Program Description March 2019

A PC Program

COMFEN 5

for Calculating the Energy Demand and Comfort Impacts of Windows in Commercial Buildings

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DRAFT

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DISCLAIMER

March 2019

COMFEN 5: Program Description

A PC Program for Calculating the Heating and Cooling Energy Use of Windows in Commercial Buildings

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1. INTRODUCTION

Overview

Today's energy-efficient windows can dramatically lower the heating and cooling costs associated with windows while increasing occupant comfort and minimizing window surface condensation problems. However, consumers are often confused about how to pick the most efficient window design for a commercial building. Product information typically offers window properties: U-factors or R-values, Solar Heat Gain Coefficients or Shading Coefficients, and air leakage rates. However, the relative importance of these properties depends on site- and building-specific conditions. Furthermore, these properties are based on static evaluation conditions that are very different from the real situation a window will be used in.

A computer tool such as COMFEN can help architects and builders pick the most energy-efficient and cost-effective window for a given application. It calculates heating and cooling energy use and associated costs as well as peak heating and cooling demand for specific window products. Users define a specific "scenario" by specifying the building type, geographic location, orientation, and window configuration. Users also specify size, shading, and thermal properties of the window they wish to investigate.

Update information, future releases, and program information about COMFEN and other software tools (such as WINDOW, THERM, and Optics) from the Windows and Daylighting Group at LBNL can be found on the following website: http://windows.lbl.gov, in the Software section. To obtain COMFEN, WINDOW, or THERM, check the web site for the current downloadable version.

2. QUICK START

2.1. Getting started

- Install the COMFEN program (see Chapter 3, "Installation").
- When the program is installed, **double click** on the COMFEN5 icon.

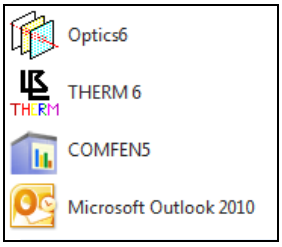


Figure 2-1. Click on the COMFEN icon in the Programs/LBNL Software list.

- The Startup Menu screen that appears allows you to either start a new project or open existing projects. There are a few example projects in COMFEN, which are listed under Recent Projects. Projects are collections of "scenarios" or façade designs, that can be compared.

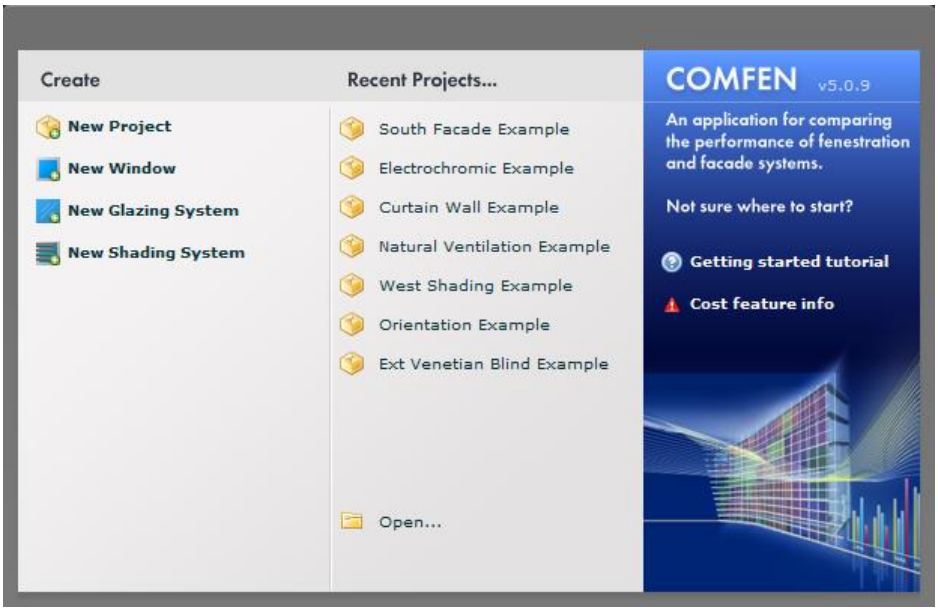
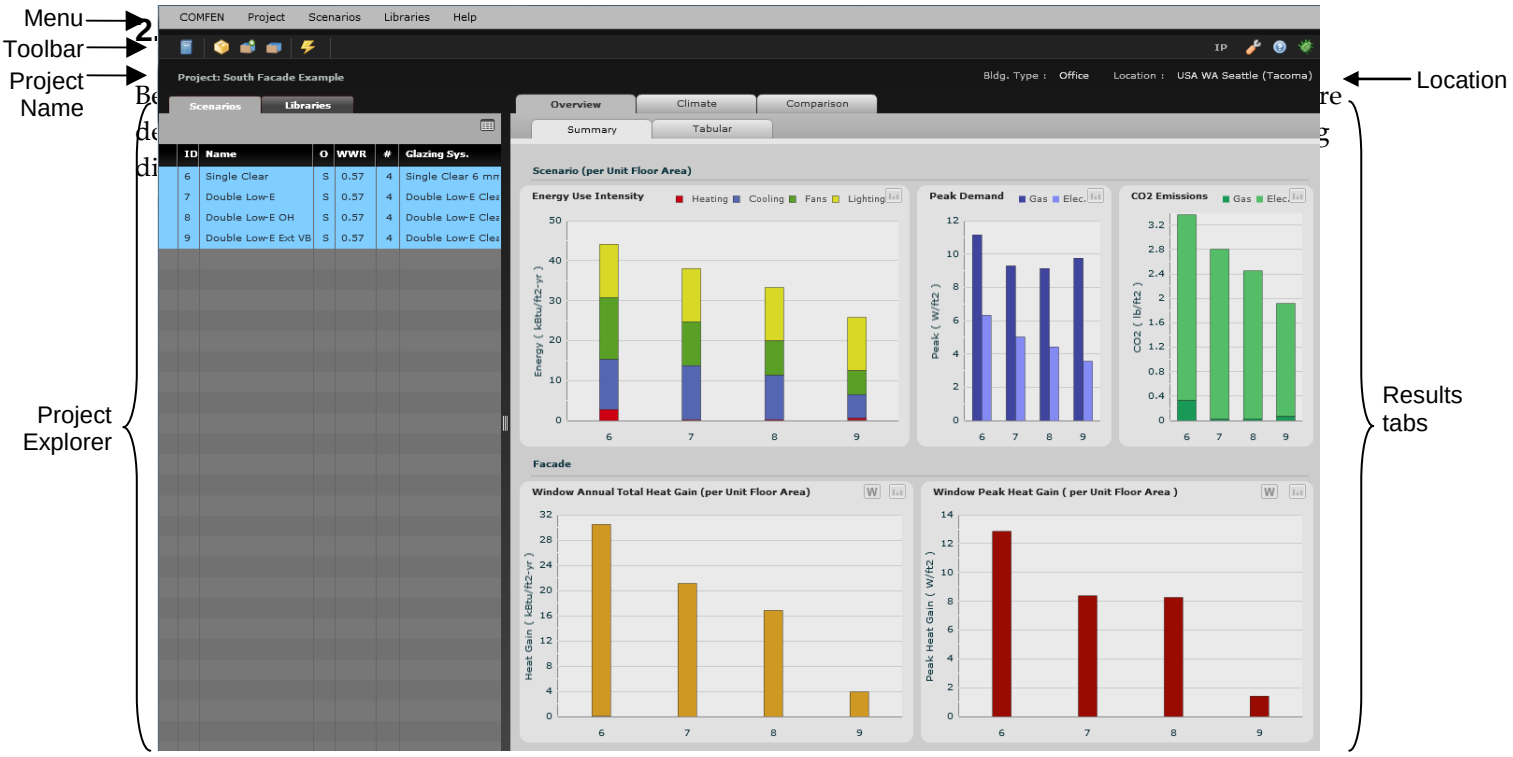
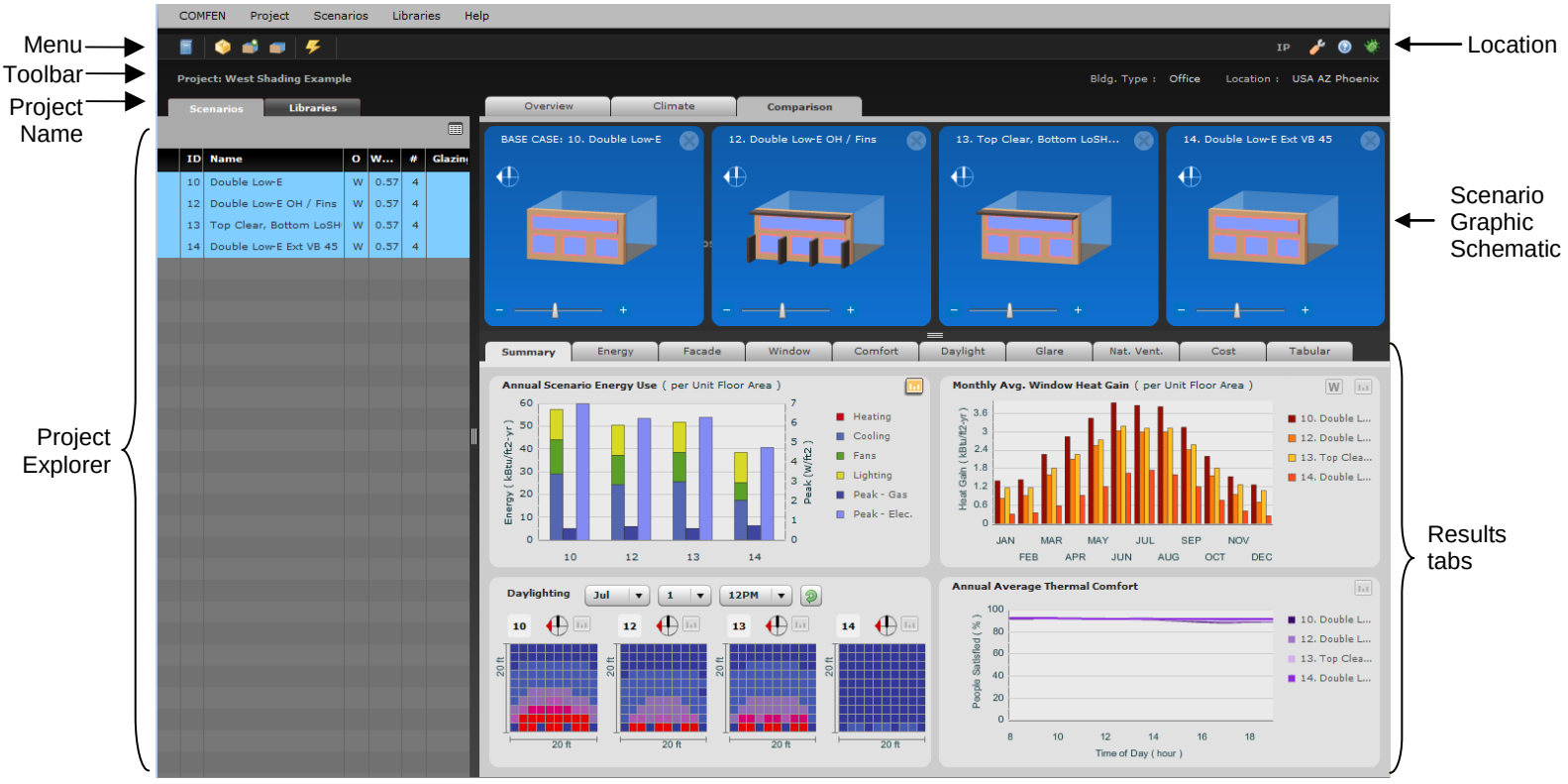


Figure 2-2. The Startup Menu screen allows you to create a new project or open already defined projects.

2.2. Quick Tour of COMFEN

To take a tour of the program, we will start by opening an existing project, **West Shading Example.**


Menu
Toolbar
Project Name
Project Explorer
Location
Results tabs
COMFEN Project Scenarios Libraries Help
Project: South Facade Example
Bldg. Type : Office
Location : USA WA Seattle (Tacoma)
Scenarios
Libraries
Overview
Climate
Comparison
Summary
Tabular
Scenario (per Unit Floor Area)
Energy Use Intensity
Heating Cooling Fans Lighting
Peak Demand
Gas Elec.
CO2 Emissions
Facade
Window Annual Total Heat Gain (per Unit Floor Area)
Window Peak Heat Gain (per Unit Floor Area)


Menu
Toolbar
Project Name
Project Explorer
Location
Scenario Graphic Schematic
Results tabs
COMFEN Project Scenarios Libraries Help
Project: West Shading Example
Bldg. Type : Office
Location : USA AZ Phoenix
Scenarios
Libraries
Overview
Climate
Comparison
BASE CASE: 10. Double Low-E
12. Double Low-E OH / Fins
13. Top Clear, Bottom LoSH...
14. Double Low-E Ext VB 45
Summary
Energy
Facade
Window
Comfort
Daylight
Glare
Nat. Vent.
Cost
Tabular
Annual Scenario Energy Use (per Unit Floor Area)
Monthly Avg. Window Heat Gain (per Unit Floor Area)
Daylighting
Annual Average Thermal Comfort

Project Explorer

The Project Explorer is the primary navigation tool in the Project. In the Project Explorer, there are two tabs, Scenarios and Libraries.

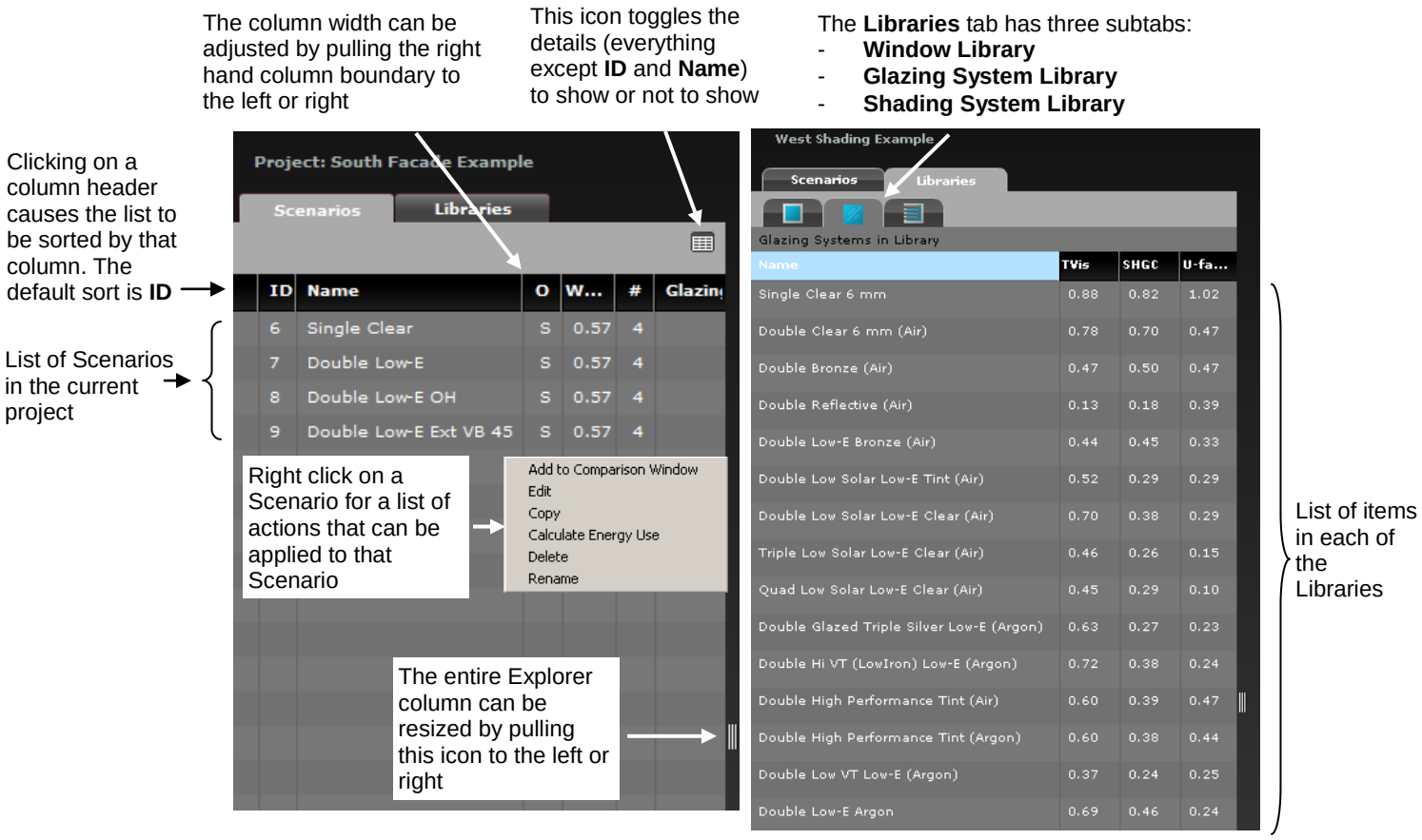


Figure 2-4. The Project Explorer.

Scenarios The Scenarios tab shows a list of all the Scenarios in the current Project

Libraries The Libraries tab has three subtabs:

- **Window Library Tab:** this shows the records in the Window Library. There is one default window. You can highlight a window and drag it onto the façade in the Edit Scenario View.
- **Glazing System Tab:** this shows the records in the Glazing System Library. You can highlight a glazing system and drag it onto a window in the Edit Scenario View.
- **Shading System Library Tab:** this shows the records in the Shading System Library. You can highlight a shading system and drag it onto a window in the Edit Scenario View.

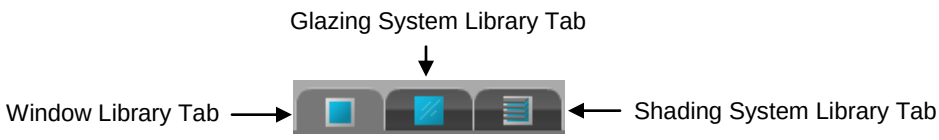


Figure 2-5. The Libraries Tab subtabs.

Scenario Visualization

Under the Comparison Tab, you can show up to four of the scenarios by dragging them from the Project Explorer Scneario tab to the upper right part of the screen. Highlight the desired Scenarios in the Scenarios tab and drag your mouse to the right.

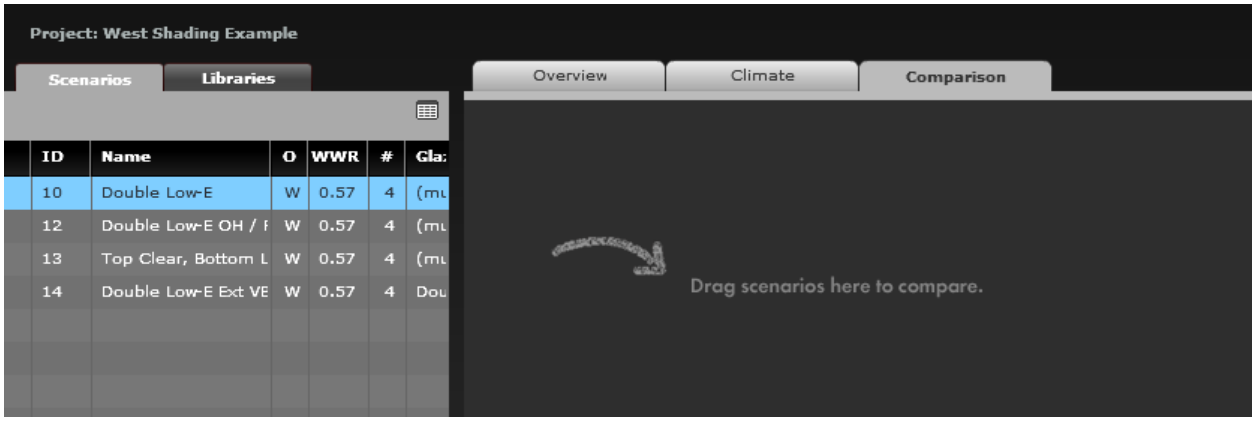


Figure 2-6. Highlight up to four scenarios and drag them to the right under the Comparison tab.

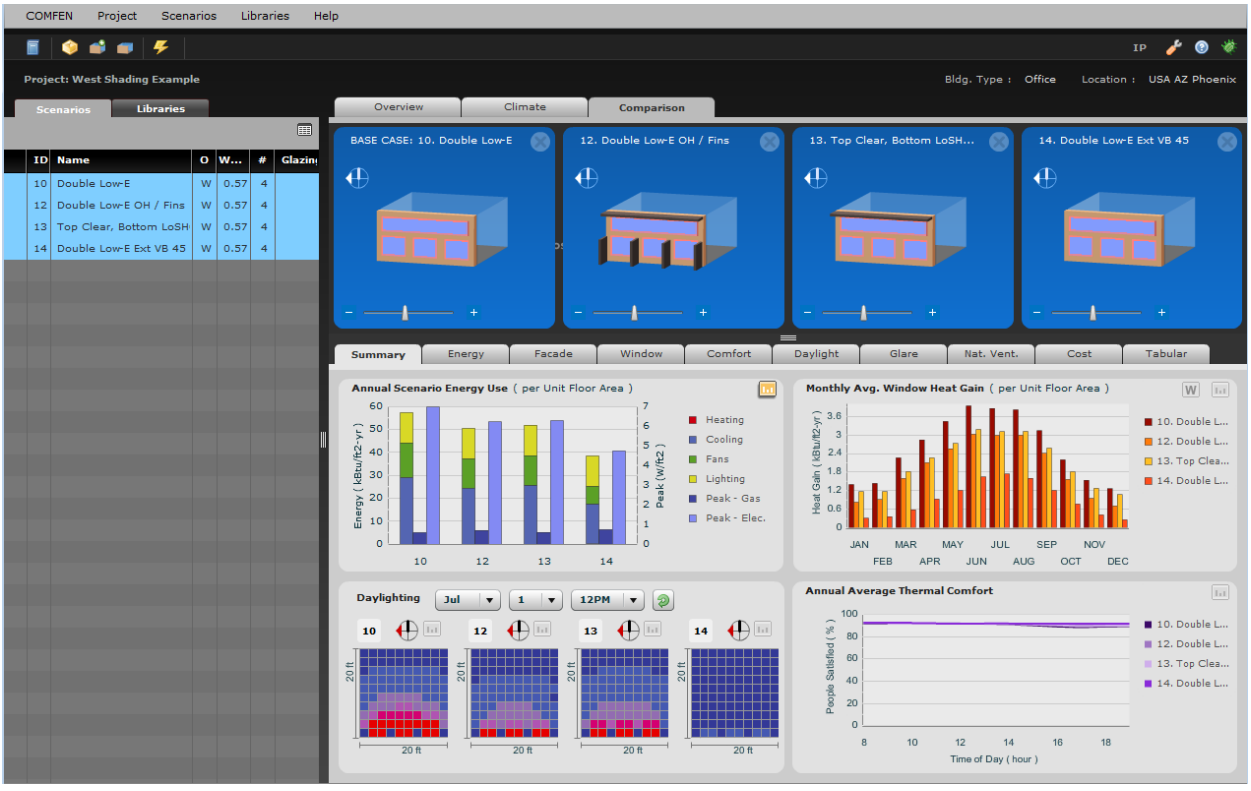


Figure 2-7. The scenarios will be displayed in "3D" and results, if they exist, will be shown below each.

The Scenario Visualization section of the main screen shows the geometry of any Scenarios in the Project Explorer that you have dragged into the Visualization section of the screen. They do not have to be simulated to be in the Visualization section, but results will only show in the Results section if they are simulated.

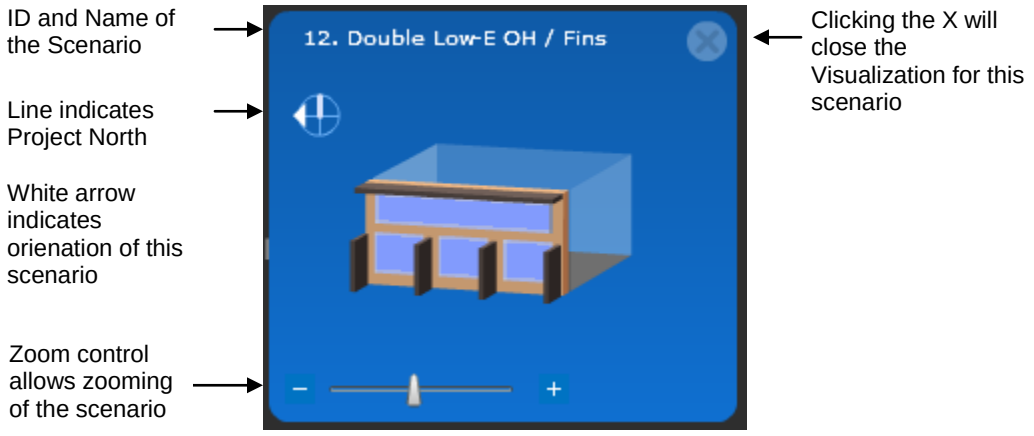


Figure 2-8. The elements of the Scenario Visualization.

2.2.2. Menu

Figure 2-9. The COMFEN menu options.

The COMFEN menu options are:

COMFEN The menu options are:

- **About COMFEN:** This option shows the program version
- **Preferences:** Controls various settings in the program
- **Hide COMFEN**
- **Quit**

Project The File menu is used to control projects and general program options

- **New Project:** Starts a new project, opening up the Project Properties dialog box
- **Open Project:** Opens a list of projects that are in the current database
- **Close Project:** Closes the current project
- **Project Properties:** Opens the Project Properties dialog box, which contains the Project Name, Building Type, Project North and Location
- **Delete Projects:** Allows you to delete projects from the database
- **Import Project Definition from CSV file:** Allows you to import projects from a CSV text file. All projects must be closed for this option to be active
- **Export current project results to CSV:** Exports the Annual Energy Use results for all the scenarios in the currently open project to a CSV file, which can then be opened in a spreadsheet program.

Scenarios The Scenarios menu is used to control the Scenarios within Projects.

- **Create Scenario:** Creates a new scenario within the currently opened project
- **Copy Scenario:** Makes a copy of the highlighted scenario
- **Import Scenario from Project:** Shows all the scenarios in all the projects in the current database, and allows import of those scenarios into the current project
- **Delete Scenario:** Deletes the highlighted scenario
- **Rename scenario:** Renames the highlighted scenario
- **Add Window to Scenario:** When in Scenario Edit mode, opens the New Window dialog box to define a new window on the scenario facade
- **Add Exterior Shade to Scenario:** When in Scenario Edit mode, opens the New Wall Shade dialog box to define a new fin or overhang.
- **Export compared scenarios images to PNG:** Exports one image per compared scenario as a PNG file to the location specified.
- **Calculate All:** Calculates the results for all the scenarios in the currently open project
- **Calculate Selected:** calculates the results for the highlighted scenarios

Libraries The Libraries menu is used to access all the Libraries

Help The Help menu is used to view the program version number as well as the program Help file.

2.2.3. Toolbar

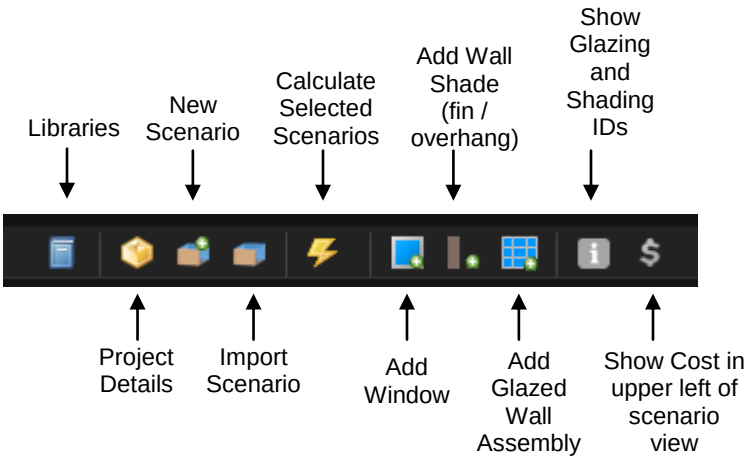


Figure 2-10. The COMFEN Toolbar.

Toolbar Icon	Description	Menu / Choice
	Library	Libraries / View All Windows
	Project Details	File / Project Properties
	Add New Scenario to Project	Scenarios / Create Scenario
	Import Scenario into Project	Scenarios / Import Scenario
	Calculate energy use for selected scenarios	Scenarios / Calculate Selected
	Add a window to the current scenario	Scenarios / Add Window to Scenario
	Add a wall shade (fin or overhang) to the current scenario	Scenarios / Add Exterior Shade to Scenario
	Add a Glazed Wall Assembly to the current scenario	
	Show Glazing System and Shading System IDs on the Scenario graphic	
	Show Scenario cost in the upper left of the Scenario Visualization	

2.3. Open an Existing Project

When you first open a Project that is already in the database, the Project Explorer is shown on the left side of the screen and the Overview Tab is shown on the right side of the screen. If the scenarios have not been calculated, there will be yellow triangles to the left of the scenarios and there will not be graphs in the Summary tab.

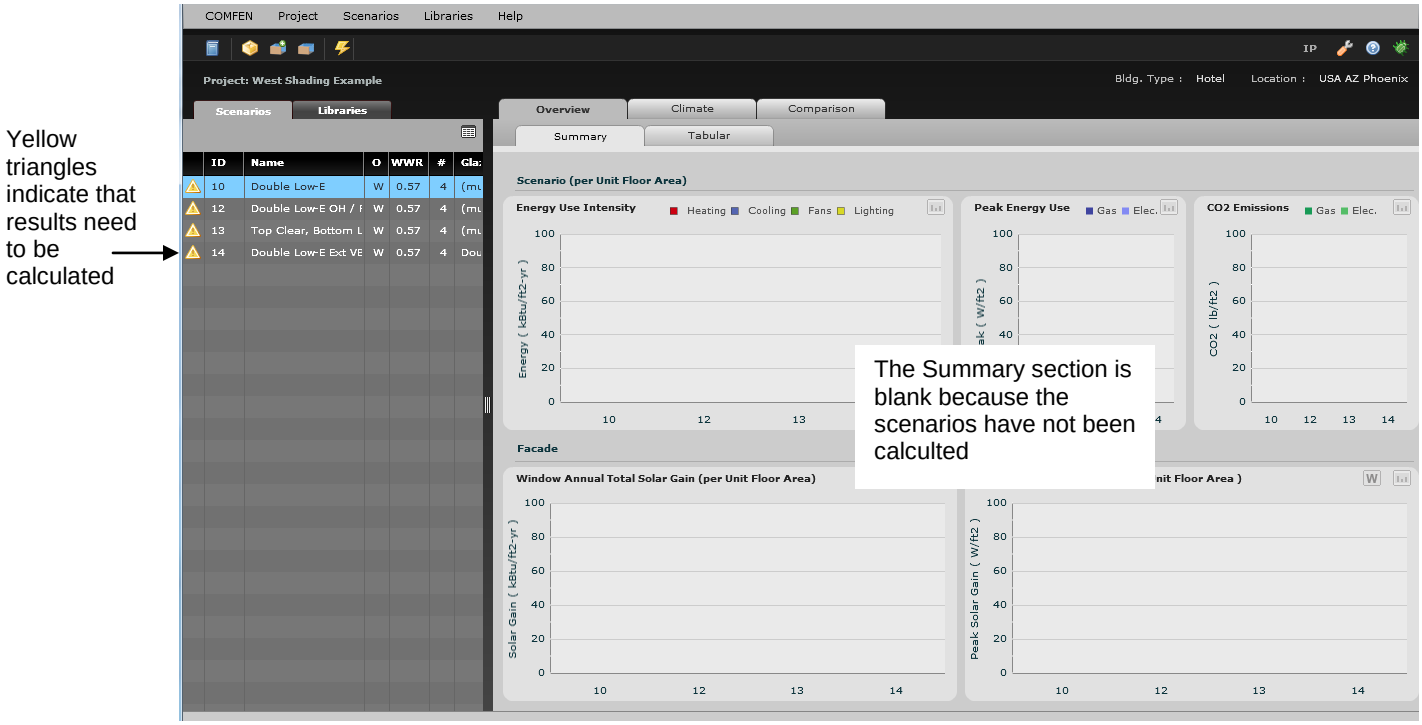


Figure 2-11. The Overview screen, which appears when you open an existing project.

You can calculate the results at this point, and they will appear in the Summary tab. To calculate the results, highlight as many scenarios as you want to calculate, and click on the Lightning Bolt toolbar, or right click and choose the Calculate Enery Use option.

Going to the Comparison tab will allow you to see the Scenario Visualization view, but it will be blank until you highlight the scenario from the Scenario List on the left, and drag it them to the right.

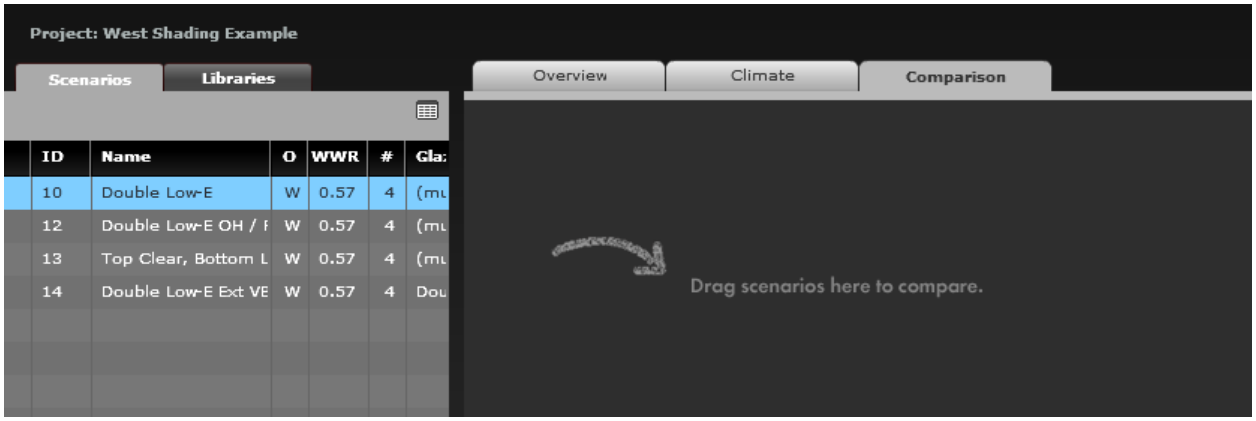


Figure 2-12. Drag scenarios to the right in the Comparison tab.

Then you will be able to see the "3D" versions of the scenarios, but there will still not be results until the scenarios are calculated.

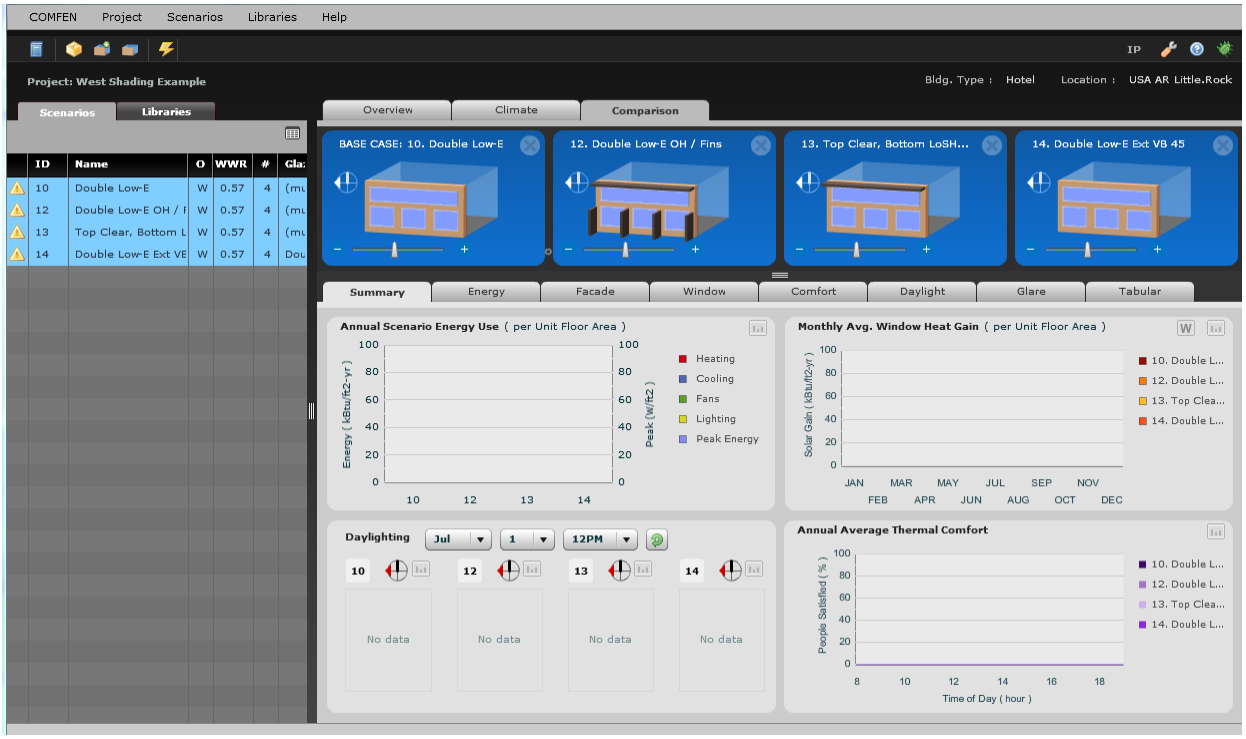


Figure 2-13. The 3D visualizations are shown in the Comparison tab.

If the scenarios have a triangle icon to the left, this means that they do not have current results (and therefore the Results Section will be blank) and must be simulated.

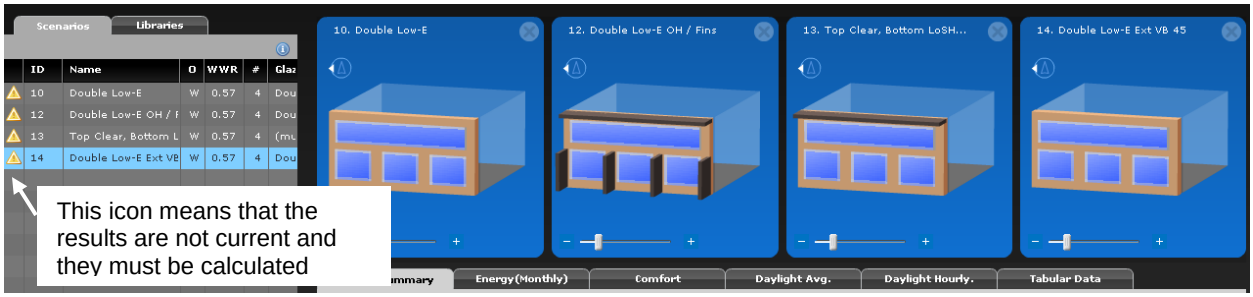


Figure 2-14. The yellow triangle icon to the left of the scenario means it needs to be calculated

To calculate the results, select as many scenarios as desired, then click the lightning bolt tool bar button, and the program will start to run the Energy Plus simulation program for each scenario.

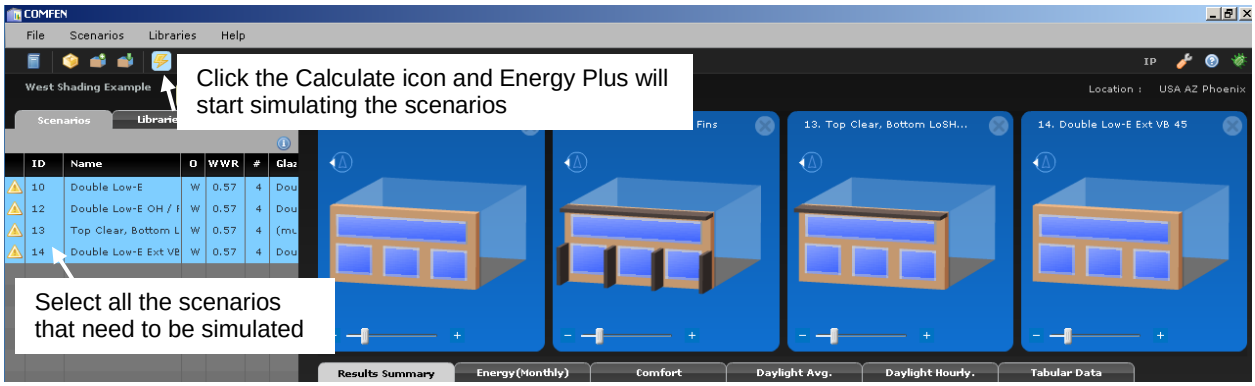


Figure 2-15. Highlight the scenarios to be calculated and press the Lightning Bolt toolbar button.

As the calculations are proceeding, a status box will appear.

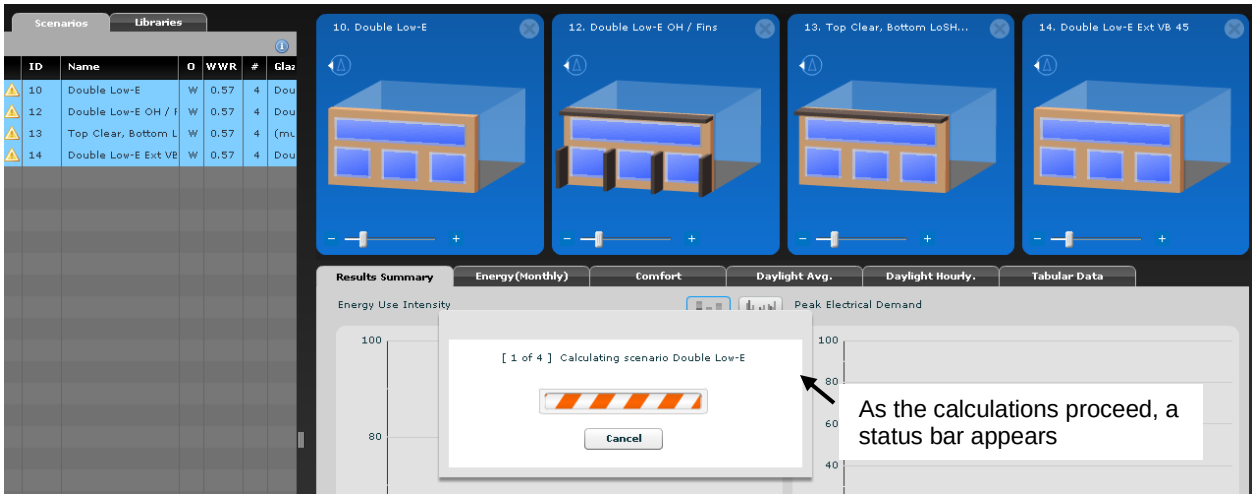


Figure 2-16. A status bar will appear as the scenarios are calculated.

When the calculations are finished, the results will appear in the Results Section

Figure 2-17. When the results have been calculated, the results will display under the Comparison tab.

2.3.1. Viewing the Scenario Details

In order to view the details of a scenario, you need to open the Edit Scenario Viewby double clicking on the graphic of the scenario.

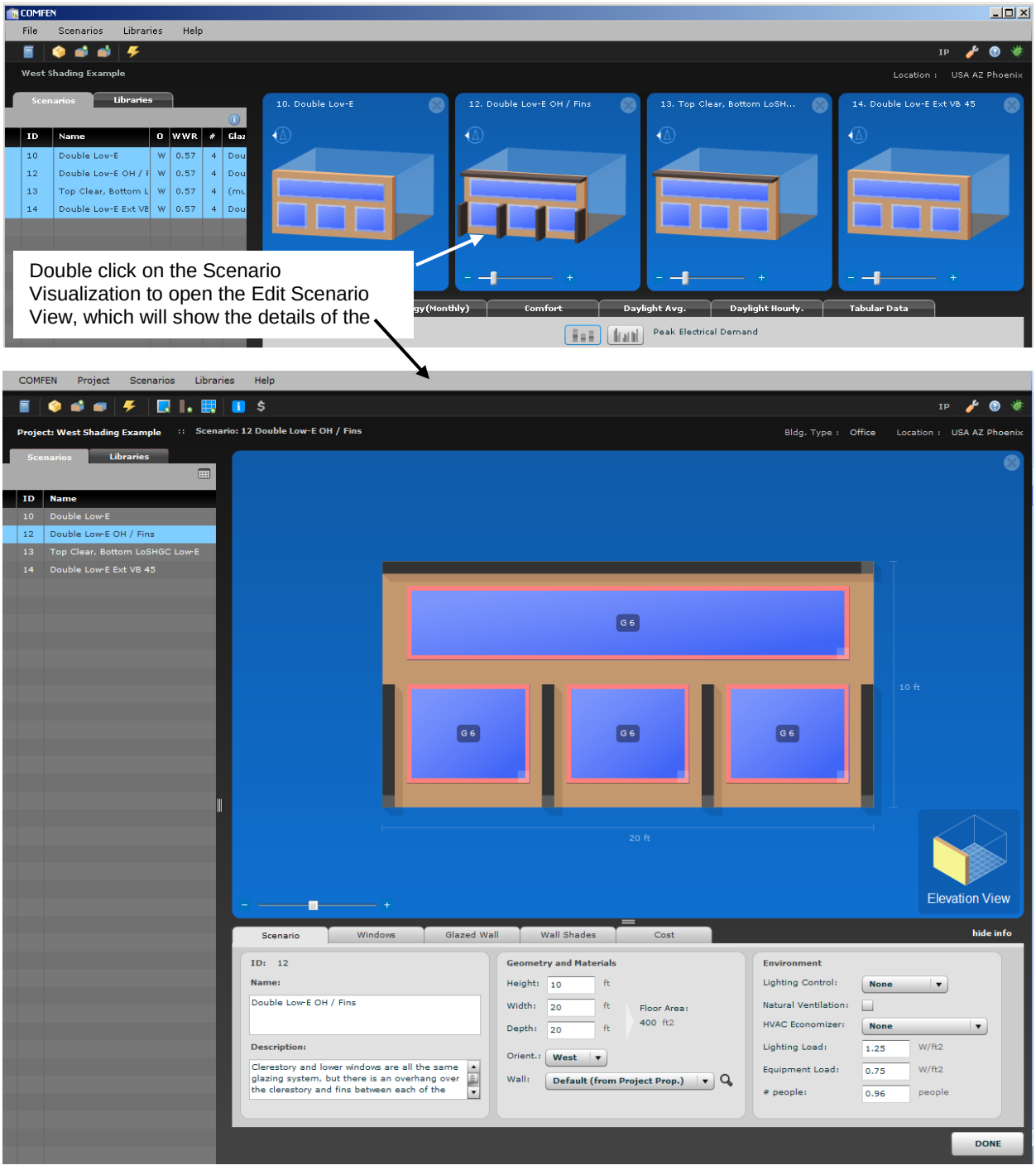


Figure 2-18. The Scenario tab on the Edit Scenario View.

Edit Scenario View

The Edit Scenario View allows you to enter information about the geometry of the space to be modeled, the lighting controls, the lighting and equipment loads, and the number of people in the space.

Scenario Tab

The scenario tab contains the title of the scenario, as well as information about the geometry and loads of the scenario.

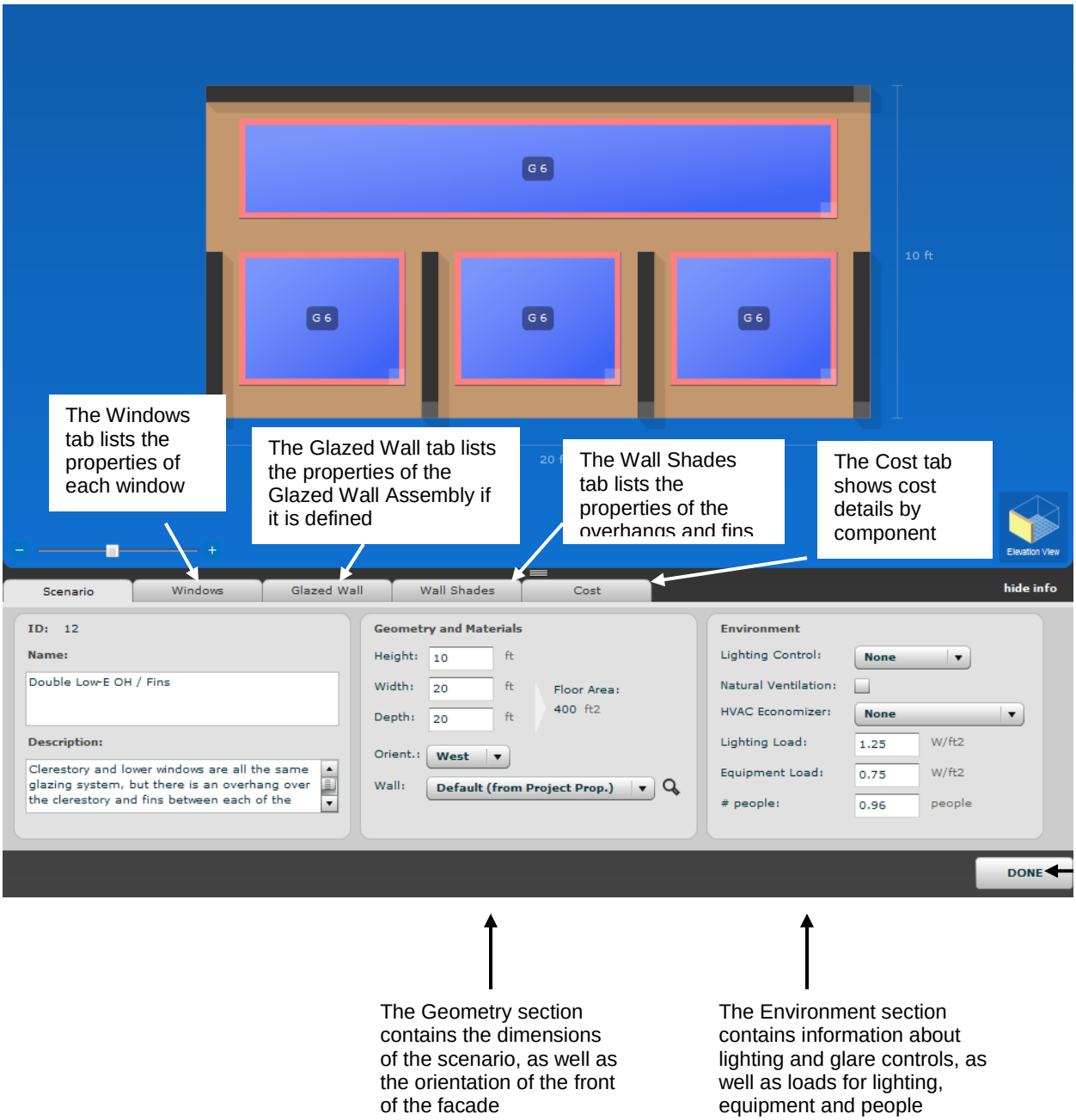


Figure 2-19. The Scenario tab on the Edit Scenario View.

Windows Tab

The **Windows Tab** shows a list of all the windows on the façade. Double click on any window in either the list or the graphic and the **Edit Window dialog box** appears, which allows you to view and edit the window information.

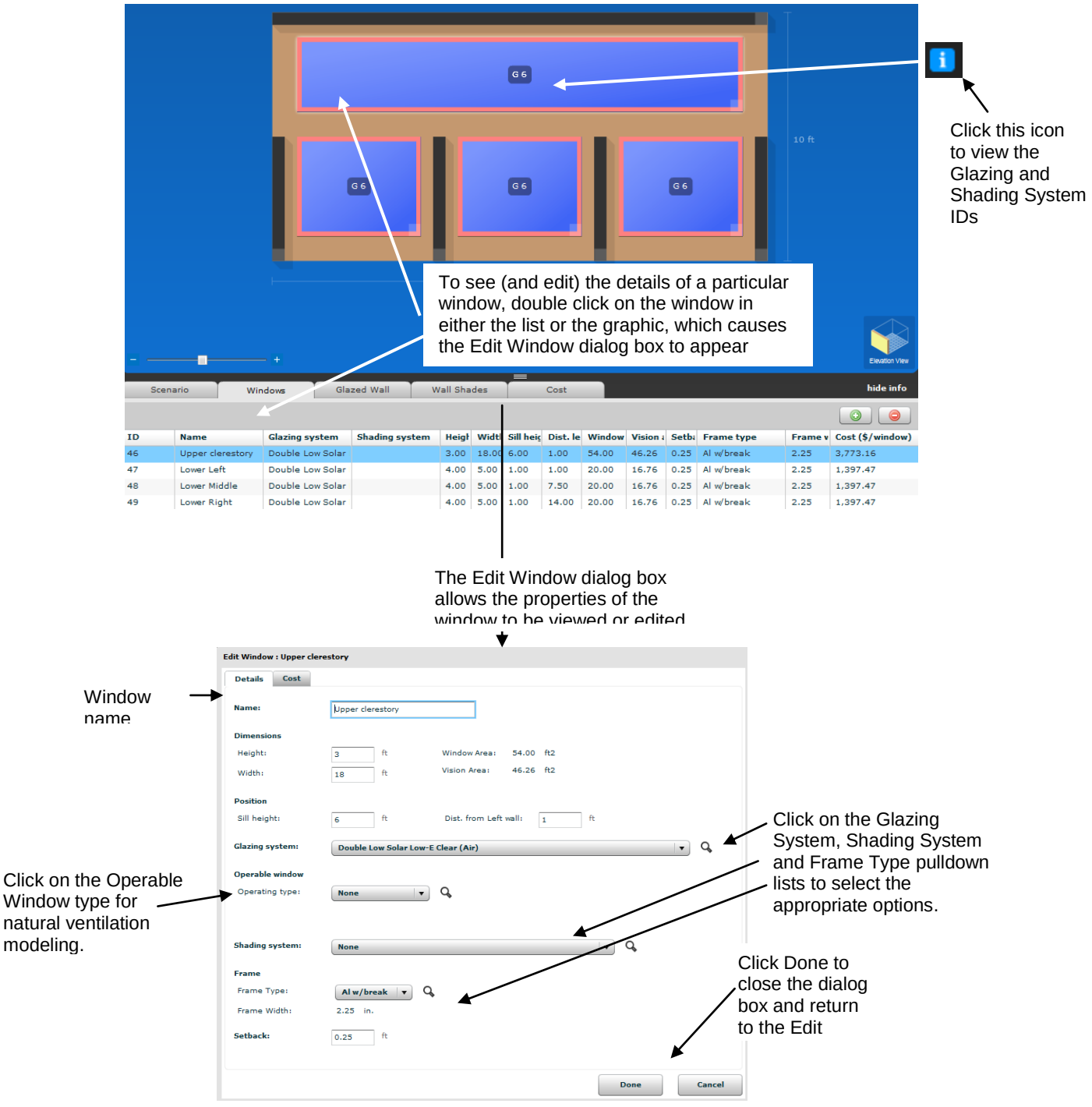
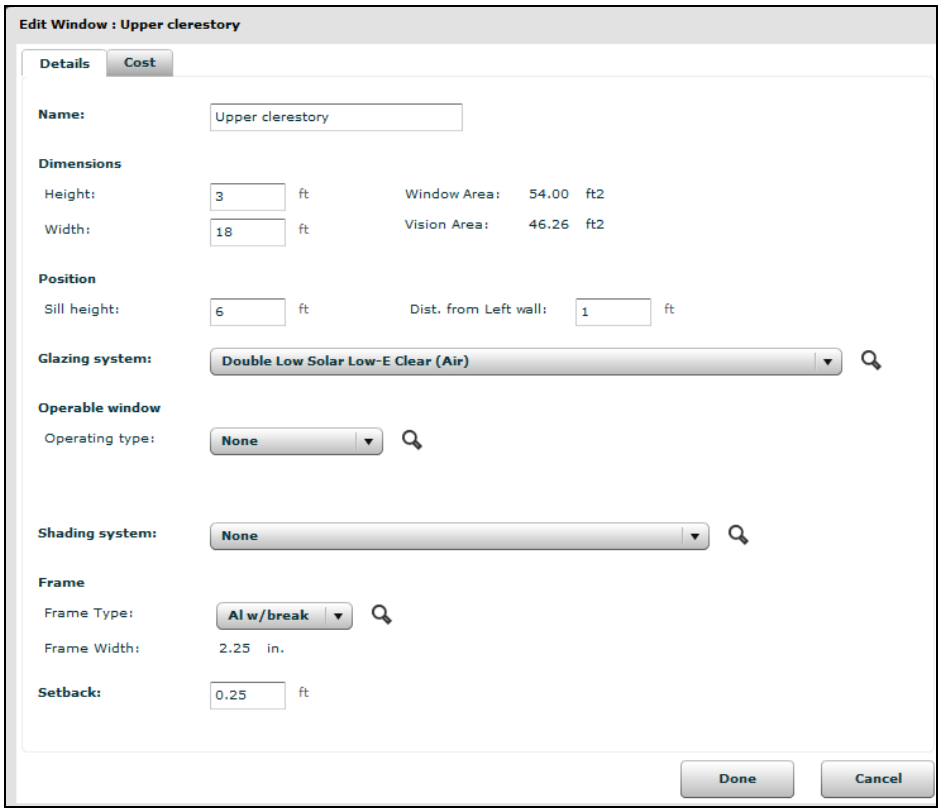


Figure 2-20. The Window tab and the Edit Window dialog box

Edit Window dialog box

The Edit Window dialog box allows you to view and edit all the information pertaining to the window.



