COMFEN – Early Design Tool for Commercial Facades and Fenestration Systems

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CEC PIER Technical Report Deliverable
March 2014

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1.1 Introduction

California leads the nation in building energy efficiency standards and is a leader in the United States for legislation to reduce greenhouse gas emissions. Achieving these goals in practice requires that design teams and owners have access to technologies, systems and decision support tools that support their design work. This California Energy Commission funded work on the COMFEN software tool, which gives building practitioners, such as architects and engineers, the ability to assess the energy consequences of building design decisions, is thus a key enabling element that supports the AEC community in achieving ever more stringent performance requirements. COMFEN can provide needed building design guidance to not achieve the shorter term code goals but supports more aggressive achievement of the net-zero energy performance and peak load reduction required for all new buildings by 2030 as well as supporting deep retrofit of existing building stock.

Achieving a net-zero energy building cannot be done solely by improving the efficiency of the engineering systems (HVAC, lighting, equipment). It also requires consideration of the essential nature of the building starting early in the design process, including factors such as architectural form, massing, orientation and enclosure. Making informed decisions about the fundamental character of a building requires continuous assessment of the effects of the complex interaction of these factors on the resulting performance of the building as the design evolves. The complexity of these interactions necessitates the use of modeling and simulation tools to dynamically analyze the effects of the relationships. Decisions about the building fundamentals are often made in the earliest stages of design, before a complete 'building' exists to model so that a focus on representative spaces in the building allows earlier guidance for the decision making.

COMFEN, an early-design energy modeling tool developed by LBNL, is designed specifically to make informed decisions about building fundamentals by considering the design of the building envelope, orientation and massing on building performance. It supports exploratory work early in the process by architects but is also useful for engineers and consultants later in the design process. It also supports innovation broadly as it allows teams to model new technologies and systems that are becoming available but have not yet reached mainstream status.

COMFEN focuses on the concept of a "space" or "room" and uses the EnergyPlus and Radiance™ engines and a simple, graphic user interface to allow the user to explore the effects of changing key early-design input variables for the façade, internal loads, lighting controls and HVAC system on energy consumption, peak energy demand, and thermal and visual comfort. COMFEN also provides the ability to import glazing systems that have been developed in Window7, utilizing the International Glazing DataBase (IGDB) for glass choices. Comparative results are rapidly presented in a variety of graphic and tabular formats to help users move toward optimal façade and fenestration design choices.

While the underlying simulation engines were developed over time as part of DOE's national windows and daylighting program, the specific design features of COMFEN were evolved over a several year period by consulting with a series of largely California-based architectural and engineering firms who provided important guidance and feedback on desirable features and then on functionality once the features were implemented.

COMFEN is available at no charge on the LBNL website:

http://windows.lbl.gov/software/comfen/comfen.html

1.2 Approach and Goals

The goal of COMFEN is to provide an integrated performance analysis software tool that allows users to quickly develop multiple variations of detailed single zone models at an early design stage, enabling comparative analysis to evaluate the impact of different energy efficiency, daylighting and thermal comfort strategies that can set the design path toward meeting client and code requirements and eventually to targets for net-zero energy consumption.The COMFEN energy modeling tool addresses three key issues pertaining to developing energy efficiency measures early building design phases; 1) improving energy efficiency beyond code requirements and often demonstrating that large savings , e.g. 50% or more, can be captured; 2) envelope optimization with occupant comfort; 3) dynamic Interaction of façade and building system.

1.2.1 Improving Energy Efficiency by 50% or More

Improving overall building energy efficiency by 20-30% over 'baseline' ASHRAE targets can often be achieved by making engineering systems more efficient, so designers initially target HVAC, lighting, and plug-loads to achieve the first level of efficiency. To increase overall energy efficiency by 50% or more requires consideration of the essential nature of the building including factors such as architectural form, massing, orientation and façade design. Making informed decisions about the fundamental character of a building requires assessment of the effects of the complex interaction of these factors on the resulting performance of the building. The complexity of these interactions necessitates the use of modeling and simulation tools to dynamically analyze the effects of the relationships early and often, because decisions about these fundamental design elements often are made in the earliest stages of design, before a well-defined 'building' exists to model. The ability to quickly set up, analyze, adapt and re-analyze multiple scenarios in detail at the single zone level, which informs design decisions related to these fundamental design elements, is crucial to setting the design course for deep energy savings.

1.2.2 Envelope Optimization and Occupant Comfort

The building envelope, in particular the fenestration systems, must be designed to optimize building thermal loads while achieving desired visual and thermal building occupant comfort levels. In addition, most buildings will seek to maximize the use of daylight, which creates challenges with tradeoffs between solar gain and glare. The ability to optimize an overall building energy model for these types of parameters, with the current state of energy modeling tool capabilities, can be very cumbersome and time confusing, and therefore doesn't typically happen on projects or happens to a reduced degree where certain variable variations are targeted. COMFEN reduces the time and effort required to optimize a developing design in terms of the façade (exterior shading, glazing systems, shading systems, etc) and allows simulation of envelope interactions with the other energy efficiency measures, such as reduced lighting and equipment loads, lighting controls and certain HVAC system measures. In addition each COMFEN scenario can be evaluated and compared to other scenarios to assess comfort, daylight distribution, and glare for different sky conditions, time of day and year.

1.2.3 Dynamic Interaction of Façade and Building Systems

Today's energy-efficient windows and glazing systems can dramatically lower the heating and cooling costs associated with the building envelope while increasing occupant comfort. Manufacturers' product information typically provides window properties such as U-factors or R-values, Solar Heat Gain Coefficients or Shading Coefficients. Such properties are, however, based on static evaluation conditions that ignore the vital effects of dynamically varying exterior environmental conditions and the interactive effects of shading systems, lighting systems and interior environmental conditions. Designers are consequently often unsure how to account for these dynamic impacts in selecting the most efficient window and glazing system design for a commercial building.

The need to address deep savings, comfort and dynamic integration of building systems drives the evolving design of the COMFEN tool. COMFEN is designed to help achieve deep energy savings and comfort by using the EnergyPlus, WINDOW, and Radiance™ calculation engines with a simple user interface to:

- Facilitate easy comparison of the effects of altering building fundamentals on the energy consumption, peak energy demand and thermal and visual comfort performance of the building,
- Assess the impact of fenestration, shading and daylighting technologies on envelope and building energy and cost performance,
- Assist a design team to design an "optimum" building envelope consistent with internal and external constraints.
- Assess thermal and visual comfort of alternatives

The COMFEN 5 features that enable the dynamic interaction include:

- A simplified but powerful user-friendly graphic interface with drag-and-drop capabilities that links to powerful calculation engines,
- Extended libraries of glass (IGDB), façade-system components and weather-data locations,
- Automatic connectivity to WINDOW to create glazing, framing and shading systems, and
- Automatic connectivity to Radiance™ to generate graphic daylighting and glare results.
- Greatly enhanced output capabilities with easy-to-select graphics and tables that illustrate side-by-side comparisons of the effects of different façade choices

1.2.4 Background

COMFEN development has been iterative, building on feedback from users at each stage of its development. COMFEN focuses on variables specific to the façade and fenestration that are considered at the earliest stages of the design. COMFEN intentionally focuses on a perimeter 'room' in a building in order to avoid the complexity involved in modeling a complete building.

The program provides results for analysis of energy consumption (for heating, cooling, lighting and fans), thermal comfort, daylighting and glare. This allows the user to understand the impacts of these different building parameters on each other.

1.2.5 Target Users and Objectives

Clearly identifying the intended user groups for a software tool and defining their product requirements in terms of features and workflows is critical to determining the appropriate functionality for a tool.

1.2.5.1 Architects:

The primary target user group for COMFEN is architects, because decisions about a building's orientation and façade configuration made early in the design process have a fundamental impact on the performance of the building. Providing tool features for architects also serves many of the interests of other important decision-making groups, such as design engineers and façade consultants. While they tend to have more in depth and engineering expertise in the early design phase, their time and fees, are limited so the COMFEN features are of value to them. Key decisions include:

- The ratio of glazed façade areas to total wall area, which also include glazing size and location
- Glazing assemblies, framing and daylight penetration and control selections that allow energy impacts to be optimized and which balance aesthetic, energy, and occupant comfort goals,
- The shading devices (exterior, interior and even integral), controllable or otherwise, appropriate for specific building orientations and transparency goals.

In the absence of a user-friendly yet sophisticated tool for evaluating the impact of such design decisions on energy and occupant comfort, choices made by architects are often dictated by market assumptions and aesthetic considerations. COMFEN can help balance and inform this decision-making process.

The key features in COMFEN that enable its use by architects are:

- A highly graphical and intuitive, user-friendly interface.
- A focus on key façade design options with the means to easily vary these parameters.
- A sophisticated simulation engine(s), hidden from view, to analyze the interactive impacts of design choices.
- A readily interpretable results display to facilitate easy comparison of the selected design alternatives at a summary level and also at a more detailed level enabling understanding of the implications of the choices.

1.2.5.2 Glazing/Framing System Manufacturers

The second group of COMFEN users are glazing/framing system manufacturers and façade sub-contractors. This group is critical to bringing new, high performance fenestration components and systems to the market, and they contribute product information to the International Glazing Database, which is part of the COMFEN library structure. COMFEN is useful for this user group because they are able to analyze the effects of new materials and components on the performance of the system as a whole. We have explored with some manufacturers the option of developing custom versions of the tool to support their corporate outreach to owners and A/E firms.

COMFEN serves the needs of the users described above to promote the design and deployment of high performance fenestration systems by making complex simulation comparisons of alternative fenestration design choices accessible to a wide audience of users. Since these choices are made on the early stages of design, there is little detail on the rest of the building.

1.3 COMFEN Structure

COMFEN is designed to simulate building façade energy performance appropriate for the very early design phases, typically before a 'building' exists with the level of detail needed to develop a 'total building energy model'. The program focuses on fenestration and external wall variations, and therefore limits room and building geometry choices and uses constant default values for HVAC system components and details, internal loads and scheduling.

Simulation results are based on comparative analysis of 'scenarios' which consist of: a rectangular room with a single exterior façade wall and adiabatic ceiling/roof, floor and interior walls. The scenario is conditioned by a packaged single zone HVAC system that is automatically sized for the façade (including interior loads). Eliminating the effects of interactive variations in whole-building designs, e.g. thermal exchange between adjacent thermal zones and varying HVAC components and system highlights the relative impacts of façade variations.

The performance of different scenarios can be compared in the detailed 'comparison' analysis output screens. This comparative approach is central to the design of COMFEN and is appropriate for early design option explorations. However later detailed design must consider whole-building issues.

1.3.1 COMFEN Project Input

The main project screen, shown in Figure 1 is divided into 3 sections; 1) the Project Browser, which shows scenarios, on the left, 2) the Scenario graphic representation in the upper right, and 3) the Results tabs in the lower right .

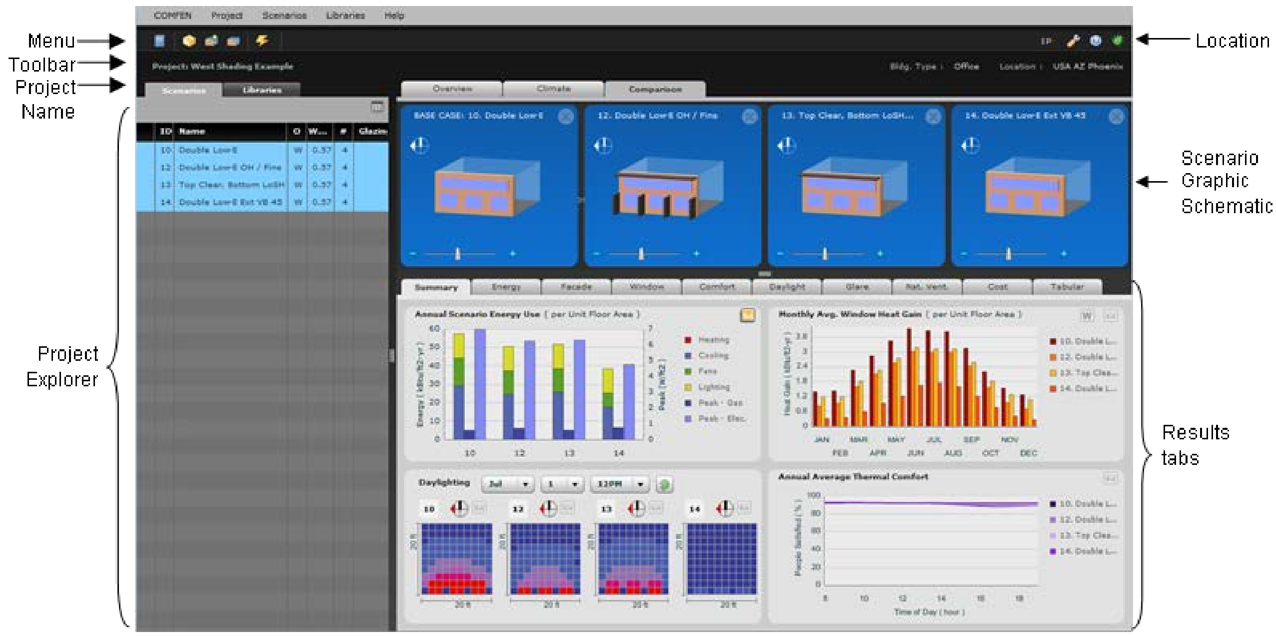


Figure 1. . The COMFEN main project screen.

A project is defined as a collection of scenarios. Each project can contain as many scenarios as needed to explore the desired design solutions. Scenarios represent a single zone with one exterior wall that is conditioned by a packaged single zone and contains internal loads. They can be differentiated by geometry, orientation, glazing systems, shading systems, framing systems, lighting controls, and occupancy and plug load values. Using this approach, the user can explore a range of façade design issues such as the relative impacts of changing orientation for the same façade design or various configurations of window, glazing systems, frames, shading surfaces, and daylighting controls.

More than one project can be created and stored in a COMFEN database. Each project is defined by a name, location, building type, vintage, and project orientation. The project location identifies the weather data used for the EnergyPlus simulation. Building type controls the occupancy, lighting, and equipment schedules and can be set to Office, Mid-Rise Residential, Hotel, Hospital (patient room), Retail and School (classroom). Vintage is currently limited to new ASHRAE 90.1-2004, but may be extended in the future. Project orientation allows the user to rotate the complete set of scenarios.

1.3.2 COMFEN Scenarios

Defining COMFEN scenarios is done in the Scenario Edit screen, shown in Figure 2. First, the user creates the room geometry by defining height, width and depth. This generates a graphic representation of the exterior façade. The user then defines orientation in terms of cardinal coordinates and the scenario can be offset using the Project North input value in the Project definition.

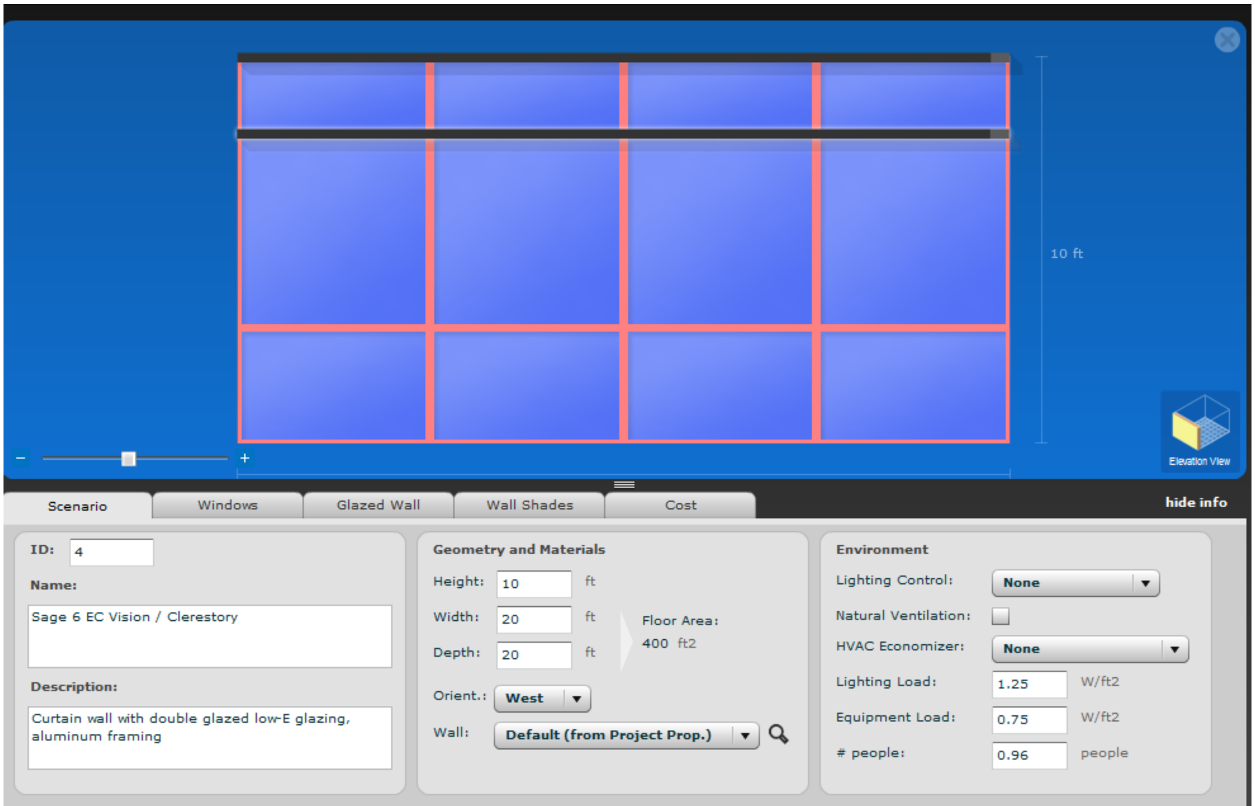


Figure 2. COMFEN Edit Screen for defining a scenario

COMFEN then generates default input values for lighting controls (based on daylighting levels), lighting and equipment loads, and number of people. The user may modify these values.

This Scenario Edit screen also contains a graphic representation of the exterior façade. Window geometry is user-defined either ‘numerically’ (values are input for height, width, distance from left wall, and sill height) or ‘graphically’ (by selecting from the Window Library tab in the Project Browser and ‘dragging’ with the mouse onto the graphic representation of the scenario façade). When a window has been placed on the façade, it can be repositioned or resized either graphically (by moving, shrinking, or stretching it with the mouse) or through the numeric input screen (by double clicking on the graphic of the window and changing the values in the pop-up input screen).

Once the window geometry has been entered, the user defines the glazing system, frame, and shading system associated with it by double clicking on each window graphic representation and selecting the appropriate choices in the popup input screens.

External building-shading devices such as rectangular overhangs and fins can be located and sized in the Scenario Edit screen/Wall Shades tab. The default scenario façade view is an Elevation, but Section and Plan views can also be displayed (although editing can only be done in Elevation view).

1.3.3 COMFEN Libraries

COMFEN 5 has an extensive set of Libraries that are used to define the building envelope and fenestration system:

- **Glass Library:** derived from the International Glazing Database which contains over 4,000 glass layers.
- **Glazing System Library:** contains sample glazing systems that can be used to define façade systems. It also allows custom glazing systems to be created based on layers from the Glass Library and Gas Library. These glazing systems are imported into EnergyPlus as material layer objects using full spectral data to maximize analysis accuracy. Glazing systems can also be imported from WINDOW.
- **Frame Library:** contains a default set of frames which can be used to define the façade systems. It also allows users to add custom frame data which affords the exploration of very high-performance window systems using highly insulated frames.
- **Wall Construction Library:** contains example exterior wall constructions that are used for defining the construction of the exterior façade wall. The user can add new constructions as needed for their scenario definitions.
- **Spandrel Library:** contains example spandrel constructions that can be used with the Glazed Wall Assembly to define spandrels in curtain walls. The user can add new spandrel constructions as needed.
- **Material Library:** contains a set of materials (derived from the ASHRAE Handbook of Fundamentals) that are used for both the Wall Construction and Spandrel Libraries.
- **Location Library: contains** a set of US and international locations. It also allows the user to add to the project any location with an EnergyPlus weather file.
- **Shading System Library:** contains a default set of shading systems which can be applied to a glazing system and allows users to create new shading systems. Venetian blinds or fabric roller shades, located inside, outside, or between layers of each window and sunscreens can currently be modeled. This library allows the user to select from a variety of shading control options (e.g., based on exterior incident solar or interior daylight illuminance levels).

1.3.4 COMFEN Analysis Output

Having created a set of scenarios, to analyze each scenario the user clicks on the ‘Calculate’ button (the yellow lightning bolt) in the tool bar at the top of the screen. COMFEN automatically generates an EnergyPlus input data file for each scenario and runs EnergyPlus for each input file. EnergyPlus creates numerical output data file for each scenario which COMFEN graphically displays.

The three main Results tabs, Overview, Climate and Comparison, are located at the top of the screen, above the scenario graphics. Each graphic in any of these tabs can be saved as a separate PNG image using the icon in the upper right of the graphic. The PNGs can be then be used in reports, presentations and other presentation media.

1.3.4.1 Overview Tab

The Overview tab, shown in Figure 3, graphically shows the summary energy usage results for up to 200 scenarios. This result presentation has proven particularly helpful for educational research users and fenestration manufacturing industry professionals.

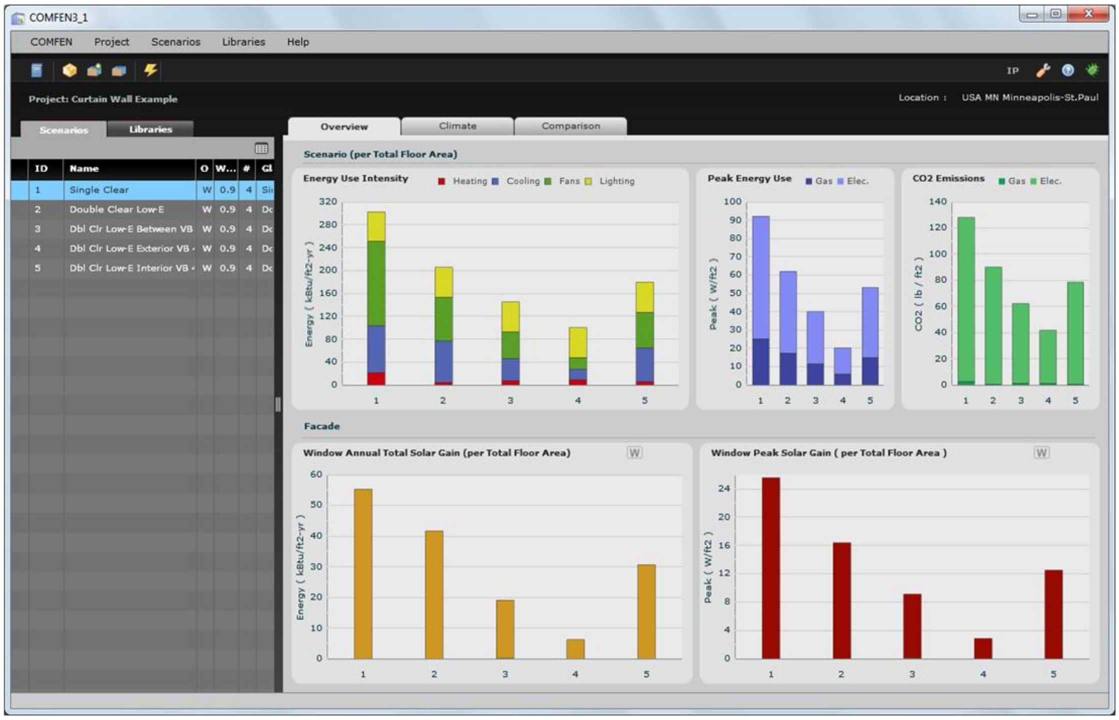


Figure 3. The Overview results tab for 5 design scenarios.

1.3.4.2 Climate Tab

Providing an understanding of the local climate conditions is particularly important as energy performance requirements increase. For example, wind data provides insights into the potential for natural ventilation at a location and solar data provides a framework for assessing the needs for shading. The Climate tab, shown in Figure 4, graphically represents weather data for the location. It includes a number of sub-tabs with graphics that illustrate different attributes (temperatures, sky-illuminance, wind-speed and direction, etc.) of the daily, monthly, seasonal and annual average outdoor climate for the project currently being evaluated.

Figure 4. The Climate tab results.

1.3.4.3 Detailed Comparison Tab

The Comparison tab allows four scenarios to be compared together, and contains the most detailed set of results. A number of sub-tabs located under the scenario input graphics allow the user to drill down to more detail.

The Summary sub-tab, shown in Figure 5, graphically illustrates a comparison of the effects of four scenario design-choices on Annual Scenario Energy Use, Monthly Solar Heat Gain (through the windows), Daylight Penetration and Annual Average Thermal Comfort. These inter-related façade performance measures were historically difficult to assemble into a single display since their calculation required the use of multiple software packages. COMFEN assembles this data in a single graphic and also allows an easy side-by-side comparison of scenarios that greatly assists in helping to make balanced performance design decisions.

Other sub-tabs afford access to graphics illustrating energy consumption and peak energy, façade and window loads, thermal comfort, daylight illuminance and penetration, and discomfort glare. Sub-sub-tabs under each of these headings access graphics at an increasing level of detail (based on the hourly results data generated by EnergyPlus). The graphics show annual, seasonal and monthly averages as well as results for each hour in a given day. There is also a new function that automatically exports input data to Radiance™ which created hourly simulation graphics for daylight and glare that can then be displayed in COMFEN, as shown in Figure 7. Details of this function are outlined below.

Figure 5. The Comparison/Summary Tab

1.3.5 Calculation Methods

COMFEN calculates results using two different calculation engines: EnergyPlus for energy and daylighting results and Radiance for more detailed daylighting and glare results.

1.3.5.1 Links to EnergyPlus Simulation Engine

As described above, EnergyPlus is the simulation engine behind most of the results calculated in COMFEN. The COMFEN GUI generates parameterized input files, i.e. pre-defined ASCII files with EnergyPlus macros, to generate an EnergyPlus input macro file (IMF). COMFEN then runs Energy Plus using this IMF file to generate an Energy Plus input file, which is run through the Energy Plus simulation engine. COMFEN then reads the Energy Plus results to generate the graphic displays described above.

1.3.5.2 Links to Radiance™

While EnergyPlus is used to generate graphic daylighting and glare results, Radiance™ is the simulation engine behind the renderings of daylighting and glare in COMFEN. Input values which describe the room geometry and fenestration are converted into Radiance™ input, where the Radiance™ program then runs and generates the renderings that are displayed in the daylighting and glare results sub-tabs. COMFEN uses the Radiance™ mkillum program, with WINDOW Bi-directional Scattering Function (BSDF) files to generate false-color images which represent the fenestration system as an illuminance source.

1.4 Program Assumptions

Many of the modeling assumptions in COMFEN are “behind the scenes” so that the user is not confronted with too many inputs (and therefore options that they may not know how to select from), which would increase the time needed to develop useful results. The program provides the greatest degree of access to a wide range of design parameters related to “façade” systems which is the focus of the tool. It provides less access and is more constraining with respect to HVAC options as these are not normally addressed by architects early in design.

1.4.1 Zone Model

Because COMFEN is used as an early design tool for facades, one perimeter “zone” or “room” is modeled, rather than a whole building. Modeling one perimeter zone allows the program simulation to run much faster, and will give results that are appropriate for this level of design analysis. Multiple zones can run and aggregated so that whole building performance can be estimated.

The exterior façade of the zone is the only surface that is exposed to the outside environment. All other surfaces (ceiling, floor, interior walls) are adiabatic, i.e., the assumption is that the zone temperature on the other side of the surface is the same as the zone they are in, so there is no heat loss modeled through those surfaces.

In COMFEN, this is graphically displayed by highlighting the exterior façade and showing the other surfaces as translucent objects.

1.4.2 Building Types

There are several building types available in COMFEN, set in the Project Properties screen. The building type information is based on the Energy Plus Prototype Building models
(http://www.energycodes.gov/development/commercial/90.1_models)

The different building types control the occupancies schedules, as well as thermostat setpoints. They have no effect on the geometry of the model

- Office
- Mid-Rise Residential
- Hotel
- Retail
- School (Classroom)

1.4.3 HVAC Type

Currently, there is only one HVAC system type available:

- Package Single Zone – natural gas or electricity for heating / electricity for cooling

However it is possible to set the Outdoor Air rate based on either

- Flow / Person
- Flow / Area

And it is possible to override the default values for both options.

It is also possible to model an economizer in COMFEN. The program will use outside air for cooling rather than the air conditioning equipment if the temperature and humidity conditions are met, i.e., the temperature outside is below the desired interior temperature.

1.4.4 Schedules

The schedules for each building type are based on the schedules from the Energy Plus Commercial Prototype Building Models. A separate schedule is defined for occupancy, lights and equipment. The schedules cannot be edited by the user. However, the loads for each schedule can be set by the user, in the Scenario definition.

1.5 Key Features and Resources Added to COMFEN

Many new features and resources have been added to COMFEN modeling capabilities, the associated knowledge base and project examples over the duration of the PIER project. These add to the building design options that can be modeled, the way in which results are displayed, and the overall usability of the tool. These new features are described below.

1.5.1 Glazed Wall Assemblies

The ability to define "Glazed Wall Assemblies" was added to COMFEN to facilitate easy definition and modeling of curtain wall systems, as shown in Figure 6. The user specifies the number of horizontal and vertical framing members, the type of frame and the type of glazing system to define a glazed wall assembly. Spandrel panels can be defined as part of this assembly. This COMFEN Knowledge Base article explains how to define a Glazed Wall Assembly:
http://windows.lbl.gov/software/comfen/4/GlazedWallAssembly.htm

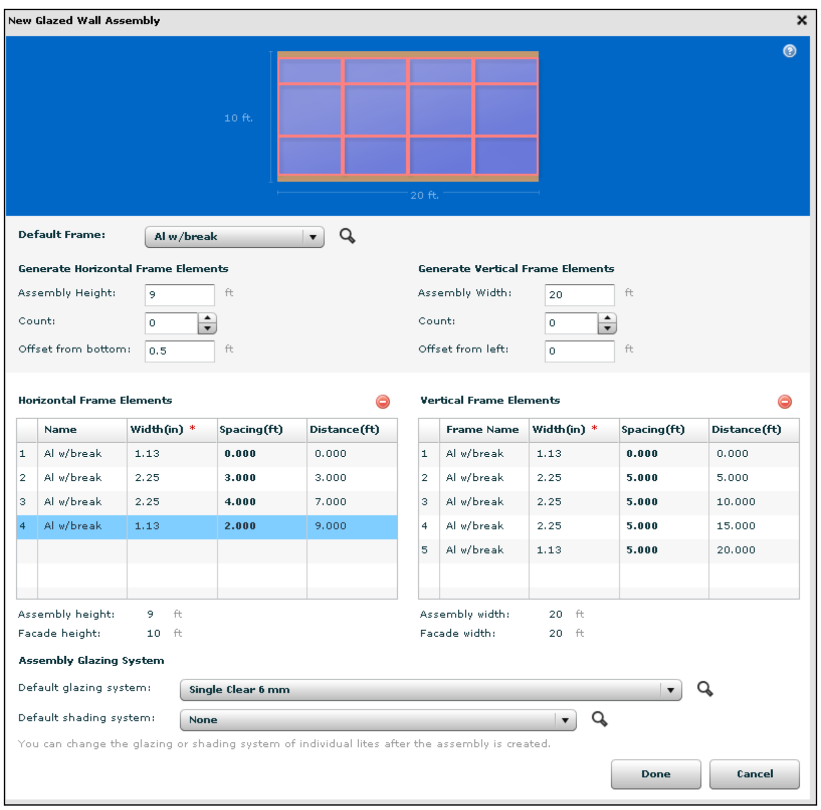


Figure 6. Glazed Wall Assembly definition

1.5.2 Building Types

During the PIER project, the Mid-Rise residential, Hotel, Retain and School (classroom) were added to COMFEN. The schedules associated with these building types were derived from the Energy Plus (US DOE) Commercial Prototype Building Models, which were developed by PNNL to evaluate the ASHRAE 90.1 standard.
http://www.energycodes.gov/development/commercial/90.1_models

1.5.3 Libraries

Additions to the Library structure were made to enable more sophisticated modeling of the façade, and include:

- **Frame Library:** the frame library was made user editable so that users could define as many different frame types as needed. A COMFEN Knowledge Base article describes this feature http://windows.lbl.gov/software/comfen/5/FAQ/FrameLib.htm
- **Spandrel Library:** A spandrel library has been added, which allows definition of a construction with a glass exterior layer and wall materials on the interior. This can be used when defining glazed wall assemblies .
- **Wall Construction Library:** a wall library has been added to define exterior façade constructions.
- **Material Library:** A material library has been added in order to define wall and spandrel constructions

1.5.4 Daylighting

Many improvements have been made to the daylighting and glare sections of the program. These include:

- Automatic generation of BSDF files for Radiance renderings: in previous versions of COMFEN, users were required to generate ("by hand" using the LBNL WINDOW program) the BSDF input files used by COMFEN to generate the Radiance renderings. This was a major stumbling block for most users, and this process was automated in November 2010.
- Graphics were developed to show the EnergyPlus daylighting results for annual, hourly, and seasonal average daylight illuminance levels.
- Radiance renderings for Glare analysis have been added, as shown in Figure 7. A COMFEN Knowledge Base article explains this feature:
  http://windows.lbl.gov/software/comfen/5/Radiance-Glare.htm
- Radiance renderings for Daylighting analysis have been added, showing daylight illuminance levels in plan view as well as a 3-D interior view. The user can control the camera view via the interface. A COMFEN Knowledge Base article explains this feature:
  http://windows.lbl.gov/software/comfen/5/Radiance-Daylight.htm

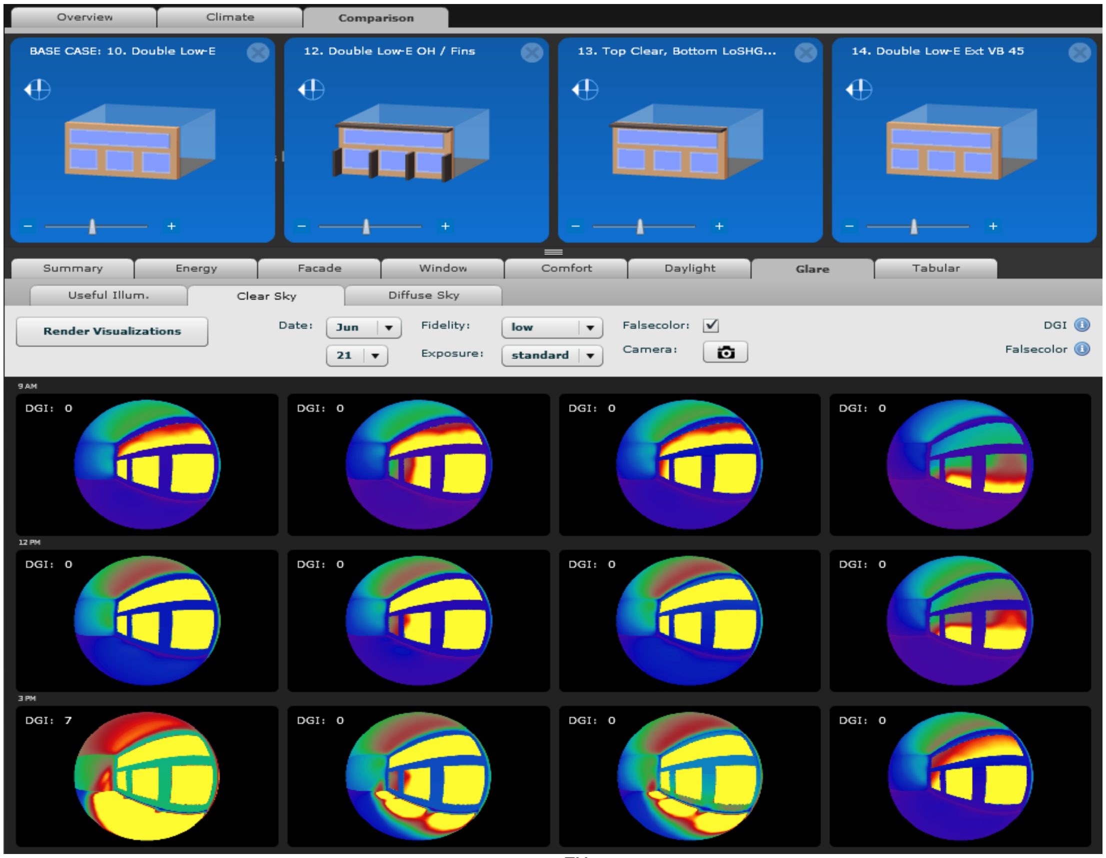


Figure 7. Sample Radiance™ hourly simulation graphics.

1.5.5 Complex Fenestration Modeling

COMFEN now has the capability to model complex fenestration systems using the EnergyPlus BSDF capability. This option is available in the program Preference settings. This option allows COMFEN to model systems that do not have an explicit model in EnergyPlus.

When the BSDF model is activated, COMFEN displays results from the EnergyPlus BSDF model for the Daylight Illuminance Graph.

The Energy Plus BSDF model requires use of the EnergyPlus BSDF control definitions and these have been added for typical shading system controls.

1.5.6 Cost Model

From interviews with design teams we discovered that many interesting high performance designs are dropped in value engineering when the matter of cost is addressed in detail, often for the first time. Users asked if cost data could be made available earlier in the process via COMFEN. A very simple Life Cycle Cost model has been added to COMFEN. Cost is always a complex subject and the users have the option of overriding the default data and entering their own. The Cost feature is described in a COMFEN Knowledge Base article: http://windows.lbl.gov/software/comfen/5/Cost.htm

- **Cost Data**: Default costs for all the building components in COMFEN have been added. All these costs can be overridden with data from the user. Data sources for the cost data included ASHRAE cost studies for fenestration systems.

- **Utility Cost:** Rates for gas and electricity have been added to the Location Library and are used (with a very simple energy cost model) to determine the energy costs for each scenario.
- **Results:** a set of graphs have been added to a Cost tab in the Comparison results section, which show the first cost, the energy cost, a simple payback, a ROI summary and ROI by system.

1.5.7 Natural Ventilation Model

A simple one-sided natural ventilation model has been added to COMFEN, and includes the ability to define operable windows, including the percentage of the window area that is defined as the "Effective open area", as shown in Figure 8. A COMFEN Knowledge Base explains the Natural Ventilation model: http://windows.lbl.gov/software/comfen/5/NatVent.htm

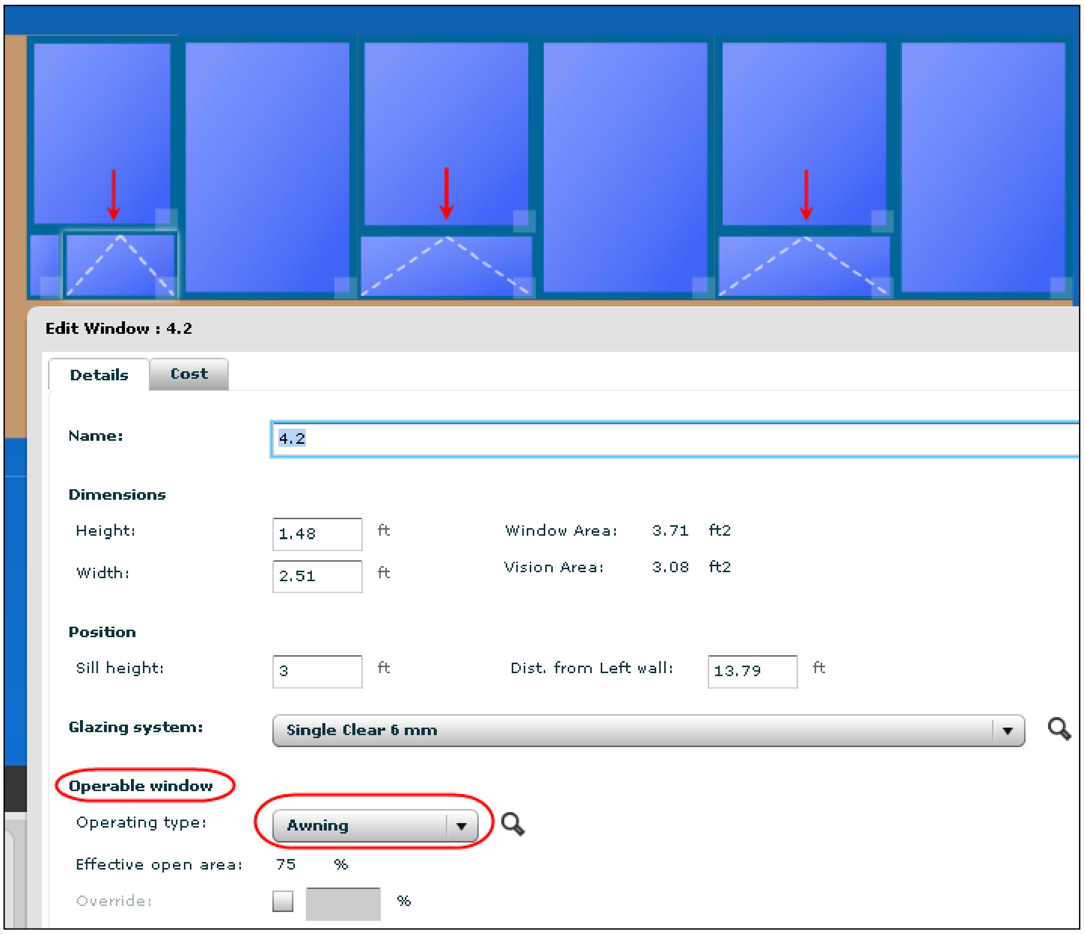


Figure 8. Defining operable windows to model natural ventilation

1.5.8 Electrochromics

In 2013, the ability to model electrochromic glazing systems using the Energy Plus model for electrochromics was added to COMFEN, shown in Figure 9. The Glass Library contains electrochromic glass layers from View and Sage, and there are example glazing systems for each of them in the Glazing System Library. Control of the electrochromic is possible using the standard set of built-in controls in Energy Plus. These are defined for each Glazing System in the Controls tab. This COMFEN Knowledge Base article describes how to model electrochromics:
http://windows.lbl.gov/software/comfen/5/Electrochromics.htm

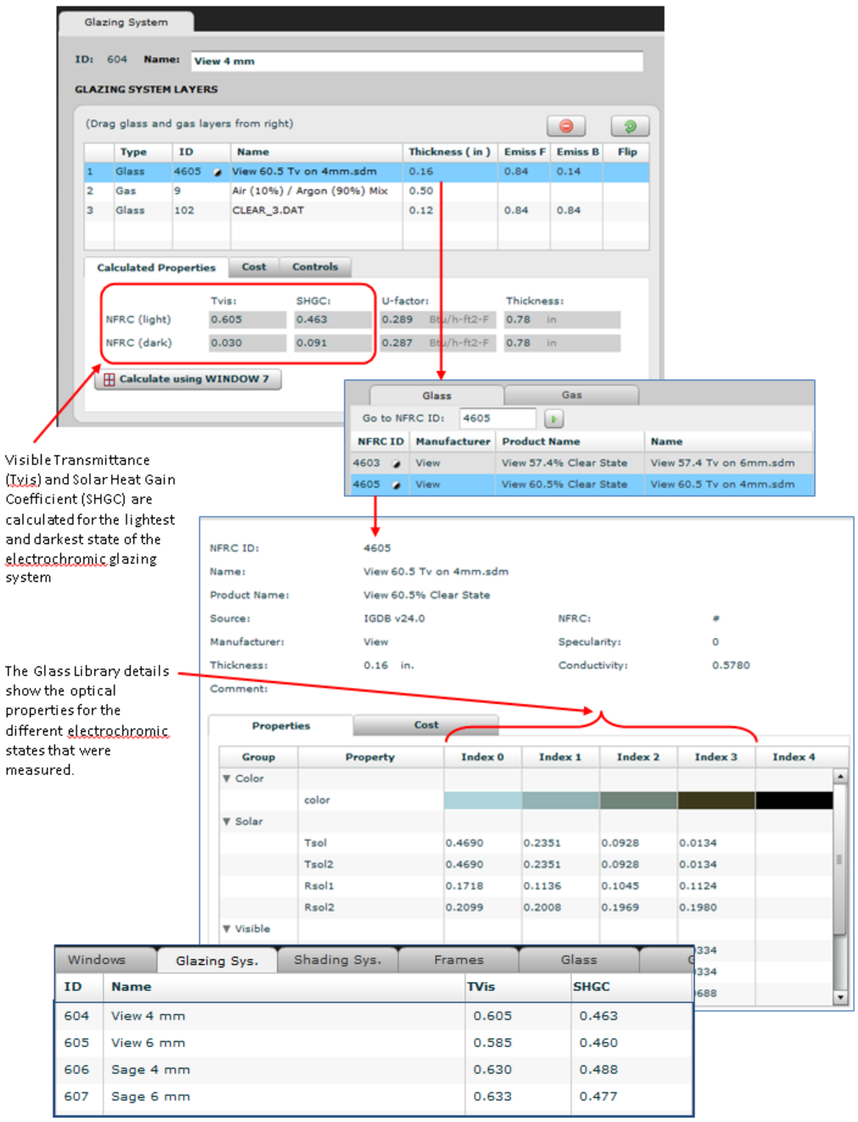


Figure 9. Modeling Electrochromic glazing in COMFEN.

1.5.9 Results

Many new Results capabilities, as well as features associated with results, have been added to COMFEN. These include:

- Export of Tabular results
- Export of result images (such as graphs) as PNG files.
- Export of compared scenarios (images) as PNG files
  The last two options are described in a COMFEN Knowledge Base article:
  http://windows.lbl.gov/software/comfen/5/FAQ/PNGCSVExport.htm

1.5.10 Energy Plus Versions

As the EnergyPlus development team has developed new versions, the COMFEN development team has kept pace, updating COMFEN to use these versions. The latest version of COMFEN 5 uses the EnergyPlus version 8.1

1.5.11 HVAC Systems

The HVAC system in COMFEN is a very simple single zone packaged system. However, the ability to model an economizer (to utilize outside air for cooling when the outside air temperature and humidity allow) was added to COMFEN in the Scenario definition portion of the program.

