SkyCalc User's Guide 6.

As described in Chapter 5, there are many factors of which to keep track when sizing skylights. We have reduced the tedium of optimizing your skylight design with a simple-to-use spreadsheet that identifies the energy and cost savings, and shows the effects of changing various aspects of the system. This Microsoft Excel® spreadsheet, named *SkyCalc*, will predict the lighting and energy outcomes of a given skylighting system over a range of skylight-to-floor area ratios. It will graph the overall energy and cost savings for lighting, heating, and cooling. This will help you to quickly pinpoint the optimal sizing of skylights to maximize your energy or cost savings.

Getting Started 6.1.

SkyCalc runs on Excel 7.0/Windows95 or a compatible version of Excel. It requires a minimum of 2 Mbytes of free hard disk space before installation; we recommend you allow 10 Mbytes for using *SkyCalc*.

SkyCalc consists of a Microsoft Excel template file, **SkyCalc.xlt**, and 16 weather data files with a ***.wea** filename extension. **SkyCalc.xlt** should be copied into the Microsoft Excel XLSTART folder on your computer. The XLSTART folder is usually found under the EXCEL folder, which is typically found in your MSOFFICE folder (your folder names may differ).

The weather data files can be stored anywhere on your computer. For ease of accessing them later, we advise you to copy them into a folder with a descriptive name such as SKYCALC or SKYWEATHER. If you have a shortage of disk space, the weather files can be accessed from a floppy or CD-ROM drive.

After the *SkyCalc* spreadsheet template has been copied to the XLSTART folder, it can be accessed by starting Excel and then by clicking on the **File** menu and selecting the **New** menu item, to bring up the **New** dialog box which contains the names of your Excel templates. Select the **General** tab and double click on the *SkyCalc* icon. A copy of *SkyCalc* named **SkyCalc#.xls** (**SkyCalc1.xls**, **SkyCalc2.xls** etc.) will open.

6.2. Using *SkyCalc*

SkyCalc is intended to help designers correctly size a skylighting system, and to calculate savings from skylighting. Because designers will be relying on the information *SkyCalc* provides, it is important to understand what the spreadsheet can and cannot do, and what key assumptions are made about your skylighting system. *SkyCalc* assumes:

- You will be using diffusing skylights positioned to provide uniform lighting over your space
- You are modeling a single-story building, or just the top floor of a multi-story building
- The average energy prices you specify will give reasonable estimates of cost savings
- The weather data you select is representative of average weather conditions for your site
- You have correctly described your building and lighting systems in the inputs

Because you will probably want to use *SkyCalc* at various stages in your design process, we have designed it to accept three levels of input:

1. **Basic Inputs** - You only need to provide the minimum amount of information that *SkyCalc* needs to perform an analysis; all of the other inputs are defaulted to reasonable values for your building.
2. **Optional Inputs** - If you have more information about your design, you can improve on the default values by providing more detailed input values.
3. **User-Defined Schedules and Values** - You can further refine the *SkyCalc* analysis by establishing user-defined schedules, lighting control curves, building types, and other technical information to the analysis.

We recommend that you use *SkyCalc* early in your building design process to develop a preliminary design and estimate of savings. This only takes a few minutes, and it will give you a target to which to design. As your building design takes shape, with structural, mechanical, and lighting systems, you can easily refine your *SkyCalc* analysis and see if its efficiency is improving. Finally, when the design is nearly complete, you can use *SkyCalc* to refine your final design and quantify the energy savings you can expect.

SkyCalc is organized into separate worksheet tabs (if you are unfamiliar with Excel's tabs feature, refer to the Excel on-line help). Most users of the program will only be interested in the four primary worksheet tabs. These tabs are entitled **Inputs**, **Optional_Input**,

Graph_Results, and **Table_Results**. The two input tabs are used to describe your building, and the two results tabs present findings of the *SkyCalc* analysis.

The **Inputs** worksheet asks for the most basic information needed to evaluate a skylighting system. A first pass analysis can be run after the inputs on this one tab are filled out.

The **Optional_Input** worksheet displays the default values that result from the choices you made on the **Inputs** worksheet and provides the means for you to modify these values for a more customized design.

The **Graph_Results** worksheet illustrates the expected indoor daylight illuminance by hour and by month for your design. It shows, on average, which hours of the day and year will have daylight in excess of your lighting setpoint, and which will have less. Two other graphs illustrate the energy and cost savings for your design, and how it compares to a range of other skylight-to-floor area ratios. Because the graphs on this worksheet require a large number of calculations to generate, they are only updated when you click on one of the update buttons shown next to the graphs. Be sure the graphs are updated before you rely on them as results.

The **Table_Results** worksheet summarizes the energy characteristics of your skylighting design in a simple table format.

All these worksheets can be printed out as reports on the design and expected performance of your skylighting design.

The other worksheets in *SkyCalc* contain the data and the equations used for the calculations. These include **Schedules**, **Lighting**, **Bld_Defaults**, **Skylights**, **Climate**, and **Module1**. They are of interest only if you wish to add user-defined defaults or schedules, or if you are interested in the mechanics of how the *SkyCalc* spreadsheet works. Much of this data is write-protected to prevent the accidental overwriting of defaults. However, most of the screens also have sections of data in a red font that are specifically unprotected for adding user-defined values, schedules, etc.

The following sections are organized by tab to provide more detailed discussions of each of the *SkyCalc* inputs and results.

The Inputs Tab 6.3.

The **Inputs** tab asks you to provide the minimum information needed to evaluate a given skylighting system. This information results in reasonable default values being applied to your skylight design. During schematic design of a new building, when few of the details about the building and the skylights are known, the basic inputs on this first tab provide the appropriate level of accuracy for this stage of design.