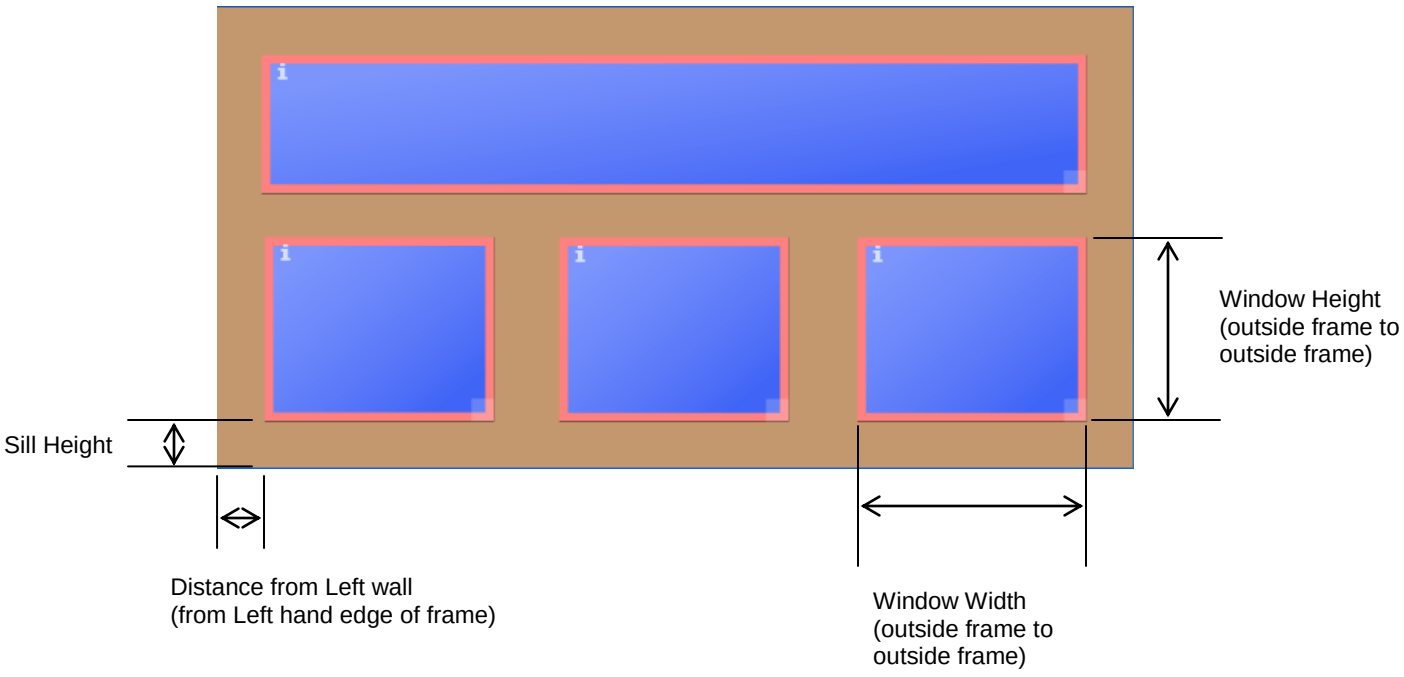


Figure 2-21. The Basic Info tab on the Edit Window dialog box.

Wall ShadesTab

The **Wall Shades Tab** shows a list of all the overhangs and fins on the façade. Double click on any overhang or fin in either the list or the graphic and the **Edit Wall Shade dialog box** will appear, which allows you to view and edit the window information.

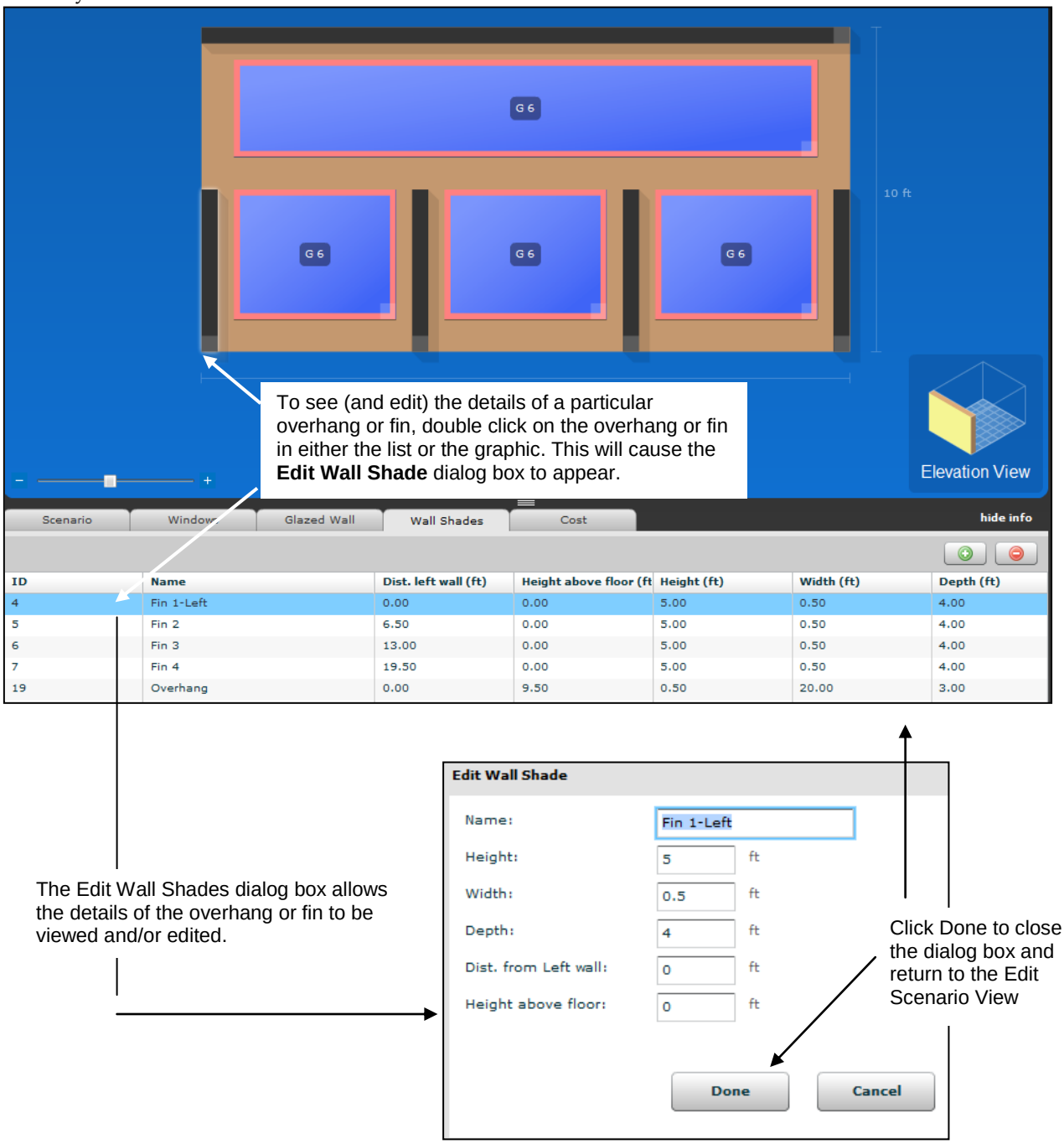


Figure 2-22. The Wall Shades tab and Edit Wall Shade dialog box.

2.4. Creating a New Project

When first starting the program, click on the **New Project** choice under **Create** to start a new project. If you are already in the program, use the Project > New Project menu option to create a new project.

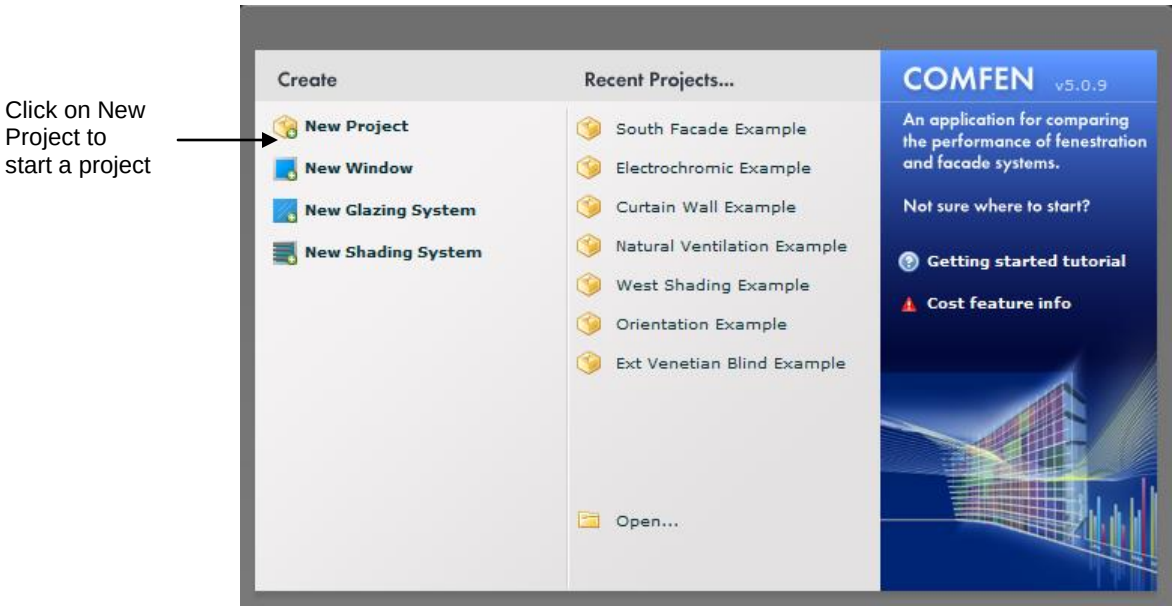


Figure 2-23. Click on New Project to start a project.

The Create COMFEN Project will appear. There are several tabs with different information to be filled out about the project.

General

The General tab is used to give the project a name (required), a description (optional), and specify a building type (required).

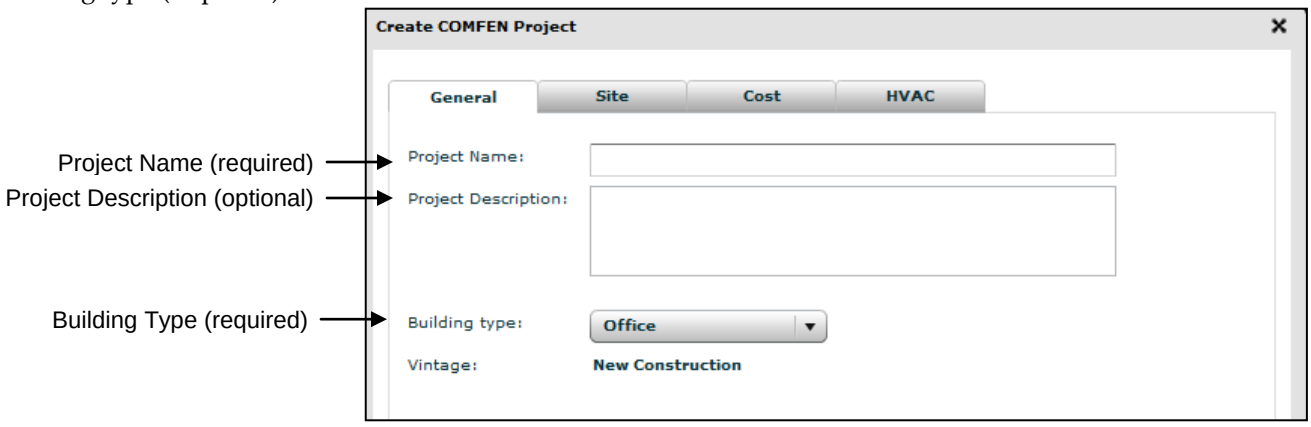


Figure 2-24. The Project Properties "General" tab

Site

The Site tab is used to define the properties of the site, such as location and project orientation

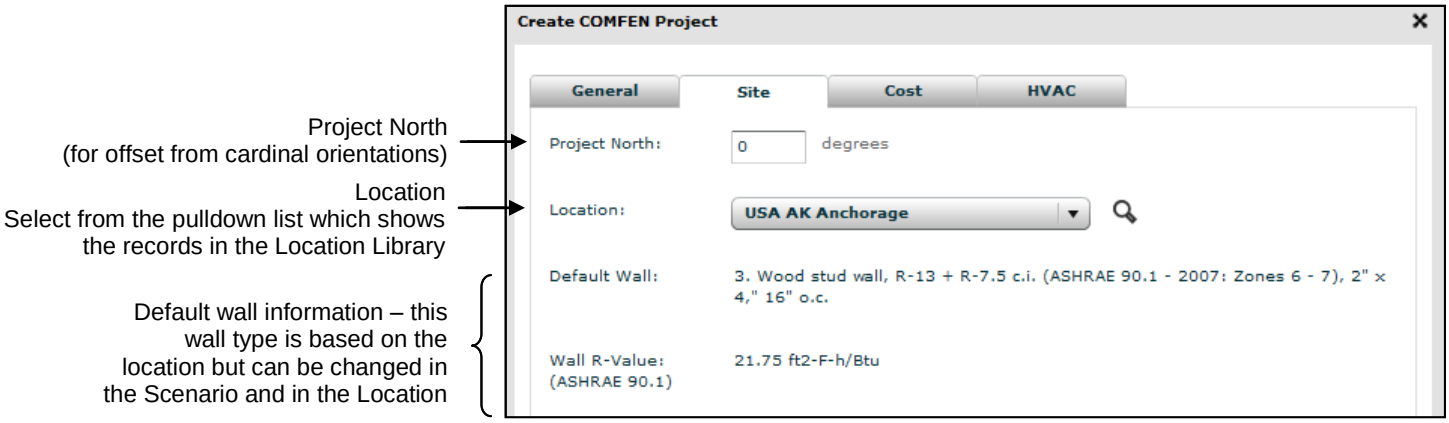


Figure 2-25. The Project Properties "Site" tab

Cost

The Cost tab is used to set overrides to the default costs in the program for lighting, HVAC, and utility rates.

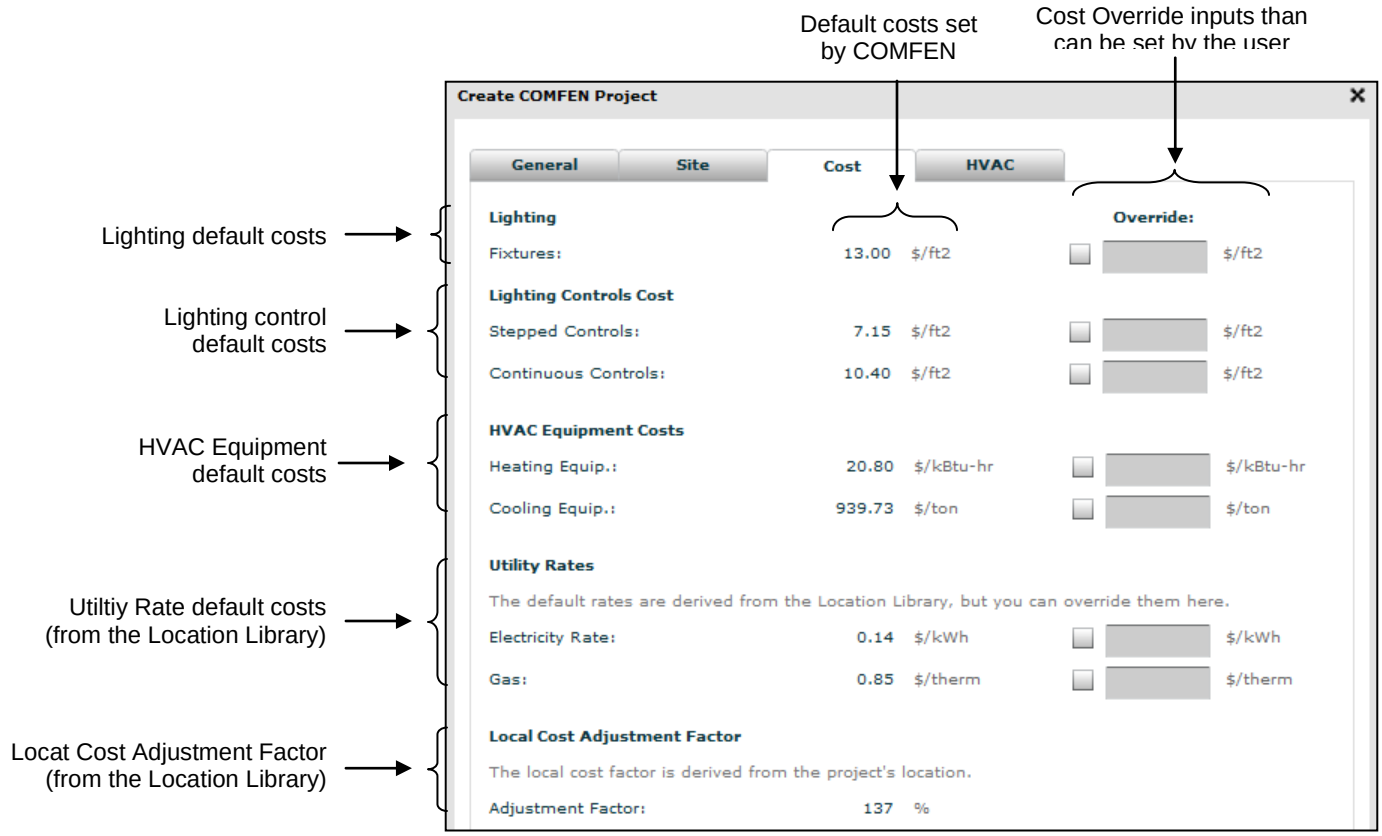


Figure 2-26. The Project Properties "Cost" tab

HVAC

The HVAC tab is used to set some default properties for how the HVAC system is operated

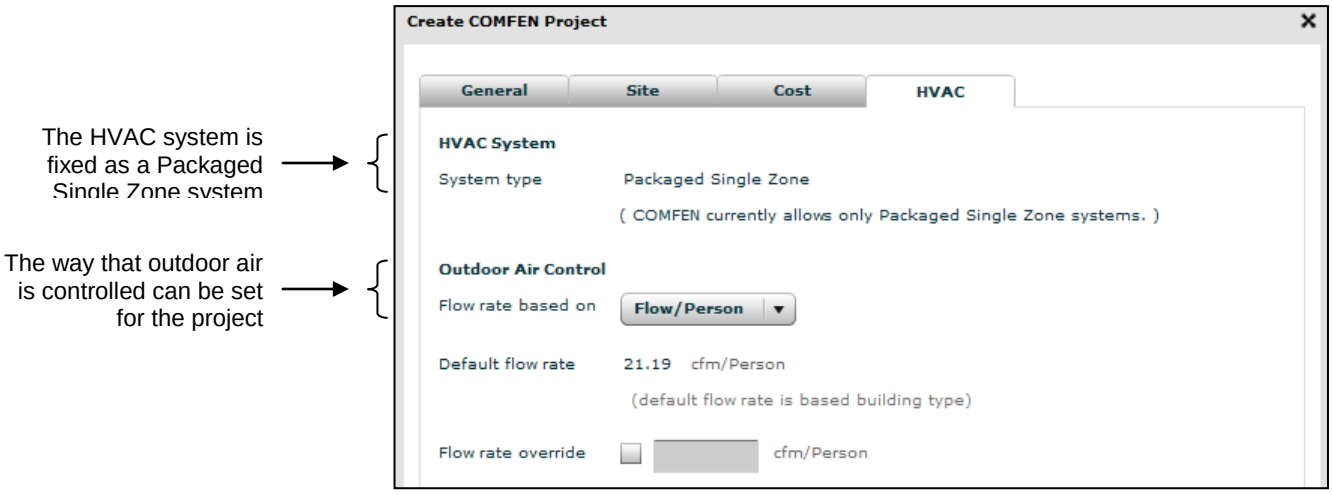


Figure 2-27. The Project Properties "HVAC" tab

2.4.1. Defining Scenarios

When you are starting a new Project, there are no scenarios defined. To define a new scenario, go to the Scenarios menu and select Create Scenario

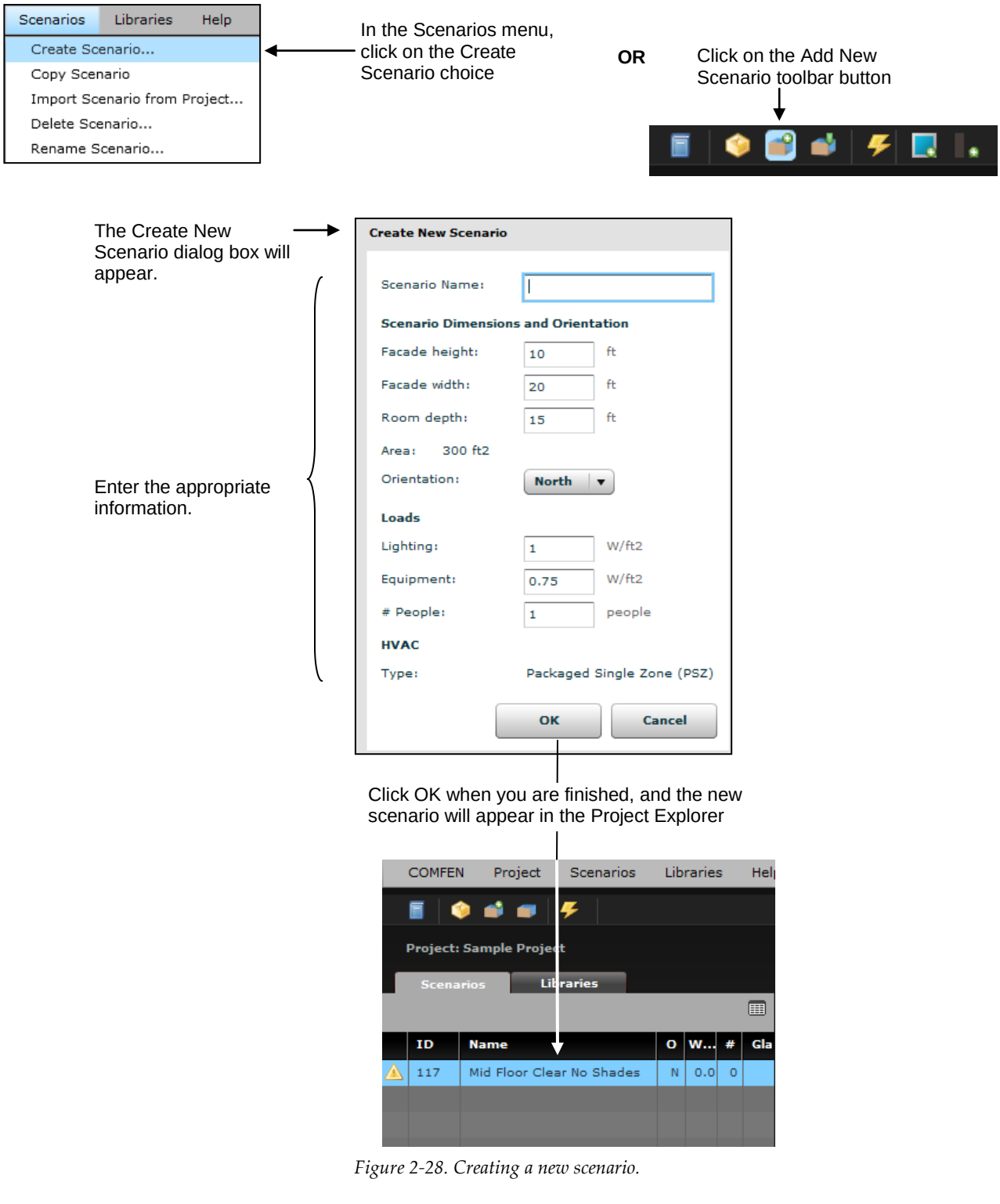


Figure 2-28. Creating a new scenario.

2.4.2. Edit Scenario

To edit the scenario (so that you can add windows, shades, etc), do the following:

- Double click on the scenario name in the Project Explorer to open the Edit Scenario View

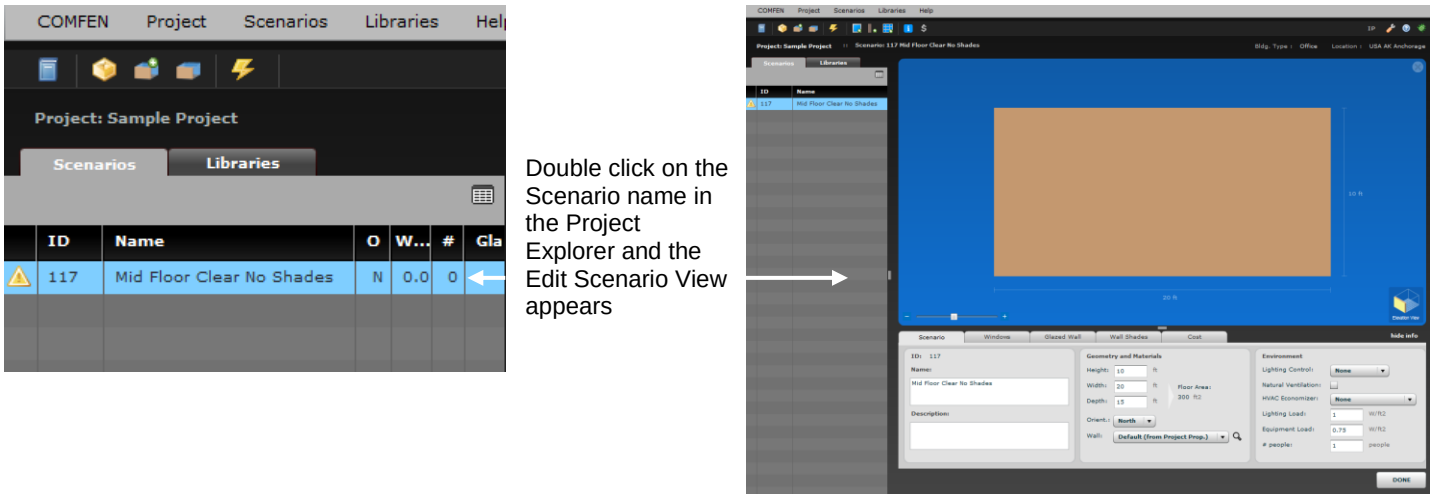
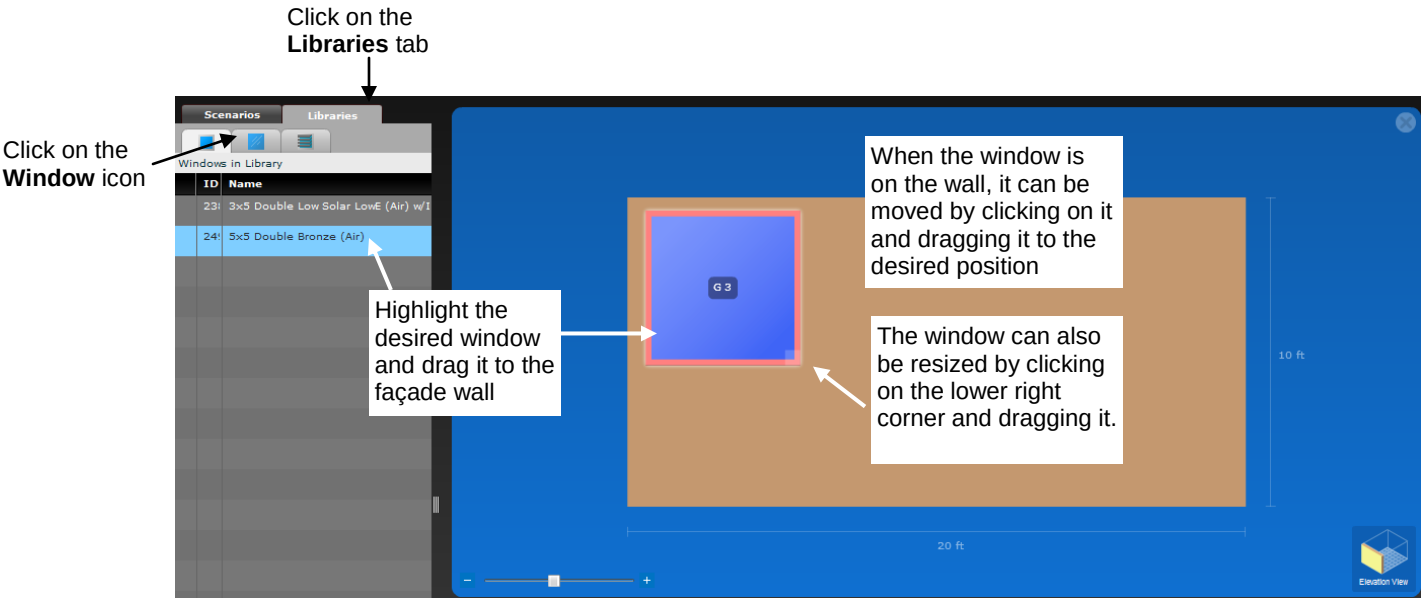


Figure 2-29. Open the Edit Scenario View from the Project Explorer

2.4.3. Add Windows

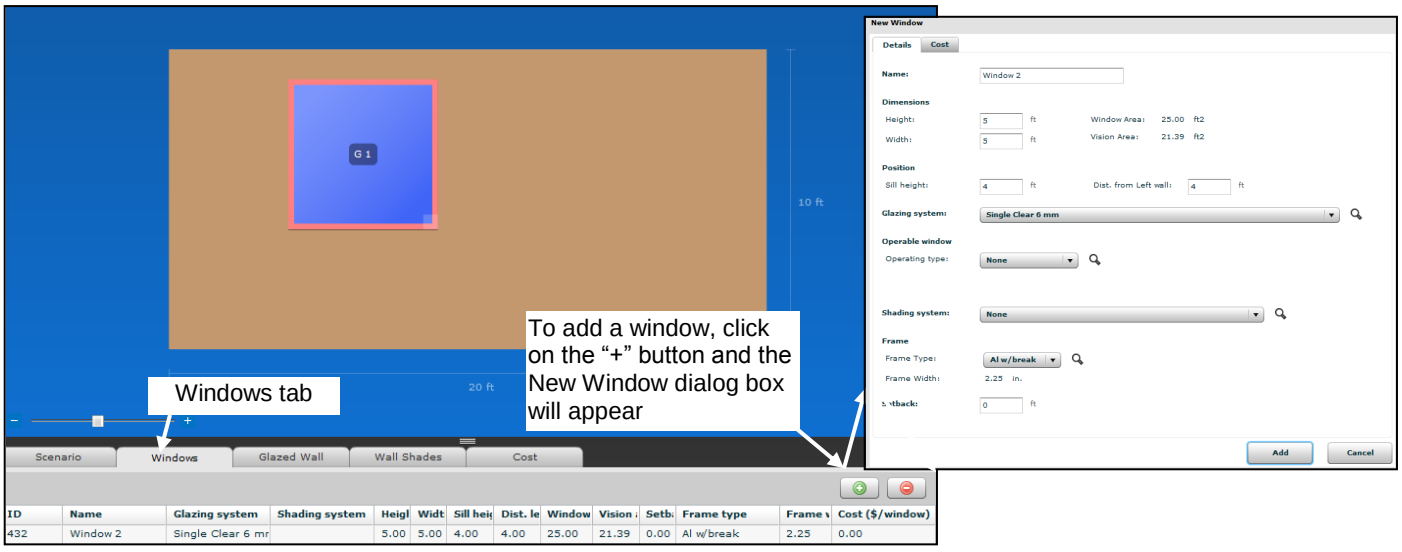
There are several ways to add a window to a scenario:

- From the Project Explorer, select the Libraries tab, Window Library icon, and drag a window to the facade



OR

- From the Edit Scenario Windows tab, click on the  button and the enter the appropriate information in the New Window dialog box. From this dialog box you can also define the Glazing System, Shading System and Frame Type from the appropriate tabs.



OR

- From the Scenarios menu, click on the "Add Window to Scenario" menu choice, which will display the New Window dialog box. From this dialog box you can also define the Glazing System, Shading System and Frame Type from the appropriate tabs.

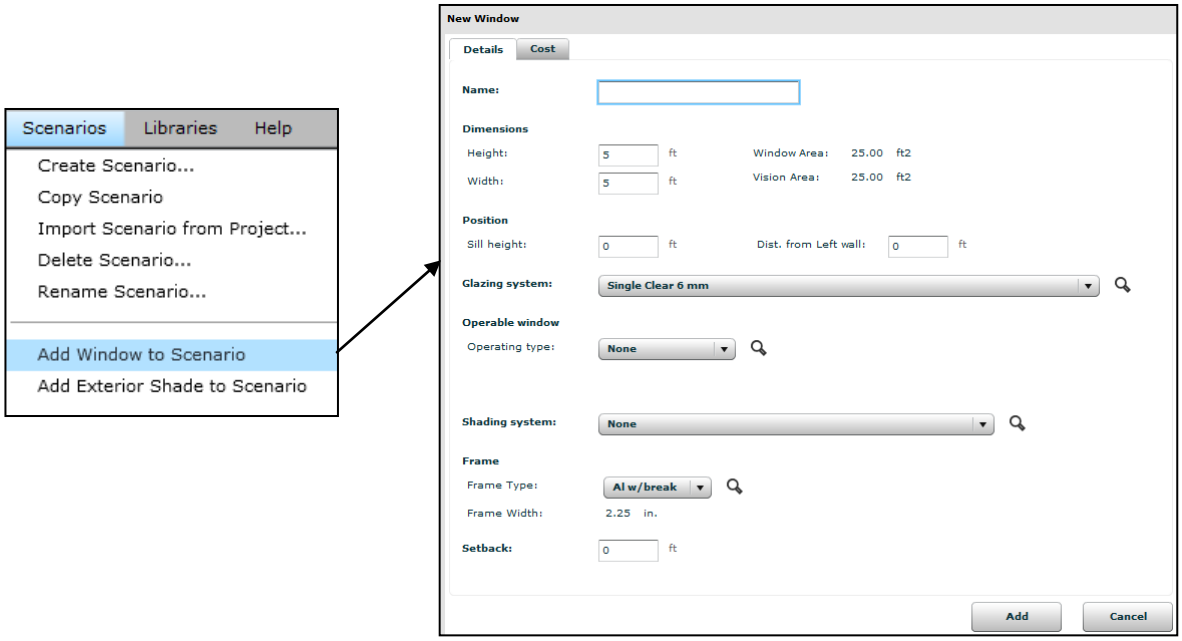
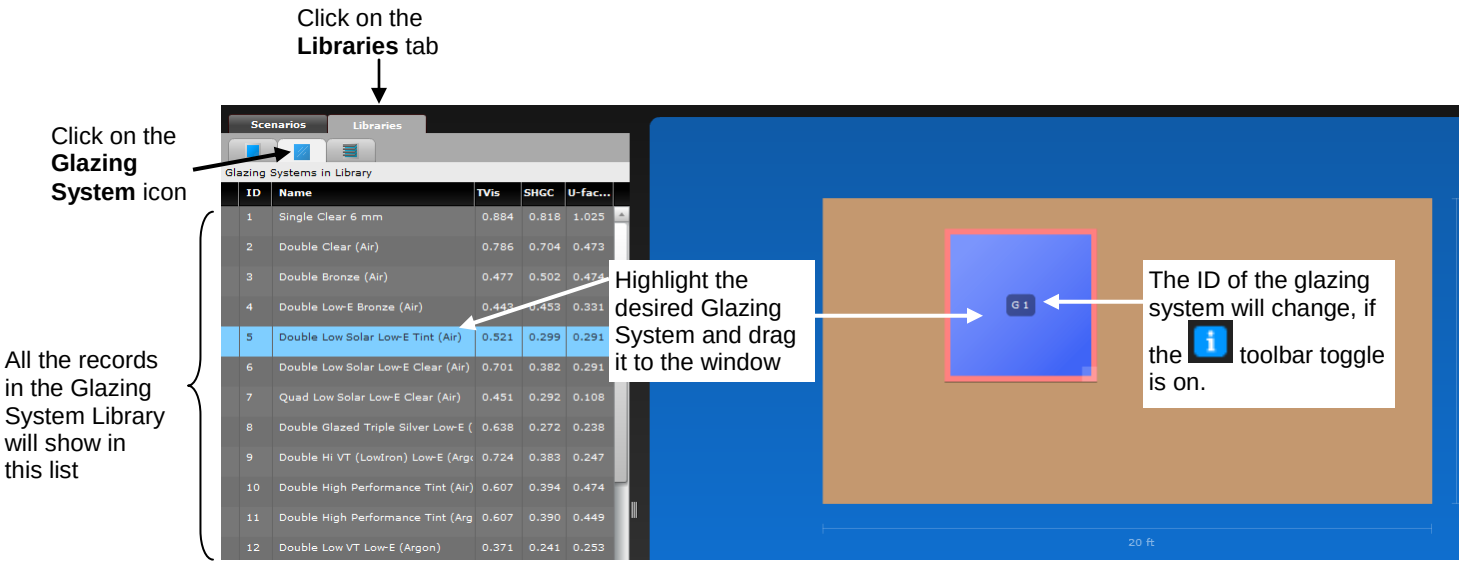


Figure 2-30. Add Windows to a Scenario.

Defining the Glazing System for the Window

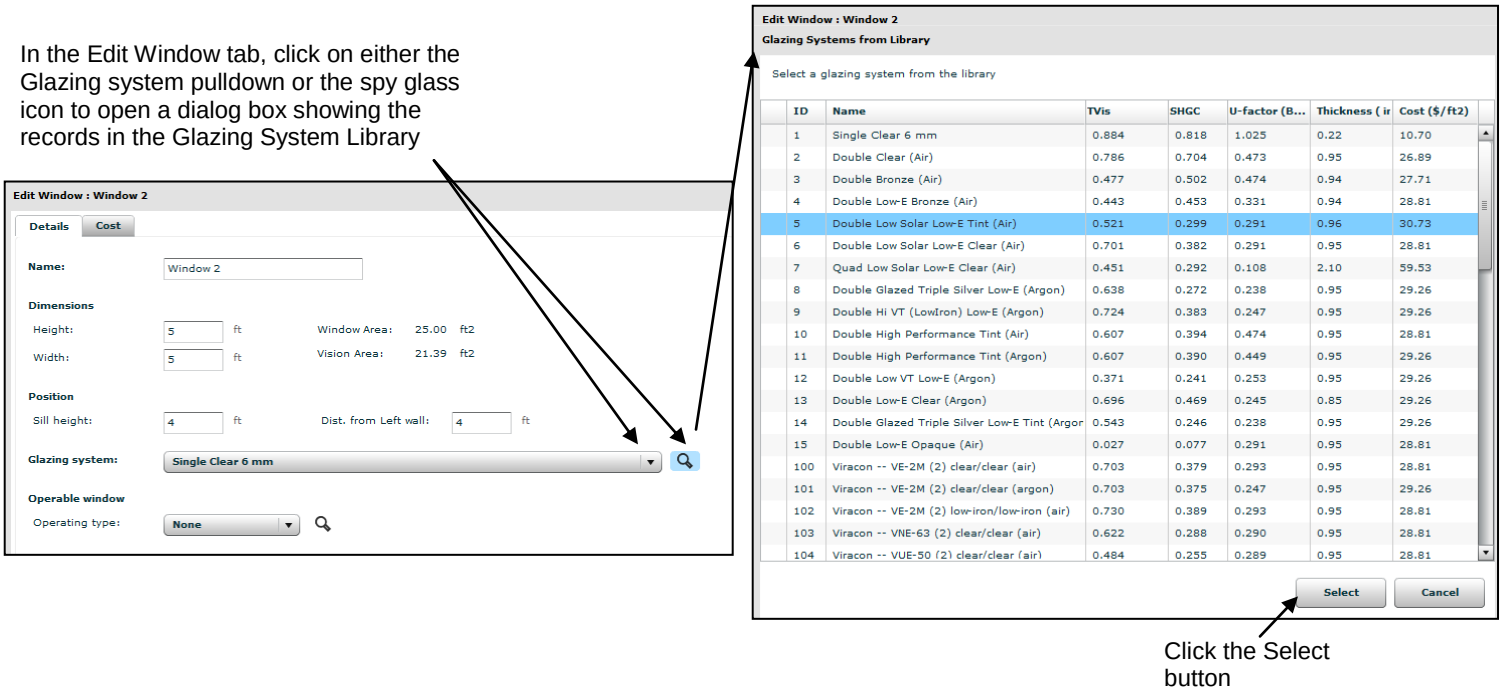
There are several ways to define or change a glazing system for a window:



- From the Project Explorer, select the **Libraries** tab, **Glazing System Library** icon, highlight the desired glazing system, and drag it to the window.

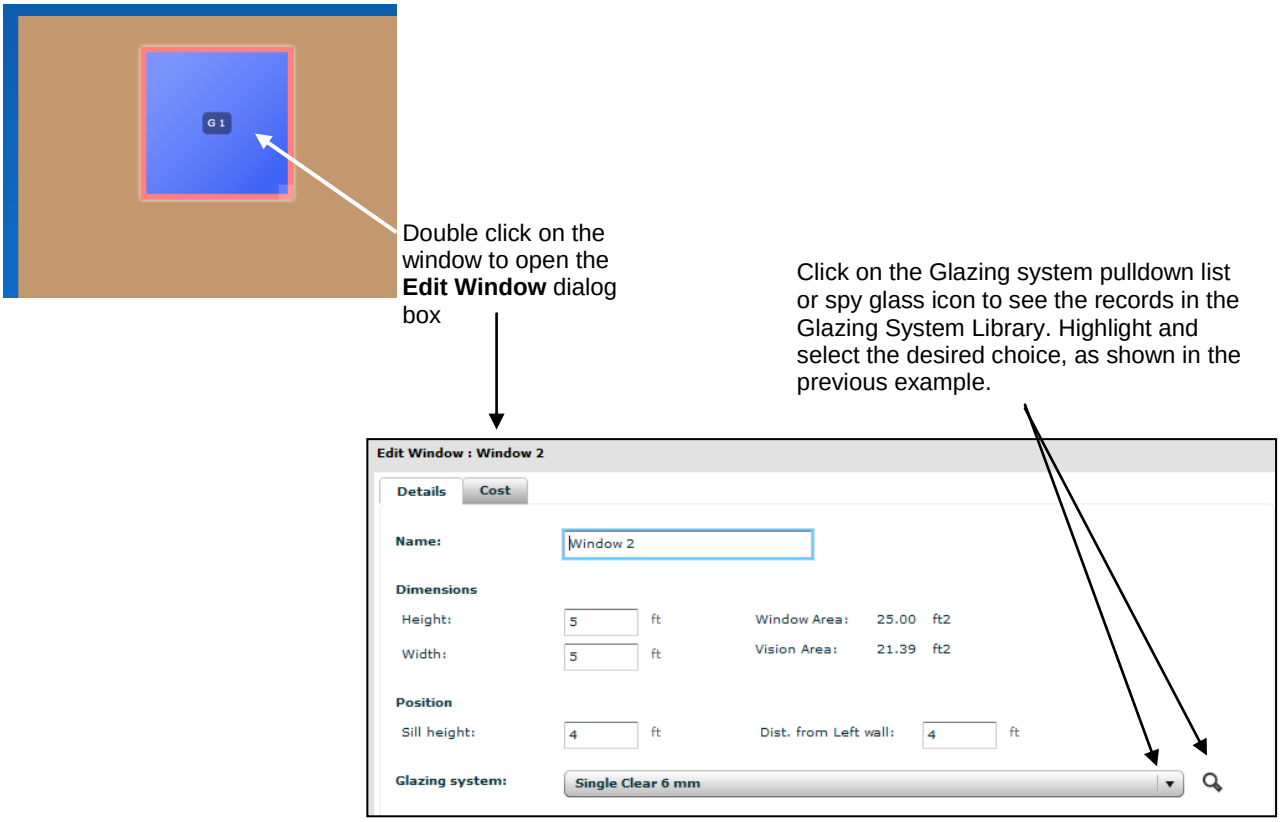
OR

- When defining the window, in the **New Window** dialog box, click on the Glazing System pulldown list or the spy glass next to it and the records in the **Glazing System Library** will be displayed. Highlight the desired glazing system and click the **Select** button.



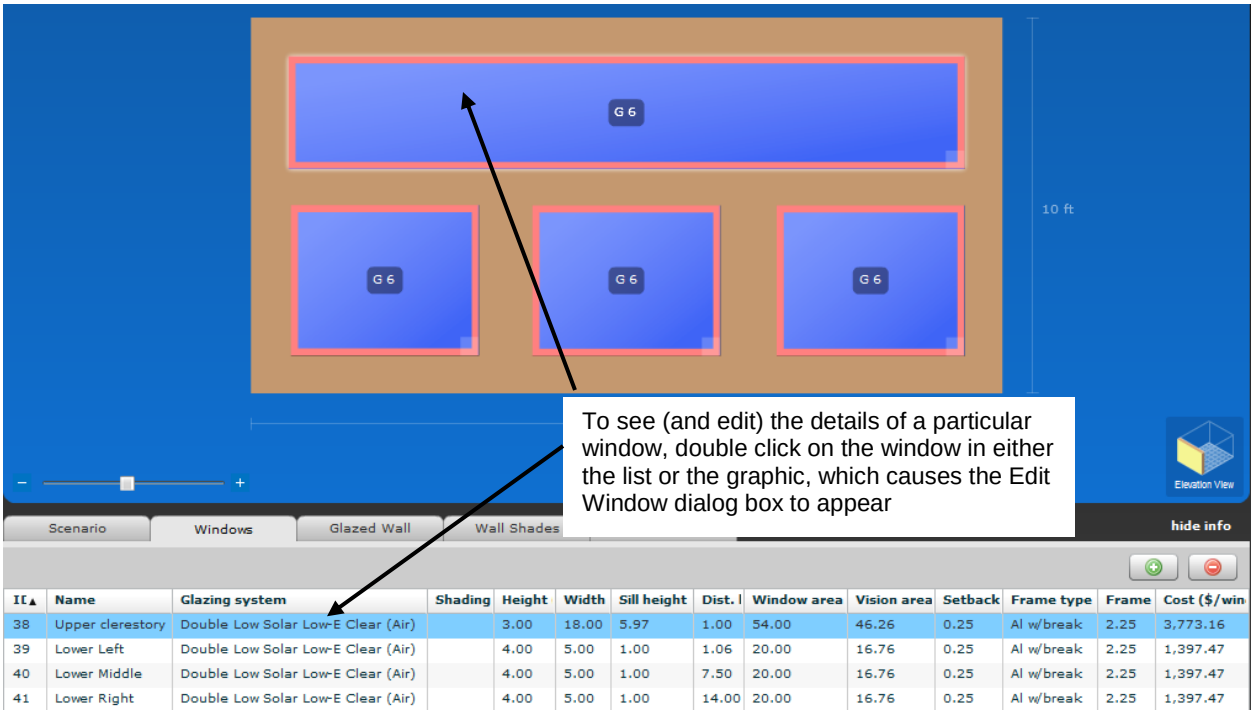
OR

- Double click on the window to open the Edit Window dialog box. Click on the Glazing System tab to define or change the glazing system for the window. Highlight the desired glazing system and click the Done button.



Windows Tab on Edit Scenario View

The **Windows Tab** shows a list of all the windows on the façade. Double click on any window in either the list or the graphic and the **Edit Window dialog box** appears, which allows you to view and edit the window information.



ID	Name	Glazing system	Shading	Height	Width	Sill height	Dist.	Window area	Vision area	Setback	Frame type	Frame	Cost ($/win
38	Upper clerestory	Double Low Solar Low-E Clear (Air)		3.00	18.00	5.97	1.00	54.00	46.26	0.25	Al w/break	2.25	3,773.16
39	Lower Left	Double Low Solar Low-E Clear (Air)		4.00	5.00	1.00	1.06	20.00	16.76	0.25	Al w/break	2.25	1,397.47
40	Lower Middle	Double Low Solar Low-E Clear (Air)		4.00	5.00	1.00	7.50	20.00	16.76	0.25	Al w/break	2.25	1,397.47
41	Lower Right	Double Low Solar Low-E Clear (Air)		4.00	5.00	1.00	14.00	20.00	16.76	0.25	Al w/break	2.25	1,397.47

The Edit Window dialog box allows the properties of the window to be viewed or edited.

The Glazing System, Shading System and Frame can be edited, as well as the Operating type of the window

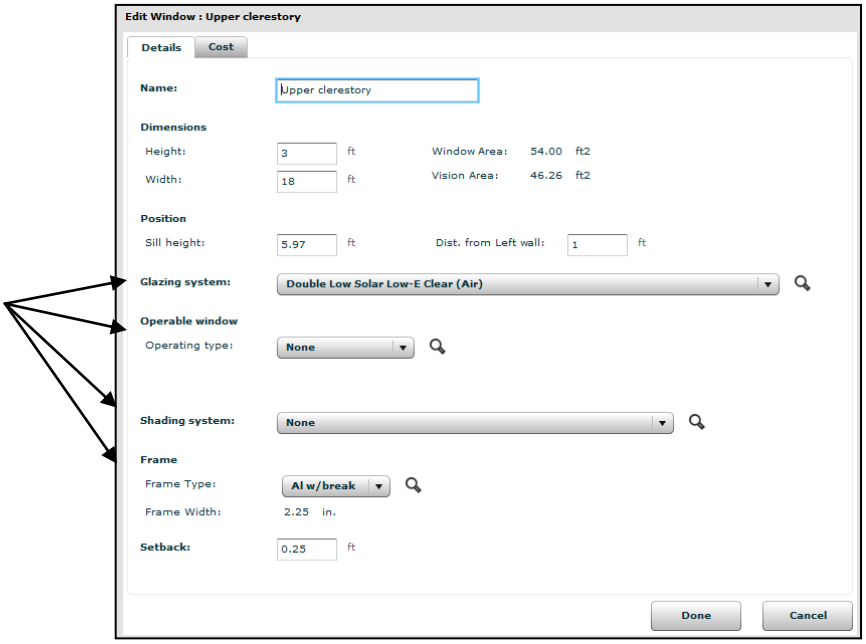


Figure 2-31. The Windows tab and the Edit Window dialog box

Edit Window dialog box

The Edit Window dialog box allows you to view and edit all the information pertaining to the window. There are several tabs in this dialog box:

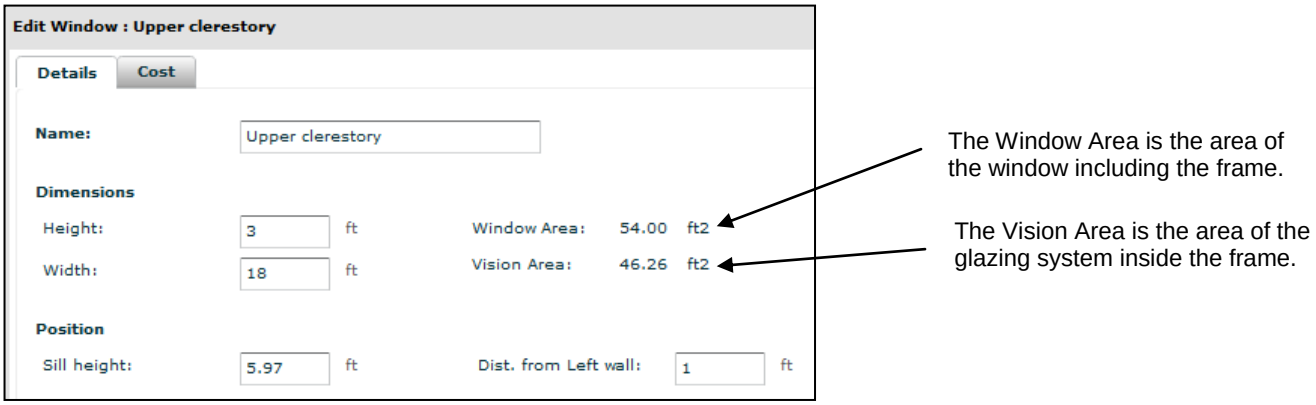


Figure 2-32. The Dimensions and Position on the Edit Window dialog box.

The Frame Width is the frame dimension when looking at the frame in elevation.

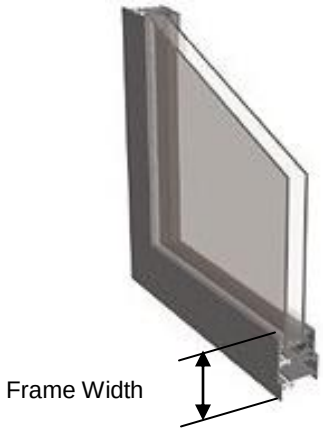


Figure 2-33. The Frame Width.

The Setback is the distance from the outside surface of the wall that the window is inset into the wall.

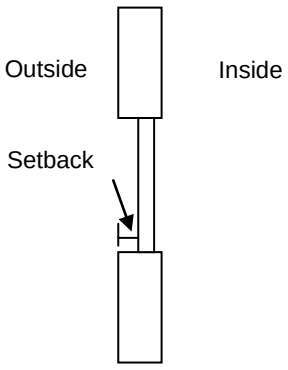


Figure 2-34. The Setback.

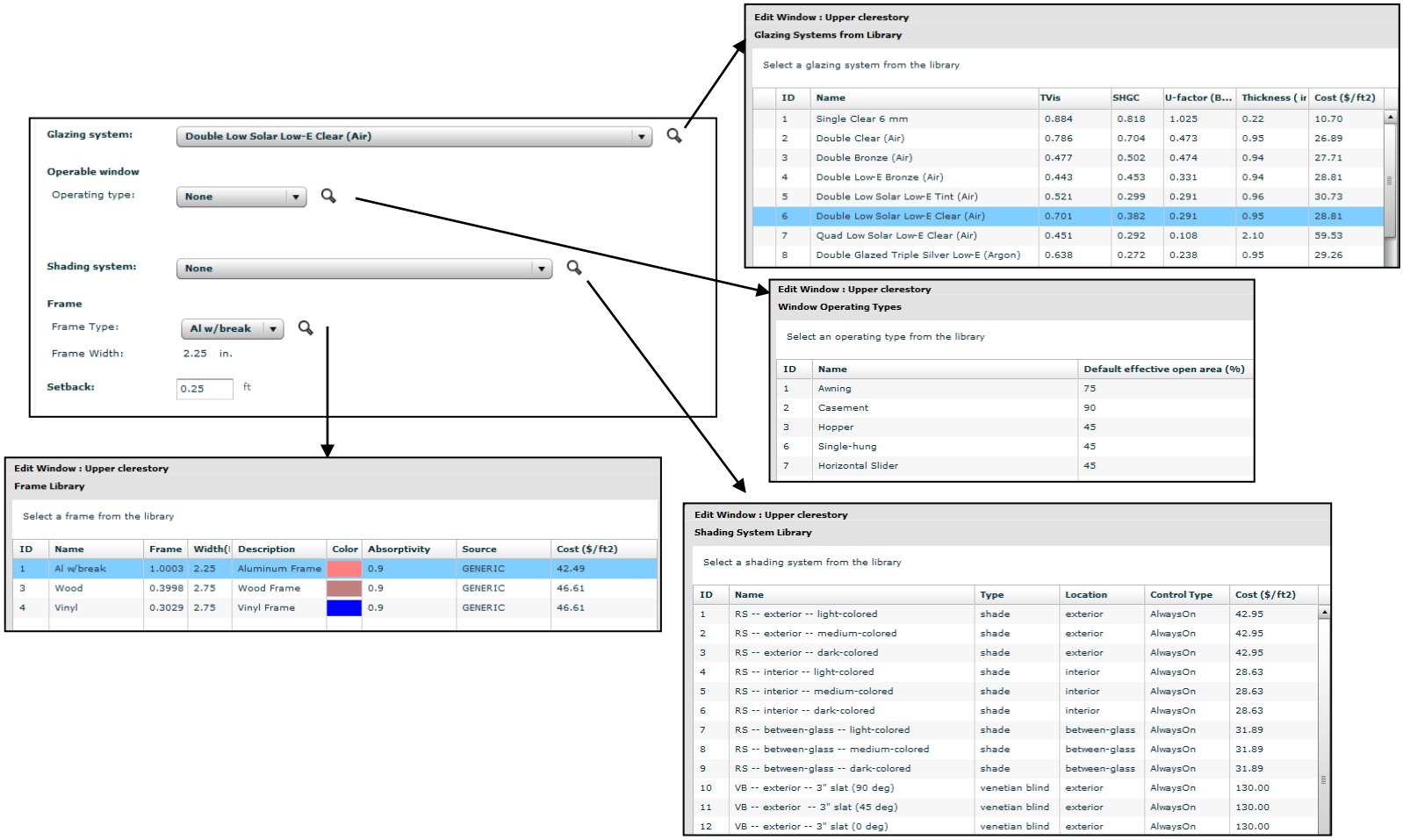


Figure 2-35. The Edit Window dialog box defining glazing system, operating type, shading system and frame type.

2.4.4. Add Wall Shades (Overhangs and Fins)

To add overhangs and fins to the scenario, go to the Wall Shades tab in the Scenario Edit view, and click on the **+** button. A dialog box will appear which allows you to define overhangs and fins.