1.5.12 Support of Parametric Analysis

Many COMFEN "power users" needed the ability to define many scenarios in order to run parametric analysis. A CSV Import feature was developed which allows users to define multiple scenarios in a spreadsheet (according to a specific format) which can then be imported into COMFEN. This methodology is described in a PDF available from the COMFEN Knowledge Base:
http://windows.lbl.gov/software/comfen/5/FAQ/COMFEN%20CSV%20Import.pdf

1.6 Support of Industry

While the AEC community is the primary user audience for COMFEN the tool has attracted the interest of the manufacturing and supplier community as well. LBNL already has very strong working ties to this group as LBNL's software is the basis for industry-wide rating and labeling programs through NFRC. (~40,000 copies of LBNL's software were downloaded in 2013).

1.6.1 Access to Product Data

COMFEN provides a unique resource to industry because it provides users access to the International Glazing Database. The IGBD is updated on a regular basis and puts the actual performance characteristics of a majority of the industry glazing products at the user's fingertips to develop analysis. In many of other simulation tools the user needs to search for this information, and then input it into the tool before being able to start the analysis process. Through the integration of the IGDB users can creatively develop and evaluate numerous glazing assemblies with the confidence that the resulting design is available in the market place. A similar capability will be developed with the Complex Glazing Data Base (CGDB) that will contain related information about the solar-optical properties of shading and daylighting systems.

1.6.2 Support for Innovation

Manufacturers strive to continuously enhance their product lines but if simulation tools cannot adequately assess performance, and if codes don't give credit for them the innovation process is slowed. COMFEN is based on the EnergyPlus engine and a significant effort is made to continuously update the engine to reflect new technology. LBNL has been involved in the façade and daylighting elements for many years and is recognized by DOE as the core R&D team in this area. LBNL will continue to develop models for high performance glazing, angle selective products, spectrally selective products, thermochromic and photochromic materials as well as new types of electrochromics, daylight redirecting systems, air flow windows, etc. As these reach market maturity and when their performance is captured in EnergyPlus it should be a relatively small step to add these features to COMFEN and make them available widely in the design community.

1.6.3 Access to Integrated Façade Systems Performance Data

Manufacturers offer new products and integrated systems on a regular basis but the uptake and acceptance of these products depends on the ability of the design team evaluate their use and properly specify them. The trend of owners requesting higher levels of energy savings for their projects continues whether driven by codes, or other market pressures. Therefore, when the traditional energy efficiency strategies are not enough to reach these goals, design teams must dig deeper and evaluate novel integrated systems in new ways. COMFEN provides the ability to evaluate the integrated façade system, which includes the interaction of exterior shading, glazing assembly, interior shading, operable controls, lighting controls, internal loads, and some HVAC system controls. Users can identify what efficiency measures and/or sets of efficiency measures will have the most impact on performance for the integrated façade system in a time effective manner, so that they can incorporate them into the overall design, and allow enhanced cycles of design. In addition, the new cost tools within COMFEN allow "cost evaluations" to occur in parallel to the evaluation of the different types of performance.

1.6.4 Retrofit Design

Although new construction is finally improving, retrofit will remain an important target for the CEC and for owners. COMFEN provides a starting point for project teams evaluating the performance of existing buildings that are considering retrofits. By developing COMFEN scenarios for typical zones on different façade orientations, the project team can identify performance drivers for the existing design, and begin to simulate and explore the impact of different retrofit strategies on performance to determine if they warrant further investigation and analysis. The results created by COMFEN also provide a strong communication tool to convey the complex interactions of integrated façade systems and how they impact comfort, daylight distribution, glare, and peak loads in addition to energy.

1.6.5 Electrochromics

COMFEN is being used by electrochromic glazing manufacturers to participate in the Environmental Product Declaration program described above. The benefit of using COMFEN for this analysis is that it allows the calculation to quantify the contribution of daylighting from glazing systems by modeling lighting controls based on daylight illuminance levels.

1.6.6 Website Support: Windows for High-Performance Commercial Buildings

LBNL used COMFEN to generate approximately 220,000 annual simulations to create a database of results used to show results for the *Façade Design Tool* on the Windows for High-Performance Commercial Buildings website (http://www.commercialwindows.org). This website was created with funding from the US DOE as a collaboration between LBNL, the Center for Sustainable Building Research at the University of Minnesota, and the Alliance to Save Energy. The site contains data for a few California cities and is a model of what could be done more broadly in California.

1.6.7 Custom Tools for Manufacturers

Most manufacturers invest time and money in developing a network of representatives who visit and market AEC firms. They develop their own product literature and increasingly offer some forms of performance data. COMFEN can generate custom performance data rapidly for a given design in any location. LBNL has explored the option of allowing manufacturers to generate custom version of COMFEN that preserve the core calculations and data but allow customization to meet marketing needs.

1.7 Outreach

LBNL has made an active effort to promote COMFEN at various conferences and has also given seminars to architectural firms and universities. This effort provides a two way information flow- we inform potential users of the capability of the tool and we get feedback from existing and potential users about their needs and interests. The list below highlights some of these seminars:

- February 2014: Seminar on Window Tools to Viracon/ Apogee- Minn, Mn.
- January 2014: Seminar on Window tools: Facades Conference at USC, LA
- October 2013: Seminar, University of California, Berkeley, Architecture class; Prof Caldas class used tool and provided feedback
- July 2013: FACADES + Conference; Presentation on façade tools and test data; SF
- July 2013: Introductory Training, Vanderweil Engineering, Boston, MA (15 staff in Boston and NYC offices)
- Fall 2012: Program Overview for City University of New York Course (30 students) Building Energy Modeling and Simulation
- October 2012: Seminar, University of California, Berkeley, Architecture class; 2 hour hands on class for Gail Brager's class led by LBNL, including customization of the database for their class project.
- October 2012: Presentation by Mark Perepelitza, "LBNL Tools and Resources: Informed Decision-Making, Integrated Façade Design and Analysis", Portland Building Enclosure Council.
- June 2012: DGEP Webinar
- *May 2012: Presentation, Living Futures UnConference, Portland, OR "Delivering Guaranteed Energy Performance – What is it going to take?"*
- January 2012: Webinar with Texas Architecture firm for specific project; 2 hour seminar led by LBNL to show how to use the software and to answer specific questions about how to model the building they were studying.
- November 2011: Presentation, HOK Architects, San Francisco, CA; 1 hour overview by LBNL about the software; included how to model some of their specific projects.
- October 2011: Seminar, Texas Society of Architects Convention, Dallas, TX. 2 hour hands on workshop by LBNL with approx. 50 participants; gave overview of the program and walked through specific tutorials with the class.
- *October 2011: Presentation, Greenbuild, Toronto, Canada; "Enabling Creative Energy Analysis from Initial Concept Model to Detailed System Design*
- July 2011: Seminar, ZGF Architects, Portland, OR and Seattle, WA; 2 hour hands-on workshop to approximately 20 people, going through how to use the program and answering specific questions about project they were interested in modeling.

- May 2011: Seminar, AIA National Convention, New Orleans, LA; 4 hour hands on workshop for approximately 20 people, going through the program and leading them through specific tutorials, as well as answering questions about specific projects the attendees were interested n modeling.

- April 2011: "COMFEN 3.0 – Evolution of an Early Design Tool for Commercial Facades and Fenestration Systems" paper, presented at the *Building Enclosure Sustainability Symposium* (BESS), Pomona, CA.

- March 2011: Seminar, University of California, Berkeley, Architecture class; overview of the program (not hands-on) to approximately 50 students of Susan Ubbelode's class.

- Dec 2010: Webinar, University of Washington; overview of the program for professors interested in teaching COMFEN; this was a fairly sophisticated audience and there were many detailed technical questions.

1.8 Case Studies

We provide a high level overview of a series of case studies conducted by A/E firms using COMFEN in a variety of applications. Some of these studies were completed using earlier versions of the tool and some of the displayed data is post processed from COMFEN output which is why the graphic presentation varies. Collectively they provide insights into the range of applications that COMFEN can cover and how A/E's are using them in their design and retrofit practice.

1.8.1 Green Proving Ground (GSA) Retrofit Studies

LBNL used COMFEN to analyze the performance of a Federal Government building in Provo, UT, in which 21 existing single pane, aluminum framed windows were retrofitted, using interior fixed Hi-R-value triple pane window panels with one low-E coating. COMFEN results matched the measured energy savings results in terms of the relative percent change due to the retrofit. Also, other retrofit options were modeled with COMFEN in order to determine whether a less expensive solution would achieve the same energy savings results.

COMFEN is also being used to analyze a GSA building in St. Louis to investigate the energy performance of a retrofit window coating on double pane bronze glass.

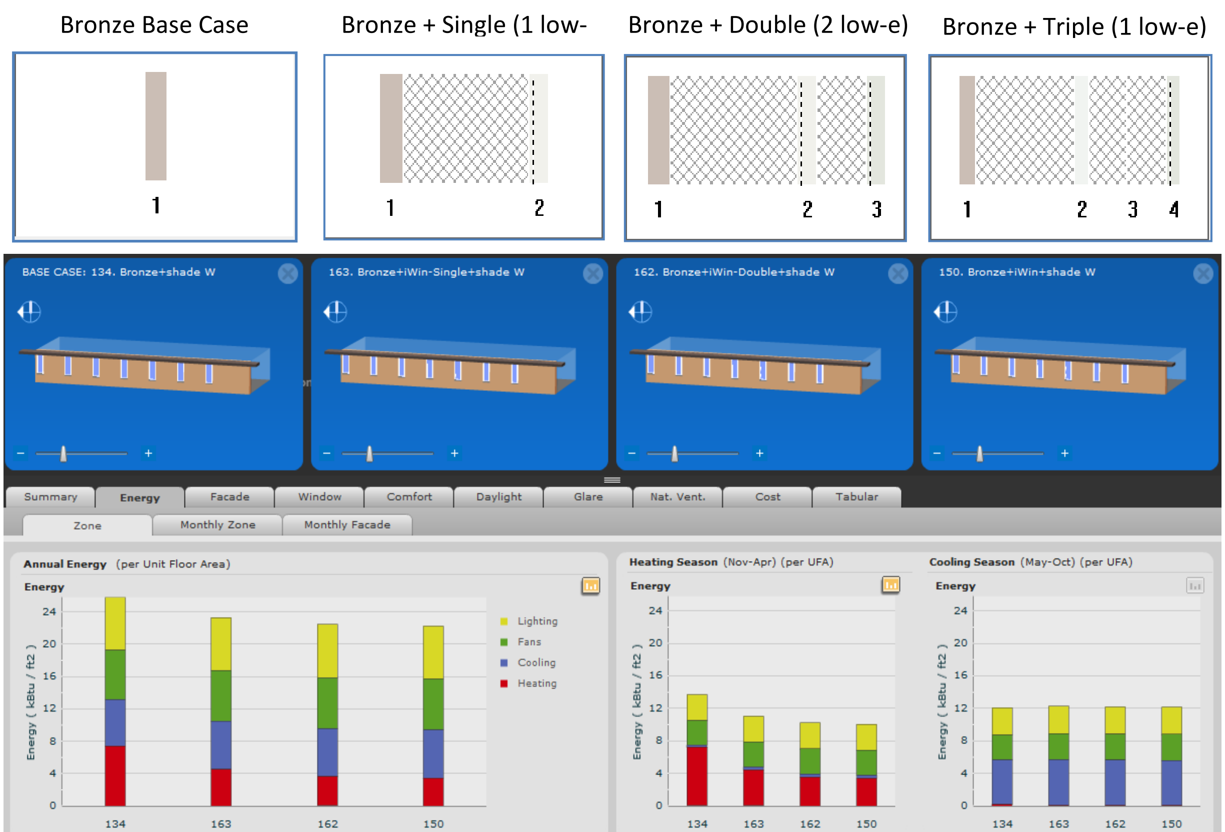


Figure 10. COMFEN analysis for Green Proving Ground project in Provo, UT.

1.8.2 Commercial Building Initiative

COMFEN analysis was done for the Commerical Building Initiative (CBI) project, including analysis of an applied solar control film (with a room-side Low-E coating) applied to windows with single bronze glass on a hotel in Houston to determine if the retrofit would reduce the cooling load.

COMFEN analysis has also been performed on the Li Ka Shing building at UC Berkeley as part of the CBI work.

1.8.3 Stanford Outpatient Facility : Redwood City CA

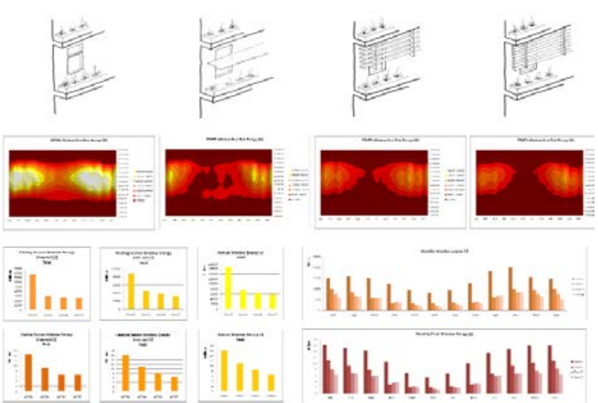
In 1996 Stanford purchased 3 spec-developer open-plan office buildings in the south-bay wishing, in 2006, to transform them into an outpatient clinic facility. Among other new-use requirements, the diagnostic requirement for assessing skin conditions under natural day-light necessitated new internal planning with cellular exam rooms and physician offices along the majority of the perimeter.

While initially improving overall energy performance was not necessarily one of the primary goals of this project, the expanse of changes needed to adapt the existing buildings to meet healthcare requirements meant that complying with current California energy code requirements quickly did become a major requirement of this retrofit.

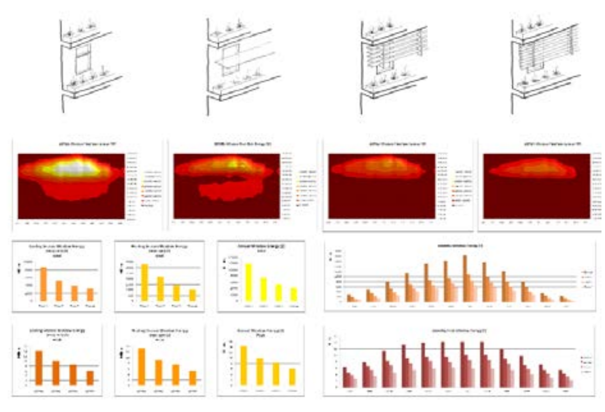
The existing buildings for the new Stanford Outpatient Facility incorporated full-height single-glazed storefront enclosure and, typical of spec-development projects, building mechanical systems and structure engineered to the minimum-limit of early 1990’s code requirements. This meant that:

- The building’s slab-edge construction could not support the added load that a high-performance, insulated-glass curtain-wall (required to meet current Title-24 energy-code) would impose,
- The building structure couldn’t accommodate the load of the additional mechanical system plant needed to offset the solar/thermal load and provide comfortable conditions for the new cellular healthcare offices/exam rooms,
- There was not enough room on the roof to accommodate the mechanical system upgrades needed.

The existing clear, single-glazed storefront (that facilitated unaltered daylight color-rendition critical for clinical diagnoses) was therefore kept and the overall envelope performance improved by adding external sunshades. Using one of the initial versions of COMFEN, these lightweight sunshades were designed to provide the solar control needed for the different façade orientations of the 3 buildings.



south-facing shading load control comparison



west-facing shading load control comparison

While optimizing natural light availability and solar control resulted in different optimal sunshade configurations (louvered horizontals for southerly orientations and louvered-vertical-screens for the easterly and westerly facing facades) all of the new aluminum sunshades employed a 'kit-of-parts' design strategy that afforded both a consistent aesthetic for the 3 buildings and economical fabrication and installation.

The increased envelope efficiency was assessed (expanse and expense of the sunshades) to reduce the needed mechanical system upgrade to that which could be accommodated both spatially and structurally on the existing buildings. The reduced need for conditioning providing energy and associated ongoing cost savings while meeting required OSHPD 3 standards. Design-phase energy analysis indicated:

- Exceeding 2005 California Energy Code by 22%,
- Energy Savings per Year : 89 kW - 654,500 kWh
- Greenhouse Gases Mitigated : 1162 tons per year
- Annual Energy Savings : $188,060.00
- PG&E Savings by Design Owner Cash Incentive : $217,648.00

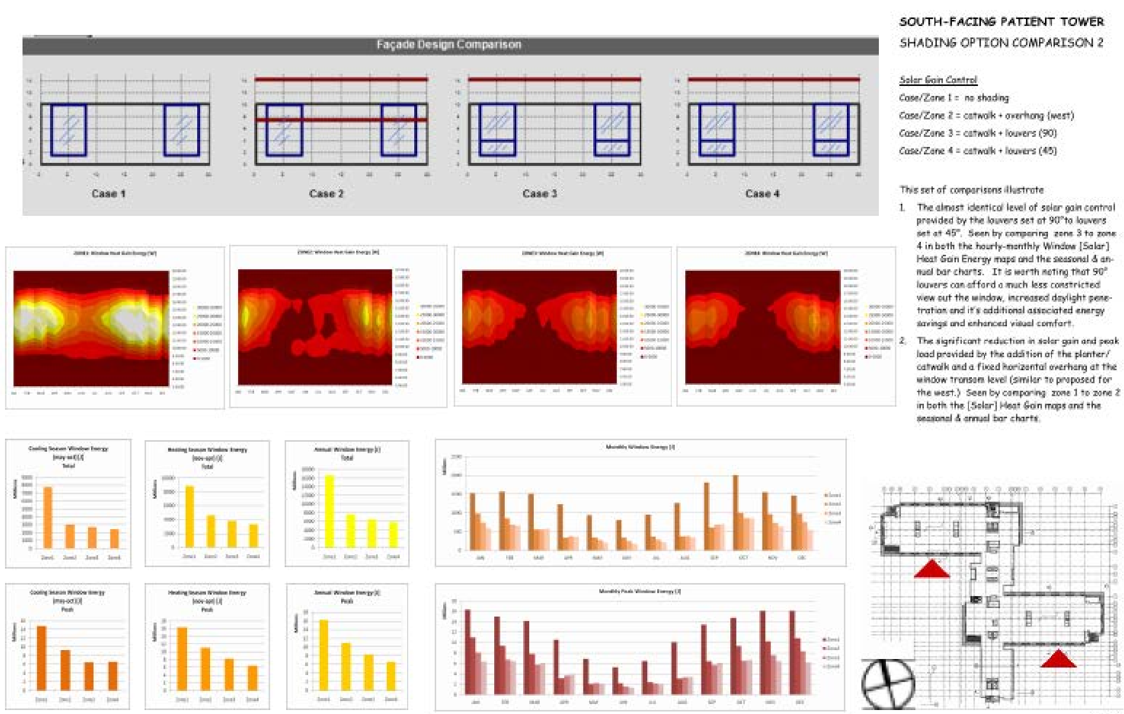
1.8.4 Lucile Packard Children's Hospital : Stanford, CA

In 2009 Stanford commenced the design for a new 521,000-square-foot, LEED-registered addition to the existing Lucile Packard Children's Hospital. Packard Children's expansion is part of the Stanford University Medical Center Renewal Project which also includes building a new Stanford Hospital and replacing outdated medical facilities at the School of Medicine.

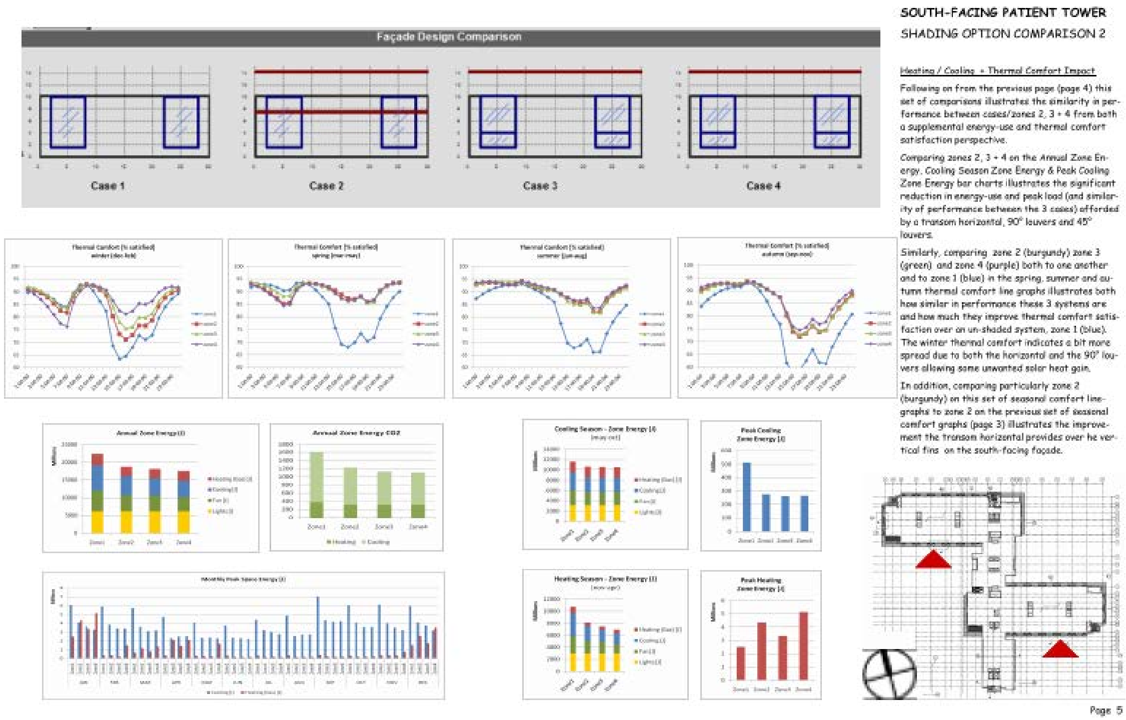
The addition will include 150 new private acute and critical care patient beds, and extensive new surgical and diagnostic services. There also will be a below-grade patient parking structure, as well as three new inviting multiuse outdoor garden spaces to link the addition to the existing hospital, which is already known for its multiple landscaped courtyard spaces. The project will embody a number of innovative design strategies that will transform the experience of patients, families, medical professionals and staff by creating a sustainable healing environment, fostering interdisciplinary discovery and education, and improving care and outcomes for patients everywhere.

As a key component to the sustainable design strategies embodied in the project, early envelope performance analysis was recognized to be a necessity.

One of the initial versions of COMFEN was used to understand what would be needed to optimize natural daylight accessibility and visual connection to the outdoors with solar load control crucial to the adoption of a low-energy mechanical conditioning system. Solar load control alongside potential energy-use reduction, thermal comfort and daylight penetration + control were assessed for a variety of vertical, horizontal and lovered-screen external shading alternatives.



Sample envelope alternatives analysis results report page



Sample envelope alternatives analysis results report page

COMFEN's analysis results displayed as a comparison of improvement between different options, over a range of energy and related resulting performance measures, were instrumental in providing the design + client team with a depth of understanding across multiple inter-related performance issues. The information provided, alongside constructability issues and construction implications, helped the design team to choose external shading strategies, materials and components to meet their low-energy and sustainable design aspirations.

Rendering of highly externally shaded patient-wing of LPCH

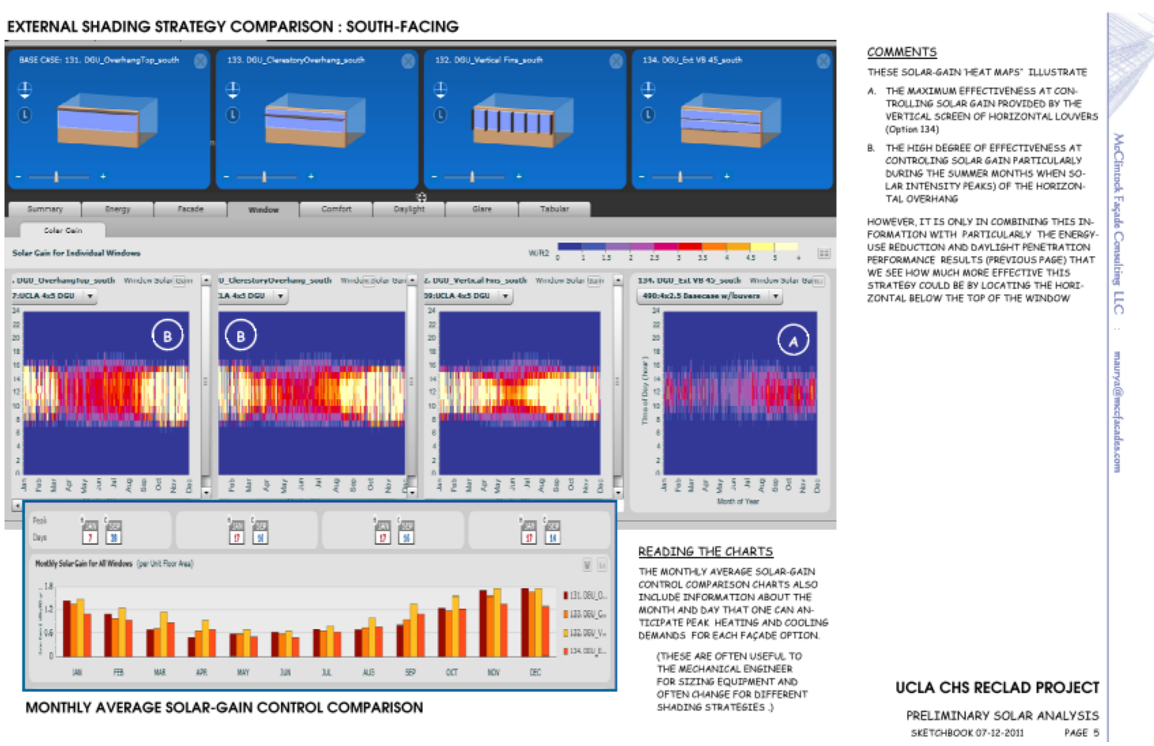
1.8.5 UCLA South Tower : Los Angeles, CA

The 12-story, 443,387 GSF South Tower (a former Medical Center Tower) is part of the 2.4 million GSF UCLA Center for the Health Sciences complex on the UCLA campus. After the 1994 Northridge earthquake, damage assessment and engineering studies funded by FEMA determined that the South Tower's structure was weakened. In response, UCLA developed a comprehensive strategy to create a replacement hospital on the campus, and to perform a seismic upgrade and renovation of the South Tower to house state-of-the-art research wet labs in support of the School of Medicine's research and educational programs.

As the extent of the adaptive re-use + seismic upgrade triggered the requirement to meet newer code requirements, the design team and client agreed that the scope of the renovation also afforded the opportunity to address the building's energy efficiency and high-rise building codes, and upgrade core and life safety infrastructure.

The building's façade of single-glazed ribbon windows with tinted glass and heavily-louvered external shading and wall areas of un-insulated brick-clad concrete was out of compliance with the newer California Title 24 energy requirements. However, improving the façade's thermal performance while increasing daylight availability for its new inhabitants needed to align within the brick wall and ribbon windows aesthetic is prevalent on the UCLA campus.

COMFEN was used to run early-design solar load control energy models of different configurations of glass types and shading strategies for the different orientations of the existing building facades.



Sample envelope alternatives analysis results report page

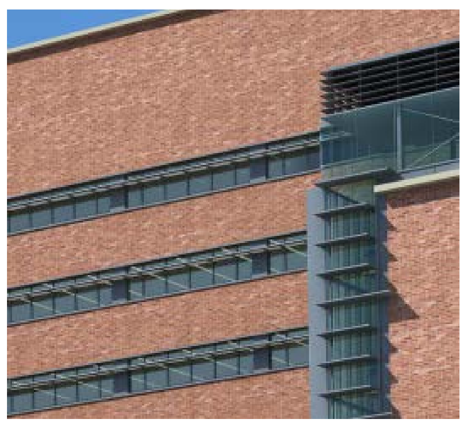
From these iterations, new high-performance ultra-clear glazing with an intermediate horizontal shade was chosen for the replacement strip windows. Whole-building energy modeling indicated that this approach, along with additional R15 batt insulation behind the masonry-clad brick, addressed compliance with California's 2008 Title 24 energy requirements and improved daylight performance dramatically. With daylight dimming lighting, energy modeling indicated the potential for associated energy reduction savings of approximately 40% in energy for the daylight zone (area next to the window). When extrapolated out to the whole building, this showed to be a savings of approximately 33KW (out of 100KW total for the lighting) or a savings of approximately 33% / $ 6,177/yr (based on the current lighting design as a baseline, which was already 45% under Title 24 requirements.)

Additionally, meeting current code requirements meant that the building's 8-10 story open-air access stairs needed to now be enclosed. Rather than add yet more energy-intensive mechanical equipment to condition each of these stair-towers, a new glazed curtain wall that included external shading, louvered intakes at ground-level soffits and operable louvers above roof-level facilitated the use of natural ventilation to condition these spaces.

Again, coordinated COMFEN-energy and air-flow modeling indicated that with optimized external shading, the stack effect between the low + high-level openings encouraged natural air flow through the towers. As such, stair-tower active-mechanical was needed only to provide pressurization for emergency evacuation of occupants, significantly reducing the size and capital cost of this equipment as well as annual conditioning energy costs.

$78 million has been saved by retrofitting the existing structure and shell, and according to design-phase energy analysis, the reduced need for conditioning provided through right-sizing HVAC equipment, use of chilled beams, daylighting controls and exterior skin upgrades, will provide ongoing energy cost savings of:

- Exceeding 2008 California Energy Code by 22.4%,
- Energy Savings per Year : 199 kW – 457,353 kWh
- Greenhouse Gases Mitigated : 566,747 lbs per year
- Annual Energy Savings : $63,860



Before After

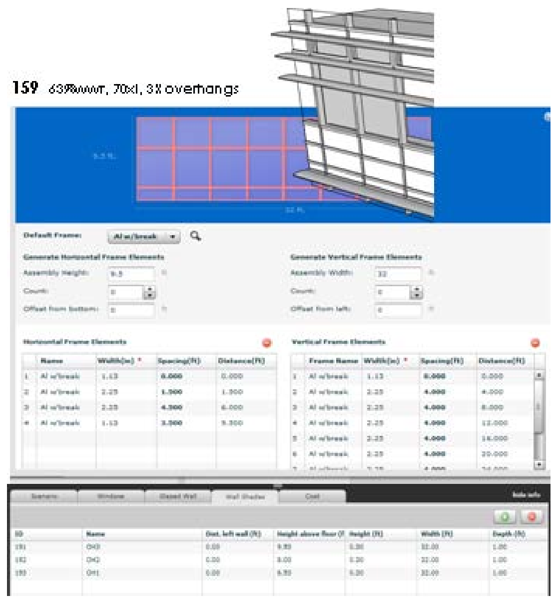
1.8.6 High-rise Residential Tower : Oakland, CA

Recently PGE commissioned a consulting team on behalf of the owner of property in Oakland interested in exploring the potential for a high-rise residential, net-zero energy project. The consulting team was asked to provide early design analysis of a variety of load reduction and low-energy systems and strategies in an analysis and design process that would most cost effectively achieve net-zero energy, market rate residential units.

Different from the current design/analysis strategy for 'traditional' low-energy aspiration projects that analyze a number of different measures' improvement potential over a base-case (typically code minimum requirements), the consultant team proposed an analysis/design strategy for a net-zero project to follow sequential optimization of:

1. Load reduction strategies, particularly shading and insulation alternatives at the envelope, but also lighting, fit-out equipment such as kitchen and laundry appliances, and plug load control,
2. Passive strategies such as daylighting and natural-ventilation driven cooling,
3. Energy efficient active strategies such as radiant cooling, which are typically only possible once maximum advantage of 1 + 2 above are obtained,
4. Energy recovery and energy generation technologies, to supply the small amount of energy required after maximizing the capabilities of 1-3 above.

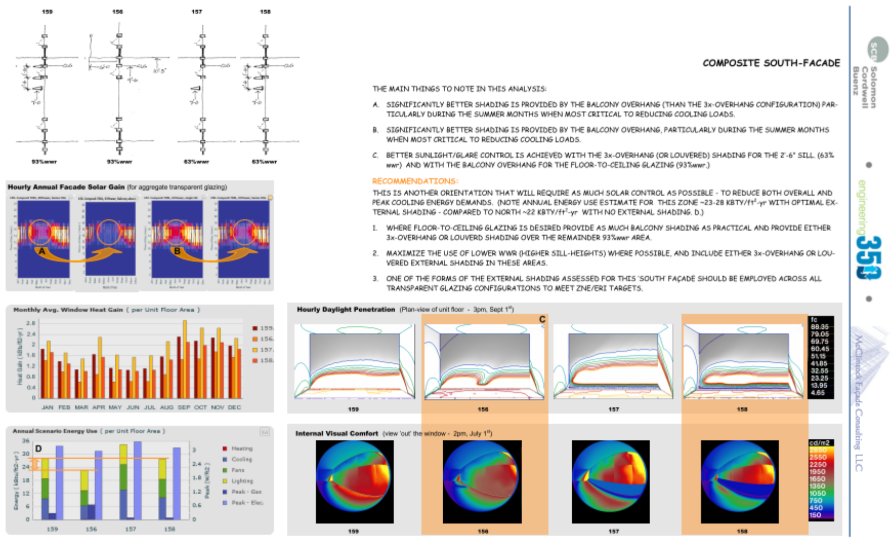
COMFEN version 4.1, with a new feature to generate glazed wall systems (in addition to the previous versions' capability to assess punched windows), facilitated assessment of envelope related energy-saving and associated performance (thermal comfort, daylight penetration, visual comfort) for steps 1 + 2 above. These sections of the analysis/design strategy were shown to be the most critical to achieving a desire for net-zero (and very low-energy use) projects, as all of the later supplemental energy decisions hinge on the design decisions of these load control elements.



Sample glazed wall input screens

COMFEN's analysis results;

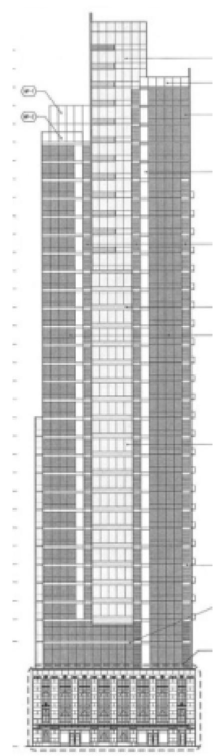
- over a range of energy and related resulting performance measures (from solar load control to energy and daylight penetration and control),
- for a wide variety of currently available envelope materials (from fritted and high-performance glazing to the newest range of fabric and honeycomb insulating blinds),
- and assortment of shade + blind operation algorithms (linking resulting daylight control to lighting use/function),
- displayed as a comparison of improvement between different options,were instrumental in providing the project owner and consulting team with a depth of understanding across multiple inter-related performance issues.

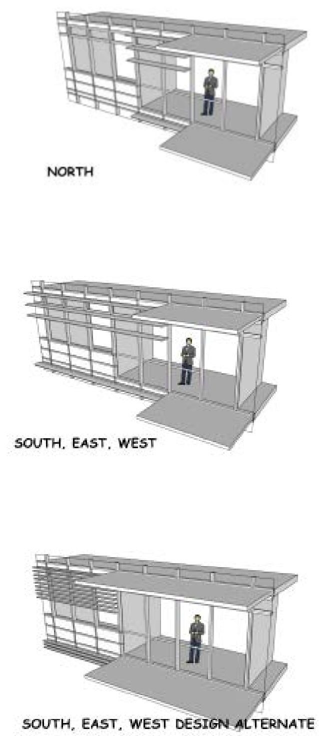


Sample envelope alternatives analysis results report page

The results from COMFEN thus allowed the owner + consulting team to make envelope design-strategy decisions informed by potential energy- reduction, critical to proceeding with exploration of low-energy active and energy generation options needed to supplement performance to achieve the required overall net-zero outcome.

Through supplemental whole-building analysis it was determined that with the inclusion of solar hot water and photovoltaics (both technologies now initially available for inclusion in the spandrel area of the vertical wall – the largest area available on a high-rise project) providing roughly 25 and 15 k-Btu/sf-year respectively alongside the low-energy active systems employed could bring the project to within striking distance of a market-rate, net-zero high-rise residential project.

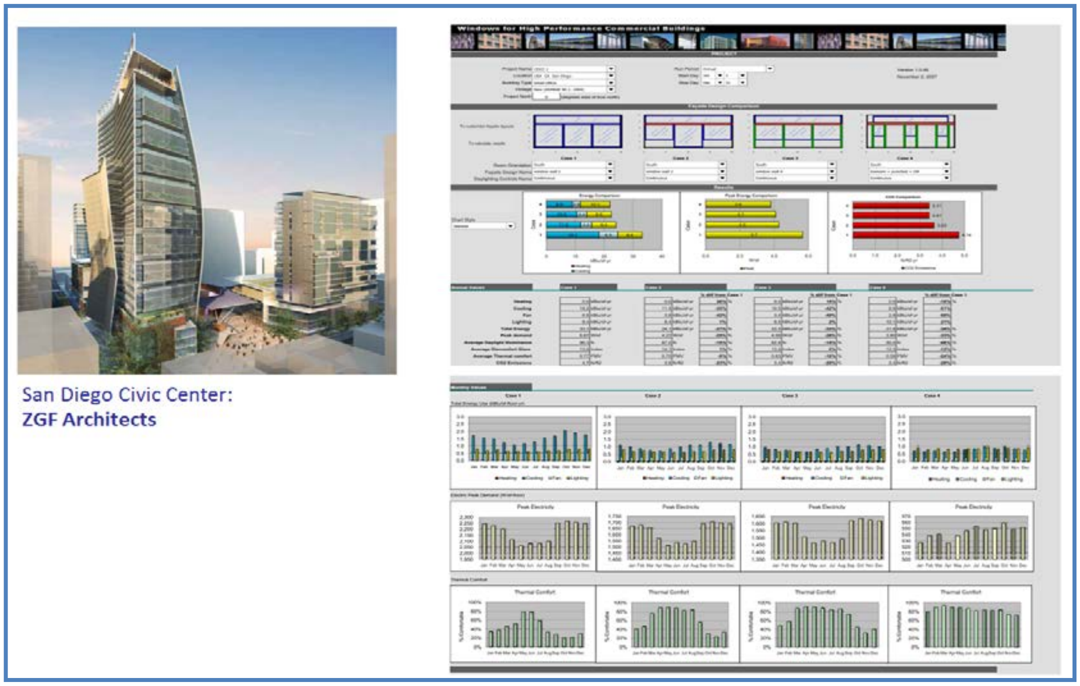




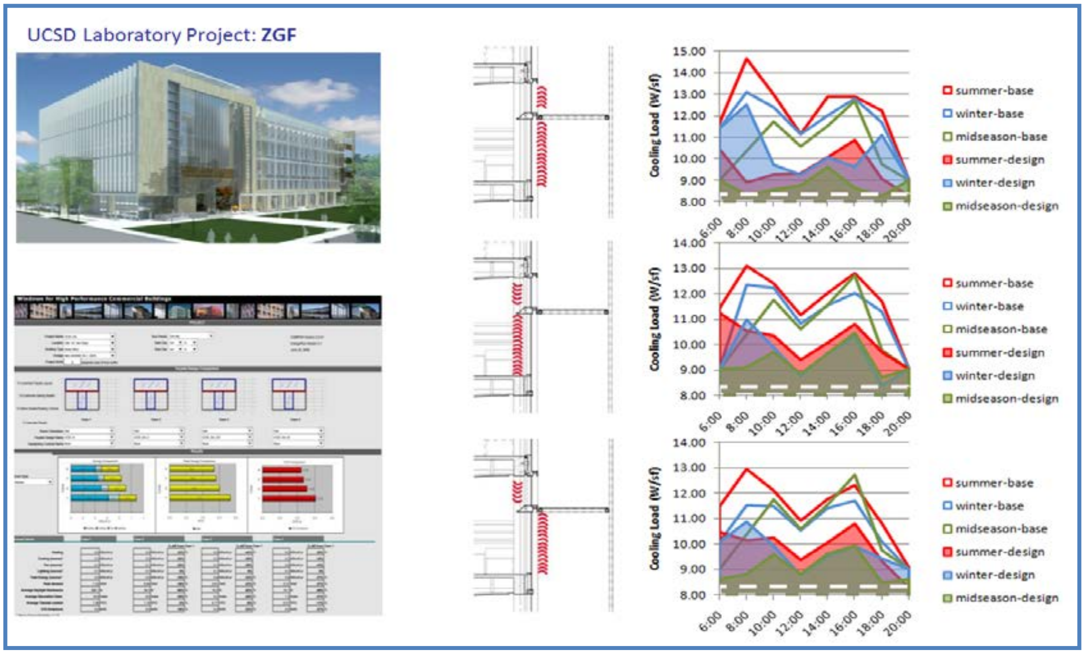
Shading recommendations

1.8.7 Architectural Conceptual Design Façade Studies

COMFEN has been used by architects to do initial design studies in California as well as nationally and internationally. For example, the architectural firm ZGF (offices in Portland, Seattle, Los Angeles, Washington DC, and New York City) have used it for several projects in California, including a laboratory at the University of California, San Diego to do a venetian blind shading study, and for the San Diego Civic Center to do an exterior overhang / fin study.



COMFEN analysis for conceptual design of San Diego Civic Center



COMFEN analysis for conceptual design of UCSD Laboratory Project

1.9 Next Steps

Enhanced simulation tools have played a critical role in advancing the energy efficiency of buildings and will continue to in the future. In fact they are likely to play an increasingly important role as standards are tightened in California over three year cycles leading to the aggressive 2030 goal of zero net energy goals. Earlier incremental savings could be accomplished by substitution of more efficient components for less efficient systems, e.g. lower lighting power density. But increasingly, the next steps building energy efficiency will be captured with smarter, dynamic integrated systems, e.g. daylight utilization will save more lighting energy than an incremental improvement in power density. But good daylighting design requires optimization of glass properties and shading for glare, lighting and cooling, a task that is not intuitive for all climates and orientations. This is area where tools like COMFEN can truly make a difference in allowing the design team to explore the "performance space" of all solutions early in the process and then successively refine solutions with performance goals in mind.

Feedback from a variety of users has confirmed the value of COMFEN and identified several areas for further enhancement. These are intended to increase the applicability of the tool to business needs as well as to improve its ease of use in the design process. These areas include providing:

1. Whole building estimates by averaging zone results
2. Code compliance targets built into the tool
3. Support for outcome based code approaches
4. Additional HVAC options
5. Expand to include skylights
6. Add Demand Response capability
7. Add BIPV capability
8. Develop custom versions to support Savings by Design incentives
9. Improve use of BIM for both design imput and export

10. Enhanced capabilities from Radiance- based annual energy analysis
11. Additional training and education programs

Some of the features may be of interest to DOE and other national entities but a number are unique to California and it is hoped that additional public resources can be used to enhance these capabilities. Ongoing support for the tool is a potential future issue as these tools (COMFEN, Energy Plus, Radiance, and WINDOW) have been largely supported with public sector funds to be sure they are unbiased and readily available to the design community.

1.10 Acknowledgments

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy, under Contract No. DE-AC02-05CH11231 and by the California Energy Commission through its Public Interest Energy Research (PIER) Program on behalf of the citizens of California.

1.11 References

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COMFEN 3.0 – Evolution of an Early Design Tool for Commercial Facades and Fenestration Systems, S. Selkowitz, LBNL; R. Mitchell.LBNL;M. McClintock, McClintock Façade Consulting LLC; D. McQuillen, McQuillen Interactive LLC; A. McNeil, LBNL; M. Yazdanian, LBNL; Presented at the Building Enclosure Sustainability Symposium (BESS) 2011, Pomona, CA, April 29–30, 2011.

