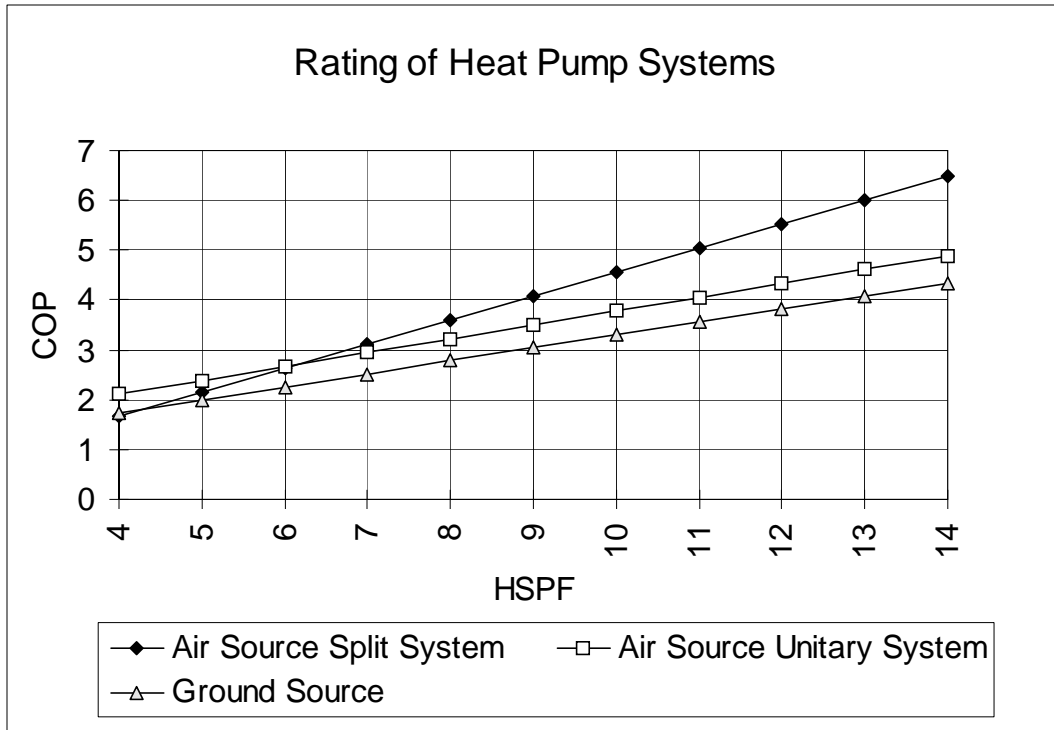
Rating of Heat Pump Systems

Figure 34. Rating of Heating Systems

USAGE MODIFIER - This variable adjusts for other efficiency impacts that have not been captured by the previous variables. For example, in order to tune the model to bills, it may be necessary to increase the USAGE MODIFIER to compensate for losses from poorly sealed heating ducts.

FUEL HEAT THRESHOLD TMP - This variable specifies the minimum mean monthly temperature for the use of electric heat. For all electric use a temperature lower than any winter temperature, such as 0. For all gas use a value higher than any summer temperature, such as 100. For hybrid electric heat with gas backup, adjust the temperature of the electric heat lockout thermostat. The typical value for a lockout thermostat is 45 deg F.

EFFICIENCY RATING - This variable specifies the rated efficiency of the heat source. All combustion heat sources specify efficiency as an AFUE (Average Fuel Utilization Efficiency). The cut sheets for most appliances will usually specify the AFUE. This variable will have values ranging from 0.5 for old furnaces to 0.7 for new efficient furnaces or 0.9 for highly efficient condensing units..

USAGE MODIFIER - This variable adjusts for other efficiency impacts that have not been captured by the previous variables. For example, in order to tune the model to bills, it may be necessary to increase the USAGE MODIFIER to compensate for losses from poorly sealed heating ducts.

FUEL HEAT ELECTRIC AUX - This variable specifies the watts of electric energy required to generate 1 watt of fuel heating. This variable is intended to recognize electrical energy

used in the furnace blower fans and other auxiliaries. This electrical energy is not an interior load and does not offset required heating. A typical value for this variable is 0.01. It does not have a significant effect on the model outcomes, and it is used only to model extreme cases with high heating auxiliary electrical loads.