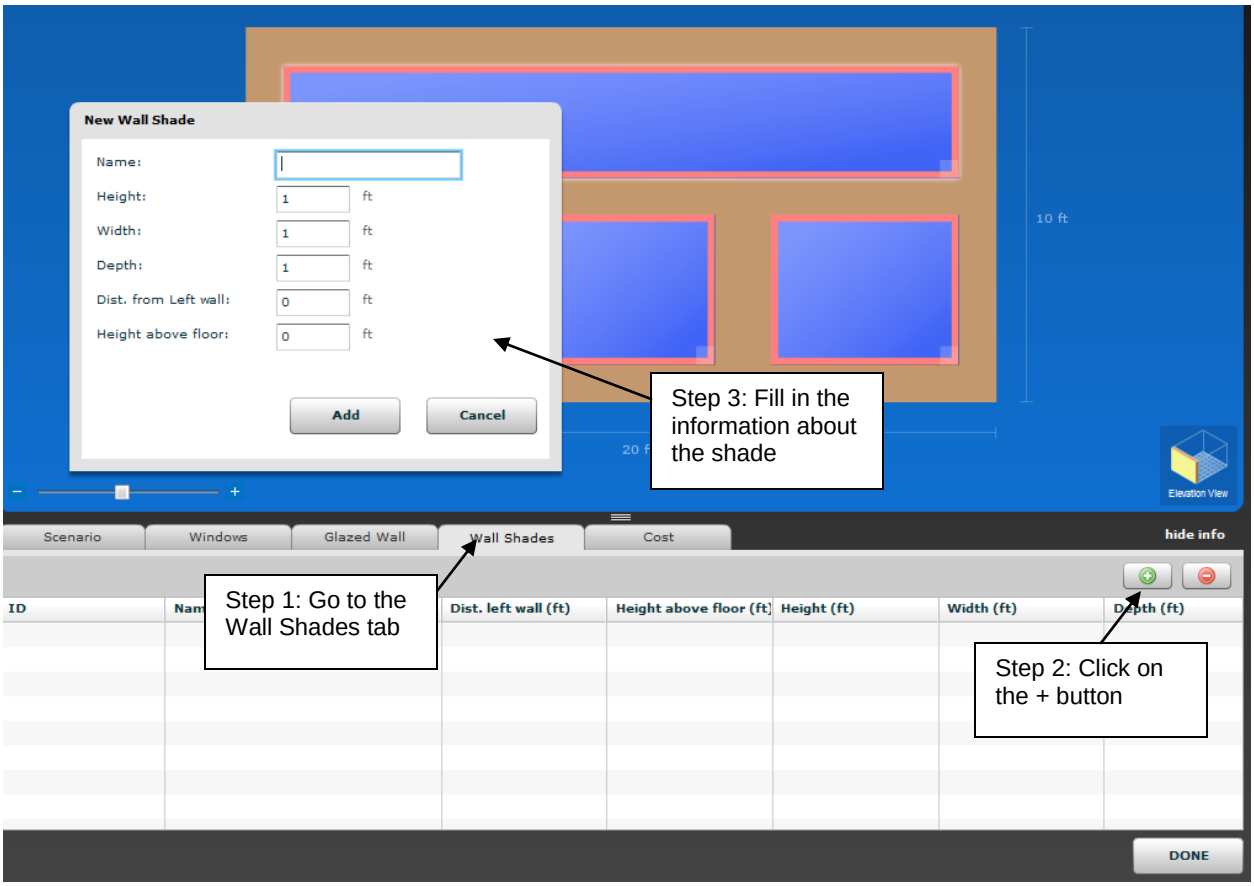
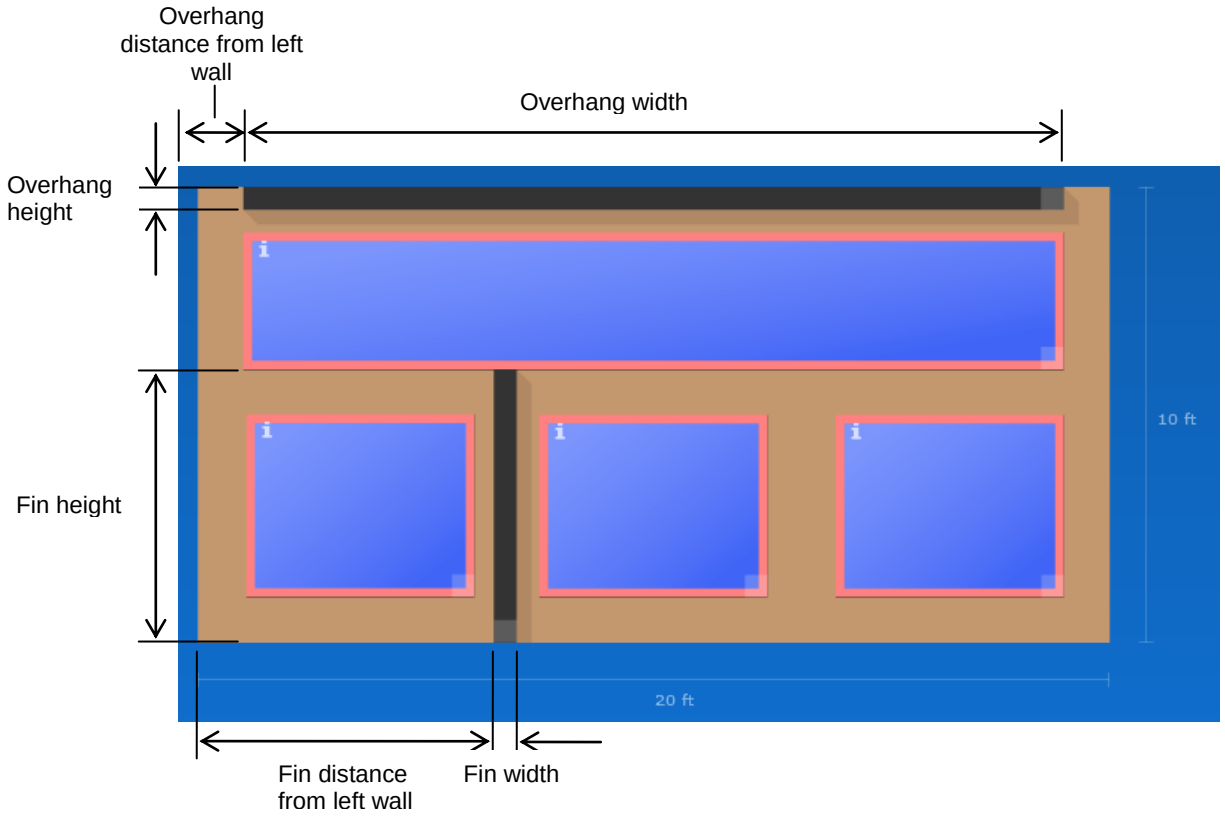
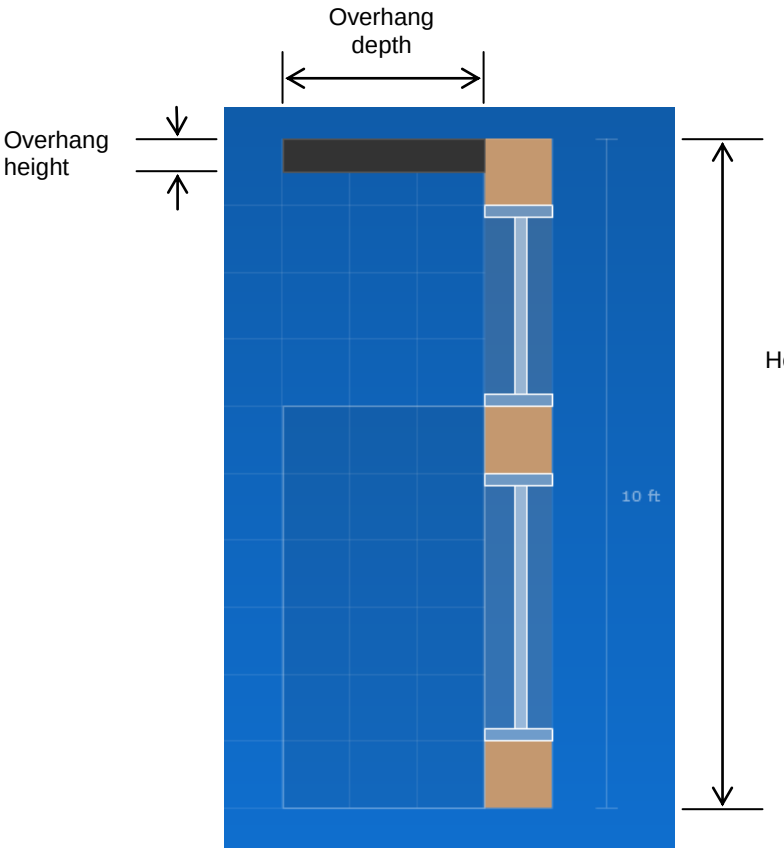
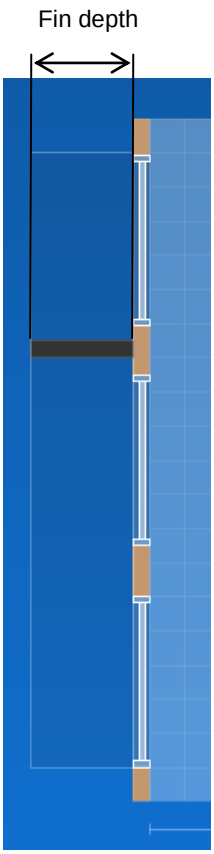


Figure 2-36. Defining an overhang or fin.





Section View



Plan View

3. INSTALLATION

3.1. Hardware Requirements

First, make sure your computer system meets these specifications:

- At least 16 MB of random access memory (RAM), configured as extended memory. 32 MB of RAM is preferred for optimum operation.
- Microsoft Windows XP™, Windows Vista™ or Windows 7™.
- Hard disk drive with at least 100 megabytes of available disk space.
- Monitor and mouse.

3.2. Setup

The installation program can be downloaded from the LBNL website at
http://windows.lbl.gov/software/comfen

Once you have downloaded the installation program, follow these steps to install the program:

1. Using Windows Explore, browse to where the installation file was downloaded and double click on it.

2. A Welcome window will display. Click the **Next** button to proceed with the installation, or **Cancel** to stop.

3. The **Software License Agreement** window will display next. Read through the license and make sure you agree to all the terms before proceeding. To proceed with the installation, click on the **Yes** button, or click on **No** to stop.

4. The **Ready to Install the Program** window will display next. Press the **Install** button to begin the installation.

5. The next screen to display is the **Setup Status** screen, which shows the files being installes.

6. When the installation is complete, the **InstallShield Wizard Complete** screen will be displayed. Press **Finish** to finalize the installation. Sometimes this screen will appear, but you can't click the **Finish** button. In this case, click on another area of the screen, then click back to this screen and you should be able to click on the **Finish** button.

7. Setup will automatically put a COMFEN Icon in the **Programs** menu under the **LBNL Software** group.

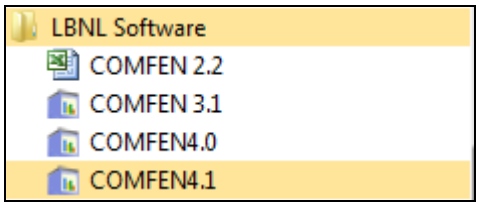


Figure 3-1. Program icon to run COMFEN.

3.3. Running COMFEN

To run COMFEN, go to the **Programs** menu, single click on the **LBNL Software** group, and single click on the **COMFEN** icon. Additionally, there may be a shortcut icon in the main list of programs, depending on the operating system: In either case, click on the shortcut, and the program will start.

COMFEN will open to the following view and you can begin using the program by selecting either a recent Project to open or creating a New Project.

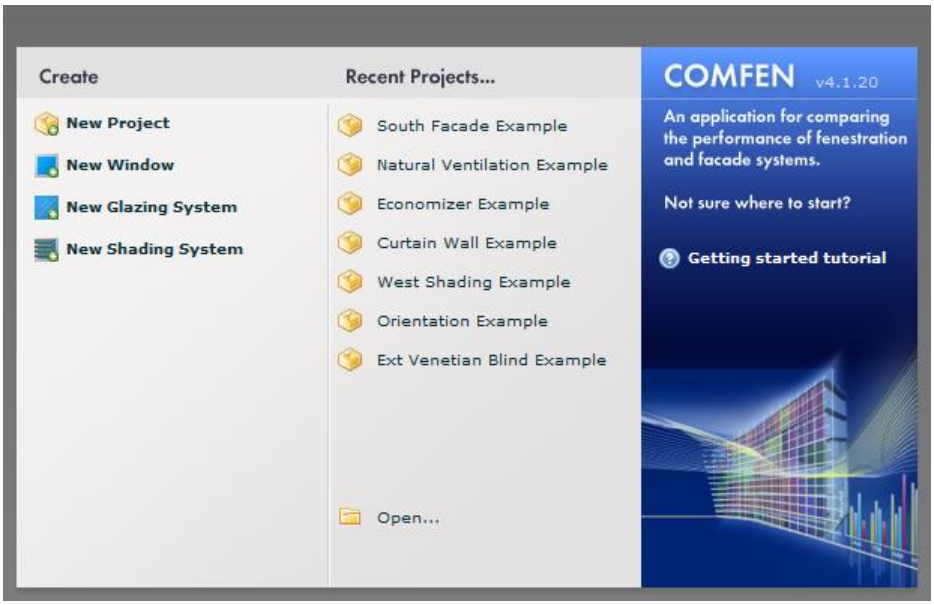


Figure 3-2. The first screen when COMFEN starts

3.4. Uninstalling COMFEN

If you need to uninstall COMFEN, follow the steps below.

1. Go to the Control Panel and go to the Programs or Add/Remove Programs (depending on the operating system) choice. Highlight the previous version of COMFEN and select uninstall or remove (depending on the operating system).

2. The program will ask if you want to completely remove the application. Click **OK** to uninstall the program, or **Cancel** to cancel the uninstall process.While the program is being uninstalled, the **Setup Status** screen will appear.

3. When the uninstall process is complete, the **Maintenance Complete** screen appears. Click **Finish** to complete the uninstall.

3.5. Troubleshooting

When you first run the program after installing it, the results may show as zeros after the first calculation. If you have this problem, close the program, run it again, and the problem should go away.

Please send E-mail to COMFENhelp@lbl.gov if you have any trouble running the program.

4. PROGRAM DESCRIPTION

4.1. Program Overview

COMFEN, short for commercial fenestration, is a simple single-zone facade analysis tool based on EnergyPlus, a powerful building simulation engine. COMFEN can be used to evaluate a range of facade configurations in order to understand the impact of different design variables on facade performance. After defining a building type, location and zone properties (dimensions and loads from equipment and people and fenestration layout), several additional scenarios can be quickly created and compared side-by-side. Orientation, window-to-wall ratio (WWR), glazing type and/or shading can easily be varied in order to assess their impact on energy use, peak loads, daylighting and thermal and visual comfort.
COMFEN includes a number of libraries with predefined facade components, including glazing, shading, material, wall and spandrel libraries. In addition to fixed exterior fins and overhangs, automated interior or exterior venetian blinds and roller shades can be evaluated using one of a number of predefined shading control options. The shading system library, developed based on performance data for commercially-available products, incorporates venetian blinds, roller shades, metal mesh screens and glazing-integrated venetian blinds.

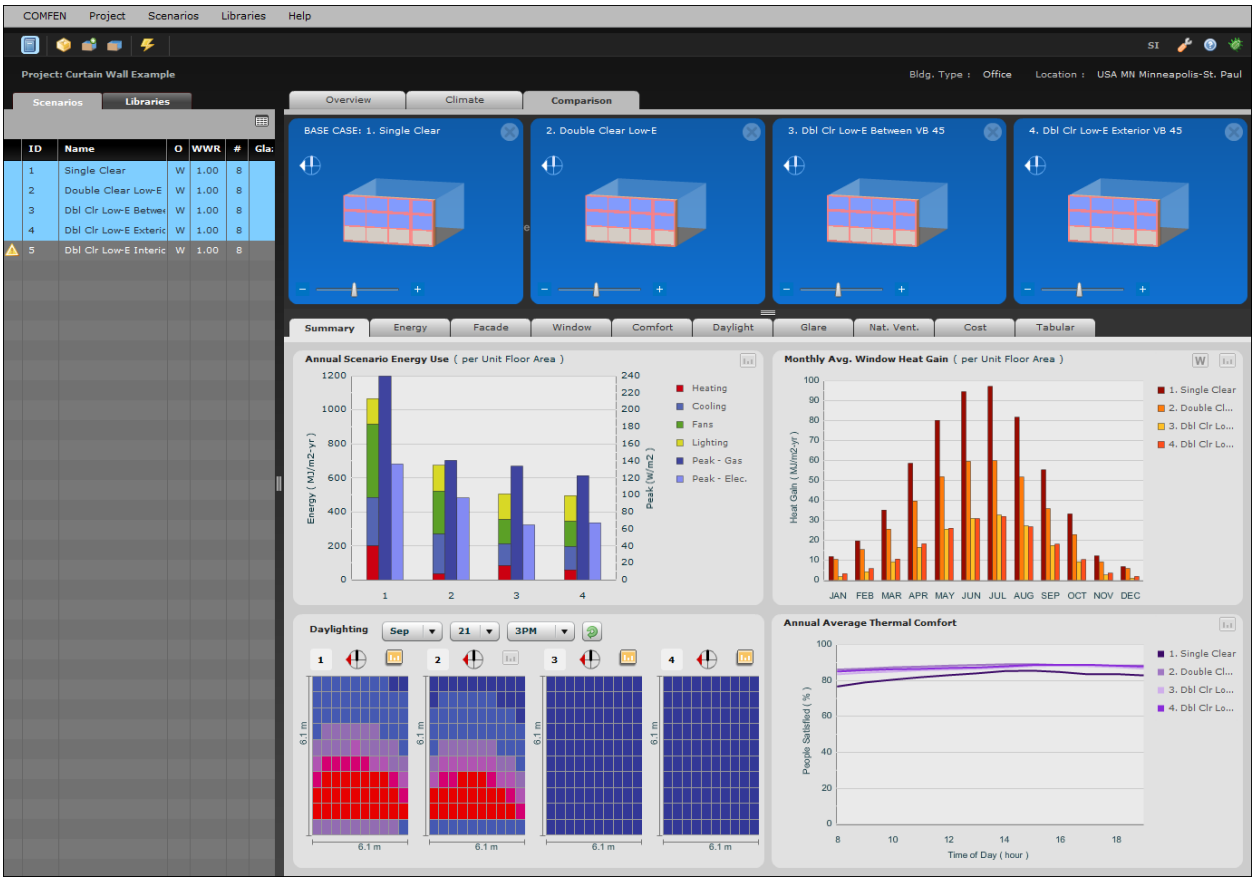


Figure 4-1. The COMFEN Project Comparison Summary screen

The primary steps to completing a COMFEN calculation are:

- **Defining the "scenarios"** (alternative facade configurations for comparison)
- **Calculating the scenarios.** This is done by highlighting one or more of the scenarios in the list on the left of the screen and clicking the lightning bolt icon . Alternatively, scenarios can be calculated by clicking the right mouse button and choosing **Calculate performance**. The program will calculate the heating, cooling, lighting, and fan energy use for each scenario, peak energy consumption, CO2 emissions, annual daylight levels, and visual and thermal comfort.
- **Comparing scenarios of interest.** Upon the completion of the calculations, the user can compare select scenarios side-by-side by navigating to the **Comparison** tab and then dragging select scenarios from the scenario list on the left of the screen to the blank area under the **Comparison** tab.

This chapter describes the program in detail.

4.1.1. COMFEN database

COMFEN projects are saved in a single database. The default database that comes with the program is comfen.sqlite and the location of this file can be determined by accessing COMFFEN > Preferences > database tab. The same database is automatically opened each time the user starts up COMFEN unless they change the path of the database in this dialog box.
When COMFEN starts, the program prompts the user to select an existing project, or create a new project, window, glazing, or shading system. Clicking on one of the existing projects opens the project screen.

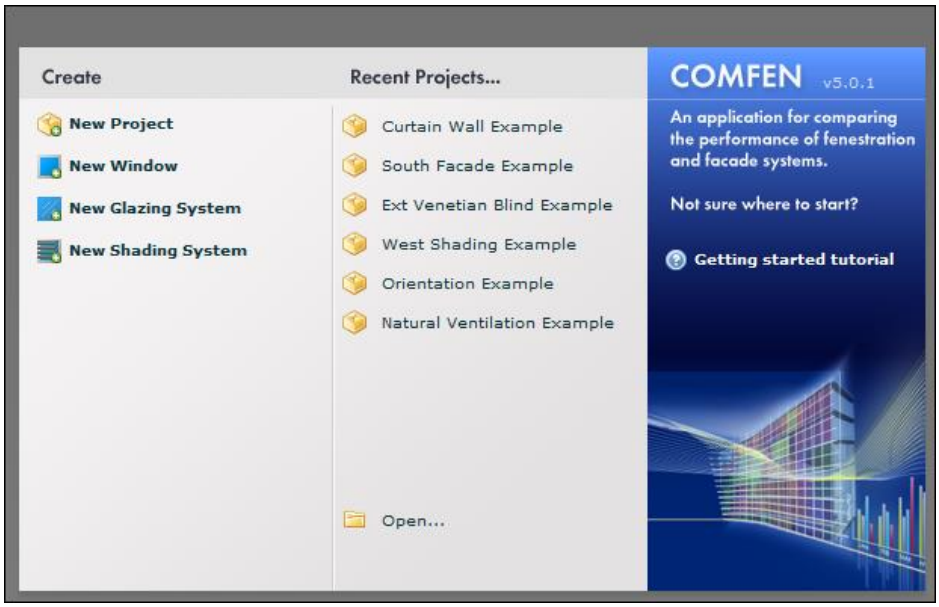


Figure 4-2. Opening Screen

4.1.2. General simulation assumptions

While specific sections of this chapter provide detailed information on simulation assumptions and calculation methodology, the following table provides an overview of key simulation assumptions for a scenario.

Table 4-1. Key simulation assumptions

Parameter	Description
Exterior wall construction	ASHRAE 90.1 construction assigned based on location

	[default]
Interior wall construction	All walls are adiabatic, interior reflectances for Radiance simulation:
Terrain	Suburban
Lighting controls	None [default], continuous, stepped
HVAC system	Packaged single zone
Economizer	None [default], temperature, enthalpy, temperature and enthalpy
Air flow rate	Flow/person [default], value varies by building type, Flow/Area
Schedules	All schedules (occupancy, lighting, equipment, infiltration) vary by building type
Setpoints	Cooling and heating setpoints vary by building type; window operation setpoint for naturally-ventilated scenarios is set to 73.4 F (23 °C)
Thermal mass	
Interior material finishes	
Simulation timestep	15 minutes

4.1.3. Typical Meteorological Year (TMY) weather data

The TMY weather data set used for the calculation consists of hourly data for twelve typical meteorological months (January through December) taken from different years and concatenated to form a single year. The data sets are generated based on measured meteorological data and modeled solar values but can also contain interpolated values if original observations are missing (Wilcox & Marion, 2008). The TMY3 data set, covering years from 1991 to 2005, contains more recent and more accurate data than the TMY2 data set, which covers years from 1961 to 1990. It should be noted that the weather data values are hourly averages calculated for the 60-minute period ending at the timestamp.

References

1. Wilcox, S., & Marion, W. (2008). *User's Manual for TMY3 Data Sets* (NREL/TP-581-43156). Golden, Colorado: National Renewable Energy Laboratory. Retrieved from http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

4.1.4. Menu

The COMFEN menu options are (ctrl+click to jump to section):

COMFEN The COMFEN menu can be used to view the program version number and modify general program options.

Project The Project menu is used to control projects.

Scenarios The Scenarios menu is used to control Scenarios within projects.

Libraries The Libraries menu is used to access all of the libraries.

Help The Help menu provides links to the COMFEN website, websites discussing various aspects of facade design, and an online resource for facade design tools and terms.

COMFEN

About COMFEN Lists program version number and program contributors

Preferences Opens the Application Preferences dialog box, which has five tabs:

Basic Settings The ***verbose logging*** allows for detailed logging of what happens in the program to the program log file (application-log.txt), i.e. in addition to warning and error messages, all debug messages are logged as well. The log file is mainly used for troubleshooting software problems.

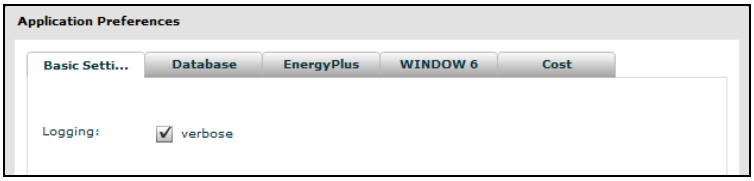


Figure 4-3. Preferences > Basic Settings

Database This sets the database that COMFEN opens when the program is started.

The ***Default database*** that comes with the program is comfen.sqlite. However, by copying and renaming the default database the user can easily create multiple databases as needed. Once a new database is created, the user can locate the new database by clicking the browse button and navigating to the correct file.

Compact database option allows user to defragment the database and reduce its file size. A backup copy of the database is created before compacting.

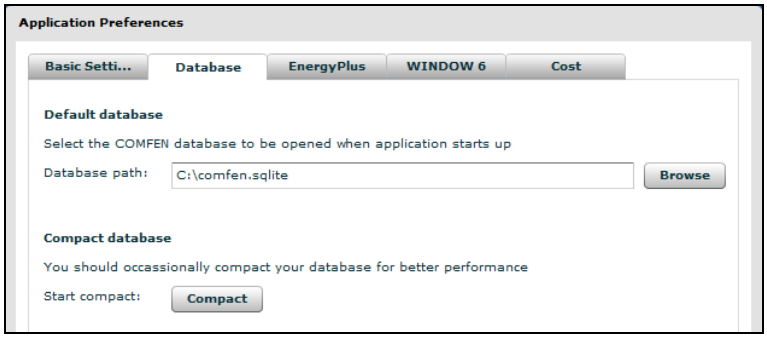


Figure 4-4. Preferences > Database

EnergyPlus This tab controls some basic settings for the Energy Plus simulation program, the underlying calculation engine for COMFEN:

The ***Site-to-source multiplier*** determines whether energy use results are displayed in terms of site or source energy. Site energy is energy used by the building on site (as measured at the meter), while source energy is a measure that accounts for energy consumed on site as well as the energy consumed during the storage, transport and delivery of the fuel to the building. Source energy is a better indicator of building environmental performance impact. By default, the multiplier is set to 1; electricity use results are displayed in terms of site energy.

The ***Daylight Illuminance Maps*** are horizontal illuminances throughout the space for a specific date and time calculated hourly by COMFEN. If the ***Calculate Illuminance*** box is checked, the results are displayed under the Comparison > Overview results tab in the form of color illuminance maps.

NOTE*: Checking this box will cause the calculation of scenarios to run slower, but no illuminance data will be collected if it is unchecked*

When EnergyPlus calculation has an error… If the "Show error log" or "Show in.imf file" are selected, these two files open automatically if EnergyPlus crashes.

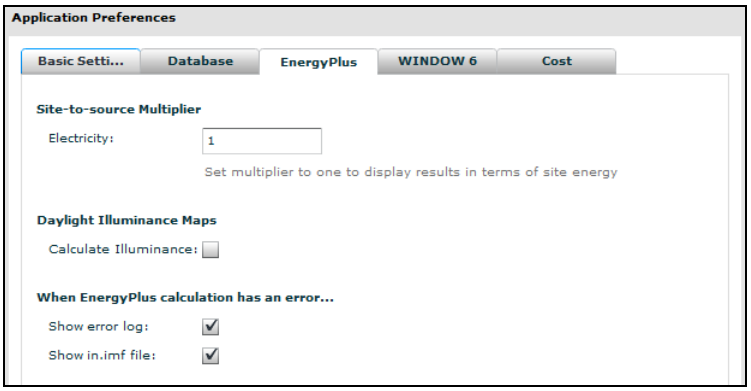


Figure 4-5. Preferences > EnergyPlus

WINDOW 6 This tab specifies the WINDOW 6 database from which additional glazing systems will be imported into COMFEN.

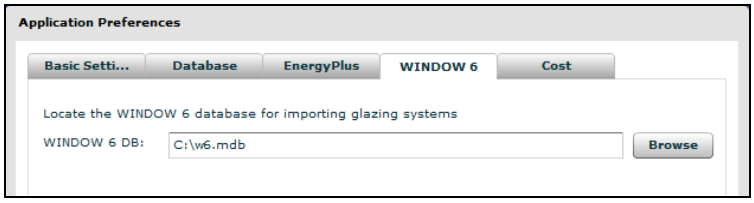


Figure 4-6. Preferences > WINDOW6

Cost The cost tab provides user with the option to override the baseline glass cost. For a definition of baseline glass cost, see the cost section.

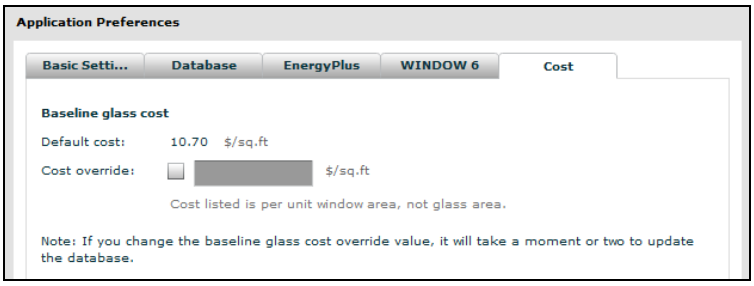


Figure 4-7. Preferences > Cost

Hide COMFEN Minimizes the COMFEN window

Quit Closes COMFEN

Project

New project Opens the Create COMFEN project dialog box where new project properties can be entered (project name, description, building type, project North, location, etc.). See the next section for more detailed information on creating projects.

Open project Opens the Open COMFEN Project dialog box, which shows all of the projects currently defined in the database in use. Projects can be opened by double-clicking or highlighting a project and then selecting Open.

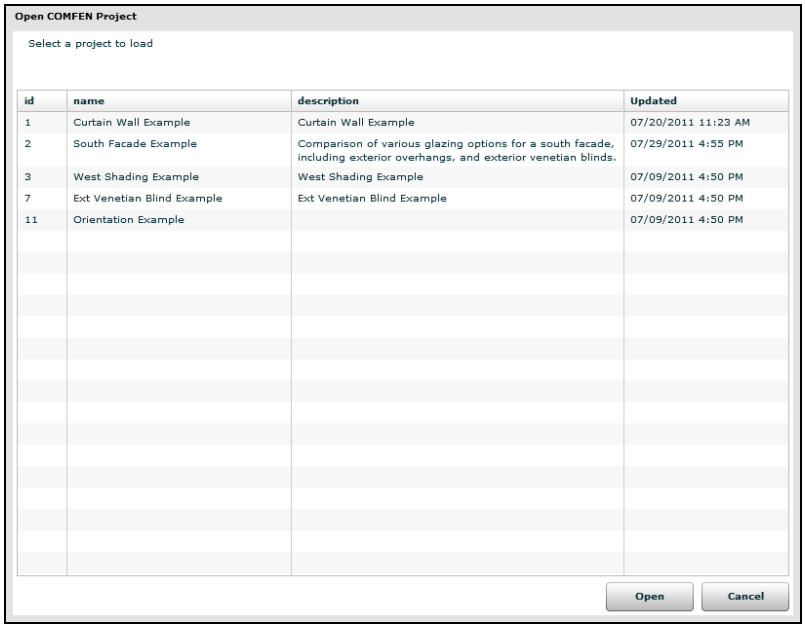


Figure 4-8. Project > Open Project

Close project Closes the currently open project, and returns to the startup menu screen.

Project Properties Opens the Project Properties dialog box, which shows the details of the currently open project. The project properties can be changed here as needed and are discussed in more detail in the next section.

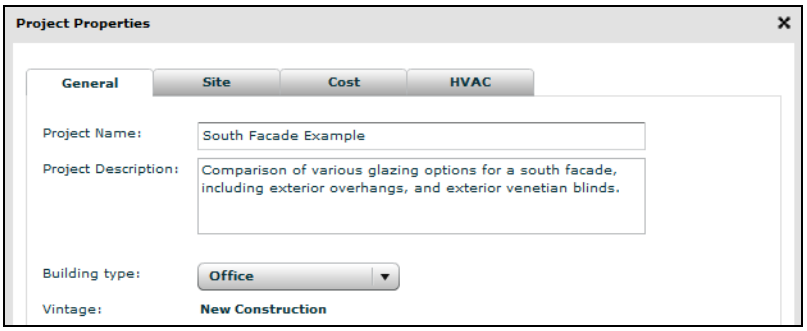


Figure 4-9. Project > Project Properties

Delete projects Opens the Delete COMFEN project dialog box, which shows the list of projects in the currently open database. Highlight a project, and click the Delete Selected to delete the entire project from the database. You will not be able to delete a project if it is already open.

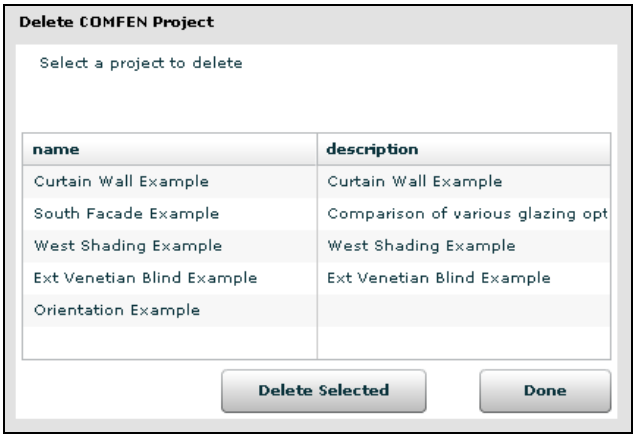


Figure 4-10. Project / Delete Projects

Import project definition from CSV file Allows the user to import project and scenario information using previously created tabulated inputs in csv format. This option is especially useful for projects with multiple scenarios. All projects must be closed in order to import a csv file (the option is grayed out if a project is open).

Export project results to CSV Option that allows the export of COMFEN project results (annual and peak energy by end use, average illuminance levels, visual and thermal comfort, etc.) and basic scenario properties (orientation, WWR, glazing, shading system, lighting control setting, etc.) to a CSV file.

Scenarios

Create Scenario Opens the Create New Scenario dialog box.

Copy Scenario Creates a copy of highlighted scenario.

Import Scenario from Project Allows the user to import a select scenario from another project.

Delete Scenario Deletes highlighted scenario.

Rename Scenario Renames highlighted scenario.

Add Window to Scenario Adds a window to scenario. Unless scenario is active (by double clicking or right clicking and choosing Edit), this option is grayed out.

Add Exterior Shade to Scenario Adds fixed exterior projection (overhangs, fins, etc.) to scenario. Unless scenario is active, this option is grayed out.

Export compared scenarios images to PNG Exports thumbnail images of select scenarios in *.png format.

Calculate All Calculates performance of all scenarios in project

Calculate Selected Calculates performance of highlighted scenarios. To select multiple scenarios in explorer hold shift or ctrl key down while making selections with the left mouse button.

Libraries

The library menu allows the user to access all system and component libraries:

- Windows
- Glazing systems
- Shading systems
- Frames
- Glass
- Gas
- Walls
- Spandrels
- Materials
- Locations

Import IGDB data… Allows the user to update the glass library using a COMFEN *.sqlite database file that can be downloaded from the COMFEN website. See section on glass library for more information on the IGDB database.

Import glazing system From WINDOW 6 Allows the user to import a glazing system from a WINDOW 6 database.

Help

COMFEN website This link is out of date. Go instead to https://windows.lbl.gov/software/comfen

Window Technologies http://www.commercialwindows.org/technologies.php

Window Selection http://www.commercialwindows.org/fdt.php

Case Studies http://www.commercialwindows.org/casestudies.php

Tools and Resources http://www.commercialwindows.org/resources.php

Once a project is open, the COMFEN icon toolbar is accessible. These provide useful shortcuts to other sections of the COMFEN menu as well as additional resources and features for the project.

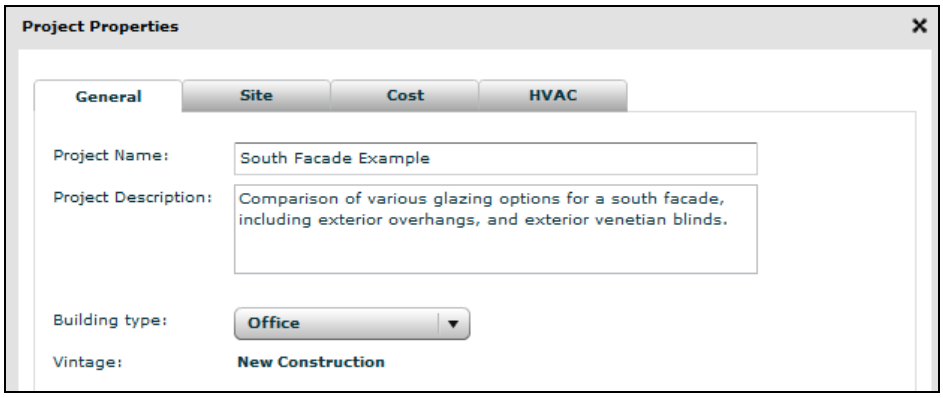
Table 4-2. Icon Toolbar

Icon	Name	Information
	Library	Shortcut to the COMFEN Library directory
	Project Properties	Shortcut to the Project Properties dialog box
	Create Scenario	Shortcut to Create New Scenario dialog box
	Import Scenario From Library	Shortcut to open the dialog box to import scenarios from existing saved projects
	Calculate Performance for Selected Scenarios	The lightning bolt icon will simulate the selected scenarios and calculate results.
	SI / IP Unit Toggle	Toggles between IP or SI units for all results and interface values in COMFEN
	Preferences	Shortcut to the Application Preferences
	Help	Shortcut to a help and support search bar

4.1.5. Project

To create a new project, select New Project from the Project menu. The Create COMFEN Project dialog box contains the same inputs as the Project Properties dialog box and includes the following tabs:

General Tab Lists project name, project description, building type and vintage.



Project Name Field used to provide a unique name for the project.

Project Description Field for user comments about project.

Building type Building type determines several default values, including occupancy schedules, heating and cooling setpoints, and default outdoor air flow rate. The following building/space type options are available:

- Office (office space)
- Mid-rise residential (apartment)
- Hotel (guest room)
- Retail (point of sale)
- School (classroom)

Vintage Default is set to New Construction and cannot currently be edited by the user.

Site Tab

Lists project North, location, default wall and Wall R-value.

Project North Defines the overall project orientation, measured clockwise from true North. A project with a Project North of 0° faces true North. The value specified for Project North is added to the scenario orientation definition (North, South, East or West) to calculate the "resolved" orientation. For example, a scenario facing South with a Project North of 45° will in effect face southwest (45° degrees west of South) and its "resolved" orientation

will be 45° + 180° = 225.° Default: 0 (project faces true north); Legal values: 0-359; Units: degrees.

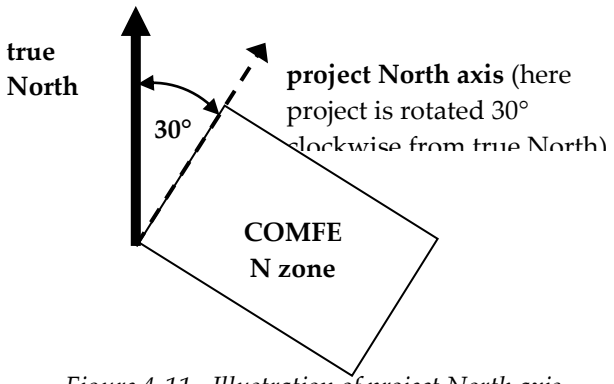


Figure 4-11. Illustration of project North axis

Location Field used to provide a unique name for the project. This drop-down will determine the weather data that will be used for the simulation.

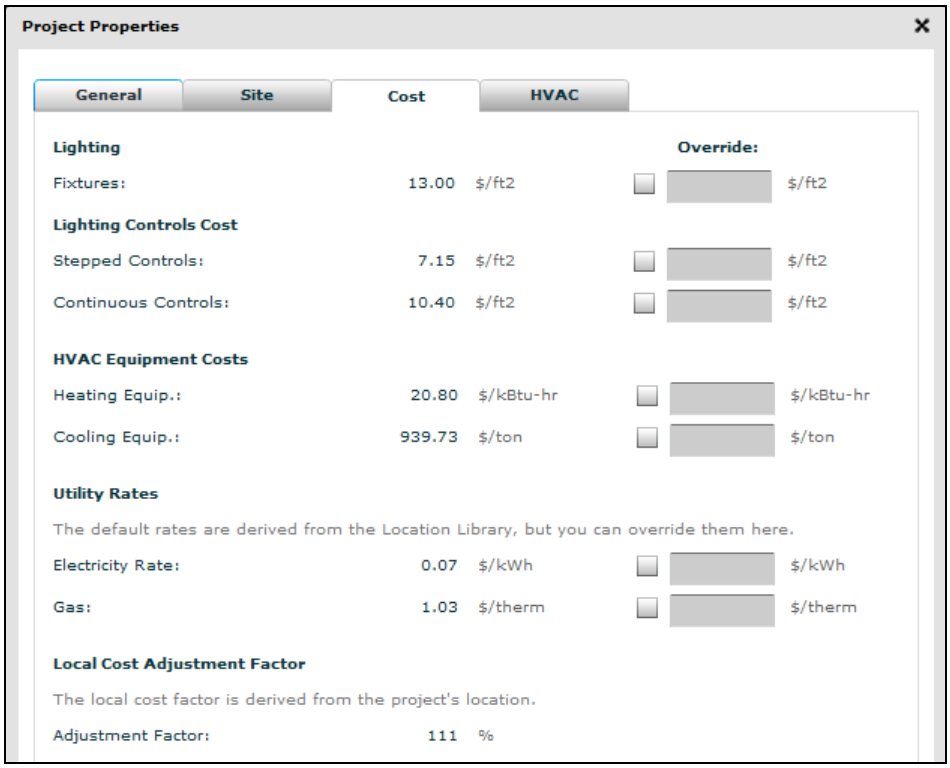
***NOTE**: CO_2 data is currently not available for locations outside of the USA.*

Default Wall This is the default exterior wall construction assigned to the project based on the project's location. When the user specifies the project location, an ASHRAE-90.1-compliant wall is automatically assigned as the default wall for the project. See components and libraries section for information on creating and assigning custom walls.

Wall R-value This is the R-value corresponding for the default exterior wall.

Cost Tab

The cost tab provides users with the option to override several default first cost values (e.g. lighting fixtures and controls, HVAC, etc.), utility rates for electricity and gas, and location adjustment factor. See cost section for a more detailed explanation of cost data.



Lighting

Fixtures COMFEN assigns default cost values according to building type and location.

Lighting Controls Cost

Stepped Controls COMFEN assigns default cost values according to building type and location.

Continuous Controls COMFEN assigns default cost values according to building type and location.

HVAC Equipment Costs

Heating Equipment COMFEN assigns cost values according to the default packaged single zone HVAC system currently available in COMFEN.

Cooling Equipment COMFEN assigns cost values according to the default packaged single zone HVAC system currently available in COMFEN.

Utility Rates

Electrical Rate COMFEN assigns default electric rate values based on location. The user should check the cost override to input known cost values.

Gas COMFEN assigns default gas rate values based on location. The user should check the cost override to input known cost values.

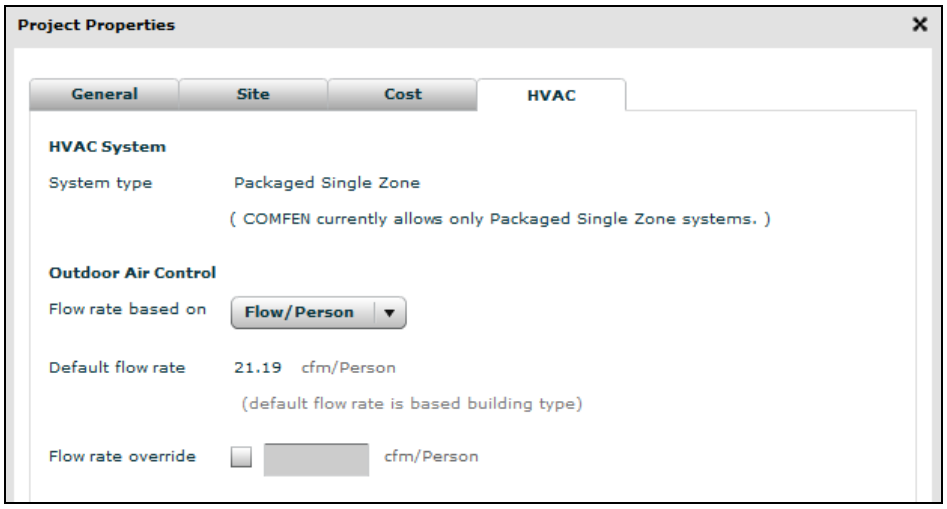
Local Cost Adjustment Factor

Adjustment factors are stored in the Location Library and account for variation in construction costs.

Adjustment Factor A location-specific multiplier to adjust the total project cost for construction cost variations.

HVAC Tab

Lists general information on HVAC system and outdoor flow rate.



HVAC system The default HVAC system is presently a packaged single zone system for all building types.

Outdoor air control This section lists the default outdoor air flow rate used for ventilation. The user can override the air flow control type (flow/person or flow/area) and flow rate.

NOTE: It is recommended to use flow/area for occupancy levels greater than one person.

4.1.6. Scenario

Once a project is open, to create a new scenario, select Create Scenario from the Scenarios menu or by clicking on the icon. This opens the Create New Scenario dialog box, shown in the image below, where new scenario information can be entered, including space dimensions, orientation and load information. The scenario orientation can be specified at one of the four cardinal directions (North, South, East, West). If the facade is not facing these cardinal orientations, this can be accounted for by entering a value in the Project North box in the Project Properties dialog box.

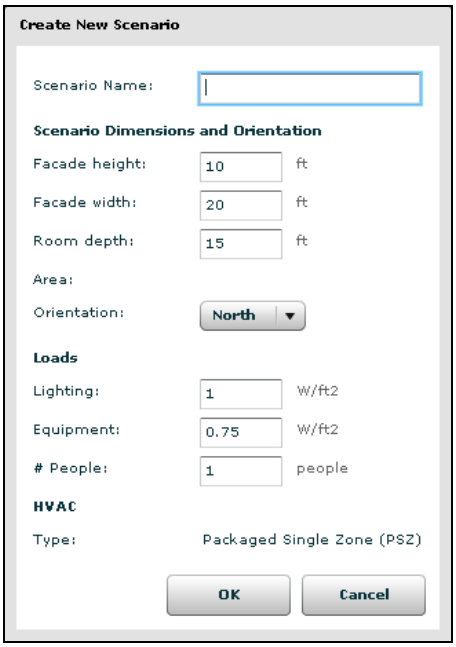


Figure 4-12. Create New Scenario

After creating the enclosure for the scenario and inputting load information through the Create New Scenario dialog box, scenario inputs can be further edited in the scenario edit screen shown on the next page. The edit screen can be accessed by 1) double-clicking on the scenario under the scenario tab on the left side of the screen or 2) double-clicking on the image of the scenario in the Comparison tab.

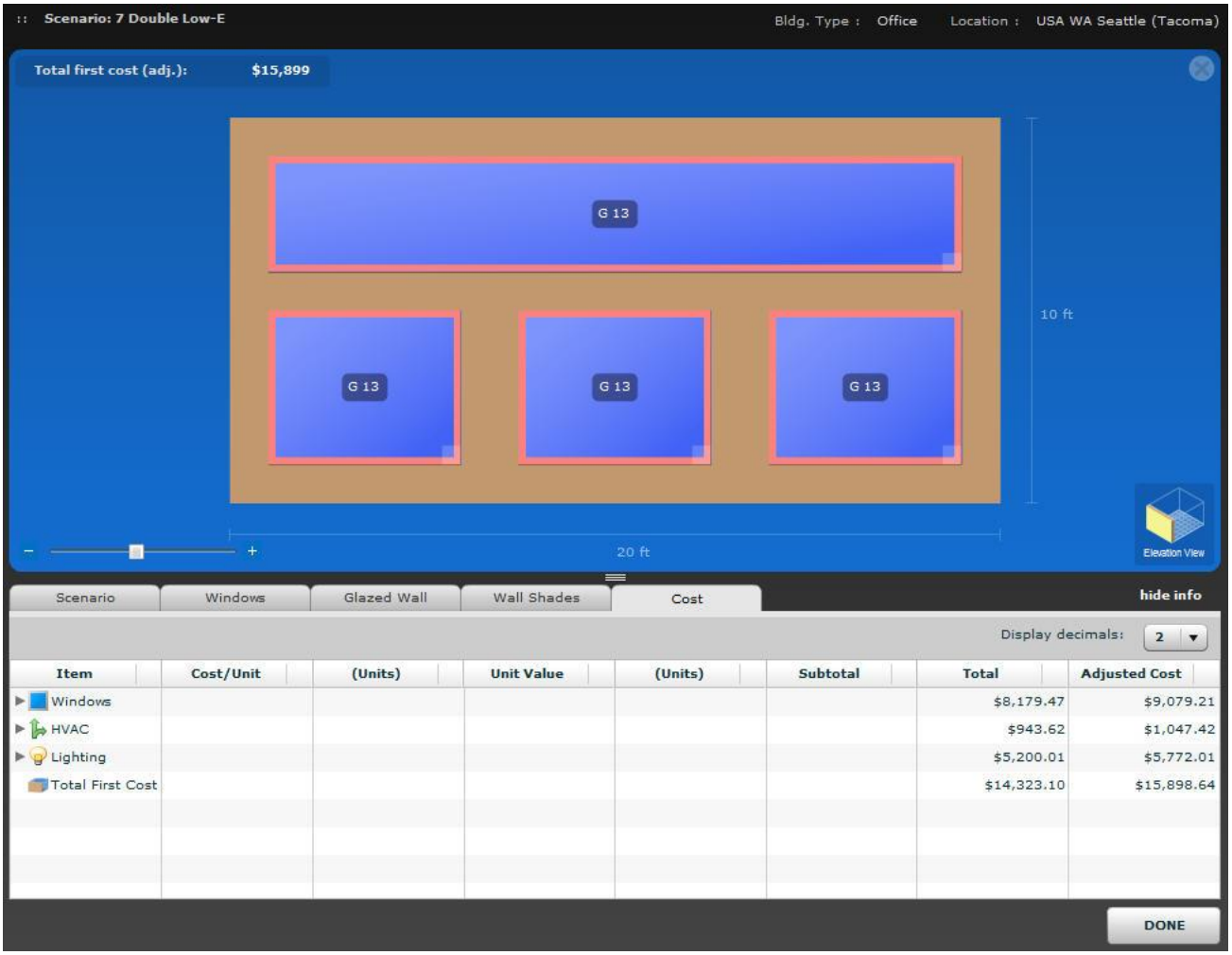


Figure 4-13. Scenario Edit Screen

In the lower right corner of the facade diagram screen the user will see the View Toggle component which will toggle views between elevation, a section cut through the facade, and a plan view of the facade. The scenario diagram default is an elevation view.

The scenario edit screen consists of the following tabs:

Scenario Tab where general scenario parameters, including geometry, orientation, loads and lighting controls are defined. The lighting control pulldown contains three choices for lighting and daylighting controls: none, continuous and stepped. See the calculation assumptions section for a more detailed description of lighting control options.

Windows Tab where window configuration is defined. Windows are added by clicking on the green "+" icon in the upper-right hand corner of the tab, which brings up the New Window dialog box. The new window inputs include window dimensions and position, glazing system, operating type, shading system (all systems except for fixed exterior projections) and frame type. Double-clicking on any entry in the table list view will bring up the edit window dialog box. Windows are deleted by highlighting the window and clicking the red "-" icon .

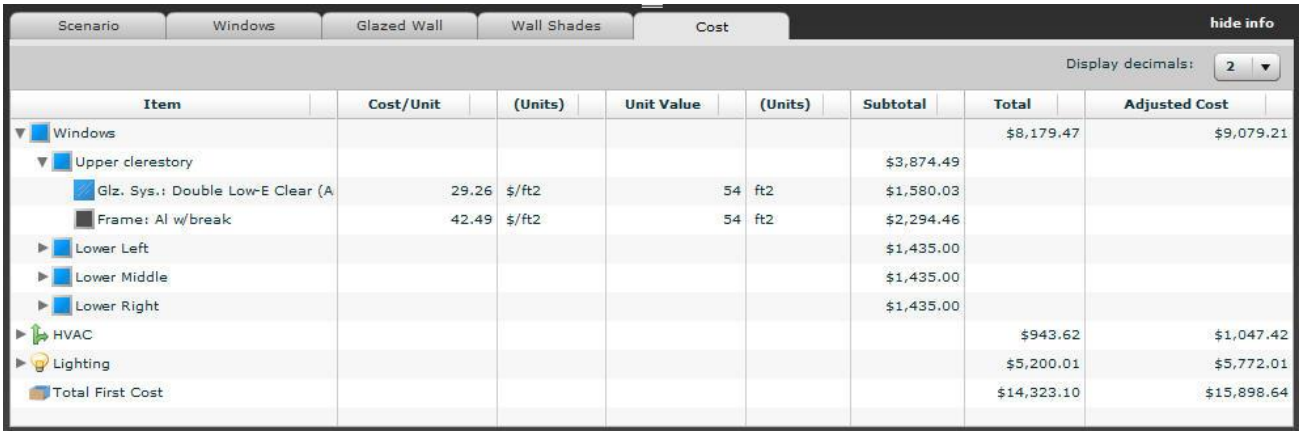
***NOTE**: The glare control checkbox will turn on the glare control option, meaning that a shading system will be activated (deployed) when the glare index setpoint is reached. The glare index setpoint is 22 and this value cannot be changed by the user. Additional shading control options can be specified under the shading system properties.*

Glazed Wall Tab is inactive until a Glazed Wall Assembly is created. This can be done by clicking the Glazed Wall icon at the top of the screen.  For more information, see section for Glazed wall assembly.

Wall Shades Tab where fixed exterior projections such as horizontal overhangs and vertical fins are defined. Similar to window definition, wall shades are added by clicking on the green "+" icon  in the upper-right hand corner of the tab, which brings up the new wall shade definitions screen. Wall shades are deleted by highlighting the shade and clicking the red "-" icon  .

Cost Tab where cost is broken down into three sections: windows, HVAC and lighting. Each of these sections can be expanded by clicking the arrow to the left of the heading for more information. In the Cost Tab, individual window glazing and frame costs are calculated for each window in the scenario, heating and cooling costs are estimated, and lighting loads are calculated. The accuracy of these calculations can be fine-tuned by increasing the display decimals from the pull down menu to the right of the scenario edit tabs. See the Cost Calculation section for a more detailed description of calculation assumptions and features.

Additionally, the scenario edit screen features an adjusted total first cost calculator. The feature is displayed beneath the window, HVAC, and lighting sections as well as in the upper left corner of the screen displaying the facade diagram. See the First Cost section for more detailed description of the calculation and assumptions.



Item	Cost/Unit	(Units)	Unit Value	(Units)	Subtotal	Total	Adjusted Cost
Windows						$8,179.47	$9,079.21
Upper clerestory					$3,874.49		
Glz. Sys.: Double Low-E Clear (A	29.26	$/ft2	54	ft2	$1,580.03		
Frame: Al w/break	42.49	$/ft2	54	ft2	$2,294.46		
Lower Left					$1,435.00		
Lower Middle					$1,435.00		
Lower Right					$1,435.00		
HVAC						$943.62	$1,047.42
Lighting						$5,200.01	$5,772.01
Total First Cost						$14,323.10	$15,898.64

Figure 4-14. Scenario Edit Cost Tab

4.2. Facade libraries and components

This section discusses construction components and COMFEN libraries in detail. The libraries contain a range of predefined facade components such as windows, glazing systems, shading systems and frames as well as

locations. They also include a comprehensive list of glazing products from a range of commercial glazing manufacturers. New entries can be created in all libraries except for the glass and gas libraries.
The COMFEN facade components and libraries discussed in this section include the following:
4.2.1. Windows
4.2.2. Glazing Systems
4.2.3. Shading Systems
4.2.4. Frames
4.2.5. Glass
4.2.6. Gas
4.2.7. Walls
4.2.8. Spandrels
4.2.9. Materials
4.2.10. Locations
4.2.11. Glazed Wall Assembly

4.2.1. Windows

The window library stores predefined windows which can later be easily added to a scenario. A COMFEN window consists of a glazing system, frame and shading system.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls

ID	Name	Height (ft)	Width (ft)	Setback (ft)	Cost ($/window)
238	3x5 Double Low Solar LowE (Air) w/Int VB 45	5.00	3.00	0.00	1,595.98
249	5x5 Double Bronze (Air)	5.00	5.00	0.00	1,754.98

Figure 4-15. Windows library list view

A window from the library is added to a scenario by dragging the window from the Libraries tab in the scenario explorer on the left side of the screen (see image below) to the facade of an open scenario.

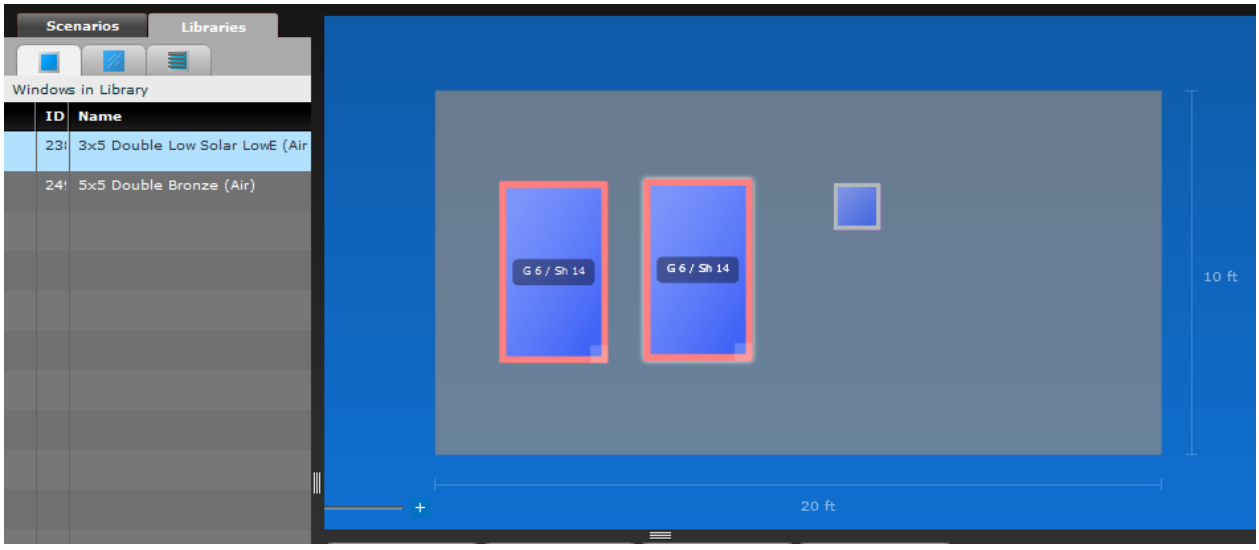


Figure 4-16. Edit frame dialog box

Selecting a window in the library and clicking Edit (or double-clicking on the selection) will open the Window edit screen. This allows the window properties, glazing system, frame and shading system to be edited.