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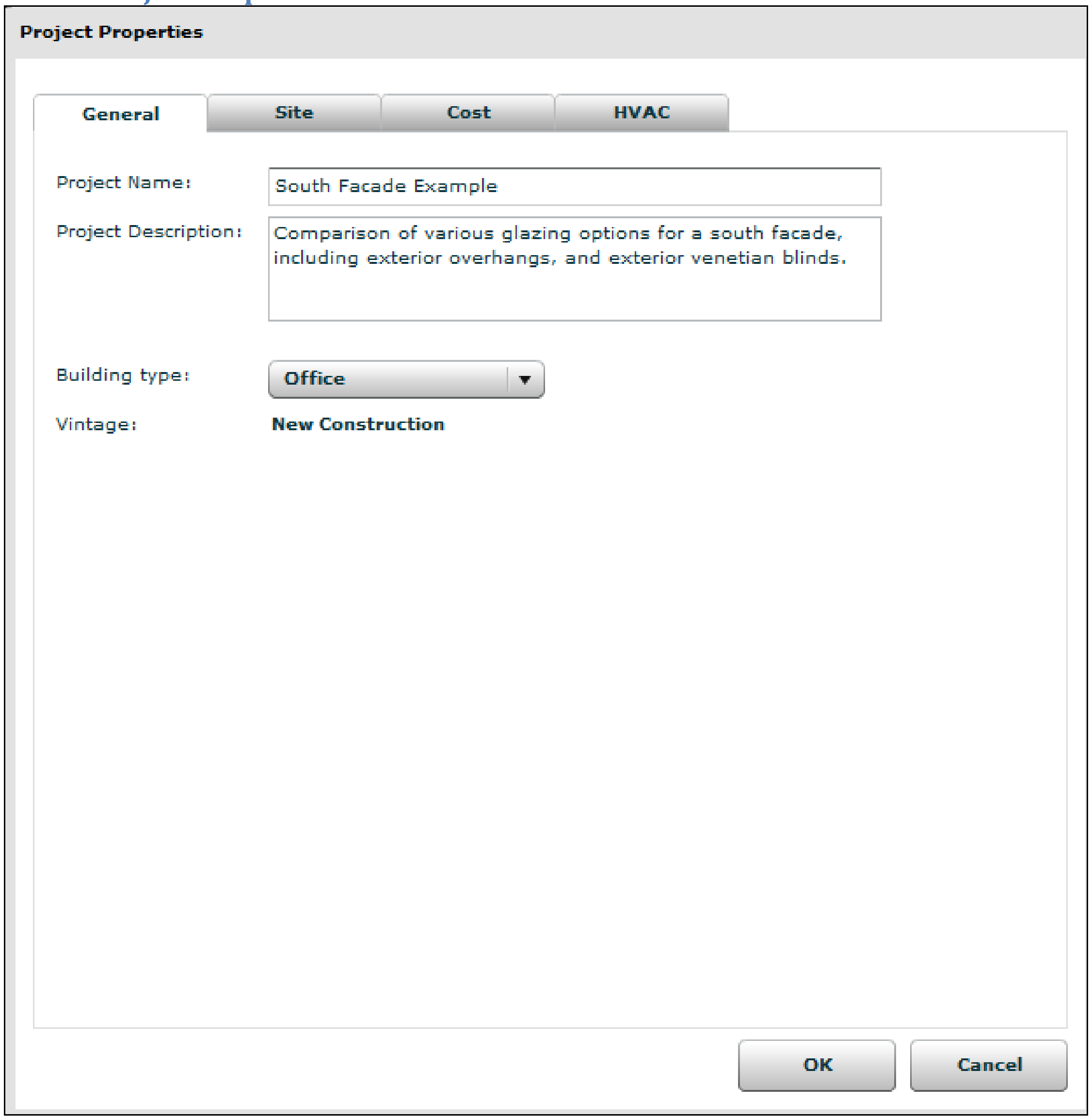
1.12 Appendix: Program Screen Shots

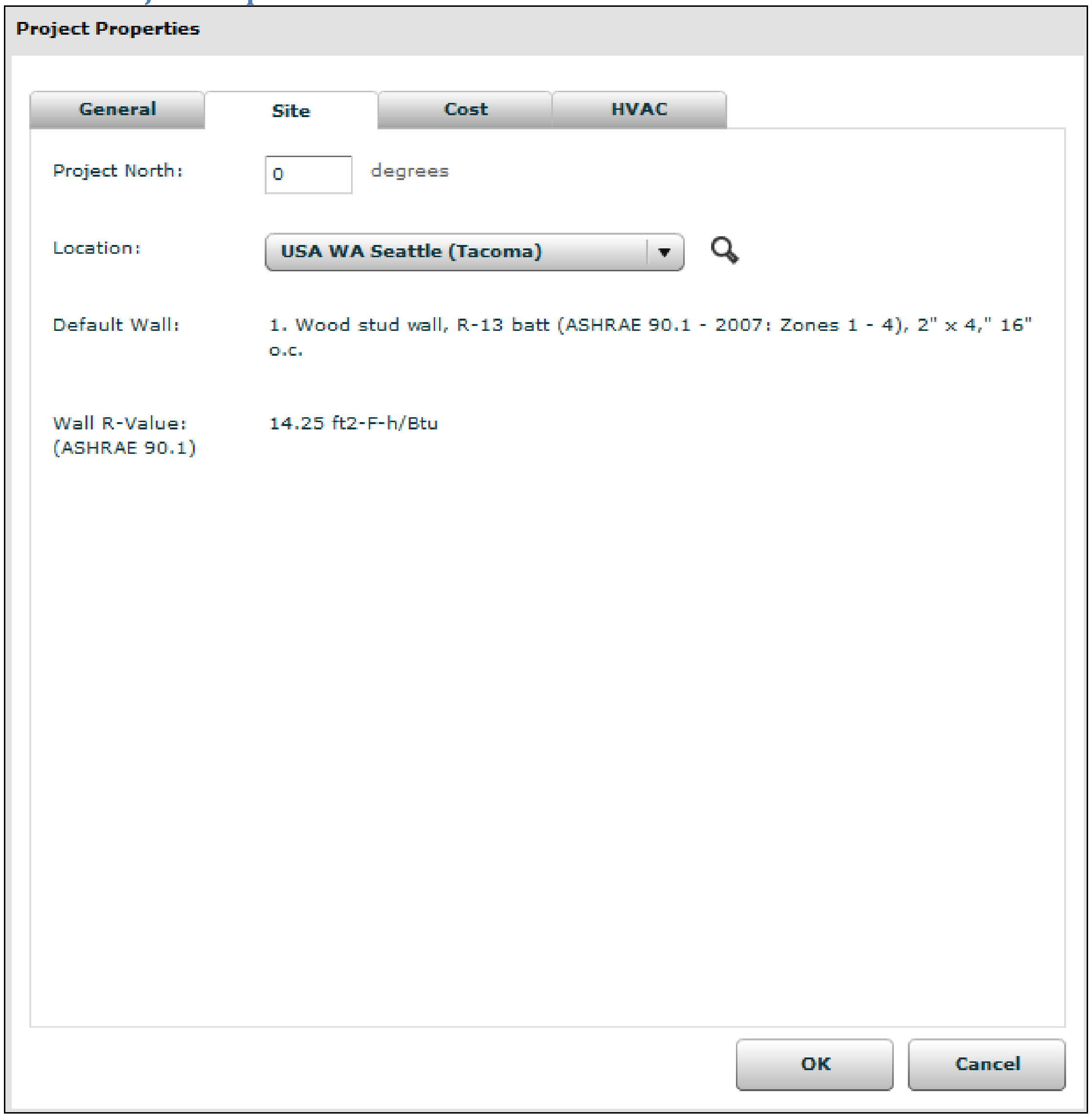
This appendix contains screen shots from the COMFEN user interface.

1.1.1 About COMFEN

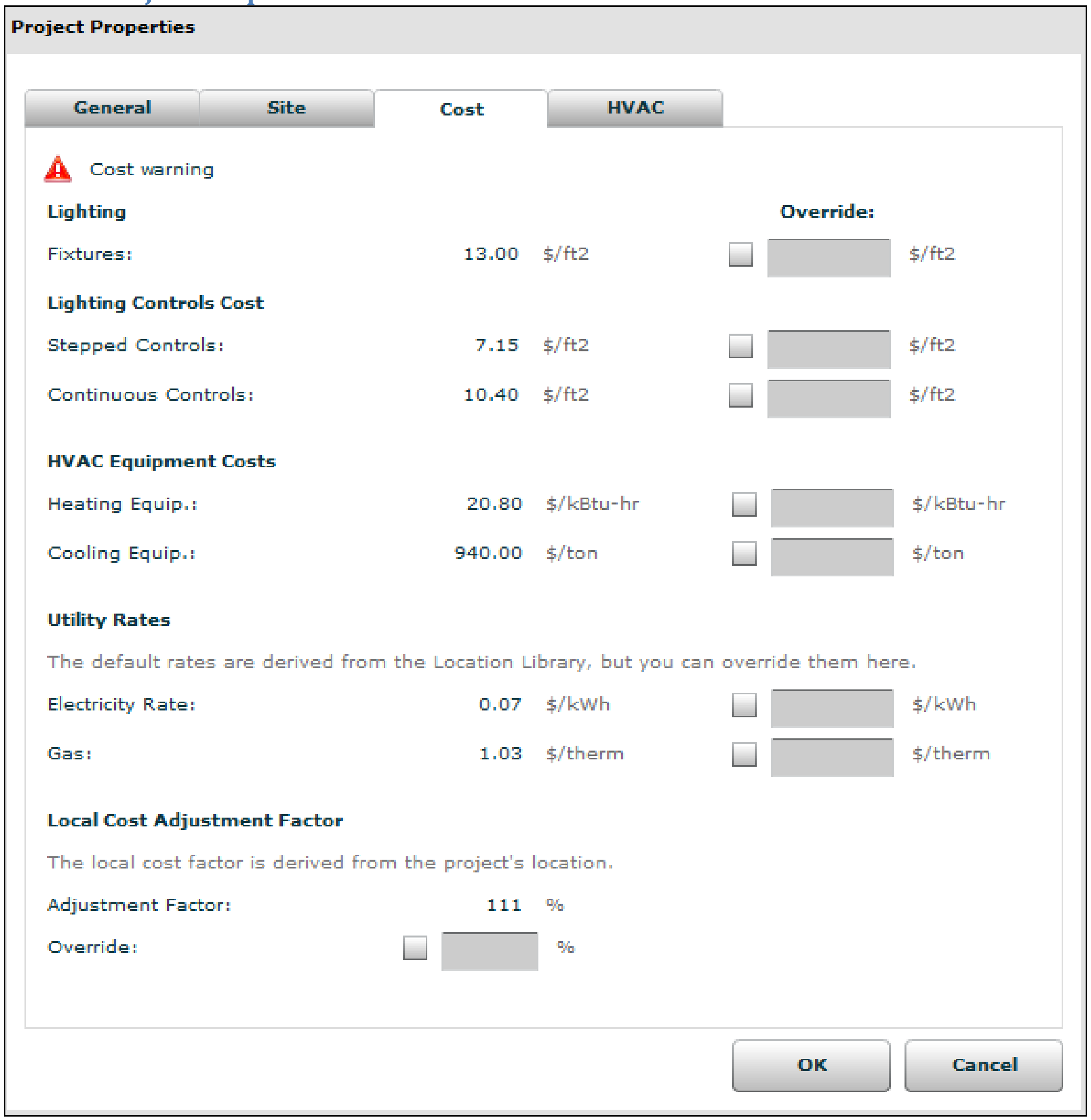
1.1.2 Project Properties General



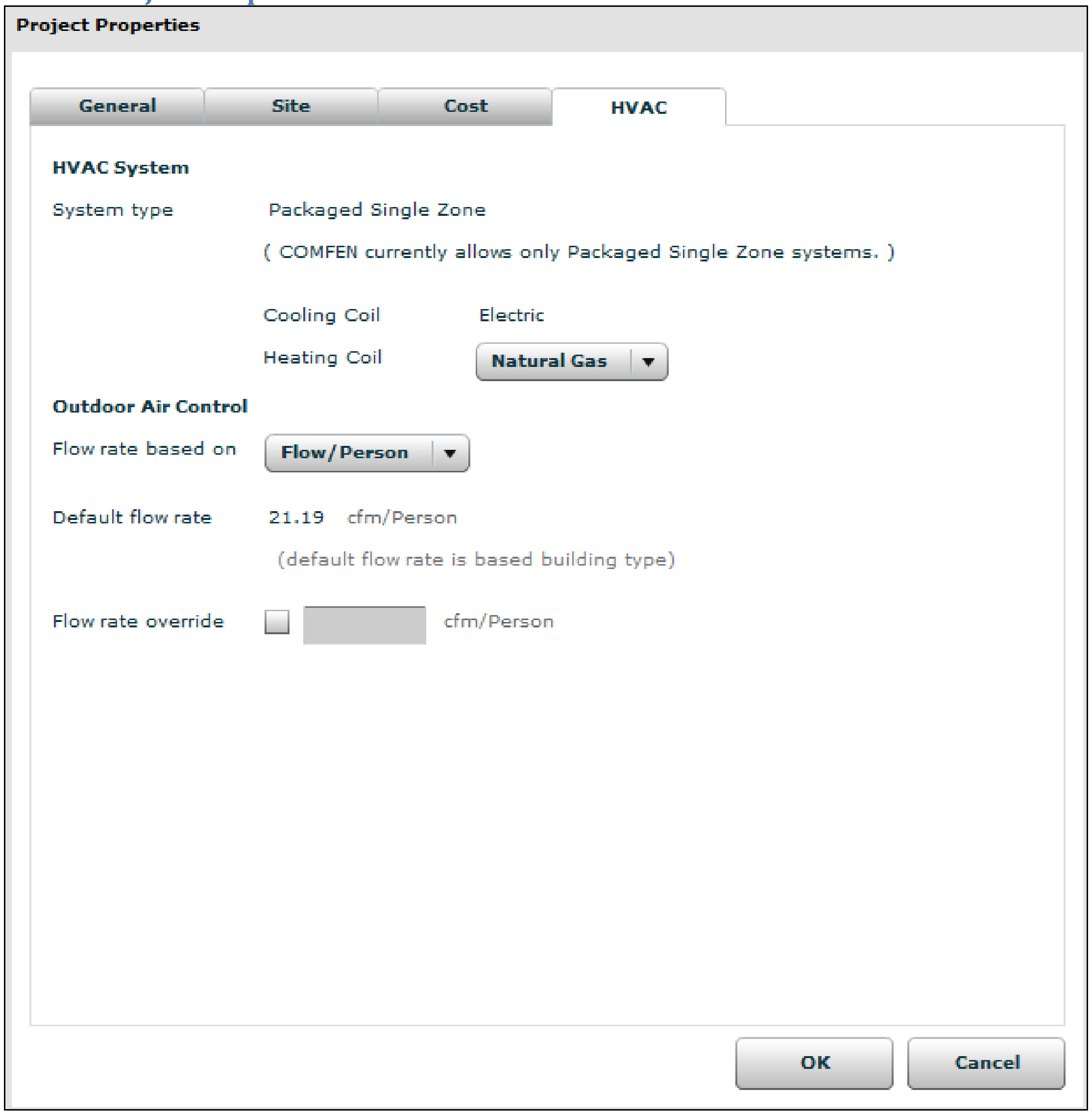
1.1.3 Project Properties Site



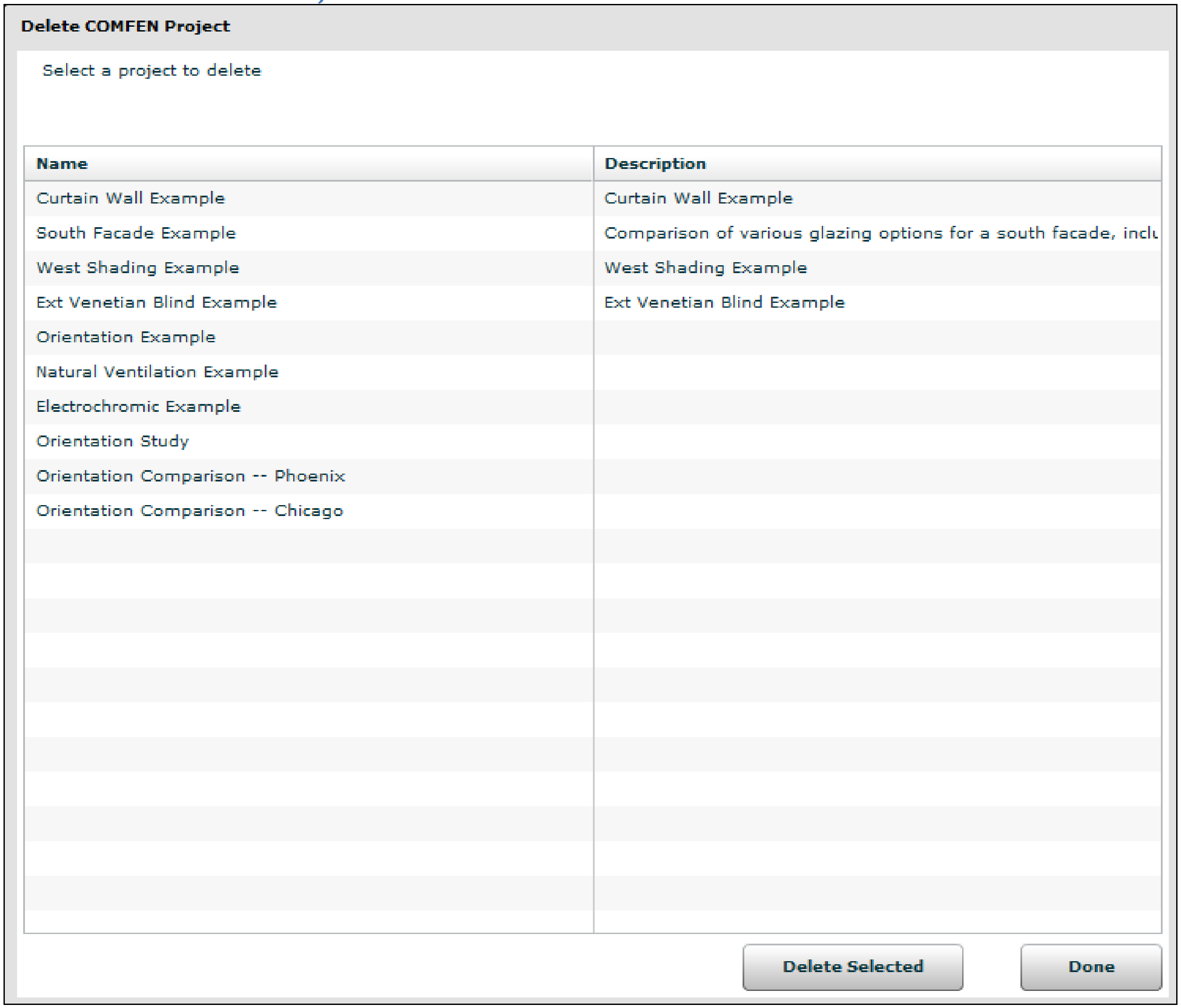
1.1.4 Project Properties Cost



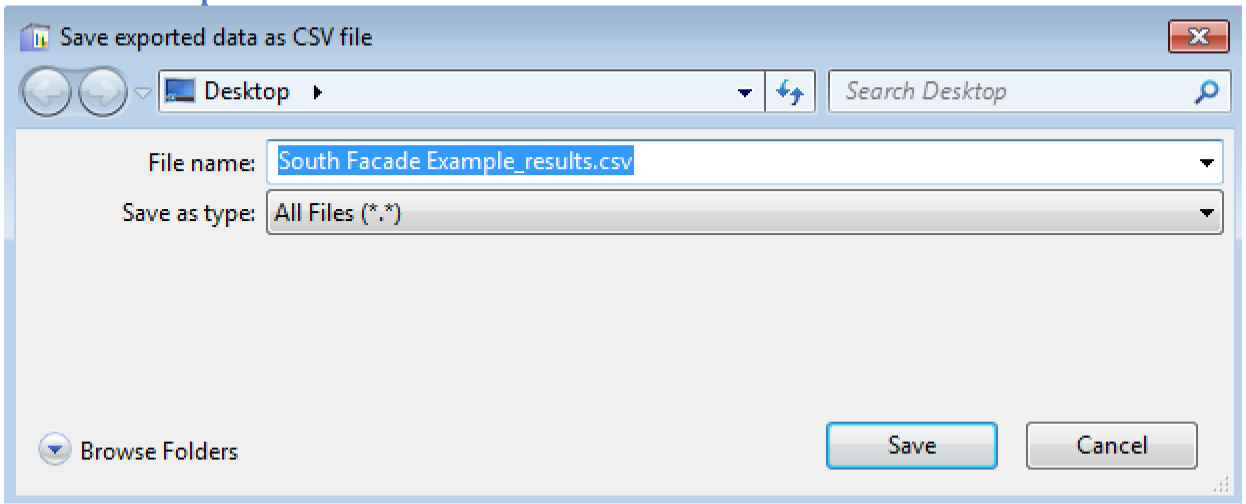
1.1.5 Project Properties Cost



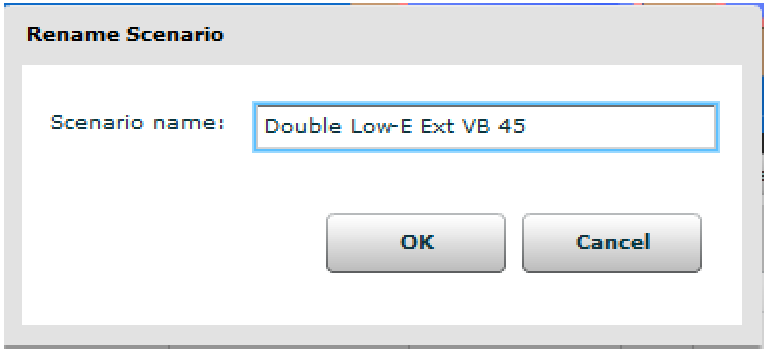
1.1.6 Delete COMFEN Project



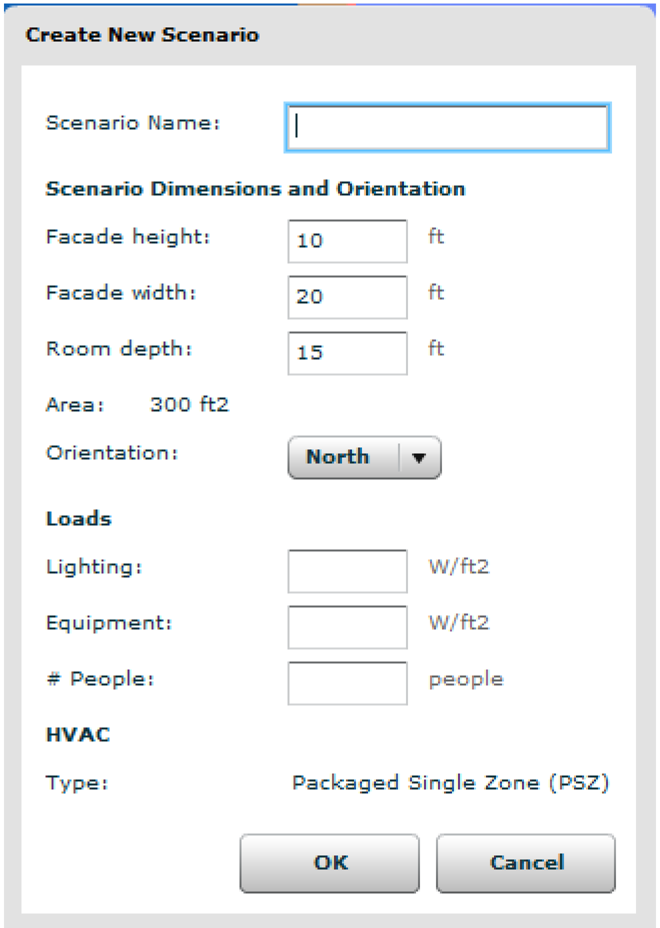
1.1.7 Save exported data as CSV file



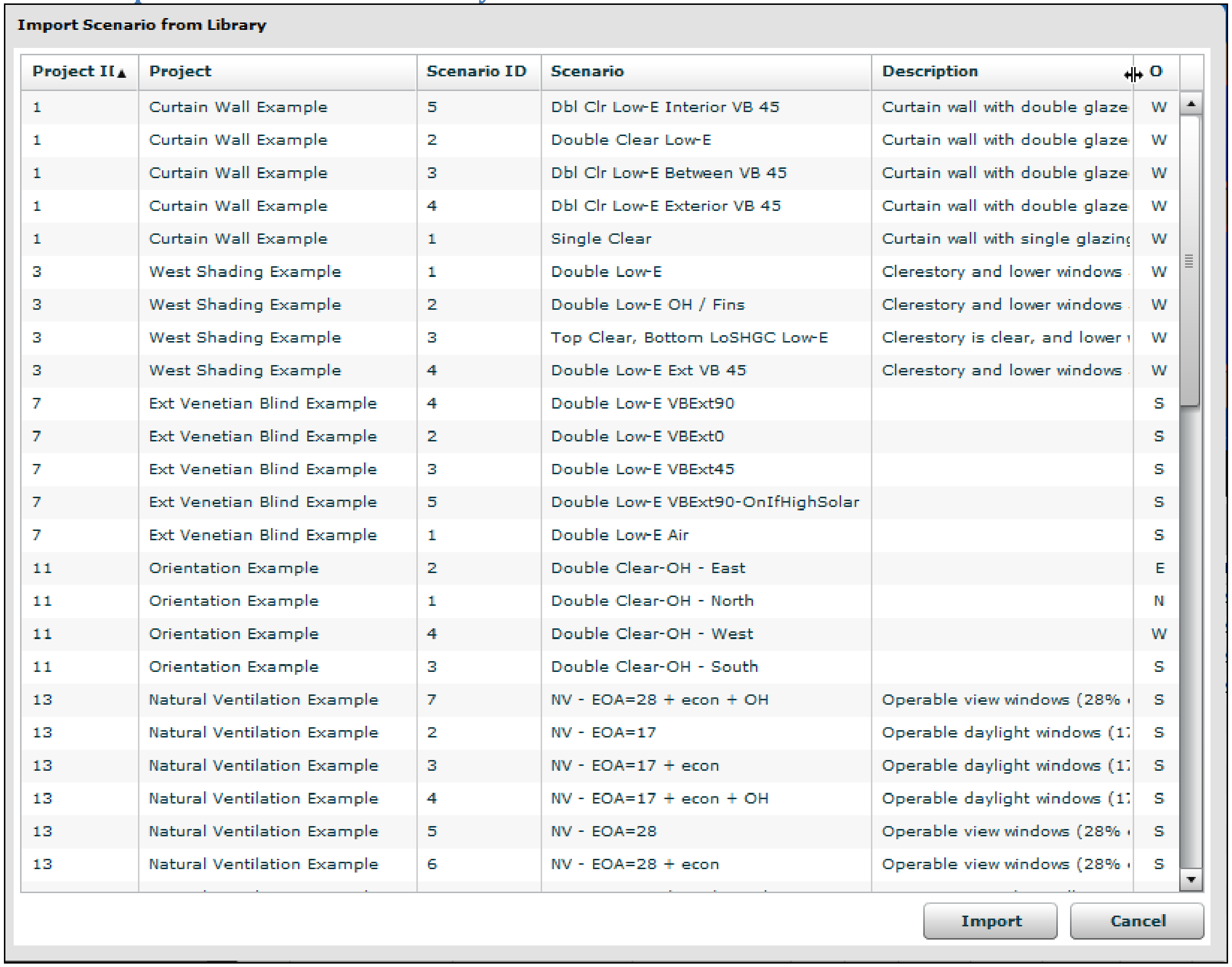
1.1.8 Rename Scenario



1.1.9 Create New Scenario



1.1.10 Import Scenario From Library

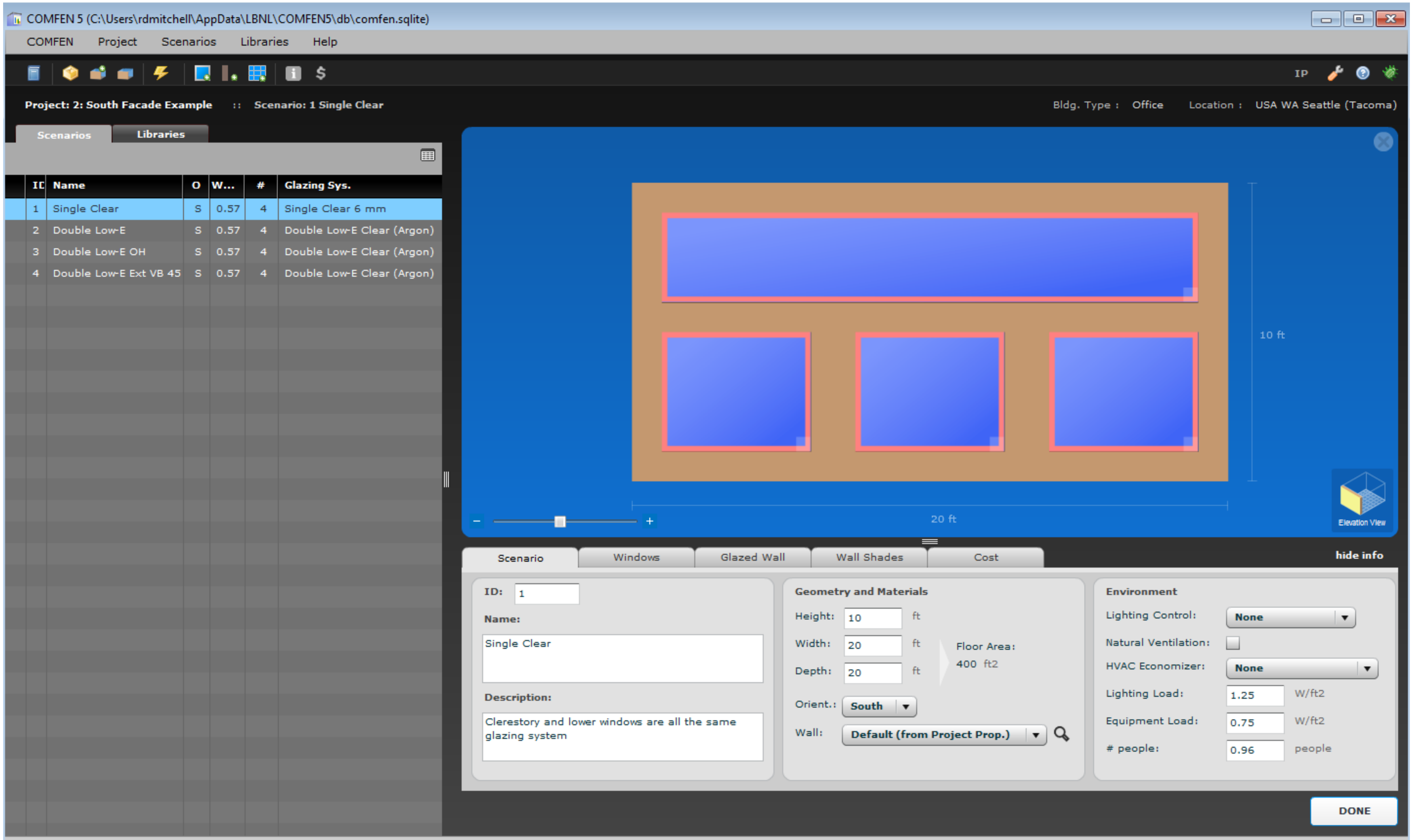


Import Scenario from Library

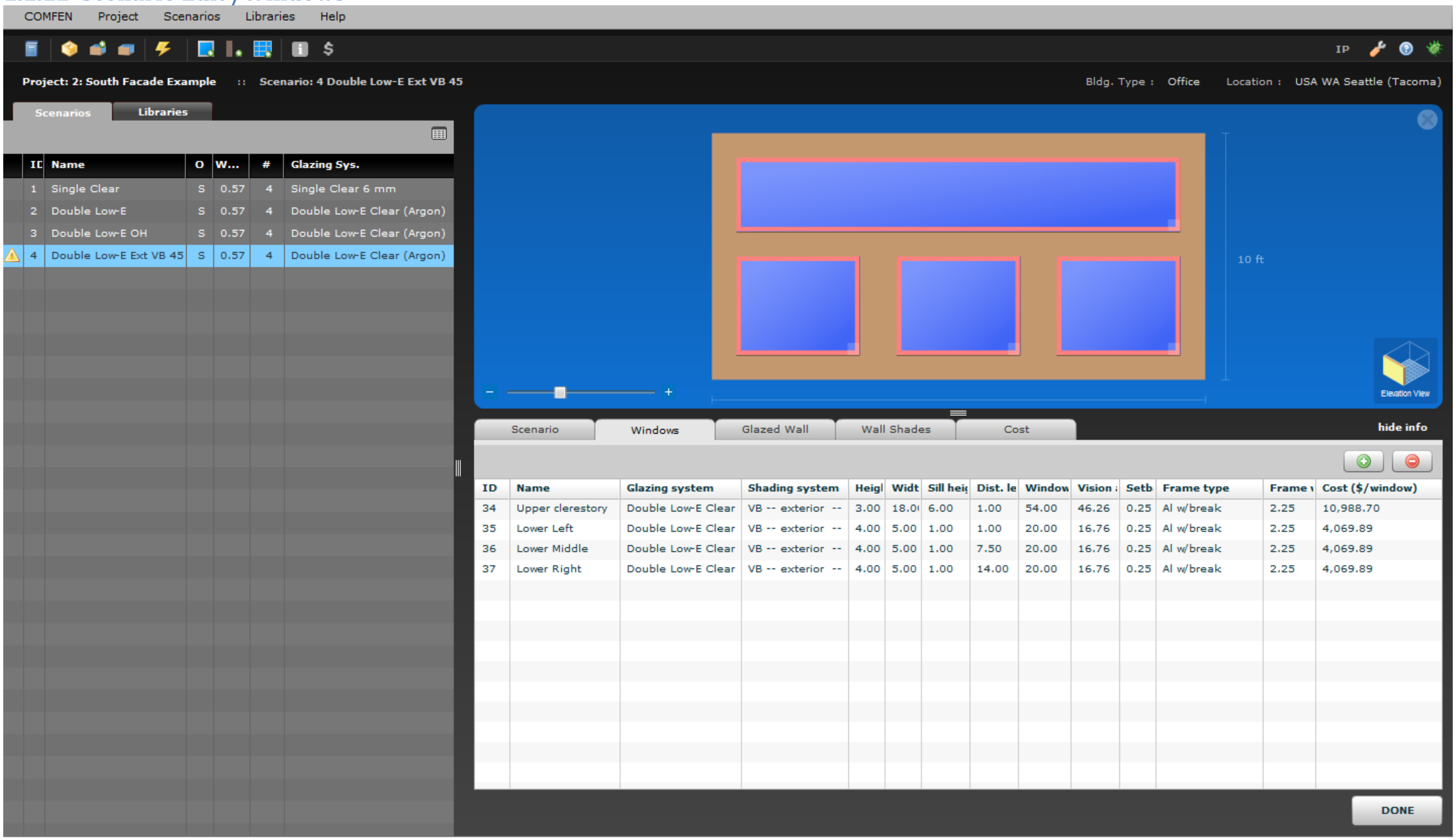
Project II▲	Project	Scenario ID	Scenario	Description	O
1	Curtain Wall Example	5	Dbl Clr Low-E Interior VB 45	Curtain wall with double glaze	W
1	Curtain Wall Example	2	Double Clear Low-E	Curtain wall with double glaze	W
1	Curtain Wall Example	3	Dbl Clr Low-E Between VB 45	Curtain wall with double glaze	W
1	Curtain Wall Example	4	Dbl Clr Low-E Exterior VB 45	Curtain wall with double glaze	W
1	Curtain Wall Example	1	Single Clear	Curtain wall with single glazin	W
3	West Shading Example	1	Double Low-E	Clerestory and lower windows	W
3	West Shading Example	2	Double Low-E OH / Fins	Clerestory and lower windows	W
3	West Shading Example	3	Top Clear, Bottom LoSHGC Low-E	Clerestory is clear, and lower	W
3	West Shading Example	4	Double Low-E Ext VB 45	Clerestory and lower windows	W
7	Ext Venetian Blind Example	4	Double Low-E VBExt90		S
7	Ext Venetian Blind Example	2	Double Low-E VBExt0		S
7	Ext Venetian Blind Example	3	Double Low-E VBExt45		S
7	Ext Venetian Blind Example	5	Double Low-E VBExt90-OnIfHighSolar		S
7	Ext Venetian Blind Example	1	Double Low-E Air		S
11	Orientation Example	2	Double Clear-OH - East		E
11	Orientation Example	1	Double Clear-OH - North		N
11	Orientation Example	4	Double Clear-OH - West		W
11	Orientation Example	3	Double Clear-OH - South		S
13	Natural Ventilation Example	7	NV - EOA=28 + econ + OH	Operable view windows (28%	S
13	Natural Ventilation Example	2	NV - EOA=17	Operable daylight windows (1	S
13	Natural Ventilation Example	3	NV - EOA=17 + econ	Operable daylight windows (1	S
13	Natural Ventilation Example	4	NV - EOA=17 + econ + OH	Operable daylight windows (1	S
13	Natural Ventilation Example	5	NV - EOA=28	Operable view windows (28%	S
13	Natural Ventilation Example	6	NV - EOA=28 + econ	Operable view windows (28%	S