Description Of Cooling Plant Model And Variables

Basic Model Operation

The cooling model is used only if the variable(1=COOLING, 0=NO COOLING) is set to 1. The variable (DESIGN SPACE COOLING TEMP) specified the highest mean monthly temperature for which the cooling system was designed, and it effects the automatic sizing of fans in the model.

Modeling a real building cooling plant can be complex if the building includes an economizer and or recovered space cooling to heating. The model allows for specifying complex cooling plants by creating a model cooling plant with two stages of cooling. The appropriate settings for each stage allow for the modeling of most complex cooling plants.

FIRST STAGE SPACE COOLING - This stage applies the free cooling available from cool fresh air through an economizer. This cooling is turned on by setting the variable (ECONOMIZER CAPABILITY) to 1. If ECONOMIZER CAPABILITY is set to 0 ,then there is no economizer. Any cooling that has already been recovered for space heat will be removed from the cooling load. Therefore, if cooling load is already being reduced by heat recovery, then opportunities for further reduction by the economizer will be limited.

SECOND STAGE COOLING - This variable designates the type of cooling to be applied to the remaining cooling load after it has been reduced by heat recovery and the economizer. The type of cooling is specified by the variable(COOLING SYSTEM CODE), and the efficiency of the second stage cooling is specified by the variable (EFFICIENCY MODIFIER). Note that this second stage cooling load includes the small cooling required to compensate for the extra heat added by the circulation fans.

Refrigeration applies only to large grocery stores and is not active in this model.

Definitions Of Cooling Variables And Typical Settings

DESIGN COOLING TEMP - This variable specifies the design cooling temperature for the building location. If this temperature is not known then set it to a value 10 deg higher than the mean July temperature.

ECONOMIZER CAPABILITY - This variable specifies the operation of an economizer. It should be set to 1 if an economizer is active, and it should be set to 0 for no economizer. An economizer can have a large effect on the modeled outcomes for large buildings if no heat recovery is active.

COOLING SYSTEM CODE - This is a choice variable designating the type of cooling applied to the cooling load. Choices are:

> Air Cooled AC, SEER
>
> Air Cooled AC, EER
>
> Ground HP, EER
>
> Ground HP, COP
>
> Chiller/tower, kW/T
>
> Chiller/air. kW/T
>
> Evaporative, EER

Note that the choices include specifying the type of efficiency rating that will be applied.

EFFICIENCY RATING - This variable specifies the efficiency of the designated cooling plant. The efficiency of most package cooling units is given in the technical specs in terms of SEER (Seasonal Energy Efficiency Ratio) or EER (Energy Efficiency Ratio). Most small units will be rated by SEER. The SEER includes adjustments for part-load and different ranges of temperatures. In contrast, EER is a rating at a specified temperature of 95 degrees. An EER of 8 is typical for an older cooling unit and an EER of 10 is typical for an efficient unit.

The units of efficiency for a chiller are kW/ton. A COP of 3 or a kW/ton of 1.1 is typical for an air-cooled chiller and a COP of 5 or a kW/ton of 0.7 is typical for a water-cooled chiller with a cooling tower. Note that the usual configuration for a chiller is actually the combination of chiller and cooling tower. If your chiller has an air-cooled condenser, select the chiller/air combination. The performance profile of these system types is quite different. Figure 35 shows the relative efficiency of different cooling system types.