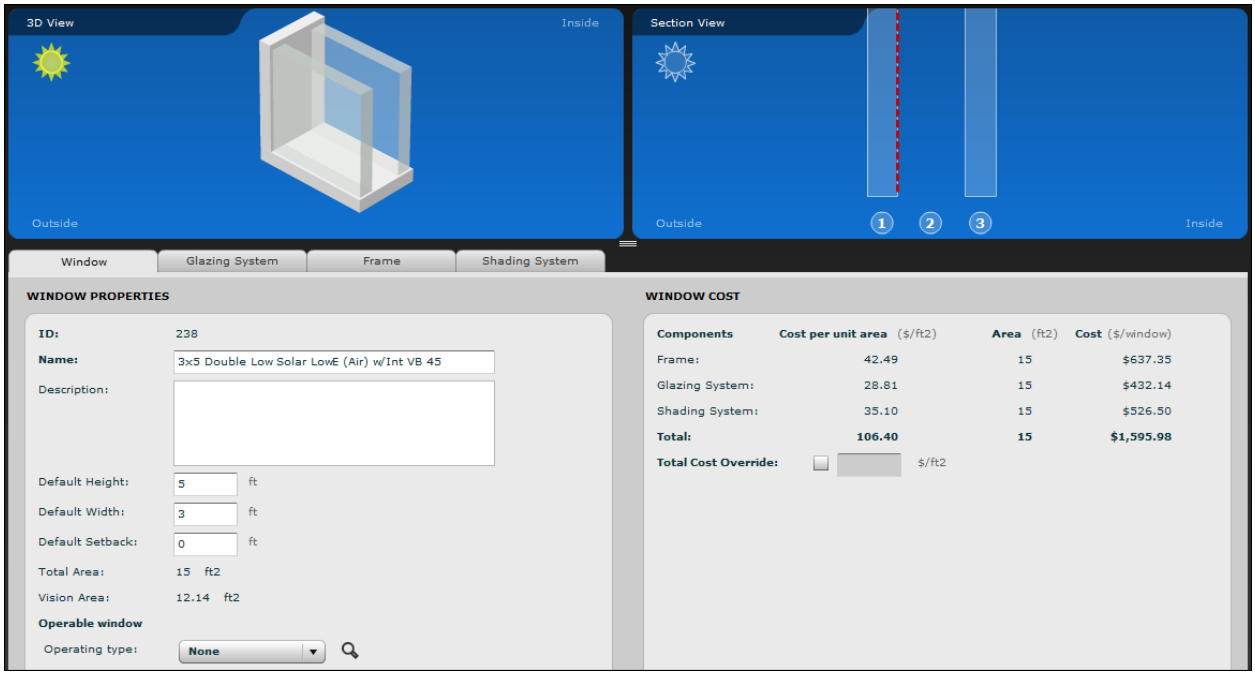


Figure 4-17. Window edit screen

4.2.2. Glazing systems

Glazing system library

There are approximately 50 predefined glazing systems in the Glazing System Library, which includes both several generic glazing systems as well as a limited selection of commercially available insulated glazing products (ID# 100 and beyond). A glazing system can consist of a single glass layer (e.g. similar to the first entry in the image below), or of two or more glass layers separated by a gas layer. Any glazing systems defined in the glazing system library can be assigned to a window, whether it is a window in the window library or a window in the scenario edit screen. New glazing systems can be added to this library as needed, by either creating the assembly directly in COMFEN or importing a glazing system from the WINDOW glazing system library.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls | Sp

ID	Name	TVis	SHGC	U-factor (Bt...	Thickness (in)
1	Single Clear 6 mm	0.884	0.818	1.025	0.22
2	Double Clear (Air)	0.786	0.704	0.473	0.95
3	Double Bronze (Air)	0.477	0.502	0.474	0.94
4	Double Low-E Bronze (Air)	0.443	0.453	0.331	0.94
5	Double Low Solar Low-E Tint (Air)	0.521	0.299	0.291	0.96
6	Double Low Solar Low-E Clear (Air)	0.701	0.382	0.291	0.95
7	Quad Low Solar Low-E Clear (Air)	0.451	0.292	0.108	2.10
8	Double Glazed Triple Silver Low-E (Argon)	0.638	0.272	0.238	0.95
9	Double Hi VT (LowIron) Low-E (Argon)	0.724	0.383	0.247	0.95
10	Double High Performance Tint (Air)	0.607	0.394	0.474	0.95
11	Double High Performance Tint (Argon)	0.607	0.390	0.449	0.95
12	Double Low VT Low-E (Argon)	0.371	0.241	0.253	0.95
13	Double Low-E Clear (Argon)	0.696	0.469	0.245	0.85
14	Double Glazed Triple Silver Low-E Tint (Argon)	0.543	0.246	0.238	0.95
15	Double Low-E Opaque (Air)	0.027	0.077	0.291	0.95
100	Viracon -- VE-2M (2) clear/clear (air)	0.703	0.379	0.293	0.95
101	Viracon -- VE-2M (2) clear/clear (argon)	0.703	0.375	0.247	0.95

Figure 4-18. Glazing system library list view

The ID of the glazing system is automatically generated in sequence by COMFEN. When glazing systems are imported into COMFEN, the ID from WINDOW will not be kept, but a new ID will be assigned based on the records existing in the COMFEN glazing system library.
The user can specify a unique glazing system name under the name field. Existing entries based on commercially available products follow a specific naming format:

Uncoated double glazing:

<Manufacturer> -- <substrate #1> <substrate #2> <gap fill>

Double insulated glazing with a low-e or solar control coating:

<Manufacturer> -- <coating name> <coating surface no.> <substrate #1> <substrate #2> <gap fill>

Triple insulated glazing with a low-e or solar control coating:

<Manufacturer> -- <coating name> <coating surface no.> <substrate #1> <substrate #2> <substrate #3> <gap fill>

Creating a new glazing system

To create a new glazing system, select the new button in the lower right-hand corner of the glazing system library. Under the Create New Glazing System screen (see image below), drag glass and gas layers from the right-hand list view to create desired assembly.

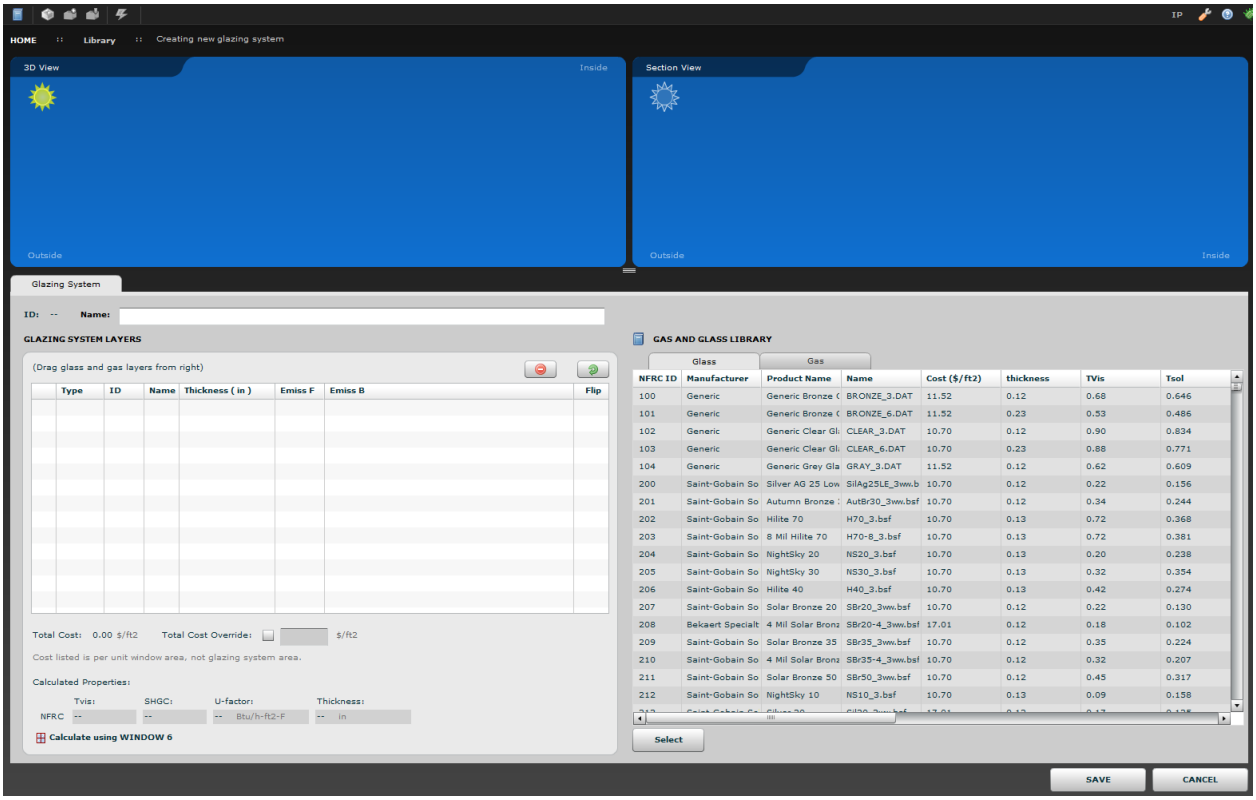


Figure 4-19. Create new glazing system screen

Layer no. field

The layer no. field (far left column in the image below) identifies the layer sequence number in the glazing system. The first layer is the layer on the outside (exterior) of the glazing system, the last layer is the layer on the inside (interior) of the glazing system. Gas spaces are also counted as layers. The outside and inside layers have to be glass layers, and each glass layer has to be separated by a gas fill.

	Type	ID	Name	Thickness (in)	Emiss F	Emiss B	Flip
1	Glass	923	TiPS_6.AFG	0.22	0.84	0.06	✓
2	Gas	9	Air (10%) / Argon (90%) Mix	0.50			
3	Glass	890	CLR_6.AFG	0.22	0.84	0.84	
4	Gas	9	Air (10%) / Argon (90%) Mix	0.50			
5	Glass	910	CMFTE2_6.AFG	0.22	0.20	0.84	

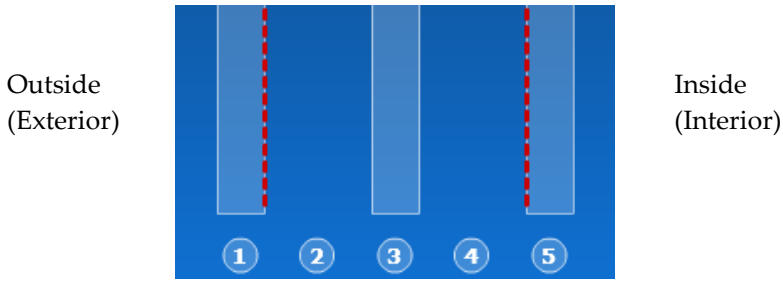


Figure 4-20. Glass and gas layers are numbered from outside to inside

The **Calculate using WINDOW 6** button calculates the thermal and optical properties for the glazing system (Tvis, SHGC, U-factor and thickness) using WINDOW 6 calculation algorithms. If the glazing system is imported from WINDOW 6, these values will usually already be calculated and will appear in this section.

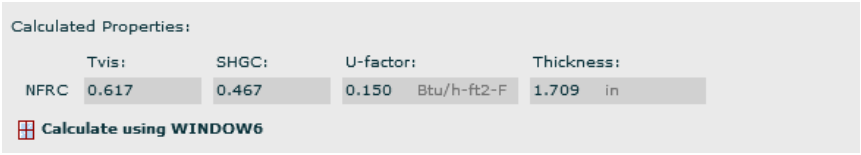


Figure 4-21. The Results section of the Glazing System Library

Tvis	Visible transmission of the complete glazing system
SHGC	Solar Heat Gain Coefficient for the whole glazing system
U-factor	U-factor for the complete glazing system, in Btu/h-ft-F (IP units) or W-m2-K (SI units)
Thickness	Thickness of the complete glazing system in in. (IP units) or mm (SI units)

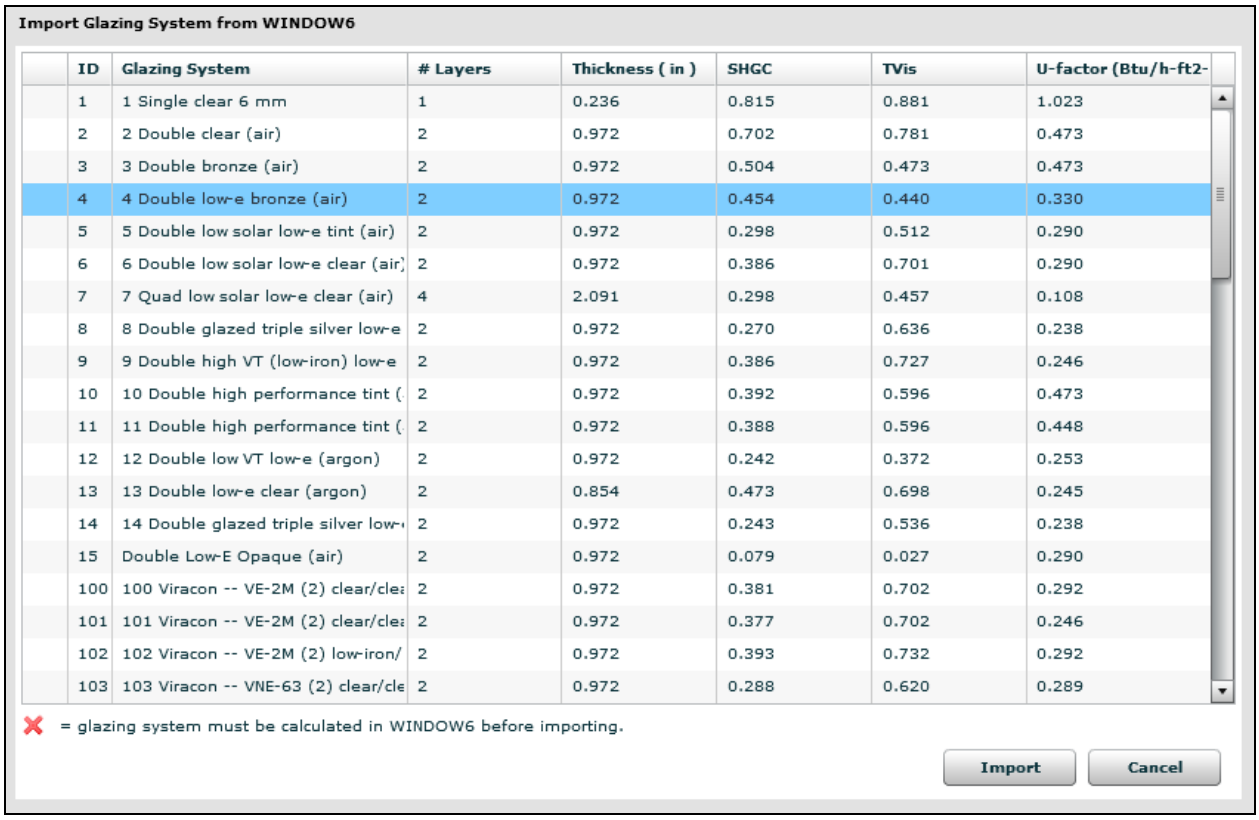
Importing a glazing system from WINDOW 6

To import a glazing system from WINDOW 6, navigate to the main glazing system library tab (Libraries > glazing systems) and click on the Import from WINDOW6 button at the bottom of the screen.

Figure 4-22. Import from WINDOW6 Glazing System Option

Or go to Libraries > Import glazing system from WINDOW 6.
This will bring up a list of glazing systems in the WINDOW 6 database. Navigate to the desired system and click Import.

NOTE: *COMFEN cannot import WINDOW 6 glazing systems that have shading systems associated with them.*



	ID	Glazing System	# Layers	Thickness (in)	SHGC	TVis	U-factor (Btu/h-ft2-
	1	1 Single clear 6 mm	1	0.236	0.815	0.881	1.023
	2	2 Double clear (air)	2	0.972	0.702	0.781	0.473
	3	3 Double bronze (air)	2	0.972	0.504	0.473	0.473
	4	4 Double low-e bronze (air)	2	0.972	0.454	0.440	0.330
	5	5 Double low solar low-e tint (air)	2	0.972	0.298	0.512	0.290
	6	6 Double low solar low-e clear (air)	2	0.972	0.386	0.701	0.290
	7	7 Quad low solar low-e clear (air)	4	2.091	0.298	0.457	0.108
	8	8 Double glazed triple silver low-e	2	0.972	0.270	0.636	0.238
	9	9 Double high VT (low-iron) low-e	2	0.972	0.386	0.727	0.246
	10	10 Double high performance tint (	2	0.972	0.392	0.596	0.473
	11	11 Double high performance tint (	2	0.972	0.388	0.596	0.448
	12	12 Double low VT low-e (argon)	2	0.972	0.242	0.372	0.253
	13	13 Double low-e clear (argon)	2	0.854	0.473	0.698	0.245
	14	14 Double glazed triple silver low-	2	0.972	0.243	0.536	0.238
	15	Double Low-E Opaque (air)	2	0.972	0.079	0.027	0.290
	100	100 Viracon -- VE-2M (2) clear/cle	2	0.972	0.381	0.702	0.292
	101	101 Viracon -- VE-2M (2) clear/cle	2	0.972	0.377	0.702	0.246
	102	102 Viracon -- VE-2M (2) low-iron/	2	0.972	0.393	0.732	0.292
	103	103 Viracon -- VNE-63 (2) clear/cle	2	0.972	0.288	0.620	0.289

Figure 4-23. WINDOW 6 glazing system import screen

NOTE: *The WINDOW 6 library from which glazing systems will be imported is specified through Preferences under the COMFEN menu. If you want to change the database, click on the Browse button and navigate to the desired WINDOW 6 database.*

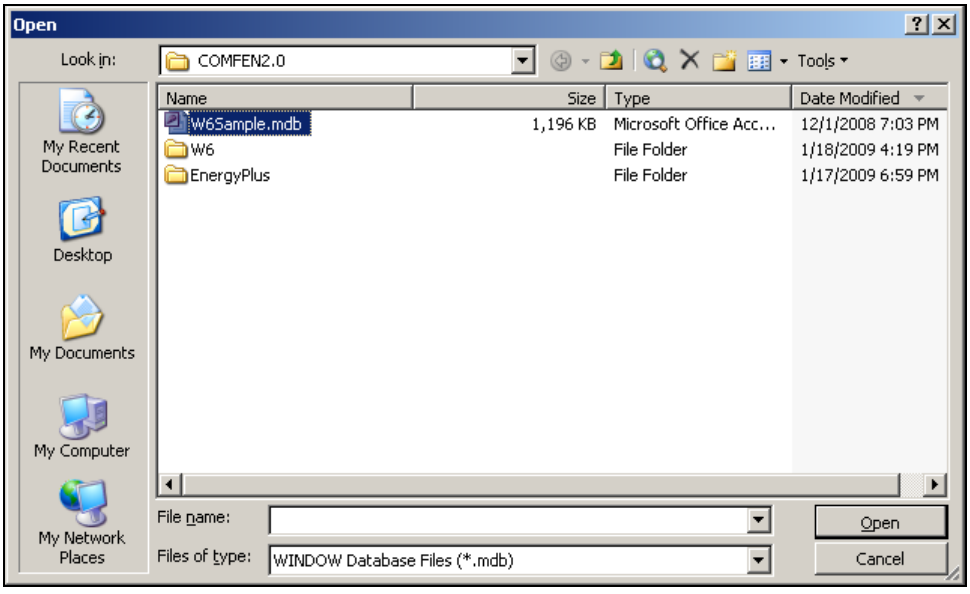


Figure 4-24. Select a WINDOW 6 database from which to import glazing systems

4.2.3. Shading systems

The shading system library is used to model venetian blinds, shades (cloth blinds, roller shades, drapes, etc.) and fixed exterior screen shading systems. The types of shading systems that can currently be modeled in COMFEN are based on the modeling capabilities of the EnergyPlus simulation engine used by COMFEN. Venetian blinds and roller shades can be controlled automatically using one of the control options in COMFEN. The list of systems and available modeling options are summarized in more detail in the sections below.

Venetian Blinds

COMFEN allows modeling of interior, exterior and in-between-glass venetian blinds, which can be defined under the shading system properties screen (see image below). All of these systems can be modeled as fixed or automated using one of COMFEN's predefined shading control algorithms. To access the shading system properties screen, double-click on any shading system under the shading system library tab, or select "New" to create a new system.

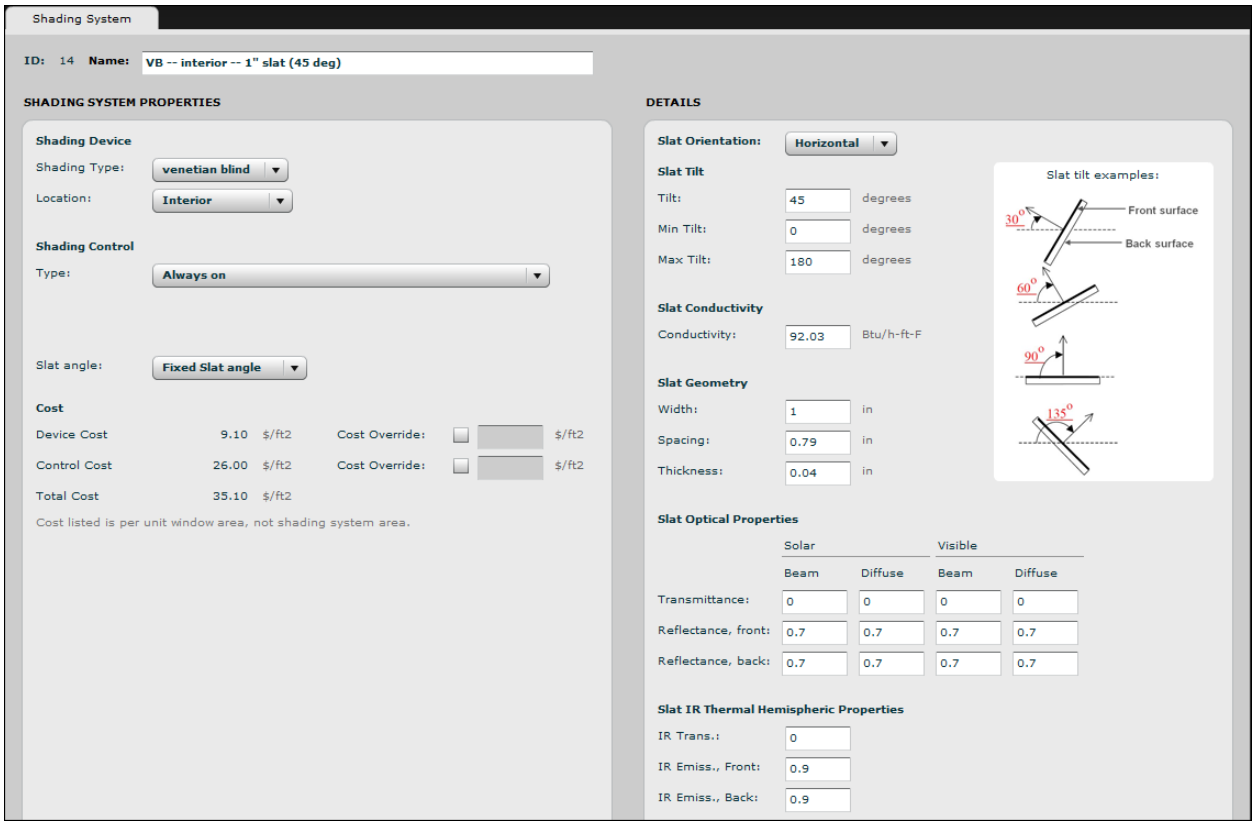


Figure 4-25. Shading system properties screen.

Shading control

The following control options are presently available in COMFEN. Some of the options are limited to specific shading systems. The default shading system setpoints are listed in Table 4-2.

NOTE: *Timestep is equal to 15 minutes.*

Type The following shading control options are available:

- **Always on:** Shading is always lowered/deployed
- **Always off:** Shading is always raised/retracted
- **On If High Solar On Window:** Shading is lowered/deployed if beam solar radiation plus diffuse solar radiation incident on the window exceeds the setpoint (W/m^2). The setpoint value is specified in the control setpoint 1 field.
- **On If High Horizontal Solar:** Shading is lowered/deployed if total (beam plus diffuse) horizontal solar irradiance exceeds setpoint (W/ m^2). The setpoint value is specified in the control setpoint 1 field.
- **On If High Outdoor Air Temp:** Shading is lowered/deployed if outside air temperature exceeds setpoint (˚C). The setpoint value is specified in the Control setpoint 1 field.
- **On If High Zone Air Temp:** Shading is lowered/deployed if the room air temperature in the previous timestep exceeds setpoint (˚C). The setpoint value is specified in the control setpoint 1 field.
- **On If High Zone Cooling:** Shading is lowered/deployed if the room cooling rate in the previous timestep exceeds setpoint (W). The setpoint value is specified in the control setpoint 1 field.
- **On If High Glare:** Shading is lowered/deployed if the daylight glare index (DGI) at the room's first daylighting reference point (sensor #1) exceeds the maximum glare index (22). The calculation is performed assuming that the occupant is positioned at the first daylighting reference point is at desk level - 2'-6" (0.76 m) above floor level.

  The glare view azimuth (i.e. rotation of the sensor) determines the rotation of the occupant from the facade. By default, the azimuth (measured clockwise from an axis normal to the facade) is set to 90˚, i.e. the sensor is rotated 90˚ clockwise from the facade so that it faces one of the zone side walls. For a south-facing zone and a glare view azimuth angle of 90˚ the occupant faces west, while for a west-facing scenario and a glare view azimuth angle of 90˚ the occupant faces north, and so on. The glare view azimuth is equal to 90˚ regardless of orientation.

  Presently the user cannot change the occupant's position or glare view azimuth angle through the COMFEN interface. They can, however, change the glare view azimuth angle by accessing the comfen_settings.xml file in the settings folder. **NOTE:** COMFEN **must be closed** when editing the glare view azimuth angle in the comfen_settings.xml file in order for the change to take effect.
- **On Night If Low Outdoor Temp / Off Day:** Shading is lowered/deployed at night if the outside air temperature is less than the setpoint (˚C). Shading is raised/retracted throughout the day. The setpoint value is specified in the control setpoint 1 field.
- **On Night If Low Inside Temp / Off Day:** Shading is lowered/deployed at night if the room air temperature in the previous timestep is less than the setpoint (˚C). Shading is raised/retracted throughout the day. The setpoint value is specified in the control setpoint 1 field.

- **On Night If Heating / Off Day:** Shading is lowered/deployed at night if the zone heating rate in the previous timestep exceeds the setpoint (W). Shading is raised/retracted throughout the day. The setpoint value is specified in the control setpoint 1 field.
- **On Night If Low Outside Temp / On Day If Cooling:** Shading is lowered/deployed at night if the outside air temperature is less than setpoint (˚C). During the day, shading is raised/retracted if the zone cooling rate in the previous timestep is non-zero. The setpoint value is specified in the control setpoint 1 field.
- **On Night If Heating / On Day If Cooling:** Shading is lowered/deployed at night if the zone heating rate in the previous timestep exceeds setpoint (W). During the day, shading is raised/retracted if the zone cooling rate in the previous timestep is non-zero. The Setpoint value is specified in the control setpoint 1 field.
- **Off Night / On Day If Cooling And High Solar On Window:** Shading is raised/retracted at night. Shading is lowered/deployed during the day if the solar radiation incident on the window exceeds setpoint (W/ m^2) and if the zone cooling rate in the previous timestep is non-zero. The setpoint value is specified in the control setpoint 1 field.
- **On Night / On Day If Cooling And High Solar On Window:** Shading is lowered/deployed throughout the night. During the day, shading is lowered/deployed if the solar radiation incident on the window exceeds setpoint (W/ m^2) and if the zone cooling rate in the previous timestep is non-zero. The setpoint value is specified in the control setpoint 1 field.
- **On If High Zone Air Temp And High Solar On Window:** Shading is lowered/deployed if the room air temperature in the previous timestep exceeds Setpoint 1 (˚C) and if the solar radiation incident on the zone window exceeds Setpoint 2 (W/ m^2). The setpoint values are specified in the control setpoint 1 and Control setpoint 2 fields.
- **On If High Zone Air Temp And High Horizontal Solar:** Shading is lowered/deployed if the room air temperature in the previous timestep exceeds the Setpoint 1 (˚C) and if the horizontal solar radiation on the zone window exceeds Setpoint 2 (W/m^2). The setpoint values are specified in the control setpoint 1 and control setpoint 2 fields.
- **On If High Outside Air Temp And High Solar On Window:** Shading is lowered/deployed if the outside air temperature exceeds Setpoint 1 (˚C) and if the solar radiation incident on the window exceeds setpoint 2 (W/ m^2). The setpoint values are specified in the control setpoint 1 and Control setpoint 2 fields.
- **On If High Outside Air Temp And High Horizontal Solar:** Shading is lowered/deployed if the outside air temperature exceeds the Setpoint 1 (˚C) and if the horizontal solar radiation on the window exceeds Setpoint 2 (W/m^2). The setpoint values are specified in the Set Point 1 and Set Point 2 fields.

Slat Angle

The following slat control options are available for venetian blinds:

- Fixed slat angle: Slat angle is fixed at the angle defined under the slat tilt input field.
- Block beam solar: Slat angle is adjusted at every simulation timestep (15 minutes) in order to block direct solar radiation from coming into the room. The minimum slat tilt (min. tilt) and maximum slat tilt (max. tilt) entries under the "Details" section of the shading properties dialog box define the range of slat rotation.

The list of available shading control types in COMFEN is based on the modeling features of Energy Plus. The Energy Plus Input/Output Reference documentation (found on their website at http://apps1.eere.energy.gov/buildings/energyplus/energyplus_documentation.cfm) contains detailed information about each control.

Table 4-3. Shading System Controls Strategies

Shading Control	Setpoint 1 default value	Setpoint 1 Units	Setpoint 1 default value	Setpoint 2 Units
Always On	N/A	N/A	N/A	N/A
On If High Solar On Window	- -	W/m² (SI) Btu/h-ft² (IP)	N/A	N/A
On If High Horizontal Solar	- -	W/m² (SI) Btu/h-ft² (IP)	N/A	N/A
On If High Outdoor Air Temperature	- -	˚C (SI) ˚F (IP)	N/A	N/A
On If High Zone Air Temperature	- -	˚C (SI) ˚F (IP)	N/A	N/A
On If High Zone Cooling	- -	Watts (SI) BTU/hr (IP)	N/A	N/A
On If High Glare*	N/A	N/A	N/A	N/A
On Night If Low Outdoor Temp And Off Day	- -	˚C (SI) ˚F (IP)	N/A	N/A
On Night If Low Inside Temp And Off Day	- -	˚C (SI) ˚F (IP)	N/A	N/A
On Night If Heating And Off Day	- -	Watts (SI) BTU/hr (IP)	N/A	N/A
On Night If Low Outdoor Temp And On Day If Cooling	- -	˚C (SI) ˚F (IP)	N/A	N/A
On Night If Heating And On Day If Cooling	- -	Watts (SI) BTU/hr (IP)	N/A	N/A
Off Night And On Day If Cooling And High Solar On Window	- -	W/m² (SI) Btu/h-ft² (IP)	N/A	N/A
On Night And On Day If Cooling And High Solar On Window	- -	W/m² (SI) Btu/h-ft² (IP)	N/A	N/A
On If High Zone Air Temp And High Solar On Window	- -	˚C (SI) ˚F (IP)	0 0	W/m² (SI) Btu/h-ft² (IP)
On If High Zone Air Temp And High Horizontal Solar	- -	˚C (SI) ˚F (IP)	0 0	W/m² (SI) Btu/h-ft² (IP)
On If High Outdoor Air Temp And High Solar On Window	- -	˚C (SI) ˚F (IP)	0 0	W/m² (SI) Btu/h-ft² (IP)
On If High Outdoor Air Temp And High Horizontal Solar	- -	˚C (SI) ˚F (IP)	0 0	W/m² (SI) Btu/h-ft² (IP)

* When this option is selected, no setpoint input is required; shading is automatically retracted when the Daylight Glare Index exceeds 22.

Slat Orientation

Orientation of the venetian blind, either:

- Horizontal - slat is parallel to window sill

- Vertical - slat is perpendicular to window sill

Slat Tilt

Tilt The rotation of the slat, measured clockwise from the glazing normal to the slat normal. (Min: 0, Max: 180)

Min Tilt The minimum rotation of the slat, measured clockwise from the glazing normal to the slat normal. Used for the "Block Beam Solar" control. Units: degrees (Min: 0, Max: 180)

Max Tilt The maximum rotation of the slat, measured clockwise from the glazing normal to the slat normal. Used for the "Block Beam Solar" control. Units: degrees (Min: 0, Max: 180)

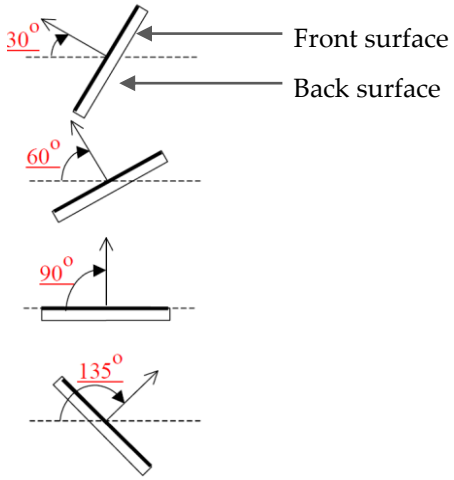


Figure 4-26. Slat angle definition

(Source: EnergyPlus Input Output Reference)

Slat Conductivity The conductivity of the slat material. Units: Btu/h-ft-oF (IP), W/m-K (SI)

Slat Geometry

Width The width of the slat. Units: inches (IP), mm (SI)

Spacing The spacing between slats. Units: inches (IP), mm (SI)

Thickness The thickness of the slat. Units: inches (IP), mm (SI)

NOTE: *COMFEN will not run if slats overlap, so when slat spacing is less than the slat width, make sure that the minimum and maximum slat angles account for the fact that slat angle will be greater than 0 (or smaller than 180) when blinds are completely closed.*

NOTE: *In-between venetian blinds can only be simulated in double and triple glazing systems.*

Slat Optical Properties

Transmittance, Beam Solar Slat tranmittance for direct beam solar radiation.

Transmittance,

Diffuse Solar	Slat tranmittance for diffuse solar radiation.
Transmittance, Beam Visible	Slat transmittance for direct beam visible radiation.
Transmittance, Diffuse Visible	Slat transmittance for diffuse visible radiation.
Reflectance, front Beam Solar	Reflectance on the front surface of the slat for direct beam solar radiation.
Reflectance, front Diffuse Solar	Reflectance on the front surface of the slat for diffuse solar radiation.
Reflectance, front Beam Visible	Reflectance on the front surface of the slat for direct beam visible radiation.
Reflectance, front Diffuse Visible	Reflectance on the front surface of the slat for diffuse visible radiation.
Reflectance, back Beam Solar	Reflectance on the back surface of the slat for direct beam solar radiation.
Reflectance, back Diffuse Solar	Reflectance on the back surface of the slat for diffuse solar radiation.
Reflectance, back Beam Visible	Reflectance on the back surface of the slat for direct beam visible radiation.
Reflectance, back Diffuse Visible	Reflectance on the back surface of the slat for diffuse visible radiation.

Slat IR Thermal Hemispheric Properties

IR Trans.	Slat transmittance for infrared radiation
IR Emiss., Front	Emissivity of the front surface of the slat. Default value: 0.9
IR Emiss., Back	Emissivity of the back surface of the slat. Default value: 0.9

Fixed Exterior Screens

COMFEN allows modeling of fixed exterior mesh screens, which can be defined under the shading system properties screen (see image below). This system can only be modeled as fixed. There are no controls associated with exterior screens. To access the shading system properties screen, double-click on any shading system under the shading system library tab, or select “New” to create a new system.

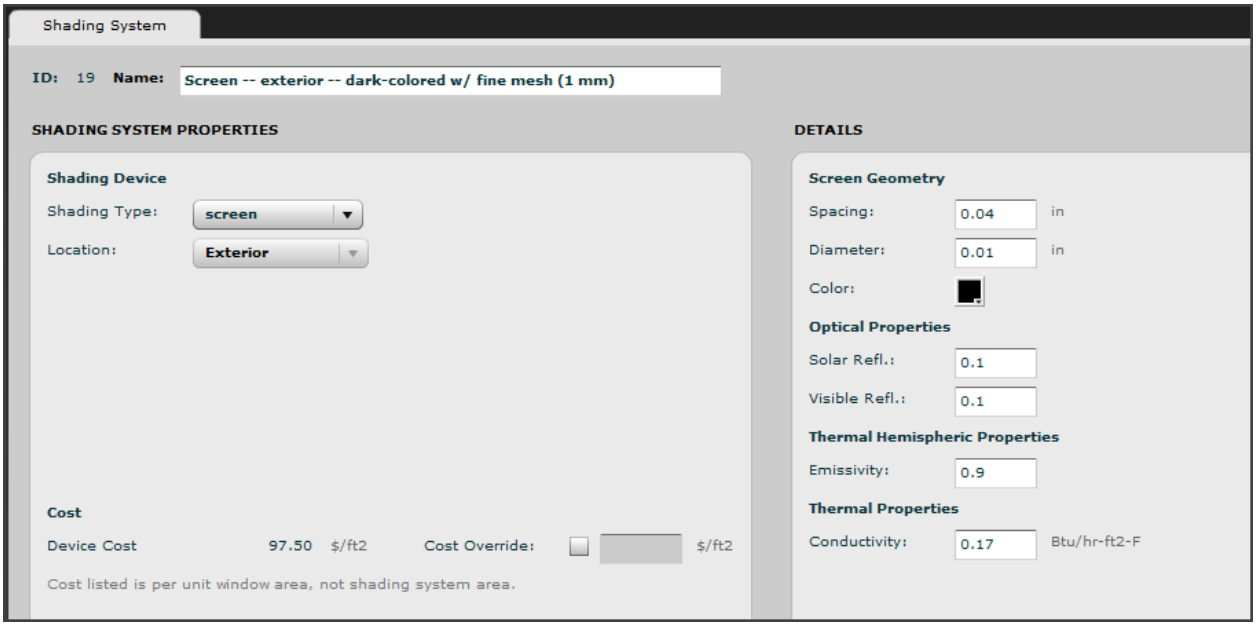


Figure 4-27. Shading system properties screen.

Screen Geometry

Spacing This value is the spacing between threads in the weave of the fabric of the woven shade.

Diameter This value is the diameter of an individual thread in the fabric of the woven shade.

Color User-selected color associated with shading system in the COMFEN model. Default is black.

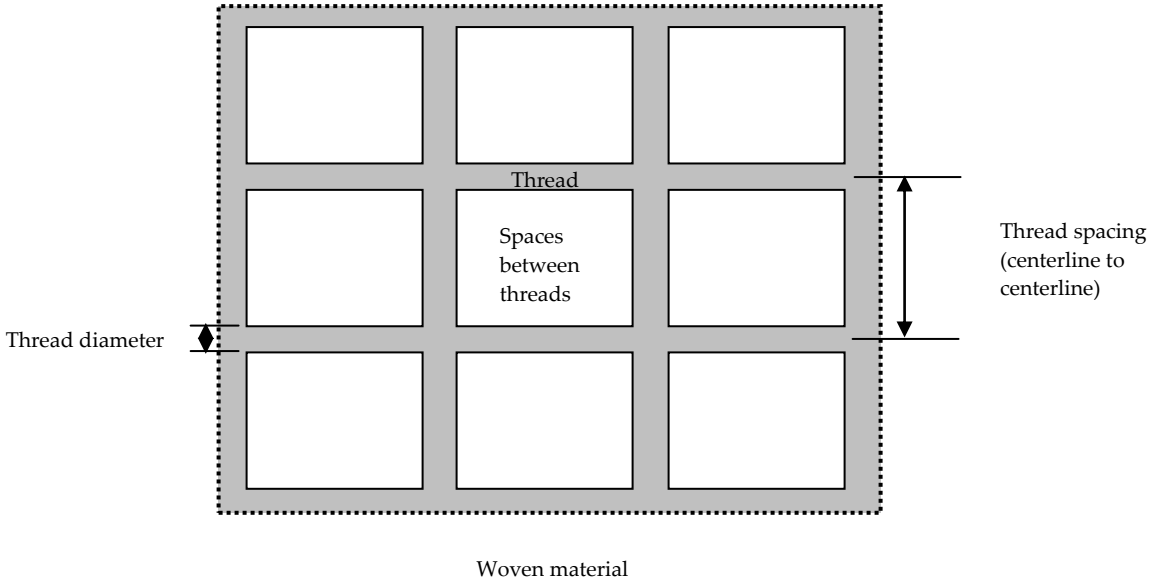


Figure 4-28. Woven shade geometry definitions.

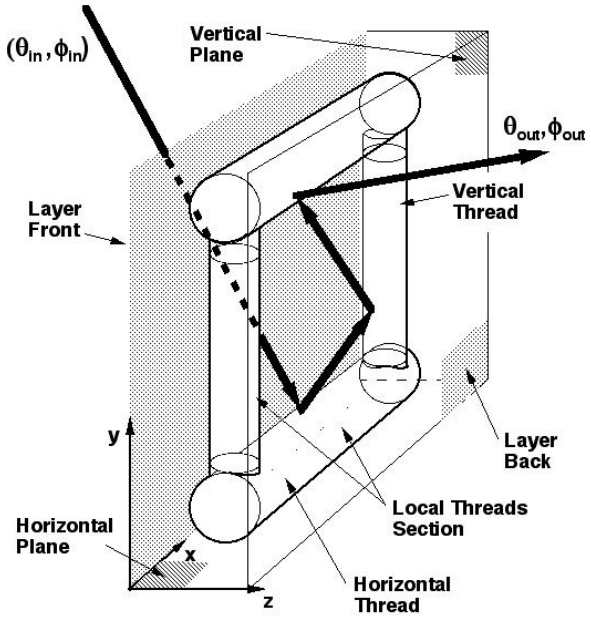


Figure 4-29. Woven shade modeling technique.

Optical Properties

Solar Reflectance Reflectance for solar radiation. Assumed same on both sides of shade.

Visible Reflectance Reflectance for visible radiation. Assumed same on both sides of shade.

Thermal Hemispheric Properties

Emissivity Emissivity of the surface of the screen, assumed same on both sides. Default value: 0 (input value must be > 0, and < 1)

Thermal Properties

Conductivity Conductivity of the screen material, assumed same on both sides. Default value: 0 (input value must be > 0, and < 1)

4.2.4. Frames

The frame library consists of a predefined set of frames. The thermal properties of these frames are characteristic of commercially-available systems. Due to limitations in the Energy Plus simulation engine, highly conductive frames such as aluminum frames without a thermal break cannot be modeled. The U-factor cannot exceed 1.1 Btu/h-ft2-F (6.2 W/m2-K). In order to account for the effect of framing with a U-factor exceeding this limit, the user could increase the area of the modeled framing.

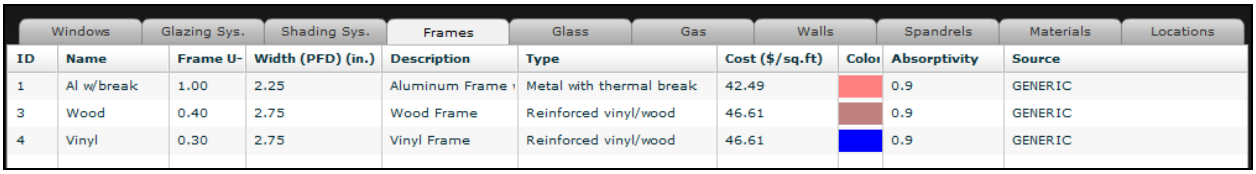


Figure 4-30. Frame library list view

The frame edit dialog box consists of the following inputs:

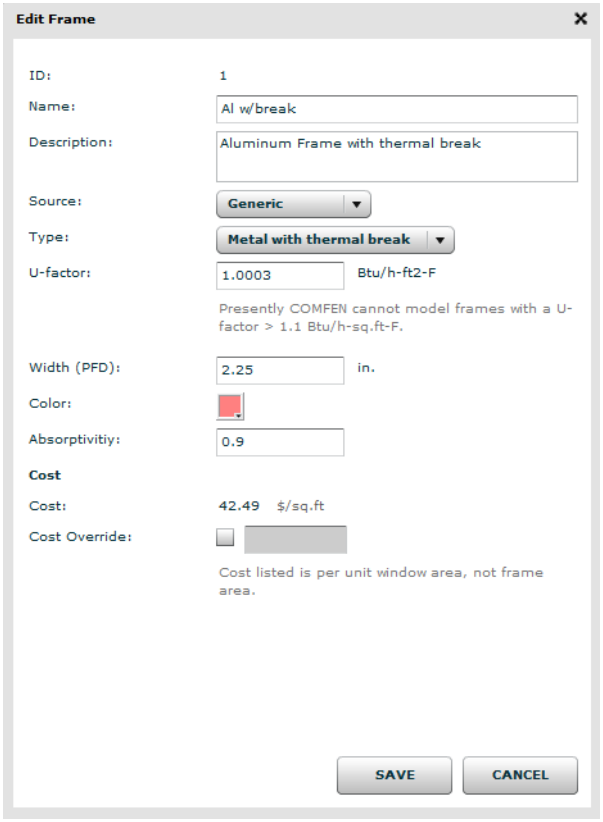


Figure 4-31 Edit frame dialog box

4.2.5. Glass

The glass library contains entries from the International Glazing Database (IGDB) – a database containing measured performance data for commercially-available glass products. This performance data is submitted by manufacturers to LBNL, where it undergoes a technical and peer review prior to its incorporation in the IGDB. While the latest version of the IGDB database is automatically installed with COMFEN, it is updated bimonthly by LBNL in an effort to ensure that it contains all of the latest commercially-available products. COMFEN users are encouraged to periodically update their libraries by downloading a COMFEN *.sqlite IGDB update file from the COMFEN online Knowledge Base.
Below is a description of select fields in the glass library:

NFRC ID The ID field in the glazing system edit view refers to the glass or gas layers, and displays the NFRC identification number from the IGDB used in WINDOW 6 software. This field cannot be edited by the user.

Name The IGDB filename for the glass layer or the name of the gas layer. These names come from the respective glass and gas selection lists, and cannot be edited by the user.

Thickness The thickness of the glass or gas layer. The glass layer thickness values cannot be edited, but the gap (gas) layer thicknesses can be edited by the user. Units: mm

Source Lists the IGDB version.

Emis1 Emissivity of the front surface of the glass layer. This value is 0.84 for uncoated glass. The emissivity values for front and back can be used to determine if a layer should be "flipped" so that the coating is on the correct surface. This field cannot be edited by the user.

Emis2 Emissivity of the back surface of the glass layer. See comment for front emissivity above.

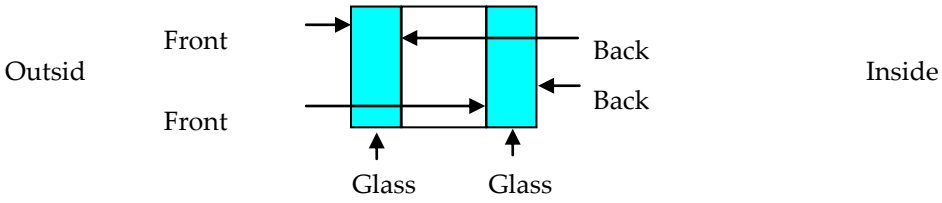
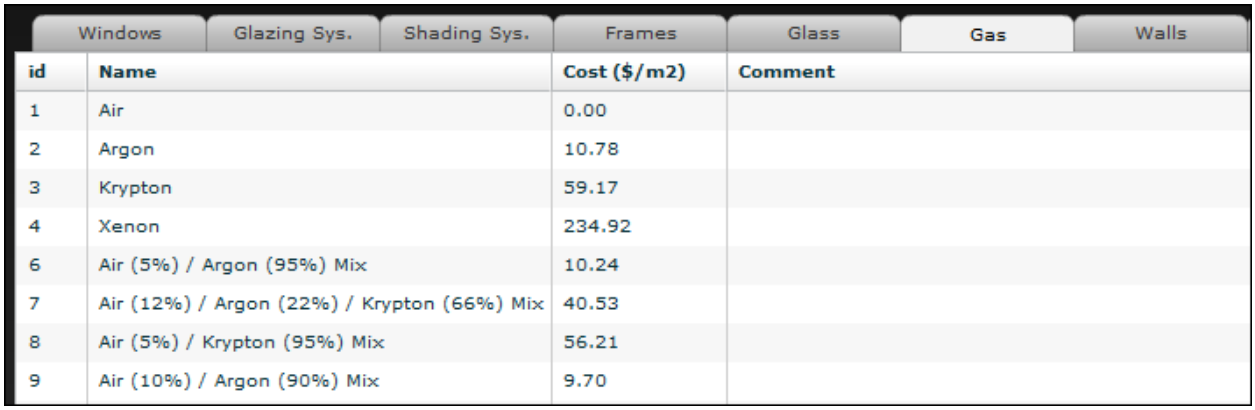


Figure 4-32. Definition of front and back glass layer surfaces

4.2.6. Gas

The entries in the COMFEN gas library come from a database that is installed with COMFEN, which contains the standard gases defined in the LBNL WINDOW software programs. The figure below shows the current gases available for glazing systems in COMFEN. The gas layers are used in the creation of COMFEN glazing systems.



id	Name	Cost ($/m2)	Comment
1	Air	0.00	
2	Argon	10.78	
3	Krypton	59.17	
4	Xenon	234.92	
6	Air (5%) / Argon (95%) Mix	10.24	
7	Air (12%) / Argon (22%) / Krypton (66%) Mix	40.53	
8	Air (5%) / Krypton (95%) Mix	56.21	
9	Air (10%) / Argon (90%) Mix	9.70	

Figure 4-33. COMFEN gas library

4.2.7. Walls

The scenario wall construction can be changed under the scenario tab, where any wall from the wall library can be selected from a drop-down menu. All of the walls listed under this drop-down can be edited and deleted under the wall library.

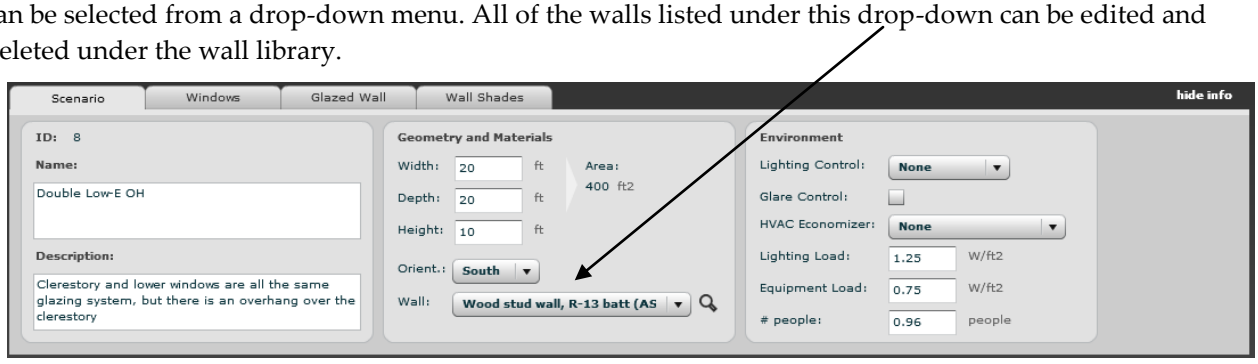
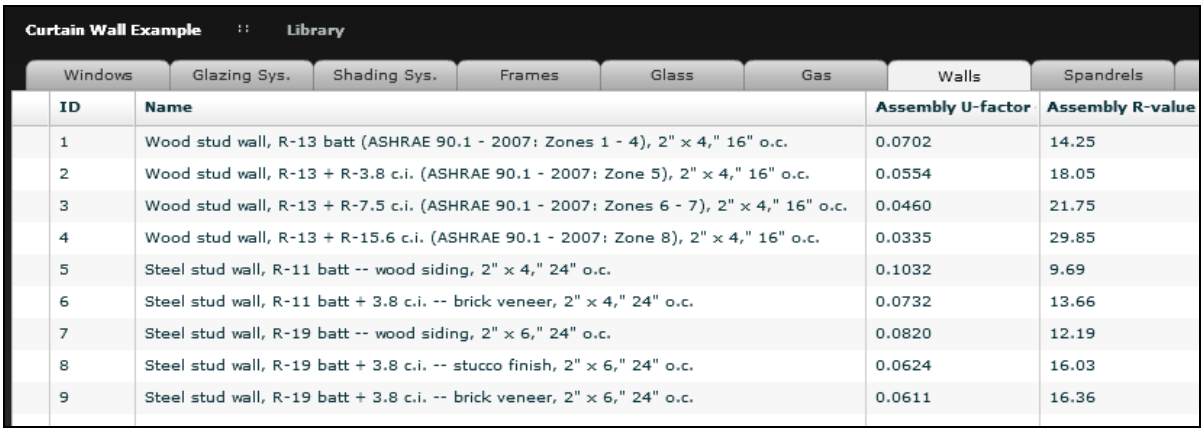


Figure 4-34. Scenario Wall Construction Reference

Wall library

To access the wall library, go to the menu - Libraries > Walls. The first few walls in the library represent wood stud walls that comply with the requirements of ASHRAE Standard 90.1; these walls meet ASHRAE minimum wall R-value requirements for specific climate zones. The effect of thermal bridging at the wood studs within the cavity is already accounted for, i.e. frame spacing and width, requirements for cavity insulation and continuous insulation (c.i.) outboard of the cavity match ASHRAE prescriptive method requirements. When a user creates a new project, an ASHRAE-compliant wall is automatically assigned to the project as the default wall based on the project's location and climate zone.



ID	Name	Assembly U-factor	Assembly R-value
1	Wood stud wall, R-13 batt (ASHRAE 90.1 - 2007: Zones 1 - 4), 2" x 4," 16" o.c.	0.0702	14.25
2	Wood stud wall, R-13 + R-3.8 c.i. (ASHRAE 90.1 - 2007: Zone 5), 2" x 4," 16" o.c.	0.0554	18.05
3	Wood stud wall, R-13 + R-7.5 c.i. (ASHRAE 90.1 - 2007: Zones 6 - 7), 2" x 4," 16" o.c.	0.0460	21.75
4	Wood stud wall, R-13 + R-15.6 c.i. (ASHRAE 90.1 - 2007: Zone 8), 2" x 4," 16" o.c.	0.0335	29.85
5	Steel stud wall, R-11 batt -- wood siding, 2" x 4," 24" o.c.	0.1032	9.69
6	Steel stud wall, R-11 batt + 3.8 c.i. -- brick veneer, 2" x 4," 24" o.c.	0.0732	13.66
7	Steel stud wall, R-19 batt -- wood siding, 2" x 6," 24" o.c.	0.0820	12.19
8	Steel stud wall, R-19 batt + 3.8 c.i. -- stucco finish, 2" x 6," 24" o.c.	0.0624	16.03
9	Steel stud wall, R-19 batt + 3.8 c.i. -- brick veneer, 2" x 6," 24" o.c.	0.0611	16.36

Figure 4-35. Wall Construction Library List View

Creating a new wall

To add a new wall to the COMFEN library, go to Libraries > Walls, to pull up the wall library, and then click "New." This pulls up the wall create/edit screen. The table on the left side of the screen shows the wall assembly. Wall layers are added by dragging entries from the material library on the right side of the screen. Layers in the wall construction table can be reordered by dragging the entries. The table columns are described below.

	The first column represents the layer number. Layers are counted from the outermost (outside) layer to the innermost (inside) layer.
ID	Unique material ID#
Material	Material name
Framing	Indicates whether the layer is continuous or discontinuous. For the latter option, the layer is designated as either framing or cavity. This option is intended for modeling layers with thermal bridging such as wood stud walls with insulated cavities (COMFEN cannot presently model steel stud cavities). The user specifies % framing area below the table. COMFEN calculates the effective wall R-value using the isothermal planes method which accounts for the effect of thermal bridging through wood studs. See appendix (ctrl+click to follow link) for a description of the calculation methodology.
Thickness	Thickness of the material layer
R-value frame	R-value of the layer designated as "framing"
R-value cavity	R-value of the layer designated as "cavity"

Wall assembly characteristics

% framing	Width of framing/framing spacing * 100%. Range: 1 to 99%
U-factor	Effective U-factor for whole wall (accounts for effect of framing and outside and inside film coefficients).