Import Cancel

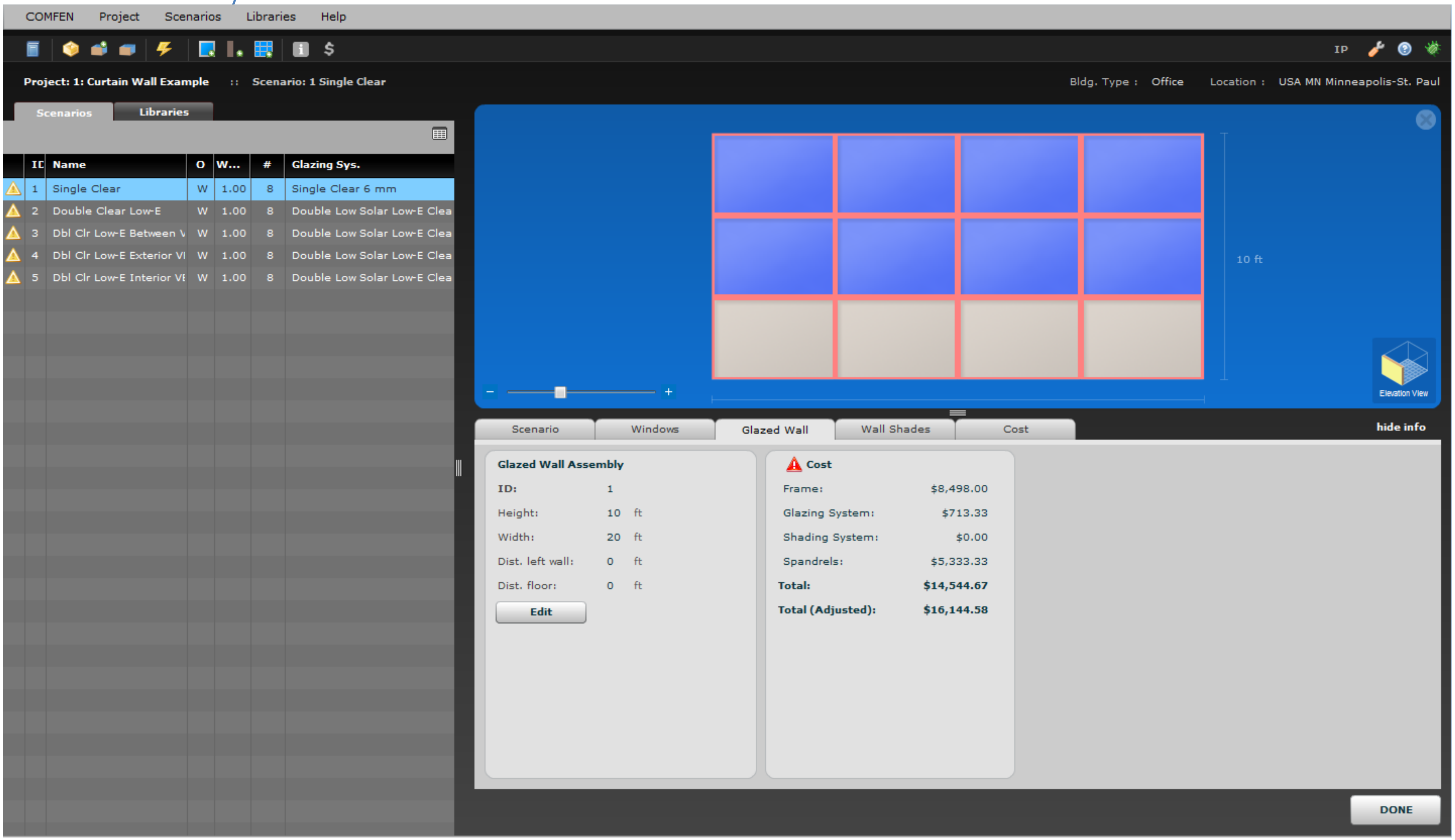
1.1.11 Scenario Edit



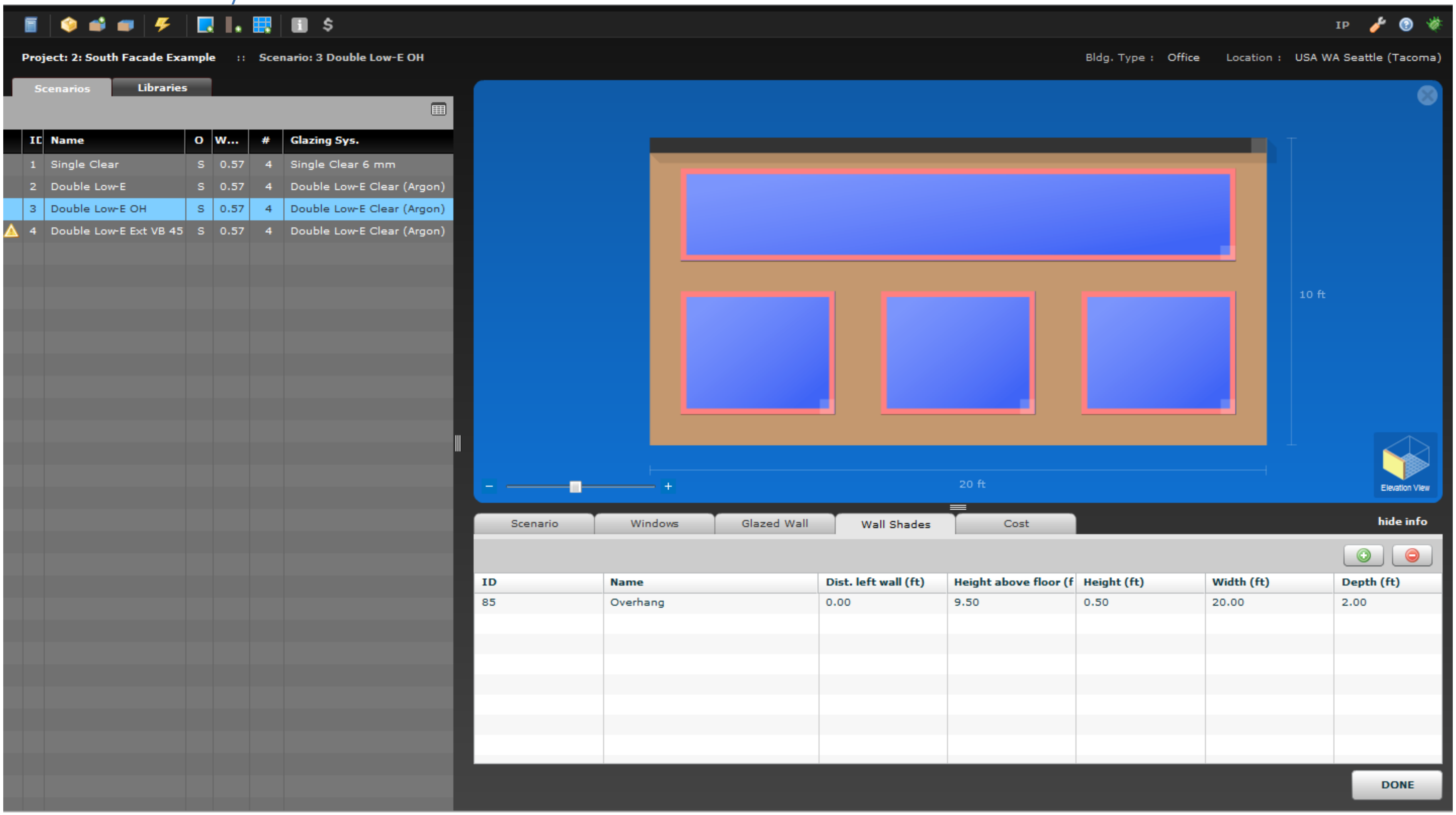
1.1.12 Scenario Edit /Windows



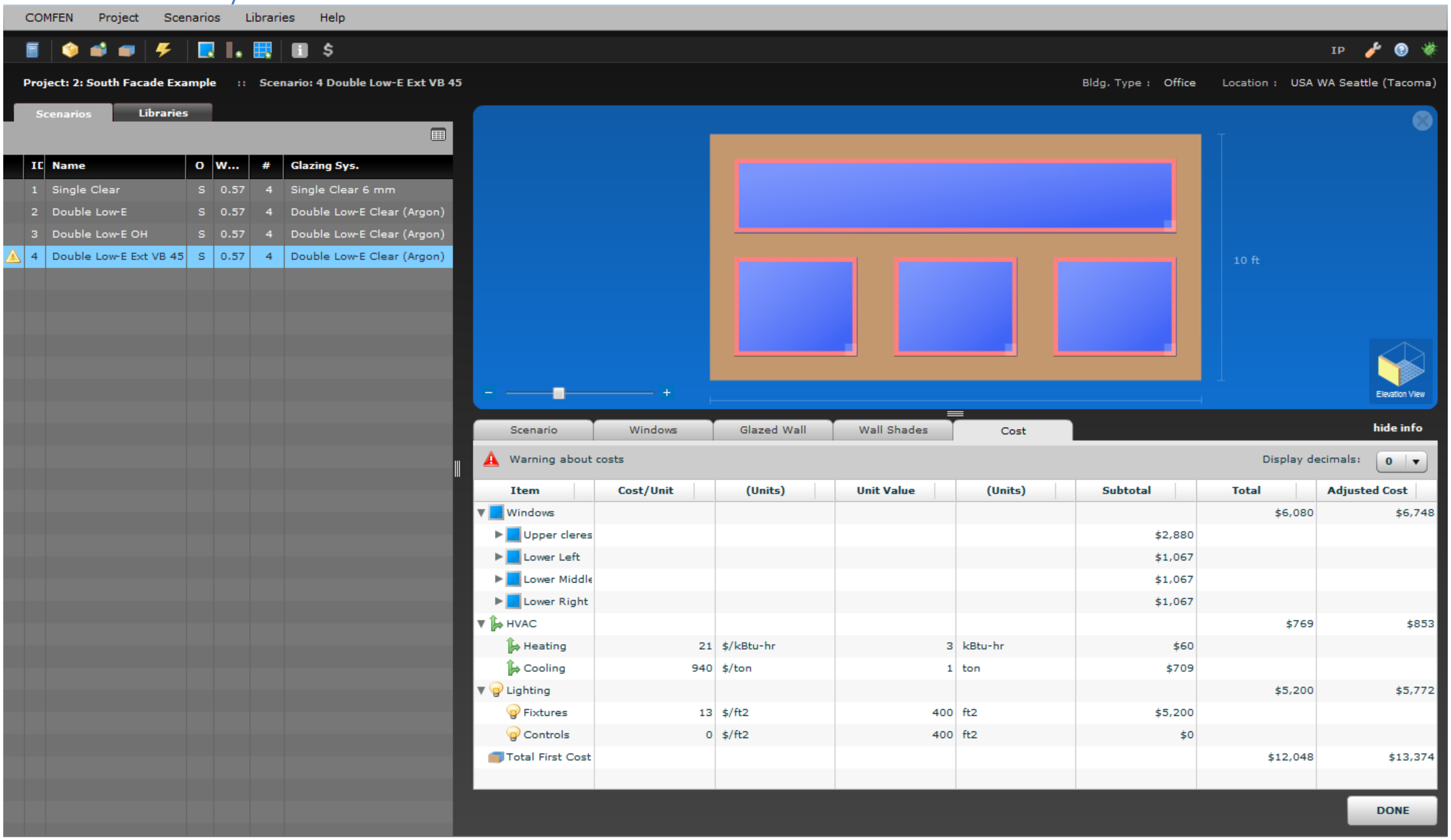
1.1.13 Scenario Edit /Glazed Wall



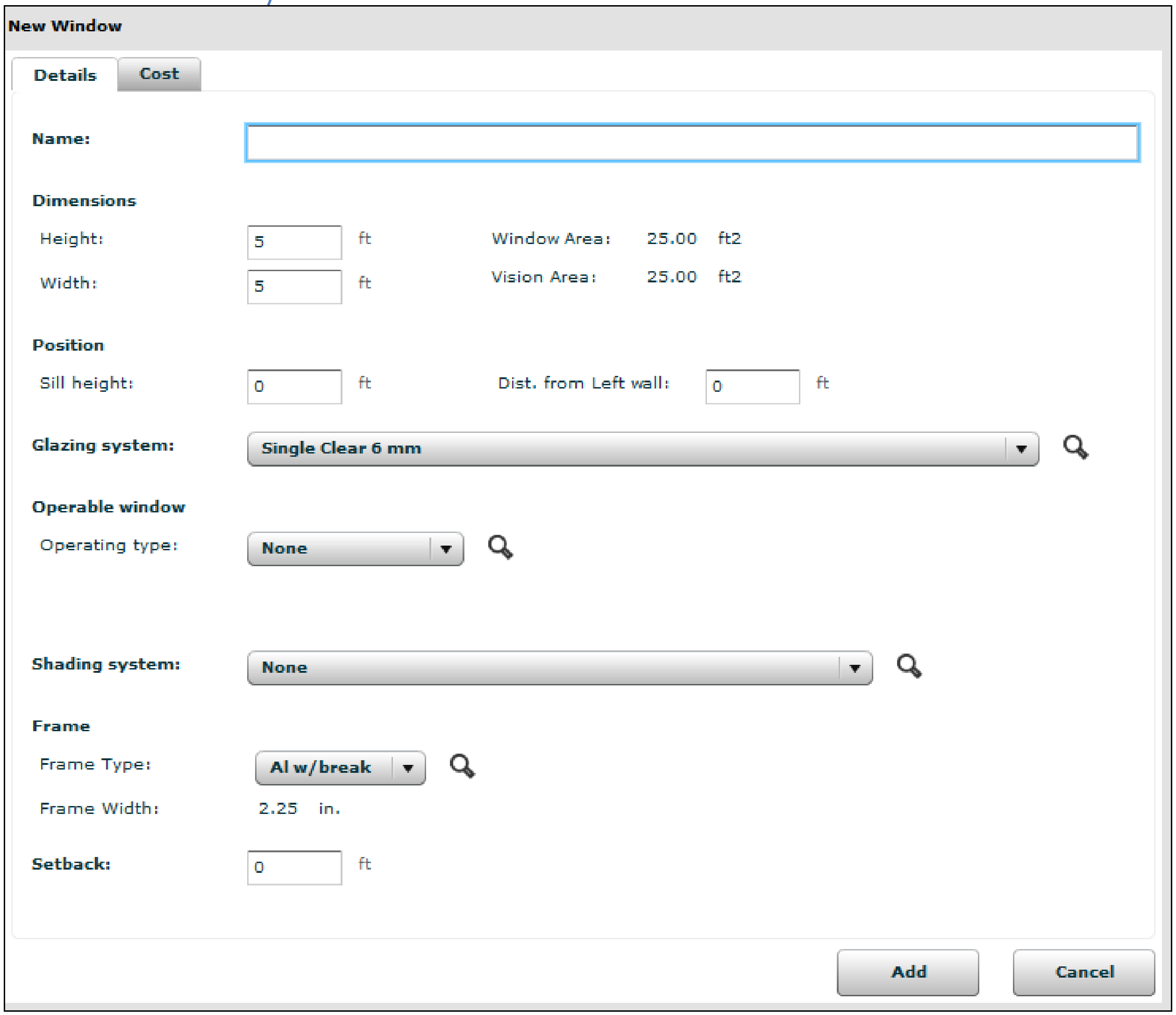
1.1.14 Scenario Edit /Wall Shades



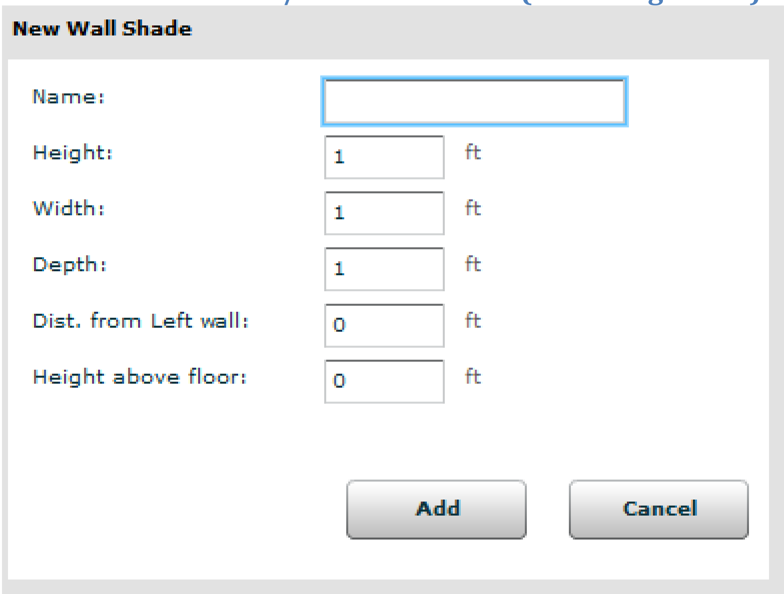
1.1.15 Scenario Edit /Cost



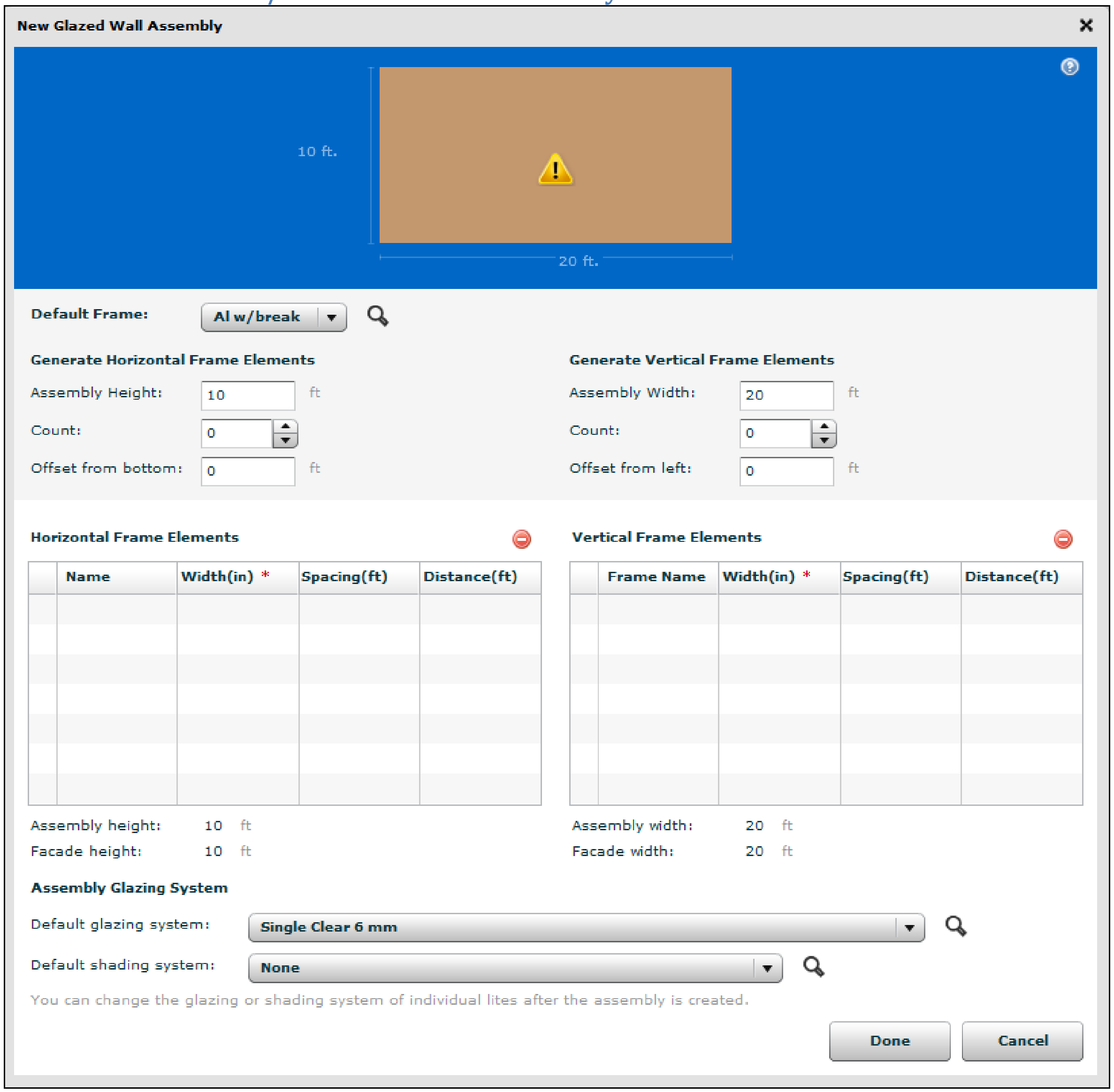
1.1.16 Scenario Edit /New Window



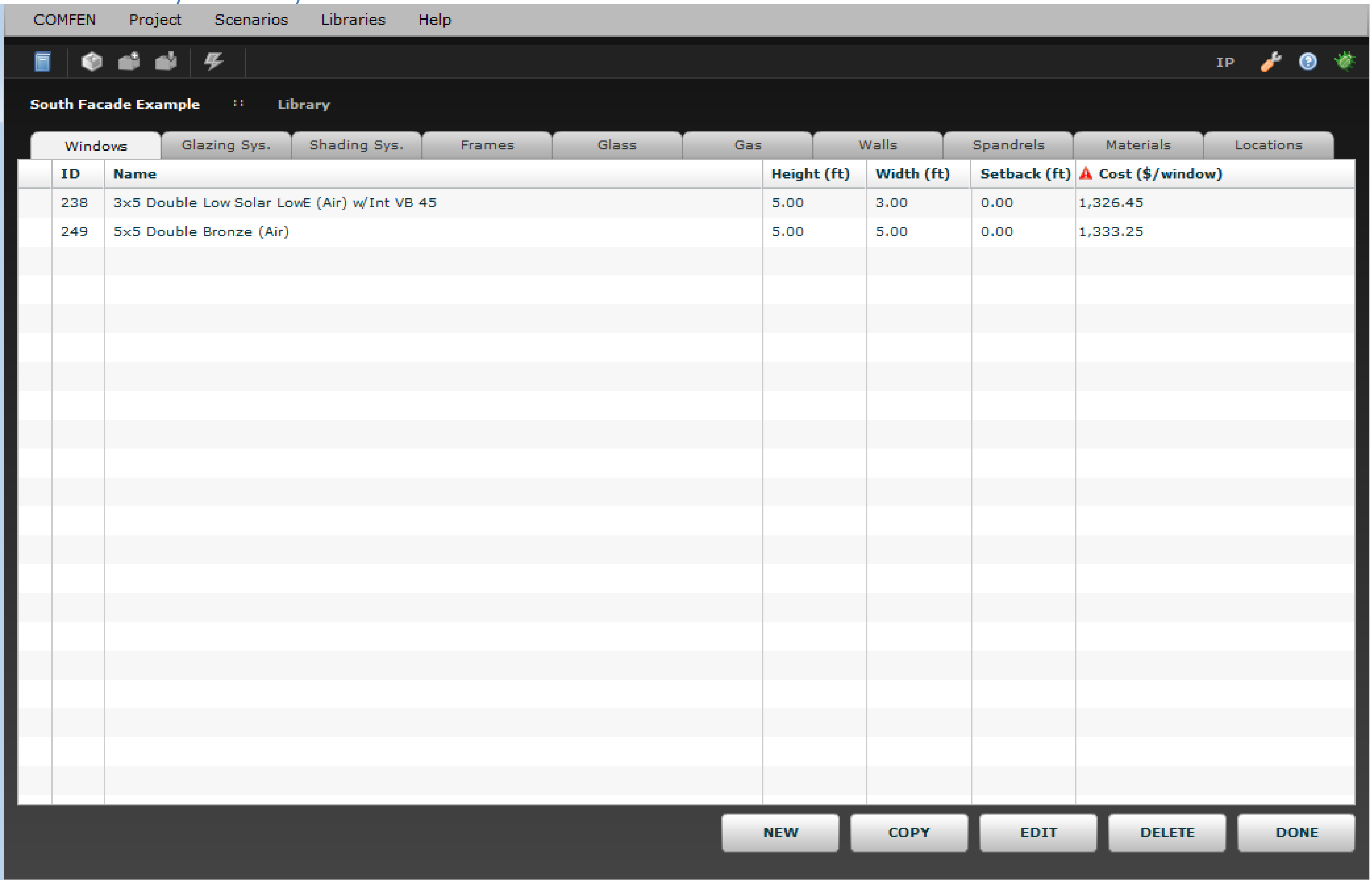
1.1.17 Scenario Edit /New Wall Shade (Overhang or Fin)



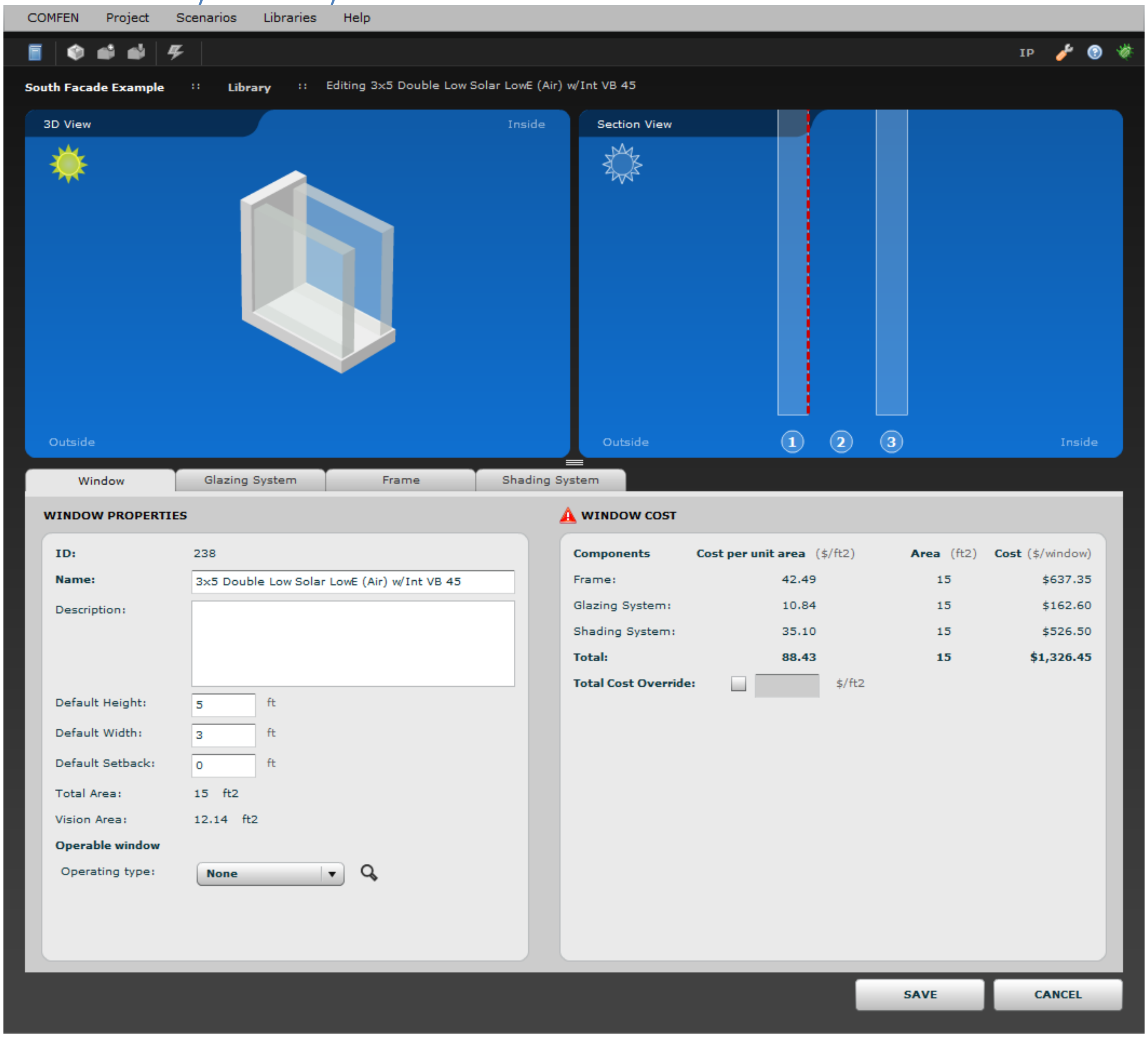
1.1.18 Scenario Edit /New Glazed Wall Assembly



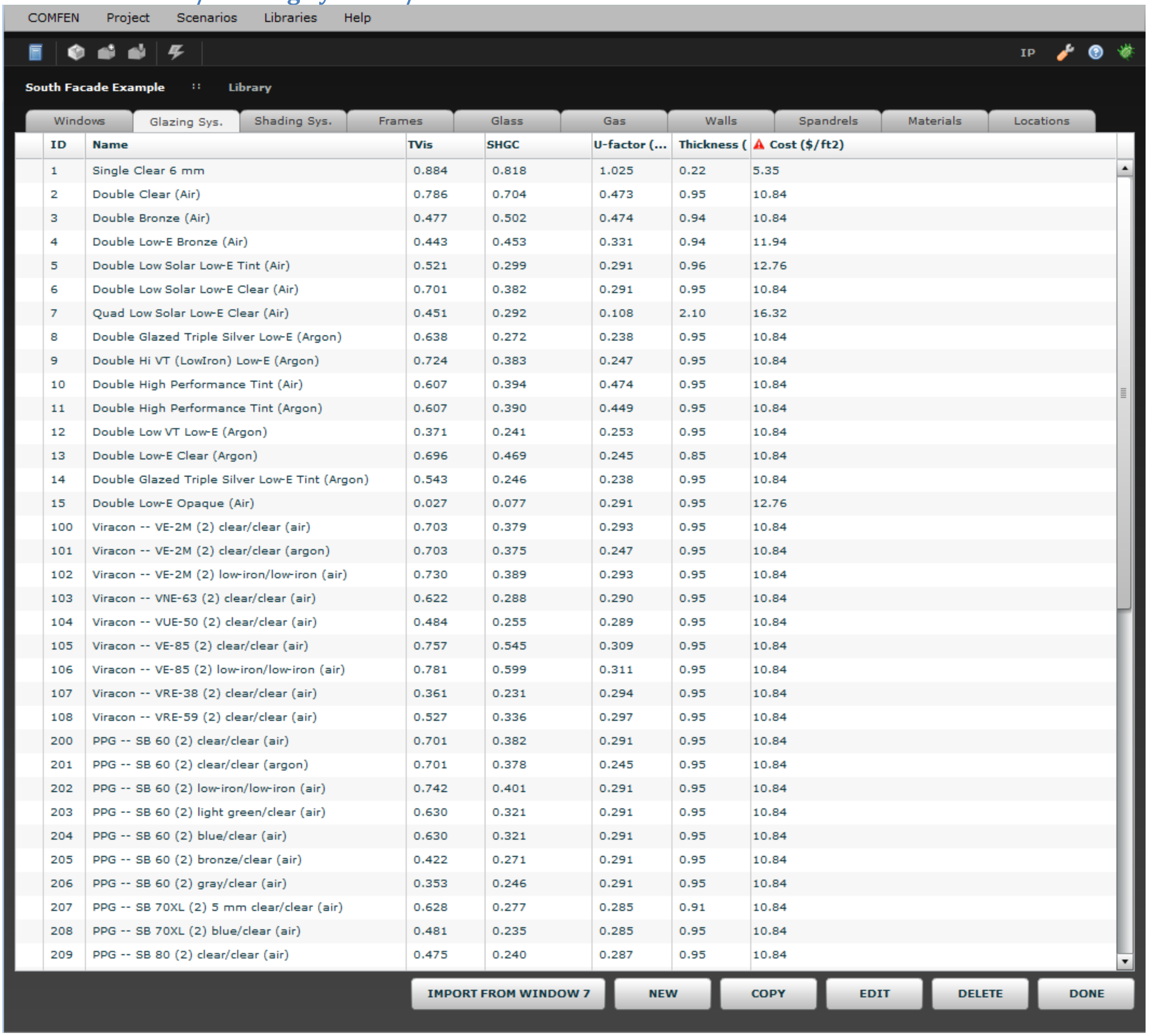
1.1.19 Libraries / Windows / List View



1.1.20 Libraries / Windows / Detail View

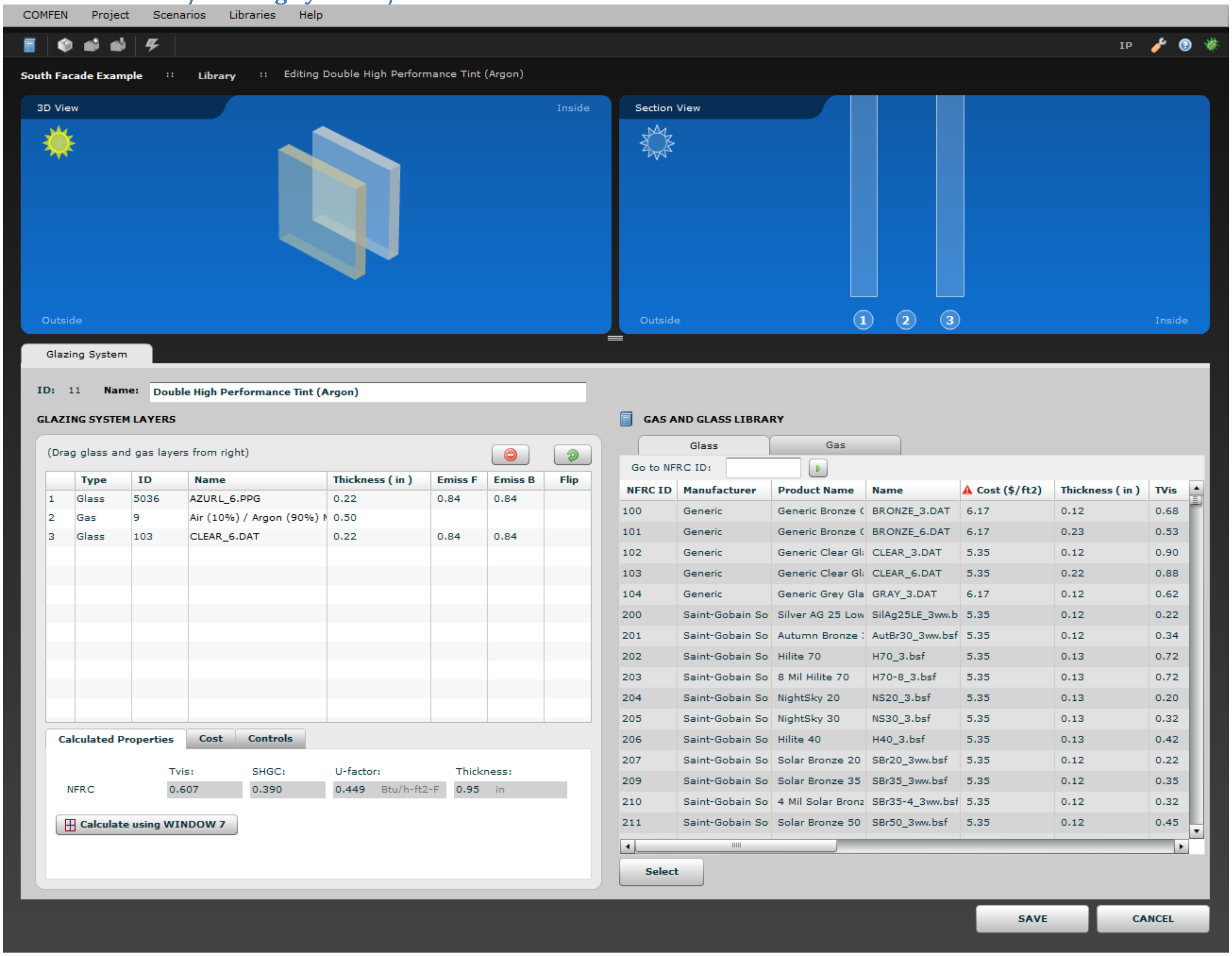


1.1.21 Libraries / Glazing Systems / List View

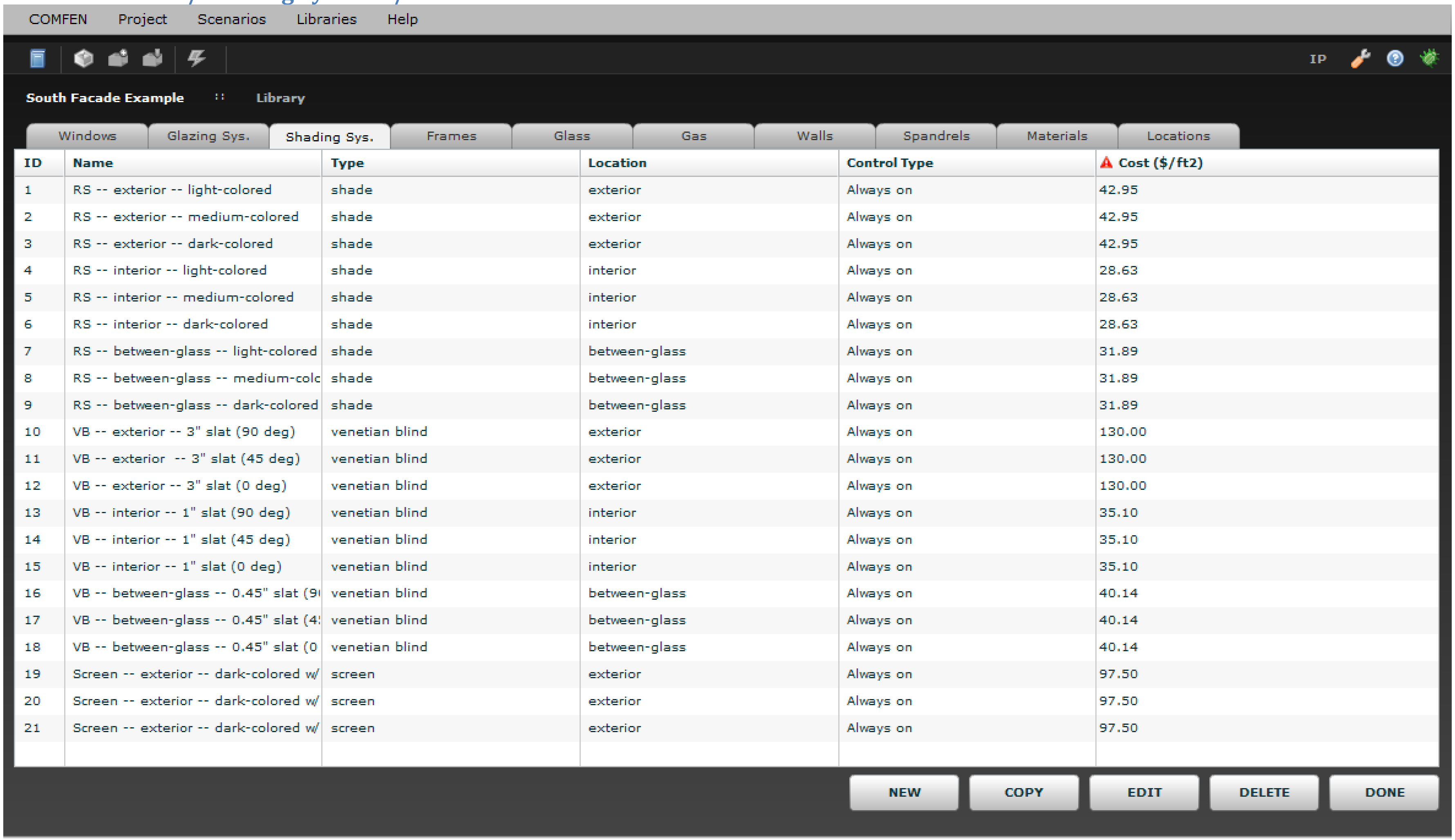


ID	Name	TVis	SHGC	U-factor (...	Thickness (	Cost ($/ft2)
1	Single Clear 6 mm	0.884	0.818	1.025	0.22	5.35
2	Double Clear (Air)	0.786	0.704	0.473	0.95	10.84
3	Double Bronze (Air)	0.477	0.502	0.474	0.94	10.84
4	Double Low-E Bronze (Air)	0.443	0.453	0.331	0.94	11.94
5	Double Low Solar Low-E Tint (Air)	0.521	0.299	0.291	0.96	12.76
6	Double Low Solar Low-E Clear (Air)	0.701	0.382	0.291	0.95	10.84
7	Quad Low Solar Low-E Clear (Air)	0.451	0.292	0.108	2.10	16.32
8	Double Glazed Triple Silver Low-E (Argon)	0.638	0.272	0.238	0.95	10.84
9	Double Hi VT (LowIron) Low-E (Argon)	0.724	0.383	0.247	0.95	10.84
10	Double High Performance Tint (Air)	0.607	0.394	0.474	0.95	10.84
11	Double High Performance Tint (Argon)	0.607	0.390	0.449	0.95	10.84
12	Double Low VT Low-E (Argon)	0.371	0.241	0.253	0.95	10.84
13	Double Low-E Clear (Argon)	0.696	0.469	0.245	0.85	10.84
14	Double Glazed Triple Silver Low-E Tint (Argon)	0.543	0.246	0.238	0.95	10.84
15	Double Low-E Opaque (Air)	0.027	0.077	0.291	0.95	12.76
100	Viracon -- VE-2M (2) clear/clear (air)	0.703	0.379	0.293	0.95	10.84
101	Viracon -- VE-2M (2) clear/clear (argon)	0.703	0.375	0.247	0.95	10.84
102	Viracon -- VE-2M (2) low-iron/low-iron (air)	0.730	0.389	0.293	0.95	10.84
103	Viracon -- VNE-63 (2) clear/clear (air)	0.622	0.288	0.290	0.95	10.84
104	Viracon -- VUE-50 (2) clear/clear (air)	0.484	0.255	0.289	0.95	10.84
105	Viracon -- VE-85 (2) clear/clear (air)	0.757	0.545	0.309	0.95	10.84
106	Viracon -- VE-85 (2) low-iron/low-iron (air)	0.781	0.599	0.311	0.95	10.84
107	Viracon -- VRE-38 (2) clear/clear (air)	0.361	0.231	0.294	0.95	10.84
108	Viracon -- VRE-59 (2) clear/clear (air)	0.527	0.336	0.297	0.95	10.84
200	PPG -- SB 60 (2) clear/clear (air)	0.701	0.382	0.291	0.95	10.84
201	PPG -- SB 60 (2) clear/clear (argon)	0.701	0.378	0.245	0.95	10.84
202	PPG -- SB 60 (2) low-iron/low-iron (air)	0.742	0.401	0.291	0.95	10.84
203	PPG -- SB 60 (2) light green/clear (air)	0.630	0.321	0.291	0.95	10.84
204	PPG -- SB 60 (2) blue/clear (air)	0.630	0.321	0.291	0.95	10.84
205	PPG -- SB 60 (2) bronze/clear (air)	0.422	0.271	0.291	0.95	10.84
206	PPG -- SB 60 (2) gray/clear (air)	0.353	0.246	0.291	0.95	10.84
207	PPG -- SB 70XL (2) 5 mm clear/clear (air)	0.628	0.277	0.285	0.91	10.84
208	PPG -- SB 70XL (2) blue/clear (air)	0.481	0.235	0.285	0.95	10.84
209	PPG -- SB 80 (2) clear/clear (air)	0.475	0.240	0.287	0.95	10.84

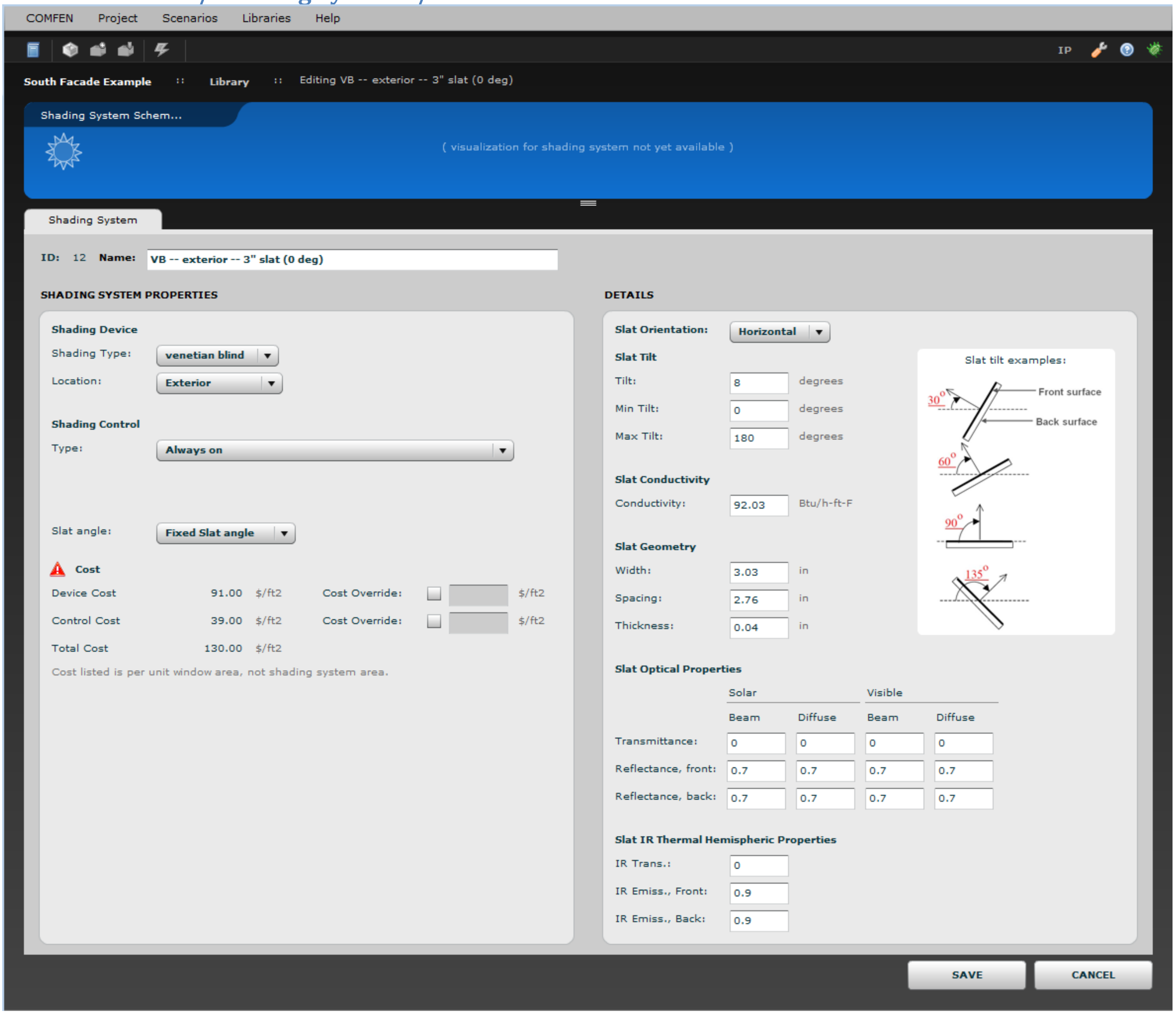
1.1.22 Libraries / Glazing Systems / Detail View



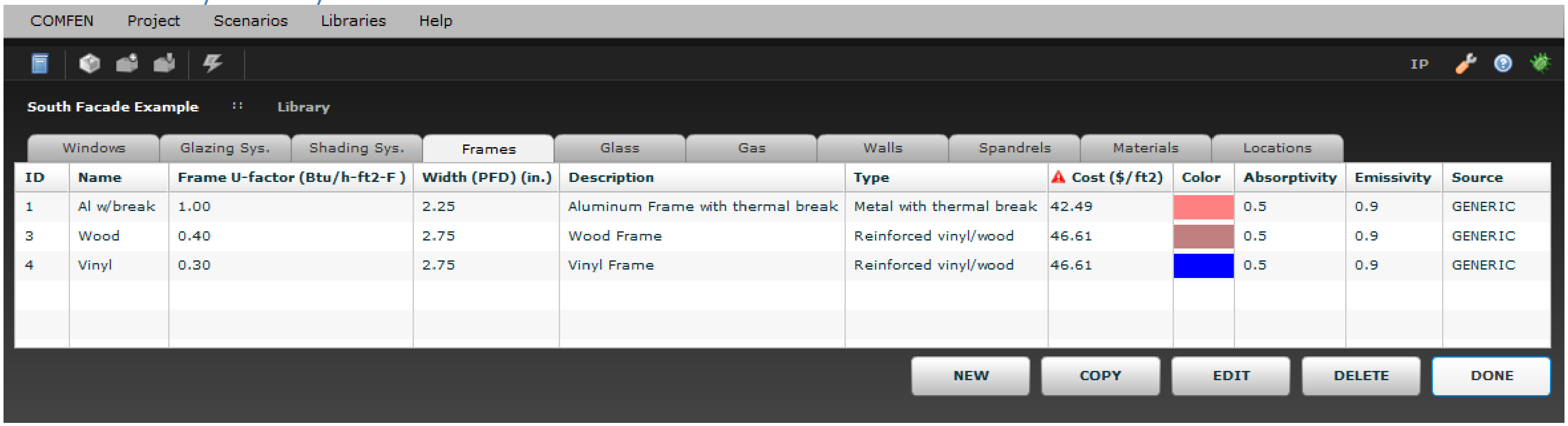
1.1.23 Libraries / Shading Systems / List View



1.1.24 Libraries / Shading Systems / Detail View

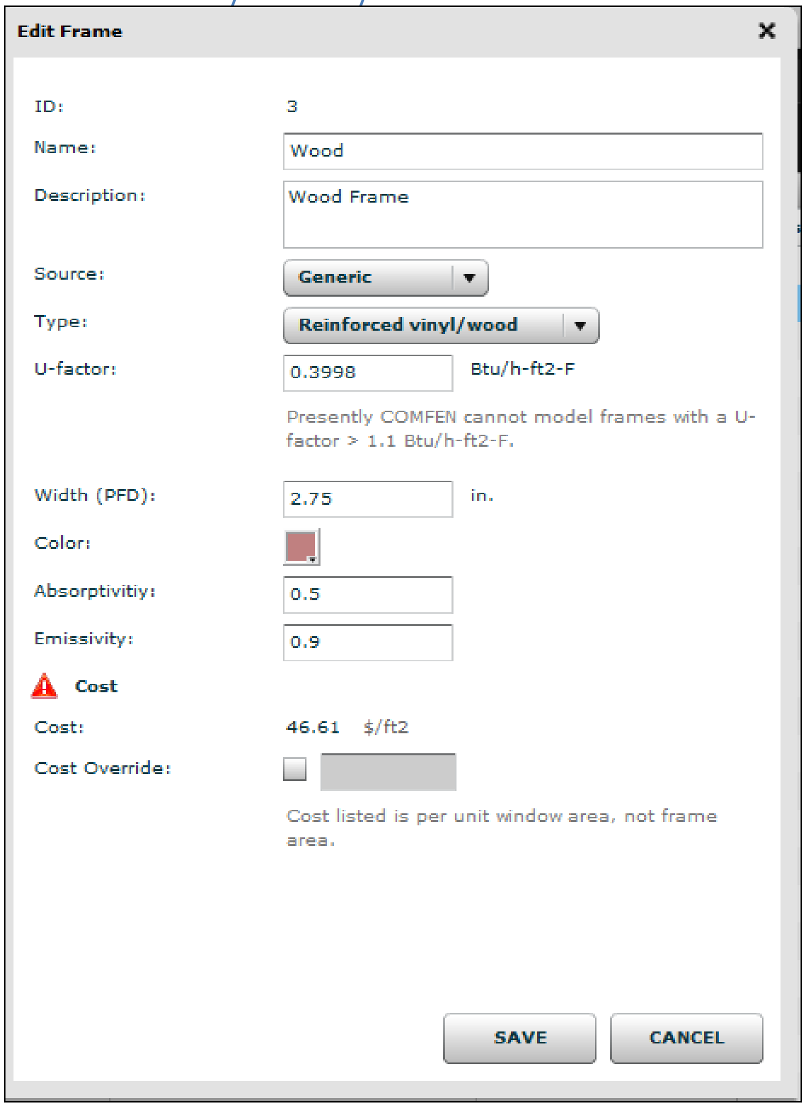


1.1.25 Libraries / Frames / List View

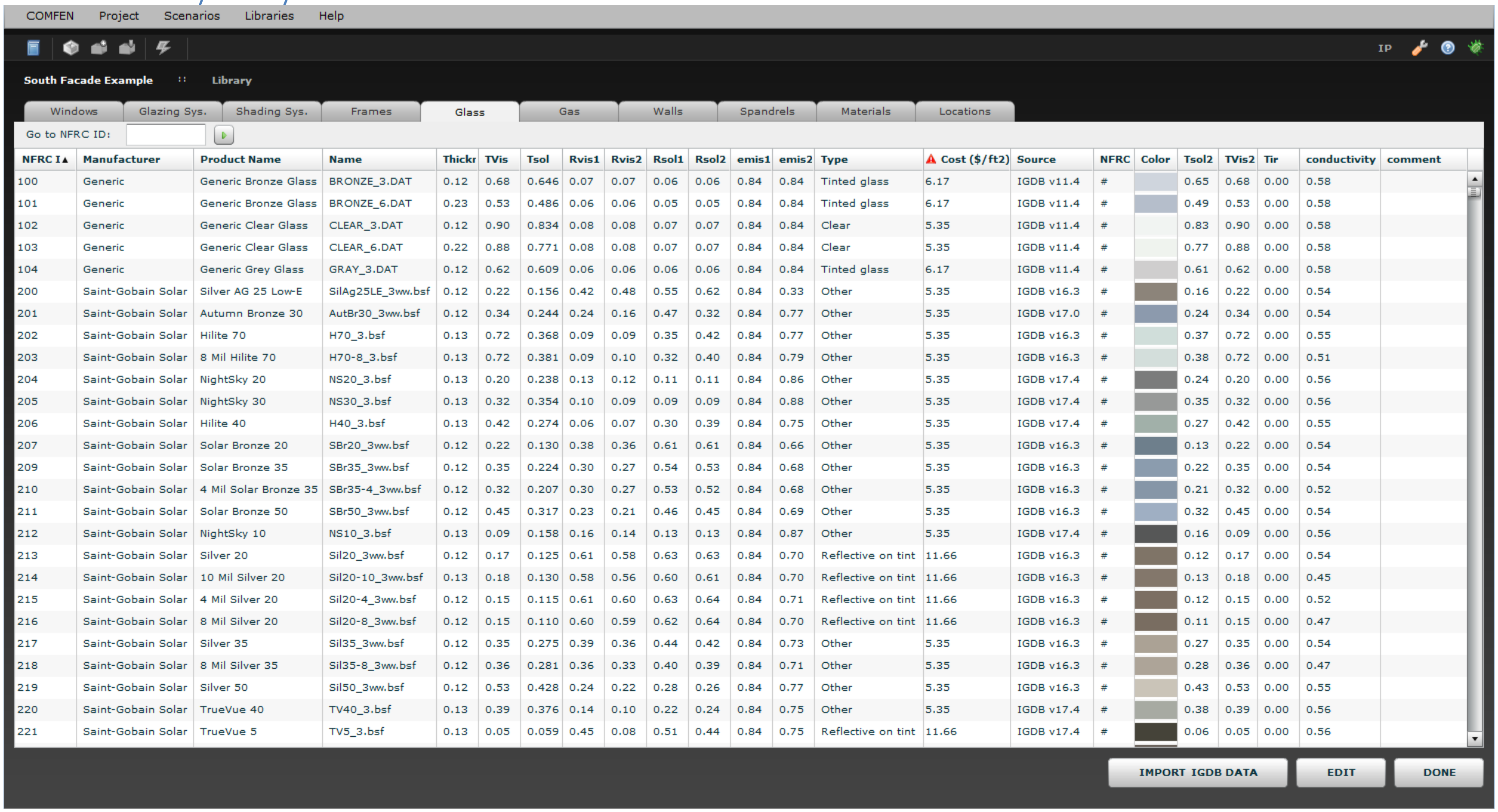


ID	Name	Frame U-factor (Btu/h-ft2-F)	Width (PFD) (in.)	Description	Type	Cost ($/ft2)	Color	Absorptivity	Emissivity	Source
1	Al w/break	1.00	2.25	Aluminum Frame with thermal break	Metal with thermal break	42.49		0.5	0.9	GENERIC
3	Wood	0.40	2.75	Wood Frame	Reinforced vinyl/wood	46.61		0.5	0.9	GENERIC
4	Vinyl	0.30	2.75	Vinyl Frame	Reinforced vinyl/wood	46.61		0.5	0.9	GENERIC