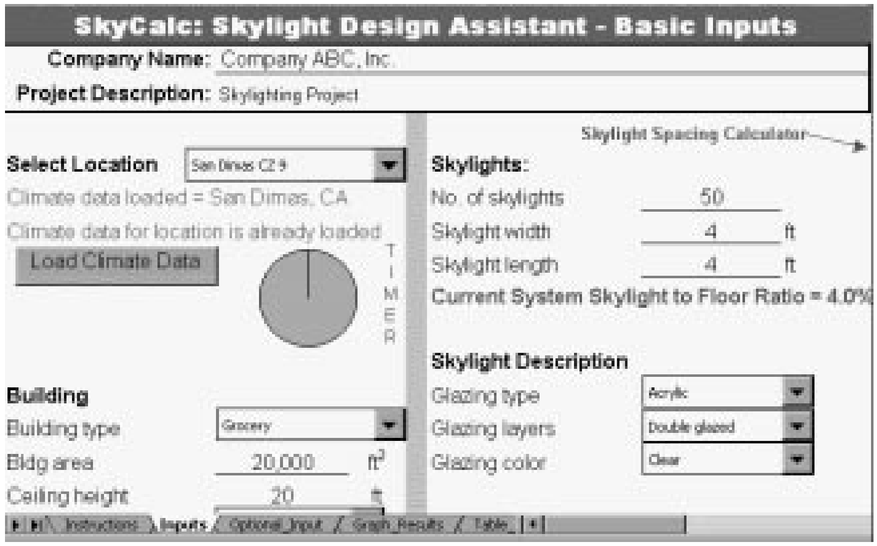


Figure 6-1:
SkyCalc - Basic Inputs

The information is entered either directly into the spreadsheet cells or by selecting from pull-down menus. Once you fill in these basic inputs, you can generate a savings estimate and analysis for your building in a few minutes. All of the information that is not entered on this tab is provided from default values selected by *SkyCalc*.

The following sections describe each of the inputs requested on this tab.

6.3.1. Company Name and Project Description

A simple description of your project helps you to keep track of your files, and also makes the reports you print out from your *SkyCalc* analysis more informative. Typing your company name and project description at the top of the **Inputs** tab also places this header information on the next three tabs.

6.3.2. Location - Importing Weather Data

The *SkyCalc* analysis is sensitive to the weather data that is used. This data tells the program how much daylight is available, the intensity of the solar heat, and how much heating and cooling will be needed. On the pull-down menu to the right of the topic *Select Location*, select the city with the climate most representative of your skylighting project. The pull-down list of climate data is sorted by order of the 16 climate zones defined in the California Title-24 energy code. Arcata for Climate Zone 1 is listed first and Mount Shasta for Climate Zone 16 is last.

In selecting a representative climate zone, the availability of daylight should be the primary point of comparison. Heating and cooling conditions are a secondary consideration, but there should not be large differences between your project location and the representative climate location.

Figure 6-2:

Map of California Climate Zones

The cell below the *Select Location* pull-down menu displays the city name for the climate data currently loaded in the spreadsheet. If the climate data is already loaded for the location you selected, cell A7 will read “Climate data for location already loaded” and you can move to the next section to define your building.

If the weather data for the city you have selected from the pull-down list is not already loaded on the spreadsheet, the next cell down will display the name of the climate data file that you need to load into the spreadsheet. Make a note of this file name and load the climate data by clicking on the *Load Climate Data* button.

An *Open* dialog box appears with a listing of files. Navigate to the folder where you have stored the weather files. Select the weather file for the city you picked, and click on the

Open button. The data will be imported into the *SkyCalc* spreadsheet. As the climate data are being loaded into the *SkyCalc* spreadsheet, the blue timer on the **Inputs** tab will indicate progress. (On most computers the update will take less than 3 minutes.)

Work efficiency tip:

If most of your projects are in a particular region, you may want to open the *SkyCalc* template, **SkyCalc.xlt**, and update the weather data directly on the template. From then on, new *SkyCalc* spreadsheets will be pre-loaded with the weather data you are most likely to use.

To open the template file, click on the **File** menu in Excel and select **Open**. When the **Open** dialog box appears, navigate to the XLSTART (template) directory and select the **SkyCalc.xlt** file. Update the weather data as described above. Then save the **SkyCalc.xlt** file or you can use "save as" to rename the file with a name which reminds you of the city which is loaded, such as **SkyLB.xlt** for Climate Zone 6 in Long Beach.

An Important Note: The calculations in the spreadsheet assume a simple, one-story rectangular floor plan based upon total floor area. SkyCalc should only be used to evaluate the daylit areas in the building. Rooms or areas of buildings with substantially different uses, configurations, schedules, or light levels should be evaluated separately.

6.3.3. Defining the Building

This section asks you to briefly describe the basic characteristics of the building, including type, floor area, ceiling height, and room reflectances. Choose the building type that most closely matches your building. The *Building Type* pull-down menu sets many of the default schedules and intensities of use for people, equipment, lighting, heating, and cooling. If you like, you can later fine-tune the building parameters. Fill in the other building data as requested. For guidance on surface reflectances see Section 3.2.

6.3.4. Shelving/Racks or Partitions

If the room of the building you are evaluating includes partitions, shelves, or racks, you can select either the *Partitions* or *Shelves/Racks* options and proceed to describe their dimensions. When *None/Open* is selected, the program changes these topic headings to **No data required**, and you can disregard filling in data for the height, length, or width of partitions.

The program assumes that the obstructions you describe are evenly distributed across the whole area of the building. When the *Shelves/Racks* button is selected, fill in *Shelf Height*, *Shelf Width*, and *Aisle Width*. The aisle length is assumed to be the width of the building.

All these obstructions absorb considerable amounts of both daylight and electric light, and the illumination and lighting power density calculations are adjusted accordingly. A building which is partially open and partially filled with racks should be evaluated as two separate spaces. You may find that these different spaces produce different energy savings and may require different skylight designs.

Please note that the calculation of illumination levels and lighting power densities for areas with shelving or partitions is a rough approximation, based on the "floor cavity" approach of the lumen method. The method loses accuracy as the shelves get higher in proportion to ceiling height. For greater accuracy, we recommend that you use a lighting design program to determine more precise values for lighting power densities for a given illuminance target. Those values can then be input directly into the **Optional_Input** tab.

6.3.5. Electric Lighting

This section requires you to describe the basic characteristics of the proposed electric lighting system and its controls. *SkyCalc* calculates a default lighting power density for your system, based on the footcandle setpoint, the fixture type, and other characteristics of your building. You can, of course, adjust these default values on the **Optional_Input** tab.

The *Lighting System* pull-down menu defines the lighting system type for general lighting. Only one lighting system can be modeled at a time.

The *Fixture Height* entry asks for the distance from the floor to the bottom of the light fixture, in feet.

The *Lighting Control* pull-down menu selects the electric lighting control strategy. The *Lighting Control Graph* below the pull-down menu illustrates the relationship between the lighting power required by the electric lighting system and the available daylight inside the building for the selected control strategy. It also indicates the current illumination target in footcandles. One of the options on the *Lighting Control* pull-down menu is "No Daylight Control." This allows you to evaluate just the heating and cooling energy impacts of skylights with no daylighting controls.