R-value Effective R-value for whole wall (accounts for effect of framing and outside and inside film coefficients)

Assembly thickness Effective wall thickness

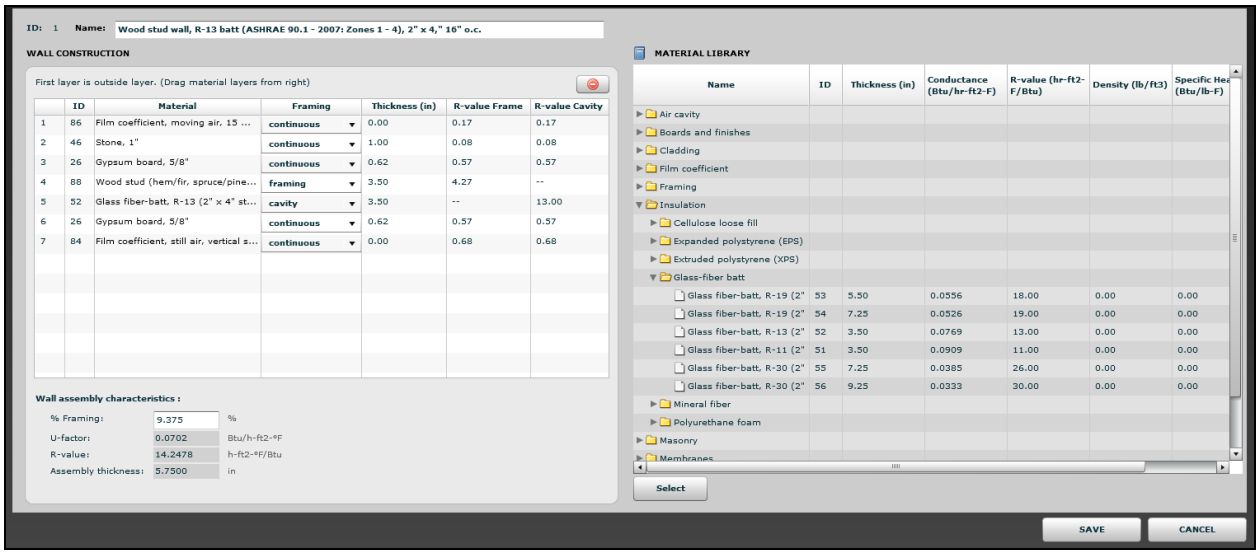
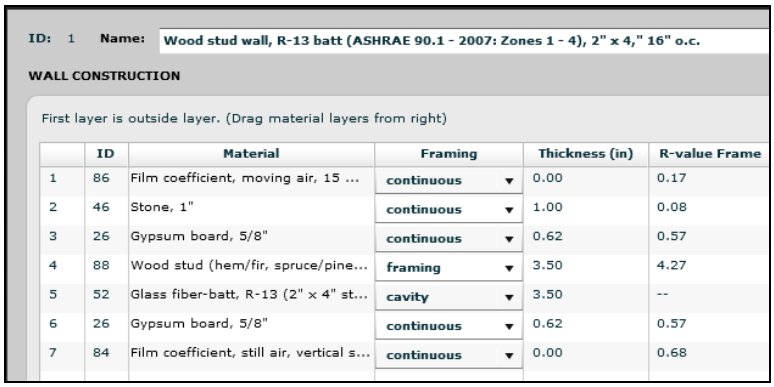


Figure 4-36. Wall Construction Detail View

NOTE: *While COMFEN can accurately model thermal bridging through wood stud cavities, it cannot presently calculate the resistance of a wall with highly conductive materials, such as metal studs. However sample steel stud walls have been provided in the wall library.*

NOTE: *When creating a wall, the following conditions must be met:*

1. *The outermost and innermost layers of the construction must be air films (materials from the "film coefficient" group).*
2. *A wall with a "composite" layer - a combination of two discontinuous materials such as wood studs (framing) with insulation in the cavity must have a continuous "enclosing" layer on either side of the composite: a "regular" or "lightweight" material type. The cavity and framing must be modeled as adjacent layers.*
3. *If you define a material as a "cavity" in the wall construction table on the left-hand screen of the wall edit screen, you also have to define a "framing" material, and vice versa.*
4. *Framing materials must come from the framing group in the material library and cavity materials must come from the air cavity or insulation group.*
5. *Air spaces must be inbetween two other construction materials (i.e. material types "regular" and/or "lightweight"). Air spaces cannot be adjacent to one another.*



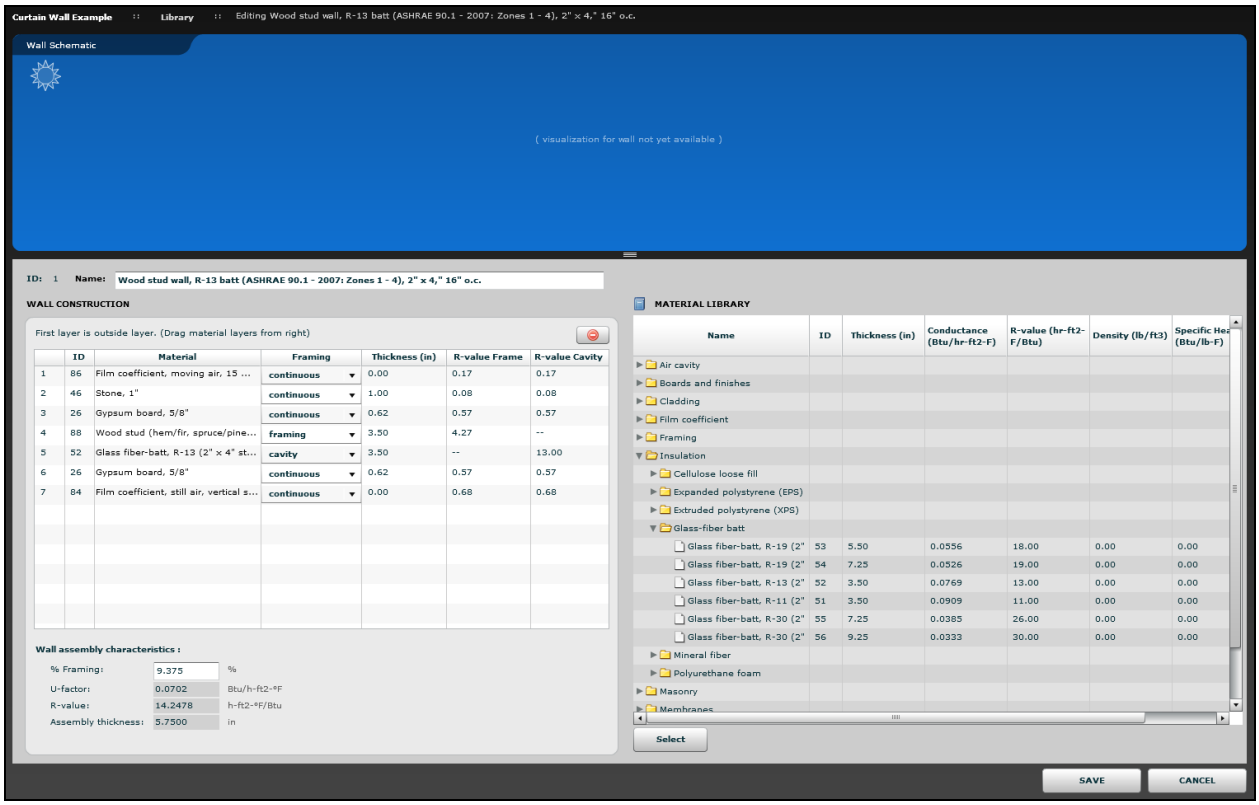


Figure 4-37. Creating a New Wall Construction

Changing the default project wall

The user can change the default project wall defined based on the project location (see Project > Project properties dialog box) at the scenario or project level. To change the wall for the scenario, double-click on the scenario in the explorer and go to the scenario tab. Under the Geometry and materials section, click on the search icon to bring up a list of walls in the library. Highlight a wall of choice and click ***Select*** to assign wall to scenario.

NOTE: *The default wall assigned to projects can also be changed under the location tab. To do this, go to the location library (Libraries > Locations) and double-click on the location (you may want to make a copy of the original location beforehand and edit the copy rather than the original location entry to conserve the defaults). Once open, select wall of*

choice under the default wall drop-down and save the revised location. Any project created with this location will now have the new default wall automatically assigned to it.

4.2.8. Spandrels

Spandrels can only be assigned to scenarios with a glazed wall assembly. To assign a spandrel to a glazed wall assembly, highlight one or more glazing units in the scenario view by clicking and dragging from left to right over the desired glazing units or clicking while holding shift. Right-click within the highlighted area to bring up the glazed wall assembly menu and select "Set to spandrel." This will bring up a list of spandrels in the library. Select the spandrel of choice and click "Select." To edit the spandrel, select "Set to spandrel" in the glazed wall assembly menu to once again bring up the list of options.

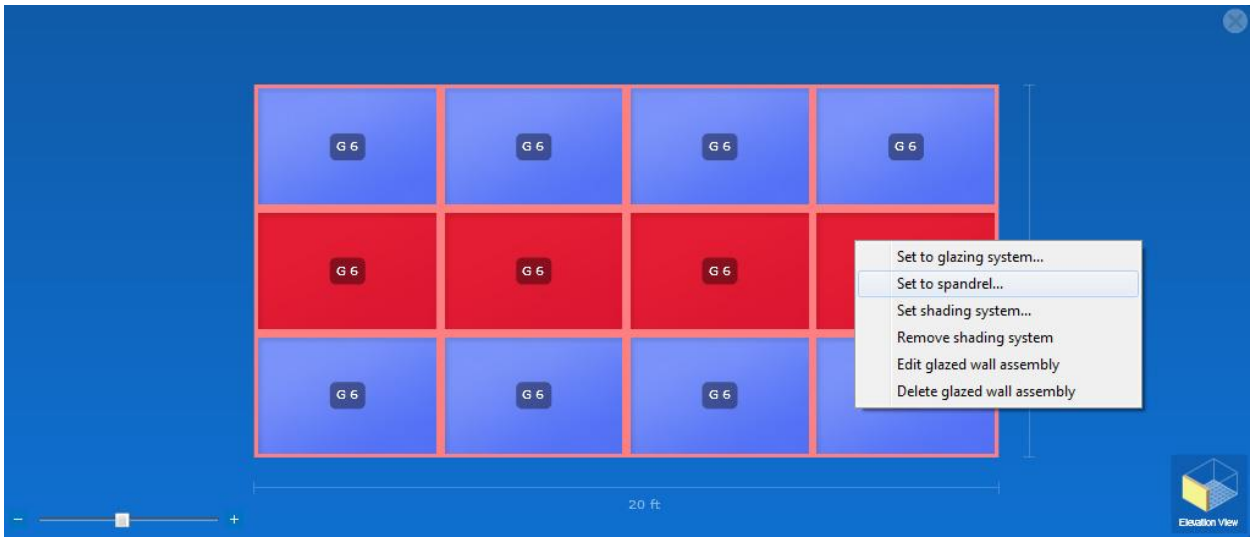


Figure 4-38. Defining Spandrels

Spandrel library

To access the spandrel library, go to the menu - Libraries > Spandrels. The existing entries represent examples of typical spandrel construction. The user can add new spandrel constructions to the library as needed.

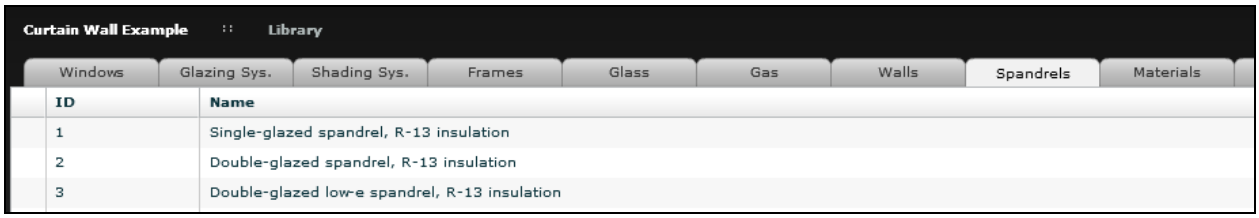


Figure 4-39. Material properties dialog box

Creating a new spandrel

To add a new spandrel to the COMFEN library, go to Libraries > Spandrels to pull up the spandrel library, and then click "New." This pulls up the spandrel create/edit screen. Here, you can drag materials from the right-side of the screen to create a custom spandrel.

NOTE: *When creating a spandrel, the following conditions must be met:*

1. *The outermost and innermost layers of the construction must be air films (materials from the "film coefficient" group).*

2. *Air spaces must be inbetween two other construction materials (i.e. material types "regular" and/or "lightweight"). There cannot be adjacent air spaces within the construction.*
3. *Only glazing systems with up to three glass layers can be specified in a spandrel.*
4. *Multiple glazing systems within a spandrel are not allowed; only one glazing system or glass layer can be used.*

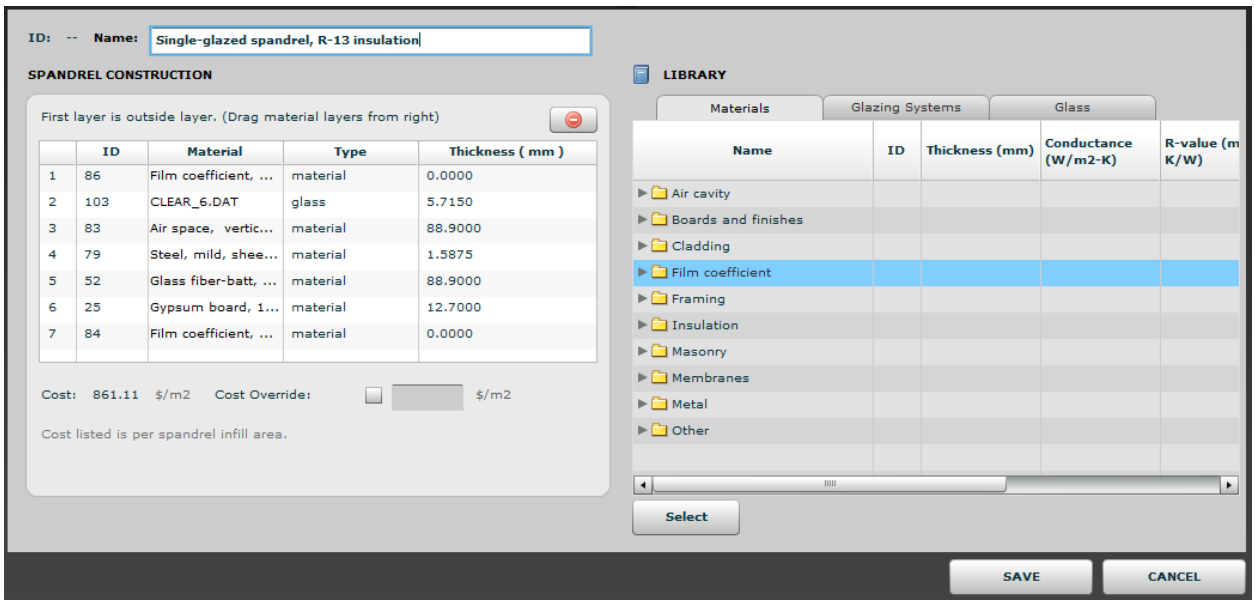
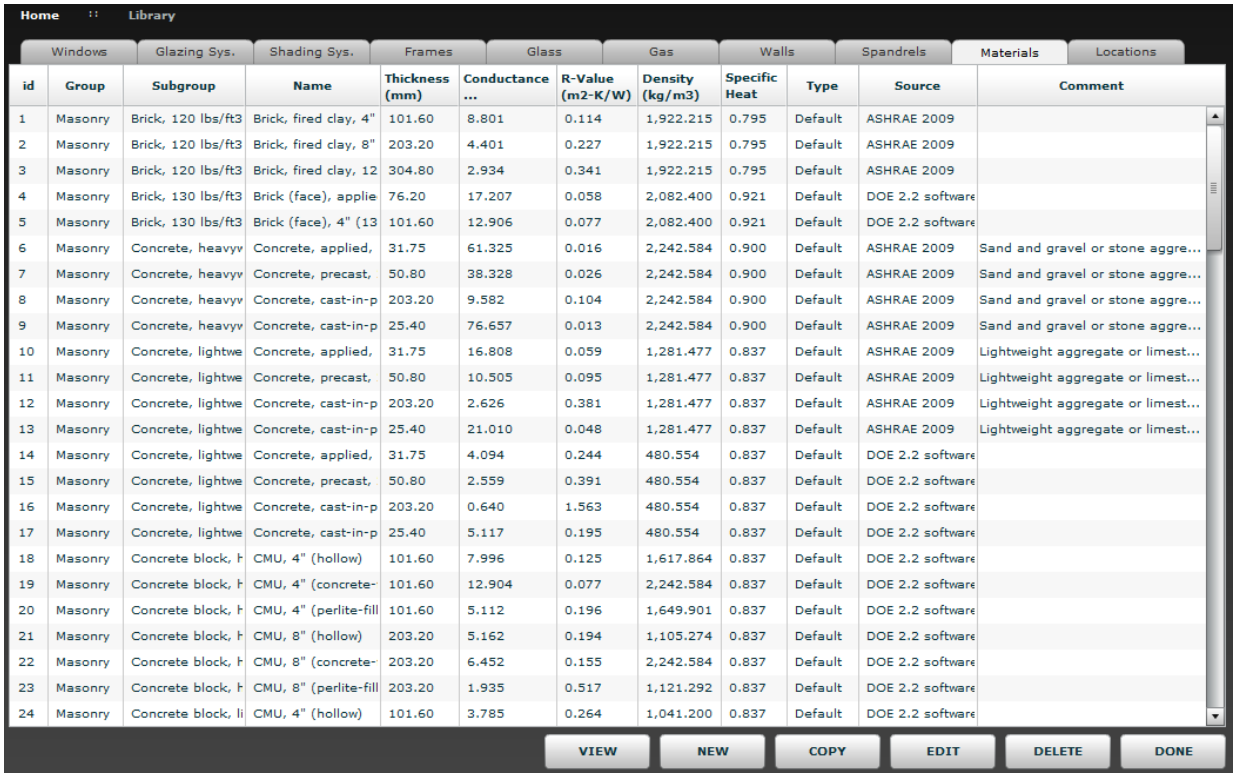


Figure 4-40. Spandrel Library Detailed View

4.2.9. Materials

The material library contains a range of predefined construction materials used for wall and spandrel assemblies. New materials can be easily added to the library. A number of properties need to be defined for a typical material in order to ensure that heat transfer through the material is modeled correctly by the program.



id	Group	Subgroup	Name	Thickness (mm)	Conductance ...	R-Value (m2-K/W)	Density (kg/m3)	Specific Heat	Type	Source	Comment
1	Masonry	Brick, 120 lbs/ft3	Brick, fired clay, 4"	101.60	8.801	0.114	1,922.215	0.795	Default	ASHRAE 2009	
2	Masonry	Brick, 120 lbs/ft3	Brick, fired clay, 8"	203.20	4.401	0.227	1,922.215	0.795	Default	ASHRAE 2009	
3	Masonry	Brick, 120 lbs/ft3	Brick, fired clay, 12	304.80	2.934	0.341	1,922.215	0.795	Default	ASHRAE 2009	
4	Masonry	Brick, 130 lbs/ft3	Brick (face), applie	76.20	17.207	0.058	2,082.400	0.921	Default	DOE 2.2 software	
5	Masonry	Brick, 130 lbs/ft3	Brick (face), 4" (13	101.60	12.906	0.077	2,082.400	0.921	Default	DOE 2.2 software	
6	Masonry	Concrete, heavyv	Concrete, applied,	31.75	61.325	0.016	2,242.584	0.900	Default	ASHRAE 2009	Sand and gravel or stone aggre...
7	Masonry	Concrete, heavyv	Concrete, precast,	50.80	38.328	0.026	2,242.584	0.900	Default	ASHRAE 2009	Sand and gravel or stone aggre...
8	Masonry	Concrete, heavyv	Concrete, cast-in-p	203.20	9.582	0.104	2,242.584	0.900	Default	ASHRAE 2009	Sand and gravel or stone aggre...
9	Masonry	Concrete, heavyv	Concrete, cast-in-p	25.40	76.657	0.013	2,242.584	0.900	Default	ASHRAE 2009	Sand and gravel or stone aggre...
10	Masonry	Concrete, lightwe	Concrete, applied,	31.75	16.808	0.059	1,281.477	0.837	Default	ASHRAE 2009	Lightweight aggregate or limest...
11	Masonry	Concrete, lightwe	Concrete, precast,	50.80	10.505	0.095	1,281.477	0.837	Default	ASHRAE 2009	Lightweight aggregate or limest...
12	Masonry	Concrete, lightwe	Concrete, cast-in-p	203.20	2.626	0.381	1,281.477	0.837	Default	ASHRAE 2009	Lightweight aggregate or limest...
13	Masonry	Concrete, lightwe	Concrete, cast-in-p	25.40	21.010	0.048	1,281.477	0.837	Default	ASHRAE 2009	Lightweight aggregate or limest...
14	Masonry	Concrete, lightwe	Concrete, applied,	31.75	4.094	0.244	480.554	0.837	Default	DOE 2.2 software	
15	Masonry	Concrete, lightwe	Concrete, precast,	50.80	2.559	0.391	480.554	0.837	Default	DOE 2.2 software	
16	Masonry	Concrete, lightwe	Concrete, cast-in-p	203.20	0.640	1.563	480.554	0.837	Default	DOE 2.2 software	
17	Masonry	Concrete, lightwe	Concrete, cast-in-p	25.40	5.117	0.195	480.554	0.837	Default	DOE 2.2 software	
18	Masonry	Concrete block, h	CMU, 4" (hollow)	101.60	7.996	0.125	1,617.864	0.837	Default	DOE 2.2 software	
19	Masonry	Concrete block, h	CMU, 4" (concrete-	101.60	12.904	0.077	2,242.584	0.837	Default	DOE 2.2 software	
20	Masonry	Concrete block, h	CMU, 4" (perlite-fill	101.60	5.112	0.196	1,649.901	0.837	Default	DOE 2.2 software	
21	Masonry	Concrete block, h	CMU, 8" (hollow)	203.20	5.162	0.194	1,105.274	0.837	Default	DOE 2.2 software	
22	Masonry	Concrete block, h	CMU, 8" (concrete-	203.20	6.452	0.155	2,242.584	0.837	Default	DOE 2.2 software	
23	Masonry	Concrete block, h	CMU, 8" (perlite-fill	203.20	1.935	0.517	1,121.292	0.837	Default	DOE 2.2 software	
24	Masonry	Concrete block, li	CMU, 4" (hollow)	101.60	3.785	0.264	1,041.200	0.837	Default	DOE 2.2 software	

Figure 4-41. Material library list view

Material properties dialog box input fields:

ID A unique material ID automatically generated when a material is created

Name A unique material name assigned by user

Group Primary material library subdivisions (e.g. masonry, boards and finishes, insulation, cladding, membranes, etc.)

Subgroup Group subdivision

Source Source from which material properties were obtained, e.g. ASHRAE Handbook of Fundamentals

Type This field is used to characterize the material's thermophyscial properties, primarily its thermal storage capacity. The field also determines the required inputs for the material properties dialog box. COMFEN recognizes three different types of materials:

1. **Regular (with thermal capacity):** A material with thermal storage capacity; this is the default material type for materials. This option should typically be selected as it will ensure that EnergyPlus will account for the thermal mass of the material and thus evaluate the effect of transient conduction. This material type requires that a range of thermophysical properties be specified.

   Required inputs: Conductance, density, specific heat, emissivity (front), emissivity (back), thickness, and optical properties: solar transmittance and reflectance (front and back), visible transmittance and reflectance (front and back), and IR transmittance.

2. **Lightweight (no thermal capacity):** Similar to a "Regular (no thermal capacity)" material, however the material's thermal storage capacity is not taken into account. Option should only be used for materials with minimal thermal storage capacity (e.g. insulation).

   Required inputs: Same as default material type, except density and specific heat are not required. Also, thermal resistance (R-value) is required in place of conductance.

3. **Air gap:** This option is used to define an air gap between layers in a construction. Similar to a lightweight material, the thermal capacity of an air gap layer is negligible. However since the layer is not exposed to any external environment, surface properties such as absorptance and reflectance are not a required input.

   Required inputs: Thermal resistance (R-value) and thickness

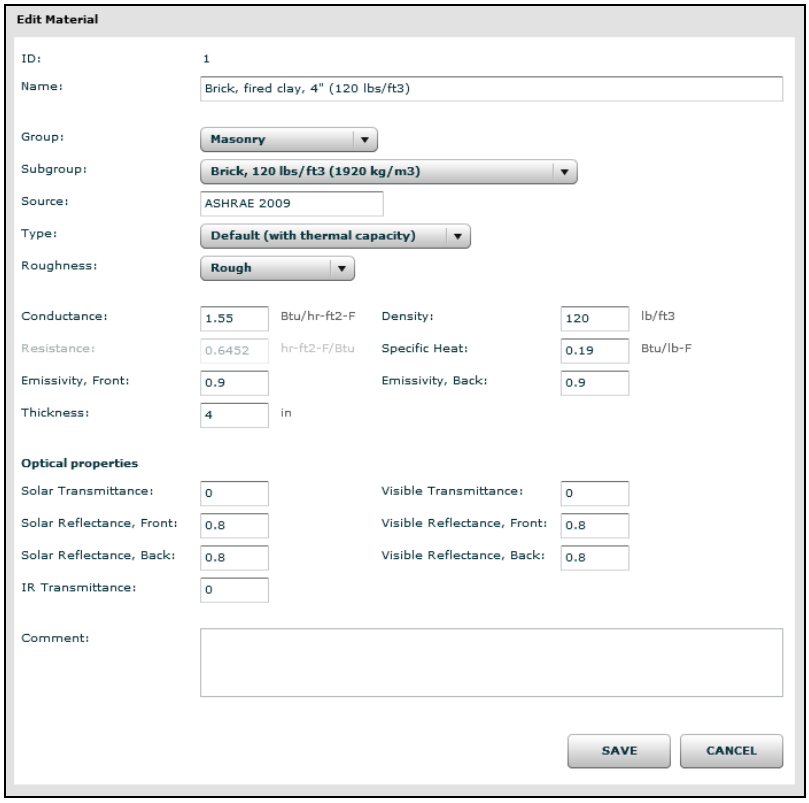


Figure 4-42. Material properties dialog box

Energy Plus Documentation: Note that the corresponding Energy Plus material descriptors for the COMFEN material types listed are "Material," "Material:NoMass" and "Material:AirGap." For a more detailed description of the Energy Plus material types please refer to the "Group – Surface Construction Elements" chapter in the *Energy Plus Input Output Reference*.

Roughness Field used to define material roughness, a property which influences convection coefficients used in the calculation of surface heat transfer. Inputs range from very rough

to very smooth. Only default and lightweight materials require a roughness input. The following table lists roughness categories and provides examples of specific construction materials.

Table 4-4. Example of different roughness materials

Roughness index	**Example material**
Very rough	Stucco
Rough	Brick, rough plaster, rough stone, unfinished terra cotta tile
Medium rough	Concrete
Medium smooth	Clear pine, wood siding
Smooth	Smooth plaster, smooth stone
Very smooth	Glass, painted pine, polished metal

The Energy Plus model used for calculating the exterior surface convection coefficients in COMFEN is the "SimplifiedCombined" model, which applies heat transfer coefficients depending on surface roughness and wind speed. The model yields a combined convection and radiation heat transfer coefficient.

Energy Plus Documentation: For a more detailed description of roughness and the calculation methodology for exterior convection coefficients please refer to the "Group – Simulation Parameters: SurfaceConvectionAlgorithm: Outside" and "Group - Surface Construction Elements: Material" chapters in the *Energy Plus Input Output Reference* and the "Outside Surface Heat Balance – Outdoor/Exterior Convection" chapter in the *Energy Plus Engineering Reference.*

Comment Field for optional comments

4.2.10. Locations

The COMFEN location library contains weather data for a range of cities in the United States, Australia, Canada, India and Russia. Many of the locations also include additional data such as CO_2 emissions factors, utility cost data, and default walls for each location.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls | Spandrels | Materials | Locations

id ▲	Country	State/Province	City	Weather File	CO2 Electricity	CO2 Gas	Elec. Rate	Gas Rate	Cost Adjustment Factor
1	United States of America	Alaska	Anchorage	USA_AK_Anchorage.Intl.A	0.6260	0.2791	0.14	0.31	1.37
2	United States of America	Alaska	Fairbanks	USA_AK_Fairbanks.Intl.AF	0.6260	0.2791	0.14	0.31	1
3	United States of America	Alabama	Birmingham	USA_AL_Birmingham.Mun	0.5942	0.2791	0.1	0.47	0.88
4	United States of America	Arkansas	Little Rock	USA_AR_Little.Rock.AFB.7	0.5851	0.2791	0.08	0.31	0.87
5	United States of America	Arizona	Phoenix	USA_AZ_Phoenix-Sky.Har	0.4763	0.2791	0.09	0.38	0.98
6	United States of America	California	Arcata	USA_CA_Arcata.AP.72594	0.2767	0.2791	0.13	0.27	1
8	United States of America	California	Bakersfield	USA_CA_Bakersfield-Mea	0.2767	0.2791	0.13	0.27	1.12
9	United States of America	California	Barstow-Daggett	USA_CA_Barstow.Daggett.	0.2767	0.2791	0.13	0.27	1
13	United States of America	California	Fresno	USA_CA_Fresno.Air.Termi	0.2767	0.2791	0.13	0.27	1.14
14	United States of America	California	Long Beach	USA_CA_Long.Beach-Dau	0.2767	0.2791	0.13	0.27	1.15
16	United States of America	California	Los Angeles	USA_CA_Los.Angeles.Intl.	0.2767	0.2791	0.13	0.27	1.15
18	United States of America	California	Oakland	USA_CA_Oakland.Intl.AP.	0.2767	0.2791	0.13	0.27	1.2
20	United States of America	California	Red Bluff	USA_CA_Red.Bluff.Muni.A	0.2767	0.2791	0.13	0.27	1
21	United States of America	California	Riverside	USA_CA_Riverside.Muni.A	0.2767	0.2791	0.13	0.27	1.12
22	United States of America	California	Sacramento	USA_CA_Sacramento.Met	0.6100	0.2791	0.13	0.27	1.14
24	United States of America	California	San Diego	USA_CA_San.Diego-Lindb	0.2767	0.2791	0.13	0.27	1.13
26	United States of America	California	San Francisco	USA_CA_San.Francisco.In	0.2767	0.2791	0.13	0.27	1.25
28	United States of America	Colorado	Denver (Stapleton	USA_CO_Denver.Intl.AP.7	0.8754	0.2791	0.08	0.27	1.01
29	United States of America	District of Columb	Washington (Dull	USA_VA_Sterling-Washing	0.5262	0.2791	0.13	0.46	1.04
30	United States of America	Delaware	Wilmington	USA_DE_Wilmington-New.	0.8301	0.2791	0.12	0.56	1.05
31	United States of America	Florida	Miami	USA_FL_Miami.Intl.AP.72	0.6305	0.2791	0.11	0.37	0.96
32	United States of America	Florida	Orlando	USA_FL_Orlando.Executiv	0.6305	0.2791	0.11	0.37	0.95
33	United States of America	Florida	Tampa	USA_FL_Tampa.Intl.AP.72	0.6305	0.2791	0.11	0.37	0.93
34	United States of America	Georgia	Atlanta	USA_GA_Atlanta-Hartsfiel	0.6214	0.2791	0.09	0.38	0.95
35	United States of America	Hawaii	Honolulu	USA_HI_Honolulu.Intl.AP.	0.7530	0.2791	0.22	1.3	1.35
36	United States of America	Iowa	Des Moines	USA_IA_Des.Moines.Intl.A	0.8528	0.2791	0.08	0.28	1.01

Figure 4-43. Location library list view

Creating a new location

Each location in the library references a weather file in Energy Plus (*.epw). New locations can be assigned to the library by selecting the ***New*** button at the bottom of the library list view screen.
The inputs for the Edit location dialog box are described in detail below.

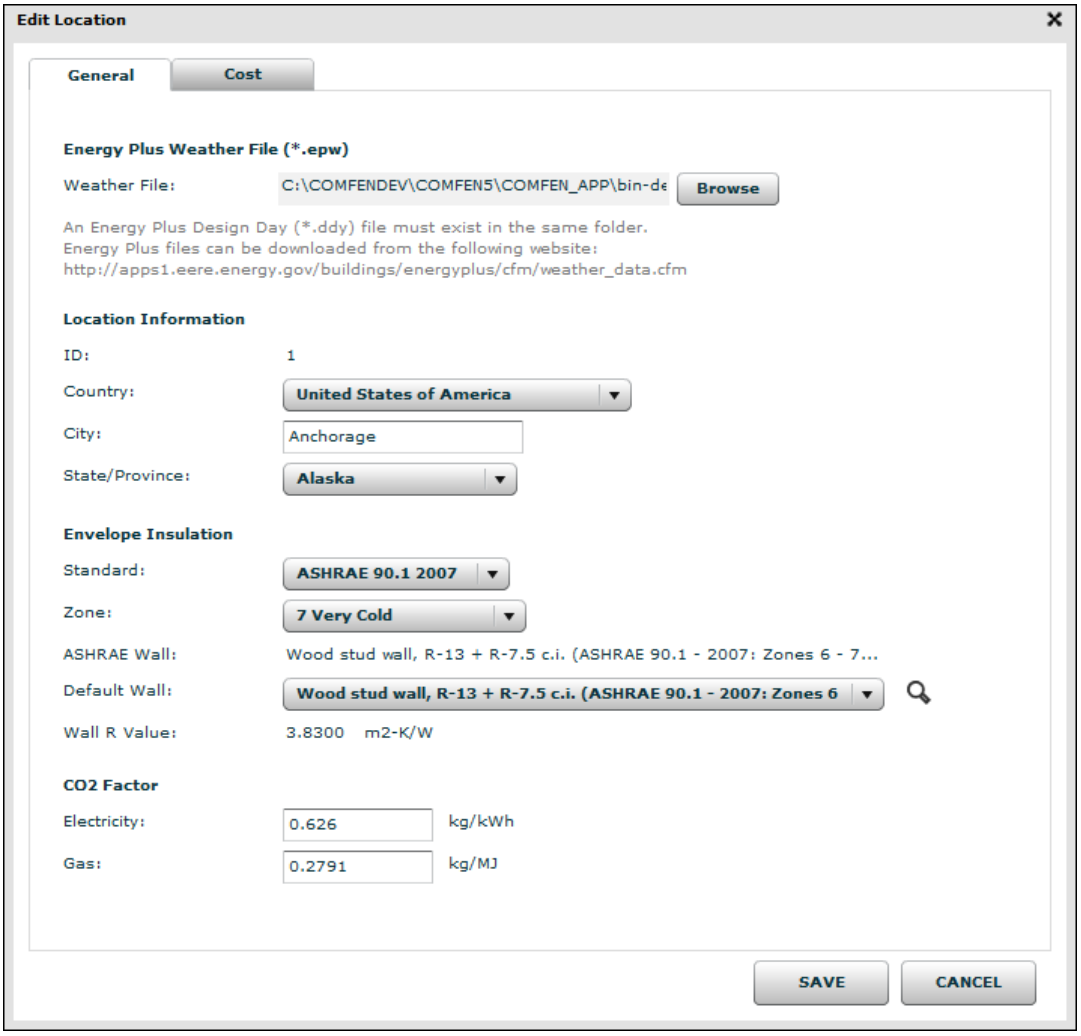


Figure 4-44. Edit location view, General tab

General Tab

Energy Plus weather file

When creating a new location, the user must specify the *.epw weather file location by clicking Browse under the General tab. An associated *.ddy must be located in the same folder as the *.epw file. Once the weather file has been loaded, the user must complete all of the missing fields. The required information for the Zone field can be found in the *.stat file by searching for the term "climate type" and looking up the ASHRAE 90.1 climate zone designation.

Weather data for additional locations can be downloaded from the Energy Plus weather data website: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

The Energy Plus website contains three types of files for each location: the *.epw, *.stat, and *.ddy. The user should download the zip file, which contains all three files.

Location information

ID COMFEN automatically assigns a new Location entry in the library an ID number.

Country	Select a country name from the drop-down menu.
City	Select a city within the chosen country from the COMFEN drop-down list.
State/Province	Select a state or province within the chosen country from the COMFEN drop-down list.

This section lists the location's unique ID#, country, city and state (or province).

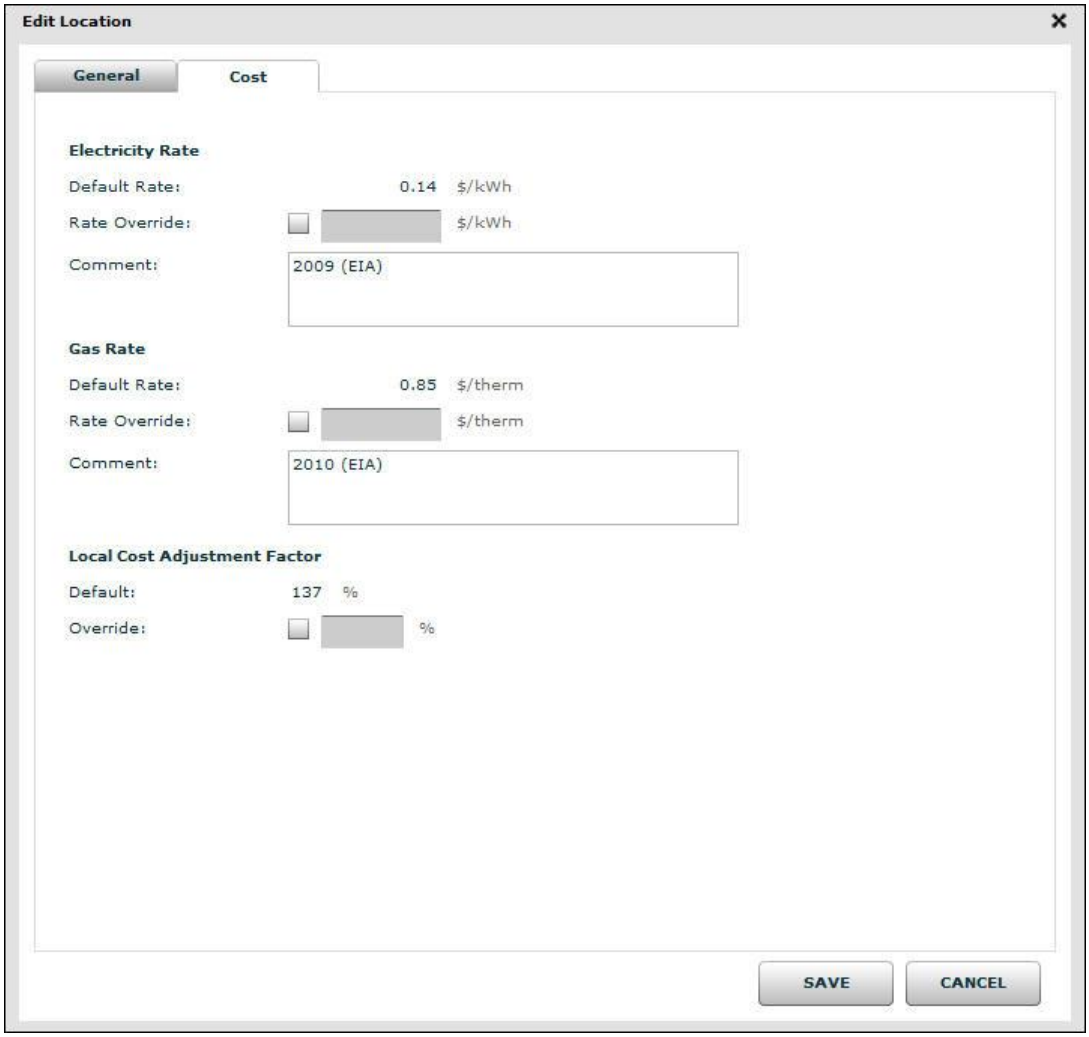
Envelope insulation

Standard	Building energy standard used to determine envelope insulation requirements for the location. Based on the required insulation levels (R-value) set by the standard, a default wall construction (listed under ASHRAE wall) is assigned to the location.
Zone	Location's ASHRAE climate zone. The climate zone information is listed in the location's *.stat file (summary weather data file), which can be downloaded from the Energy Plus website.
ASHRAE Wall	A wall meeting the insulation (R-value) requirements of the standard listed in the Standard field.
Default Wall	Default wall that is assigned to projects in the location. The user can use the construction listed under ASHRAE wall if they want to ensure that the construction meets the requirements of the standard listed under the Standard field, or they can assign a custom wall construction by selecting a wall from the drop-down list. The walls listed here correspond to walls defined in the wall library.
Wall R-value	Effective wall R-value for the wall specified under the *Default wall* field.

CO2 factor

Electricity	Average carbon emissions per unit of electricity generated by utility and nonutility electric generators for the 1998-2000 time period (EIA, 2002). Since these factors can vary considerably by year for some U.S. states, it is recommended that the user input updated values if available.
Gas	Average carbon emissions per unit of natural gas (kBtu) generated by utility and nonutility electric generators for the 1998-2000 time period (EIA, 2002). Since these factors can vary considerably by year for some U.S. states, it is recommended that the user input updated values if available.

In the Cost Tab, default utility rate values based on project location are displayed and can be overridden by user-defined inputs.



Electricity Rate

Default Rate The average price of electricity used by end-user in the commercial sector for the year listed in the comment box.

Rate Override If this box is checked, the user can input a custom electricity rate value to override the default rate.

Comment Year for which electricity price data used for the Default Rate was collected and source from which price data was obtained.

Gas Rate

Default Rate The average price of natural gas used by end-user in the commercial sector for the year listed in the comment box. The price is inclusive of all tax, delivery, commodity, demand and other charges. Here, the commercial sector is defined as the sector encompassing nonmanufacturing establishments engaged in the sale of goods or services and local, State and Federal agencies engaged in nonmanufacturing activities.

Rate Override — If this box is checked, the user can input a custom gas rate value to override the default rate.

Comment — Year for which gas price data used for the default rate was collected and source from which price data was obtained.

Local Cost Adjustment Factor

Default — The location-specific cost multiplier COMFEN stores in the Location Library.

Override — If this box is checked, the user can input a custom adjustment factor value to override the default.

References

1. Energy Information Administration [EIA] (2002). [Table 1. 1998-2000 Average State-level Carbon Dioxide Emissions Coefficients for Electric Power]. *Updated State-level Greenhouse Gas Emission Coefficients for Electricity Generation, 1998-2000*. Retrieved from: http://www.eia.gov/FTPROOT/environment/e-supdoc-u.pdf
2. Energy Information Administration [EIA] (2011a). [Commercial natural gas prices]. *U.S. and state natural gas prices for wellhead, imports, exports, citygate, and end-use sectors*. Retrieved from http://205.254.135.24/dnav/ng/ng_pri_sum_a_EPG0_FWA_DMcf_a.htm
3. Energy Information Administration [EIA] (2011b). [Table 5B. Commercial Average Monthly Bill by Census Division, and State, 2009]. *Electric Sales, Revenue, and Average Price 2009*. Retrieved from http://205.254.135.24/cneaf/electricity/esr/table5_b.html

4.2.11. Glazed wall assembly

In addition to the option of creating individuals windows, i.e. punched windows within a scenario, the user can create a series of windows that fill up a part of or the whole facade by using the glazed wall assembly option. This feature is particularly useful for modeling storefronts and curtain wall assemblies as it makes it possible to create these quickly and easily.

Creating a glazed wall assembly

To create a glazed wall assembly, create a new scenario and enter the edit scenario screen by double clicking the scenario or clicking with the right mouse button and clicking edit. In the edit view, the icon toolbar is available. Open the New glazed wall assembly dialog box by clicking on the "add glazed wall assembly icon" in the toolbar:

Figure 4-45. Toolbar with Glazed Wall Assembly icon

This will bring up the glazed wall assembly dialog box:

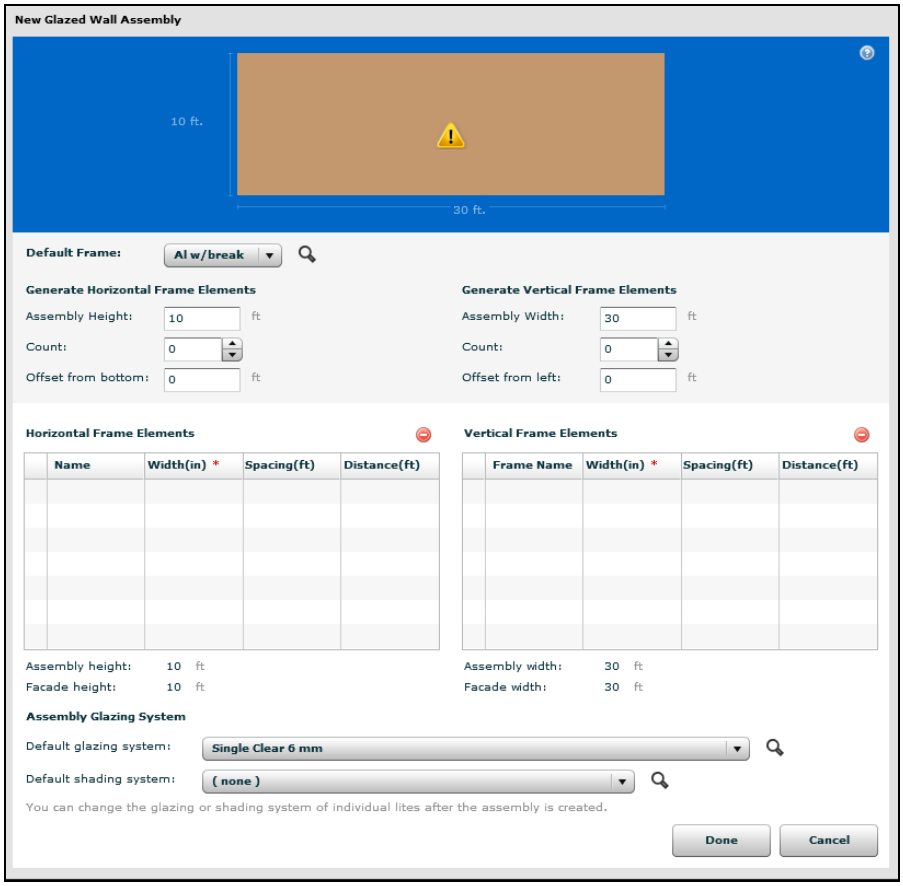


Figure 4-46 New glazed wall assembly dialog box

NOTE: *Only one glazing assembly can be created within a scenario and a scenario with a glazed wall assembly cannot have a punched window, or vice versa.*

The inputs for this dialog box are explained below:

Default frame This is the frame that will be used for the glazed wall assembly. Only one type of frame can be specified.

Assembly Height Height of the glazed wall assembly, measured from the bottom edge of the first framing member to the top edge of the last member.

Assembly Width Width of the glazed wall assembly, measured from the outside of the first framing member to the outside of the last member.

Count Number of horizontal or vertical framing elements. Minimum number of horizontal or vertical framing elements is 2.

Offset from bottom Position of the bottom edge of glazed wall assembly relative to the bottom edge of the scenario.

Offset from left Position of the left edge of glazed wall assembly relative to the left edge of the scenario.

The table below the inputs lists each framing element (horizontal elements on the left and vertical on the right), along with its width, spacing and distance:

Width — Width of framing element, equal to the width of the framing defined under the default frame input above.

NOTE: *Since it is assumed that the glazed wall assembly represents a "slice" through a glazed wall, perimeter framing elements are automatically modeled at 1/2 of the width of the framing member selected as the default frame.*

Spacing — Framing spacing, measured from center line to center line of framing member. The spacing of the first framing member is always 0.

Distance — Distance of framing from edge of scenario elevation (either left or bottom edge) and the center line of framing member.

After defining the type and position of the framing, the user specifies the default glazing and shading for the assembly (individual glazing units can be later edited interactively in the scenario elevation view).

Figure 4-47. Select the Glazed Wall Assembly Default Shading System and Glazing System

When the glazed wall assembly framing and glazing is defined, click **Done** to save changes and exit.

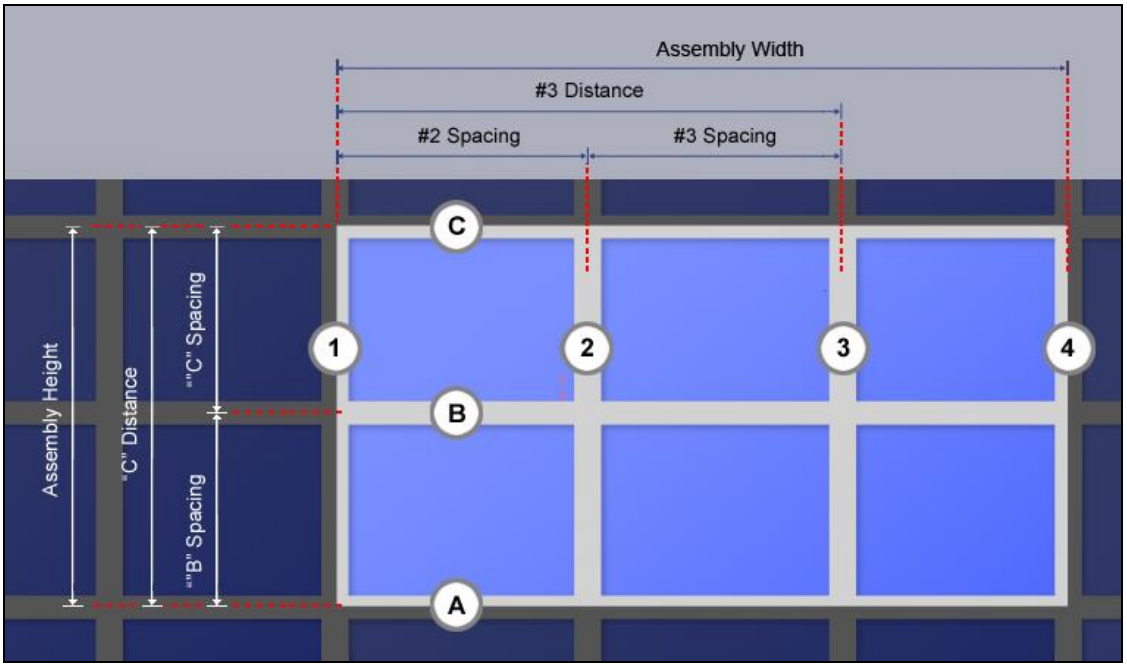


Figure 4-48 Framing member spacing and distance

Editing a glazed wall assembly

Individual lites can be edited in the interactive scenario view if needed by left-clicking on a lite to highlight the lite and then right-clicking within the highlighted area to bring up the edit glazed wall assembly menu:

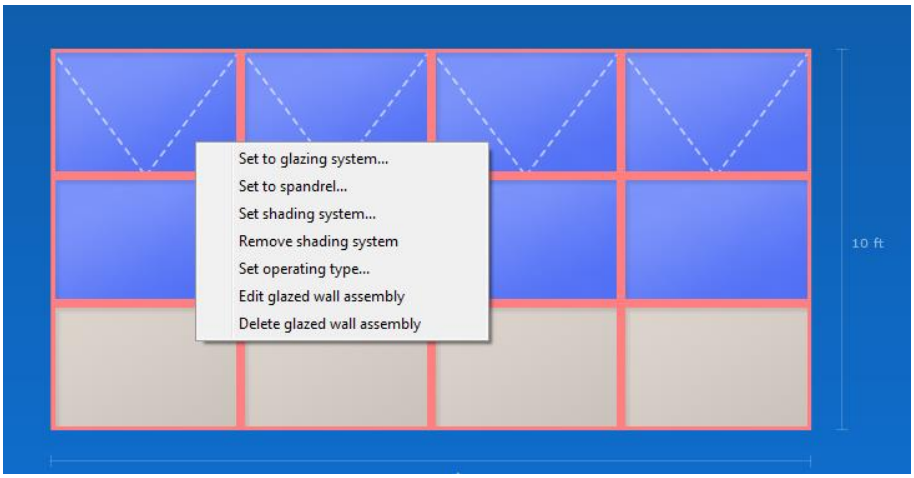


Figure 4-49. Glazed wall assembly menu

From this menu, the user can opt to edit a glazing system, assign or delete a shading system, specify an operable window or a spandrel. "Edit glazed wall assembly" will bring up the **New glazed wall assembly** dialog box.

> ***NOTE:*** *Any changes (e.g. glazing, shading an spandrel definitions) made in the interactive scenario view will be overwritten if changes are made under the* ***New glazed wall assembly*** *dialog box.*

To select multiple lites, click and drag from left to right. Any lites that overlap with the drawn window will be highlithed. At this point, if you right-click, the menu with the options listed above will appear.

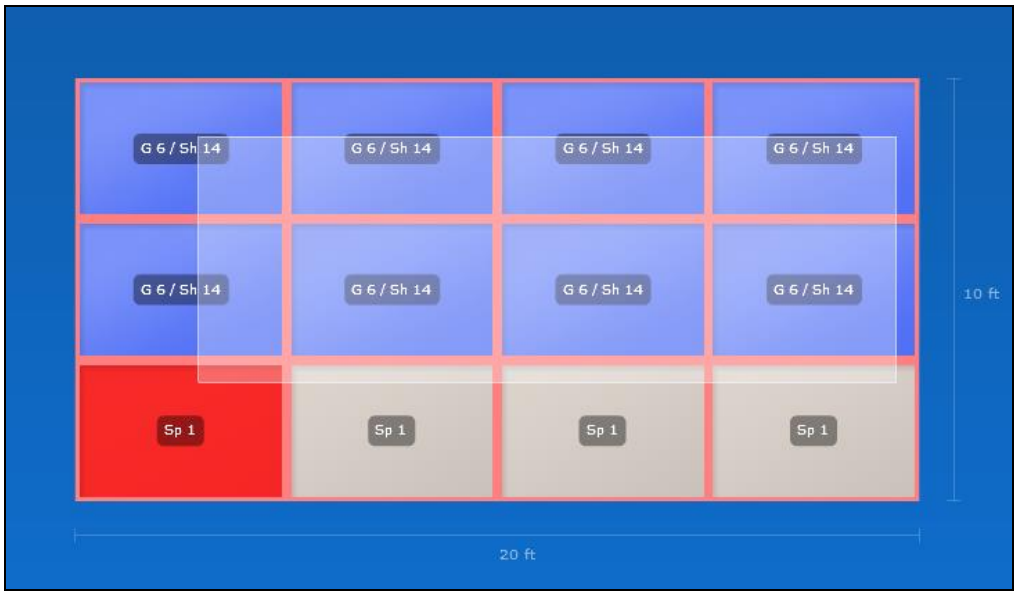
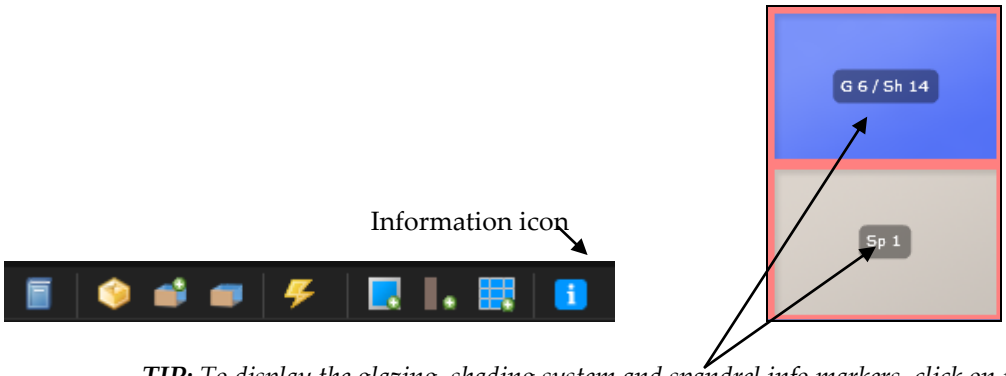


Figure 4-50 Multiple glazing unit selection



TIP: *To display the glazing, shading system and spandrel info markers, click on the information icon in the toolbar.*

General glazed wall assembly properties are summarized under the glazed wall tab. This is also where the user can select the edit button to return to the glazed wall assembly dialog box.

Figure 4-51 Glazed wall tab

4.3. HVAC

The default HVAC system is presently a packaged single zone system for all building types. Cooling and heating setpoints and schedules vary by building type. The economizer option provides a means to reduce the need for cooling by introducing outdoor air when the conditions are favorable.

4.3.1. Ventilation

The default outdoor air flow rate is listed under the Project Properties > HVAC tab. The default flow rate type is set to flow/person and the volume of supplied air varies by building type. The user can override the air flow control type (flow/person or flow/area) and flow rate.

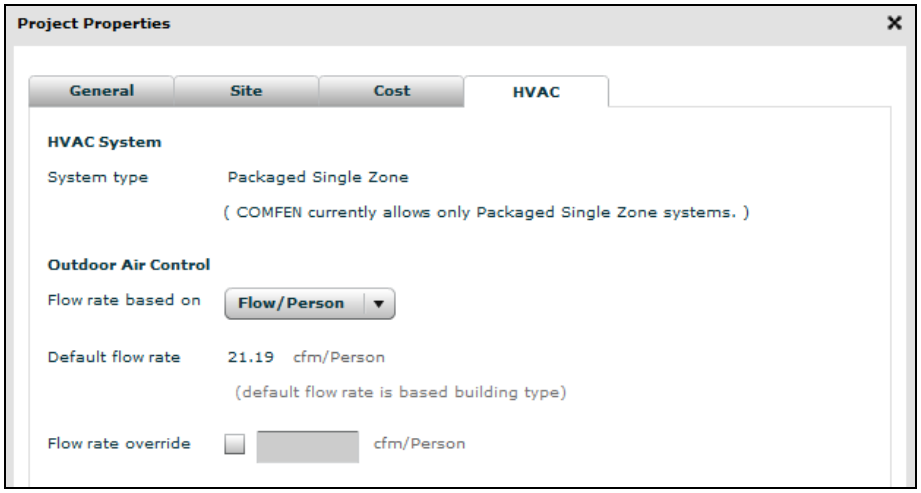


Figure 4-52. Project Properties > HVAC tab

4.3.2. Economizer

The economizer option in COMFEN is accessed from the scenario tab in the main screen (see figure below). The user can choose from three economizer control options:

1. Temperature – economizer is enabled when the cooling setpoint is not met and the drybulb temperature of outdoor air is lower than the dry-bulb temperature of return air.
2. Enthalpy - economizer is enabled when the cooling setpoint is not met and the enthalpy of outdoor air is lower than the enthalpy of return air.
3. Temperature and enthalpy – economizer is enabled when the cooling setpoint is not met and both the drybulb temperature and enthalpy of outdoor air are lower than the dry-bulb temperature and enthalpy, respectively, of return air.

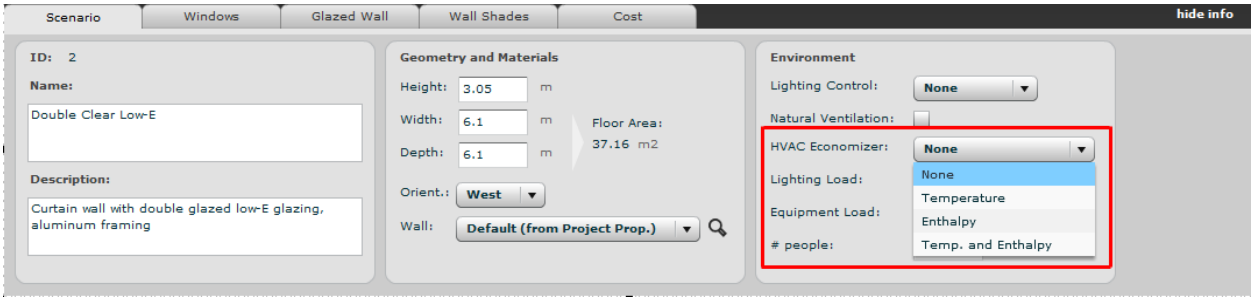


Figure 4-53. HVAC economizer

4.4. Occupancy, lighting and equipment loads

Default occupancy, lighting and equipment loads are set to the following when the user creates a new scenario:

Lighting load: 1 W/ft2
Equipment load: 0.75 W/ft2
Occupancy: 1 person per zone

NOTE: *The loads listed above are the maximum loads, i.e. loads in a fully-occupied office. Actual loads at any given time will vary based on occupancy, lighting and equipment schedules.*

NOTE: *Since the current default loads presently do not vary by building type, it is recommended that the user review and adjust loads and occupancy based on building type.*

4.5. Daylighting and glare analysis

A daylight analysis for scenarios can be performed under the Comparison tab. Here users can evaluate up to four scenarios side-by-side by calculating illuminance levels, luminances and occupant visual discomfort due to the glare. COMFEN uses two underlying simulation engines for daylight calculations – Energy Plus and Radiance, a state-of-the-art daylight simulation software. Some of the daylight simulations are calculated for the whole year while others are calculated for a user-defined date and time, i.e. point-in-time simulations. Radiance, a photometrically-accurate raytracing program, has been extensively tested and validated against physical measurements. The following sections discuss the types of analyses available and how to define different types of daylight simulations in more detail.