1.1.26 Libraries / Frames / Detail View

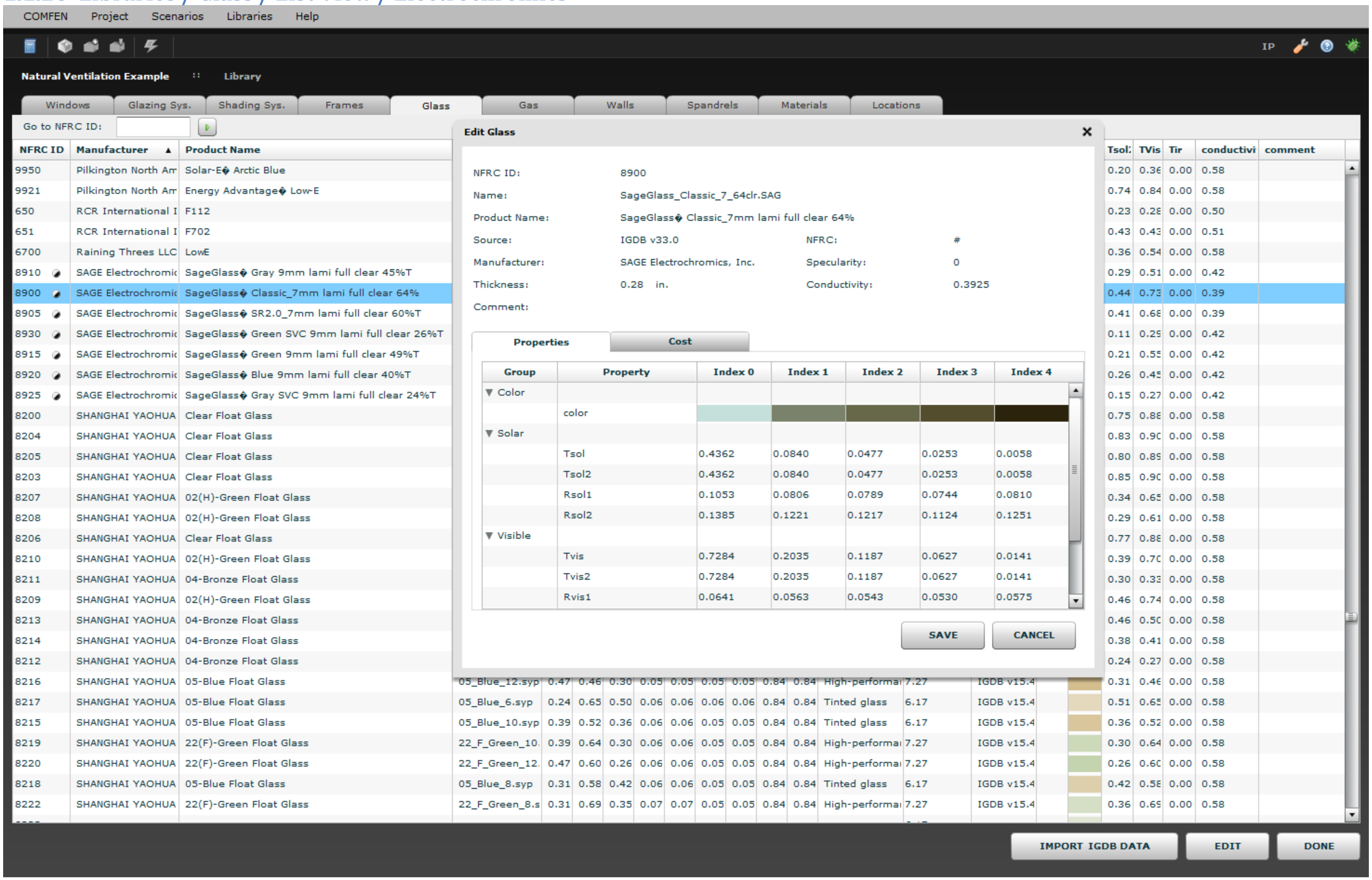


1.1.27 Libraries / Glass / List View

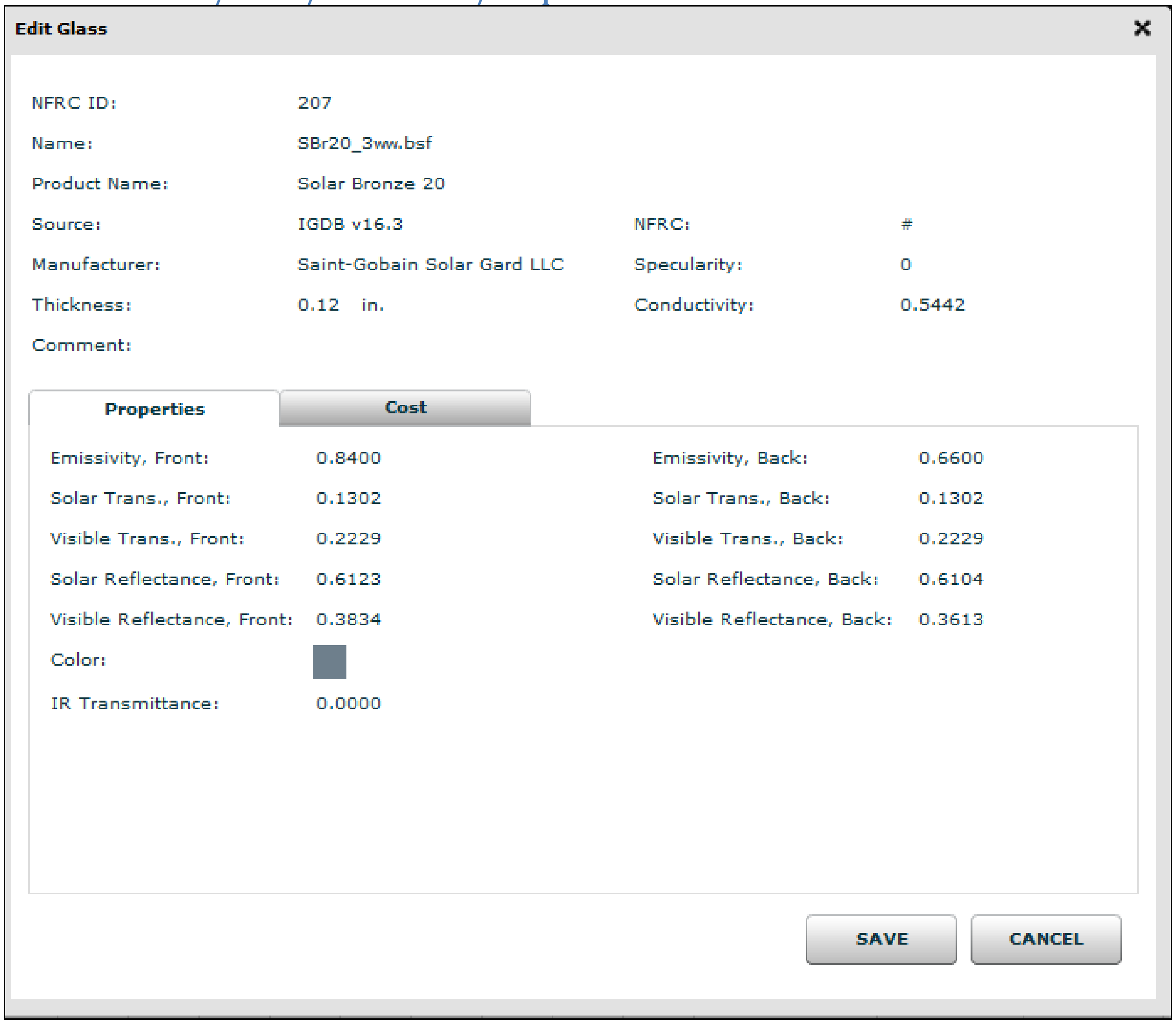


NFRC I▲	Manufacturer	Product Name	Name	Thickr	TVis	Tsol	Rvis1	Rvis2	Rsol1	Rsol2	emis1	emis2	Type	Cost ($/ft2)	Source	NFRC	Color	Tsol2	TVis2	Tir	conductivity	comment
100	Generic	Generic Bronze Glass	BRONZE_3.DAT	0.12	0.68	0.646	0.07	0.07	0.06	0.06	0.84	0.84	Tinted glass	6.17	IGDB v11.4	#		0.65	0.68	0.00	0.58	
101	Generic	Generic Bronze Glass	BRONZE_6.DAT	0.23	0.53	0.486	0.06	0.06	0.05	0.05	0.84	0.84	Tinted glass	6.17	IGDB v11.4	#		0.49	0.53	0.00	0.58	
102	Generic	Generic Clear Glass	CLEAR_3.DAT	0.12	0.90	0.834	0.08	0.08	0.07	0.07	0.84	0.84	Clear	5.35	IGDB v11.4	#		0.83	0.90	0.00	0.58	
103	Generic	Generic Clear Glass	CLEAR_6.DAT	0.22	0.88	0.771	0.08	0.08	0.07	0.07	0.84	0.84	Clear	5.35	IGDB v11.4	#		0.77	0.88	0.00	0.58	
104	Generic	Generic Grey Glass	GRAY_3.DAT	0.12	0.62	0.609	0.06	0.06	0.06	0.06	0.84	0.84	Tinted glass	6.17	IGDB v11.4	#		0.61	0.62	0.00	0.58	
200	Saint-Gobain Solar	Silver AG 25 Low-E	SilAg25LE_3ww.bsf	0.12	0.22	0.156	0.42	0.48	0.55	0.62	0.84	0.33	Other	5.35	IGDB v16.3	#		0.16	0.22	0.00	0.54	
201	Saint-Gobain Solar	Autumn Bronze 30	AutBr30_3ww.bsf	0.12	0.34	0.244	0.24	0.16	0.47	0.32	0.84	0.77	Other	5.35	IGDB v17.0	#		0.24	0.34	0.00	0.54	
202	Saint-Gobain Solar	Hilite 70	H70_3.bsf	0.13	0.72	0.368	0.09	0.09	0.35	0.42	0.84	0.77	Other	5.35	IGDB v16.3	#		0.37	0.72	0.00	0.55	
203	Saint-Gobain Solar	8 Mil Hilite 70	H70-8_3.bsf	0.13	0.72	0.381	0.09	0.10	0.32	0.40	0.84	0.79	Other	5.35	IGDB v16.3	#		0.38	0.72	0.00	0.51	
204	Saint-Gobain Solar	NightSky 20	NS20_3.bsf	0.13	0.20	0.238	0.13	0.12	0.11	0.11	0.84	0.86	Other	5.35	IGDB v17.4	#		0.24	0.20	0.00	0.56	
205	Saint-Gobain Solar	NightSky 30	NS30_3.bsf	0.13	0.32	0.354	0.10	0.09	0.09	0.09	0.84	0.88	Other	5.35	IGDB v17.4	#		0.35	0.32	0.00	0.56	
206	Saint-Gobain Solar	Hilite 40	H40_3.bsf	0.13	0.42	0.274	0.06	0.07	0.30	0.39	0.84	0.75	Other	5.35	IGDB v17.4	#		0.27	0.42	0.00	0.55	
207	Saint-Gobain Solar	Solar Bronze 20	SBr20_3ww.bsf	0.12	0.22	0.130	0.38	0.36	0.61	0.61	0.84	0.66	Other	5.35	IGDB v16.3	#		0.13	0.22	0.00	0.54	
209	Saint-Gobain Solar	Solar Bronze 35	SBr35_3ww.bsf	0.12	0.35	0.224	0.30	0.27	0.54	0.53	0.84	0.68	Other	5.35	IGDB v16.3	#		0.22	0.35	0.00	0.54	
210	Saint-Gobain Solar	4 Mil Solar Bronze 35	SBr35-4_3ww.bsf	0.12	0.32	0.207	0.30	0.27	0.53	0.52	0.84	0.68	Other	5.35	IGDB v16.3	#		0.21	0.32	0.00	0.52	
211	Saint-Gobain Solar	Solar Bronze 50	SBr50_3ww.bsf	0.12	0.45	0.317	0.23	0.21	0.46	0.45	0.84	0.69	Other	5.35	IGDB v16.3	#		0.32	0.45	0.00	0.54	
212	Saint-Gobain Solar	NightSky 10	NS10_3.bsf	0.13	0.09	0.158	0.16	0.14	0.13	0.13	0.84	0.87	Other	5.35	IGDB v17.4	#		0.16	0.09	0.00	0.56	
213	Saint-Gobain Solar	Silver 20	Sil20_3ww.bsf	0.12	0.17	0.125	0.61	0.58	0.63	0.63	0.84	0.70	Reflective on tint	11.66	IGDB v16.3	#		0.12	0.17	0.00	0.54	
214	Saint-Gobain Solar	10 Mil Silver 20	Sil20-10_3ww.bsf	0.13	0.18	0.130	0.58	0.56	0.60	0.61	0.84	0.70	Reflective on tint	11.66	IGDB v16.3	#		0.13	0.18	0.00	0.45	
215	Saint-Gobain Solar	4 Mil Silver 20	Sil20-4_3ww.bsf	0.12	0.15	0.115	0.61	0.60	0.63	0.64	0.84	0.71	Reflective on tint	11.66	IGDB v16.3	#		0.12	0.15	0.00	0.52	
216	Saint-Gobain Solar	8 Mil Silver 20	Sil20-8_3ww.bsf	0.12	0.15	0.110	0.60	0.59	0.62	0.64	0.84	0.70	Reflective on tint	11.66	IGDB v16.3	#		0.11	0.15	0.00	0.47	
217	Saint-Gobain Solar	Silver 35	Sil35_3ww.bsf	0.12	0.35	0.275	0.39	0.36	0.44	0.42	0.84	0.73	Other	5.35	IGDB v16.3	#		0.27	0.35	0.00	0.54	
218	Saint-Gobain Solar	8 Mil Silver 35	Sil35-8_3ww.bsf	0.12	0.36	0.281	0.36	0.33	0.40	0.39	0.84	0.71	Other	5.35	IGDB v16.3	#		0.28	0.36	0.00	0.47	
219	Saint-Gobain Solar	Silver 50	Sil50_3ww.bsf	0.12	0.53	0.428	0.24	0.22	0.28	0.26	0.84	0.77	Other	5.35	IGDB v16.3	#		0.43	0.53	0.00	0.55	
220	Saint-Gobain Solar	TrueVue 40	TV40_3.bsf	0.13	0.39	0.376	0.14	0.10	0.22	0.24	0.84	0.75	Other	5.35	IGDB v17.4	#		0.38	0.39	0.00	0.56	
221	Saint-Gobain Solar	TrueVue 5	TV5_3.bsf	0.13	0.05	0.059	0.45	0.08	0.51	0.44	0.84	0.75	Reflective on tint	11.66	IGDB v17.4	#		0.06	0.05	0.00	0.56	

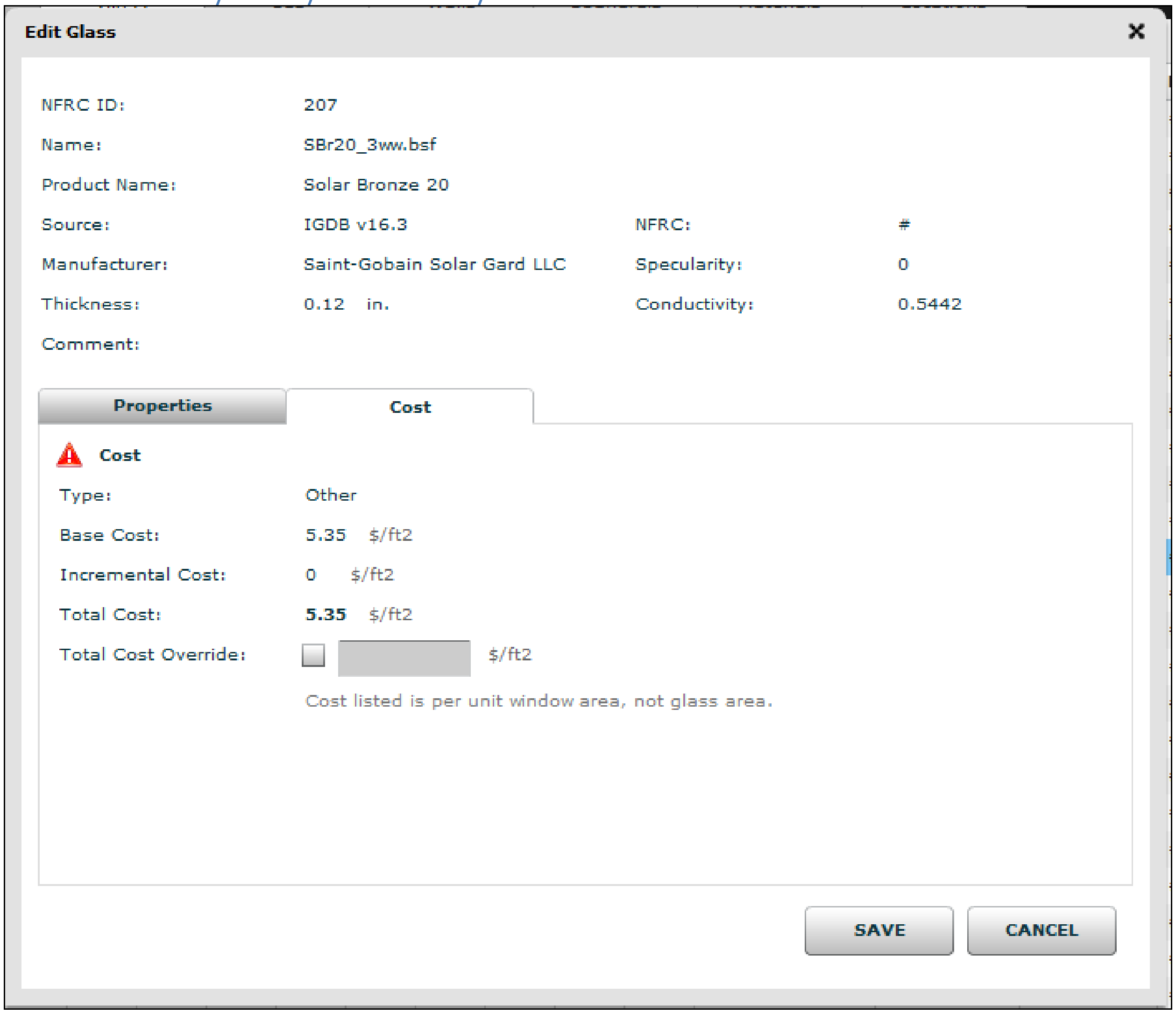
1.1.28 Libraries / Glass / List View / Electrochromics



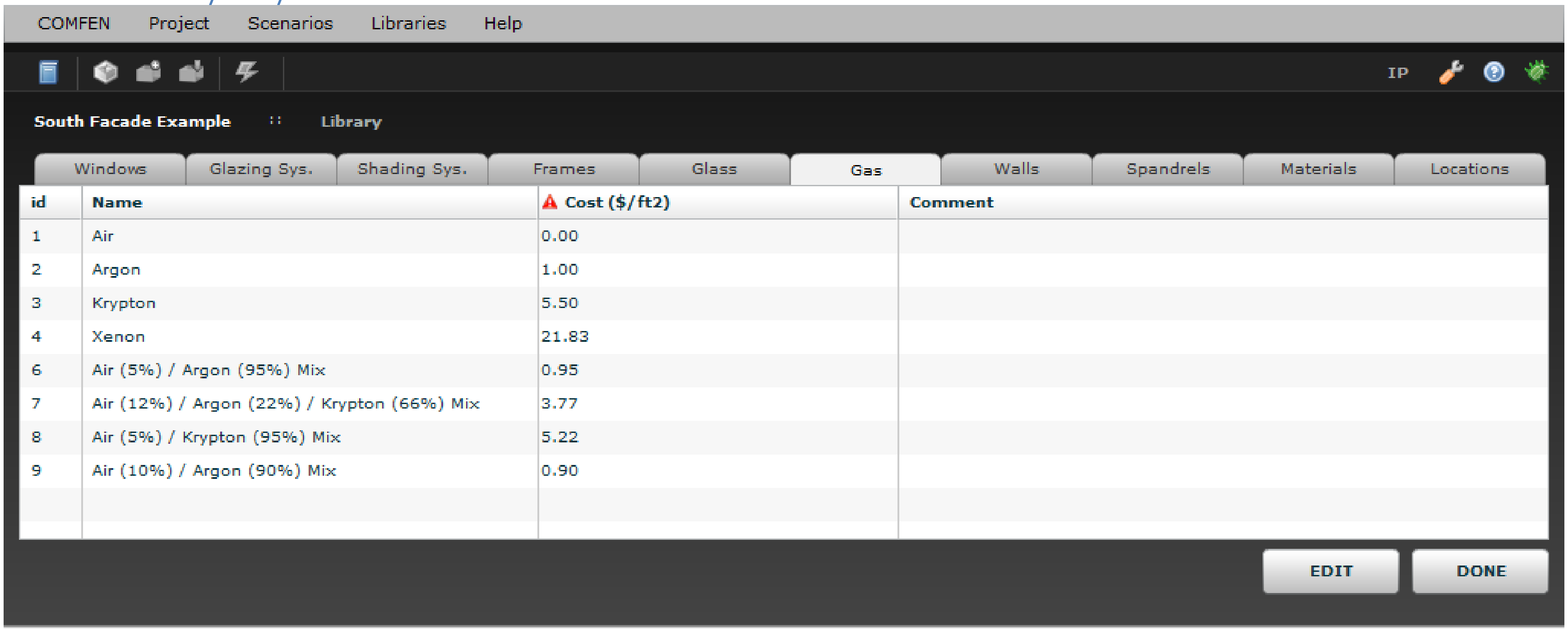
1.1.29 Libraries / Glass / Detail View / Properties



1.1.30 Libraries / Glass / Detail View / Cost

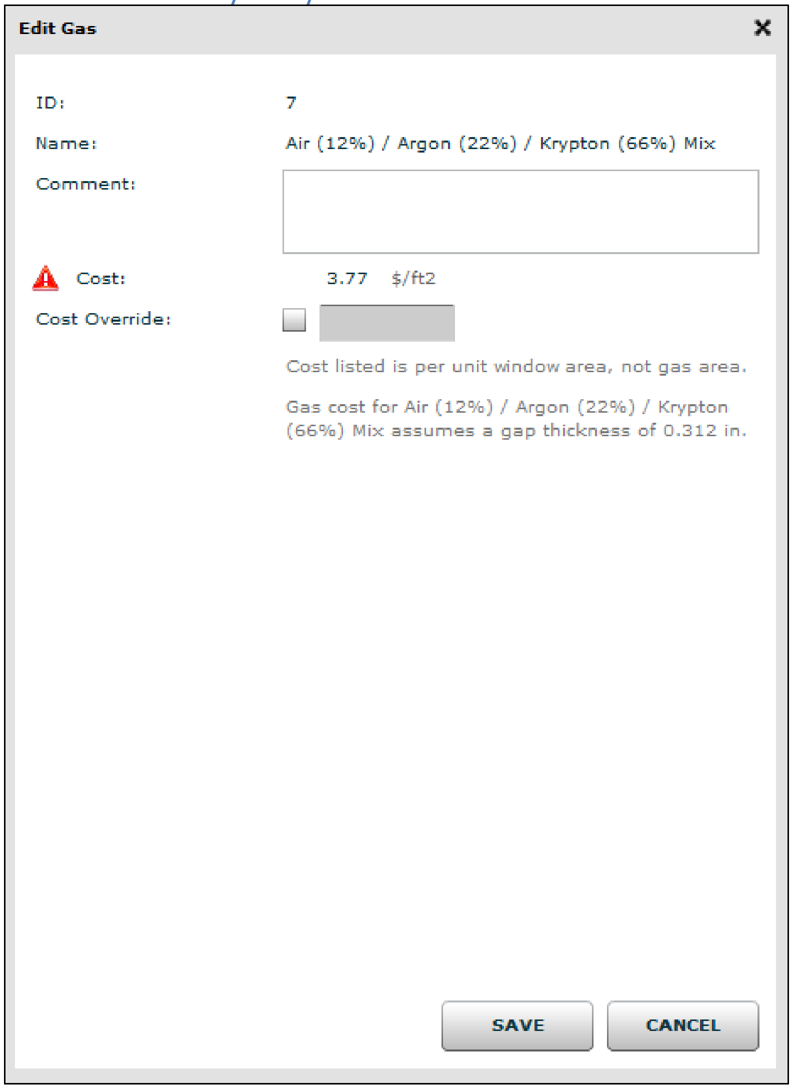


1.1.31 Libraries / Gas / List View

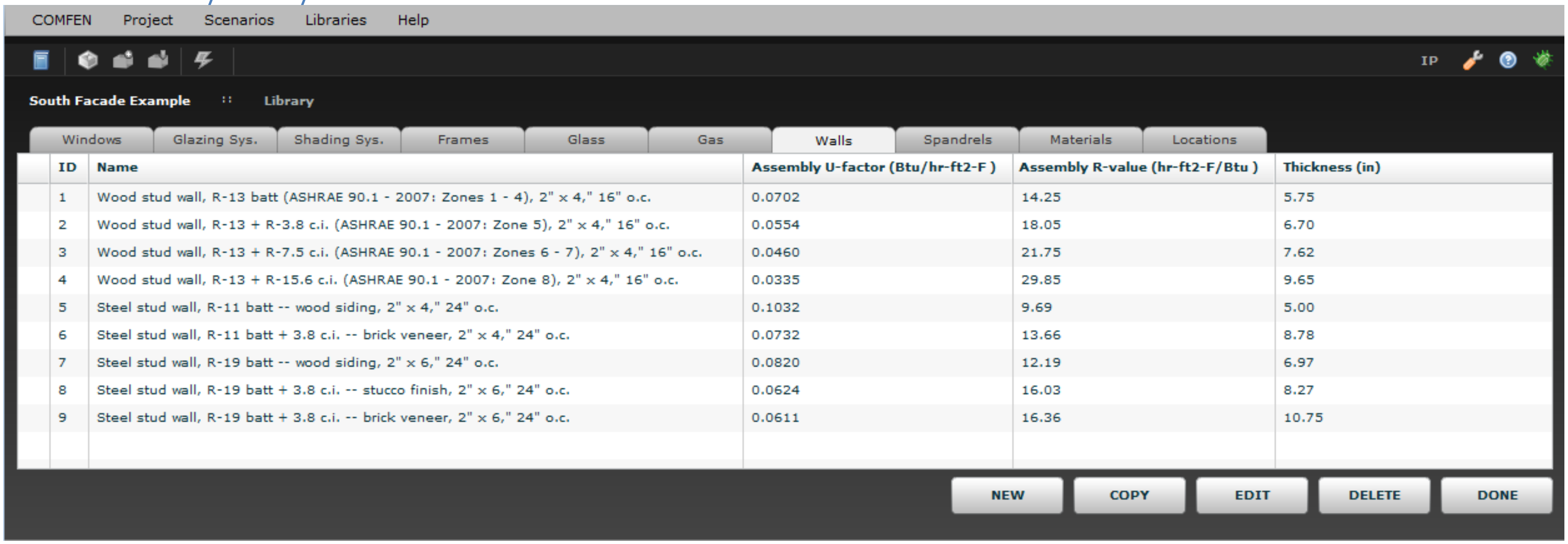


id	Name	Cost ($/ft2)	Comment
1	Air	0.00	
2	Argon	1.00	
3	Krypton	5.50	
4	Xenon	21.83	
6	Air (5%) / Argon (95%) Mix	0.95	
7	Air (12%) / Argon (22%) / Krypton (66%) Mix	3.77	
8	Air (5%) / Krypton (95%) Mix	5.22	
9	Air (10%) / Argon (90%) Mix	0.90	

1.1.32 Libraries / Gas / Detail View

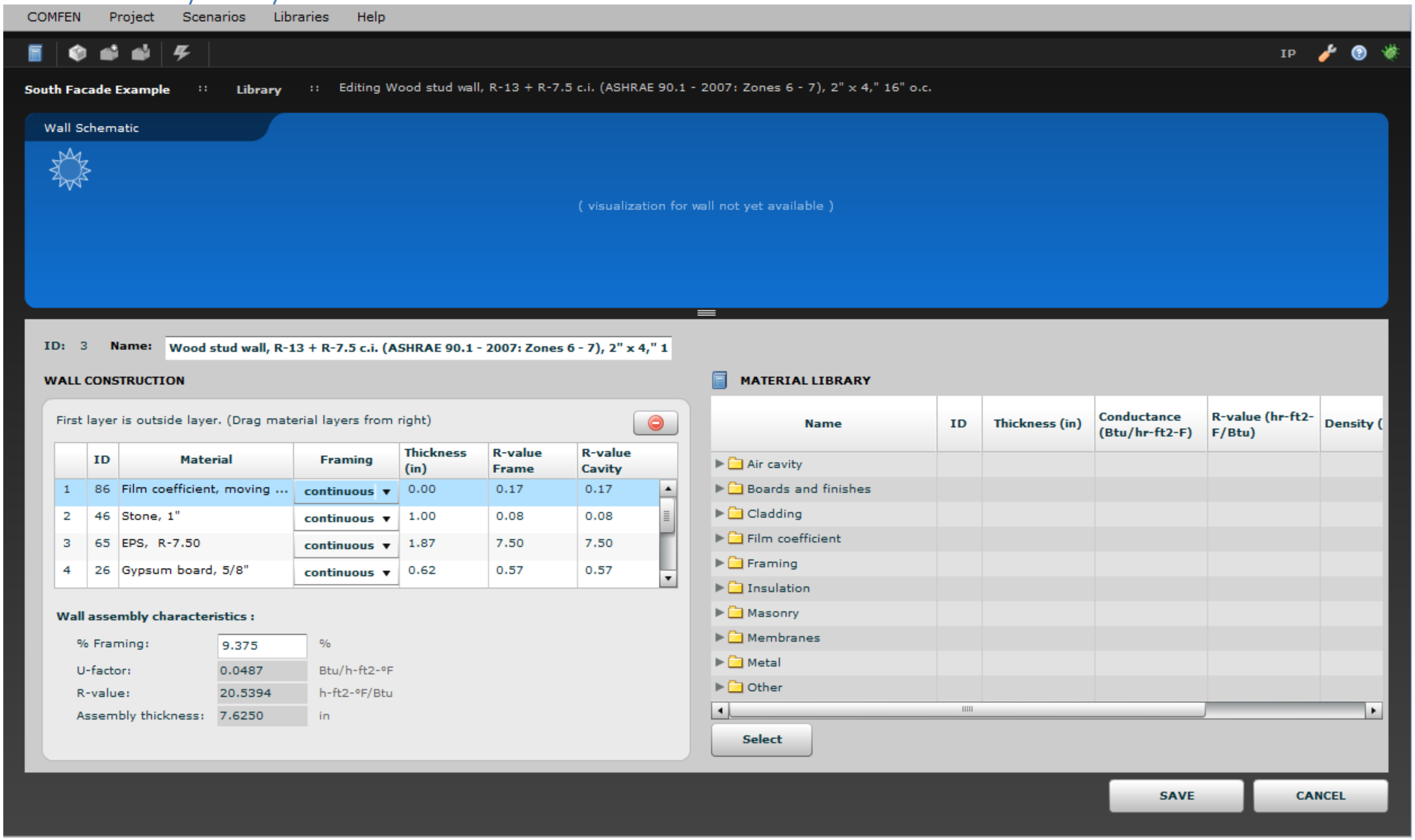


1.1.33 Libraries / Walls / List View

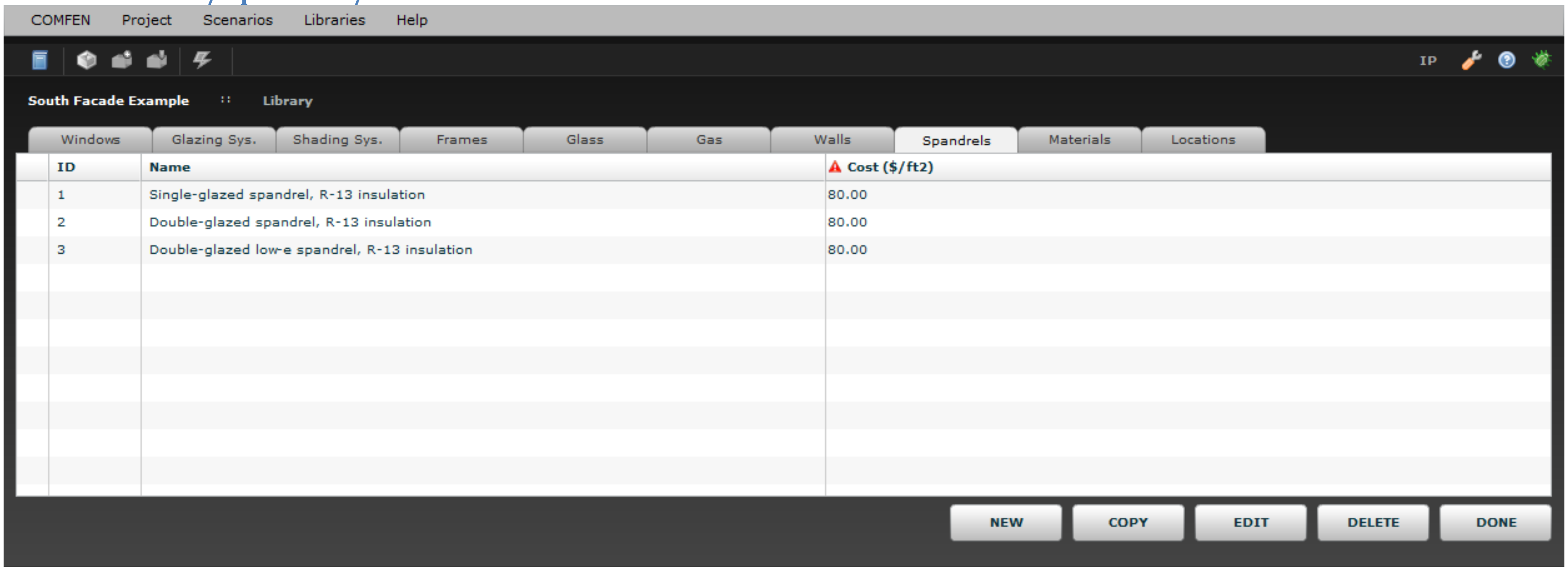


ID	Name	Assembly U-factor (Btu/hr-ft2-F)	Assembly R-value (hr-ft2-F/Btu)	Thickness (in)
1	Wood stud wall, R-13 batt (ASHRAE 90.1 - 2007: Zones 1 - 4), 2" x 4," 16" o.c.	0.0702	14.25	5.75
2	Wood stud wall, R-13 + R-3.8 c.i. (ASHRAE 90.1 - 2007: Zone 5), 2" x 4," 16" o.c.	0.0554	18.05	6.70
3	Wood stud 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	7.62
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	9.65
5	Steel stud wall, R-11 batt -- wood siding, 2" x 4," 24" o.c.	0.1032	9.69	5.00
6	Steel stud wall, R-11 batt + 3.8 c.i. -- brick veneer, 2" x 4," 24" o.c.	0.0732	13.66	8.78
7	Steel stud wall, R-19 batt -- wood siding, 2" x 6," 24" o.c.	0.0820	12.19	6.97
8	Steel stud wall, R-19 batt + 3.8 c.i. -- stucco finish, 2" x 6," 24" o.c.	0.0624	16.03	8.27
9	Steel stud wall, R-19 batt + 3.8 c.i. -- brick veneer, 2" x 6," 24" o.c.	0.0611	16.36	10.75

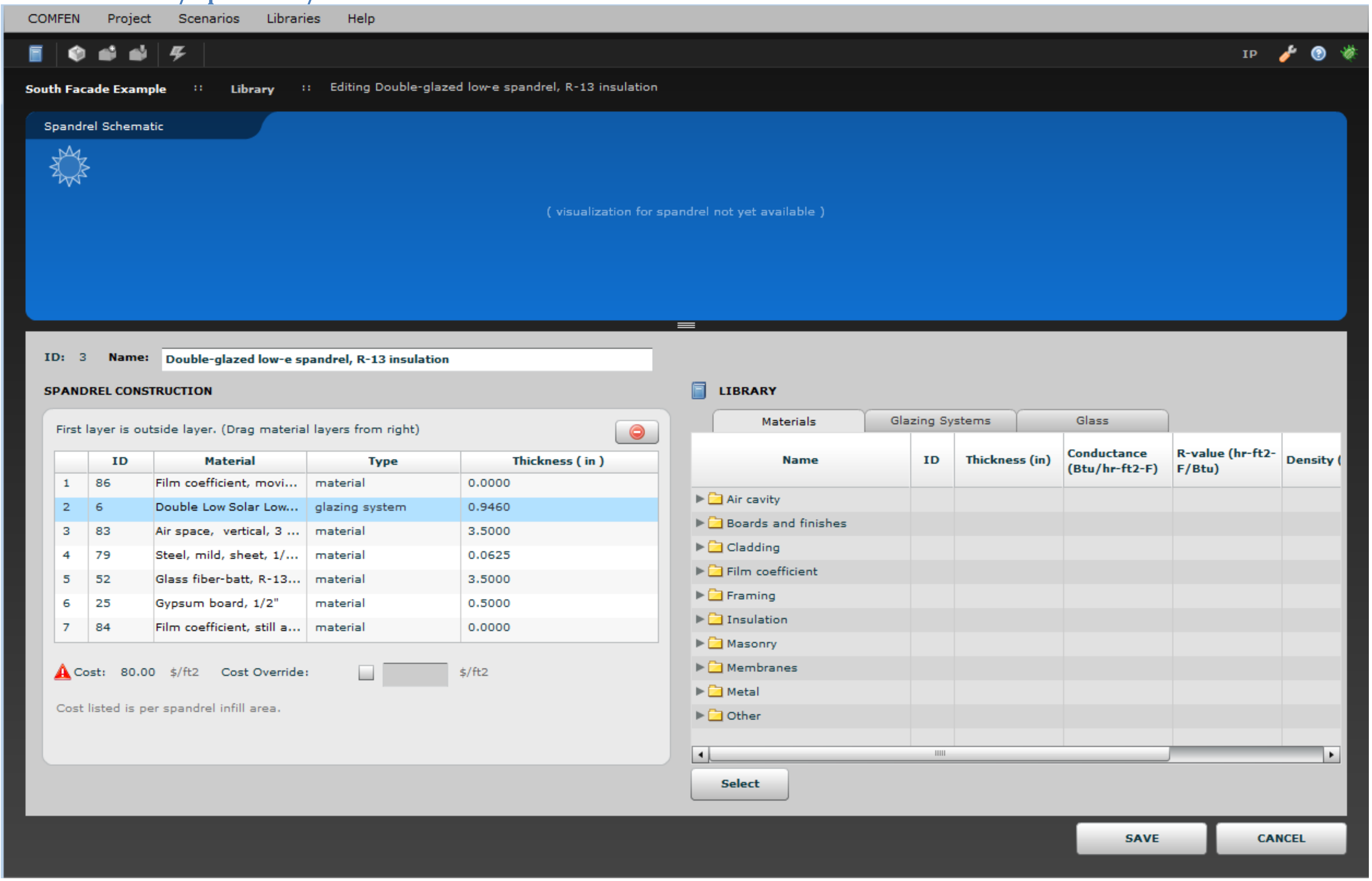
1.1.34 Libraries / Walls / Detail View



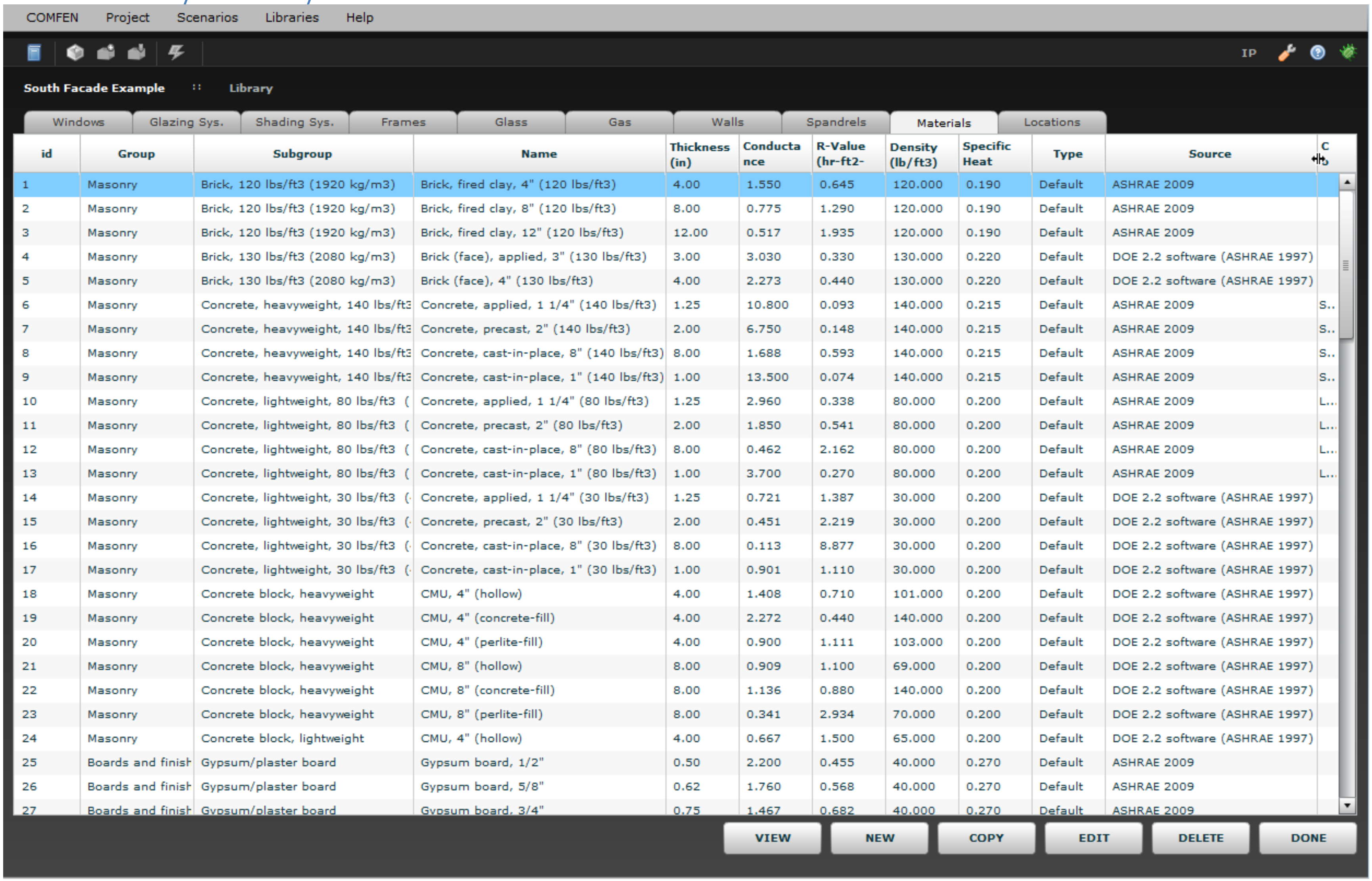
1.1.35 Libraries / Spandrels / List View