However, Figure 36 is more useful since it presents information in the same format as the "tuning" graph. This figure shows an example of the cooling energy required for the building. Cooling load increases as a function of temperature. Combined with the relative efficiency of the cooling plant, the model computes amount of energy required for cooling. In this figure, one can clearly distinguish the performance of an air-cooled AC unit from that of a chiller with cooling tower.
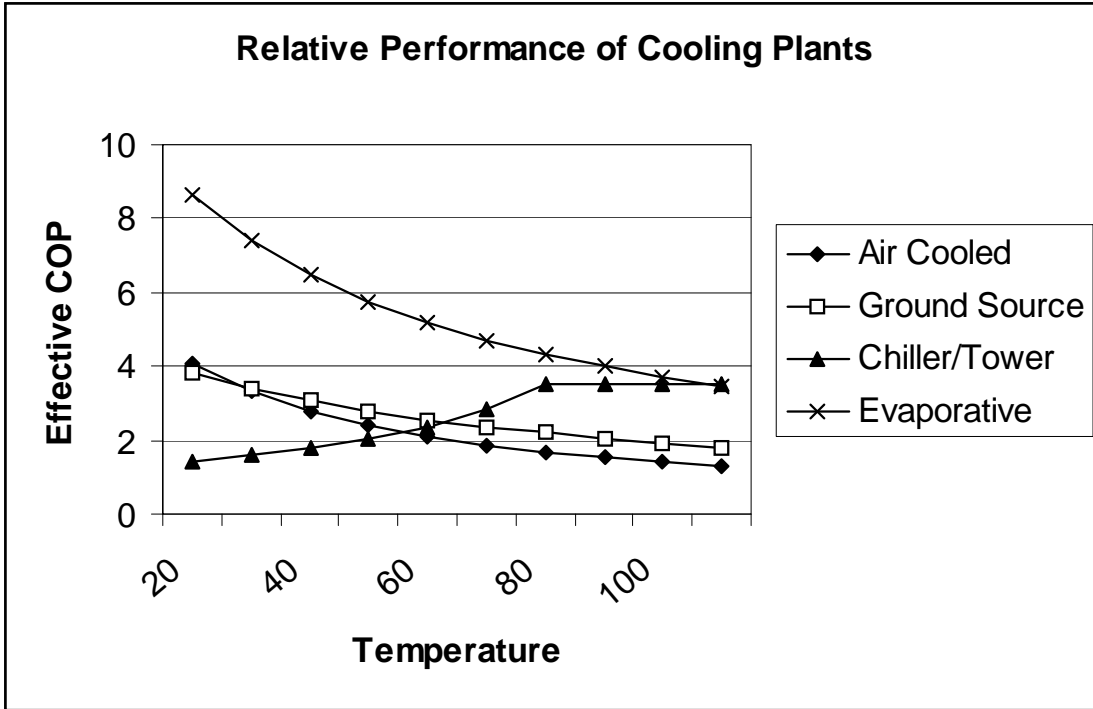
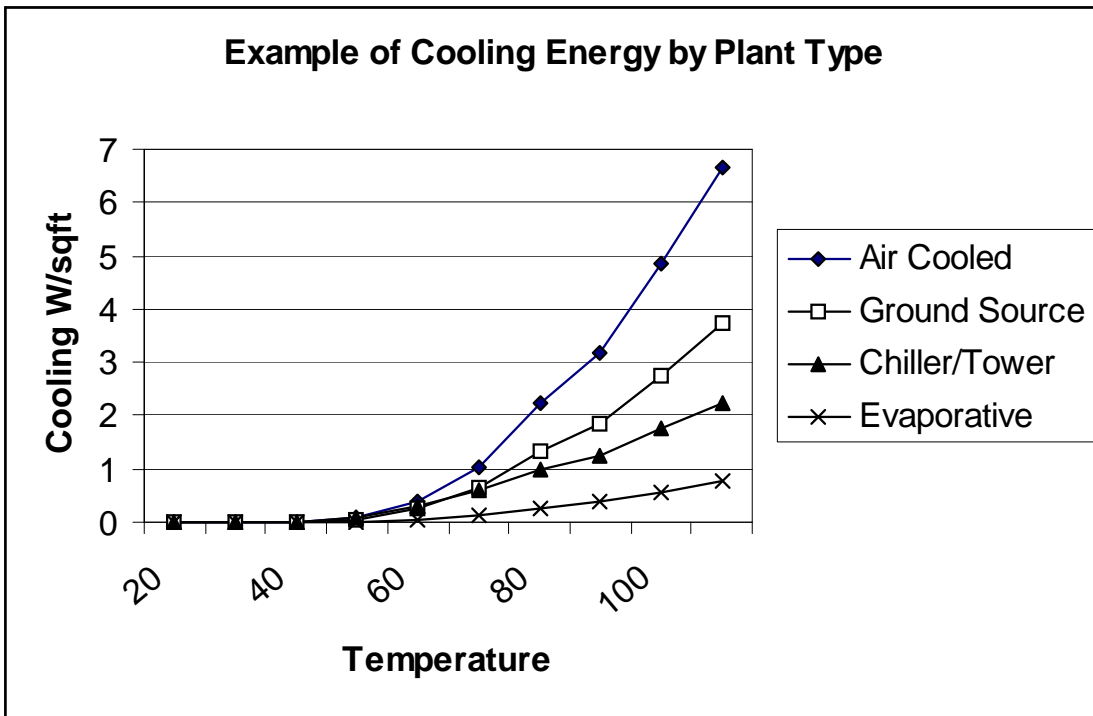**Figure 35. Relative Cooling Performance**

Figure 36. Relative Cooling Energy

USAGE MODIFIER - This variable adjusts for other efficiency impacts that have not been captured by the previous variables. For example, in order to tune the model to bills, it may be necessary to increase the USAGE MODIFIER to compensate for losses from poorly sealed heating ducts.