4.6.1. Point-in-time daylight simulations

Point-in-time simulations refer to simulations conducted for a user-defined date and time. In contrast to annual daylight simulations, for which solar radiation data is obtained from the location's weather file, point-in-time simulations require that the user specify the sky condition (e.g. clear, overcast or intermediate) for the calculation. In addition, some daylight calculations such as the glare analysis or the 3D contour map may require the user to specify the occupant's position and angle of view. The next few pages discuss the Radiance-based daylight simulations, which include the illuminance contour maps found under the daylight tab and the glare analysis.

Illuminance contour maps

The illuminance contour maps generated in COMFEN under the Plan Contour and 3D Contour tabs show lines of equal illuminance for a plan view of the space and a user-defined perspective view. In order to generate either plan or perspective view contours for a set of scenarios, the user needs to define several simulation parameters in the Radiance toolbar.

The Radiance toolbar options are defined below. Parameters on the right of the Radiance toolbar are used to adjust how results are displayed (e.g. legend maximum and divisions) but they do not affect the results, i.e. they will not change the calculated illuminance values.

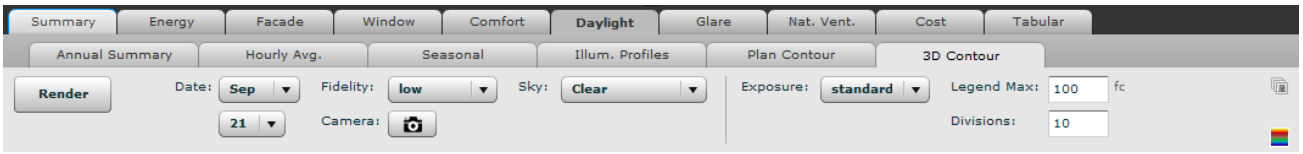


Figure 4-54. Radiance toolbar

Render	Starts the simulation and updates image display
Date	Month and day for simulation
Fidelity	Precision of the simulation
Camera	View angle for the perspective view (option is only displayed under the 3D contour tab)
Sky	Sky condition for the simulation (clear, partly cloudy or overcast)
Exposure	Displayed image brightness
Legend Max	Maximum illuminance value displayed [Units: fc (IP), lux (SI)]
Divisions	Number of legend divisions
	Export all renderings icon for exporting all renderings as individual *.png image files
	Icon for displaying color legend for illuminance contour lines [Units: fc (IP), lux (SI)]

NOTE: *COMFEN automatically generates a rendering for 9 am, noon, and 3 pm for the specified date, however the user can override the default by selecting different times from the drop-down lists on the left of the display.*

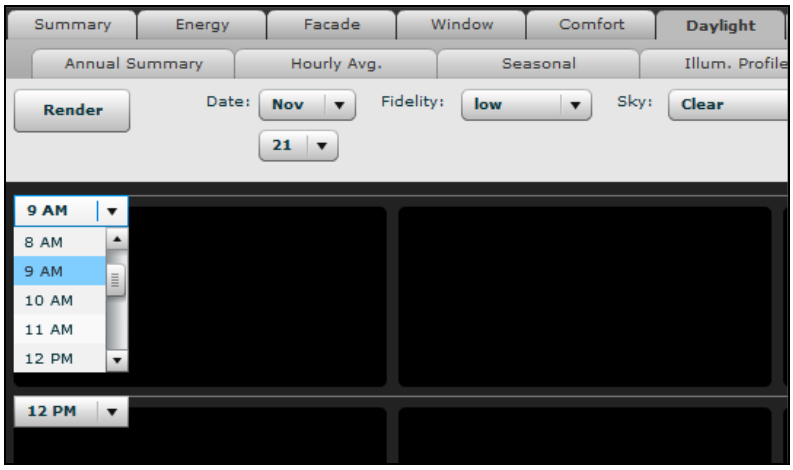


Figure 4-55. Specifying the time for the daylight simulation

When the user clicks on the camera view icon, the "Position RADIANCE camera" dialog box appears. Here the user can define the x and y position of the camera (in ft or m) as well as the direction of the view. The position of the camera (i.e. how far it is from the window and side walls) is measured relative to the origin in the upper-left corner. The view direction is defined from the camera position.

NOTE: *By default, the angle of view represents a 180° cone of vision (fish-eye view), so there is no input for view angle or zoom.*

After defining simulation parameters, the user selects Render to run the simulations. Three renderings corresponding to three different times (default times are set to 9 am, noon, and 3 pm) will be generated for each scenario. Depending on the fidelity selected, the simulation may take some time. Upon making any changes to the scenario or to the simulation parameters in the Radiance toolbar, the user needs to click the Render button to recalculate and/or update the images.

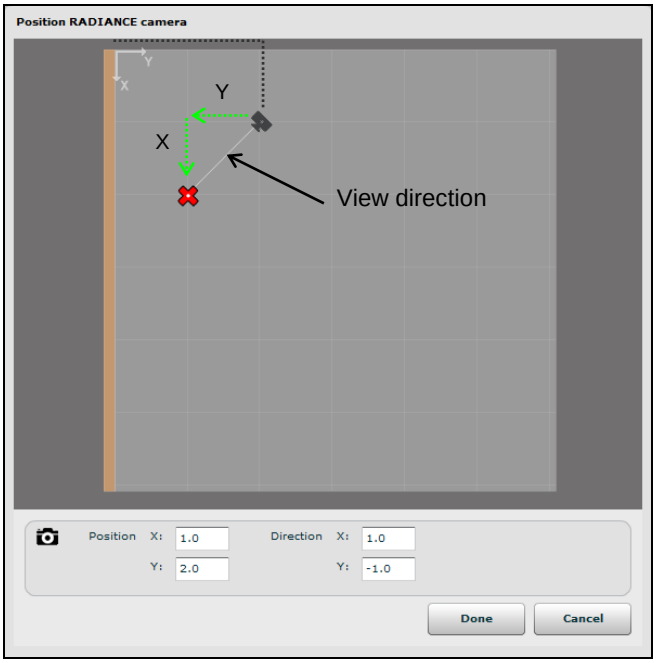


Figure 4-56. Radiance camera dialog box for defining camera position and angle

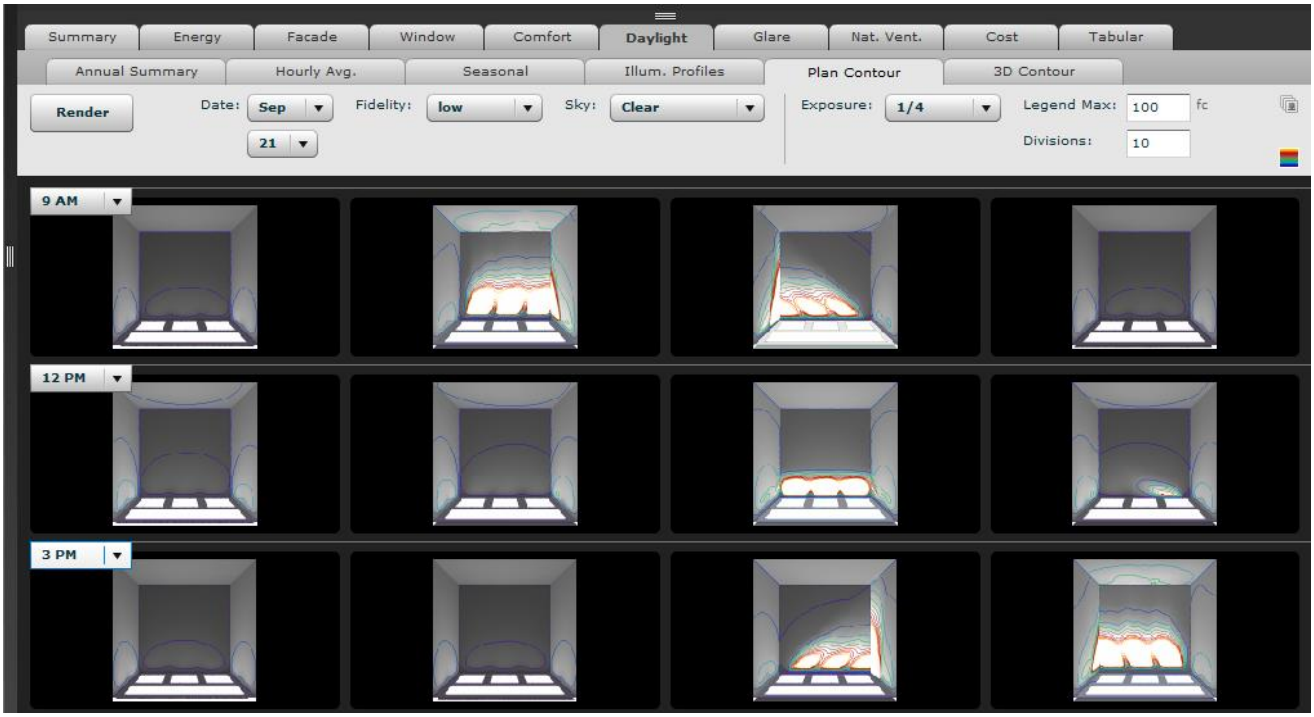


Figure 4-57. Plan view illuminace contour lines

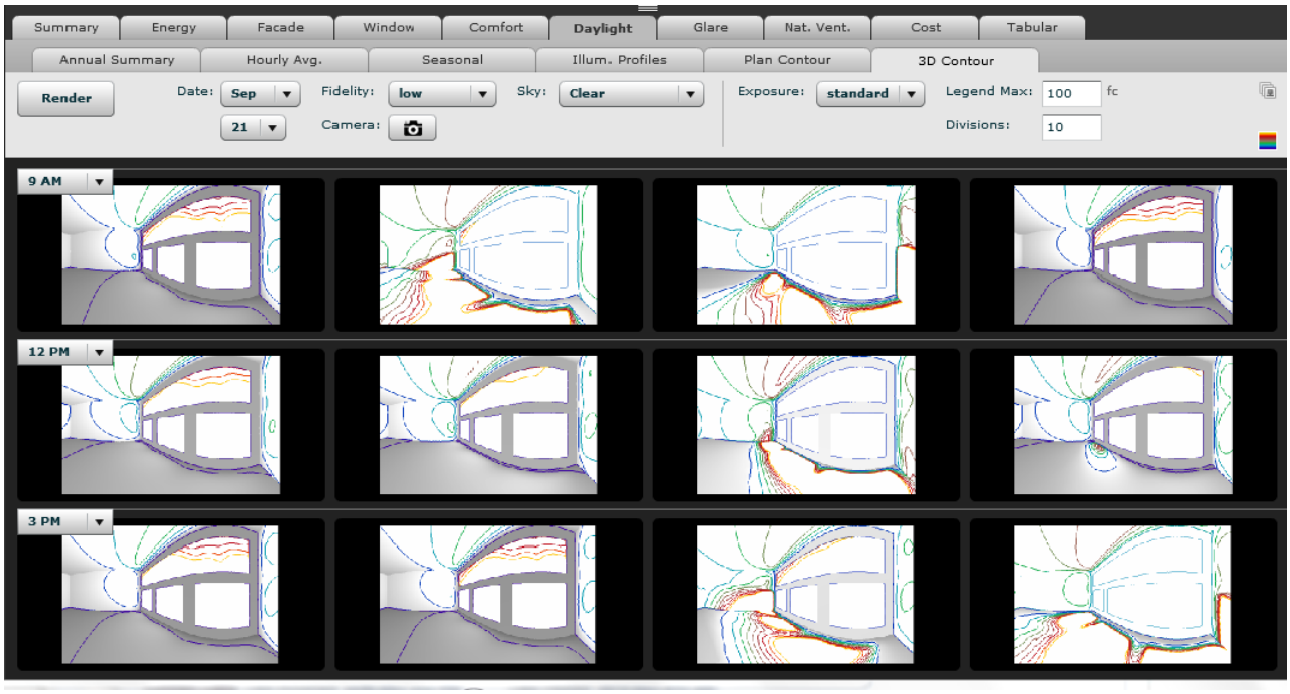


Figure 4-58. Perspective view illuminance contour lines

Glare

Glare analyses can be conducted under the Useful Illuminance, Clear Sky and Overcast Sky tabs under Comparison > Glare. Here, the user can render images of the space, apply false color filters to show

luminance ranges within the rendered view. The Radiance toolbar under these tabs is quite similar to the toolbar under illuminance contour tabs. While most of the toolbar options have already been discussed above, the following options differ:

Falsecolor Checkbox used to apply a color mask to the rendered image to show luminances

Legend Max Maximum luminance value displayed in color mask [Units: cd/m² (IP and SI)]

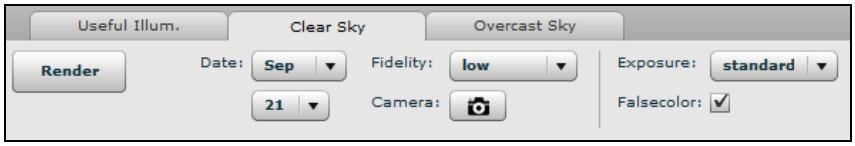


Figure 4-59. Radiance toolbar

4.6.2. Annual daylight simulations

Annual illuminance values in COMFEN are calculated by Energy Plus based on the annual solar radiation data contained in the weather file used for the energy use calculations. These annual daylight simulations are automatically calculated by COMFEN when the user calculates the energy performance of scenarios. Results of these calculations are displayed in several tabs under the Comparison > Daylight tab (e.g. Annual Summary, Hourly Average, Seasonal Average and Illuminance Profiles). See results section for a detailed discussion of results.

Calculations are performed for two predefined sensor points. The position of these sensor points is automatically assigned by COMFEN; the user presently has no control over these points:

- **Sensor # 1:** Daylight sensor #1 is positioned 2/3 of the primary daylight zone depth from facade wall (centered in the width of the facade zone) and positioned at desk height: 2'-6" (0.76 m) above the floor. Sensor #1 controls a fraction of the facade zone lights equal to the primary daylight zone depth divided by the facade zone depth.
- **Sensor # 2:** Any remaining depth in the facade zone is considered a secondary daylight zone. Sensor #2 is positioned halfway between the primary daylight zone depth and the "back wall." Similar to sensor #1, the sensor is centered in the width of the facade zone and positioned at desk height: 2'-6" (0.762 m) above the floor. Sensor #2, if used, controls the remaining fraction of lights.
- **Zone Depth:** A primary daylight zone depth is calculated as the minimum of a) the room depth, b) 1.5 times the facade wall height, and c) 15 feet.

4.6.3. Daylight illuminance maps

The user can choose to generate an additional set of illuminance results in the form of daylight illuminance maps. These maps are generated by Energy Plus and displayed under the Comparison > Summary tab. The maps display work surface illuminances, calculated at 2'-6" (0.762 m) above the floor, for the entire space in the form of a 10 x 10 grid. The grid is scaled to fit the space, so the dimensions of each grid square (or rectangle) will vary depending on the dimensions of the scenario.
Illuminance values are displayed for the date and time specified in the drop-down menu above the map. After selecting a date, the user needs to click on the refresh button (green arrow to the right of the date) to

regenerate results for the new date. When hovering the mouse over a particular point in the grid, the illuminance value for that point is displayed.

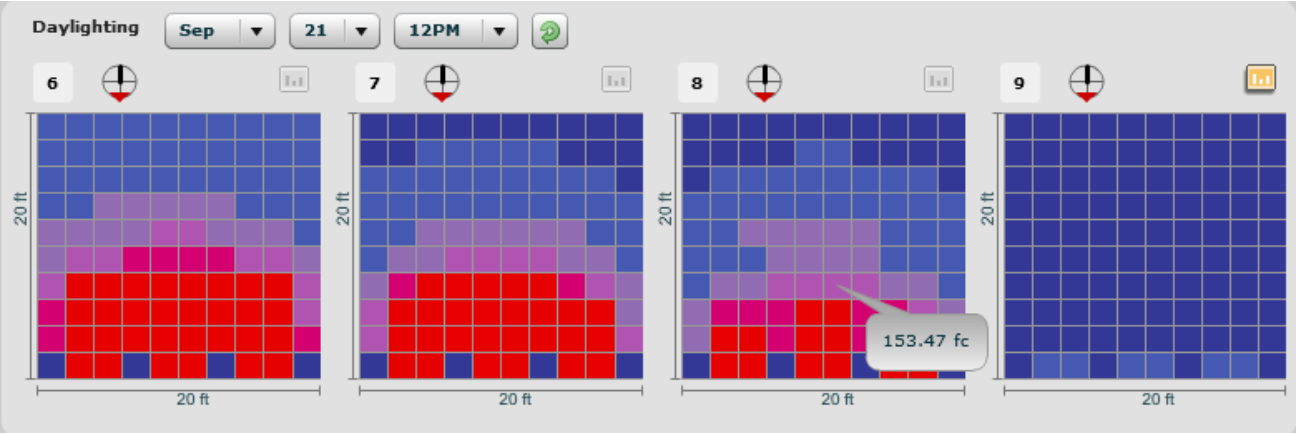


Figure 4-60. Daylight illuminance maps

Since the daylight illuminance map calculation can considerably increase the length of the simulation (Energy Plus calculates values for each hour of the year), the illuminance maps are disabled by default to conserve simulation time. The illuminance map option can be enabled by accessing the Energy Plus tab under COMFEN > Preferences and selecting the "Calculate Illuminance" checkbox.

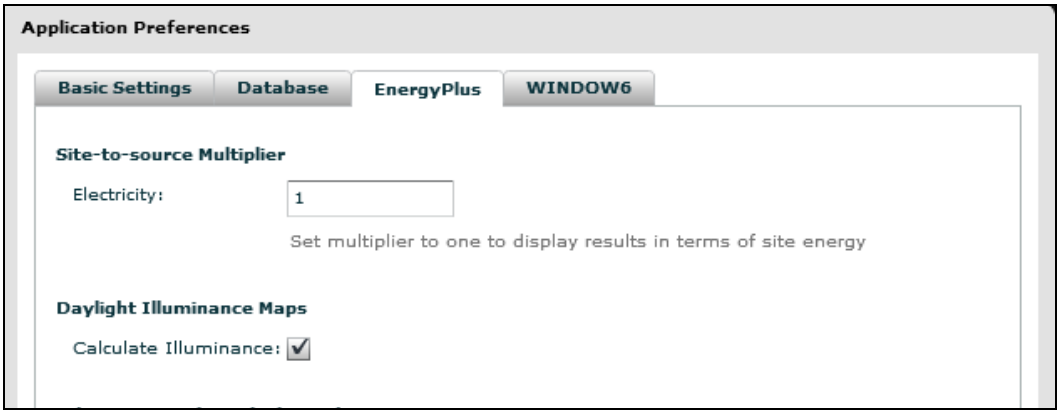


Figure 4-61. Enabling the daylight illuminance map calculation

4.6. Natural ventilation

COMFEN allows the user to model the effect of natural ventilation in single-sided zones, i.e. zones with window openings on one elevation. When the natural ventilation option is selected, COMFEN will automatically model the scenario without mechanical cooling. It is thus not possible to model mixed-mode scenarios, i.e. scenarios where natural ventilation is used in combination with mechanical cooling. Before using the natural ventilation feature, it is recommended that the user first read this entire section and thoroughly familiarize themselves with the assumptions as well as the limitations of the natural ventilation module.

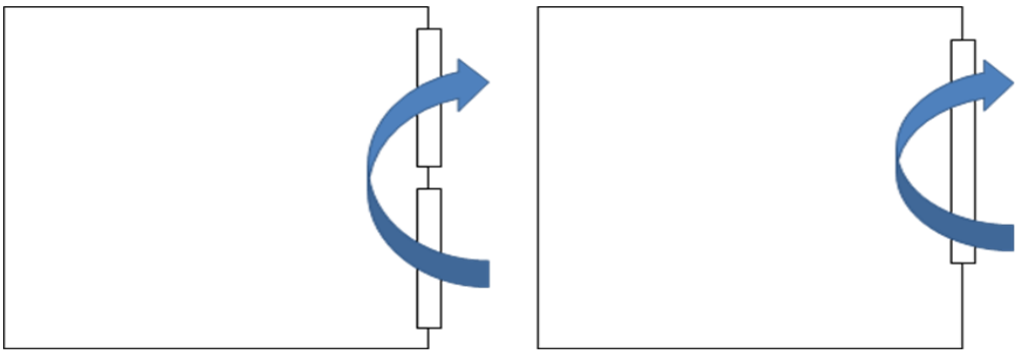


Figure 4-62. Sections showing two possible single-sided ventilation scenarios in COMFEN

4.7.1. Assumptions

There are several assumptions related to the geometry of the building, site, HVAC, and window implicit in the COMFEN natural ventilation model:

1. Window operation is entirely automated and optimized in terms of energy performance. It does not reflect how occupants actually operate windows in buildings. The operation sequence of the windows is described in more detail below.
2. Cooling is disabled for the whole year when natural ventilation is enabled.
3. The default effective open areas for predefined operable window types do not take into consideration the effect of insect screens on air flow.
4. Wind speeds are calculated assuming that the space is located on the 4th floor of the building – 32.8 ft (10 m) above ground level, half-way between the scenario floor and ceiling.
5. The wind pressure coefficients used in the model were sourced from Chapter 16 of the 2004 ASHRAE Handbook of Fundamentals.
6. The zone is located on the 4th floor of a low-rise building (building height is less than three times its width), 10 m (32.8 ft) above ground level.
7. The building is assumed roughly square in plan and is located in a suburban area.

4.7.2. Window operation

The operation of windows is controlled by the Energy Management System (EMS). Once open, window opening size is incrementally adjusted at defined timesteps in order to optimize energy performance while meeting basic occupant comfort requirements. The window control model implemented in COMFEN is a highly optimized model that is representative of an automated control system.
The following points describe the window control sequence in more detail:

1. There is no schedule for window operation; windows can open at any hour if the criteria for opening windows are met.
2. Windows open whenever the indoor temperature exceeds 73.4 F (23 °C) provided that the outdoor air is cooler than the indoor air. Windows close when indoor temperature falls below 73.4 F (23 °C).
3. Once open, the window opening size may be adjusted to reduce thermal discomfort due to cool incoming air based on the temperature difference between inside and outside:

   If temperature difference is:

   < 41 F (5°C) windows are open at 100%
   41 – 59 F (5 - 15°C) window opening size modulates between 100 and 30%

> 59 F (> 15°C) windows are open at 30%

This is illustrated in the figure below. The venting open factor represents the unobstructed portion of the open window area.

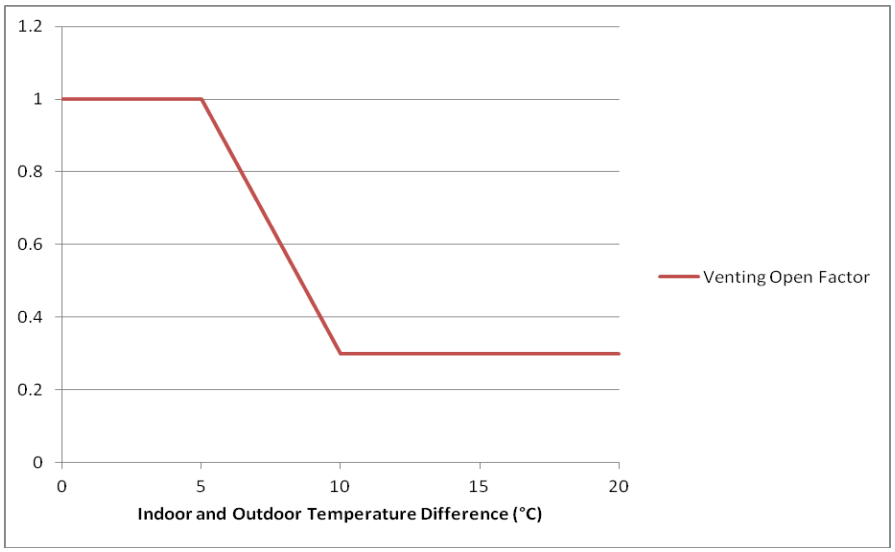


Figure 4-63. Relationship between indoor outdoor temperature difference and window venting open factor

1. In order to prevent occupant discomfort due to drafts, window opening size is modulated to ensure that air speed at the window is below 1 m/s (3.3 ft/s). Air speed at the window is approximated by dividing the volume flow rate of air through each window by the window opening area. If the resulting speed does not exceed 0.7 m/s (2.3 ft/s), windows remain fully open. If the speed is greater than 5 m/s (16.4 ft/s), windows close. At all other speeds the windows modulate between 100% and 70% open.
2. It is assumed that ventilation through the windows is sufficient to meet space requirements for fresh air, so when windows are open, fans and economizer are off unless additional air for cooling is required. If windows are closed, fans and economizer operate as they would in a non-naturally-ventilated scenario.
3. If windows are open yet additional outside air is required to cool the space (i.e. indoor temperature exceeds target for two consecutive timespteps), the fan turn ons, but only if the windows are open at 100% (i.e. the difference between inddor and outdoor temperature is < 5°C).

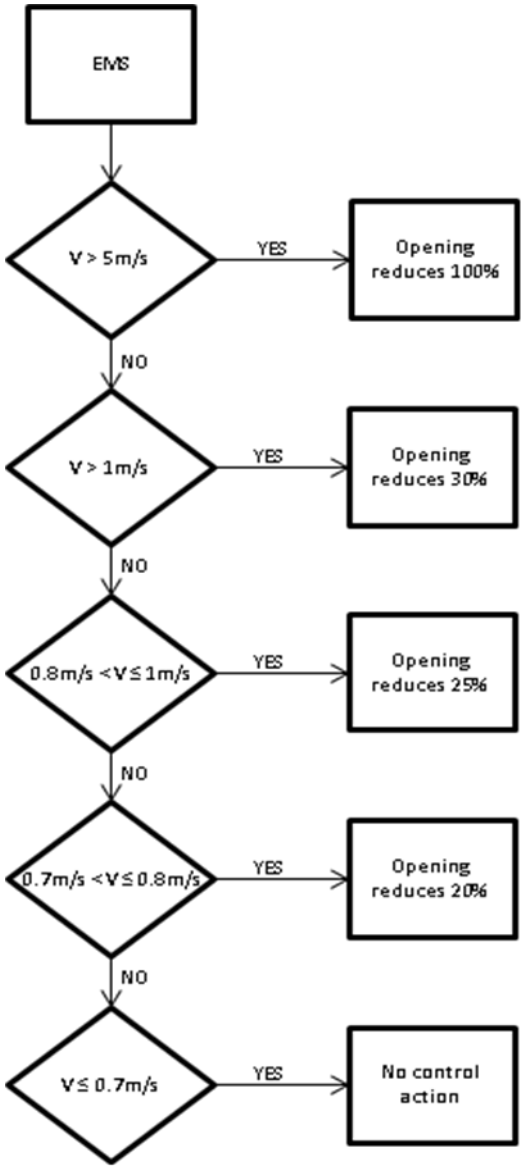


Figure 4-64. Schematic of control sequence for window modulation based on airspeed

4.7.3. Limitations

The COMFEN natural ventilation model has several limitations:

1. Mechanical cooling cannot be modeled in conjunction with natural ventilation.
2. The natural ventilation model does not account for the impact of exterior projections (overhangs and fins, open operable sashes of windows, etc.) on air flow. While the user is allowed to model shading systems and exterior projections (such as overhangs and fins) in conjunction with natural ventilation, they should be aware that COMFEN does not model their impact, so air flow may thus be overestimated. This also applies to the open operable sash of hinged windows (casement, awning, and hopper, etc.) In order to ensure that air flow is not overestimated in scenarios with shading or exterior projections, the user may want to consider applying a factor to the window effective open area. Similarly, since the impact of insect screens is presently not factored in the effective open area of

the different operating types, the user may want to again apply a factor to the EOA value to account for the insect screen.

3. Thermal and optical performance of partially- or fully-open windows is not fully accounted for in the energy model, i.e. the model does not adjust operable window solar and visible light transmittance at times when the window is open. As a result, the visible light transmittance and solar radiation transmitted by the window may be somewhat under- or overestimated at times.

4.7.4. Creating a scenario with natural ventilation

In order to simulate a scenario with natural ventilation, the user has to first define which windows are operable and then check the natural ventilation checkbox under the scenario tab under the scenario edit screen.

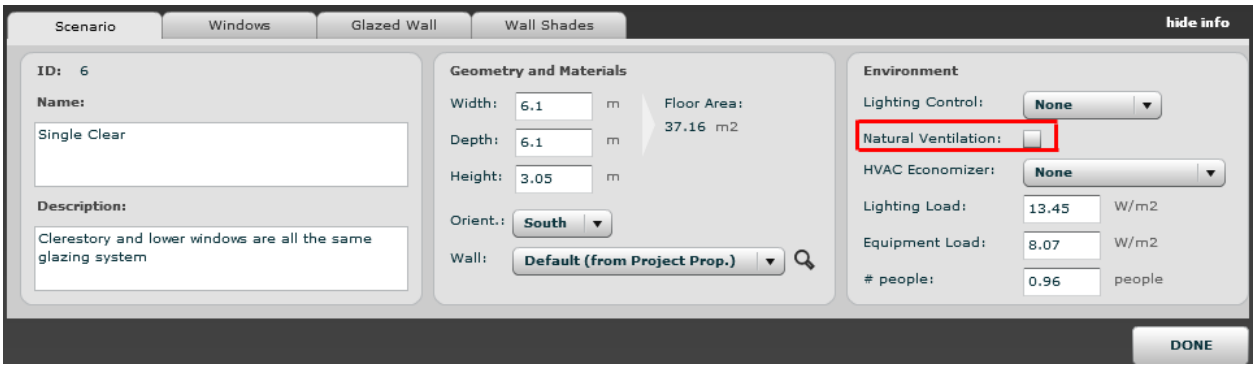


Figure 4-65. Natural ventilation checkbox

Adding an operable window to a scenario
Operable windows can be defined in two ways:

1. By adding a predefined operable window from the window library to the scenario.
2. By editing a specific scenario window under the scenario edit window.

To define an operable window in the window library, the user creates a window just as they would a fixed window and then specify an operable window type under the "operating type" pull-down under the window tab. Options include hinged windows (casement, awning and hopper windows) and two sliding windows (horizontal slider and single-hung). The operating types are differentiated by effective open area and by the position of the effective opening with respect to the window (discussed in more detail below). Depending on the option selected, a different value is displayed in the effective open area dialog box below the "operating type" pull-down.

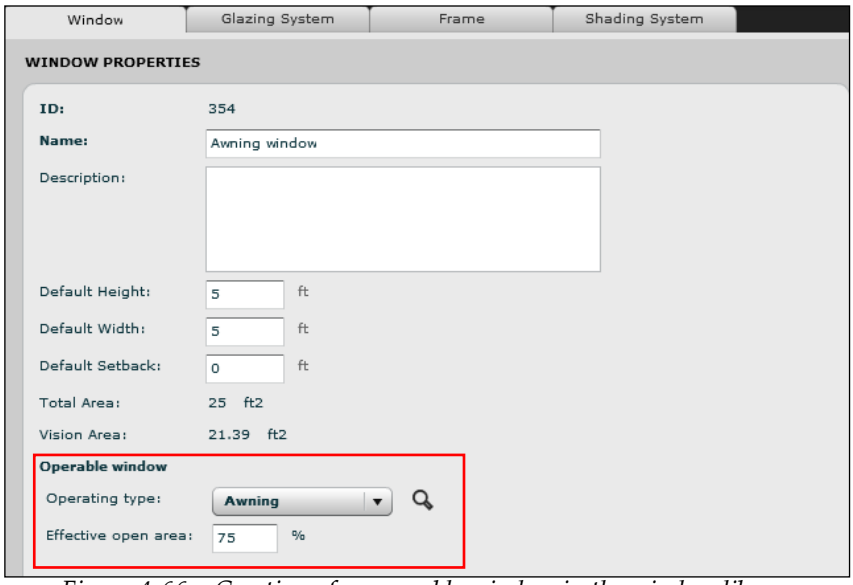


Figure 4-66. Creating of an operable window in the window library

Select an operating type from the library

ID	Name	Default effective open area (%)
1	Awning	75
2	Casement	90
3	Hopper	45
6	Single-hung	45
7	Horizontal Slider	45

Figure 4-67. Operating types

Operating type can also be specified after the user creates a window in a scenario. For scenarios with punched windows, operating type is specified under the window edit dialog box where the user can select an option from the "operating type" pull-down. To define the operating type for scenarios with glazed wall assemblies, left-click to highlight a lite and then right-click and select "set operating type" to pull up a dialog box with the list of operating types. See section 4.2. *Facade libraries and components* for more information on creating operable windows for punched windows and glazed wall assemblies.

Window effective open area

The effective open area (EOA) describes the portion of the opening area that is open (i.e. not obstructed by glazing and operable sashes of windows) and is calculated as follows:

EOA = width $_{eff}$ x height $_{eff}$ / window area [%]

where

window area = window height x window width and includes glazing and frame area
width $_{eff}$ is the effective opening width (see diagram below)
height $_{eff}$ is the effective opening height (see diagram below)

The diagram below illustrates that the vertical projection of the operable sash unto the window delineates the edge of the open area.

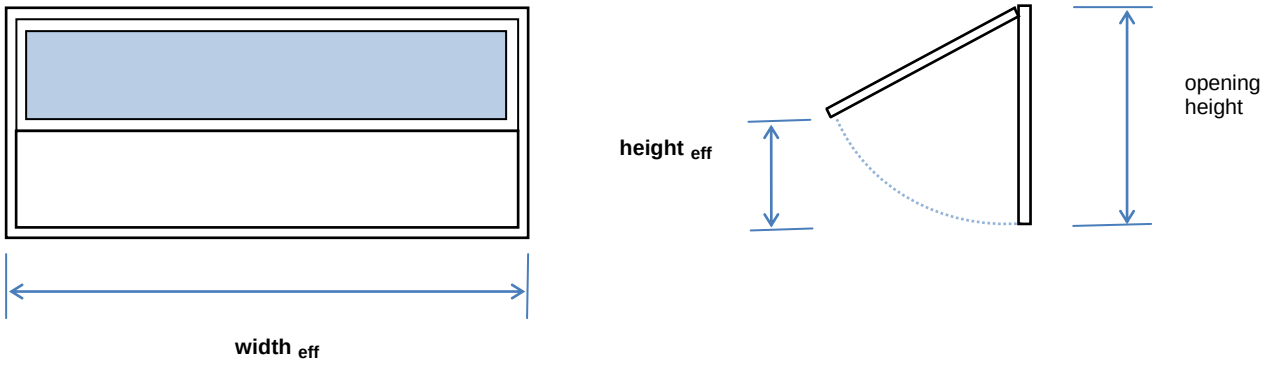


Figure 4-68. Effective opening width and height

The position of the opening is determined based on the position of the window and it is assumed that the lower left-hand corner of the opening coincides with the lower left-hand corner of the window when looking at the scenario in elevation view for all operating window types except hoppers, where the upper left-hand corner of the opening coincides with the upper left-hand corner of the window.
NOTE: *The width of the window frame is not considered when calculating the position of the opening – the corner of the opening always coincides with the outer corner of the frame regardless of the width of the frame.*

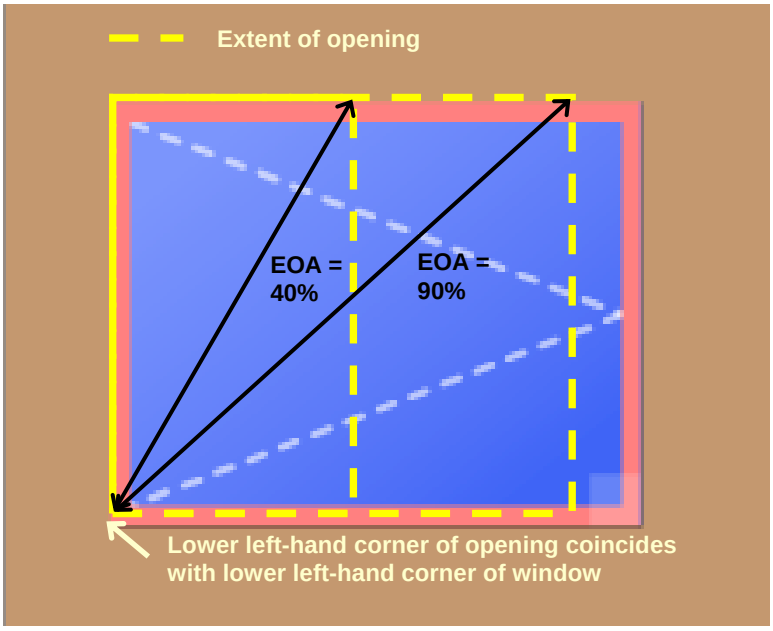


Figure 4-69. Position of effective opening relative to window area (casement window)

The width and height of the opening are determined in accordance with the operating window type, where one of the dimensions is held fixed. For example, for a casement window, changing the EOA affects the width of the window while the height of the opening is held fixed (equal to the height of the window). The diagram below illustrates how the value of EOA and the position of the opening varies with the different operating

window types. The EOA values listed are the default values used in COMFEN however the user can override these by inputting a custom EOA value under the window edit screen.

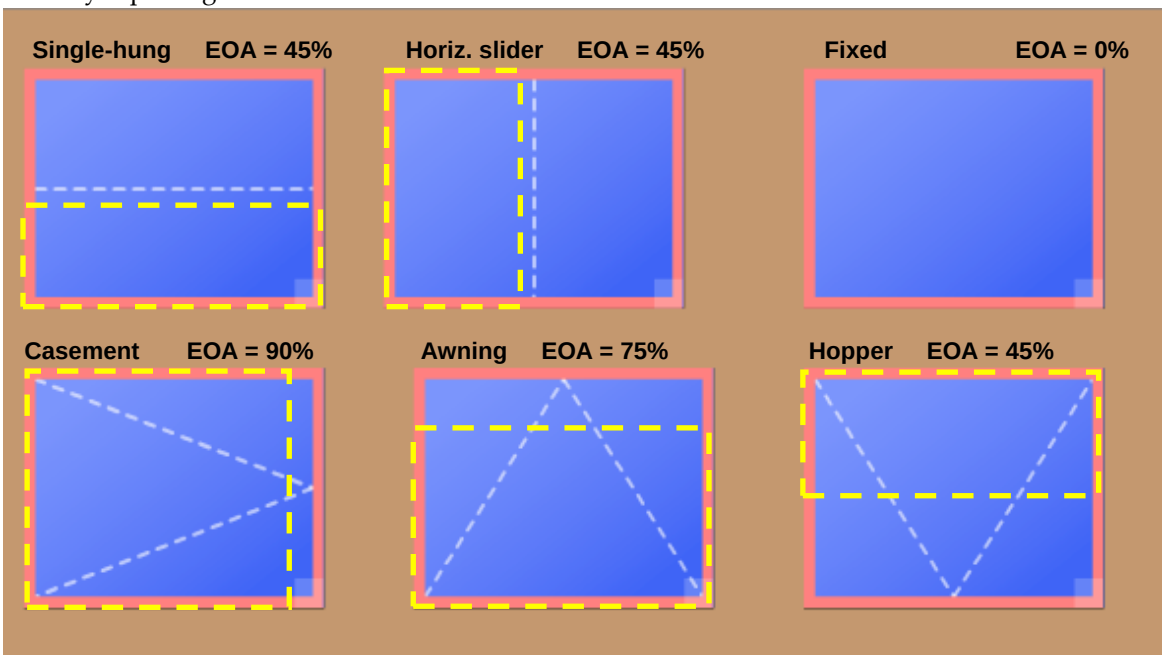


Figure 4-70. Default effective open areas for different window types

4.7.5. References

1. ASHRAE (2004). *2004 ASHRAE Handbook – Fundamentals*, Chapter 16, Air Flow Around Buildings, Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
2. Chandra, S., Fairey, P., & Houston, M. (1986). *Cooling with ventilation*. A Product of the Solar Technical Information Program, Published by the Solar Energy Research Institute. Publication number FSEC-CR-1658-86. Cape Canaveral, Florida: Florida Solar Energy Center. Retrieved from http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1658-86.pdf
3. Chandra, S. (1983). *A Design Procedure to Size Window for Naturally Ventilated Rooms*. Cape Canaveral, Florida: Florida Solar Energy Center.
4. Selecting Windows for Energy Efficiency (1997). DOE/GO-DE-AC03-76SF00098. U.S. Department of Energy. Retrieved from: http://windows.lbl.gov/pub/selectingwindows/window.pdf

4.7. Cost calculation

A simple cost model is incorporated into COMFEN to help the user compare the economic feasibility of different scenarios. Basic cost data obtained from R.S. Means and ASHRAE documentation is provided for the following components:

- Glass layers
- Gases
- Frames

- Glazing systems
- Shading systems
- Window systems
- HVAC system
- Lighting and lighting controls
- Assumptions for specific systems and components are discussed below.

4.8.1. Overview

1. All costs listed throughout the COMFEN interface include a material and labor cost, i.e. the cost of all components and systems is the *installed* cost and includes a 30% markup to account for contractor and subcontractor costs. This applies to both total costs listed in the scenario cost tab as well as component costs listed in the libraries.
2. After total project cost has been calculated, it is multiplied by a location-specific adjustment factor to account for variation in construction costs. The resulting value is called the "Adjusted cost." Since this adjustment is location-specific, none of the component costs in the libraries are adjusted. This adjustment is made under the scenario's cost tab.
3. Costs for glass, gas, frame, glazing, and shading are listed per unit window area, i.e. area of the window rough opening. Lighting and HVAC costs are listed per unit floor area.

Costs for opaque wall construction and exterior projections (overhangs and fins) are not available.
The user can override the cost of most components by inputting their own value. Since the current cost data is only approximate, it is recommended that the user input their own data whenever possible. The cost toggle icon in the menu bar –  , determines if the total scenario cost is displayed in the upper left corner of the scenario view.

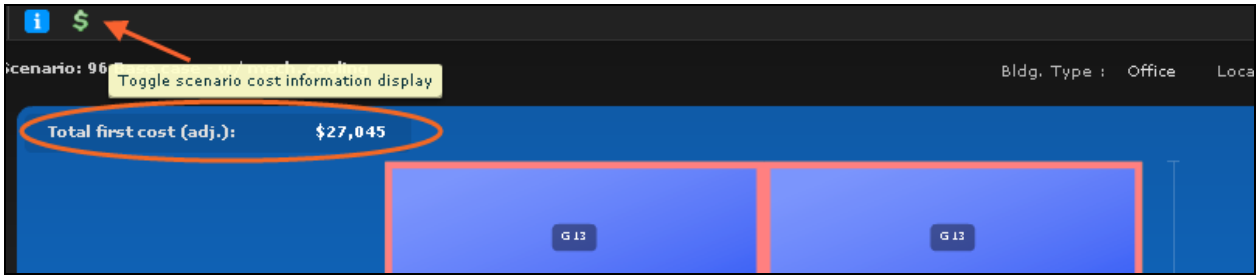


Figure 4-71. Cost toggle icon

4.8.2. Component cost assumptions

Glass layer cost

NOTE: *COMFEN glass layer costs assume 6 mm glass and do not account for varying thicknesses of glass.*
Present glass layer unit costs, C_{glass} ($/ft² window), are approximate and provided in terms of a baseline glass (6 mm clear uncoated glass) cost – 10.70 $/ft² (115.17 $/m²). An incremental cost is added to the baseline glass cost for to account for additional cost premiums (based on the data provided in the table below):

$C_{glass} = C_{glass\ base} + C_{glass\ inc} = 10.70\ \$/ft2 + C_{glass\ inc}$ [$/ft2 window area]

Table 4-5. Glass layer incremental costs

	Glass characteristic	Notes	Incremental cost ($/ft2 of window)	Incremental cost ($/m2 of window)
1	Clear		+$0.00	+$0.00
2	Tinted	Green, bronze, gray	+$0.82	+$8.83
3	High-performance tint	Green, blue	+$1.92	+$20.67
4	Reflective	Pyrolitic or sputter coating on clear glass	+$4.11	+$44.24
5	Reflective on Tint	Pyrolitic or sputter coating, all tints	+$6.31	+$67.92
6	Low-E	Pyrolitic or sputter coating on clear glass	+$1.10	+$11.84
7	Tint + low-e	All tints, all low-e types	+$2.74	+$29.49
8	Sunbelt low-e	Sunbelt Low-e	+$1.92	+$20.67
9	Suspended film	Mylar film with low-e coating	+$10.97	+$118.08
10	Double suspended film	Double film and special edge treatment	+$21.95	+$236.57

*Baseline glass (6mm clear uncoated glass) cost is 10.70 $/ft2 (115.17 $/m2). To calculate total glass cost, add incremental cost to baseline glass cost.

The default glass cost can be modified by checking the override box in the Edit glass dialog box and inputting a custom value in the field. The "Type" drop-down determines the incremental cost (or premium) added to the base glass cost based on the values listed in the table.

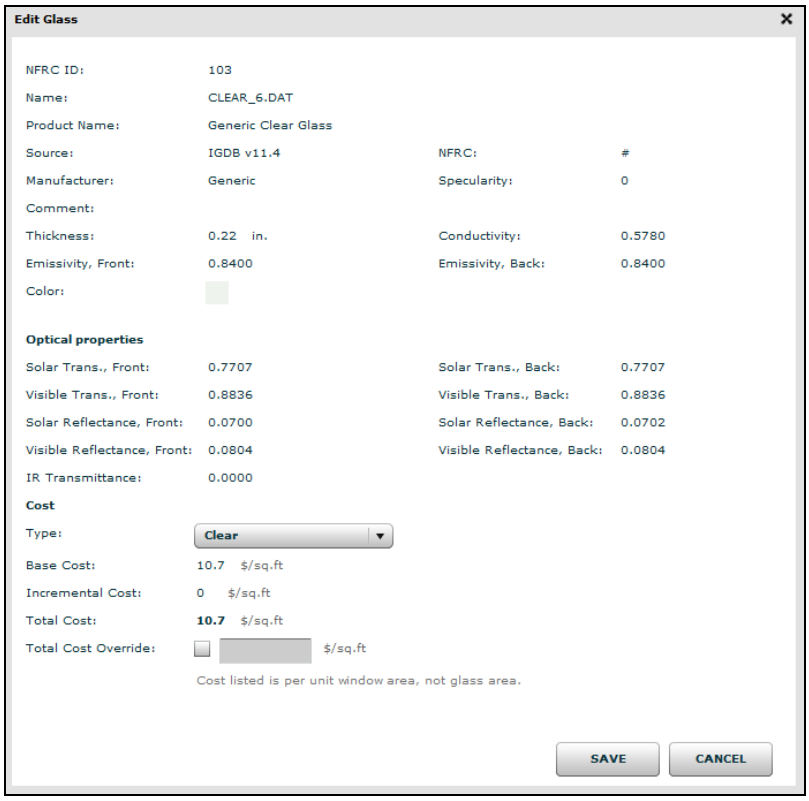


Figure 4-72. Edit glass dialog box

Gas costs are listed per unit window area. The gas costs assume 2′-6″ by 4′-0″ glazing and the gap thicknesses listed in the table below.

NOTE: *Cost per unit area values are fixed, i.e. they are not adjusted depending on gap thickness.*

Table 4-6. Gas layer widths

ID	Gas	Gap width (in.)	Gap width (mm)	$/ft²	$/m²
1	Air	1/2"	12.70	$0.00	$0.00
2	Argon	1/2"	12.70	$1.00	$10.78
3	Krypton	5/16"	7.94	$5.50	$59.17
4	Xenon	1/4"	6.35	$21.83	$234.92
6	Air (5%) / Argon (95%) Mix	1/2"	12.70	$0.95	$10.24
7	Air (12%) / Argon (22%) / Krypton	5/16″	7.94	$3.77	$40.53
8	Air (5%) / Krypton (95%) Mix	5/16″	7.94	$5.22	$56.21
9	Air (10%) / Argon (90%) Mix	1/2"	12.70	$0.90	$9.70

Glazing system cost

Glazing system unit cost (in $/ft² window area) is calculated based on glass layer, gas layer and fabrication cost:

$$C_{glz\ sys} = (C_{glass\ 1} + \ldots + C_{glass\ n}) + (C_{gas\ 1} + \ldots + C_{gas\ n}) + \text{fabrication cost} \quad [\$/ft^2\ \text{window area}]$$

Where

1. $C_{glass\ 1} + \ldots + C_{glass\ n}$ is the combined cost of individual glass layers [$/ft² window area]

2. $C_{gas\,1} + \ldots + C_{gas\,n}$ is the combined cost of individual gas layers [$/ft² window area]
3. Fabrication cost is the additional cost (per unit area of window area) associated with the making of an insulated glazing system; it includes the cost of an aluminum spacer and fabrication:
   - Single glazing = $0/ft²
   - Double glazing = $5.49/ft²
   - More than two glass layers = $2.74/ ft² for each additional glazing layer

ID	Name	TVis	SHGC	U-factor (Btu/h-ft2-F)	Thickness (in)	Cost ($/ft2)
1	Single Clear 6 mm	0.884	0.818	1.025	0.22	10.70
2	Double Clear (Air)	0.786	0.704	0.473	0.95	26.89
3	Double Bronze (Air)	0.477	0.502	0.474	0.94	27.71
4	Double Low-E Bronze (Air)	0.443	0.453	0.331	0.94	28.81
5	Double Low Solar Low-E Tint (Air)	0.521	0.299	0.291	0.96	30.73
6	Double Low Solar Low-E Clear (Air)	0.701	0.382	0.291	0.95	28.81
7	Quad Low Solar Low-E Clear (Air)	0.451	0.292	0.108	2.10	59.53
8	Double Glazed Triple Silver Low-E (Argon)	0.638	0.272	0.238	0.95	29.26
9	Double Hi VT (LowIron) Low-E (Argon)	0.724	0.383	0.247	0.95	29.26
10	Double High Performance Tint (Air)	0.607	0.394	0.474	0.95	28.81
11	Double High Performance Tint (Argon)	0.607	0.390	0.449	0.95	29.26
12	Double Low VT Low-E (Argon)	0.371	0.241	0.253	0.95	29.26
13	Double Low-E Clear (Argon)	0.696	0.469	0.245	0.85	29.26

Figure 4-73. Glazing system library

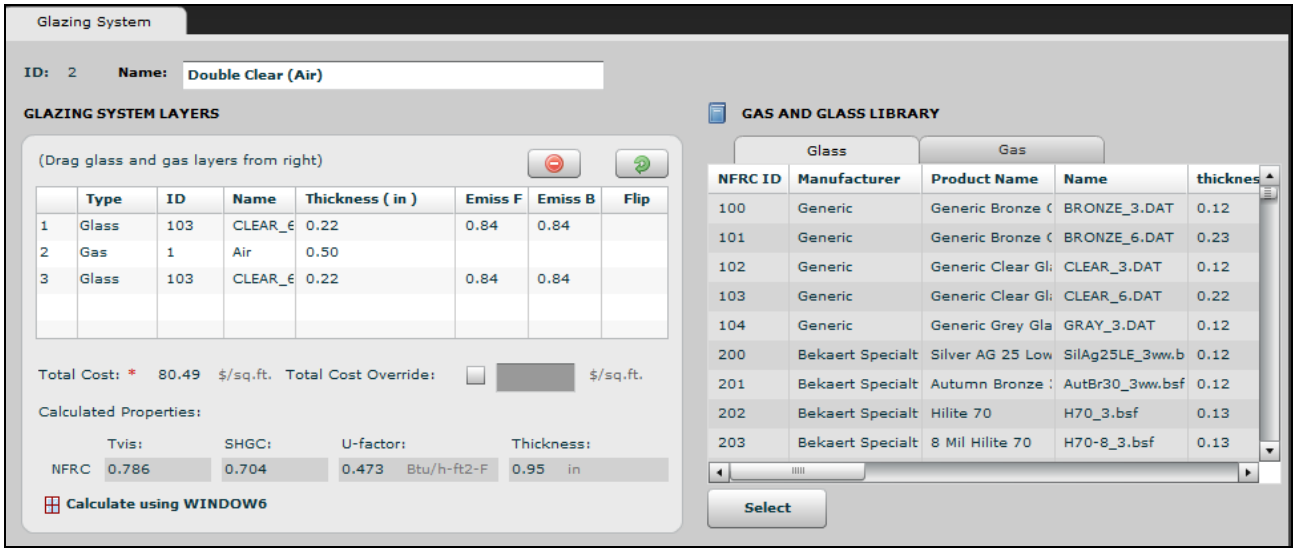


Figure 4-74. Glazing system edit screen

Frame cost

Similar to other window component cost data, frame cost, C_{frame}, is listed per unit window area, i.e. area of the window rough opening. User should note that frame costs are approximate – costs do not change if area of framing is increased since the framing cost is per unit window area, not frame area.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls | Spandrels | Materials | Locations

ID	Name	Frame U-factor	Width (PFD) (▲	Description	Type	Cost ($/sq.ft)	Color	Absorptivity	Source
1	Al w/break	1.00	2.25	Aluminum Frame with	Metal with thermal break	42.49		0.9	GENERIC
3	Wood	0.40	2.75	Wood Frame	Reinforced vinyl/wood	46.61		0.9	GENERIC
4	Vinyl	0.30	2.75	Vinyl Frame	Reinforced vinyl/wood	46.61		0.9	GENERIC

The user can override the cost of framing by checking the cost override checkbox under the *Edit frame* dialog box and inputting a custom value.

Spandrel cost

Glazed wall assembly spandrel costs are approximated due to lack of adequate cost data. One of two fixed numbers – \$80/ft² and \$50/ft² is assumed for spandrels with and without glazing, respectively. These costs assume a "standard" spandrel construction: exterior cladding, air space, metal backpan, 4" of insulation and interior finish. The cost for the spandrel is not adjusted if any of these layers change.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls | Spandrels

ID	Name	Cost($/ft2)
1	Single-glazed spandrel, R-13 insulation	80.00
2	Double-glazed spandrel, R-13 insulation	80.00
3	Double-glazed low-e spandrel, R-13 insulation	80.00

Shading system cost

Shading system cost, $C_{shad\ sys}$ (\$/ft² window area) is calculated based on shading system type (venetian blind, roller shade and screen), shading position (interior, exterior, inbetween glazing) and presence of automated shading systems controls. The cost of the shading system is calculated as follows:

$$C_{shad\ sys} = C_{shad\ device} + C_{control} \quad [\$/ft^2\ window\ area]$$

Where

$C_{shad\ device}$ shading device cost [\$/ft² window area]

$C_{control}$ shading system control cost [\$/ft² window area]

Venetian blind device costs presently do not vary by slat depth – it is assumed that interior blinds have a 1"-deep slat while exterior blinds have a 3"-deep slat. Exterior metal screen cost represents the cost of a mid-range metal architectural screen.

The user can override the shading device and/or control cost under the shading system edit screen.