1.1.36 Libraries / Spandrels / Detail View

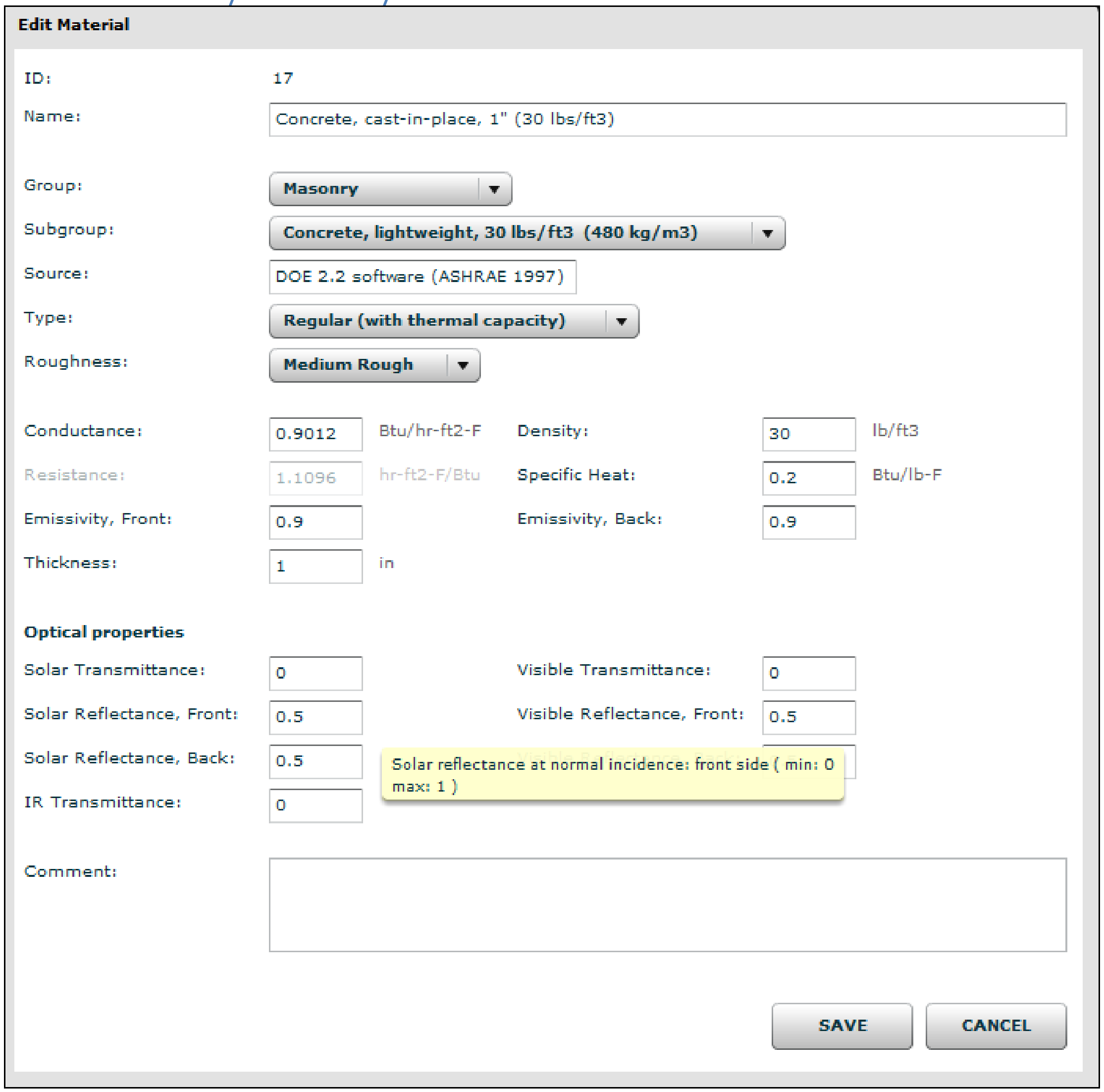


1.1.37 Libraries / Materials / List View

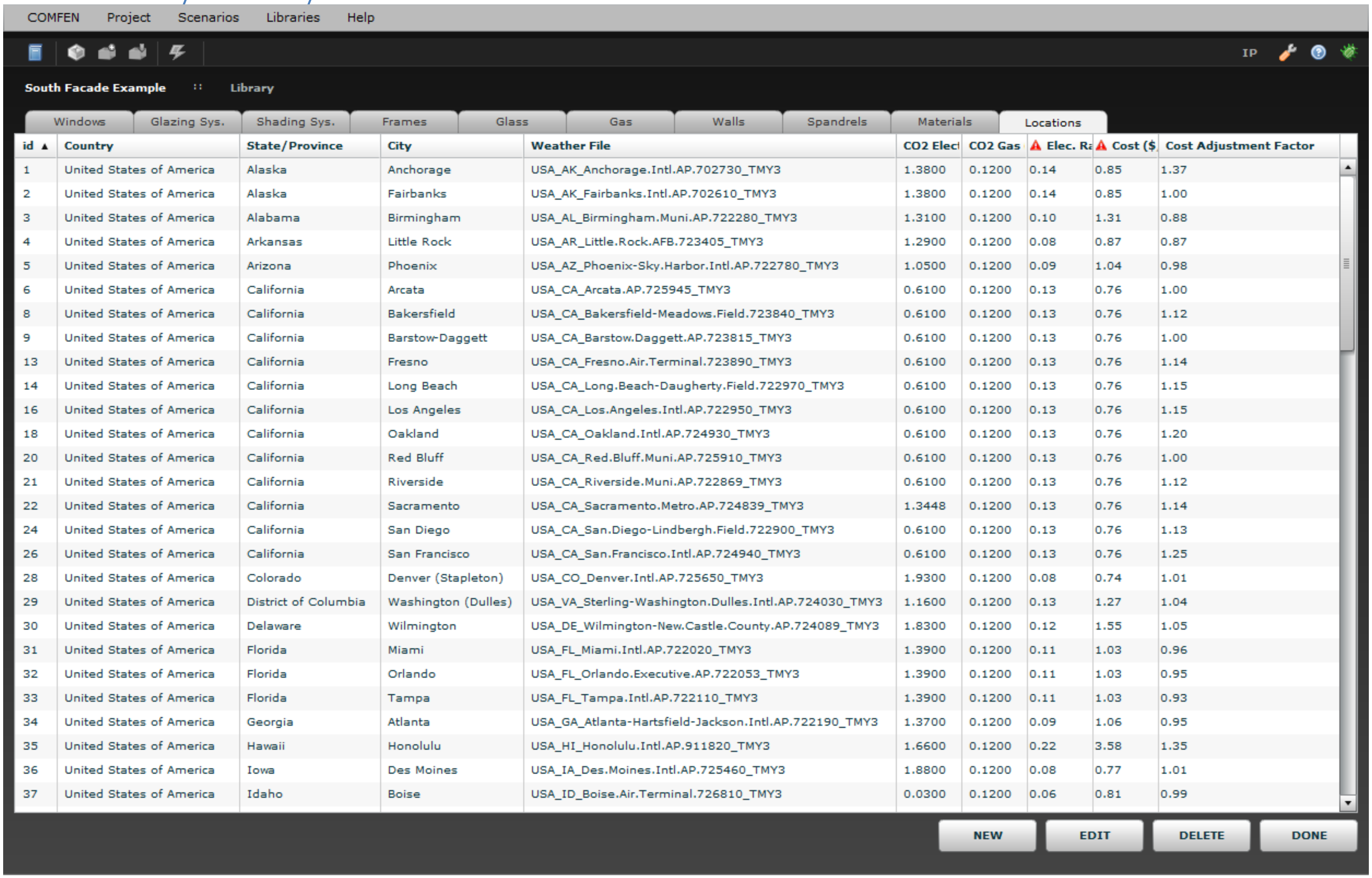


id	Group	Subgroup	Name	Thickness (in)	Conductance	R-Value (hr-ft2-	Density (lb/ft3)	Specific Heat	Type	Source	C
1	Masonry	Brick, 120 lbs/ft3 (1920 kg/m3)	Brick, fired clay, 4" (120 lbs/ft3)	4.00	1.550	0.645	120.000	0.190	Default	ASHRAE 2009	
2	Masonry	Brick, 120 lbs/ft3 (1920 kg/m3)	Brick, fired clay, 8" (120 lbs/ft3)	8.00	0.775	1.290	120.000	0.190	Default	ASHRAE 2009	
3	Masonry	Brick, 120 lbs/ft3 (1920 kg/m3)	Brick, fired clay, 12" (120 lbs/ft3)	12.00	0.517	1.935	120.000	0.190	Default	ASHRAE 2009	
4	Masonry	Brick, 130 lbs/ft3 (2080 kg/m3)	Brick (face), applied, 3" (130 lbs/ft3)	3.00	3.030	0.330	130.000	0.220	Default	DOE 2.2 software (ASHRAE 1997)	
5	Masonry	Brick, 130 lbs/ft3 (2080 kg/m3)	Brick (face), 4" (130 lbs/ft3)	4.00	2.273	0.440	130.000	0.220	Default	DOE 2.2 software (ASHRAE 1997)	
6	Masonry	Concrete, heavyweight, 140 lbs/ft3	Concrete, applied, 1 1/4" (140 lbs/ft3)	1.25	10.800	0.093	140.000	0.215	Default	ASHRAE 2009	S..
7	Masonry	Concrete, heavyweight, 140 lbs/ft3	Concrete, precast, 2" (140 lbs/ft3)	2.00	6.750	0.148	140.000	0.215	Default	ASHRAE 2009	S..
8	Masonry	Concrete, heavyweight, 140 lbs/ft3	Concrete, cast-in-place, 8" (140 lbs/ft3)	8.00	1.688	0.593	140.000	0.215	Default	ASHRAE 2009	S..
9	Masonry	Concrete, heavyweight, 140 lbs/ft3	Concrete, cast-in-place, 1" (140 lbs/ft3)	1.00	13.500	0.074	140.000	0.215	Default	ASHRAE 2009	S..
10	Masonry	Concrete, lightweight, 80 lbs/ft3 (	Concrete, applied, 1 1/4" (80 lbs/ft3)	1.25	2.960	0.338	80.000	0.200	Default	ASHRAE 2009	L...
11	Masonry	Concrete, lightweight, 80 lbs/ft3 (	Concrete, precast, 2" (80 lbs/ft3)	2.00	1.850	0.541	80.000	0.200	Default	ASHRAE 2009	L...
12	Masonry	Concrete, lightweight, 80 lbs/ft3 (	Concrete, cast-in-place, 8" (80 lbs/ft3)	8.00	0.462	2.162	80.000	0.200	Default	ASHRAE 2009	L...
13	Masonry	Concrete, lightweight, 80 lbs/ft3 (	Concrete, cast-in-place, 1" (80 lbs/ft3)	1.00	3.700	0.270	80.000	0.200	Default	ASHRAE 2009	L...
14	Masonry	Concrete, lightweight, 30 lbs/ft3 (	Concrete, applied, 1 1/4" (30 lbs/ft3)	1.25	0.721	1.387	30.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
15	Masonry	Concrete, lightweight, 30 lbs/ft3 (	Concrete, precast, 2" (30 lbs/ft3)	2.00	0.451	2.219	30.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
16	Masonry	Concrete, lightweight, 30 lbs/ft3 (	Concrete, cast-in-place, 8" (30 lbs/ft3)	8.00	0.113	8.877	30.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
17	Masonry	Concrete, lightweight, 30 lbs/ft3 (	Concrete, cast-in-place, 1" (30 lbs/ft3)	1.00	0.901	1.110	30.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
18	Masonry	Concrete block, heavyweight	CMU, 4" (hollow)	4.00	1.408	0.710	101.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
19	Masonry	Concrete block, heavyweight	CMU, 4" (concrete-fill)	4.00	2.272	0.440	140.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
20	Masonry	Concrete block, heavyweight	CMU, 4" (perlite-fill)	4.00	0.900	1.111	103.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
21	Masonry	Concrete block, heavyweight	CMU, 8" (hollow)	8.00	0.909	1.100	69.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
22	Masonry	Concrete block, heavyweight	CMU, 8" (concrete-fill)	8.00	1.136	0.880	140.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
23	Masonry	Concrete block, heavyweight	CMU, 8" (perlite-fill)	8.00	0.341	2.934	70.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
24	Masonry	Concrete block, lightweight	CMU, 4" (hollow)	4.00	0.667	1.500	65.000	0.200	Default	DOE 2.2 software (ASHRAE 1997)	
25	Boards and finish	Gypsum/plaster board	Gypsum board, 1/2"	0.50	2.200	0.455	40.000	0.270	Default	ASHRAE 2009	
26	Boards and finish	Gypsum/plaster board	Gypsum board, 5/8"	0.62	1.760	0.568	40.000	0.270	Default	ASHRAE 2009	
27	Boards and finish	Gypsum/plaster board	Gypsum board, 3/4"	0.75	1.467	0.682	40.000	0.270	Default	ASHRAE 2009	

1.1.38 Libraries / Materials / Detail View

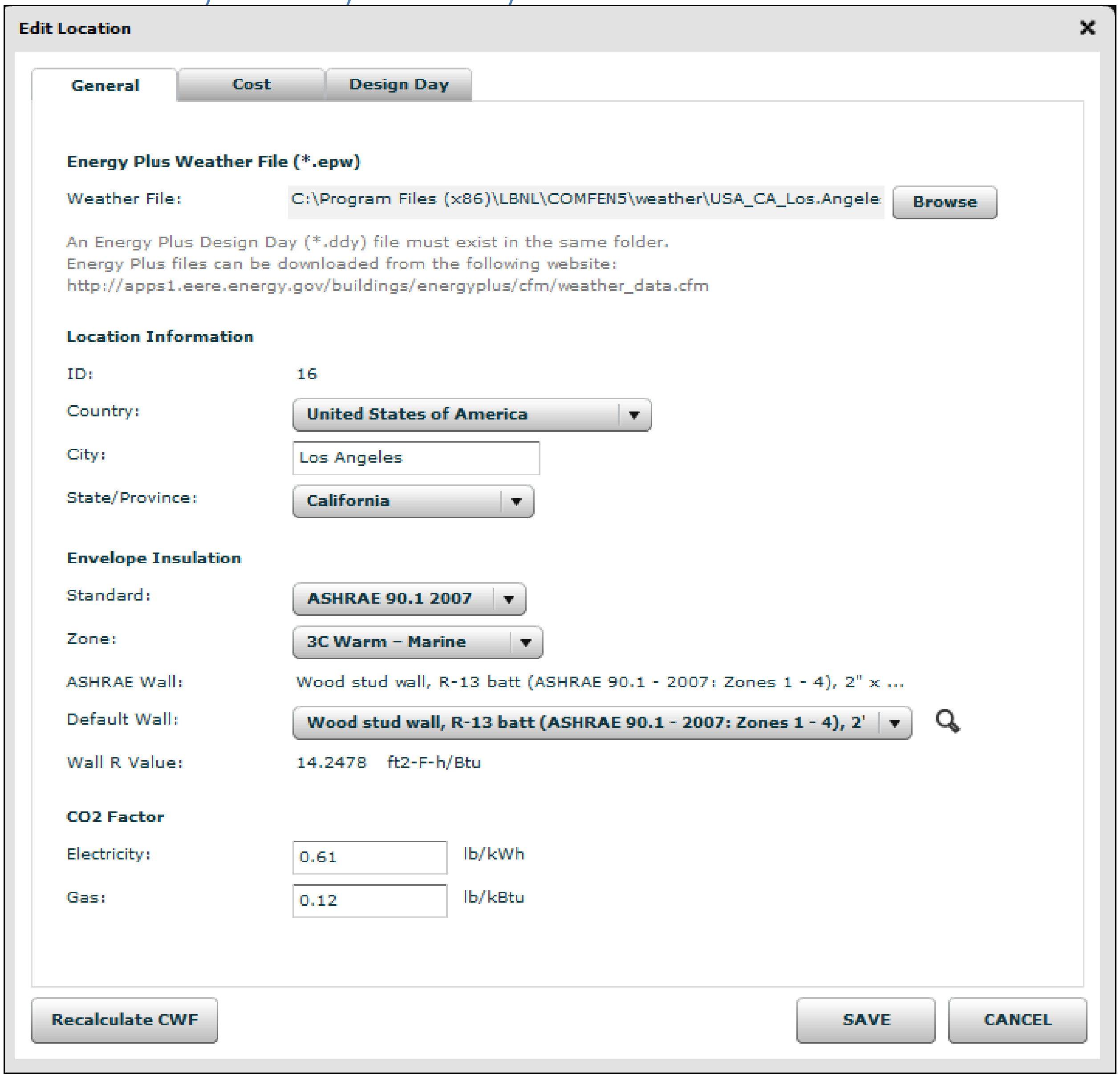


1.1.39 Libraries / Locations / List View

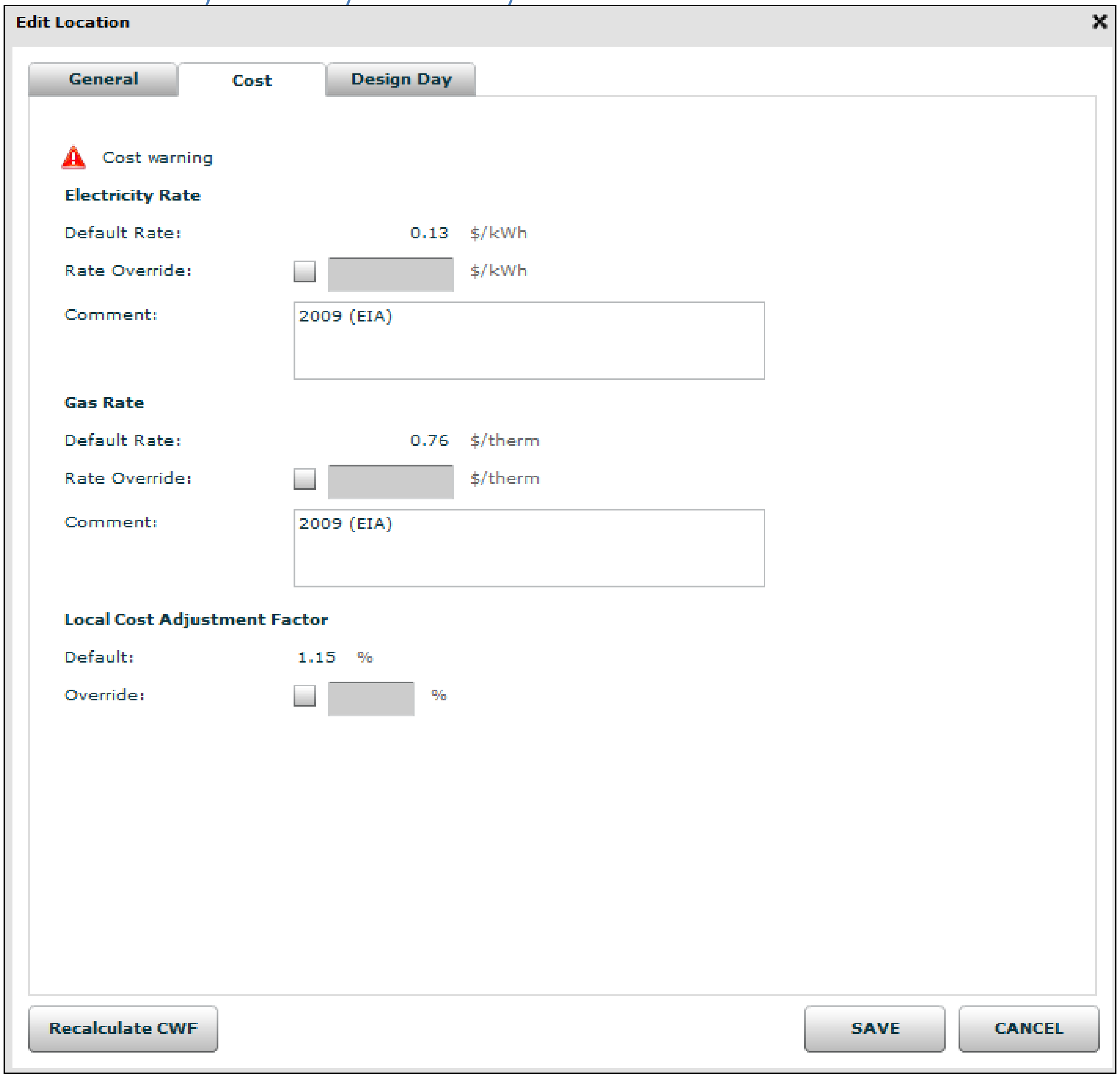


id ▲	Country	State/Province	City	Weather File	CO2 Elect	CO2 Gas	Elec. Ra	Cost ($	Cost Adjustment Factor
1	United States of America	Alaska	Anchorage	USA_AK_Anchorage.Intl.AP.702730_TMY3	1.3800	0.1200	0.14	0.85	1.37
2	United States of America	Alaska	Fairbanks	USA_AK_Fairbanks.Intl.AP.702610_TMY3	1.3800	0.1200	0.14	0.85	1.00
3	United States of America	Alabama	Birmingham	USA_AL_Birmingham.Muni.AP.722280_TMY3	1.3100	0.1200	0.10	1.31	0.88
4	United States of America	Arkansas	Little Rock	USA_AR_Little.Rock.AFB.723405_TMY3	1.2900	0.1200	0.08	0.87	0.87
5	United States of America	Arizona	Phoenix	USA_AZ_Phoenix-Sky.Harbor.Intl.AP.722780_TMY3	1.0500	0.1200	0.09	1.04	0.98
6	United States of America	California	Arcata	USA_CA_Arcata.AP.725945_TMY3	0.6100	0.1200	0.13	0.76	1.00
8	United States of America	California	Bakersfield	USA_CA_Bakersfield-Meadows.Field.723840_TMY3	0.6100	0.1200	0.13	0.76	1.12
9	United States of America	California	Barstow-Daggett	USA_CA_Barstow.Daggett.AP.723815_TMY3	0.6100	0.1200	0.13	0.76	1.00
13	United States of America	California	Fresno	USA_CA_Fresno.Air.Terminal.723890_TMY3	0.6100	0.1200	0.13	0.76	1.14
14	United States of America	California	Long Beach	USA_CA_Long.Beach-Daugherty.Field.722970_TMY3	0.6100	0.1200	0.13	0.76	1.15
16	United States of America	California	Los Angeles	USA_CA_Los.Angeles.Intl.AP.722950_TMY3	0.6100	0.1200	0.13	0.76	1.15
18	United States of America	California	Oakland	USA_CA_Oakland.Intl.AP.724930_TMY3	0.6100	0.1200	0.13	0.76	1.20
20	United States of America	California	Red Bluff	USA_CA_Red.Bluff.Muni.AP.725910_TMY3	0.6100	0.1200	0.13	0.76	1.00
21	United States of America	California	Riverside	USA_CA_Riverside.Muni.AP.722869_TMY3	0.6100	0.1200	0.13	0.76	1.12
22	United States of America	California	Sacramento	USA_CA_Sacramento.Metro.AP.724839_TMY3	1.3448	0.1200	0.13	0.76	1.14
24	United States of America	California	San Diego	USA_CA_San.Diego-Lindbergh.Field.722900_TMY3	0.6100	0.1200	0.13	0.76	1.13
26	United States of America	California	San Francisco	USA_CA_San.Francisco.Intl.AP.724940_TMY3	0.6100	0.1200	0.13	0.76	1.25
28	United States of America	Colorado	Denver (Stapleton)	USA_CO_Denver.Intl.AP.725650_TMY3	1.9300	0.1200	0.08	0.74	1.01
29	United States of America	District of Columbia	Washington (Dulles)	USA_VA_Sterling-Washington.Dulles.Intl.AP.724030_TMY3	1.1600	0.1200	0.13	1.27	1.04
30	United States of America	Delaware	Wilmington	USA_DE_Wilmington-New.Castle.County.AP.724089_TMY3	1.8300	0.1200	0.12	1.55	1.05
31	United States of America	Florida	Miami	USA_FL_Miami.Intl.AP.722020_TMY3	1.3900	0.1200	0.11	1.03	0.96
32	United States of America	Florida	Orlando	USA_FL_Orlando.Executive.AP.722053_TMY3	1.3900	0.1200	0.11	1.03	0.95
33	United States of America	Florida	Tampa	USA_FL_Tampa.Intl.AP.722110_TMY3	1.3900	0.1200	0.11	1.03	0.93
34	United States of America	Georgia	Atlanta	USA_GA_Atlanta-Hartsfield-Jackson.Intl.AP.722190_TMY3	1.3700	0.1200	0.09	1.06	0.95
35	United States of America	Hawaii	Honolulu	USA_HI_Honolulu.Intl.AP.911820_TMY3	1.6600	0.1200	0.22	3.58	1.35
36	United States of America	Iowa	Des Moines	USA_IA_Des.Moines.Intl.AP.725460_TMY3	1.8800	0.1200	0.08	0.77	1.01
37	United States of America	Idaho	Boise	USA_ID_Boise.Air.Terminal.726810_TMY3	0.0300	0.1200	0.06	0.81	0.99

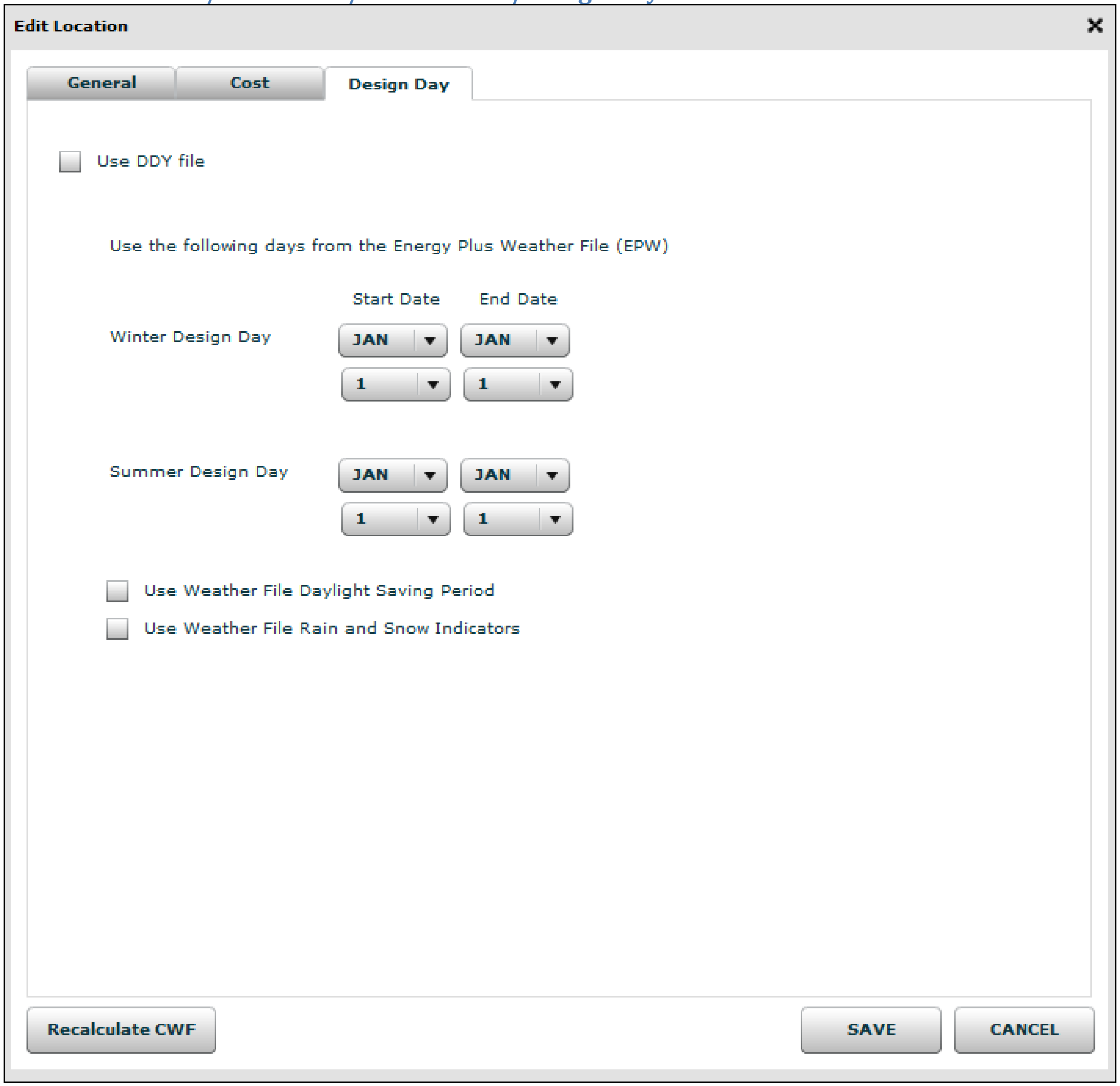
1.1.40 Libraries / Locations / Detail View /General



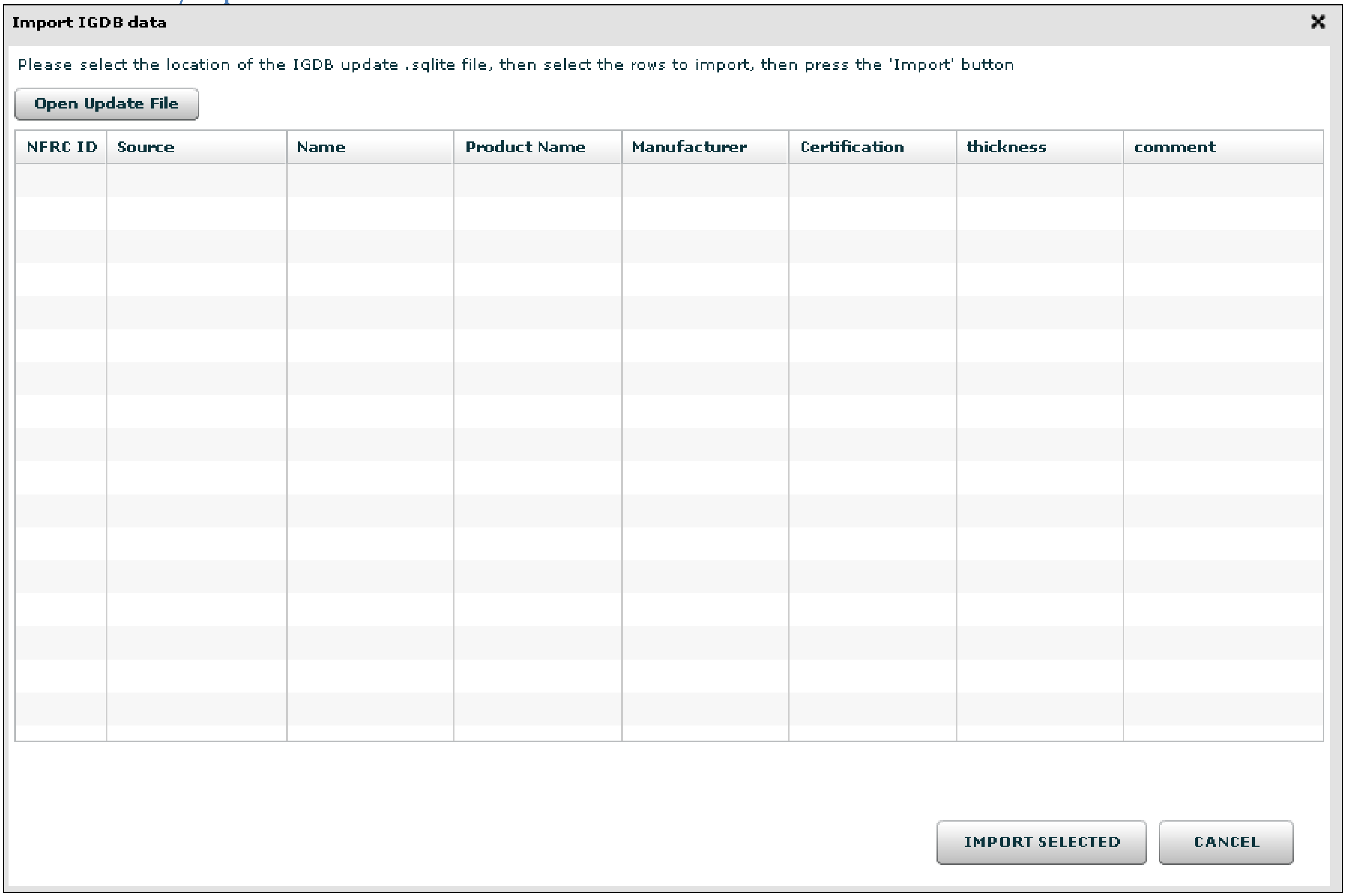
1.1.41 Libraries / Locations / Detail View /Cost



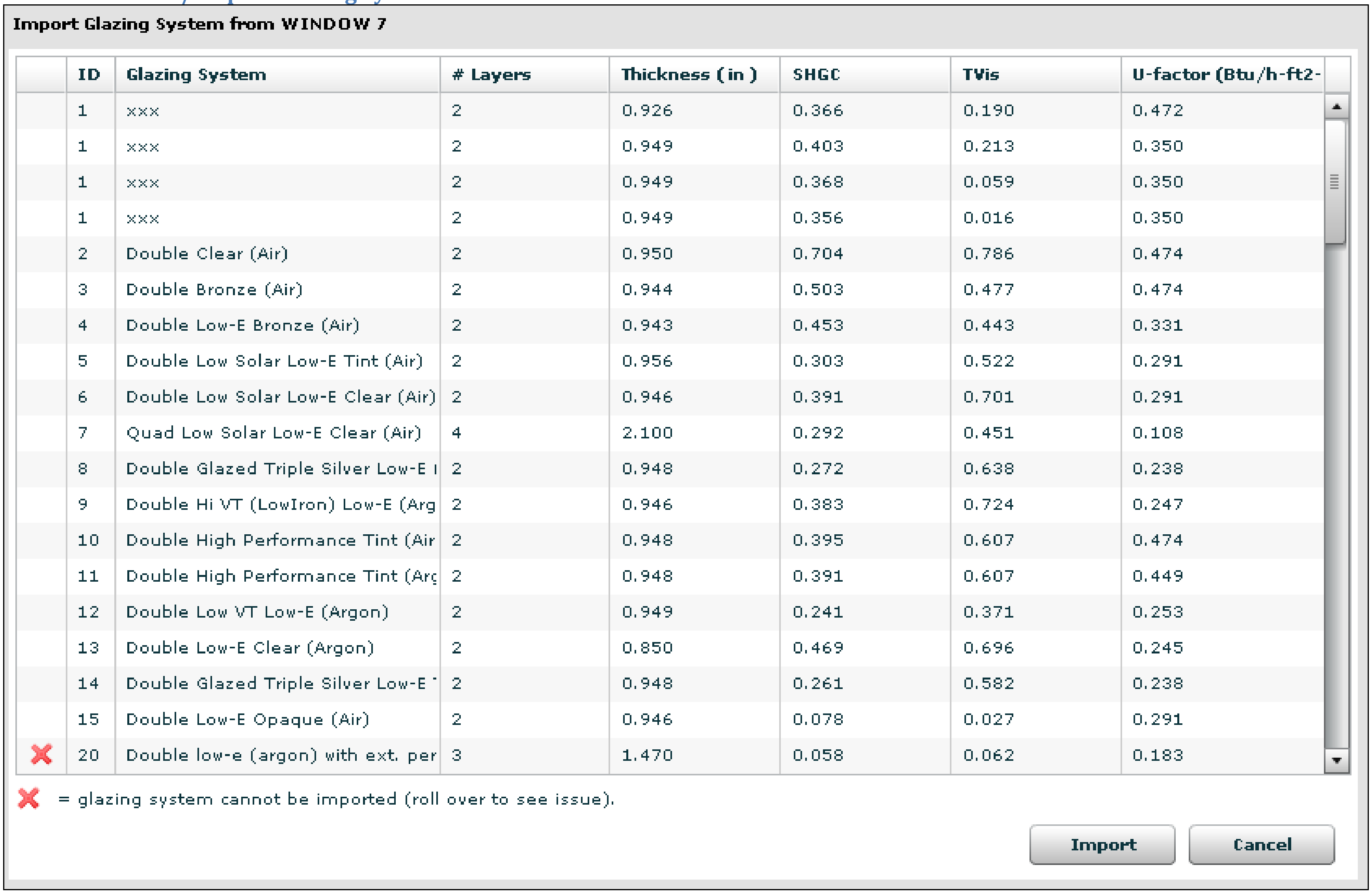
1.1.42 Libraries / Locations / Detail View /Design Day



1.1.43 Libraries / Import IGDB Data



1.1.44 Libraries / Import Glazing System from WINDOW 7



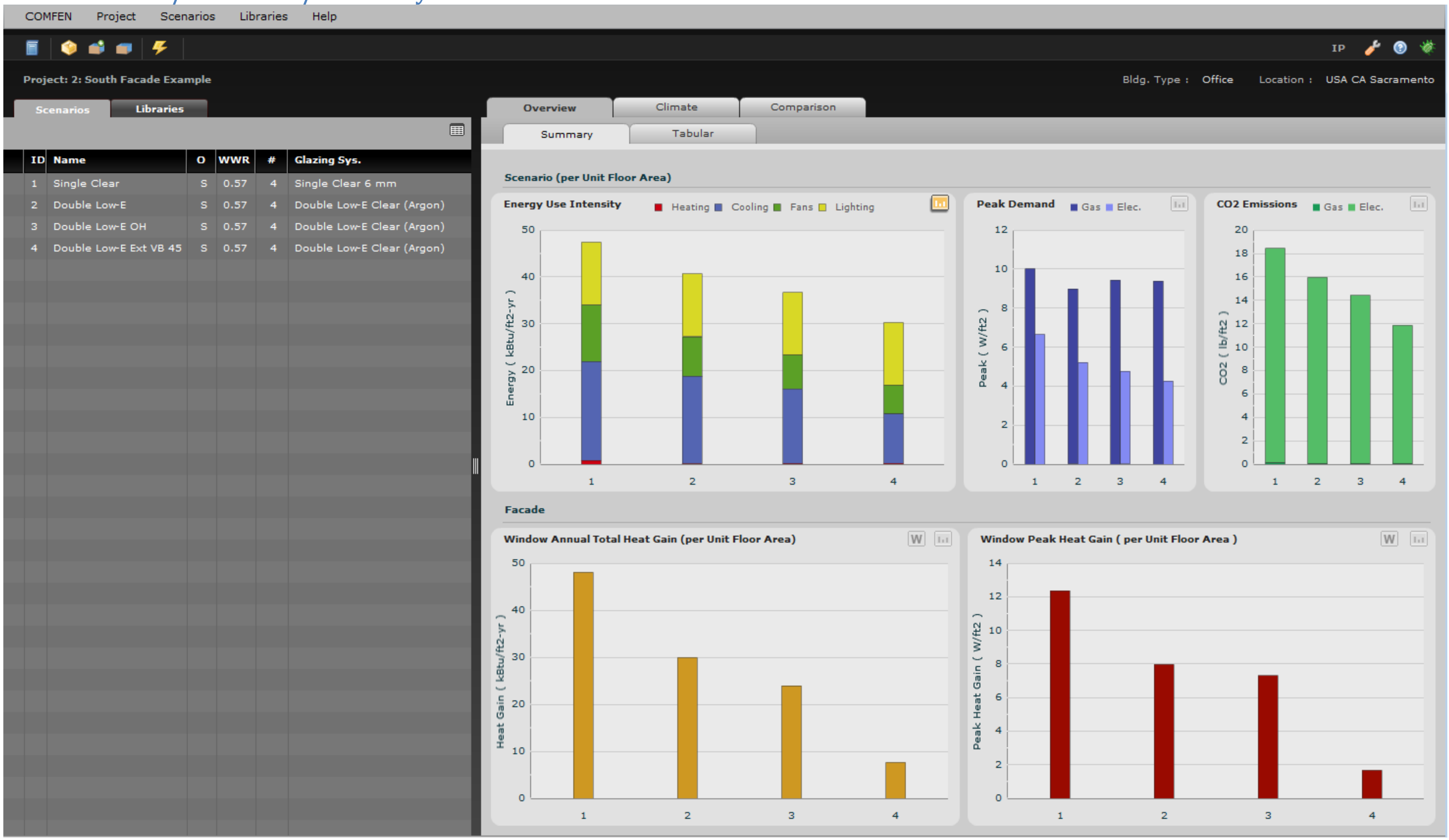
Import Glazing System from WINDOW 7

	ID	Glazing System	# Layers	Thickness (in)	SHGC	TVis	U-factor (Btu/h-ft2-
	1	xxx	2	0.926	0.366	0.190	0.472
	1	xxx	2	0.949	0.403	0.213	0.350
	1	xxx	2	0.949	0.368	0.059	0.350
	1	xxx	2	0.949	0.356	0.016	0.350
	2	Double Clear (Air)	2	0.950	0.704	0.786	0.474
	3	Double Bronze (Air)	2	0.944	0.503	0.477	0.474
	4	Double Low-E Bronze (Air)	2	0.943	0.453	0.443	0.331
	5	Double Low Solar Low-E Tint (Air)	2	0.956	0.303	0.522	0.291
	6	Double Low Solar Low-E Clear (Air)	2	0.946	0.391	0.701	0.291
	7	Quad Low Solar Low-E Clear (Air)	4	2.100	0.292	0.451	0.108
	8	Double Glazed Triple Silver Low-E I	2	0.948	0.272	0.638	0.238
	9	Double Hi VT (LowIron) Low-E (Arg	2	0.946	0.383	0.724	0.247
	10	Double High Performance Tint (Air	2	0.948	0.395	0.607	0.474
	11	Double High Performance Tint (Arg	2	0.948	0.391	0.607	0.449
	12	Double Low VT Low-E (Argon)	2	0.949	0.241	0.371	0.253
	13	Double Low-E Clear (Argon)	2	0.850	0.469	0.696	0.245
	14	Double Glazed Triple Silver Low-E	2	0.948	0.261	0.582	0.238
	15	Double Low-E Opaque (Air)	2	0.946	0.078	0.027	0.291
✗	20	Double low-e (argon) with ext. per	3	1.470	0.058	0.062	0.183

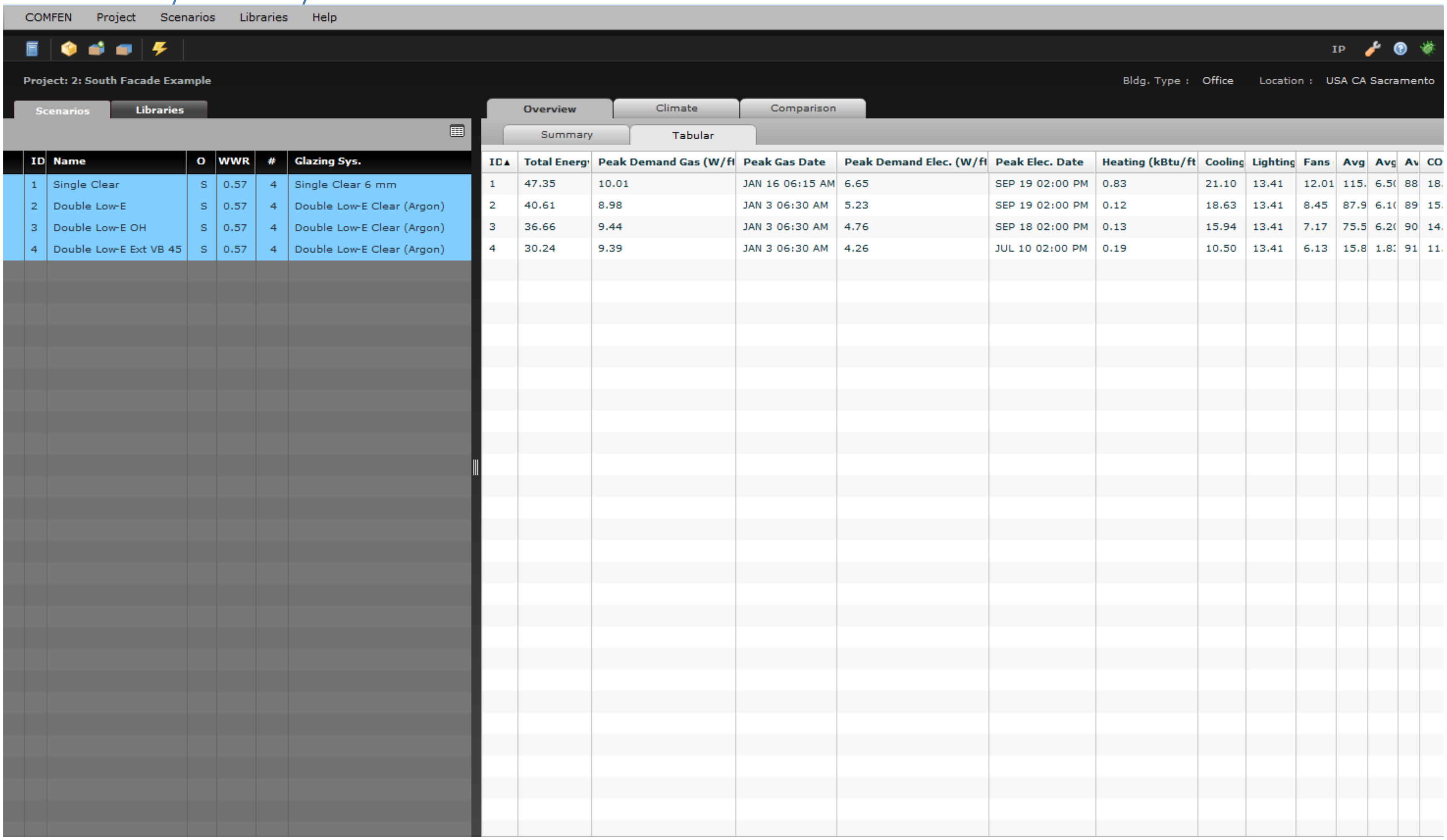
✗ = glazing system cannot be imported (roll over to see issue).