User-defined lighting systems and controls can be created on the **Lighting** tab. See the Advanced Modifications description in Section 6.7 for more details.

6.3.6. Skylights

The information you enter here describes the physical characteristics of the skylights and light wells. From this information, *SkyCalc* selects typical lighting and thermal performance characteristics for the type of skylights you have selected.

First, you are asked to enter the number of skylights and the dimensions of a unit skylight. Note that the skylight dimensions are in feet. *SkyCalc* determines the gross percentage of roof area which this number and size of skylights represents, and displays it in blue as the *Skylight-to-Floor Ratio*. This value is an important indicator of skylight sizing, and it is used in the graphic results to show you how your design relates to an optimum design.

The pull-down menus for *Glazing Type*, *Glazing Layers*, and *Glazing Color* are used to define the default values for visible transmittance, solar heat gain coefficient, and thermal transmittance (U-value) of typical skylights with the specified glazing characteristics.

The *Light Well Height* should include the height of the curb. Note the units of the light well height are in feet. The *Well Color* pull-down menu lists a range of materials used in light wells. For the *Safety Grate* or *Screen* entry, select "Yes" only if the skylights will have safety grates or insect screens that block some of the light (i.e. not screens that are on the opaque sides of a vented skylight).

6.3.7. Skylight Spacing Calculator

The *Skylight Spacing Calculator*, to the right of the *Skylights* inputs, provides guidance on an even spacing for the skylights, given the total area of skylights in the design. Often the structural grid of the roof constrains the spacing in one direction. Thus, *SkyCalc* asks you to specify spacing in one direction, and calculates the spacing in the other direction. In recommending a spacing dimension, *SkyCalc* takes into account the ceiling height and the number of skylights desired.

The *Skylight Spacing Calculator* also identifies when the calculated spacing is likely to cause uniformity problems, and then makes a recommendation on how to adjust the size and spacing of skylights while keeping the total skylight area the same. If the spacing you have selected is greater than one and a half times the ceiling height, the calculator will issue a warning and will ask you to enter a closer spacing in the direction you have selected. If the spacing you have selected results in less than one row of skylights, the spacing calculator will ask you to increase the spacing distance or increase the number of skylights.

Once your skylight spacing entry has met the two conditions above, the calculator will describe the number and spacing of skylights widthwise and lengthwise. In many cases the spacing results in a slightly lower number of skylights than you entered in the *Skylights* section of the **Inputs** tab. The *Skylight Spacing Calculator* will correct for the lower number of skylights by adjusting the unit skylight size so the total skylight area is held constant.

This calculator provides a convenient check on your skylighting system specification. As you change the inputs for your design and explore how they affect its performance, we recommend that you check back in this section to make sure that your design will still provide good daylight distribution in your space.

6.3.8. Heating and Air Conditioning Systems

The pull-down menus in this section ask you to describe the heating and air conditioning (HVAC) system types for the building. *SkyCalc* uses this information in its calculations, allowing you to evaluate the effect of skylights on heating and cooling energy consumption. The first item on both of these menus is "None." Some buildings, such as unconditioned warehouses, are neither heated nor cooled. This would be indicated by selecting "None" on both the *Air Conditioning* and *Heating System* pull-down menus. Most buildings, however, will have one or both types of systems.

SkyCalc is not a full energy simulation program, so the heating and cooling calculations are rather simplified. It only reports on the net change in heating and cooling energy use that result from the skylighting system.

6.3.9. Utility Costs

SkyCalc estimates the energy cost savings (or increases) for lighting, heating, and cooling, and sums them up to give you a net impact that can be expected in the building's energy costs. *SkyCalc* assumes that lighting and cooling systems use electricity, and that the heating system may use electricity or other fuels.

Enter the average yearly cost of electricity per kWh. This can be found by dividing the total electricity costs on a bill by the total consumption of electricity in kWh for that period. This cost is typically higher than the quoted usage cost per kWh of electricity because it includes other charges, such as peak electrical demand costs. If you don't have utility bills for the building or a similar building, the electric utility representative for the area where the building will be located should be able to provide average electricity costs for your building type.

The *Heating Fuel Units* pull-down menu allows you to specify the costs of heating fuels in the units the supplier provides, eliminating the need for unit conversions. Thus you can list the cost of fuel in terms of $/therm for natural gas or $/gal of oil. In the case of electric heating, the units would be kWh, and the cost may be different from the cost for lighting and cooling electricity specified above.

The Optional Input Tab 6.4.

As your design for the skylighting system becomes more complete, you will have more detailed information about the characteristics of the design, which could affect its overall performance. You may, for example, have the actual specifications of the skylight glazing materials, or a more accurate lighting power density for the lighting system. As this information becomes available, you should visit the **Optional_Input** tab to refine the inputs, and then you can look at the results tabs to see how the system performance has changed.

This tab is used to modify the many default values used in the *SkyCalc* analysis. Filling in any data in the **Optional_Input** worksheet is optional; in many cases the entries from the **Inputs** worksheet will sufficiently describe your building and your skylighting design. You only need to adjust these values if your design is substantially different or if you have better information about your system components.

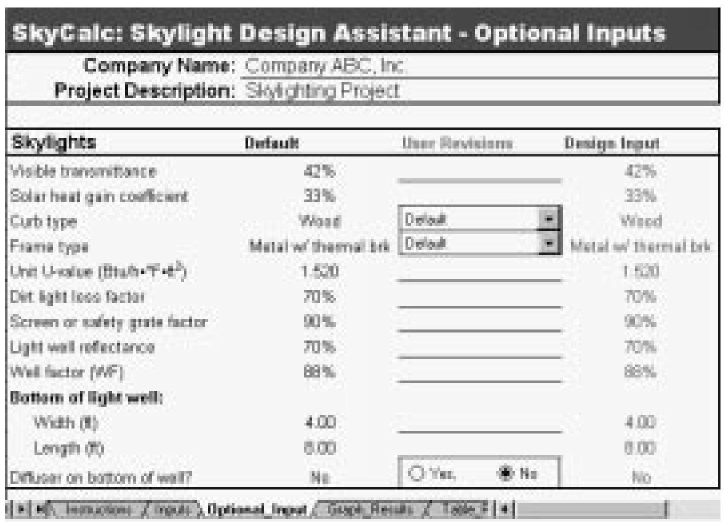
The **Optional_Input** tab has four columns:

Descriptions *Defaults* *User Revisions* *Design Input*

The *Defaults* column displays the default values that *SkyCalc* uses based on the choices you made on the **Inputs** worksheet tab. The *User Revisions* column allows you to replace the default value with a custom value that more closely represents your project. (Make sure that any user revision values are expressed in the units specified!) The *Design Input* column displays either the default or the user-revision values actually used by the spreadsheet to calculate results.