Windows | Glazing Sys. | Shading Sys. | Frames | Glass | Gas | Walls | Spandrels | Materials

ID	Name	Type	Location	Control Type	Cost ($/ft2)
1	RS -- exterior -- light-colored	shade	exterior	Always on	42.95
2	RS -- exterior -- medium-colore	shade	exterior	Always on	42.95
3	RS -- exterior -- dark-colored	shade	exterior	Always on	42.95
4	RS -- interior -- light-colored	shade	interior	Always on	28.63
5	RS -- interior -- medium-colore	shade	interior	Always on	28.63
6	RS -- interior -- dark-colored	shade	interior	Always on	28.63
7	RS -- between-glass -- light-col	shade	between-glass	Always on	31.89
8	RS -- between-glass -- medium	shade	between-glass	Always on	31.89
9	RS -- between-glass -- dark-co	shade	between-glass	Always on	31.89
10	VB -- exterior -- 3" slat (90 deg	venetian blind	exterior	Always on	130.00
11	VB -- exterior -- 3" slat (45 de	venetian blind	exterior	Always on	130.00
12	VB -- exterior -- 3" slat (0 deg)	venetian blind	exterior	Always on	130.00
13	VB -- interior -- 1" slat (90 deg	venetian blind	interior	Always on	35.10
14	VB -- interior -- 1" slat (45 deg	venetian blind	interior	Always on	35.10
15	VB -- interior -- 1" slat (0 deg)	venetian blind	interior	Always on	35.10
16	VB -- between-glass -- 0.45" sl	venetian blind	between-glass	Always on	40.14
17	VB -- between-glass -- 0.45" sl	venetian blind	between-glass	Always on	40.14
18	VB -- between-glass -- 0.45" sl	venetian blind	between-glass	Always on	40.14
19	Screen -- exterior -- dark-color	screen	exterior	Always on	97.50
20	Screen -- exterior -- dark-color	screen	exterior	Always on	97.50
21	Screen -- exterior -- dark-color	screen	exterior	Always on	97.50

Figure 4-75. Glazing system library

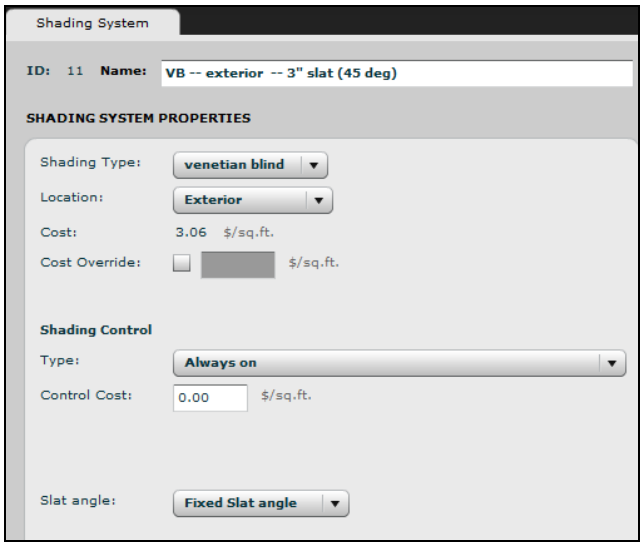


Figure 4-76. Shading system edit screen

Window cost

Window cost is the sum of the frame, glazing and shading system costs. The cost of the window is calculated as follows:

$$C_{win} = A_{win} \times (C_{frame} + C_{shad\ sys} + C_{glz}) \quad [\$/window]$$

Where

A_{win} Area of rough opening (includes frame area) [ft²]

C_{frame} Unit frame cost [$/ft² window area]

$C_{shad\ sys}$ Unit shading system cost [$/ft² window area]

C_{glz} Unit glazing system cost [$/ft² window area]

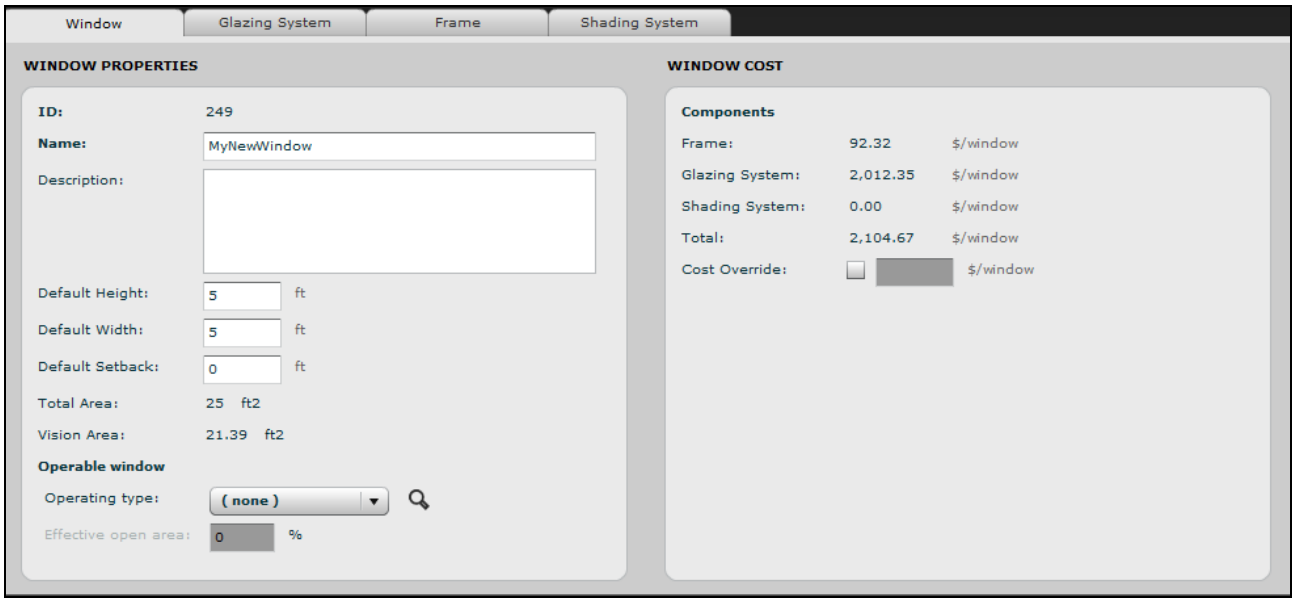


Figure 4-77. Window edit screen

HVAC cost

HVAC system costs are determined based on heating and cooling equipment size. Thus, in order to obtain HVAC system costs, the user must first calculate the scenario so that the program can determine the equipment sizing. Equipment costs are then calculated by multiplying the following default unit costs by the equipment size:

- Heating equipment: 20.80 $/kBtu-hr (70.97 $/kW)
- Cooling equipment: 939.73 $/ton (267.27 $/kW)

Similar to other default cost values in COMFEN, the default HVAC equipment costs can be overriden by the user under the cost tab in the Project Properties dialog box.

Lighting cost

Cost data for the lighting system is calculated as follows:

lighting power density, cost per lighting load specified by the user under the scenario tab:

$$C_{light\ sys} = A_{zone} \times (C_{fixture} + C_{control}) \quad [\$]$$

Where

$C_{fixture}$ Fixture cost per unit floor area [W/ft²]

$C_{control}$ Control cost per unit floor area [W/ft²]

A_{zone} Scenario floor area [ft²]

Lighting fixture and control costs can be overriden under the cost tab in the Project Properties dialog box.

4.8.3. Payback period

Energy-efficiency strategies in buildings are often evaluated in terms of their economic feasibility. One such measure is the simple payback – the amount of time (usually in years) required to recover the initial project

cost in an opportunity. For example, simple payback can be used to calculate the time it will take for cost savings accrued during the building operation phase to offset the increased capital cost associated with a specific design strategy or set of design strategies, such as better-performing windows or lighting controls. While increased investment in advanced facade design strategies may yield savings in other ways, including higher worker productivity and improved building market value, the payback calculation in COMFEN only takes into consideration the annual energy savings of the scenario.

The payback is calculated as follows:

$$\text{Payback (years)} = (FC_{\text{Case 1}} - FC_{\text{BC}}) / (EC_{\text{Case 1}} - EC_{\text{BC}})$$

Where

$FC_{\text{Case 1}}$ – first cost of scenario

FC_{BC} – first cost of base case (reference) scenario

$EC_{\text{Case 1}}$ – energy cost of scenario

EC_{BC} – energy cost of base case (reference) scenario

4.8.4. First cost

The first cost is the initial cost of construction. In the case of COMFEN it is the installed cost of the HVAC equipment, the lighting fixtures and controls, windows and shading (exterior projections and opaque wall construction are not included in these costs at present), adjusted by location to account for the cost of construction. In order to account for variation in construction costs in different locations, the first cost includes an adjustment factor for the project location. The adjustment factors are stored in the location library.

The project first cost is calculated as follows:

$$FC_{\text{Adj}} = \text{Adj factor} \times (FC_{\text{Light}} + FC_{\text{Win}} + FC_{\text{HVAC}})$$

Where

Adj factor – location-specific construction cost adjustment factor

FC_{Light} - first cost of lighting fixtures and lighting controls ($)

FC_{Win} - first cost of windows and shading (excluding exterior projections) ($)

FC_{HVAC} - first cost of heating, cooling and ventilation equipment ($)

4.8.5. Energy cost

Annual energy cost in COMFEN is the sum of the annual cost of gas and electricity consumed by the scenario. Due to differences in the cost of natural resources, the electric and gas rates vary by location. These utility rates are stored in the location library.

The project energy cost is calculated as follows:

$$EC = r_{\text{elec}} \times E_{\text{elec}} + r_{\text{gas}} \times E_{\text{gas}}$$

Where

EC – annual energy cost ($)

r_{elec} – electricity rate ($/kWh)

r_{gas} – gas rate ($/m^3 or $$/therm)

E_{elec} – annual electricity consumption (MJ or kBtu)

E_{gas} – annual gas consumption (MJ or kBtu)

4.8. Results

This section describes COMFEN output results in detail. While the section is primarily focused on results displayed through the COMFEN interface, the user should be aware that additional result files are saved in

the COMFEN folder. The user can also generate additional reports as needed for a range of other variables; the procedure is described below.
The user should note the following important points related to COMFEN results:

1. **Results are calculated and displayed in terms of solar, not local time, i.e. COMFEN does not account for daylight savings time (DST) or time zone adjustments.** This has a couple of important implications on COMFEN results. Firstly, results for a scenario calculated without DST are likely to be different from a case with DST, since not accounting for daylight savings time means that occupancy schedules are not shifted by an hour for part of the year, which can affect HVAC operation, lighting use, etc. Secondly, hourly results and peak demand dates are displayed in terms of solar time, not local time.
2. **An hourly result displayed in COMFEN is calculated as an average of data for the preceding hour.** So a result displayed for 9:00 am corresponds to *approximately* 8:30 am. This is because the hourly data results reported in COMFEN are based on Energy Plus results and the TMY weather file reporting. The TMY hourly weather data is based on hourly averages calculated for the 60-minute period ending at the given hour. For example, hour 9 on a particular day is an average of the data from 8:00 am to 9:00 am (Wilcox & Marion, 2008). Similarly, the Energy Plus hourly output is calculated as an average of the results at each timestep (15-minutes) for the preceding hour, i.e. results for 9:00 am are calculated as an average of 8:15, 8:30, 8:45, and 9:00 am.

   This applies to all hourly results in COMFEN that are determined based on the weather file (e.g. results under the climate tab) as well as results calculated by Energy Plus. Point-in-time renderings calculated using Radiance (i.e. renderings for a specific point in time) are an exception: a result calculated for 9:00 am represents 9:00 am solar time (not 8:30 am solar time).
3. **Seasonal results reporting.** Seasonal results, such as the ones under the Comparison > comfort > seasonal tab, are binned based on the following months:
   - SPRING: March, April, May
   - SUMMER: June, July, August
   - FALL: Sept., Oct., Nov.
   - WINTER: Dec., Jan., Feb.

4.8.1. Comfort Results

EnergyPlus reports predicted percentage dissatisfied (PPD). COMFEN and the Façade Design Tool reports predicted percentage satisfied (PPS), which is 100-PPD.

COMFEN uses the EnergyPlus Fanger method for thermal comfort calculations that takes into account all major modes of energy losses from the human body at a steady state condition. It is calculated from PMV (Predicted Mean Vote), using the following formula:

```
PPD = 100.0 - 95.0*EXP(-0.03353*PMV**4 - 0.2179*PMV**2)
```

The "Zone Averaged" method was used to calculate MRT (Mean Radiant Temperature) in the thermal comfort calculation. MRT is a measure of the combined effects of temperatures of surfaces within the space. Specifically it is the surface area × emissivity weighted average of the zone inside surface temperatures, where emissivity is the Thermal Absorptance of the inside material layer of each surface.

References

1. Wilcox, S., & Marion, W. (2008). *User's Manual for TMY3 Data Sets* (NREL/TP-581-43156). Golden, Colorado: National Renewable Energy Laboratory. Retrieved from http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

4.8.1. Detailed reports

The user wanting additional information on simulation parameters and results may find the following files in the COMFEN results folder (LBNL\COMFEN5\Results) useful:

- **scen_ID.idf** – Energy Plus input file containing scenario information, such as geometry, construction material types, etc.
- **scen_ID_binned_ eplus_output_data.csv**
- **scen_ID_eplusmap.csv**
- **scen_ID_ eplusout.csv –** hourly Energy Plus simulation output
  While the default output is limited to a set of pre-defined variables, including X, y and z, Energy Plus can generate reports with hourly data for a range of other variables. By editing the user_report_variables.xml file in the LBNL\COMFEN4\settings folder the user can generate additional variables, for which results are written to a file called scen_ID_user_report.csv. See below for more detailed information.
- **scen_ ID_eplusTbl_Table.csv –** Energy Plus output results summary
  All of the input parameters as well as the output variables and reports are described in detail in the Energy Plus documentation, by searching for a specific term. The Energy Plus Input/Output Reference is generally the most useful starting point.

4.8.2. Generating additional detailed reports

An additional file with hourly results for user-defined variables (*scen_ID_user_report.csv)* can be generated by editing the *user_report_variables.xml* file in the LBNL\COMFEN5\settings folder. By default, none of these variables are selected so the file is not generated. The user can specify reports they want generated by enclosing variables of interest with the following markers:

<!-- denotes beginning of section
--> denotes end of section

In the following example, which shows only a few of the variables in the .xml file, hourly "Direct Solar "and "Solar Azimuth Angle" reports will be generated.

<variable keyValue="*" nameInReport="Diffuse Solar" nameInRVI="Diffuse Solar" />
<!-- <variable keyValue="*" nameInReport="Direct Solar" nameInRVI="Direct Solar" />
<variable keyValue="*" nameInReport="Solar Azimuth Angle" nameInRVI="Solar Azimuth Angle" />
<variable keyValue="*" nameInReport="Solar Altitude Angle" nameInRVI="Solar Altitude Angle" /> **-->**
<variable keyValue="*" nameInReport="Solar Hour Angle" nameInRVI="Solar Hour Angle" />

The output file which contains these results is called

userReportOut.csv

and is located in

C:\Users\<username>\AppData\LBNL\COMFEN<version#>\EnergyPlus

The **userReportOut.csv** file is overwritten each time a scenario is calculated, so to get that file for multiple runs, make sure to rename it or copy it to another directory before doing the next run.

***NOTE**: It is recommended that the user create a copy of the user_report_variables.xml file prior to editing in order to keep the original with complete list of variables. A more advanced text editor (e.g. TextPad) is recommended for editing the file because the lack of paragraph formatting in Notepad makes it difficult to view the list of report variables.*

4.8.3. Overview tab

Summary

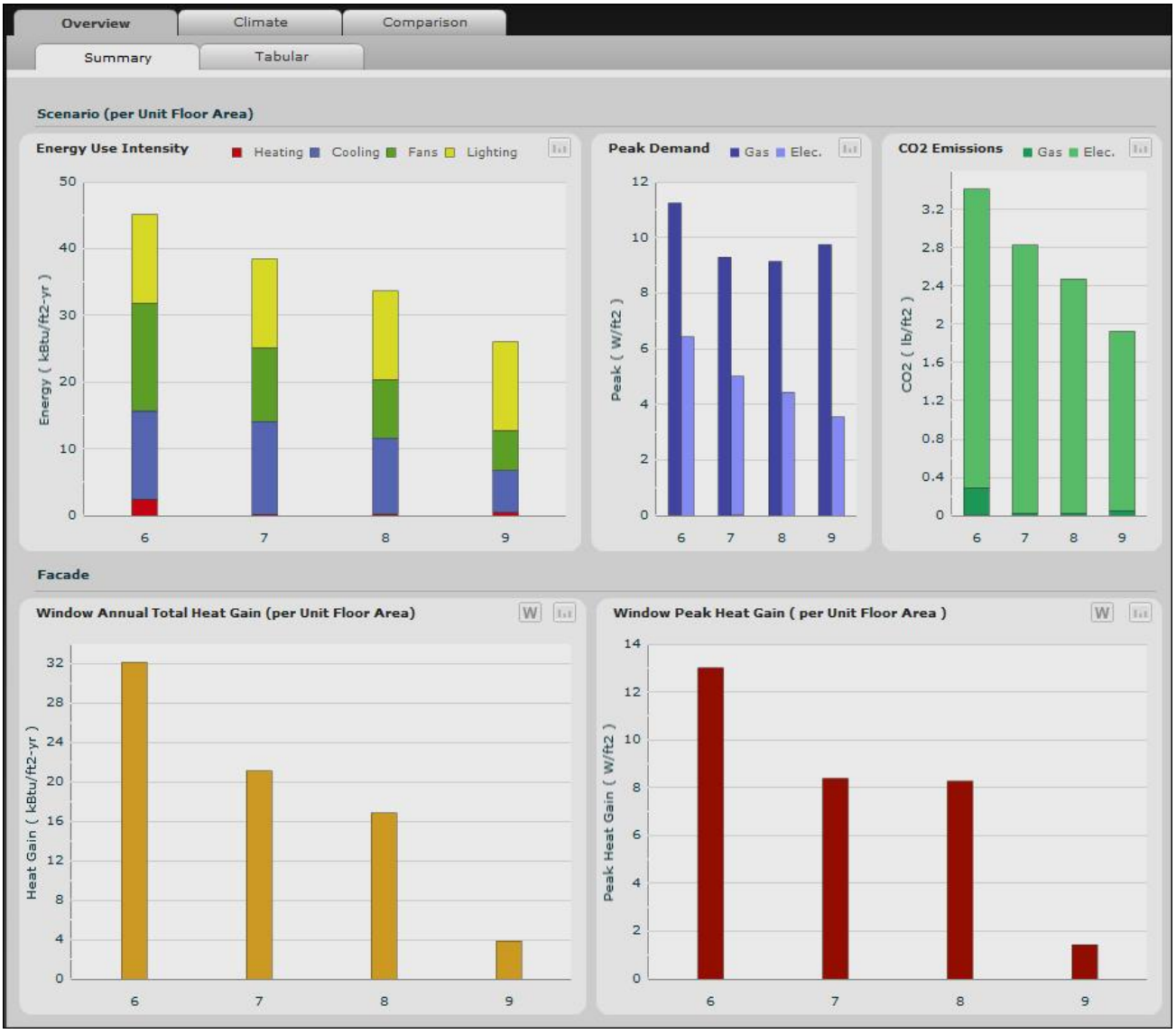


Figure 4-78. Overview > Summary Tab

In the Overview Summary Tab, the user will find an initial report of the energy usage of various aspects of each scenario created in the project. Bar graphs display each scenarios performance, organized by ID number. If the mouse is hovered over a particular bar, information about the graph and key data points are displayed numerically. The charts in this screen can all be exported as a *csv data file and a *.png image file by clicking this button in the upper right corner of the chart. Whether COMFEN is in IP or SI mode will determine which units are used in the exported files.

Tabular

ID	Total Ene	Peak Den	Peak Gas	Peak Dem	Peak Elec	Heating	Cooling	Lighting	Fans	Avg. Da	Avg. Dis	Avg. T	CO2 emissi
6	45.07	11.23	DEC 18 06	6.42	AUG 29 0:	2.34	13.31	13.37	16.05	62.96	7.10	85.52°	3.41
7	38.47	9.30	JAN 3 06::	5.00	AUG 29 0:	0.16	13.96	13.37	10.98	48.36	6.65	91.22°	2.82
8	33.62	9.14	JAN 3 06::	4.44	FEB 8 01::	0.20	11.42	13.37	8.63	42.78	6.65	91.23°	2.47
9	26.03	9.75	JAN 3 06::	3.54	AUG 29 0:	0.44	6.27	13.37	5.95	5.04	2.12	90.52°	1.93

Figure 4-79. Overview > Tabular Tab

The Tabular Tab displays the energy analysis results numerically. Results are automatically displayed in order of scenario ID but can be organized in any other fashion by clicking on the result heading. An arrow will appear in the heading tab that will point up or down depending on if the results are ordered highest to lowest or vice versa.

4.8.4. Climate tab

Annual Summary

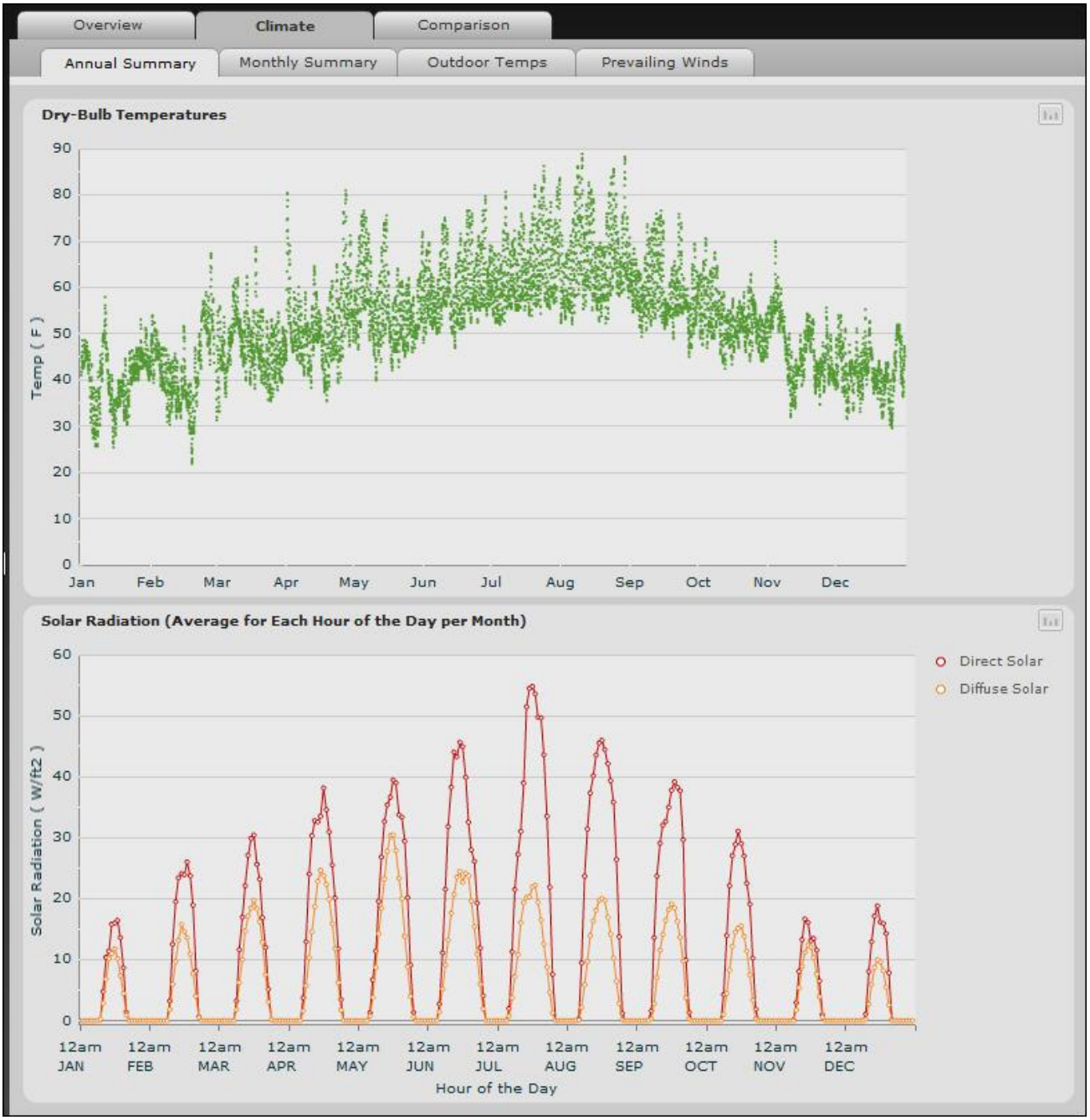


Figure 4-80. Climate > Annual Summary Tab

The Annual Summary Tab stores weather data based on project location.

Monthly Summary

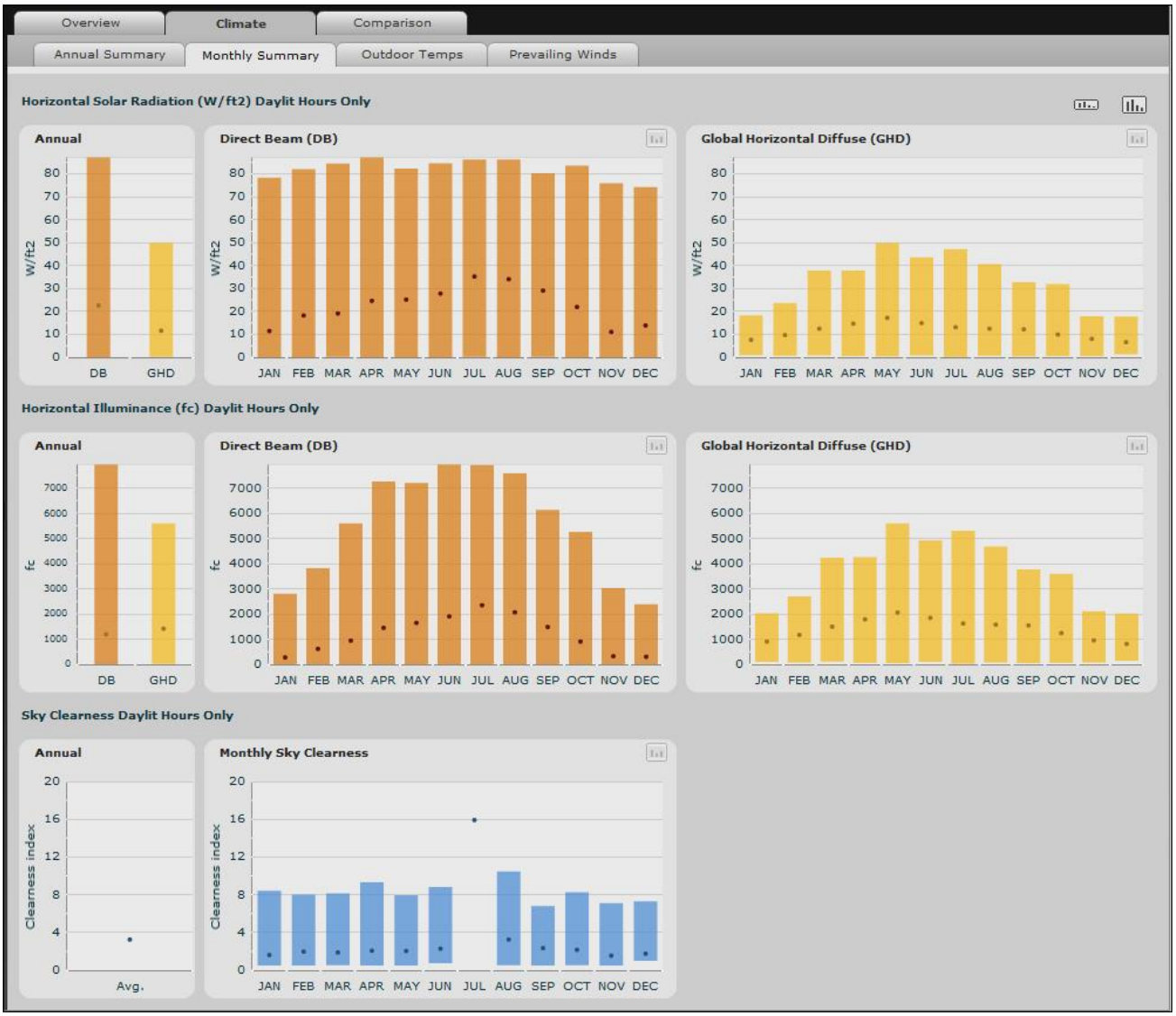


Figure 4-81. Climate > Monthly Summary Tab

The Monthly Summary Tab contains solar, daylighting, and sky condition information dependent on location.

Outdoor Temps

Figure 4-82. Climate > Outdoor Temps Tab

More weather data regarding outdoor temperatures and humidity is visually represented in the Outdoor Temps Tab.

Prevailing Winds

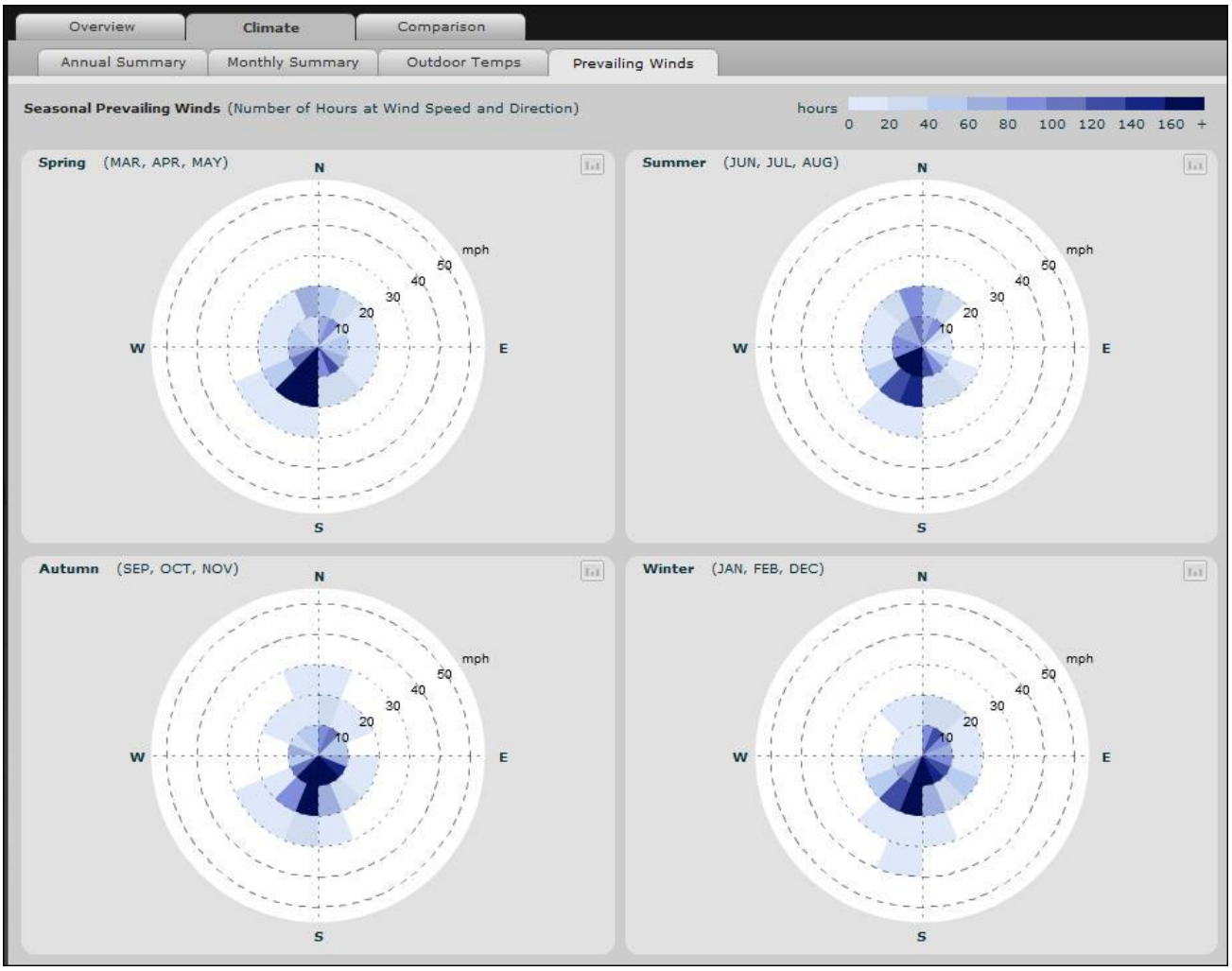


Figure 4-83. Climate > Prevailing Winds Tab

The Prevailing Winds tab provides further location-specific weather information graphically representing wind direction, speed and duration in a wind rose for each season.

4.8.5. Comparison tab

The Comparison tab allows you to compare up to four different scenarios, and presents results compared to the first of the scenarios, which the program considers the “Base Case”.

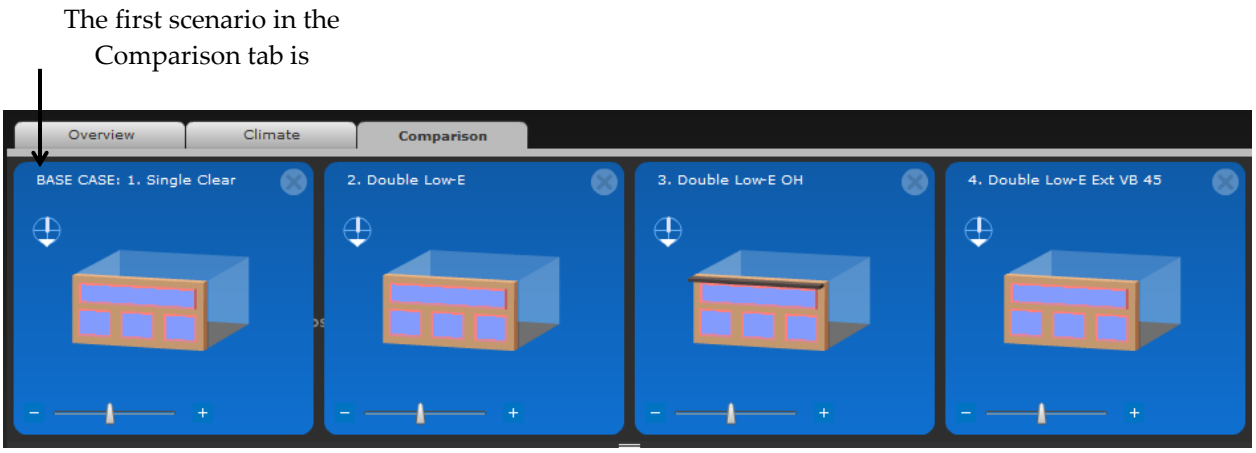


Figure 4-84. The first scenario is considered the Base Case.

Summary

The Comparison > Summary tab shows graphs that summarize the main results between the compared scenarios. These include

- Annual Energy Use
- Monthly Average Window Heat Gain
- Daylighting Illuminance Graphs
- Annual Average Thermal Comfort

Scenarios are added to the Comparison tab by dragging them from the Explorer on the left side of the screen into the Comparison area of the screen. It is easy to compare the scenarios with these clear graphical representations of the analysis results.

Figure 4-85. Comparison > Summary Tab

Energy

There are three sub tabs under the Comparison > Energy Tab. The first (shown below) contains some of the same bar graphs used in the Overview > Summary Tab. The Zone tab further breaks down energy usage and results into heating and cooling seasons.

The **Monthly Zone** tab shows the same three charts as before but in more detail.

The **Monthly Facade** tab breaks down the facade heat gain for all windows bar graph from the Comparison Summary tab into monthly data, and provides dates of peak gain for each scenario.

Figure 4-86. Comparison > Energy > Zone Tab

Facade

Figure 4-87. Comparison > Facade Tab

The graphics in the Comparison Facade tab explain the scenario heat gain in a high level of detail. The heat gain is mapped according to W/ft2 (W/m2), the month and the time of day.

To the right of the colored legend, the user can hide the table and expand the graphics by clicking on , and the user can choose to display the facade heat gain in terms of window area as opposed to per total floor area with this button .

Window

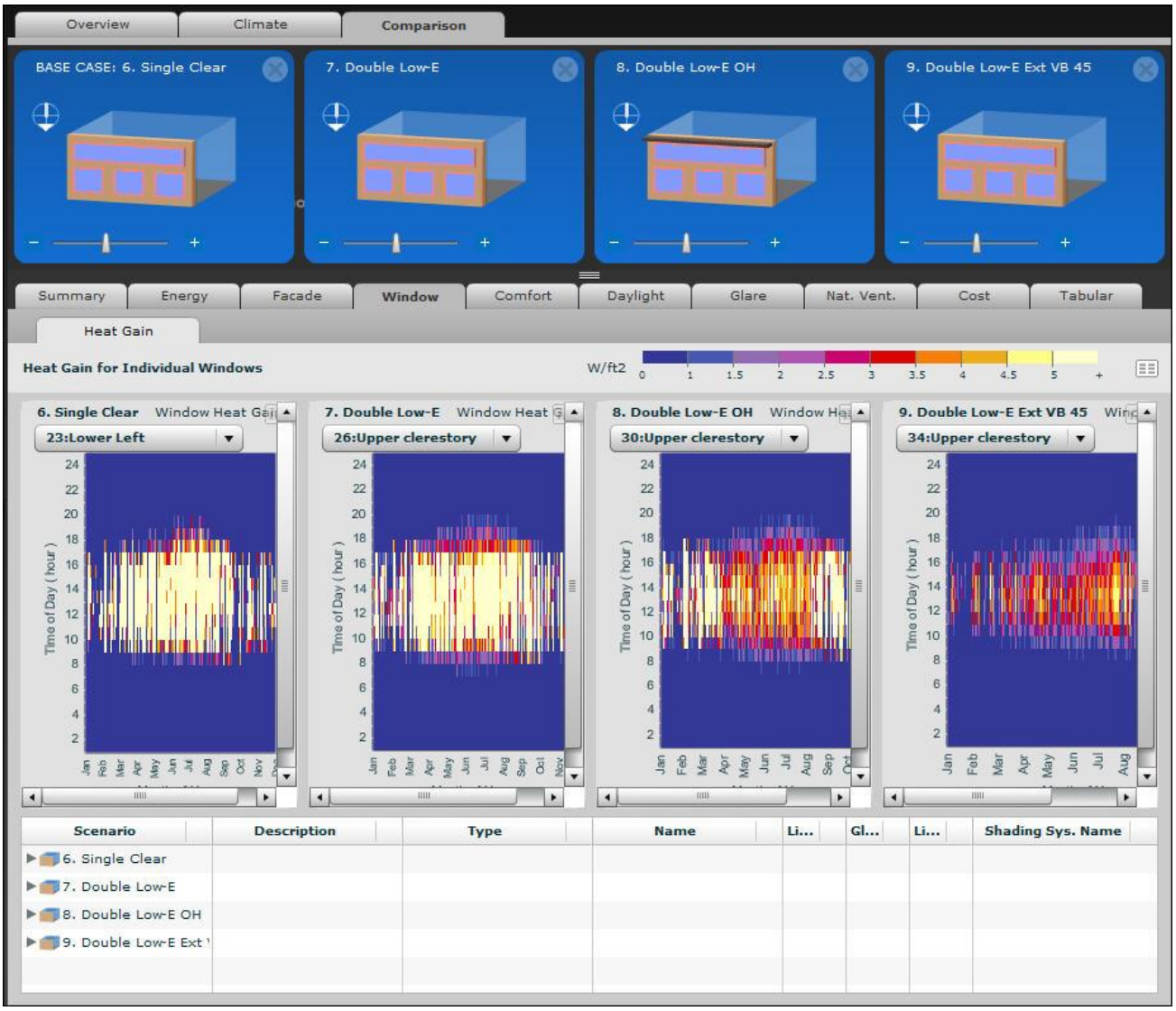


Figure 4-88. Comparison > Window Tab

The Comparison Window tab further explores the heat gain results by displaying the gain through an individual window on the facade of each scenario. The user can select which window (or lite in the case of a glazed wall assembly) to analyze by using the pulldown menu under the title of each scenario to select the name of the window.

Comfort

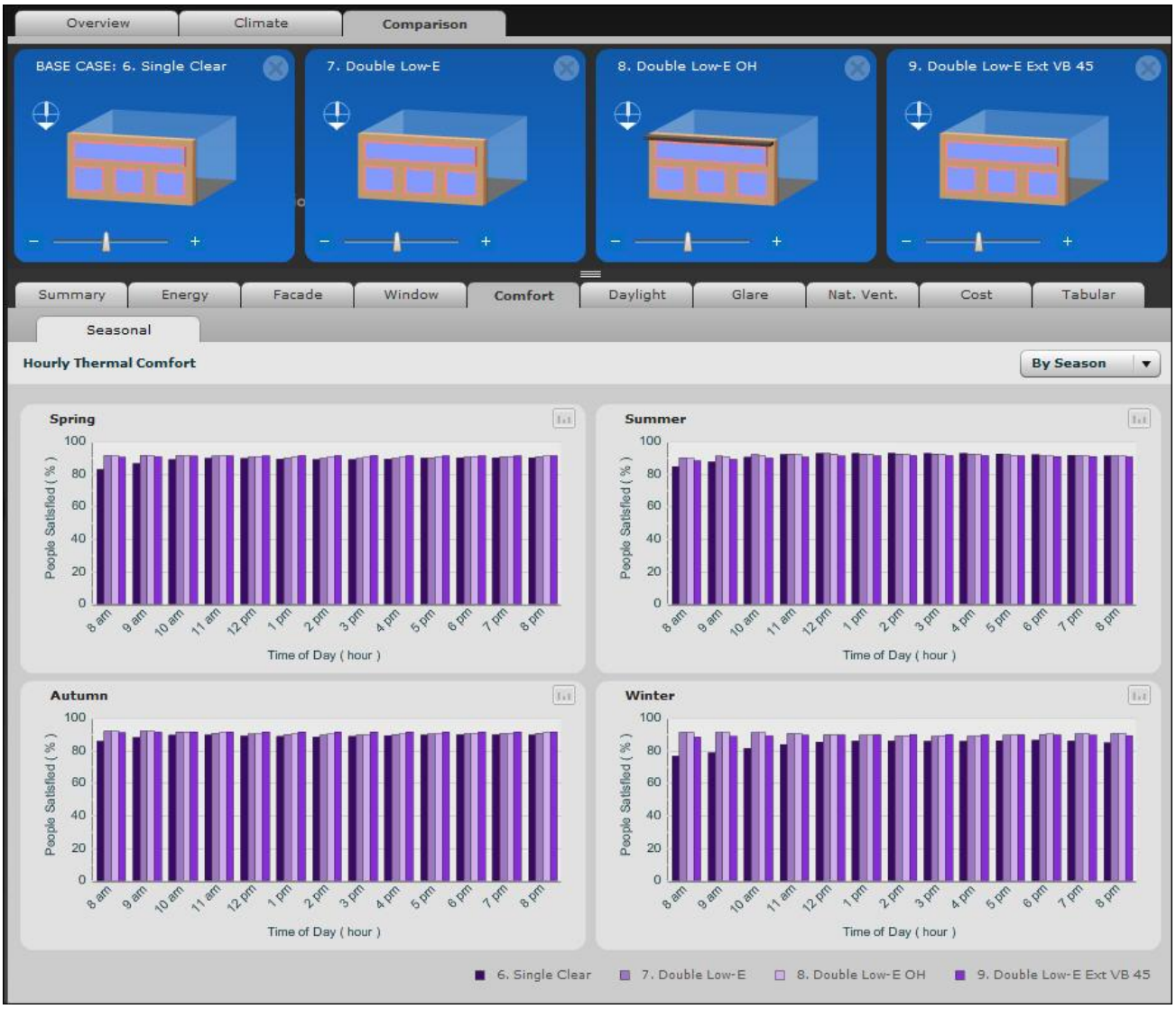


Figure 4-89. Comparison > Comfort Tab

Each scenario performance is assessed based on user comfort. Bar graphs are separated by season and display the percent of people satisfied at every hour from 8am to 8pm.

Daylight

There are six sub tabs under the Comparison Daylight tab.

- **Annual Summary:** describes average illuminance levels measured from reference point 1 and 2 for each scenario in comparison during every month.
- **Hourly Average:** describes average illuminance levels measured from reference point 1 and 2 for each scenario in comparison during every hour from 8am to 8pm.
- **Seasonal:** describes average illuminance levels measured for each scenario in comparison during every hour from 8am to 8pm broken down into graphs per season. The user can use the drop down menu in the upper right corner to view data from reference point 1 or point 2.
- **Illuminance Profiles:** graph of the seasonal illuminance information at specific distances from the facade. Hovering the mouse over data points will pop up further information about the graph and numeric data at the specified point. The values in these graphs are calculated as follows:
    - Energy Plus divides the space into a 10x10 grid of illuminance levels for each hour of the year
    - COMFEN averages the values between the 5 and 6 column (basically the center of the space from left to right) to get a series of 10 values from the front of the room to the back
    - COMFEN then bins and averages these values by hour over each season and over the whole year

  NOTE: *The y-axis scale is logarithmic.*
- **Plan Contour:** runs Radiance to produce renderings with mapped illuminance contour lines. See the Illuminance Contour Maps section in Daylighting and Glare analysis for further information.
- **3D Contour:** similar to Plan Contour but represents a 3D model of the space. See the Illuminance Contour Maps section in Daylighting and Glare Analysis for further information.

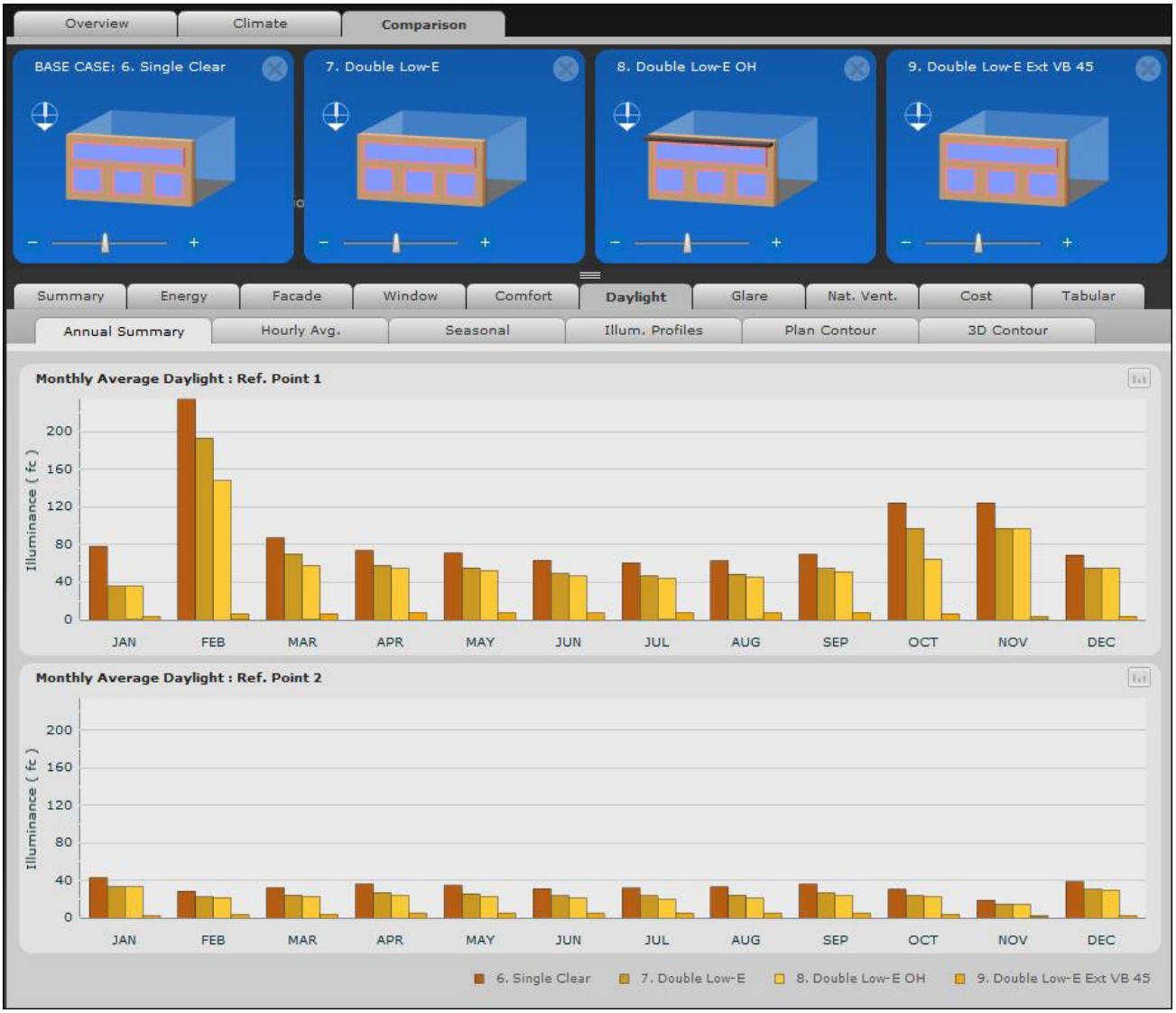


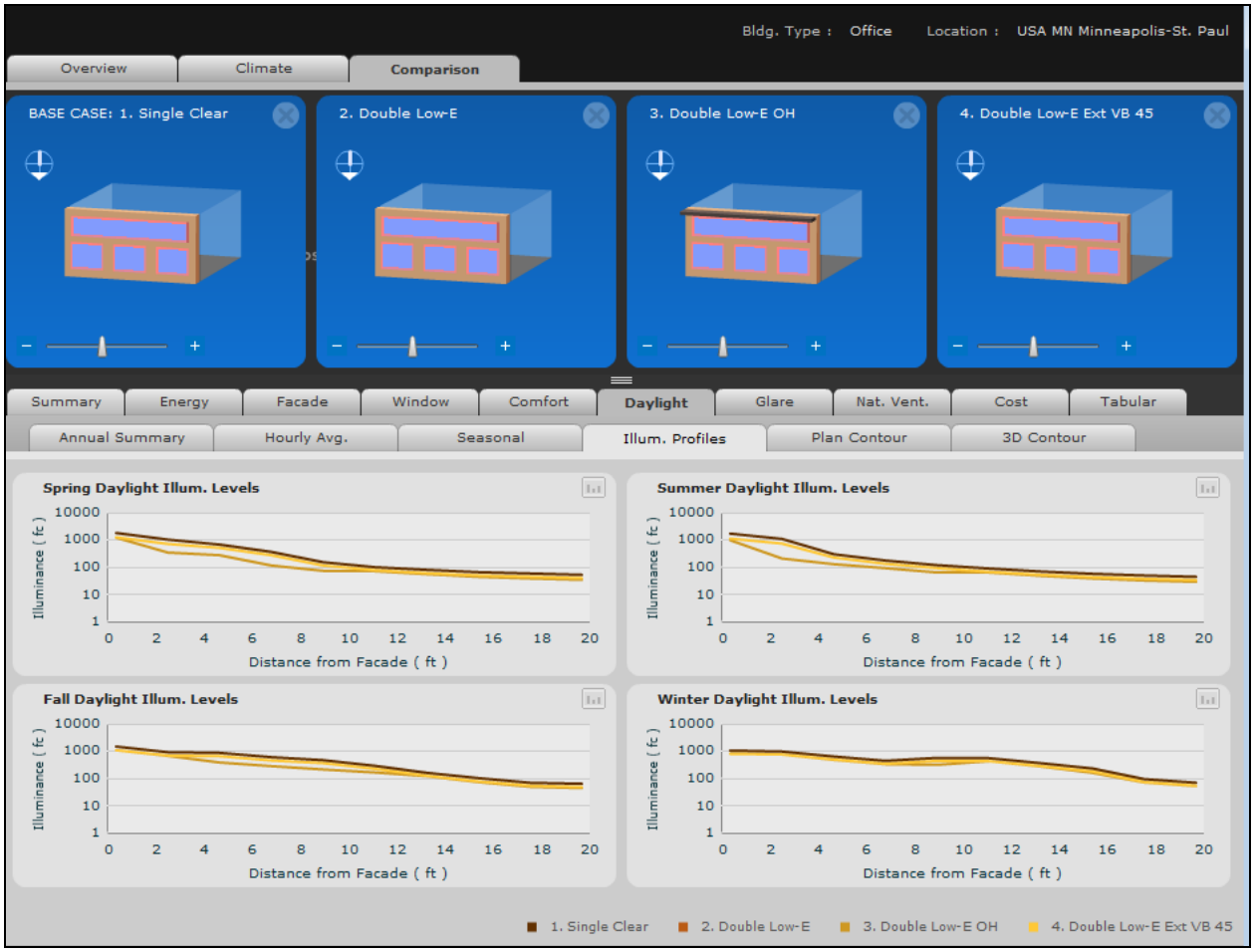
Figure 4-90. Comparison > Daylight > Annual Summary Tab

Illuminance Profiles

The Illuminance Profile graph of the seasonal illuminance information at specific distances from the facade. Hovering the mouse over data points will pop up further information about the graph and numeric data at the specified point. The values in these graphs are calculated as follows:

- Energy Plus divides the space into a 10x10 grid of illuminance levels for each hour of the year (saved into a file called
- COMFEN averages the values between the 5 and 6 column (basically the center of the space from left to right) to get a series of 10 values from the front of the room to the back
- COMFEN then bins and averages these values by hour over each season and over the whole year

NOTE: *The y-axis scale is logarithmic.*



Glare

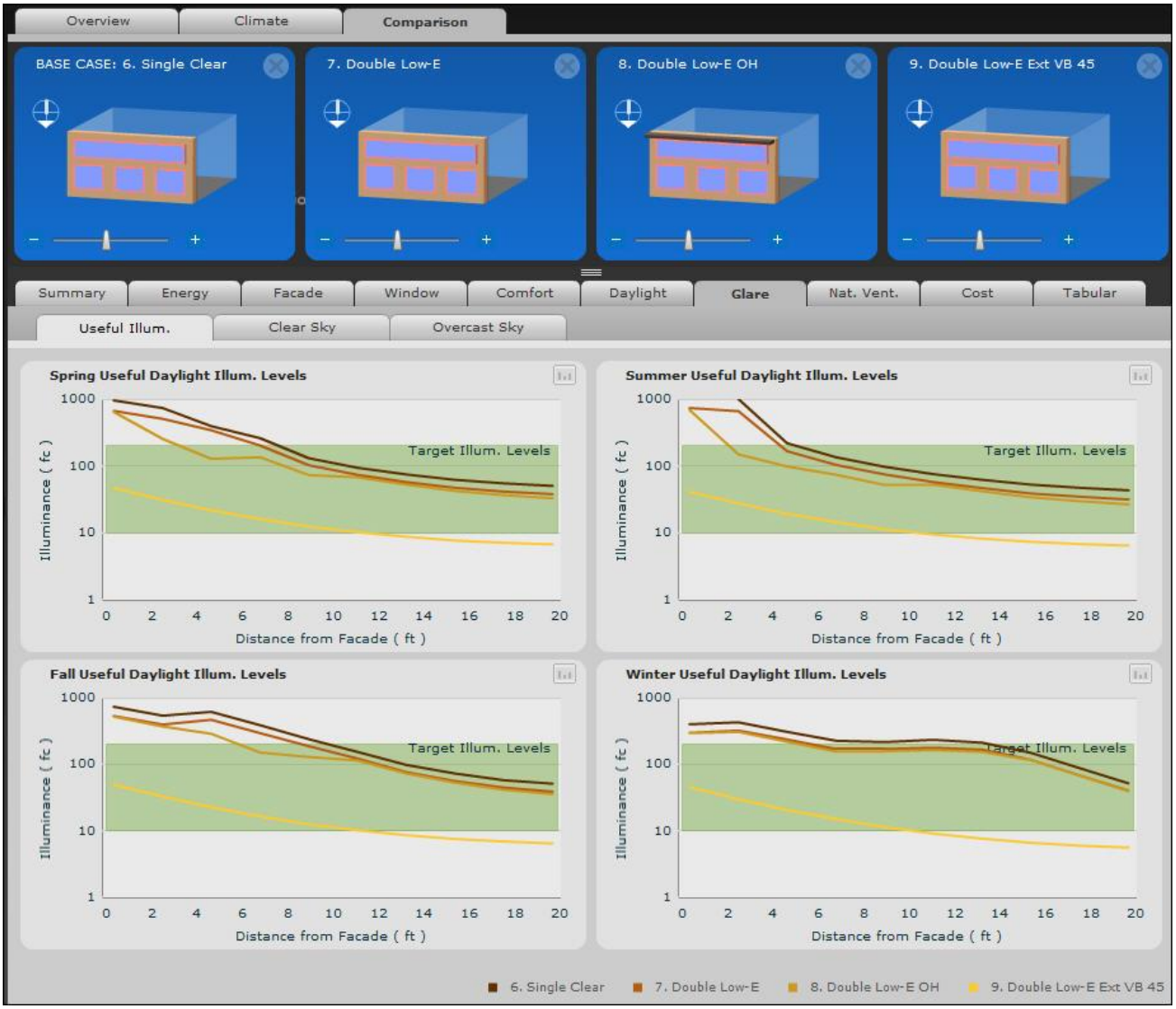


Figure 4-91. Comparison > Glare > Useful Illuminance Tab

The Comparison Glare tab also has sub tabs. **Clear Sky** and **Overcast Sky** run Radiance simulations to represent the visual discomfort in the space and are further explained in the Glare Analysis section of the Daylighting and Glare Analysis subchapter. The first tab, **Useful Illum.** looks like the same graph as the Illuminance Profiles tab under Comparison > Daylight, except the shaded green area represents the target illuminance levels for visual comfort.