Description of Refrigeration Plant Model and Variables

Basic Model Operation

The refrigeration model is used for supermarkets, restaurants, and other facilities where extensive refrigeration is present. Refrigeration is a highly interactive variable because it removes heat from the conditioned space, finding an effect on the heating, cooling and heat recovery for the whole building. When refrigeration is specified by assigning to any of the refrigeration case types a finite length greater than 0, then the heating and cooling interactions are taken care of automatically. Where refrigeration heat recovery is used it must be specified as above in the heating plant model and with the compressor control variable.

The refrigeration model offers a choice of the fundamental refrigerated case types and temperatures. The defaults for typical cases will be used unless specific values for case conductivity or case auxiliary are specified.

The refrigeration model also accounts for case defrost options, compressor control modes (fixed and floating head pressure), and condenser efficiency and fan power.

Definitions of Refrigeration Variables and Typical Settings

CASE TYPE - This is a choice variable that the type of refrigeration case and it's operating temperature. For each selected case type, the linear feet of that case are input by the variable CASE LINEAR FEET.

CASE CONDUCTIVITY - For each selected case type, a default case conductivity is selected, but the default can be overridden and a specific case conductivity can be input. CASE CONDUCTIVITY is expressed as BTU/deg hr/linear ft. A low value might be 8 for case with double glazed doors, and a high value corresponding to an open case with an air curtain would be 40-50.

CASE AUXILLIARY - For each selected case type, a default case auxiliary is selected, but the default can be overridden and a specific case auxiliary can be input. Case Auxiliary is expressed in watts/linear ft. This variable accounts for the electrical uses inside the refrigerated case, particularly the recirculating fan and the lighting. A low value might be 10-20 watts/ft, and a high value would be 40-60 watts/ft.

REFRIGERATION LOAD FACTOR - This factor is used to adjust refrigeration demand on the Demand Graph page. A load factor of 1 means a flat load with no peaking. In that case, the refrigeration demand is the average refrigeration power level. A load factor of less than 1 means that the peak demand is larger than the average power level so more demand is attributed to refrigeration. A load factor of 0.7 is typical.

REFRIGERATION USAGE FACTOR - This factor is used to vary the total case refrigeration load. Normally this factor is 1, but it can be set to other values to manipulate refrigeration load in the course of bill fitting when the refrigeration specifics are unknown or irrelevant to the measures being considered.

DEFROST RESISTANCE FRACTION - This variable expresses the fraction of refrigeration load subject to defrost by resistance heater. The default value for this variable is 0, corresponding to the use of "hot gas defrost". The most efficient way to defrost the refrigeration cases (about every 6-12 hours) is by pumping the hot refrigerant gasses through the case coils. The cheaper, old-fashioned way is to use resistance defrost.

COMPRESSOR TYPE - Two compressor types are selectable: piston and scroll. The more common type is the piston compressor.

COMPRESSOR EFFICIENCY - Normally this variable is 1. But a more or less efficient compressor can be defined by setting the value to other than 1. A value greater than 1 represents a more efficient compressor.

COMPRESSOR DISTRIBUTION EFFECIENCY - This variable accounts for thermal losses in the cool refrigerant distribution and return piping. A value of .9 is used by default. Perfect pipe insulation would be expressed by a value of 1.

COMPRESSOR CONTROL - This variable specifies the compressor control strategy. Typical control is the fixed head pressure, which specifies that the compressor is supplying the condenser with hot vapor (about 110 degF) regardless of outdoor temperature. The more efficient floating head pressure controls the hot vapor temperature depending on the outdoor temperature; during the cooler months this can lead to compressor energy savings. Where refrigeration heat recovery is used the fixed head pressure must be specified to maximize the heat available for recovery.

CONDENSER TYPE - This is a choice variable allowing selection between a wet and a dry condenser. The dry condenser is much more common, but the wet condenser will operate at a lower temperature leading to compressor savings.

CONDENSER PERFORMANCE MODIFIER - This variable is usually set to 1. But a more or less efficient condenser would be specified by setting the variable to other than 1. A value greater than 1 indicates a more efficient condenser.

CONDENSER FAN FRACTION - This variable specifies the condenser fan energy as a fraction of condenser thermal load. It is typically set to .1 watts fan/watt load.