Once you have entered a user-revision value, it will remain operative in the file until you change it. Thus, if you want to start a new analysis in the same file, be sure to check your user-revision values.

FIGURE 6 3: *SKYCALC*, OPTIONAL INPUTS TAB



The following sections describe these inputs in detail.

6.4.1. Skylights

The default *Visible Transmittance*, *Solar Heat Gain Coefficient*, and *Thermal Transmittance (U-Value)* values result from glazing selections made on the **Inputs** tab and modifications made to the defaults on the **Optional_Input** tab. If you have a particular skylight in mind, ask the manufacturer for their test results on visible transmittance, solar heat gain coefficient, and skylight unit U-value and enter these numbers under *User Revisions*.

If you have the unit U-value, it is not necessary to fill out the *Curb Type* and *Frame Type* details. Note that the unit U-value relates the overall thermal transmission of the skylight to the nominal area that the skylight covers. For skylights that project substantially from the surface of the roof such as barrel vaults or pyramids, the unit U-value should be adjusted upward to reflect the increased surface area.

The selections under *Curb Type* are: wood curb (the default); integral frame, where the curb material is the same as the skylight frame material; and flush mount, which would be typical for a site-assembled skylight.

The *Frame Types* are organized by increasing thermal resistance: metal, metal with a thermal break, metal clad wood, and wood or vinyl.

The *Screen* or *Safety Grate Factor* should represent how much of the light is transmitted through the screen or grate (i.e., a screen that obstructs 10 percent of the light has a factor of 90 percent).

The *Light Well Reflectance* default results from the choice of surfaces listed on the *Skylight Well Color* pull-down menu on the **Inputs** tab. The light well reflectance can be fine-tuned by taking site measurements of reflectance, or asking the paint manufacturer to report the reflectance of the paint to be used in the light well.

The *Bottom of Light Well Length* and *Width* describes the dimensions of the light well at the ceiling plane. The default condition is a straight-sided well. You can indicate a splayed light well by increasing the bottom of light well width and length.

Example: A 4' by 5' skylight, with a 2' deep light well, will have a default bottom of light well width = 4' and a length = 5'. To describe the same skylight with a light well that is splayed 45°, the bottom of light well dimensions should be width = 8' and length = 9' (for each one foot of well height, the bottom dimensions are also increased one foot)

6.4.2. Building

The *Building* section of this tab describes in greater detail the building characteristics that are used in the *SkyCalc* analysis. Keep in mind that by building, we mean the skylit space that is being analyzed, which may actually be only a portion of the actual building. In *SkyCalc*, the default building is assumed to be one story tall and twice as long as it is wide. You can override this assumption by revising the building width. The length will be recalculated based upon the overall area of the building. Ceiling, wall, floor, and shelving reflectances can also be revised here if more accurate values are available.

The default roof U-value is the maximum value allowed by the prescriptive requirements of the California Nonresidential Building Energy Efficiency Standards (Title 24) for the selected climate zone. Note that this describes the U-value for the opaque sections of the roof only and is NOT the overall U-value of the entire roof including skylights. *SkyCalc* assumes that the skylights are replacing an equivalent area of opaque roof with no changes to the roof insulation levels.

6.4.3. Electric Lighting

This section describes the characteristics of the electric lighting system and its schedule of operation. The operation schedule is important because *SkyCalc* assumes that the lighting control system turns down the electric lighting when daylight is available only while the lights are scheduled to be on. The lighting power density, in Watts per square foot, is calculated from the design *Lighting Setpoint*, the type of lighting system, and the shape and reflectances of the building and shelving[1]. More accurate lighting power densities, taken either from your experience or from a more exacting lighting design calculation, can be entered in the *User Revisions* column. *Task Height* describes the height of a horizontal task surface above the floor (such as a desk surface). If the primary activity of the space is walking (as in a lobby), the task height would be zero (the floor).

The *Fraction Lighting Uncontrolled* describes the fraction of the ambient lighting system that is not controlled in response to daylight; for example, 10 percent of the lighting fixtures might be operated on an emergency circuit that leaves them on at all times. The *Room and Luminaire Depreciation* describes the percentage of light that will be available from the electric lighting system in several years' time, as compared to the light available from a new fixture and a building with clean surfaces. (Lamp lumen depreciation is already accounted for by *Skycalc* based on the average life of each lamp technology.)

Note that the *Lighting Schedule* (the fraction of lights operating during a given hour) can be revised via a *Lighting Schedule* pull-down menu. This graph displays three schedules: Weekdays (M-F), Saturdays, and Sundays. The *Lighting Schedule Graph* instantly updates when changes in the *Lighting Schedule* are selected. The *Lighting Schedule* pull-down menu includes the possibility of specifying user-defined schedules that can be modified in the **Schedules** tab. See the Advanced Modifications in Section 6.7 of this manual for more details on creating a user-defined schedule.

6.4.4. Internal Loads

This section describes the amount of heat generated internally (other than electric lighting handled in the previous section). The *Number of People* and the *Process* (plug) loads entries refer to the peak, or highest, values expected over the course of the week. In an office setting, for example, the process loads are the computers and other equipment that give off heat. In a warehouse setting, the process loads results from any equipment such as forklifts or packaging equipment. Note that plug loads are in units of Watts per square foot of floor area.

The actual values for number of occupants or process loads for any given hour are usually some fraction of their peak value. These hourly fractions are defined in the *Occupancy Schedule* and *Process Schedule* pull-down menus. The corresponding graphs are immediately updated so you can see the shape of the load profile selected. Note that both of these pull-down menus have a "default" entry as the first menu item; this refers back to the building type entry you made on the **Inputs** tab.

6.4.5. HVAC

This section describes the operating characteristics of the HVAC system that was specified on the **Inputs** tab. The HVAC system has a "0" or "1" schedule. When the HVAC schedule is "1," the specified heating and cooling setpoint temperatures are maintained in the space for that hour. When HVAC schedule is "0," the heating setback and the cooling setback temperatures apply. You can specify an economizer which brings in outside air to provide cooling when the outside air is cool enough. The economizer setpoint defines a temperature above which the economizer is not used. All temperatures are in degrees Fahrenheit.