Import Cancel

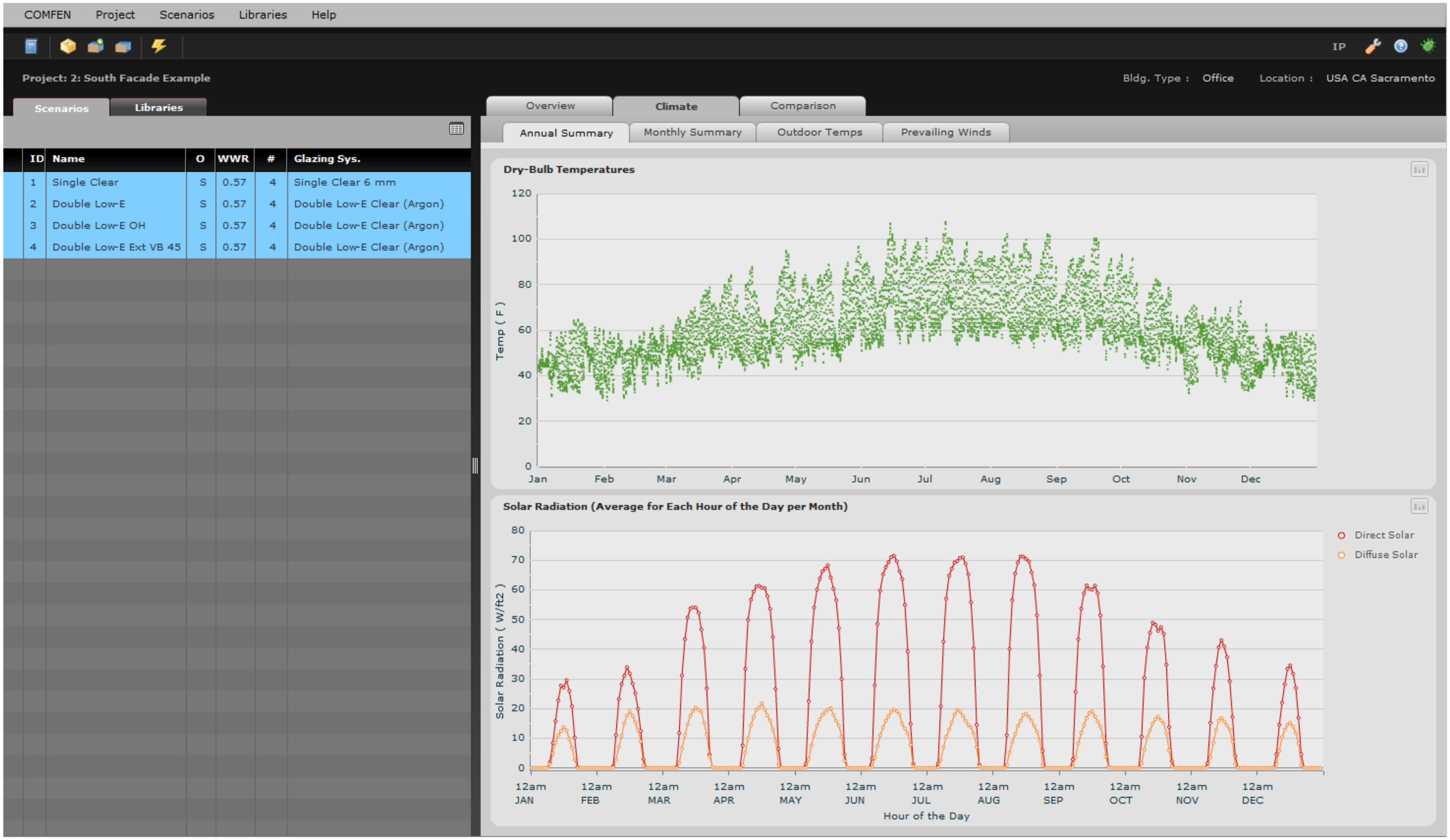
1.1.45 Results / Overview / Summary



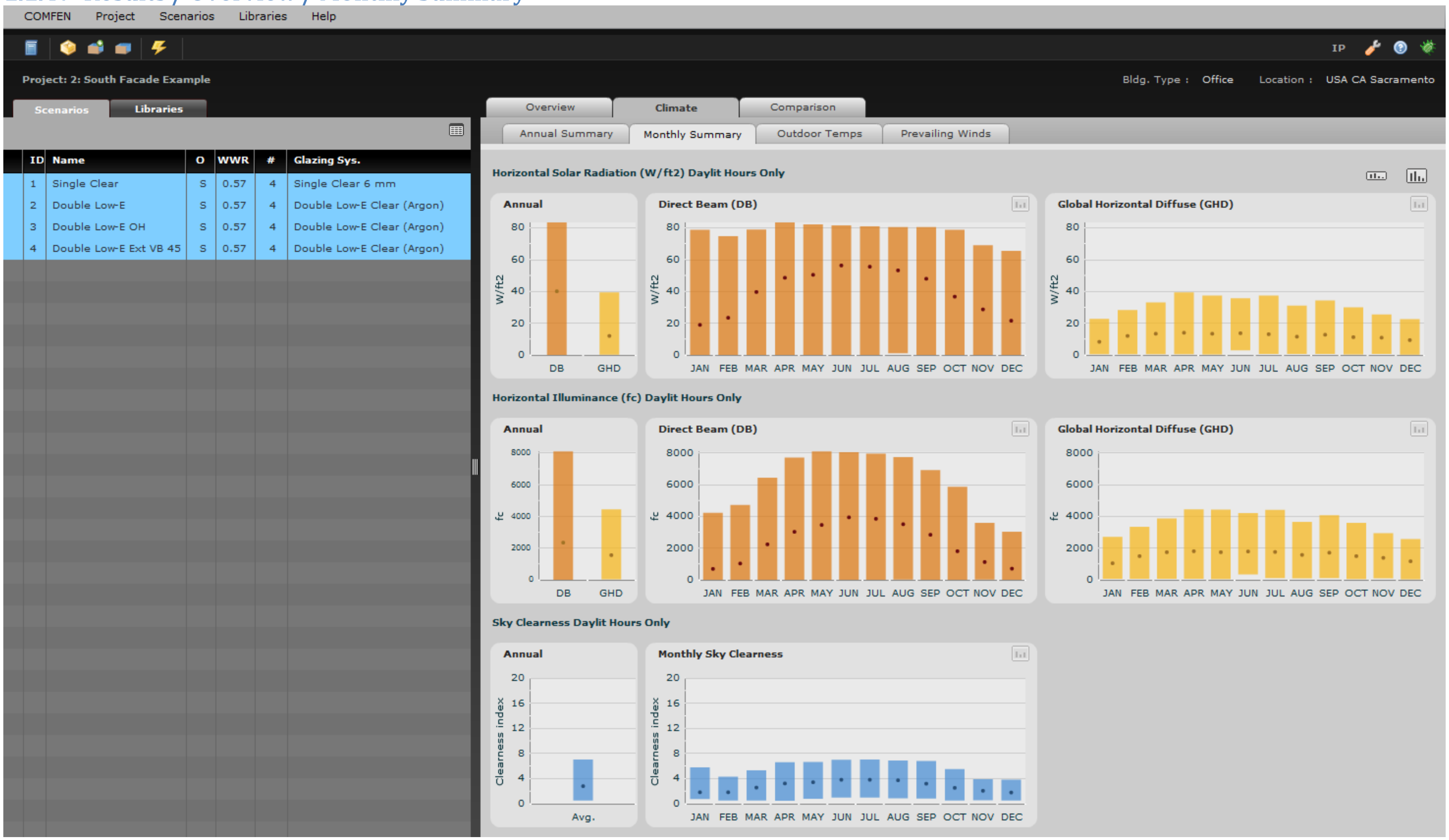
1.1.46 Results / Overview / Tabular



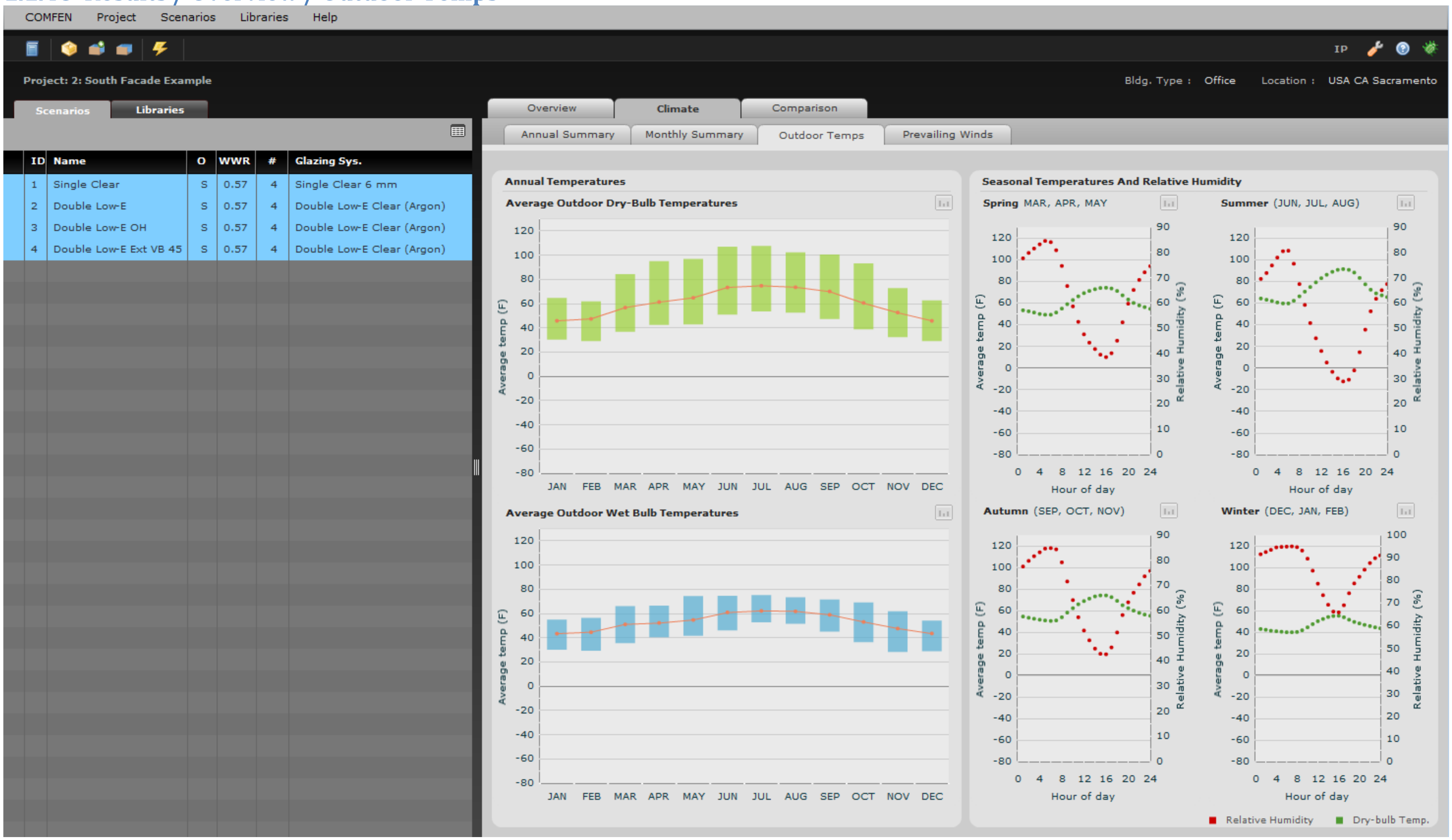
Results / Climate / Annual Summary



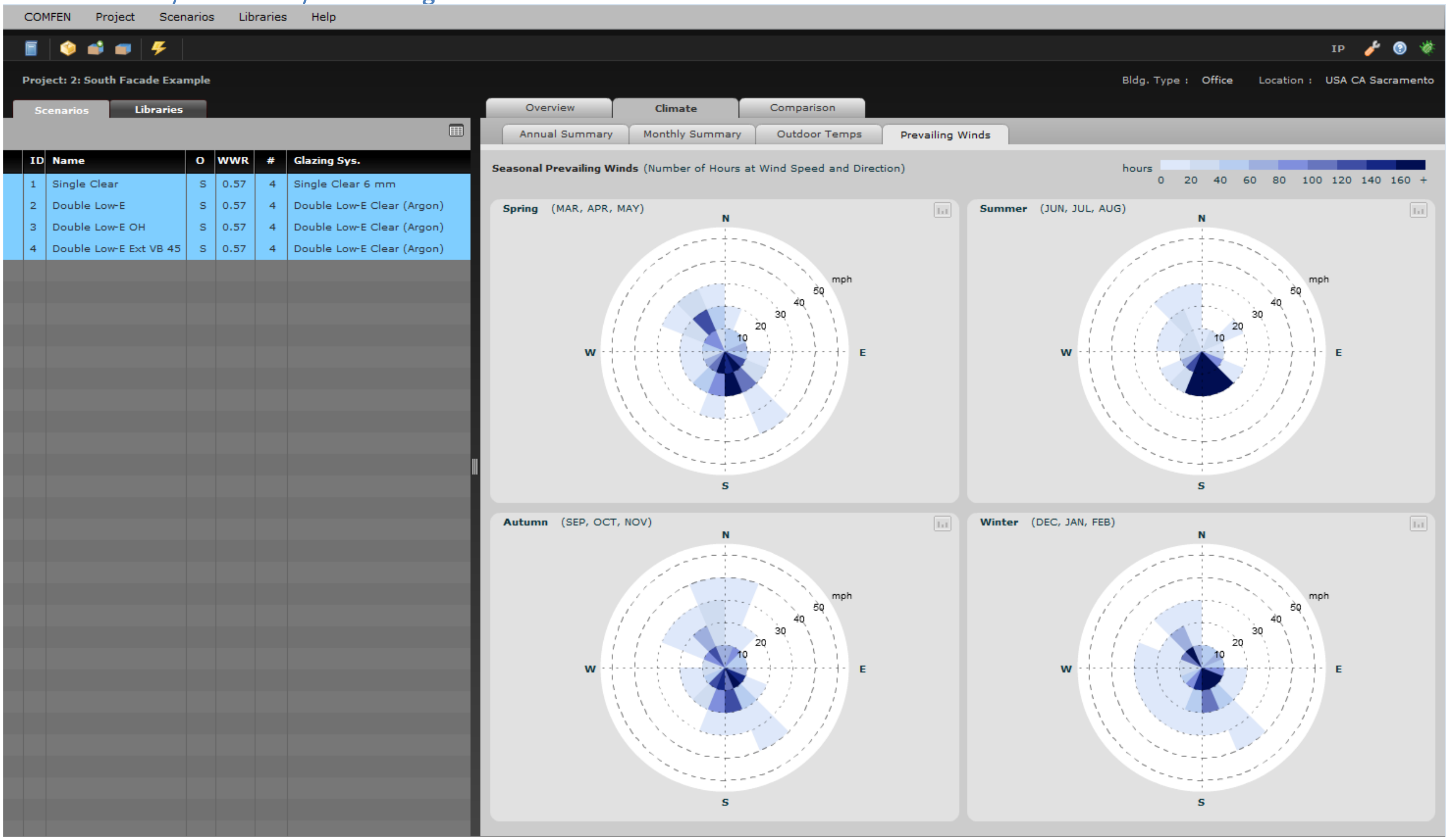
1.1.47 Results / Overview / Monthly Summary



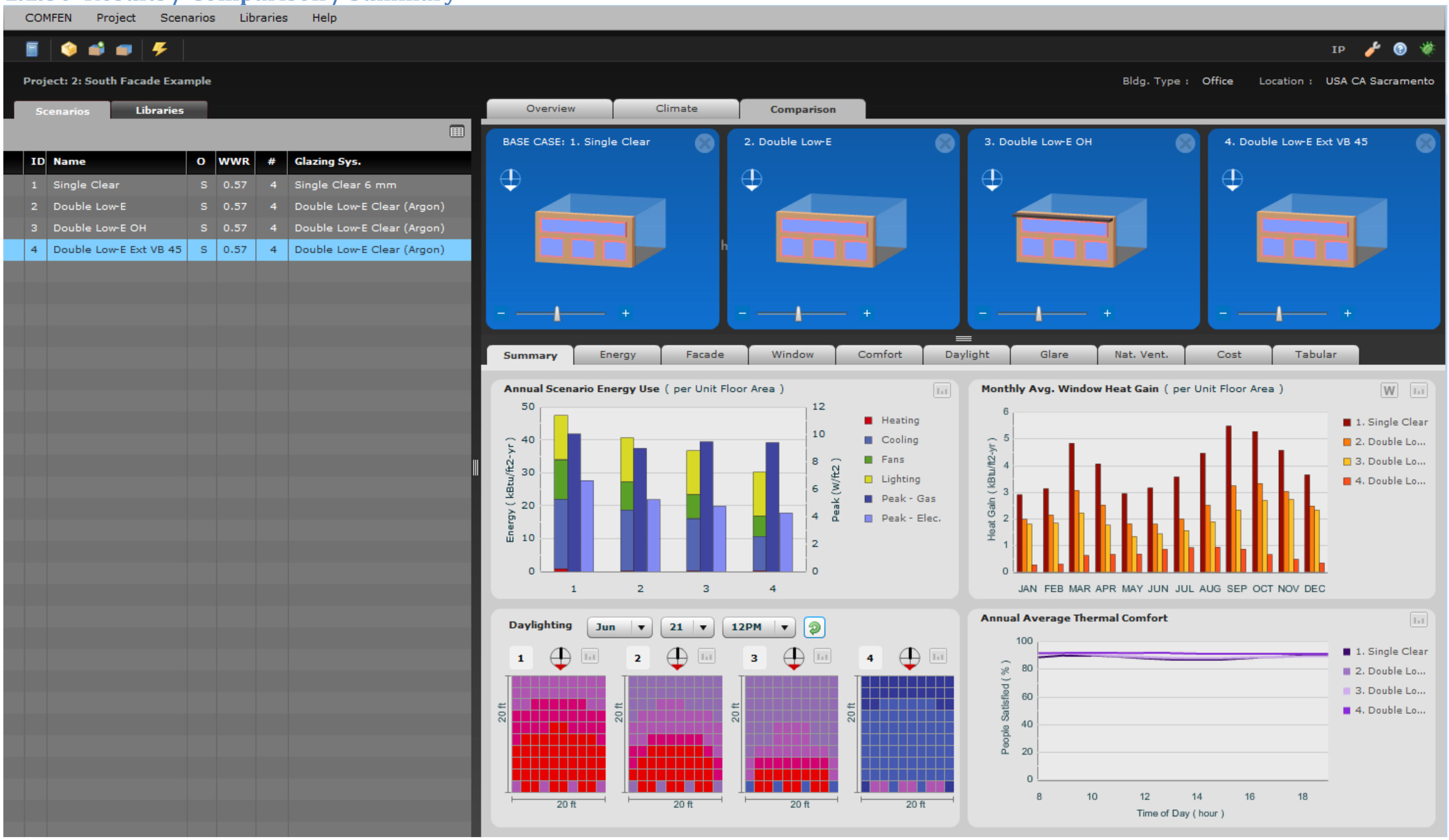
1.1.48 Results / Overview / Outdoor Temps



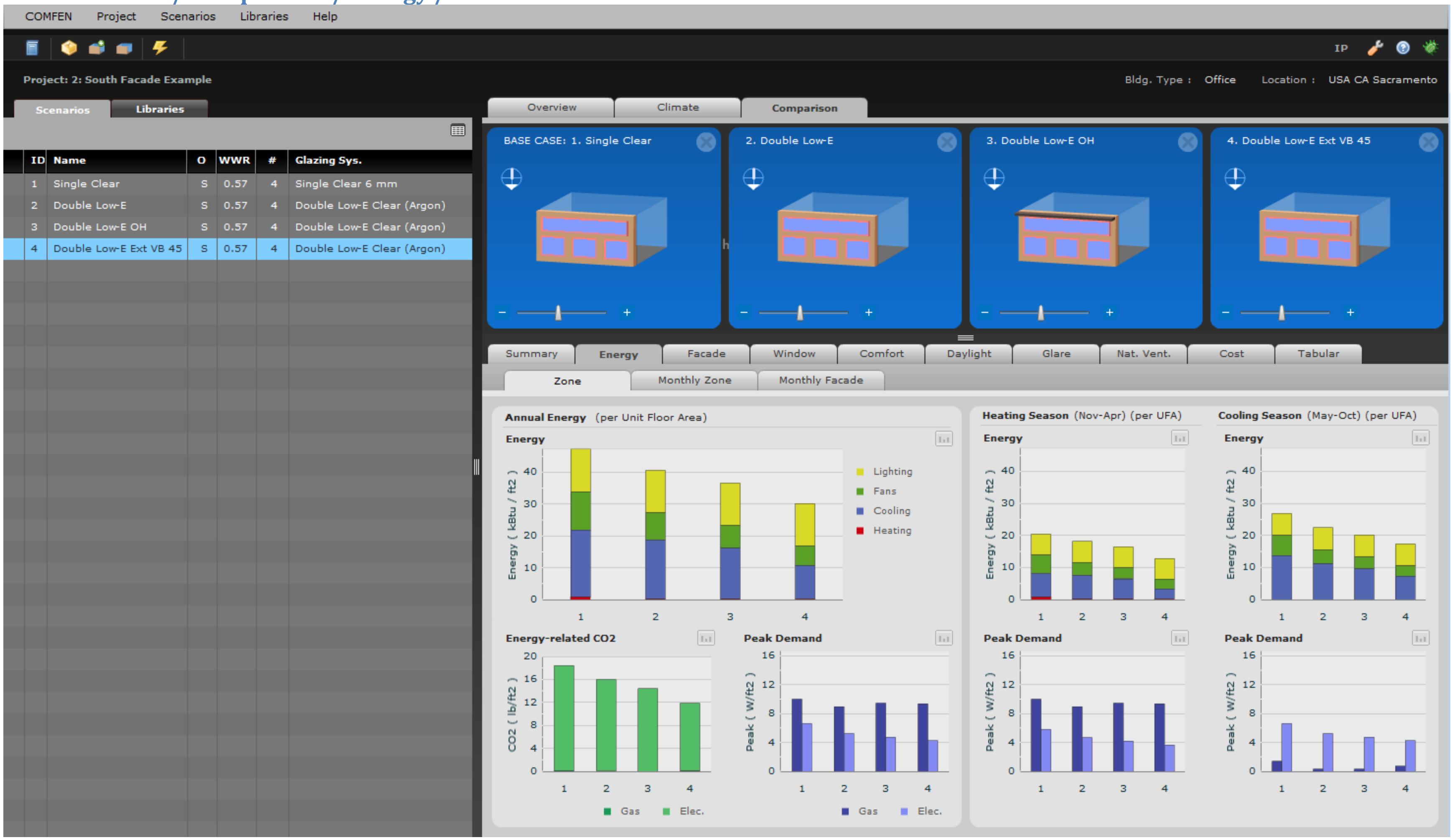
1.1.49 Results / Overview / Prevailing Winds



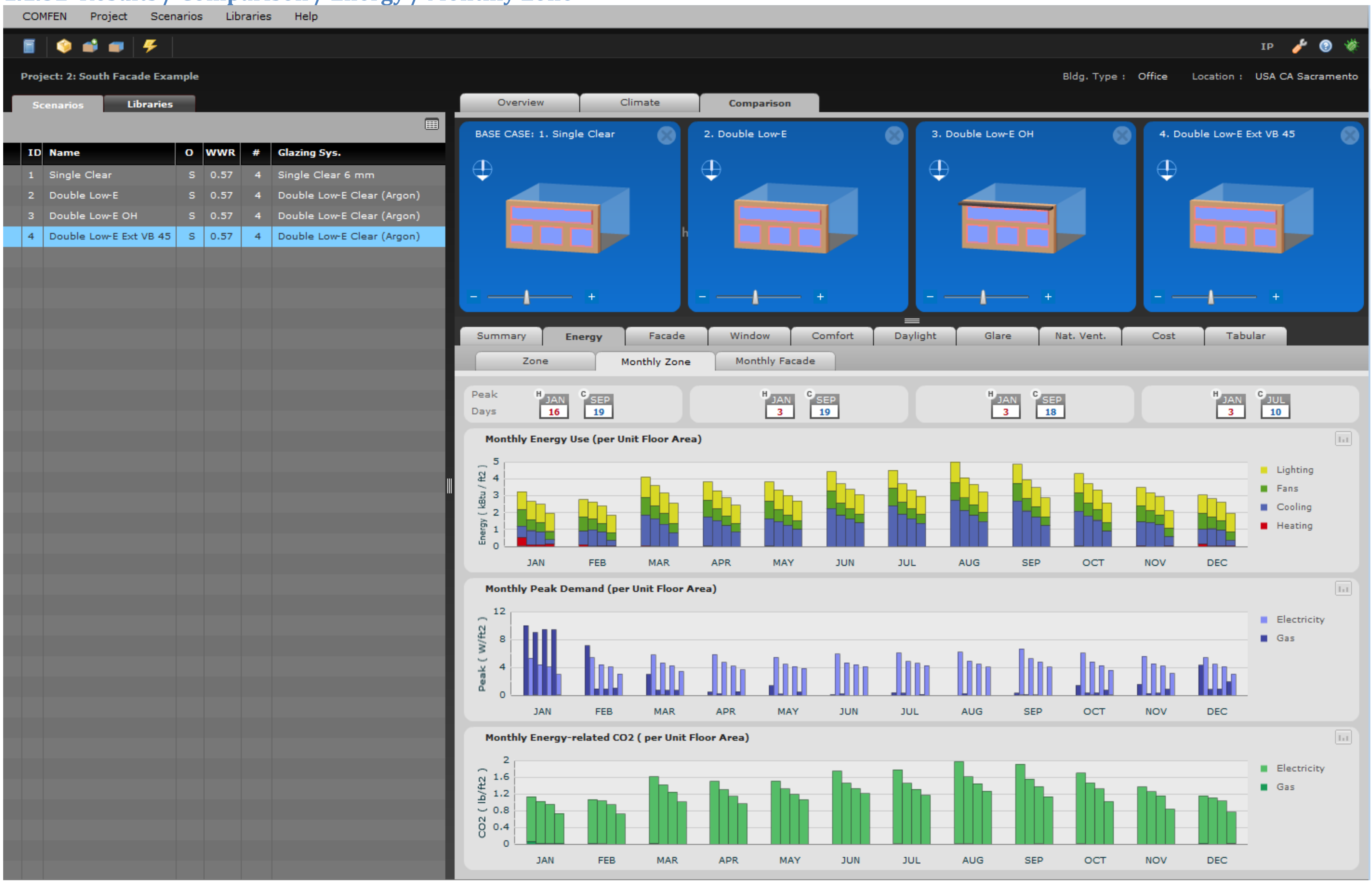
1.1.50 Results / Comparison / Summary



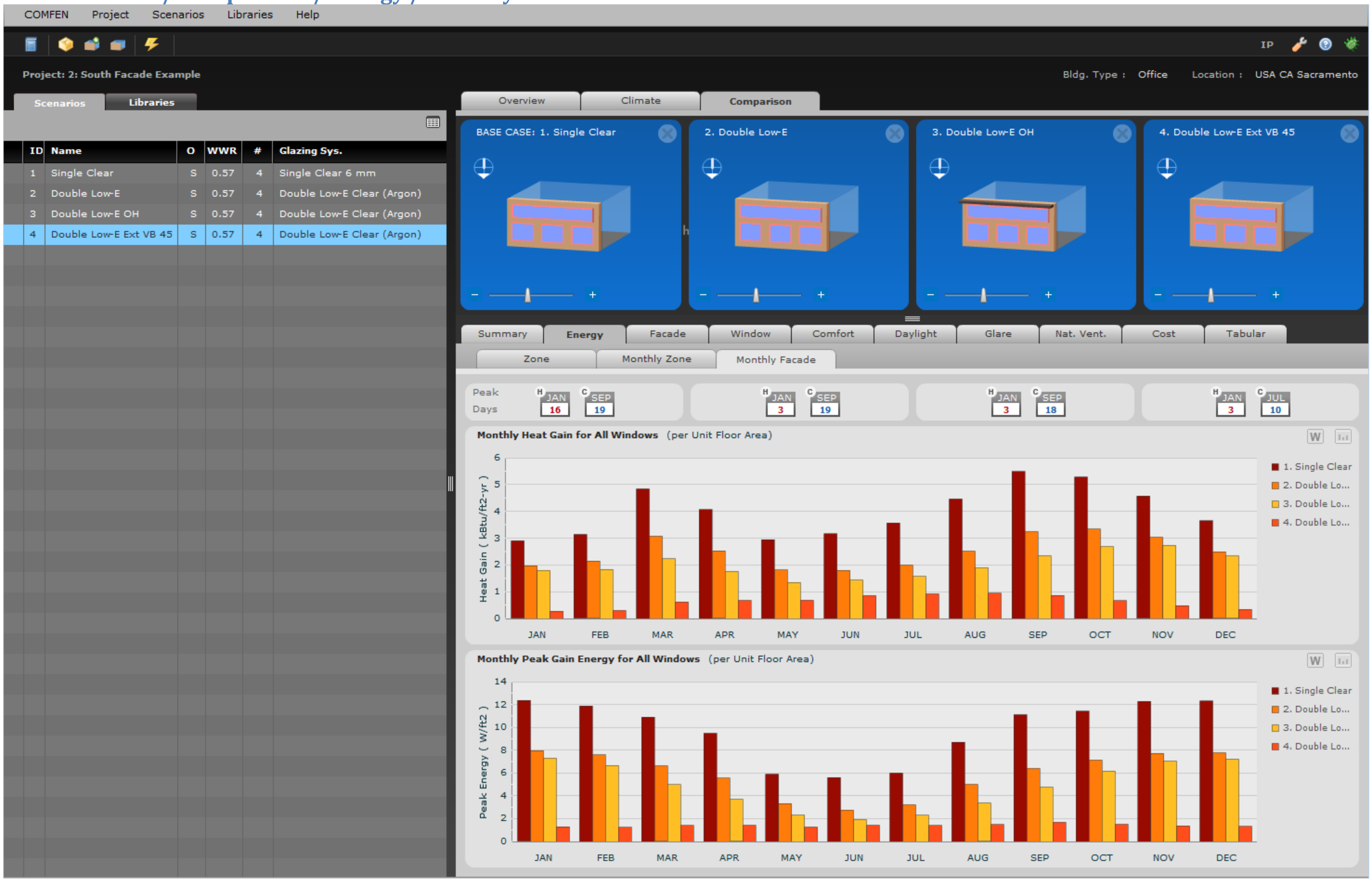
1.1.51 Results / Comparison / Energy / Zone



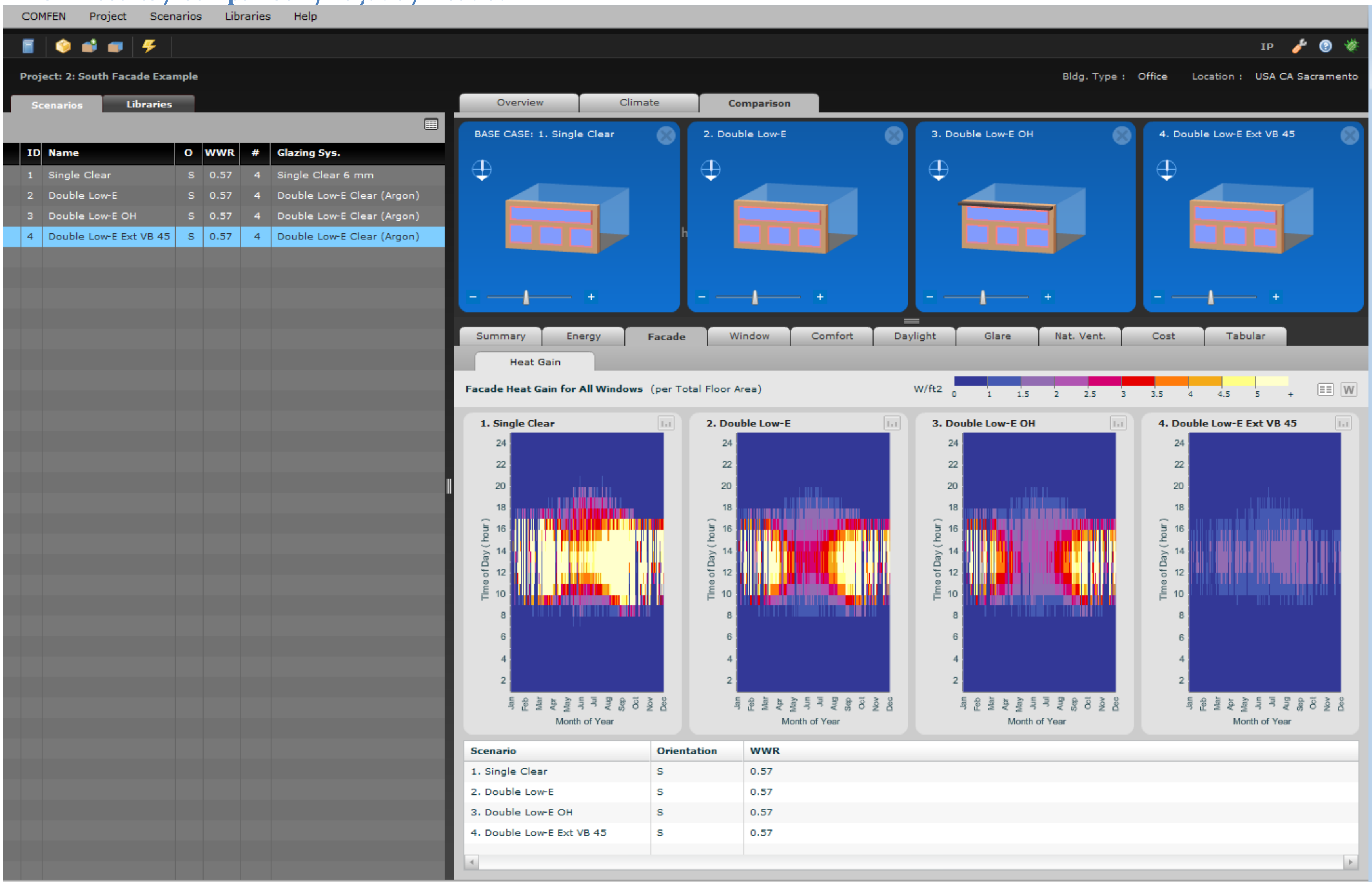
1.1.52 Results / Comparison / Energy / Monthly Zone



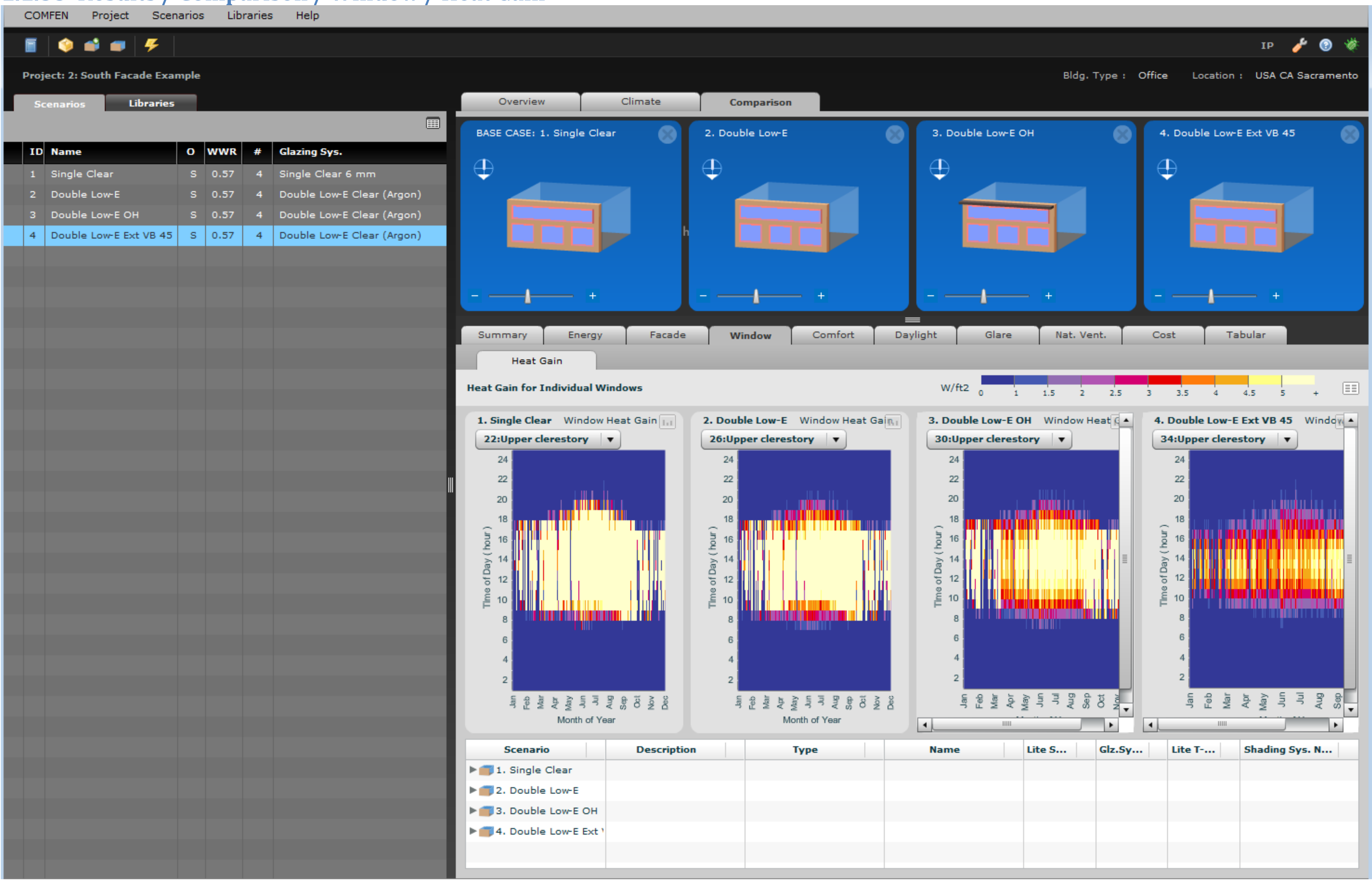
1.1.53 Results / Comparison / Energy / Monthly Facade



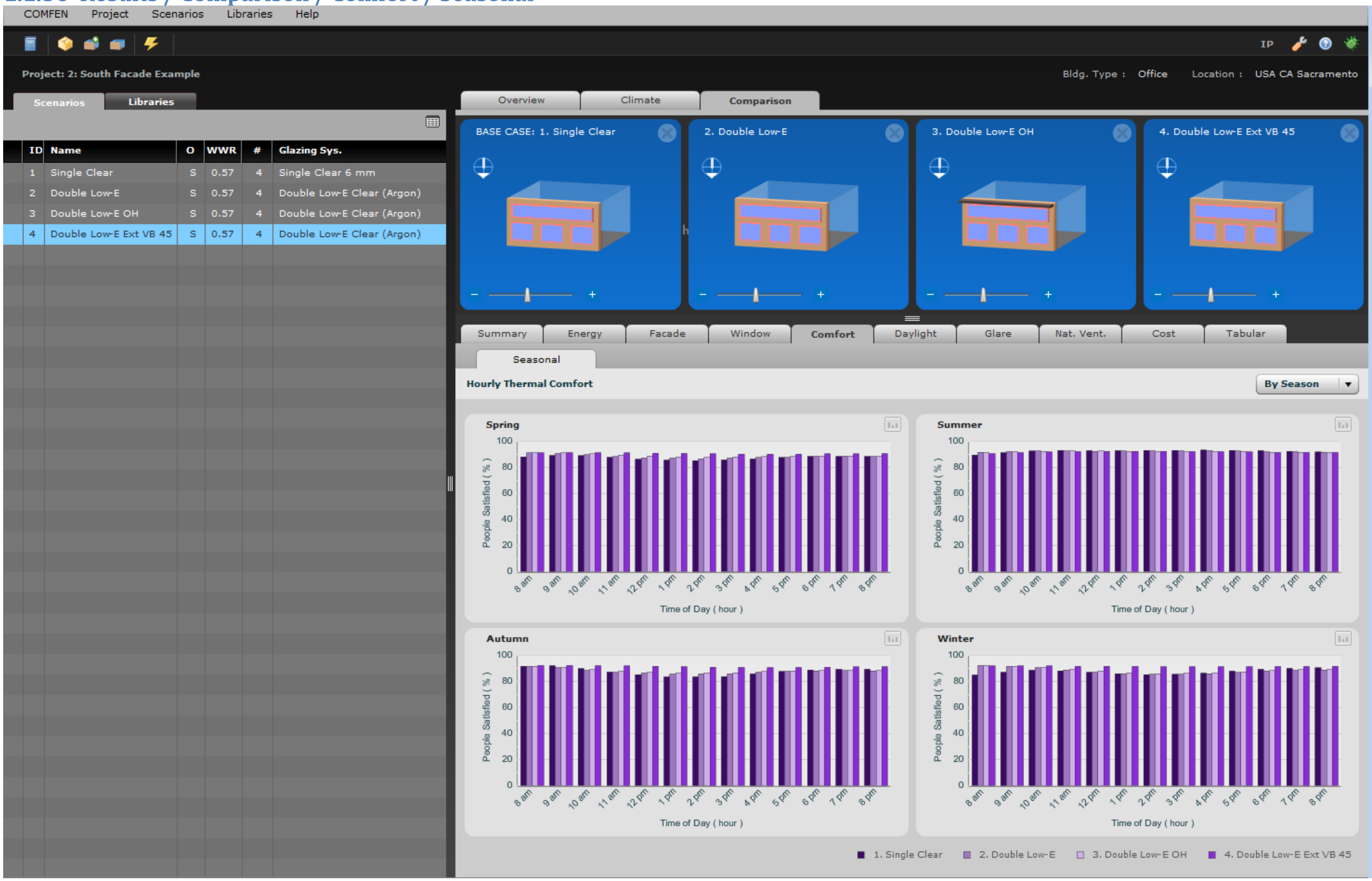
1.1.54 Results / Comparison / Façade / Heat Gain



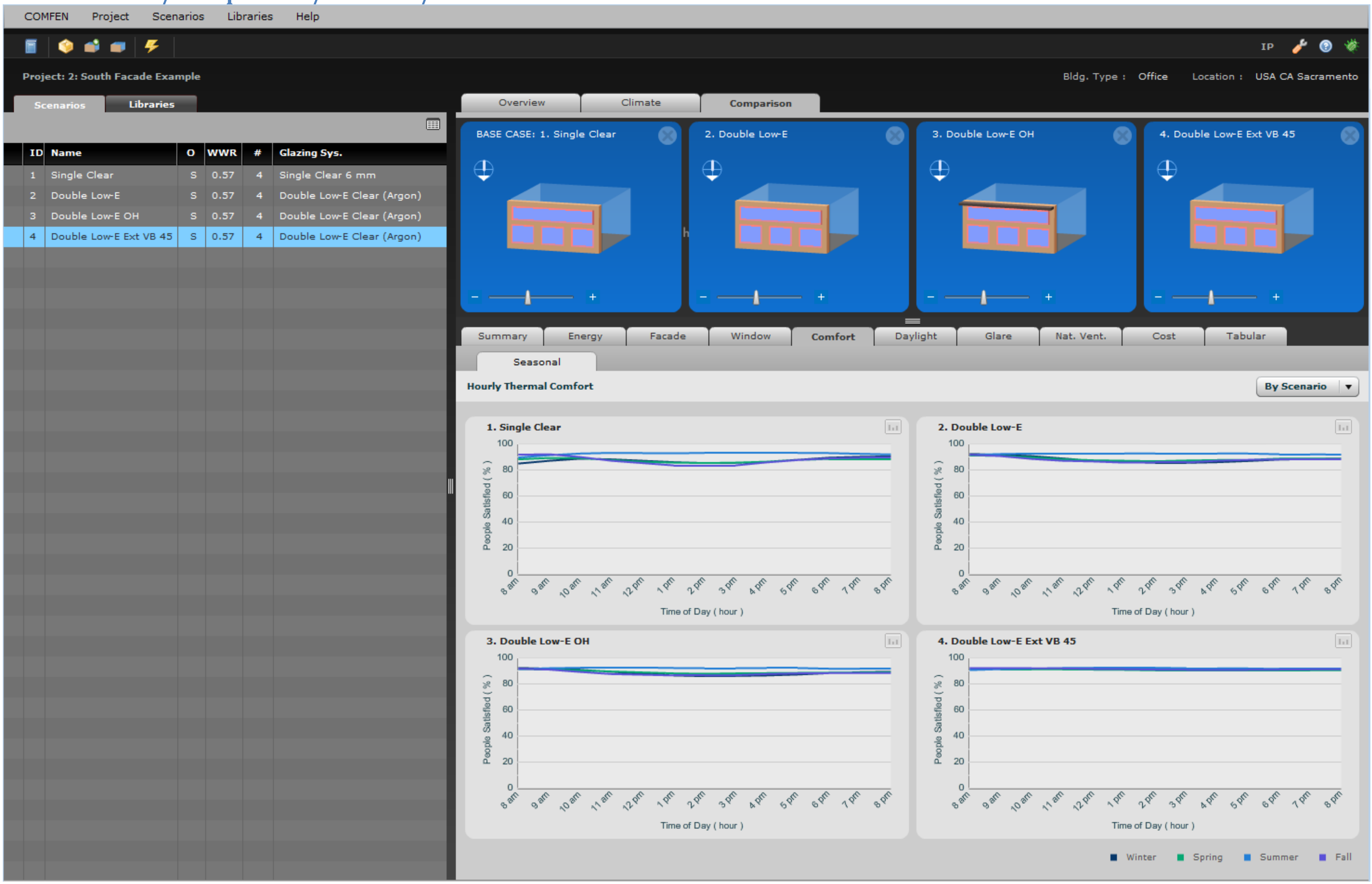
1.1.55 Results / Comparison / Window / Heat Gain



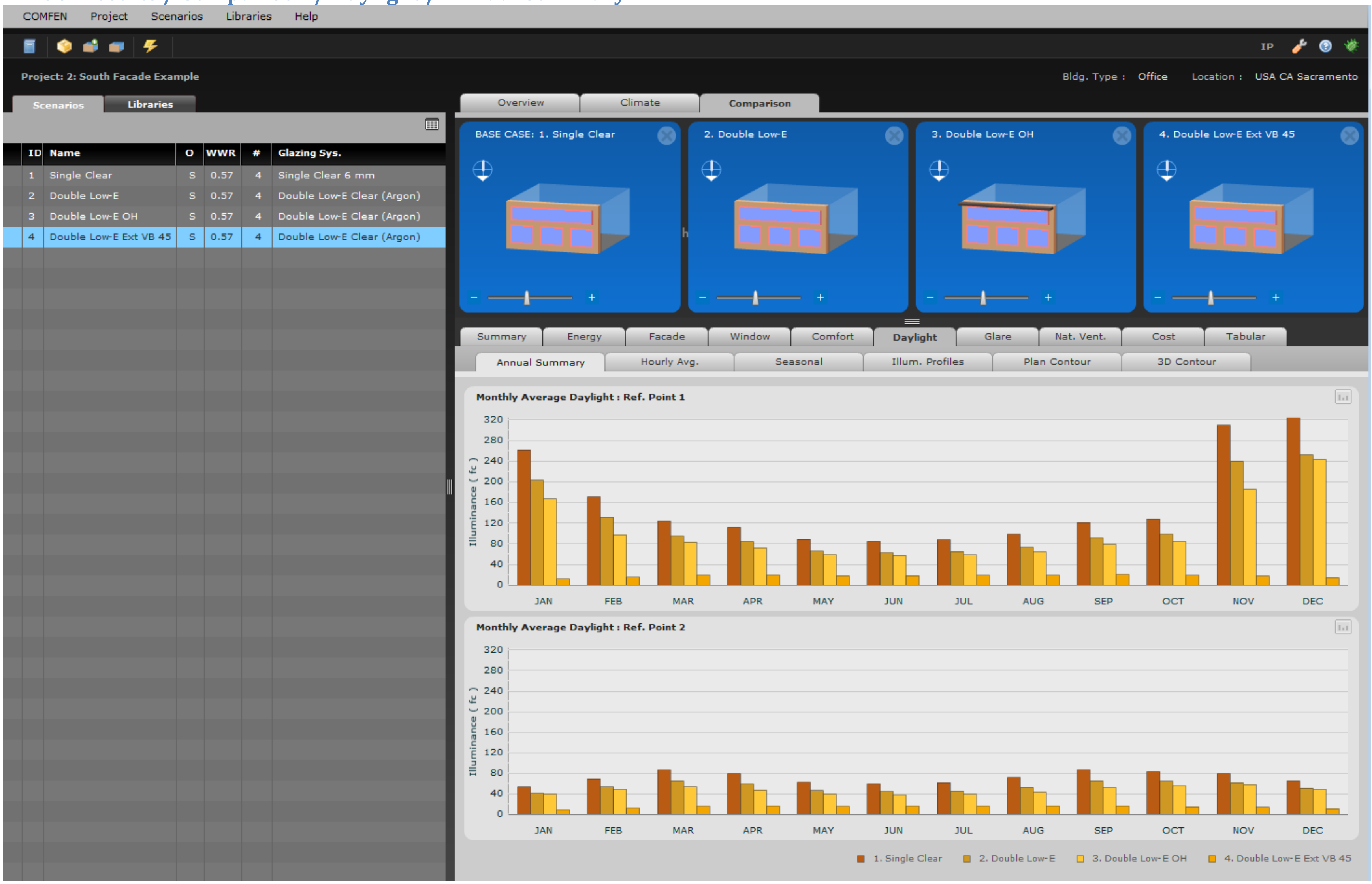
1.1.56 Results / Comparison / Comfort / Seasonal