Natural ventilation

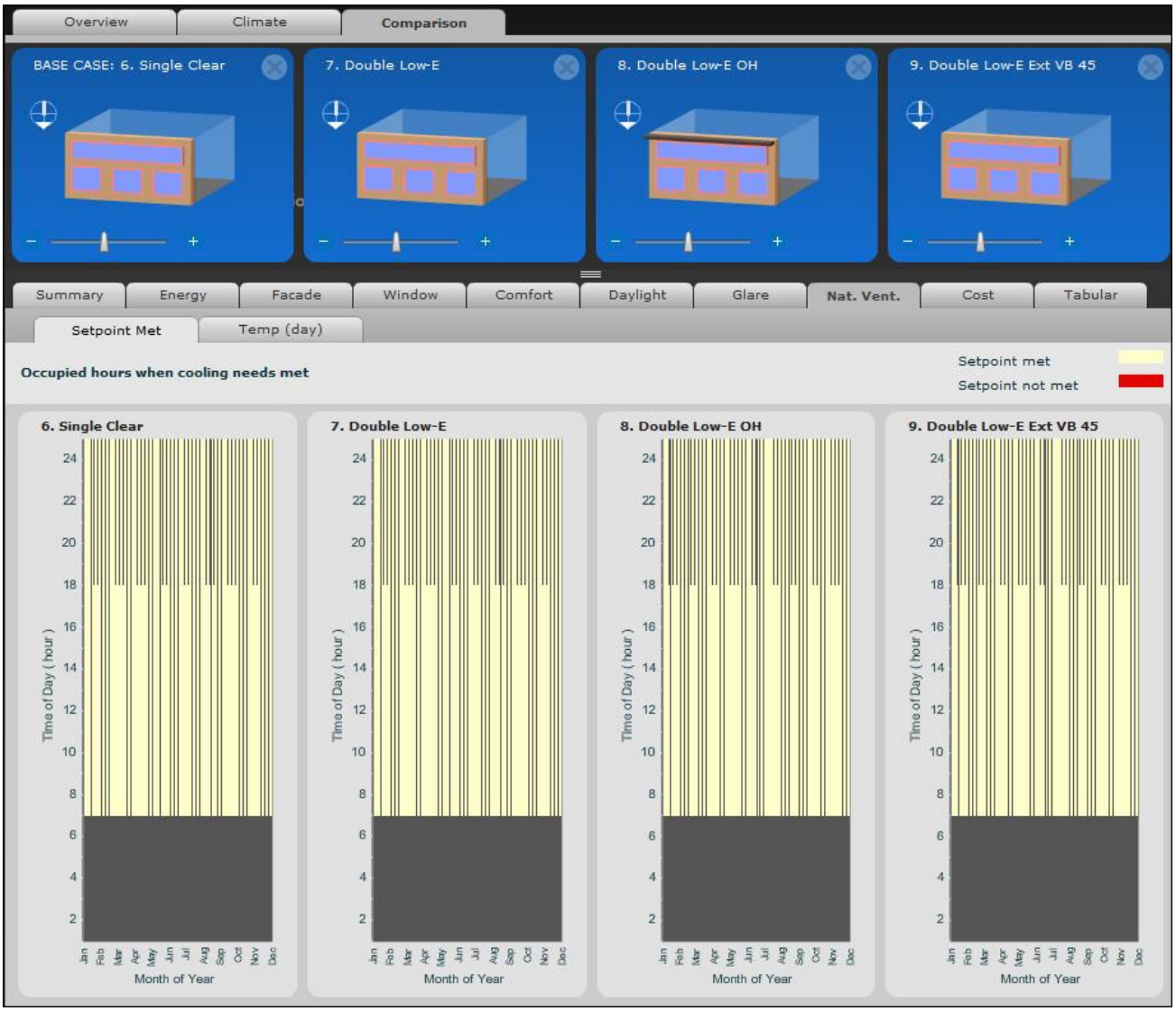


Figure 4-92. Comparison > Natural Ventilation > Setpoint Met Tab

Cost

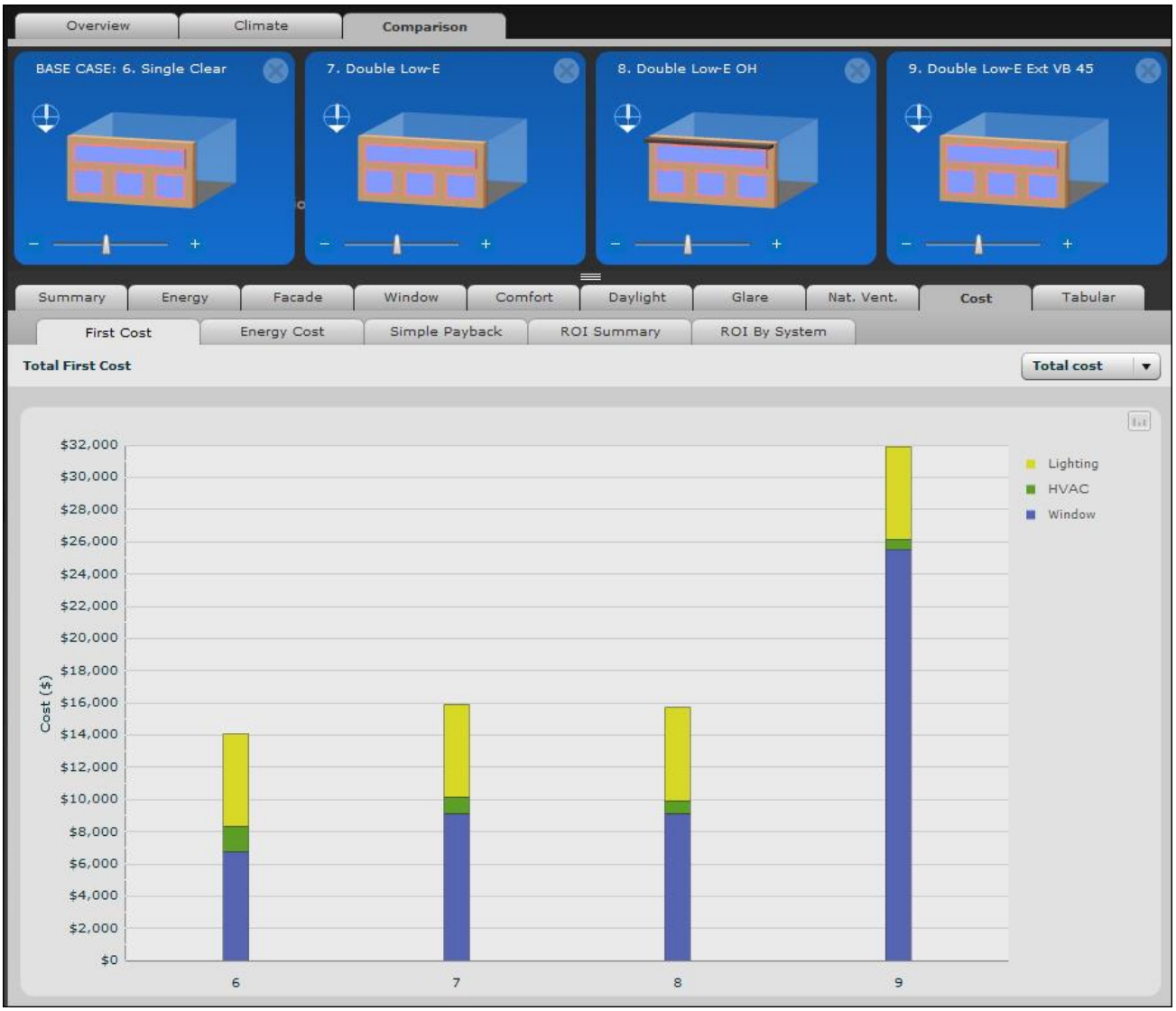
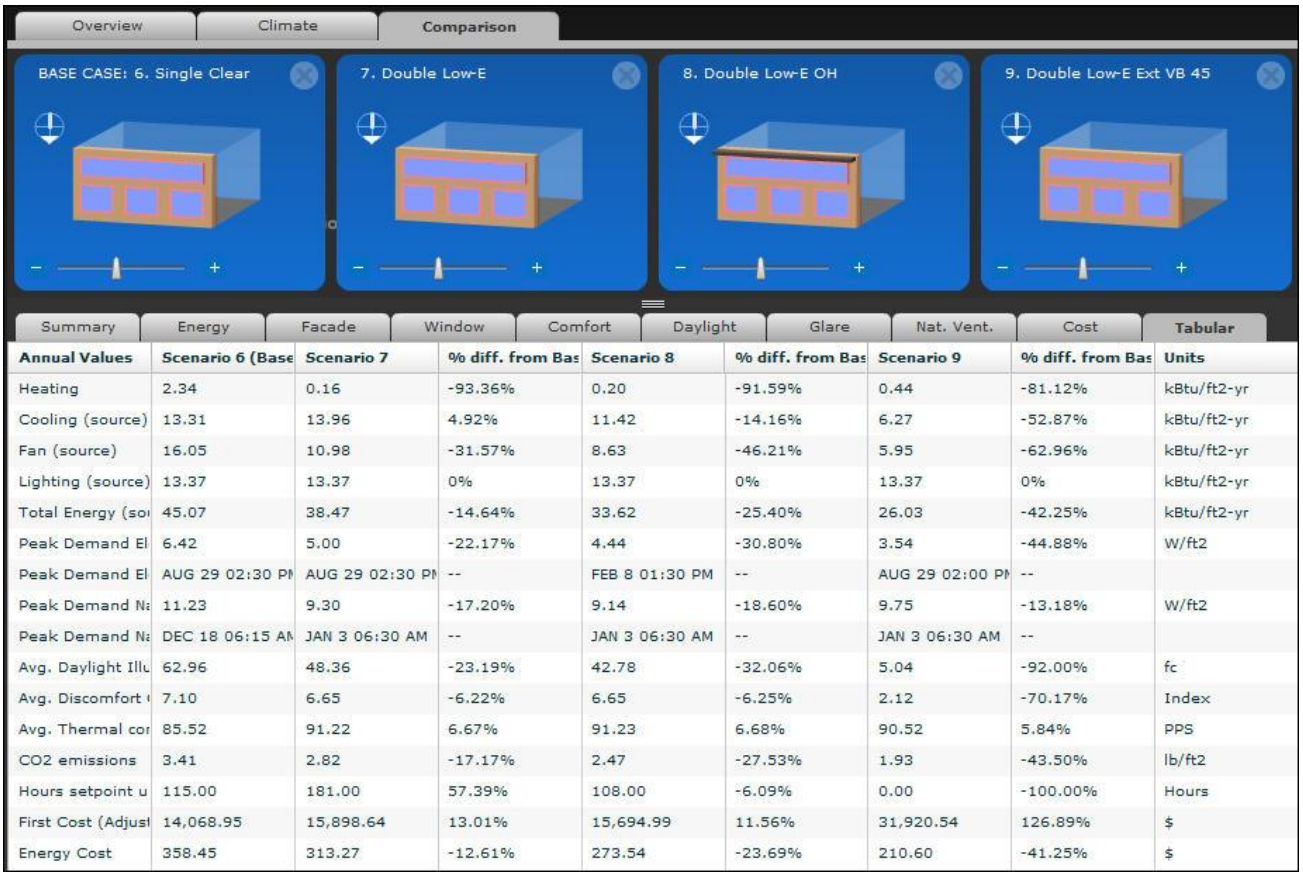


Figure 4-93. Comparison > Cost > First Cost Tab

Tabular



Annual Values	Scenario 6 (Base	Scenario 7	% diff. from Bas	Scenario 8	% diff. from Bas	Scenario 9	% diff. from Bas	Units
Heating	2.34	0.16	-93.36%	0.20	-91.59%	0.44	-81.12%	kBtu/ft2-yr
Cooling (source)	13.31	13.96	4.92%	11.42	-14.16%	6.27	-52.87%	kBtu/ft2-yr
Fan (source)	16.05	10.98	-31.57%	8.63	-46.21%	5.95	-62.96%	kBtu/ft2-yr
Lighting (source)	13.37	13.37	0%	13.37	0%	13.37	0%	kBtu/ft2-yr
Total Energy (sor	45.07	38.47	-14.64%	33.62	-25.40%	26.03	-42.25%	kBtu/ft2-yr
Peak Demand El	6.42	5.00	-22.17%	4.44	-30.80%	3.54	-44.88%	W/ft2
Peak Demand El	AUG 29 02:30 PM	AUG 29 02:30 PM	--	FEB 8 01:30 PM	--	AUG 29 02:00 PM	--	
Peak Demand Na	11.23	9.30	-17.20%	9.14	-18.60%	9.75	-13.18%	W/ft2
Peak Demand Na	DEC 18 06:15 AM	JAN 3 06:30 AM	--	JAN 3 06:30 AM	--	JAN 3 06:30 AM	--	
Avg. Daylight Illu	62.96	48.36	-23.19%	42.78	-32.06%	5.04	-92.00%	fc
Avg. Discomfort (	7.10	6.65	-6.22%	6.65	-6.25%	2.12	-70.17%	Index
Avg. Thermal cor	85.52	91.22	6.67%	91.23	6.68%	90.52	5.84%	PPS
CO2 emissions	3.41	2.82	-17.17%	2.47	-27.53%	1.93	-43.50%	lb/ft2
Hours setpoint u	115.00	181.00	57.39%	108.00	-6.09%	0.00	-100.00%	Hours
First Cost (Adjust	14,068.95	15,898.64	13.01%	15,694.99	11.56%	31,920.54	126.89%	$
Energy Cost	358.45	313.27	-12.61%	273.54	-23.69%	210.60	-41.25%	$

Figure 4-94. Comparison > Tabular Tab

4.9. Modeling Assumptions

General simulation parameters such as schedule, building type, etc. are written to the in.idf file located in the COMFEN Energy Plus Input folder. It is recommended that the user interested in understanding the calculation assumptions review this file and reference the Energy Plus Input/Output Reference documentation (available for download from the Energy Plus website) for an explanation of each parameter.

4.9.1. Building Envelope

The zone modeled by COMFEN is composed of one exterior wall, the façade wall, and five "adiabatic" interior walls.

The exterior wall can be defined in the Wall Library, but currently, the interior adiabatic walls are predefined in the program and cannot be changed through the user interface. Their constructions are as follows:

Floor	Carpet with fibrous pad 4" of light weight (80 lb) concrete
Ceiling	4" of light weight (80 lb) concrete
Interior Walls	5/8" gypsum 3 ¾ " vertical air space 5/8" gypsum

4.9.2. Occupancy, lighting and equipment loads

Information on occupancy, lighting and equipment loads can be found in the in.idf file, a section of which is included below. The Number of People, LightingLevel, EquipmentLevel inputs correspond to values defined by the user. Occupancy, lighting and equipment load schedules vary by building type.

```
People,
  COMFENZone People 1,     !- Name
  COMFENZone,              ! Zone Name
  OCC-SCHED,               ! People Schedule Name
  People,                  ! Number of people calculation method
  0.96,                 !- Number of People
  ,                        !- People per Zone Floor Area {person/m2}
  ,                        !- Zone Floor Area per Person {m2/person}
  0.3,                     !- Fraction Radiant
  ,                        !- Sensible Heat Fraction
  ACTIVITY-SCHED,          !- Activity Level Schedule Name
  ,                        !- Carbon Dioxide Generation Rate {m3/s-W}
  ,                        !- Enable ASHRAE 55 Comfort Warnings
  zoneaveraged,            !- Mean Radiant Temperature Calculation Type
  ,                        !- Surface Name/Angle Factor List Name
  WORK_EFF-SCHED,          !- Work Efficiency Schedule Name
  CLOTHING-SCHED,          !- Clothing Insulation Schedule Name
  AIR_VELO-SCHED,          !- Air Velocity Schedule Name
  Fanger;                  !- Thermal Comfort Model 1 Type
```

```
Lights,
  COMFENZone Lights,      !- Name
  COMFENZone,             !- Zone Name
  LIGHT-SCHED,            !- Schedule Name
  LightingLevel,          !- Design Level Calculation Method
   500.820068359,         !- Lighting Level {W}
  ,                       !- Watts per Zone Floor Area {W/m2}
  ,                       !- Watts per Person {W/person}
  0.,                     !- Return Air Fraction
  0.7,                    !- Fraction Radiant
  0.2,                    !- Fraction Visible
  1.,                     !- Fraction Replaceable
  GeneralLights;          !- End-Use Subcategory

 ElectricEquipment,
  COMFENZone ElecEq,      !- Name
  COMFENZone,             !- Zone Name
  EQUIP-SCHED,            !- Schedule Name
  EquipmentLevel,         !- Design Level Calculation Method
   300.492034912,  ! Design Level {W}
  ,                       !- Watts per Zone Floor Area {W/m2}
  ,                       !- Watts per Person {W/person}
  0.,                     !- Fraction Latent
  0.5,                    !- Fraction Radiant
  0.,                     !- Fraction Lost
  0;                      !- End-Use Subcategory
```

4.9.3. Schedules and setpoints

The following building types can be presently modeled in COMFEN.

- Office (office space)
- Mid-rise residential
- Hotel (guest room)
- Retail (point of sale)
- School (classroom)

This section includes heating and cooling setpoints and schedules (occupancy, lighting, electrical equipment and infiltration) by building/space type.

Holidays:

- New Years Day (January 1st)
- Martin Luther King Day (3rd Monday in January)
- Washington's Birthday (3rd Monday in February)
- Memorial Day (last Monday in May)
- Independence Day (July 4th)
- Labor Day (1st Monday in September)
- Veteran's Day (November 11th)

- Thanksgiving Day (4th Thursday in November)
- Christmas Day (December 25th)
- New Year's Eve (December 31st)

Office (office space)

Cooling and heating setpoints

Cooling Schedule (Through 12/31)

Type of Day	Time	Temperature
Weekdays (Summer)	24:00 – 6:00	26.7 °C (80.1 °F)
Weekdays (Summer)	6:00 – 22:00	24.0 °C (75.2 °F)
Weekdays (Summer)	22:00 – 24:00	26.7 °C (80.1 °F)
Saturdays	24:00 – 6:00	26.7 °C (80.1 °F)
Saturdays	6:00 – 18:00	24 °C (75.2 °F)
Saturdays	18:00 – 24:00	26.7 °C (80.1 °F)
All Other Days	24:00 – 24:00	26.7 °C (80.1 °F)

Heating Schedule (Through 12/31)

Type of Day	Time	Temperature
Weekdays	24:00 – 6:00	15.6 °C (60.1 °F)
Weekdays	6:00 – 22:00	21.0 °C (69.8 °F)
Weekdays	22:00 – 24:00	15.6 °C (60.1 °F)
Saturdays	24:00 – 6:00	15.6 °C (60.1 °F)
Saturdays	6:00 – 18:00	21.0 °C (69.8 °F)
Saturdays	18:00 – 24:00	15.6 °C (60.1 °F)
Winter Design Day	24:00 – 24:00	21.0 °C (69.8 °F)
All Other Days	24:00 – 24:00	15.6 °C (60.1 °F)

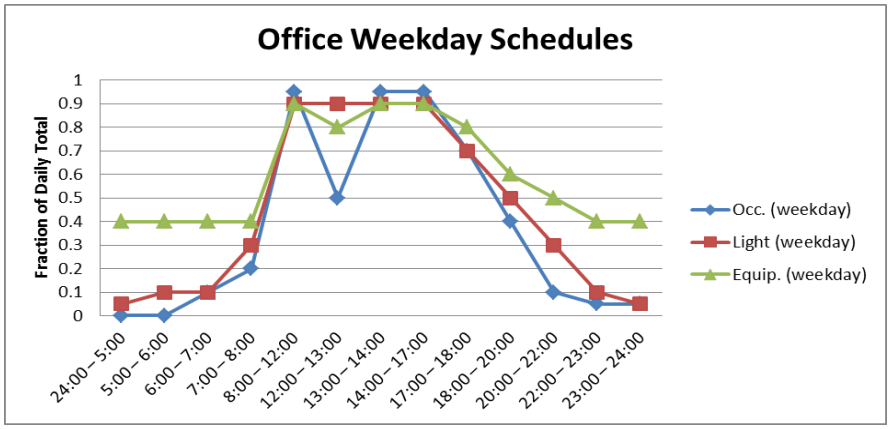
Infiltration

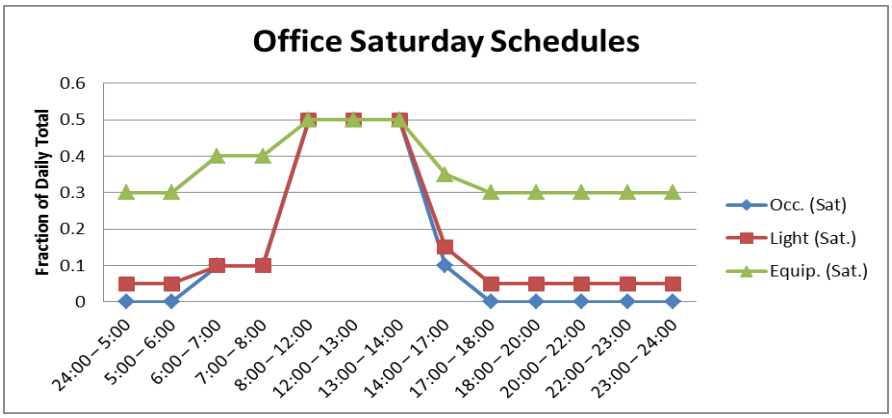
Time	**Infiltr.** (week day)	**Infiltr.** (Sat.)	**Infiltr.** (all other days)
24:00 – 6:00	1	1	1
6:00 – 18:00	0.25	0.25	1
18:00 – 22:00	0.25	1	1
22:00 – 24:00	1	1	1

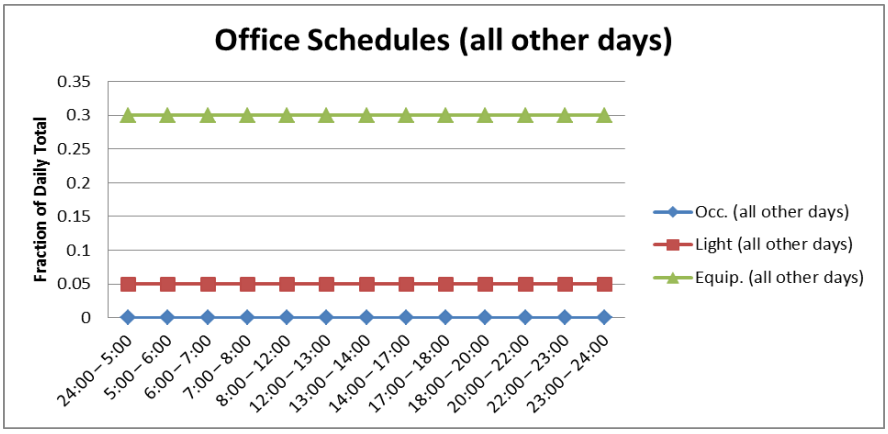
Occupancy Lighting and Equipment

Time	Occ. (week day)	Occ. (Sat)	Occ. (all other days)	Light (week day)	Light (Sat.)	Light (all other days)	Equip. (weekday)	Equip. (Sat.)	Equip. (all other days)
24:00 – 5:00	0.0	0.0	0.0	0.05	0.05	0.05	0.4	0.3	0.3
5:00 – 6:00	0.0	0.0	0.0	0.1	0.05	0.05	0.4	0.3	0.3
6:00 – 7:00	0.1	0.1	0.0	0.1	0.1	0.05	0.4	0.4	0.3
7:00 – 8:00	0.2	0.1	0.0	0.3	0.1	0.05	0.4	0.4	0.3
8:00 – 12:00	0.95	0.5	0.0	0.9	0.5	0.05	0.9	0.5	0.3
12:00 – 13:00	0.5	0.5	0.0	0.9	0.5	0.05	0.8	0.5	0.3
13:00 – 14:00	0.95	0.5	0.0	0.9	0.5	0.05	0.9	0.5	0.3
14:00 – 17:00	0.95	0.1	0.0	0.9	0.15	0.05	0.9	0.35	0.3
17:00 – 18:00	0.7	0.0	0.0	0.7	0.05	0.05	0.8	0.3	0.3
18:00 – 20:00	0.4	0.0	0.0	0.5	0.05	0.05	0.6	0.3	0.3
20:00 – 22:00	0.1	0.0	0.0	0.3	0.05	0.05	0.5	0.3	0.3
22:00 – 23:00	0.05	0.0	0.0	0.1	0.05	0.05	0.4	0.3	0.3
23:00 – 24:00	0.05	0.0	0.0	0.05	0.05	0.05	0.4	0.3	0.3

Time	Summer design day				Winter design day			
	Occ.	Light.	Equip.	Infiltr.	Occ.	Light.	Equip.	Infiltr.
24:00 – 6:00	0	1	1	1	0	0	0	1
6:00 – 18:00	1	1	1	0.25	0	0	0	0.25
18:00 – 22:00	1	1	1	0.25	0	0	0	1
22:00 – 24:00	0.05	1	1	1	0	0	0	1







Mid-rise residential (apartment)

Cooling and heating setpoints

Cooling Schedule (Through 12/31)

Type of Day	Time	Temperature
All Days	24:00 – 24:00	23.9°C (75.0 °F)

Heating Schedule (Through 12/31)

Type of Day	Time	Temperature
All Days	24:00 – 24:00	21.1 °C (70.0 °F)

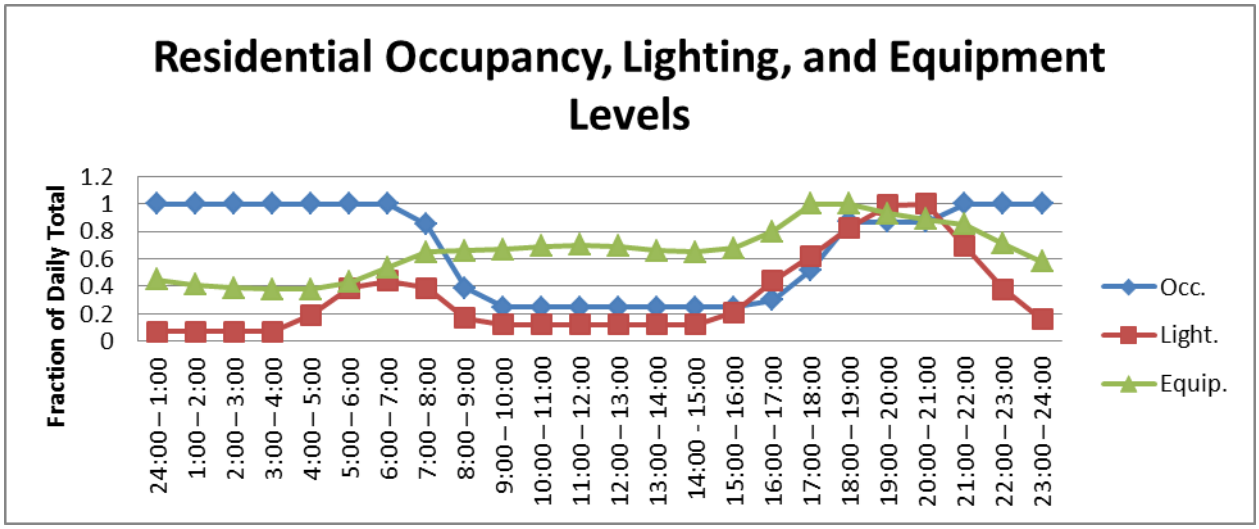
Occupancy, Lighting, and Equipment

All Days

Time	Occ.	Light.	Equip.		Time	Occ.	Light.	Equip.
24:00 – 1:00	1.00	0.07	0.45		12:00 – 13:00	0.25	0.12	0.69
1:00 – 2:00	1.00	0.07	0.41		13:00 – 14:00	0.25	0.12	0.66
2:00 – 3:00	1.00	0.07	0.39		14:00 - 15:00	0.25	0.12	0.65
3:00 – 4:00	1.00	0.07	0.38		15:00 – 16:00	0.25	0.21	0.68
4:00 – 5:00	1.00	0.19	0.38		16:00 – 17:00	0.30	0.44	0.80
5:00 – 6:00	1.00	0.39	0.43		17:00 – 18:00	0.52	0.62	1.00
6:00 – 7:00	1.00	0.44	0.54		18:00 – 19:00	0.87	0.83	1.00

All Days

7:00 – 8:00	0.85	0.39	0.65		19:00 – 20:00	0.87	0.99	0.93
8:00 – 9:00	0.39	0.17	0.66		20:00 – 21:00	0.87	1.00	0.89
9:00 – 10:00	0.25	0.12	0.67		21:00 – 22:00	1.00	0.69	0.85
10:00 – 11:00	0.25	0.12	0.69		22:00 – 23:00	1.00	0.38	0.71
11:00 – 12:00	0.25	0.12	0.70		23:00 – 24:00	1.00	0.16	0.58



Hotel (guest room)

Cooling and heating setpoints

Cooling Schedule (Through 12/31)

Type of Day	Time	Temperature
All Days	24:00 – 24:00	24.0°C (75.2 °F)

Heating Schedule (Through 12/31)

Type of Day	Time	Temperature
All Days	24:00 – 24:00	21.0 °C (69.8 °F)

Infiltration

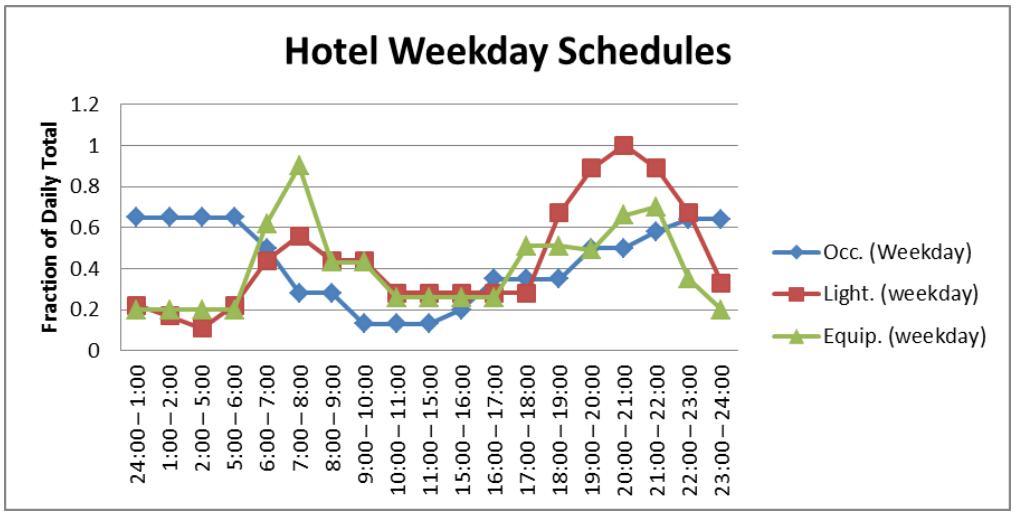
All times 0.25

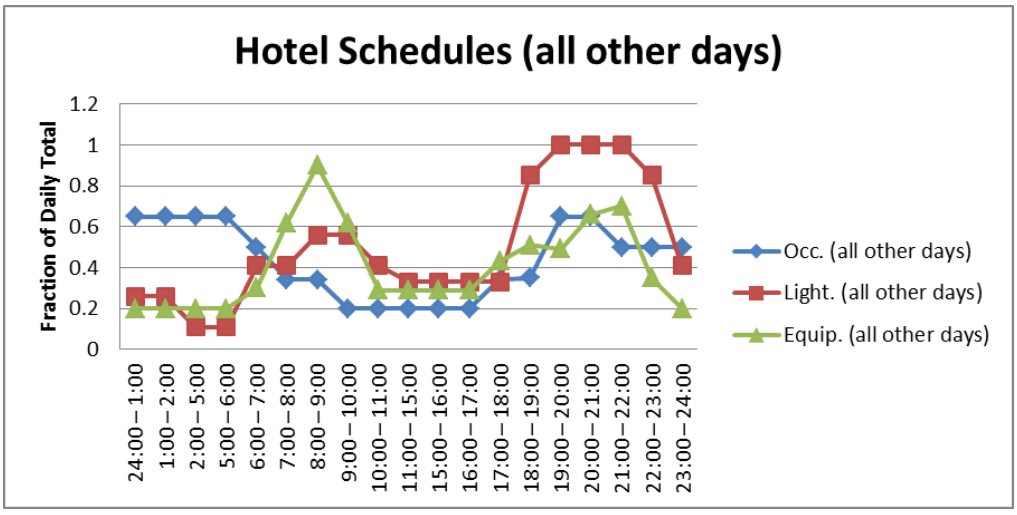
Occupancy, Lighting, and Equipment

Time	Occ. (Week day)	Occ. (all other days)	Light. (week day)	Light. (all other days)	Equip. (weekday)	Equip. (all other days)
24:00 – 1:00	0.65	0.65	0.22	0.26	0.20	0.20
1:00 – 2:00	0.65	0.65	0.17	0.26	0.20	0.20
2:00 – 5:00	0.65	0.65	0.11	0.11	0.20	0.20
5:00 – 6:00	0.65	0.65	0.22	0.11	0.20	0.20
6:00 – 7:00	0.5	0.5	0.44	0.41	0.62	0.30
7:00 – 8:00	0.28	0.34	0.56	0.41	0.90	0.62
8:00 – 9:00	0.28	0.34	0.44	0.56	0.43	0.90
9:00 – 10:00	0.13	0.20	0.44	0.56	0.43	0.62
10:00 – 11:00	0.13	0.20	0.28	0.41	0.26	0.29
11:00 – 15:00	0.13	0.20	0.28	0.33	0.26	0.29
15:00 – 16:00	0.20	0.20	0.28	0.33	0.26	0.29
16:00 – 17:00	0.35	0.20	0.28	0.33	0.26	0.29

17:00 – 18:00	0.35	0.34	0.28	0.33	0.51	0.43
18:00 – 19:00	0.35	0.35	0.67	0.85	0.51	0.51
19:00 – 20:00	0.50	0.65	0.89	1.0	0.49	0.49
20:00 – 21:00	0.50	0.65	1.0	1.0	0.66	0.66
21:00 – 22:00	0.58	0.50	0.89	1.0	0.70	0.70
22:00 – 23:00	0.64	0.50	0.67	0.85	0.35	0.35
23:00 – 24:00	0.64	0.50	0.33	0.41	0.20	0.20

Time	Summer design day			Winter design day		
	Occ.	Light.	Equip.	Occ.	Light.	Equip.
All day	1	1	1	0	0	0





Retail (point-of-sale)

Cooling and heating setpoints

Cooling Schedule (Through 12/31)

Type of Day	Time	Temperature
Weekdays (Summer)	24:00 – 6:00	30.0 °C (86.0 °F)
Weekdays (Summer)	6:00 – 21:00	24.0 °C (75.2 °F)
Weekdays (Summer)	21:00 – 24:00	30.0 °C (86.0 °F)
Saturdays	24:00 – 6:00	30.0 °C (86.0 °F)
Saturdays	6:00 – 22:00	24.0 °C (75.2 °F)
Saturdays	18:00 – 24:00	30.0 °C (86.0 °F)
Winter Design Day	24:00 – 24:00	30.0 °C (86.0 °F)
Sunday Holidays and All Other Days	24:00 – 8:00	30.0 °C (86.0 °F)
Sunday Holidays and All Other Days	8:00 – 19:00	24.0 °C (75.2 °F)
Sunday Holidays and All Other Days	19:00 – 24:00	30.0 °C (86.0 °F)

Heating Schedule (Through 12/31)

Type of Day	Time	Temperature
Weekdays	24:00 – 6:00	15.6 °C (60.1 °F)
Weekdays	6:00 – 21:00	21.0 °C (69.8 °F)
Weekdays	21:00 – 24:00	15.6 °C (60.1 °F)
Summer Design Day	24:00 – 24:00	15.6 °C (60.1 °F)
Winter Design Day	24:00 – 24:00	21.0 °C (69.8 °F)
Saturdays	24:00 – 6:00	15.6 °C (60.1 °F)
Saturdays	6:00 – 22:00	21.0 °C (69.8 °F)
Saturdays	22:00 – 24:00	15.6 °C (60.1 °F)
Sunday Holidays	24:00 – 8:00	15.6 °C (60.1 °F)
Sunday Holidays	8:00 – 19:00	21.0 °C (69.8 °F)
Sunday Holidays	19:00 – 24:00	15.6 °C (60.1 °F)

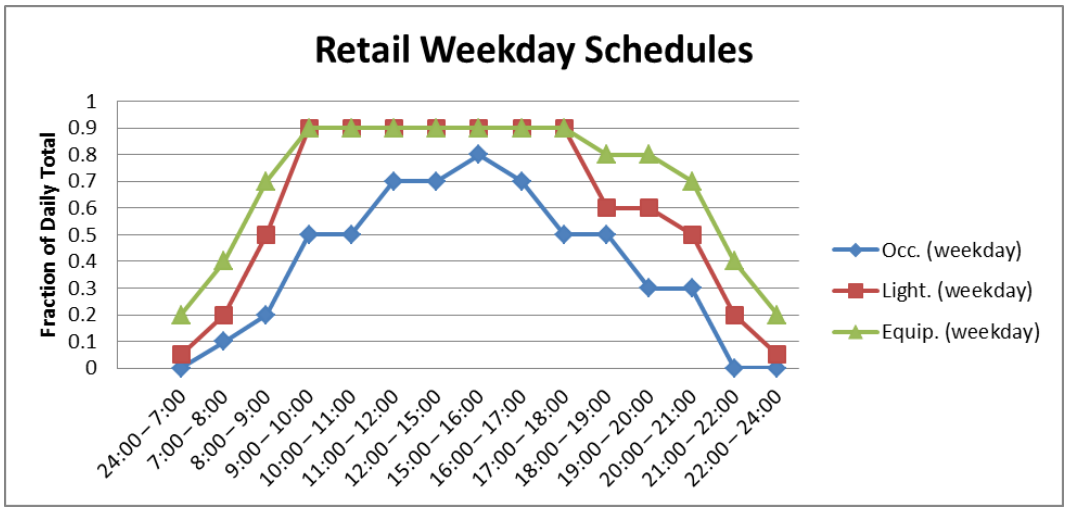
Infiltration

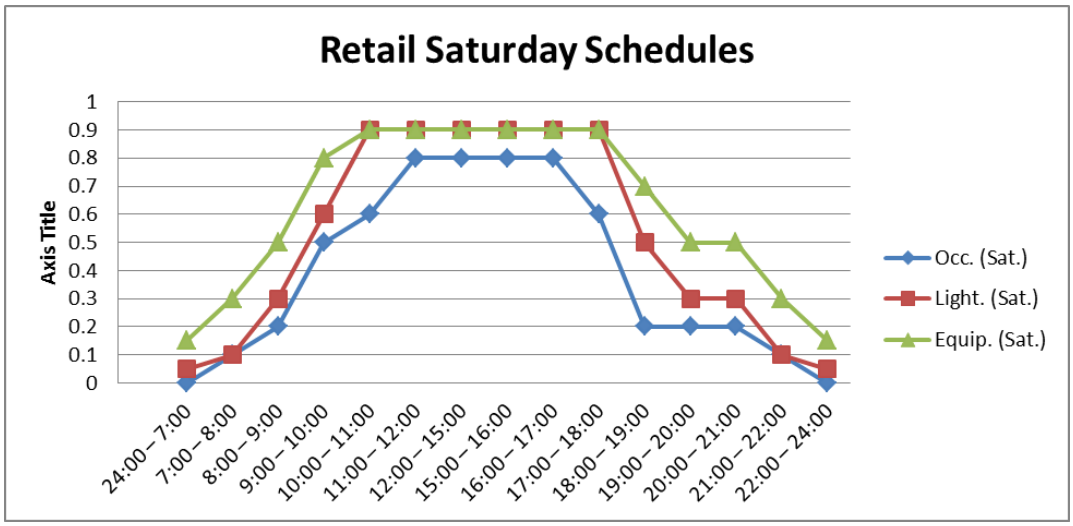
Time	Infiltr. (week day)	Infiltr. (Sat.)	Infiltr. (all other days)
24:00 – 6:00	1	1	1
6:00 – 8:00	0.5	0.5	1
8:00 – 17:00	0.5	0.5	0.5
17:00 – 21:00	0.5	0.5	1
21:00 – 22:00	1	0.5	1
22:00 – 24:00	1	1	1

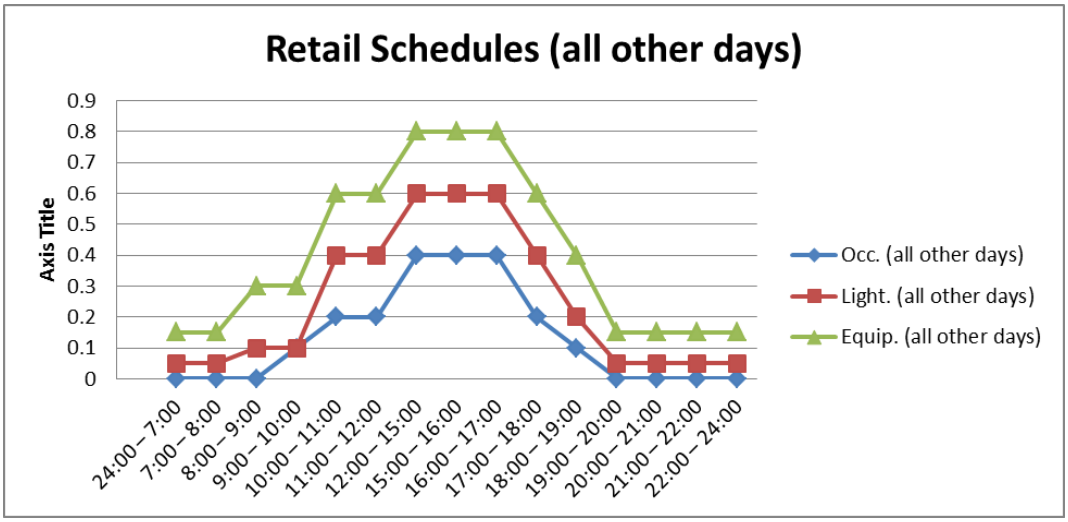
Occupancy, Lighting, and Equipment

Time	Occ. (weekday)	Occ. (Sat.)	Occ. (all other days)	Light. (weekday)	Light. (Sat.)	Light. (all other days)	Equip. (weekday)	Equip. (Sat.)	Equip. (all other days)
24:00 – 7:00	0.0	0.0	0.0	0.05	0.05	0.05	0.2	0.15	0.15
7:00 – 8:00	0.1	0.1	0.0	0.2	0.1	0.05	0.4	0.3	0.15
8:00 – 9:00	0.2	0.2	0.0	0.5	0.3	0.1	0.7	0.5	0.3
9:00 – 10:00	0.5	0.5	0.1	0.9	0.6	0.1	0.9	0.8	0.3
10:00 – 11:00	0.5	0.6	0.2	0.9	0.9	0.4	0.9	0.9	0.6
11:00 – 12:00	0.7	0.8	0.2	0.9	0.9	0.4	0.9	0.9	0.6
12:00 – 15:00	0.7	0.8	0.4	0.9	0.9	0.6	0.9	0.9	0.8
15:00 – 16:00	0.8	0.8	0.4	0.9	0.9	0.6	0.9	0.9	0.8
16:00 – 17:00	0.7	0.8	0.4	0.9	0.9	0.6	0.9	0.9	0.8
17:00 – 18:00	0.5	0.6	0.2	0.9	0.9	0.4	0.9	0.9	0.6
18:00 – 19:00	0.5	0.2	0.1	0.6	0.5	0.2	0.8	0.7	0.4
19:00 – 20:00	0.3	0.2	0.0	0.6	0.3	0.05	0.8	0.5	0.15
20:00 – 21:00	0.3	0.2	0.0	0.5	0.3	0.05	0.7	0.5	0.15
21:00 – 22:00	0.0	0.1	0.0	0.2	0.1	0.05	0.4	0.3	0.15
22:00 – 24:00	0.0	0.0	0.0	0.05	0.05	0.05	0.2	0.15	0.15

Time	Summer design day				Winter design day			
	Occ.	Light.	Equip.	Infiltr.	Occ.	Light.	Equip.	Infiltr.
24:00 – 6:00	1	1	1	1	1	0	0	1
6:00 – 21:00	1	1	1	0.5	1	0	0	1
21:00 – 24:00	1	1	1	1	1	0	0	1






Retail Schedules (all other days)
Axis Title
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
24:00 – 7:00
7:00 – 8:00
8:00 – 9:00
9:00 – 10:00
10:00 – 11:00
11:00 – 12:00
12:00 – 15:00
15:00 – 16:00
16:00 – 17:00
17:00 – 18:00
18:00 – 19:00
19:00 – 20:00
20:00 – 21:00
21:00 – 22:00
22:00 – 24:00
Occ. (all other days)
Light. (all other days)
Equip. (all other days)

School (classroom)

Cooling and heating setpoints, °C

Cooling Schedule (9/2 – 6/30)

Type of Day	Time	Temperature
Summer Design Day	24:00 – 24:00	24.0 °C (75.2 °F)
Weekends, Holidays and Winter Design Days	24:00 – 24:00	27.0 °C (80.6 °F)
All Other Days	24:00 – 6:00	27.0 °C (80.6 °F)
All Other Days	6:00 – 21:00	24.0 °C (75.2 °F)
All Other Days	21:00 – 24:00	27.0 °C (80.6 °F)

Cooling Schedule (7/1 – 9/1)

Type of Day	Time	Temperature
Summer Design Day	24:00 – 24:00	24.0 °C (75.2 °F)
Weekends, Holidays and Winter Design Days	24:00 – 24:00	27.0 °C (80.6 °F)
All Other Days	24:00 – 7:00	27.0 °C (80.6 °F)
All Other Days	7:00 – 18:00	24.0 °C (75.2 °F)
All Other Days	18:00 – 24:00	27.0 °C (80.6 °F)

Heating Schedule (9/2 – 6/30)

Type of Day	Time	Temperature
Winter Design Day	24:00 – 24:00	21.0 °C (69.8 °F)
Weekends, Holidays and Summer Design Days	24:00 – 24:00	16.0 °C (60.8 °F)
All Other Days	24:00 – 6:00	16.0 °C (60.8 °F)
All Other Days	6:00 – 21:00	21.0 °C (69.8 °F)
All Other Days	21:00 – 24:00	16.0 °C (60.8 °F)

Heating Schedule (7/1 – 9/1)

Type of Day	Time	Temperature
Winter Design Day	24:00 – 24:00	21.0 °C (69.8 °F)
Weekends, Holidays and Summer Design Days	24:00 – 24:00	16.0 °C (60.8 °F)

All Other Days	24:00 – 7:00	16.0 °C (60.8 °F)
All Other Days	7:00 – 18:00	21.0 °C (69.8 °F)
All Other Days	18:00 – 24:00	16.0 °C (60.8 °F)

Infiltration
All days

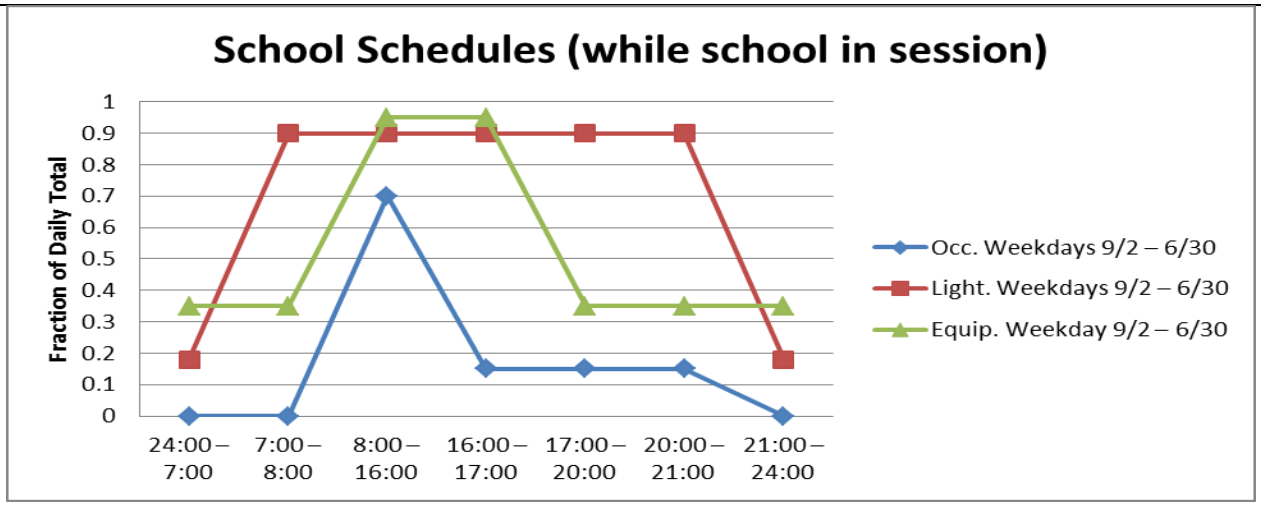
Time	**Infiltration**
24:00 – 7:00	1
7:00 – 21:00	0.5
21:00 – 24:00	1

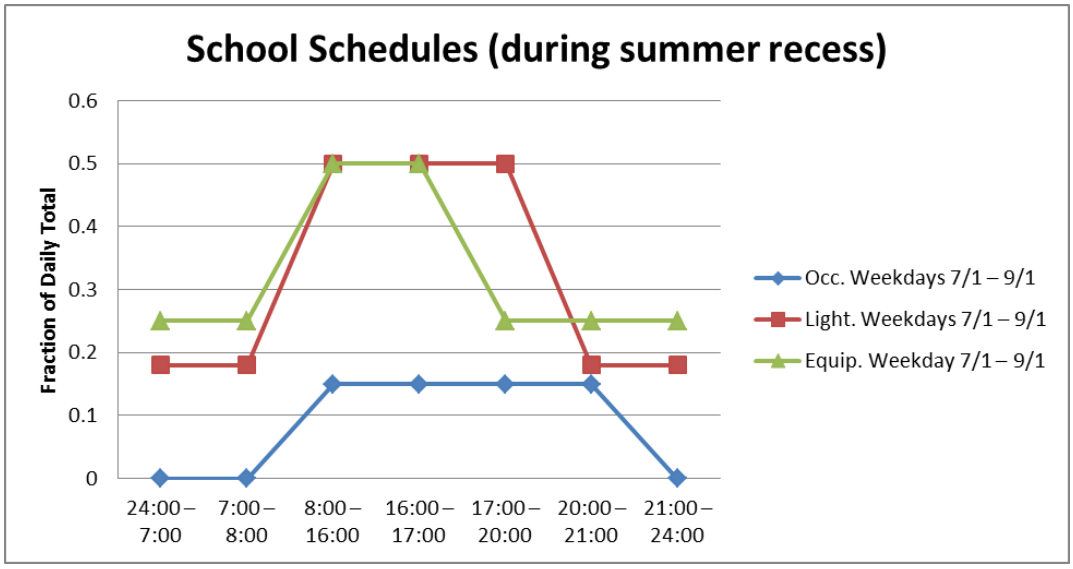
Occupancy, Lighting, and Equipment
Weekdays

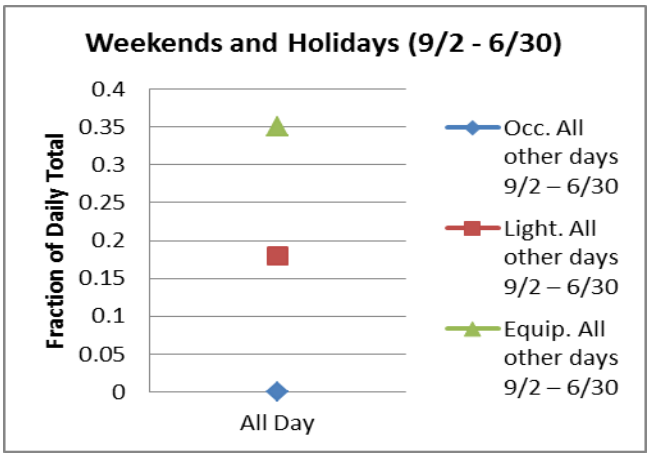
Time	**Occ.** Week days 9/2 – 6/30	**Occ.** Week days 7/1 – 9/1	**Light.** Week days 9/2 – 6/30	**Light.** Week days 7/1 – 9/1	**Equip.** Weekday 9/2 – 6/30	**Equip.** Weekday 7/1 – 9/1
24:00 – 7:00	0.0	0.0	0.18	0.18	0.35	0.25
7:00 – 8:00	0.0	0.0	0.9	0.18	0.35	0.25
8:00 – 16:00	0.7	0.15	0.9	0.5	0.95	0.5
16:00 – 17:00	0.15	0.15	0.9	0.5	0.95	0.5
17:00 – 20:00	0.15	0.15	0.9	0.5	0.35	0.25
20:00 – 21:00	0.15	0.15	0.9	0.18	0.35	0.25
21:00 – 24:00	0.0	0.0	0.18	0.18	0.35	0.25

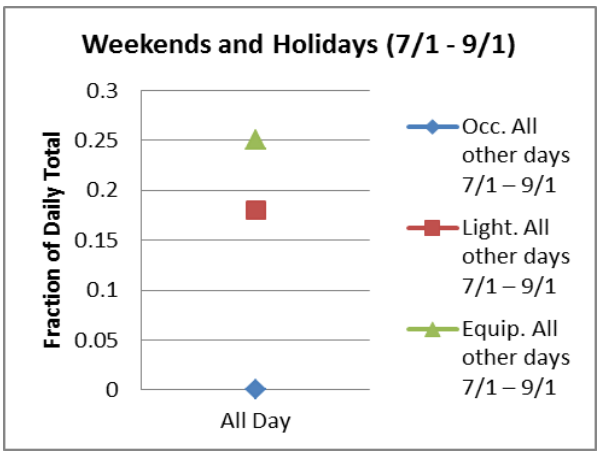
All Other Days

Time	**Occ.** All other days 9/2 – 6/30	**Occ.** All other days 7/1 – 9/1	**Light.** All other days 9/2 – 6/30	**Light.** All other days 7/1 – 9/1	**Equip.** All other days 9/2 – 6/30	**Equip.** All other days 7/1 – 9/1
All Day	0.0	0.0	0.18	0.18	0.35	0.25


School Schedules (while school in session)
Fraction of Daily Total
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
24:00 – 7:00
7:00 – 8:00
8:00 – 16:00
16:00 – 17:00
17:00 – 20:00
20:00 – 21:00
21:00 – 24:00
Occ. Weekdays 9/2 – 6/30
Light. Weekdays 9/2 – 6/30
Equip. Weekday 9/2 – 6/30


School Schedules (during summer recess)
Fraction of Daily Total
0.6
0.5
0.4
0.3
0.2
0.1
0
24:00 – 7:00
7:00 – 8:00
8:00 – 16:00
16:00 – 17:00
17:00 – 20:00
20:00 – 21:00
21:00 – 24:00
Occ. Weekdays 7/1 – 9/1
Light. Weekdays 7/1 – 9/1
Equip. Weekday 7/1 – 9/1


Weekends and Holidays (9/2 - 6/30)
Fraction of Daily Total
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
All Day
Occ. All other days 9/2 – 6/30
Light. All other days 9/2 – 6/30
Equip. All other days 9/2 – 6/30


Weekends and Holidays (7/1 - 9/1)
Fraction of Daily Total
0.3
0.25
0.2
0.15
0.1
0.05
0
All Day
Occ. All other days 7/1 – 9/1
Light. All other days 7/1 – 9/1
Equip. All other days 7/1 – 9/1

4.9.4. Lighting control

The lighting control logic is embedded in the program as illustrated in the diagram below:

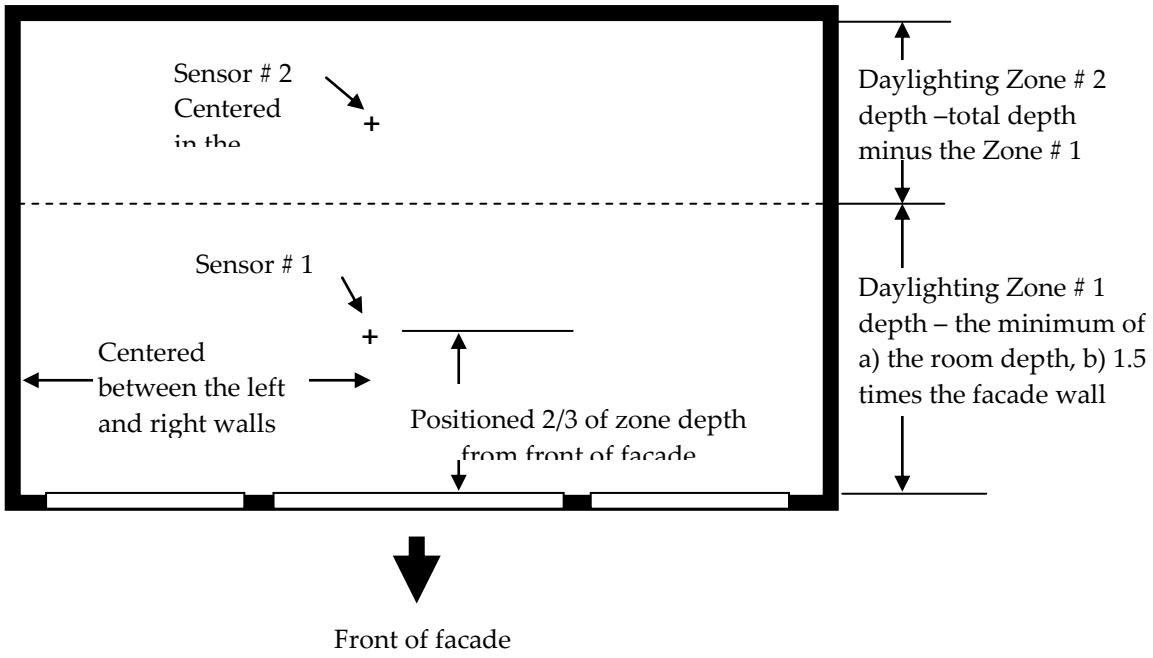


Figure 4-95. Plan view of daylighting control sensors.

- **Daylight Illuminance:** The daylight illuminance setpoint is currently set at 50 footcandles.
- **Zone Depth:** A primary daylight zone depth is calculated as the minimum of a) the room depth, b) 1.5 times the facade wall height, and c) 15 feet.
- **Sensor # 1:** Daylight sensor #1 is positioned 2/3 of the primary daylight zone depth from facade wall (centered in the width of the facade zone) and positioned at desk height: 2'-6" (0.76 m) above the floor. Sensor #1 controls a fraction of the facade zone lights equal to the primary daylight zone depth divided by the facade zone depth.
- **Sensor # 2:** Any remaining depth in the facade zone is considered a secondary daylight zone. Sensor #2 is positioned halfway between the primary daylight zone depth and the "back wall." Similar to sensor #1, the sensor is centered in the width of the facade zone and positioned at desk height: 2'-6" (0.76 m) above the floor. Sensor #2, if used, controls the remaining fraction of lights.

The Lighting Control pulldown under the scenario edit screen contains three choices for lighting controls:

- **None:** No lighting controls based on daylight levels.
- **Continuous:** Continuous lighting controls based on daylight levels.

Min Power Fraction = 0.1
Min Light Fraction = 0.05

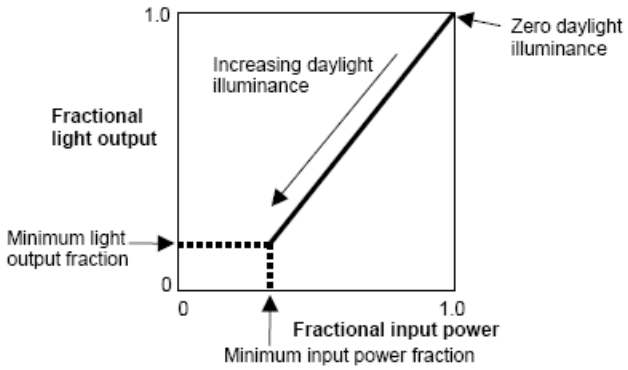


Figure 4-96. Continuous light dimming based on daylight levels. (from the EnergyPlus Input/Output documentation)

- **Stepped:** Stepped lighting controls based on daylight levels. Min Power Fraction = 0, Min Light Fraction = 0, Number of Steps = 3, Probability of Reset = 1.0 (perfect occupants)

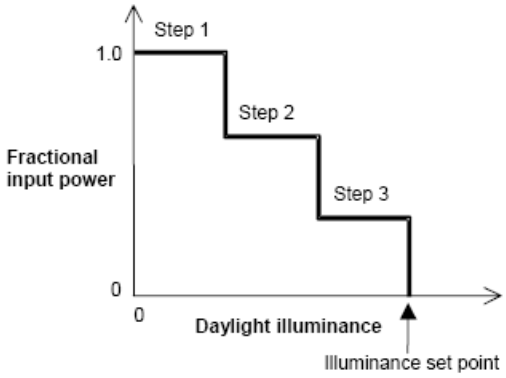


Figure 4-97. Stepped lighting controls based on daylight levels. (from the EnergyPlus Input/Output documentation)