The Graph Outputs Tab 6.5.

The **Graph_Outputs** tab displays the key results of the *SkyCalc* analysis in three simple graphs: 1) *Average Daylight Footcandles*, 2) *Total Energy Savings from Skylights*, and 3) *Annual Cost Savings from Skylights*.

The first graph shows you the daylight illuminance levels achieved with your skylighting design. The second two help you identify the optimum skylight-to-floor area ratio, given all the other parameters you have entered. These graphs can be updated as you modify the *SkyCalc* inputs, so it is easy to see the impacts of changes to your skylighting design.

6.5.1. Average Daylight Footcandles Graph

The *Average Daylight Footcandles* graph displays the average indoor daylight illuminance in footcandles for each hour of each month for the skylighting system you have defined.

SkyCalc: Skylight Design Assistant - Graphic Results

Company Name: Company ABC, Inc.

Project Description: Skylighting Project

Effective Aperture = 1.95%, Skylight to Floor Ratio (SFR) = 4.00%

Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	4	18	40	61	74	74	64	43	19	6	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	1	8	27	53	71	82	88	78	61	34	12	2	0	0	0	0	0	0
Mar	0	0	0	0	0	0	4	19	47	75	96	102	103	98	74	45	19	5	0	0	0	0	0	0
Apr	0	0	0	0	0	2	10	30	59	81	100	105	102	95	79	55	28	9	1	0	0	0	0	0
May	0	0	0	0	0	4	18	45	71	101	121	127	119	110	91	66	36	14	3	0	0	0	0	0
Jun	0	0	0	0	0	6	22	50	78	106	122	131	130	120	106	82	50	20	5	0	0	0	0	0
Jul	0	0	0	0	0	4	18	45	80	108	133	144	147	138	117	89	55	22	5	0	0	0	0	0
Aug	0	0	0	0	0	3	15	44	82	110	132	143	144	134	111	79	43	15	3	0	0	0	0	0
Sep	0	0	0	0	0	1	9	31	63	87	113	126	127	112	88	55	23	5	0	0	0	0	0	0
Oct	0	0	0	0	0	0	4	19	46	74	89	99	96	82	60	29	9	1	0	0	0	0	0	0
Nov	0	0	0	0	0	0	2	12	35	62	81	88	80	63	41	17	3	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	6	22	41	61	69	64	50	31	13	3	0	0	0	0	0	0	0

Update Shading

Design Illuminance = 50 fc

< 5 fc; < 25 fc; < 50 fc; > 50 fc;

Figure 6-4: Average Footcandles Graph

This gives an indication of how bright it will be inside from daylight only. The calculations are based on the average weather conditions for each hour of the month, using typical weather data (TMY) for the location selected. Of course, on any given day, the value may be higher or lower, depending on the actual weather. The shading on the graph, which is relative to the design target illuminance of the electric lighting system, indicates the hours during which the electric lighting system will be completely on, at minimum power, or somewhere in between.

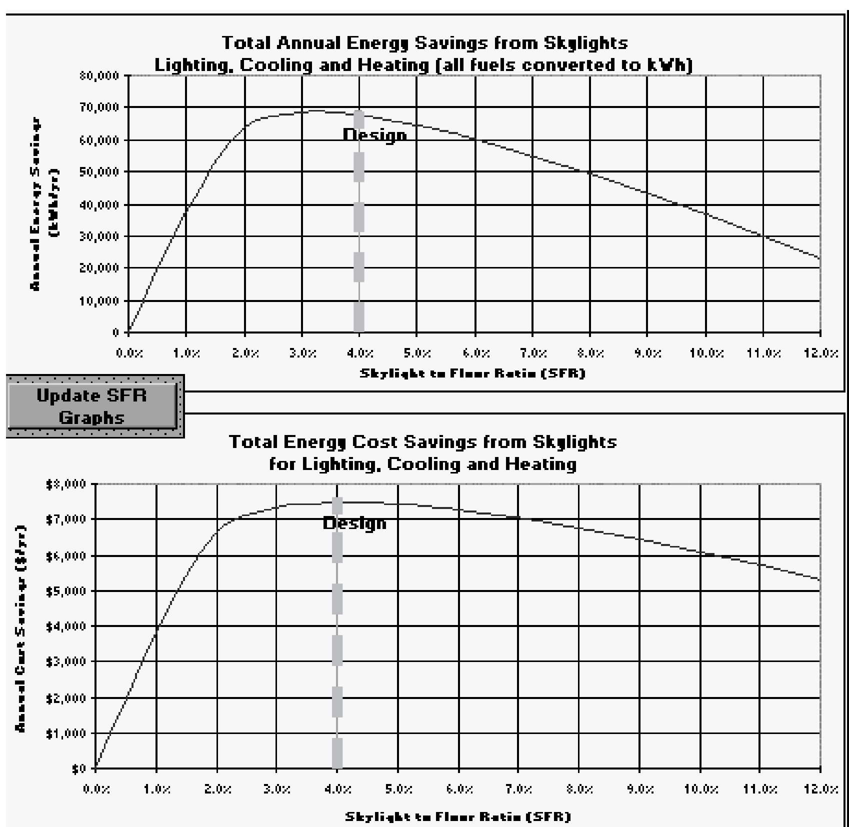
6.5.2. Total Energy Savings and Cost Savings Graphs

These two graphs show you how close your skylight area is to the optimum design condition. With all other variables held constant, they vary the skylight-to-floor ratio (SFR) from 0 percent to 12 percent. The resulting performance curve is plotted both for whole building energy savings and dollar value of those savings. The performance of the proposed design is also indicated.

If you were to change the size or number of skylights in your proposed design, the shape of the curve would change little; however, the vertical line for your design's SFR would move. If you were to change the physical characteristics of the skylights, the daylighting control system, energy costs, or details about the building and its operation, then the shape of the curves would change.

Figure 6-5:

Skylight Area Optimization Graphs



These graphs help you to quickly identify the skylight area in terms of SFR, which yields the maximum energy and cost savings. In addition, these graphs show where your skylighting design lies along the continuum of energy and cost savings.

In many cases the optimum SFR for maximizing energy savings will be different from the optimum SFR for maximizing cost savings. This is due to the various unit costs for electricity versus heating fuels, and the relative impacts on heating and cooling energy uses by the skylighting system.

Just to the right of these graphs are the tables of numbers used to generate them. Looking at the numbers in the tables may help you in understanding the patterns displayed in the graphs. The graphs display only the whole-building savings, while the tables break the information down into effects on heating, cooling, and lighting energy. Typically, the heating and cooling numbers will show negative savings, because the skylights have increased the heating and cooling loads on the mechanical system. If the skylights are not oversized, however, the lighting savings will offset these increased loads.

6.5.3. Update Buttons

The numbers in the *Average Daylight Footcandles* graph are instantly updated whenever any aspect of the skylighting system is changed. However, the shading on the graph is only updated when the *Update Shading* button is clicked. This takes a few seconds.

The values in the *Total Energy Savings* and the *Annual Cost Savings* graphs require a great deal of calculation, and they must be updated each time input values are changed. This is done by clicking the *Update SFR Graphs* button. Thus, they are only current since the last time the *Update SFR Graphs* button was pushed. Updating these graphs takes approximately one minute (depending upon the speed of your computer).

Pushing this button is also linked to revising the data on the **Table_Results** tab, described next. Thus the *Update Results* button on the **Table_Results** tab need not be pushed as long as the inputs have not been changed since the Energy and Cost Savings graphs were updated.

The Table Results Tab 6.6.

The **Table_Results** tab summarizes the key information used to calculate energy savings from skylights in tabular form. This tab also presents the energy and cost savings results for the skylighting system defined from the inputs.

Most of the terms on this tab are defined in the Glossary. The terms that are specific to the

Table_Results table are defined below:

Hours Full Daylighting: the number of hours that the interior daylight levels were above the lighting setpoint.

Overall Skylight System T_{vis}: the fraction of the light from the sky that leaves the skylight well. It is the product of the visible transmittance of the glazing, the well factor, the dirt factor, and the screen or safety grate factor.

Skylight CU: the fraction of the light leaving the skylight well that reaches the work plane. In addition to T_{vis}, this is also a function of the geometry and reflectances of the interior space.

6.6.1. Savings from Design Daylighting System

The *Savings* Table itemizes the savings from the proposed skylighting system, as compared to the same building with no skylights, for lighting, heating, and air conditioning. Note that negative savings means that the skylighting system will use more energy for that component. It is quite typical for a well-designed skylighting system to have negative heating or cooling savings, but this is overshadowed by substantially higher lighting energy savings. If the total skylight area gets too large, the negative savings can overwhelm the positive savings.

If there have been no changes to the inputs since you last updated the *Total Energy Savings* and *Cost Savings Graphs,* then the energy savings figures are current. Otherwise press the *Update Results* button to view the energy impacts of the revised skylighting design.

6.7. Advanced Modifications

Most occasional users of the *SkyCalc* spreadsheet will be interested in only the two primary inputs tabs and the two outputs tabs. This provides sufficient detail for 90 percent of the buildings and designs likely to be encountered. The other tabs store the default schedules and values used in the calculations and are available for examination. The data fields are write-protected to avoid inadvertent data loss.

It is also possible to create your own values for user-defined inputs on these tabs. This section describes the data in more detail, and explains how to add user-defined options. A general caveat: Customization of *SkyCalc* as described in this section should not be undertaken by users who are not reasonably familiar with Excel and its operations. The instructions which follow assume this familiarity and may appear cryptic to users who lack it.

The fields available for entry of user-defined values are shown in red text. The features that can be modified are:

- Schedules
- Lighting Controls

- Lighting Technologies
- Lighting Fixtures
- Building Type
- Skylight Properties

Manufacturers or distributors of skylights, control equipment, or lighting fixtures can create user-defined properties or schedules that describe their equipment. Frequent users of *SkyCalc* may also want to customize some of the above features to reflect design choices they typically make.

6.7.1. Schedules

SkyCalc comes with nine default schedules (*Classroom K-12, Class University, Grocery, Hotel Lobby, Office, Restaurant, Retail, Warehouse, and 24_hour*) for lighting, occupancy, process (plug) loads, and HVAC operation[2]. You may have a project where none of these pre-existing schedules adequately describes the pattern of energy consumption for some of these loads. You can create a user-defined schedule that matches the consumption pattern in the design you are evaluating.

The **Schedules** worksheet tab contains four tables with the schedules for lighting, occupancy, process (plug) loads, and HVAC operation The tables are organized so that the columns describe the hour of the day (1 to 24) and the rows describe the type of day: Weekdays (M-F), Saturdays (Sat), and Sundays (Sun). To the left of the weekday data is a schedule name which appears on the pull-down menus in the **Optional_Inputs** tab.

The schedules designed to be modified are those in red text and are named "user-defined-1," "user-defined-2," etc. Enter data into the cells for each day type (M-F, Sat, Sun) and each hour of the day. Copying and pasting data speeds up the data entry but it is important not to move cells. Inadvertantly moving a cell may cause *Skycalc's* calculations to misfunction. Change the schedule name from "user-defined-1" to a more descriptive name for your project, such as "Gym_Light" for a gymnasium. When changing the schedule name it is important that you use a name that is not already used by another schedule.

The schedules for lighting, occupancy, and process (plug) loads describe the hourly fraction of some maximum value for each of these loads. These schedules should contain numbers between zero and one. The HVAC schedule describes whether the heating and cooling system is in normal mode or off-hour mode. Only the values of zero or one should appear in each hour of the HVAC schedule. Off-hour operation is represented by a zero and normal operation by a one.

6.7.2. Lighting Controls

SkyCalc has an extensive list of pre-defined lighting controls. This list has three sections:

controls with performance characteristics that are common to all lighting technologies (switching controls), controls with performance characteristic that are specific to a specific lighting technology (dimming and hi-lo ballasts), and user-defined controls. Thus, the second section of the *Lighting Controls* pull-down list can change depending upon which lighting system you choose. You can quickly observe the performance of lighting controls on the **Inputs** worksheet by selecting various controls on the *Lighting Controls* pull-down menu and viewing the *Lighting Control* graph. If it appears that none of these controls are appropriate for the lighting system type you have selected, you can create a user-defined lighting control curve.

The *Electric Lighting Controls* table, found near the top of the **Lighting** worksheet tab, describes the fraction of power used by electric lights for differing amounts of interior daylight available. The first column labels the interior illuminances for each row. Each of the following columns describes, for a specified control type, the fraction of power drawn by the controlled electric lighting system as the interior daylight contribution increases from zero to 100 footcandles in increments of two footcandles.

Directly above each of these columns are two numbers which describe the minimum fraction of rated light output and the minimum fraction of rated power output for dimming and hi/lo ballasts[3]. The performance curves assume that the performance of dimming ballasts can adequately be characterized by a straight line (linear interpolation) between the minimum light output and minimum power input to full light output and full power input. The hi/lo ballast and switching control performance curves are designed so that combined daylight and electric lighting provides at least the footcandle setpoint without any deadband.

If you want to create a user-defined control curve for a given electric lighting control, you can change the minimum light output and the minimum power input values for either the dimming, hi/lo, or three-phase hi/lo strategies. The minimum light output and the minimum power input variables for the user-defined controls are in red text to indicate that they are specifically intended for modification. If you desire to have a control function that is neither linear nor a step function, the sheet can be unprotected and the equations overwritten with values that you choose. Note that the target design illuminance is listed just to the right of this table and can be used in your control function.

6.7.3. Lighting Technologies

When you select a specific lighting system on the **Inputs** tab, it is used to determine the amount of lighting power needed to achieve your design target illuminance[4]. The pre-defined lighting systems in *Skycalc* are:

- Open cell fluorescent - deep cell parabolic fixtures containing T-8 fluorescent lamps and electronic ballasts
- Lensed fluorescent - lensed troffers containing T-8 lamps and electronic ballasts
- Direct/Indirect fluorescent - suspended fixtures with reflector grid, with 39% uplight

and 32% downlight, with T-8 lamps and electronic ballasts

- Indirect fluorescent - suspended luminous bottom indirect fixtures with 66% uplight and 12% downlight with T-8 lamps and electronic ballasts
- Industrial fluorescent - industrial strip fixtures with a porcelain enameled reflector, T-8 lamps, and electronic ballasts
- High Bay Metal Halide - high bay intermediate distribution ventilated reflector with clear metal halide lamp and magnetic ballasts
- Low Bay Metal Halide - low bay lensed bottom reflector unit with a clear metal halide lamp and magnetic ballasts
- High Bay HPS - same as high bay metal halide except with clear HPS lamp
- Low Bay HPS - same as low bay metal halide except with clear HPS lamp

The performance of these fixtures is as defined in the IESNA Handbook Reference numbers for each fixture and can be found starting at cell D-84 on the **Lighting** tab.

If you want to specify a light source with a different efficacy, such as metal halide lamps with a high efficiency ballast, you can create a user-defined lighting system that reflects the changed efficacy.

To create a user-defined lighting system:

On the **Lighting** tab below the *Electric Lighting Controls* table is the *L_type* table. The first column lists the types of electric lighting systems. These are the items you see when using the *Lighting System* pull-down menu. The *Maintained Luminous Efficacy* column lists the light source efficacy, including lamp lumen depreciation at 40 percent of rated life of the lamp. Enter a maintained source efficacy for your lighting system.

The next column, Table *"L_intens" Column#* references the appropriate column in the *L_Intens* table to describe the luminance distribution of the fixtures used in the lighting. Select the column number for the appropriate fixture type. The remaining columns are for reference and are not designed to be modified.

6.7.4. Lighting Fixtures

If you would like to add another fixture type that has a different light distribution from any of the light fixtures listed, enter the luminous intensities for the desired fixture in the *L_Intens* table. The *L_Intens* table is below the *Electric Lighting Controls* table and to the right of the *L_Type* table. These luminous intensities in candelas are normalized per 1,000 source lamp lumens and must be listed for the midpoint of each 10° conic solid angle. The format of this table and the source of more data for other fixture types can be found on page 443 of the 8th Edition of the IESNA Lighting Handbook.

6.7.5. Building Type

When you make a selection from the *Building Type* pull-down menu on the initial **Inputs** worksheet, it controls a wide array of defaults, from the lighting setpoint to the HVAC schedules. You can create new user-defined building types that describe building types you are frequently asked to evaluate.

Go to the *Bldg* table on the **Bld_Defaults** tab. The headings of the columns describe the data required for a user-defined building type. When creating a default schedule, it is best to reference the cell containing the schedule name rather than typing the name in. This way, if the name of the schedule is changed, the *Bldg* table is automatically updated. See the other pre-defined schedules for an examples of how the schedule name is referenced.

Building types in the red font have been set aside for user modifications. Use these rows for new building types. You can change the name of the building type to something more descriptive than "user-defined-1," but be sure to give it a unique name.

Example - How to reference a schedule name: Suppose that you want to create a new building type called "manufacturing" (instead of "user-defined-1") and you want to use the *24_hour* lighting schedule. You have overwritten "user-defined-1" with "manufacturing," by typing "manufacturing" in cell A18. In the cell for lighting schedule (cell B18), you type an = sign and then click on the **Schedules** tab. On the **Schedules** tab, find where the *24_hour* light schedule name is referenced (cell E29). Click on the cell and then hit return on your keyboard. The "manufacturing" building type now references the *24_hour* light schedule.

6.7.6. Skylight Properties

The *Glazing Type*, *Glazing Layers*, and *Glazing Color* pull-down menus on the **Inputs** tab, and the *Curb Type* and *Frame Type* pull-down menus on the **Optional_Input** tab build up a description of the skylights that is used to look up default performance characteristics of the specified skylights. The resulting performance characteristics of visible transmittance, solar heat gain coefficient, and thermal transmittance (U-value) are presented on the *Default* column of the **Optional_Input** worksheet.

If you occasionally design with a specific skylight in mind and you have performance test results from the manufacturer, changing the default values that return from the *Skylight* pull-down menus is probably not worth the effort. The simplest method of using these skylight specific performance results is to ignore the *Skylight* pull down menus and enter the data directly in the *User Revisions* column on the **Optional_Input** tab for *Visible Transmittance*, *Solar Heat Gain Coefficient*, and *U-value* (Btu/hr•°F•ft^2).

However, if you frequently specify a particular skylight, or if you are a skylight manufacturer who wishes to make it easy to evaluate designs using your skylights, you may wish to add these specific skylight products to the pull-down menus.

How to add a new skylight product:

At the top of the **Skylights** tab is the *G-type* table that contains the listing of available glazing types. Replace the entry "User Defined" in red font with a more descriptive name, such as the skylight manufacturer's name and product number.

To the right of the *G_type* table, past the *G_layers* and *G_color* tables, is the *Glazing Layers* table. The custom name you entered above should now be visible at the top right of this table. The names in the *Glazing Layers* table describe any categories that will have an influence on visible transmittance and shading coefficient, other than glazing color. These influences might include number of glazing layers and glazing thickness, for example. The results of this table are also used when defining the overall U-value of the skylight. Enter your choice of names in the last column of this table; the text in these cells is in red font to indicate the cells are available to be modified.

To the right of the *Glazing Layers* table is the *Glazing Colors* table. Your custom skylight name should also appear here. In the last column of this table, describe the color or other glazing characteristics that affect visible transmittance and solar heat gain coefficient only.

Below the *G_type* table is a large look-up table which lists the visible transmittance (T_{vis}), and the solar heat gain coefficient (SHGC), for all the combinations of glazing types, layers, and colors. At the bottom of this table are listed the glazing type and glazing layers names which you defined earlier. Enter the visible transmittances and solar heat gain coefficients for the skylights you are defining in the appropriate column. The cells you can change are indicated by a red font.

Below the *Glazing Layers* table is the *U-Values for Different Frame and Curb Configurations* table. This table contains unit U-Values for combinations of glazing types, layers, curbs, and frame types. Note that the option is not available to add to the frame or layer types. If you have only one frame and curb type, you may want to put the same unit U-Value across all the frame and curb types so the correct result is obtained regardless which curb and frame type was selected. Fill in the corresponding unit U-Values in the cells highlighted with red text for the skylights you have defined.

The Calculations 6.8.

SkyCalc, as a simple daylight and building simulation spreadsheet, considers the following effects that skylights have on building energy consumption:

- Reduced electricity consumption by electric lighting (when daylighting controls are used)

- Reduced internal heat gains by electric lighting (when daylighting controls are used)
- Increased solar gains
- Increased thermal transmittance of roof

The thermal effects cannot be simply added together to find the overall energy impacts of skylights. On a cold day, the solar gain is not necessarily increasing cooling electricity consumption—it might be reducing heating load. Whether the building is in heating or cooling mode depends upon other factors such as how many people are in the building and how much process equipment (plug loads) is operating. Thus, a good estimate of overall energy impacts of skylights requires some knowledge about the rest of the building.

The climate data for *SkyCalc* is actually an hourly output file from a DOE-2 simulation of a "reference" building. These outputs are modified to represent the building with the skylighting design and a "base" building similar to the skylit building in all ways but one—the base building doesn't have skylights.

The *SkyCalc* spreadsheet has four major components for calculating the performance of skylighting systems:

- Simple user inputs
- A database of default schedules, skylight performance characteristics, and material properties
- Hourly climate data generated by the DOE-2.1E building energy simulation program containing interior illuminances, sensible heat gains, solar heat gains, and outdoor dry bulb temperatures for a reference building
- Calculation algorithms embedded in cell equations, user defined functions, and subroutines

The extensive defaults convert simple user inputs such as "white paint" into values the spreadsheet can use, such as "reflectance = 80 percent." This combination of simple user inputs and defaults creates a detailed description of the building, its loads, electric lighting, and skylighting systems.

The DOE-2 reference building has the following characteristics:

- 100' by 100' building with a 20 foot ceiling, task height is 2.5 feet above the floor
- 4 % skylight-to-floor ratio, shading coefficient = 1.0, effective aperture = 2 % (overall T_{vis} = 0.5)
- Roof U-Value = 0.057, Skylight overall U-Value = 1.0 Btu/hr•°F•ft^2, adiabatic walls
- Both lighting and equipment power density are 1.5 W/ft^2
- Occupant density is 1 person per 100 ft^2
- Setpoints: Cooling 72°, Heating 68°
- All schedules (lighting, occupancy, process loads) are set at 100% for 24 hr/day and 7 day/wk
- Daylighting controls are disabled

Simple ratios are used to relate the illuminances in a skylight design to the reference building. The two factors to be compared are the effective apertures and coefficients of utilization. The effective aperture describes what fraction of the light impinging upon the roof penetrates the skylight and light well. The coefficient of utilization describes what fraction of light exiting from the bottom of the light well reaches the task. The lumen method algorithm as published in Chapter 9 of the 8th Edition of IES Lighting Handbook is used to calculate the coefficient from skylights. The key assumptions of this method are:

- The skylights are completely diffusing (Lambertian distribution) and uniformly spaced
- Each surface in the room is diffusely reflecting
- Each major surface of the room is uniformly illuminated

Thus, this method will not accurately model clear skylights, non-uniform spacing, or high partitions.

The lumen method, using luminance distribution patterns for specific light fixtures and a light source efficacy, calculates the default electric lighting power density for the lighting setpoint selected.[4] In this manner, lighting levels, lighting power density, and interior daylight are all interrelated.

The corrected interior daylight levels for each hour of the year and the daylighting control function modify the base case electric lighting power for that hour. Thermal losses due to skylights are modeled using a simple UA (conductance area product) equation. This steady-state heat transfer method does not consider thermal storage of heat in the mass of the building. In contrast, the solar heat gain model, which scales the hourly solar loads from the DOE-2 reference building by the relative area of the skylights and their solar heat gain coefficient, does reflect the thermal capacitance of the reference building. The other thermal loads of occupancy and equipment are also added in to arrive at the total zone heating or cooling load for that hour.

At this point, the zone loads for each hour and the sum of electricity consumption for electric lighting for both the base case building without skylights and the skylit designed building have been stored. The maximum cooling load is also stored for sizing of the heating and air conditioning systems.

A HVAC system model then evaluates the energy consumption required by the hourly building loads. This model allows the user to specify an outside air economizer that can displace some or all of the cooling load when the outside air is sufficiently cool. This model also varies the heat pump efficiency depending upon outside temperature. (As the outside temperature drops, the heat pump needs more electricity per Btu of heat generated.)

Savings are calculated by subtracting the energy consumption of the daylit building by component (lighting, cooling, and heating) from the base building without skylights. These savings are recorded in the results table and graphs.

[1] *SkyCalc* uses the lumen method as defined by the 8th Edition of the Handbook of the Illuminating Engineering Society of North America. See Sections 7.7.3 and 7.7.4 for more information on assumptions about light sources and fixture types.

[2] The schedules are based on data collected by Southern California Edison from a large set of monitored buildings representative of each building type.

[3] Performance curves are based on averages of manufacturer-provided data, using two or three typical products when available, or only one product when no competitors could be located.

[4] Note the caveats about high partition or rack areas hold for electric lighting. We recommend that you modify the lighting power density in high rack areas with values that are consistent with a more sophisticated lighting design tool or your design experience.