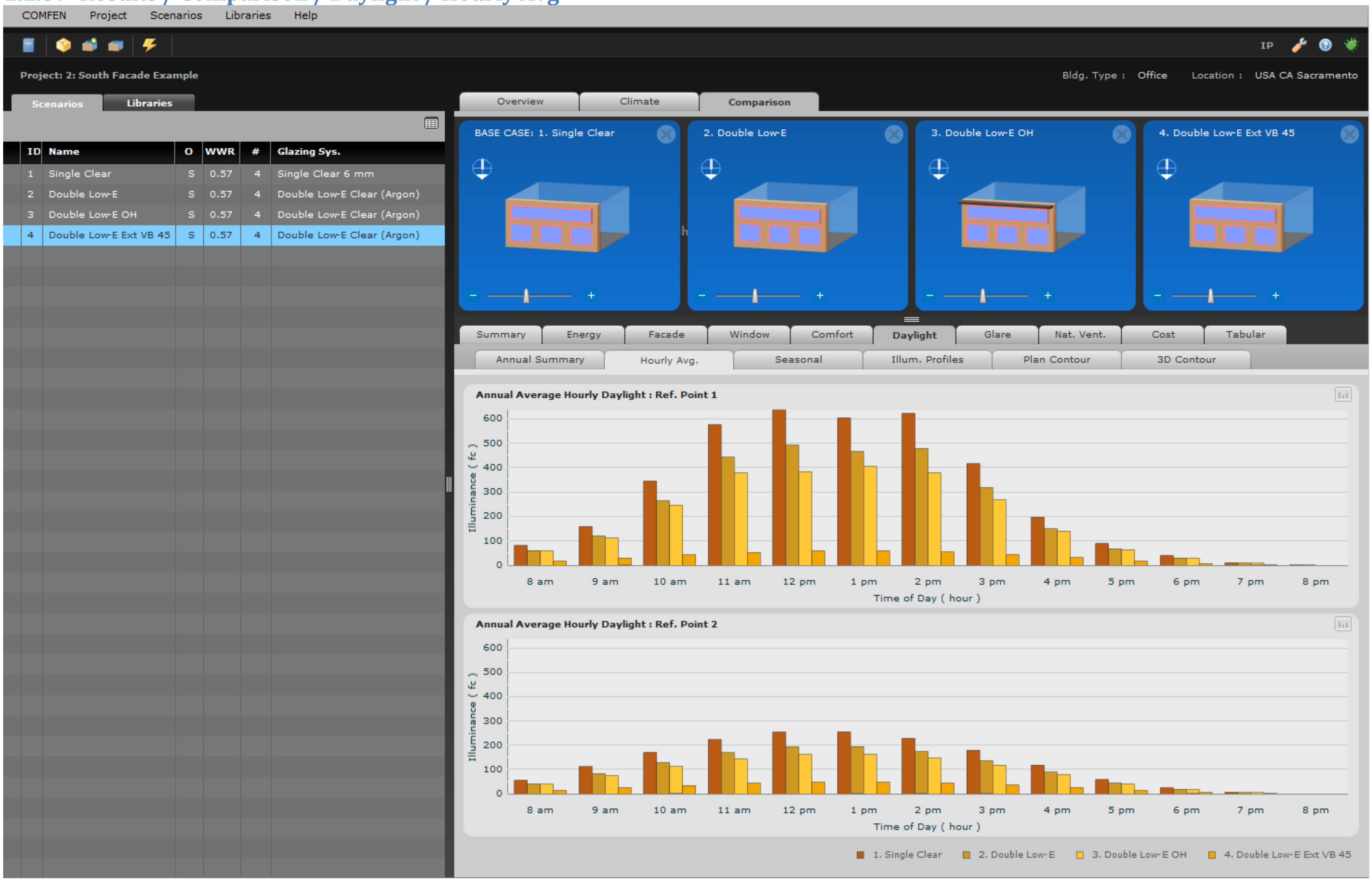
1.1.57 Results / Comparison / Comfort / Seasonal



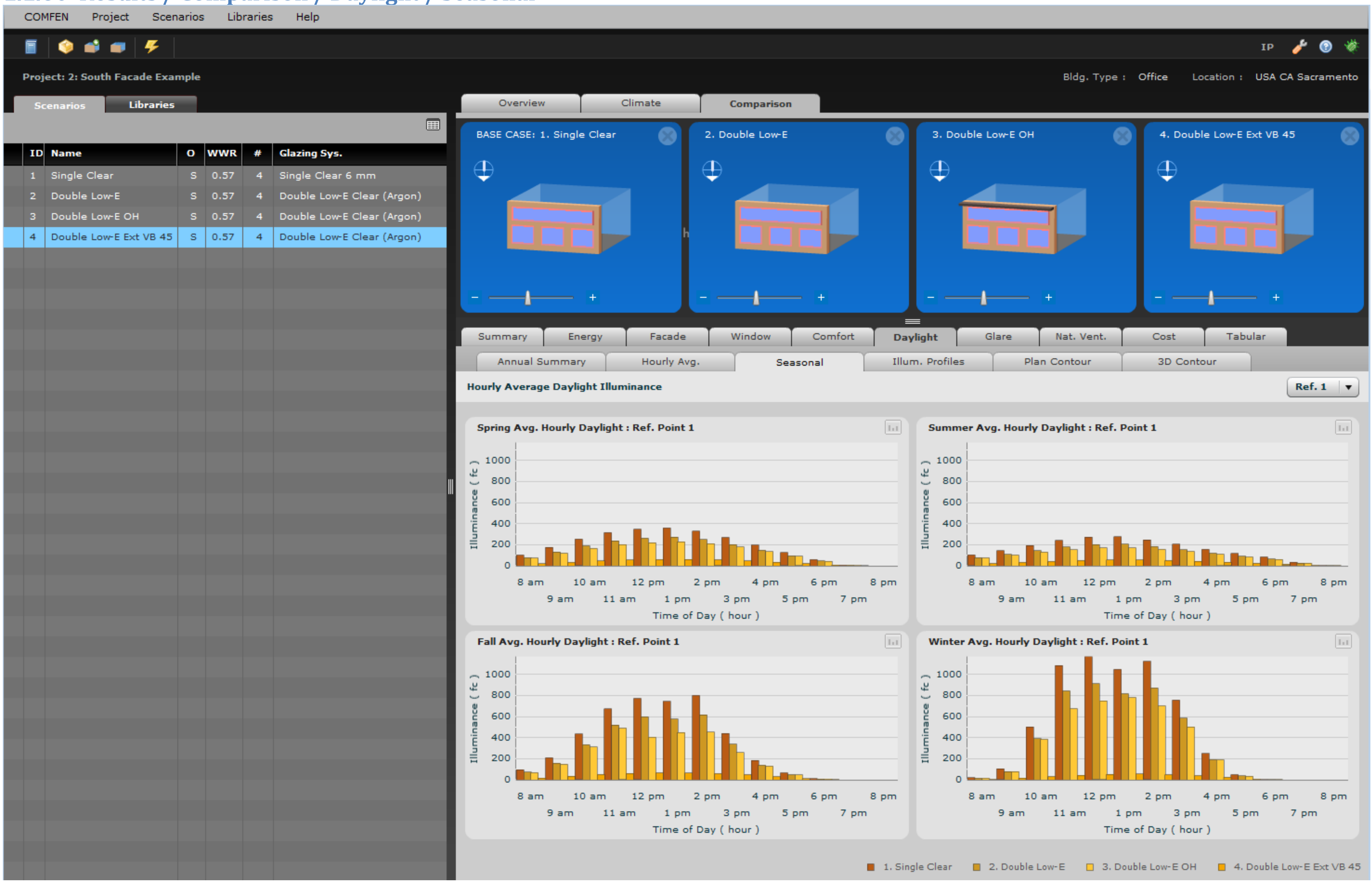
1.1.58 Results / Comparison / Daylight / Annual Summary



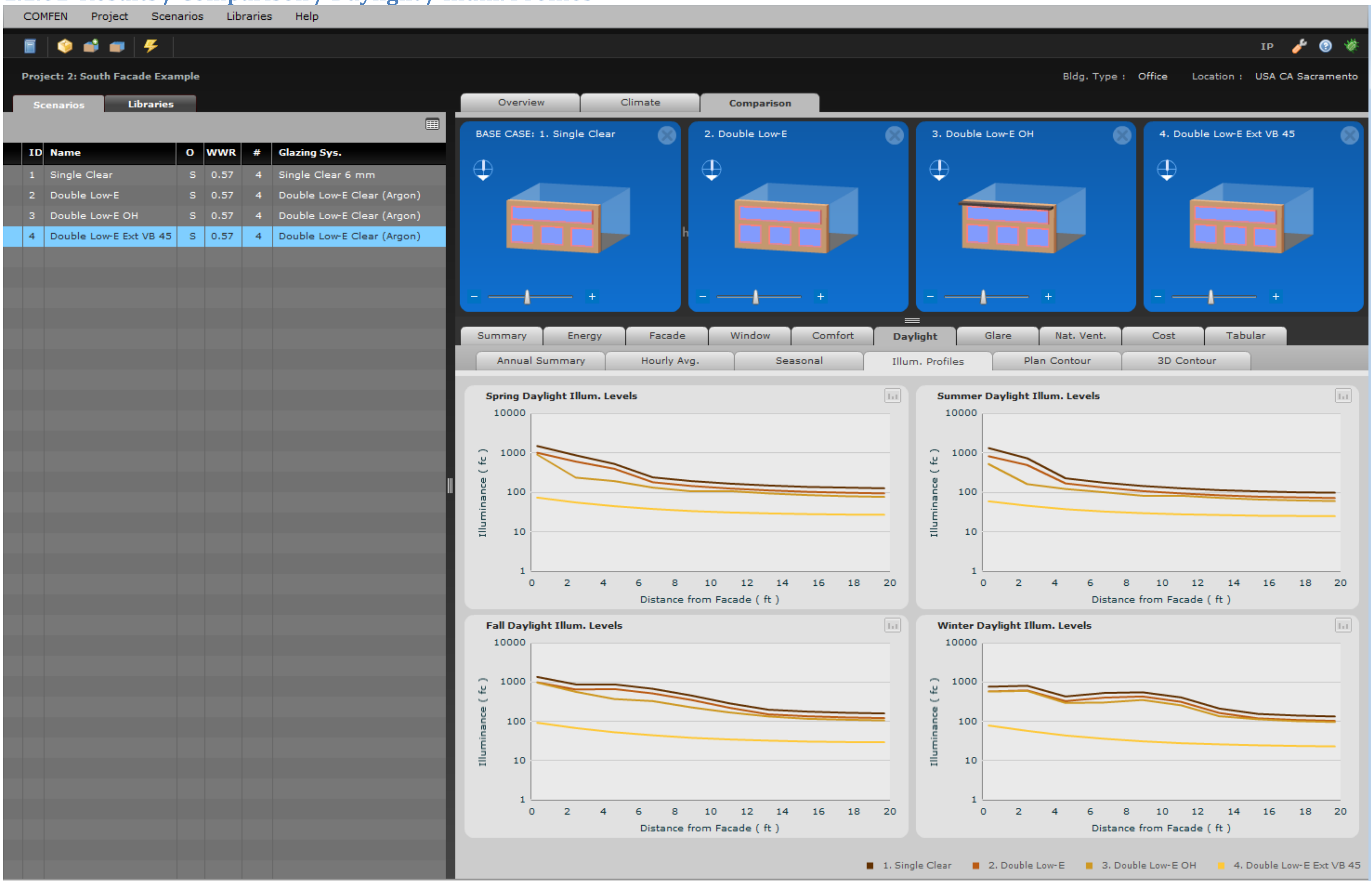
1.1.59 Results / Comparison / Daylight / Hourly Avg



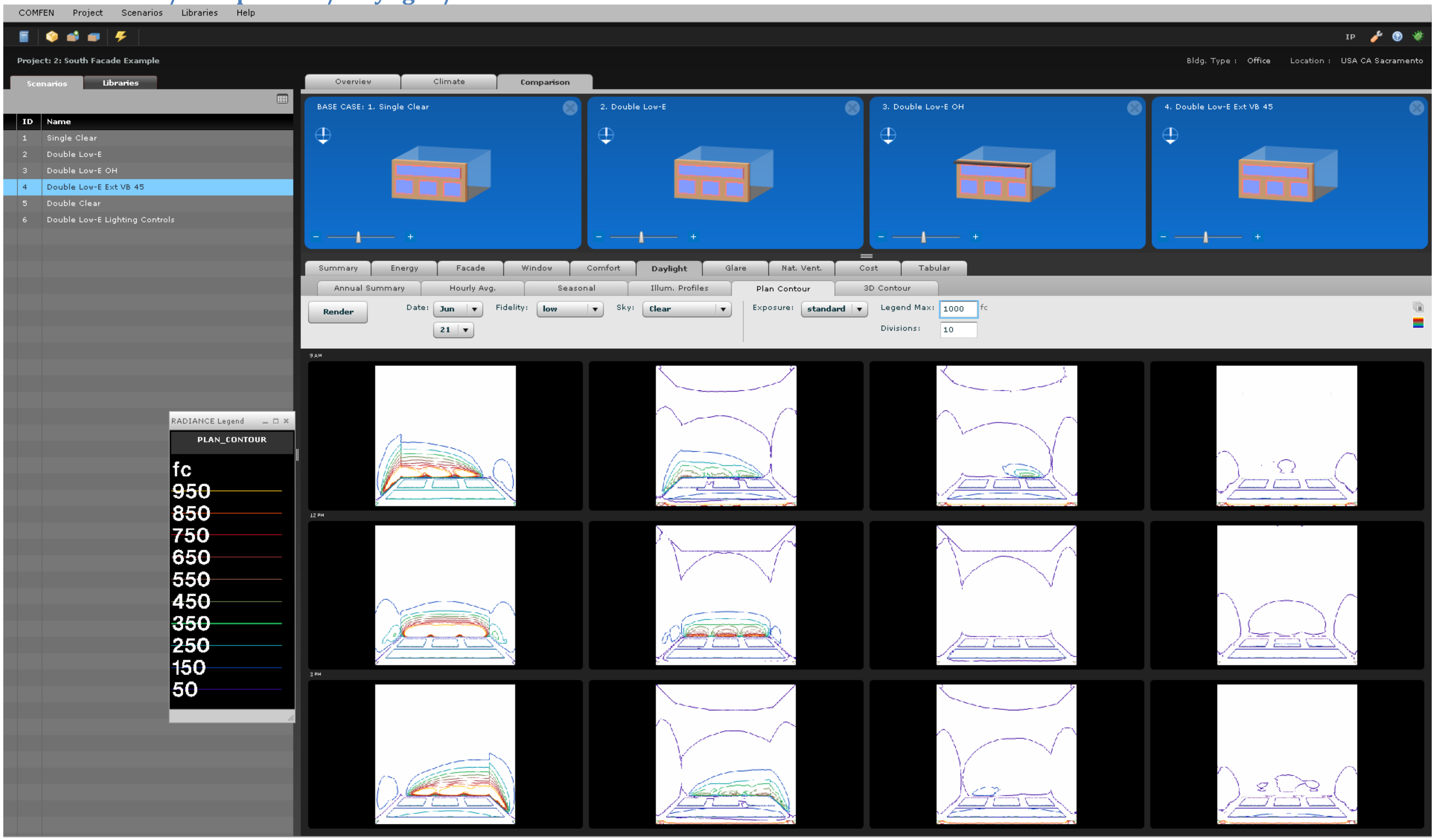
1.1.60 Results / Comparison / Daylight / Seasonal



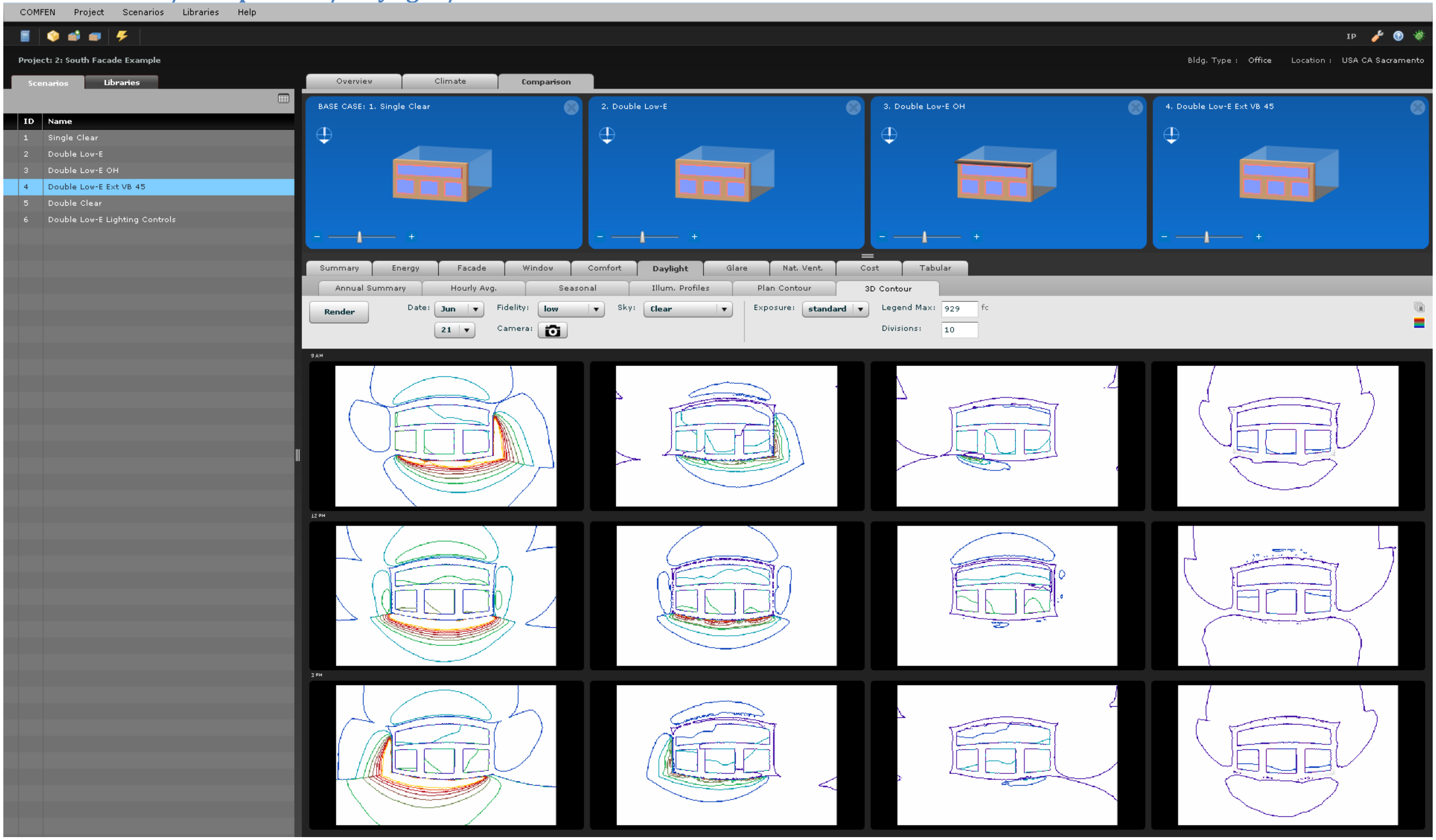
1.1.61 Results / Comparison / Daylight / Illum. Profiles



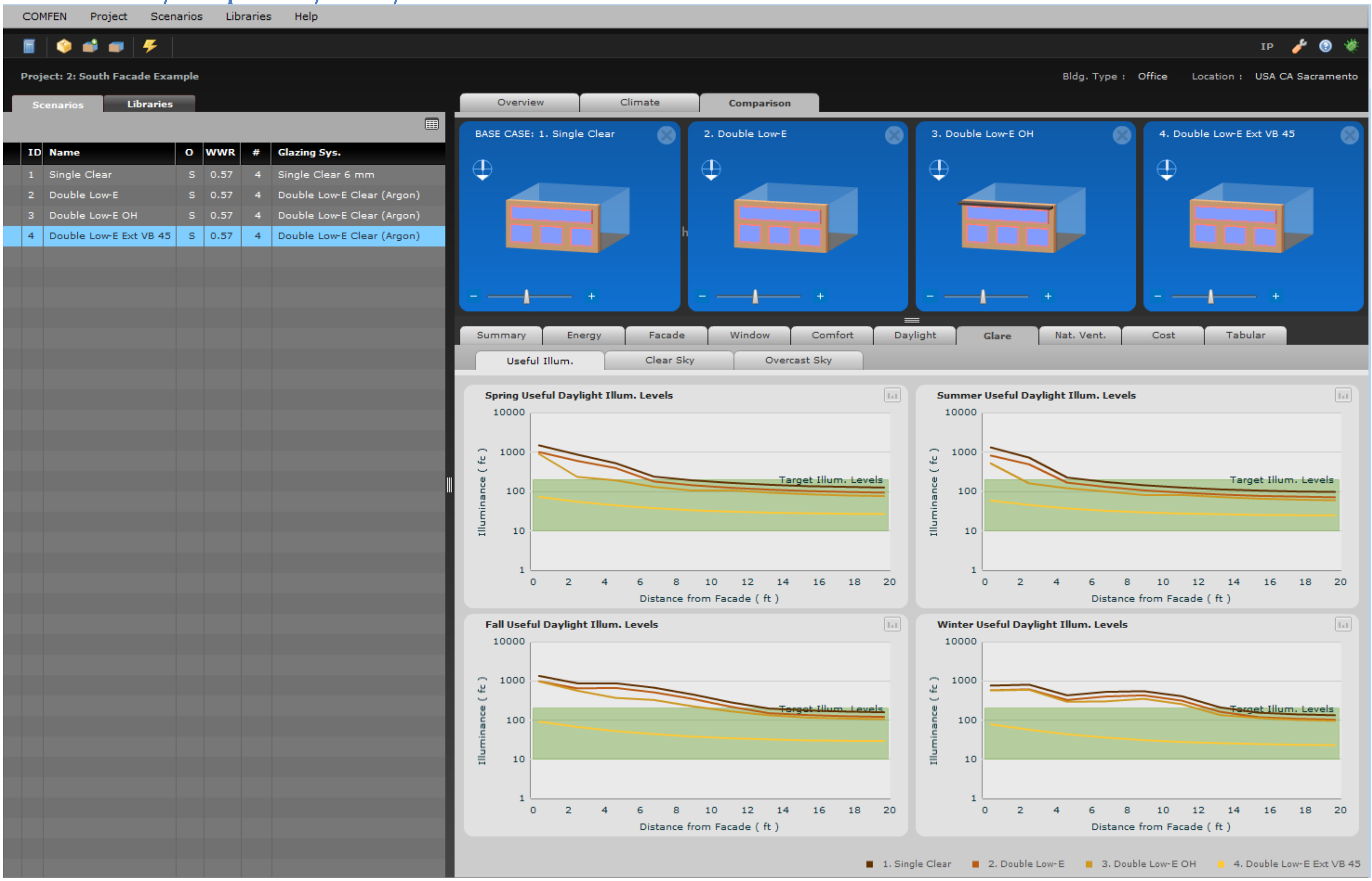
1.1.62 Results / Comparison / Daylight / Plan Contour



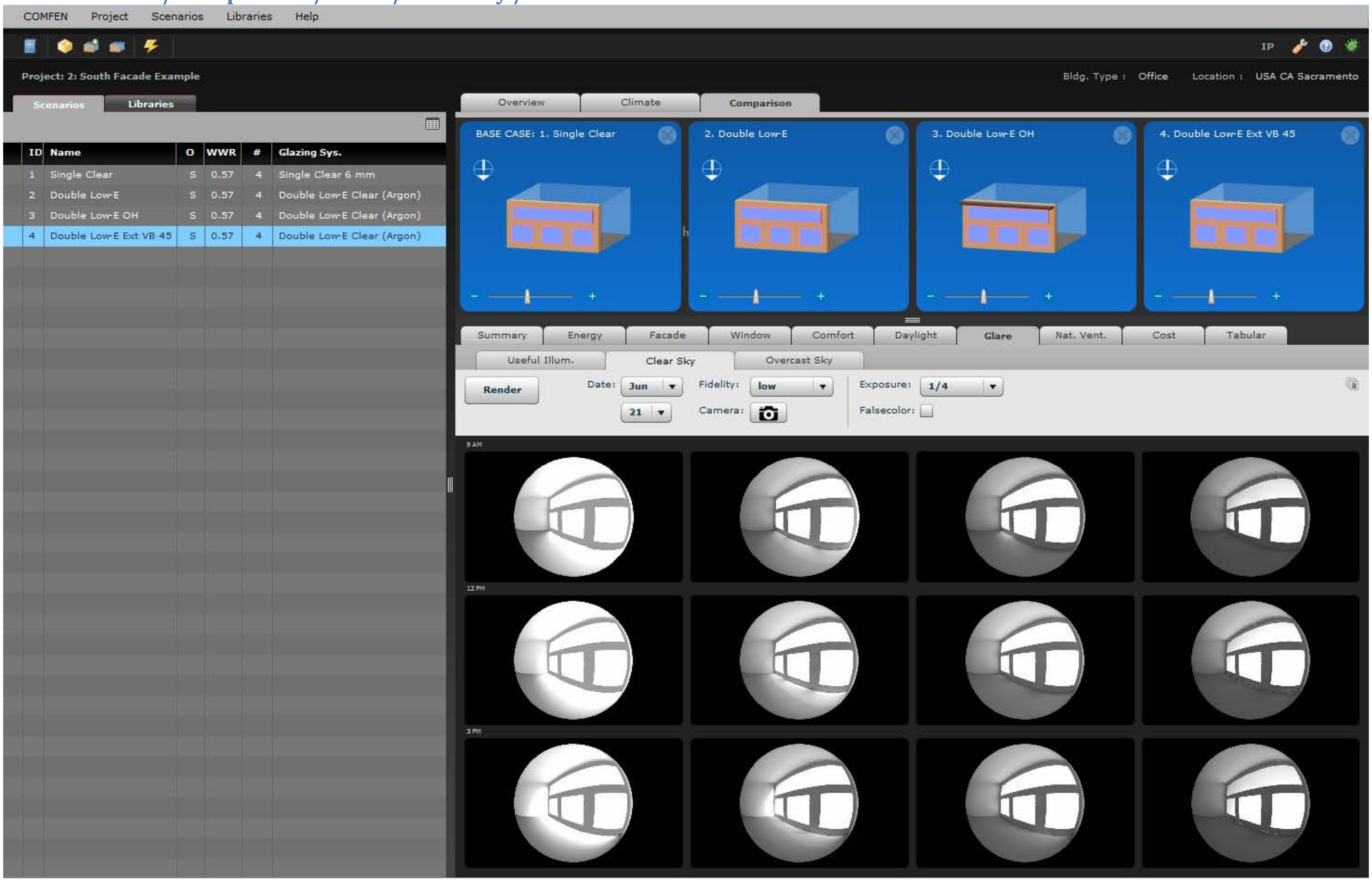
1.1.63 Results / Comparison / Daylight / 3D Contour



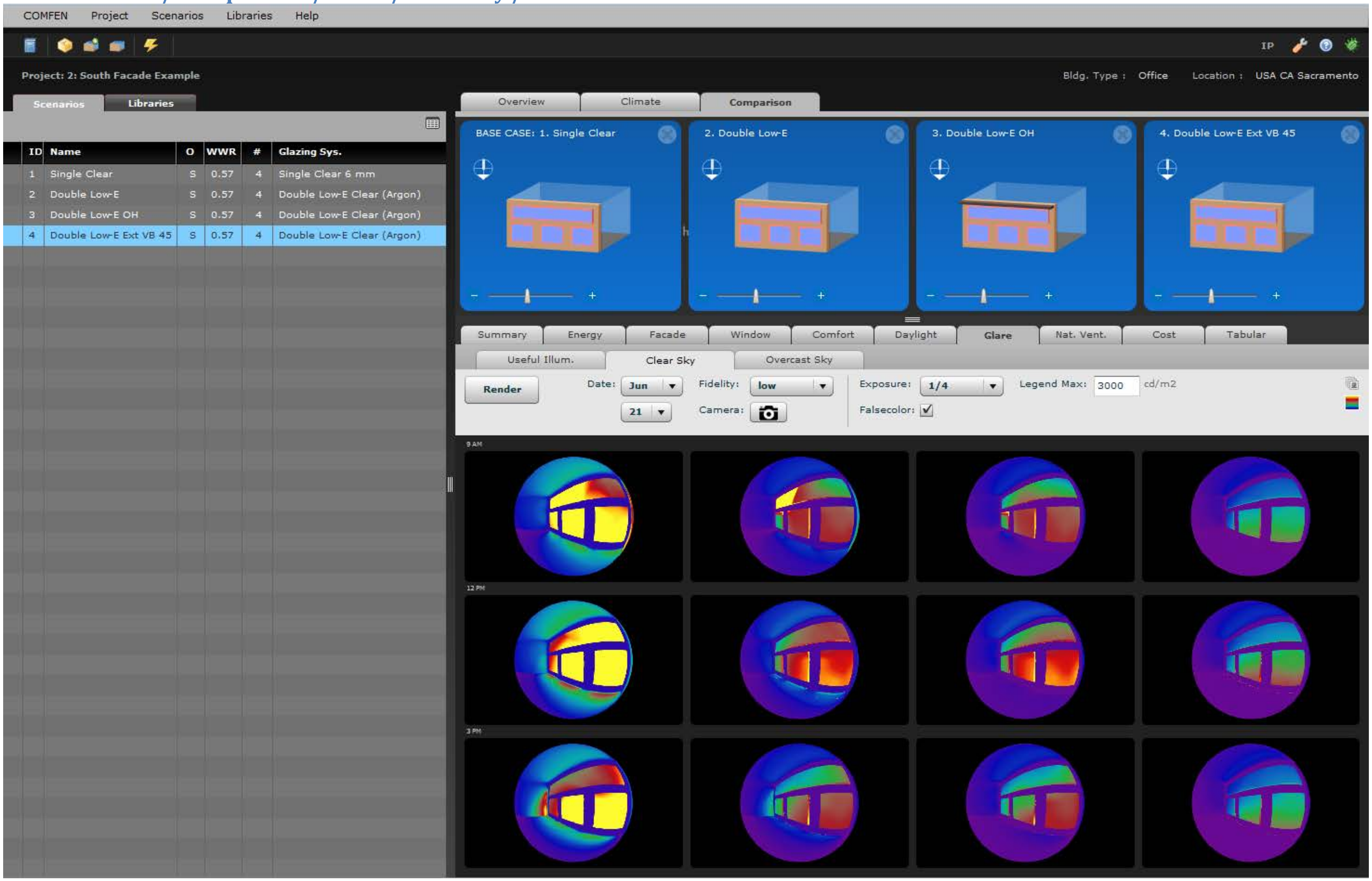
1.1.64 Results / Comparison / Glare / Useful Illum



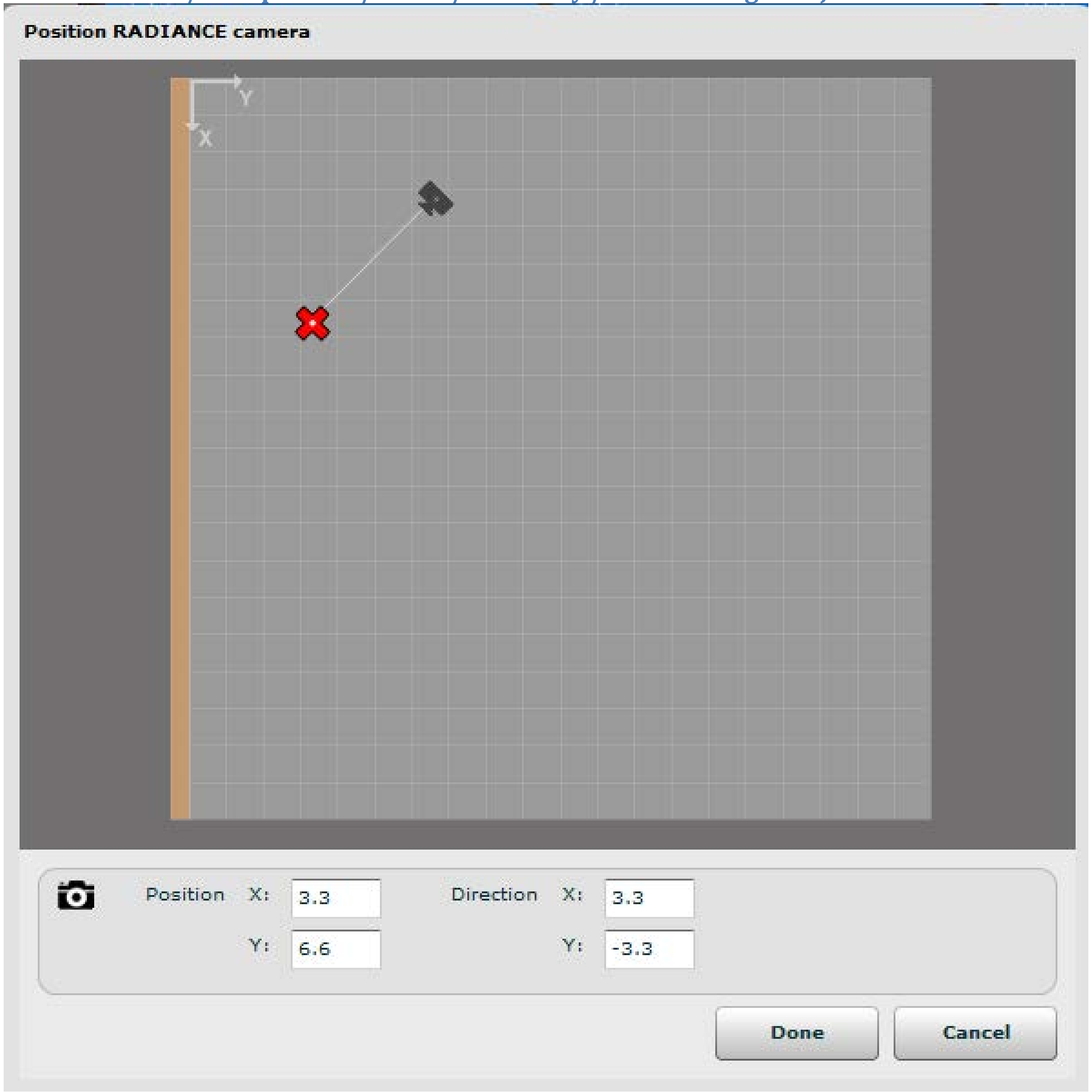
1.1.65 Results / Comparison / Glare / Clear Sky / Black and White



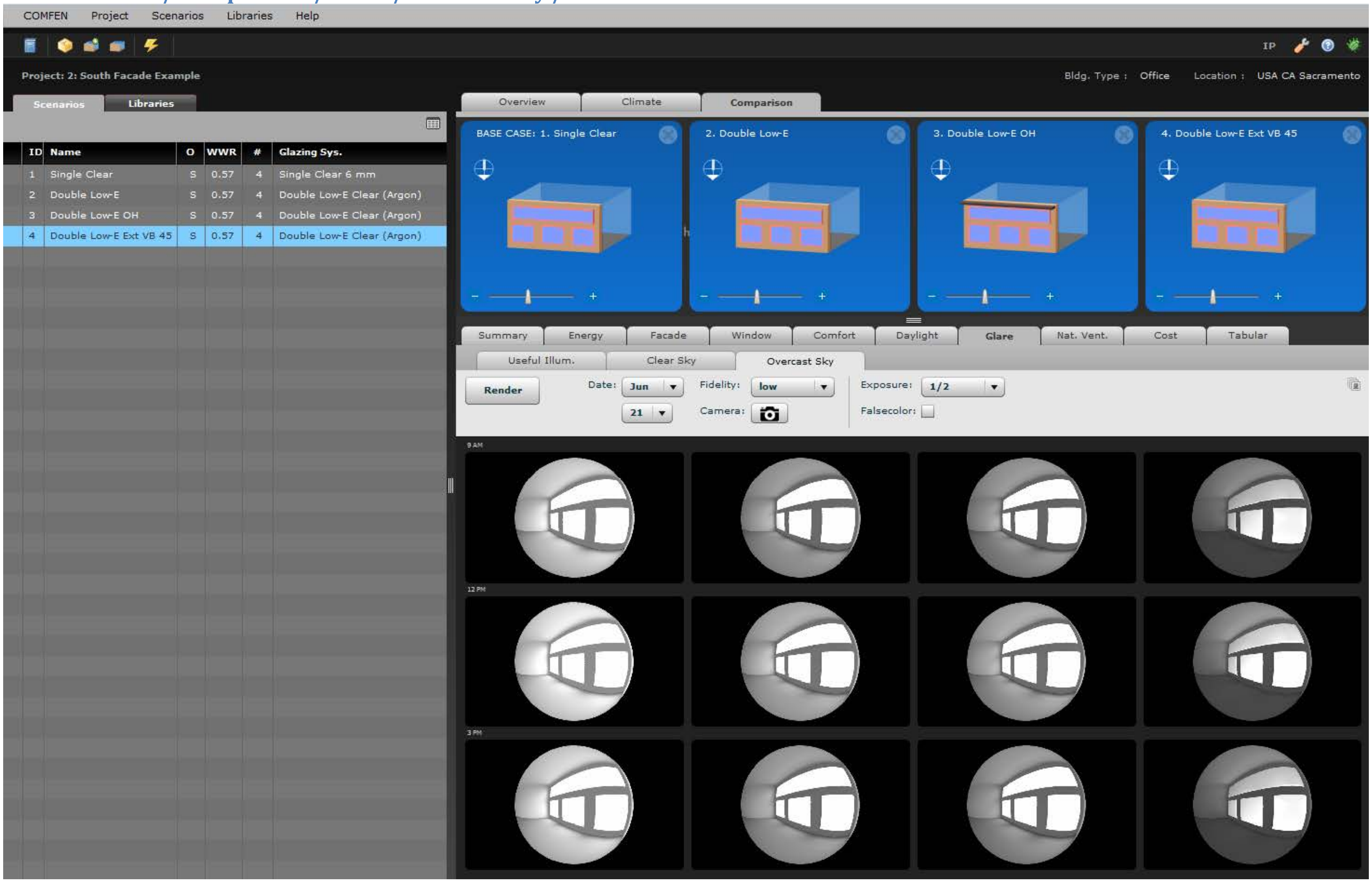
1.1.66 Results / Comparison / Glare / Clear Sky / False Color



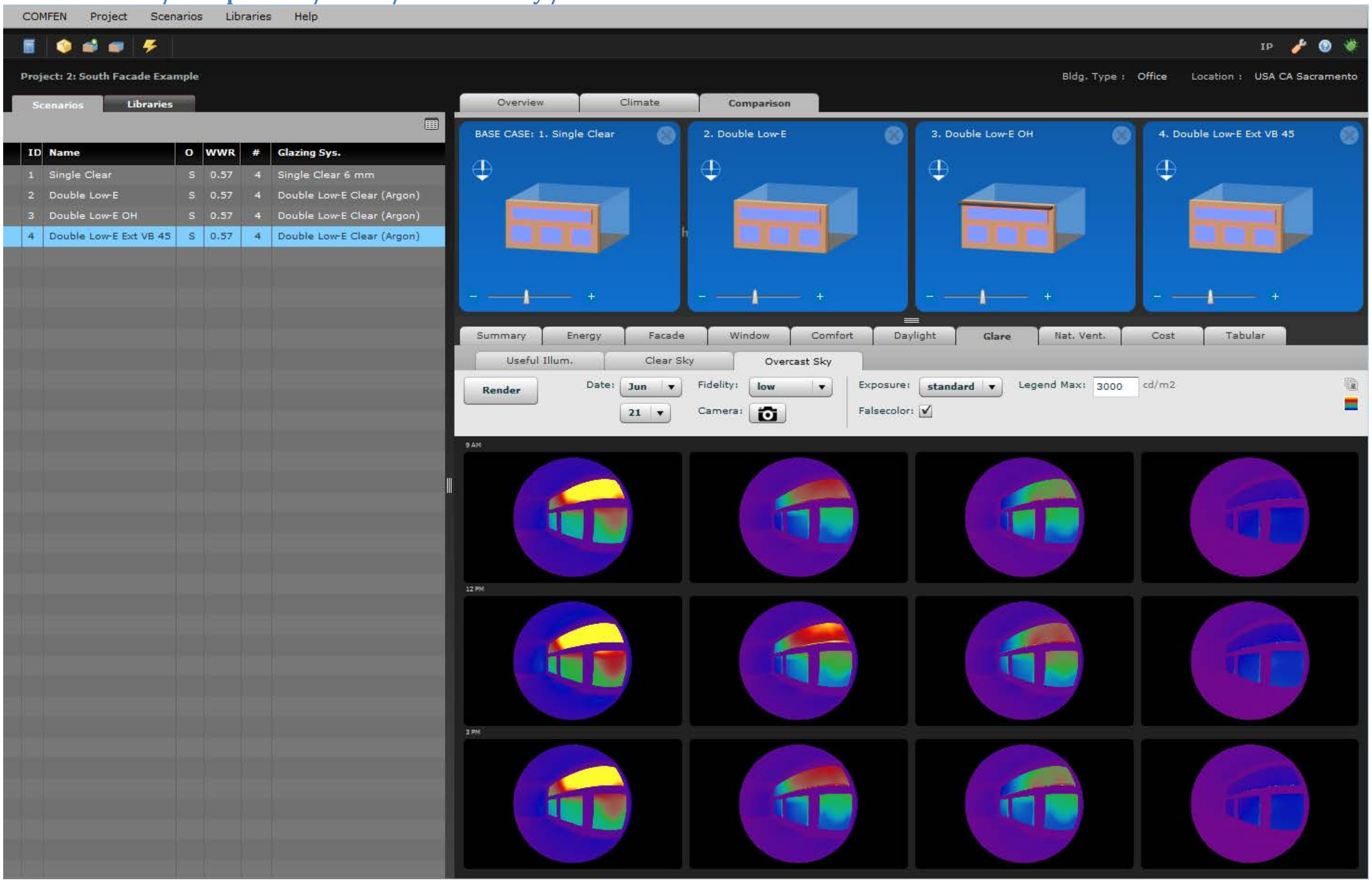
1.1.67 Results / Comparison / Glare / Clear Sky / Camera Angle Adjustment



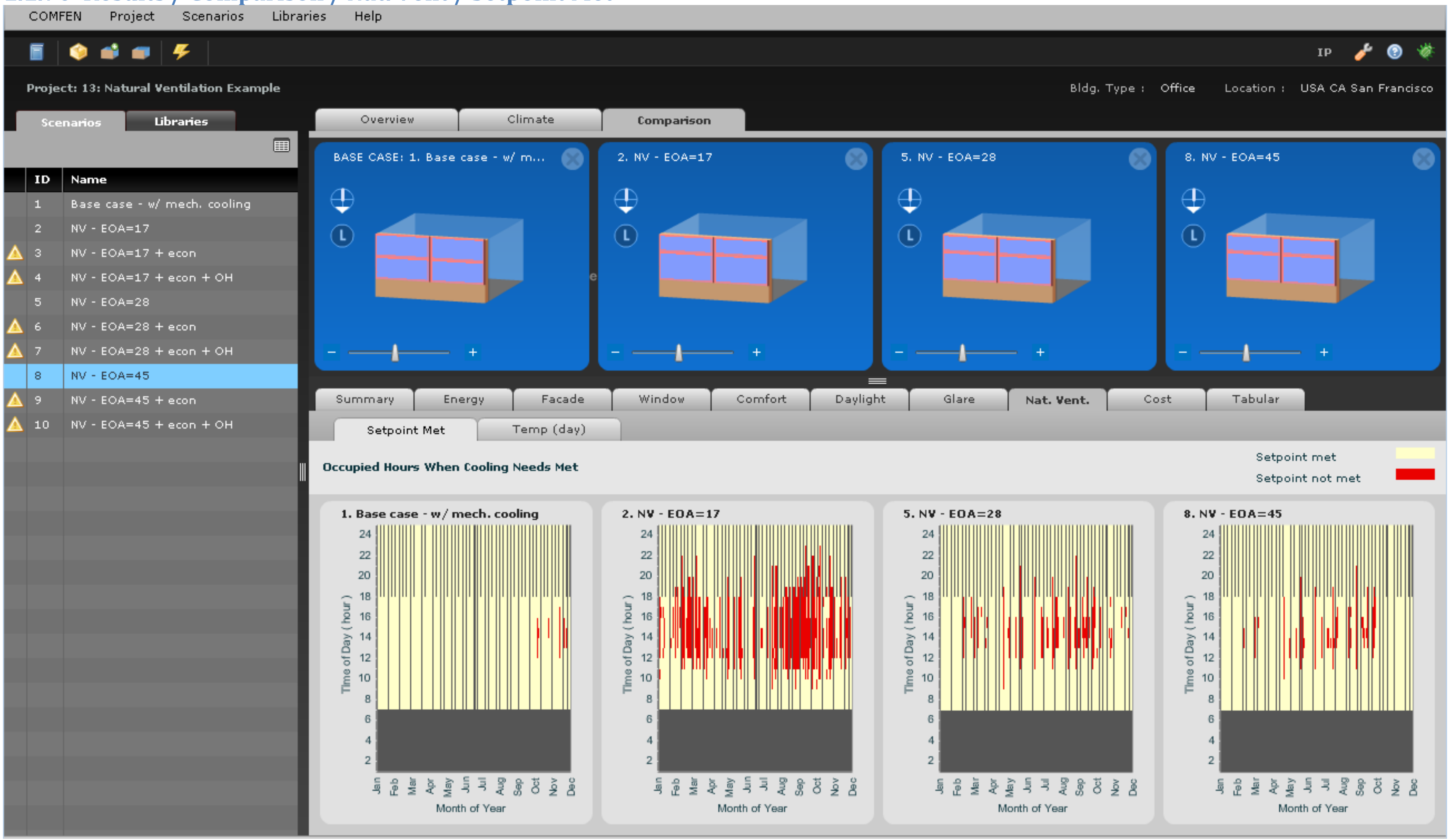
1.1.68 Results / Comparison / Glare / Overcast Sky / Black and White



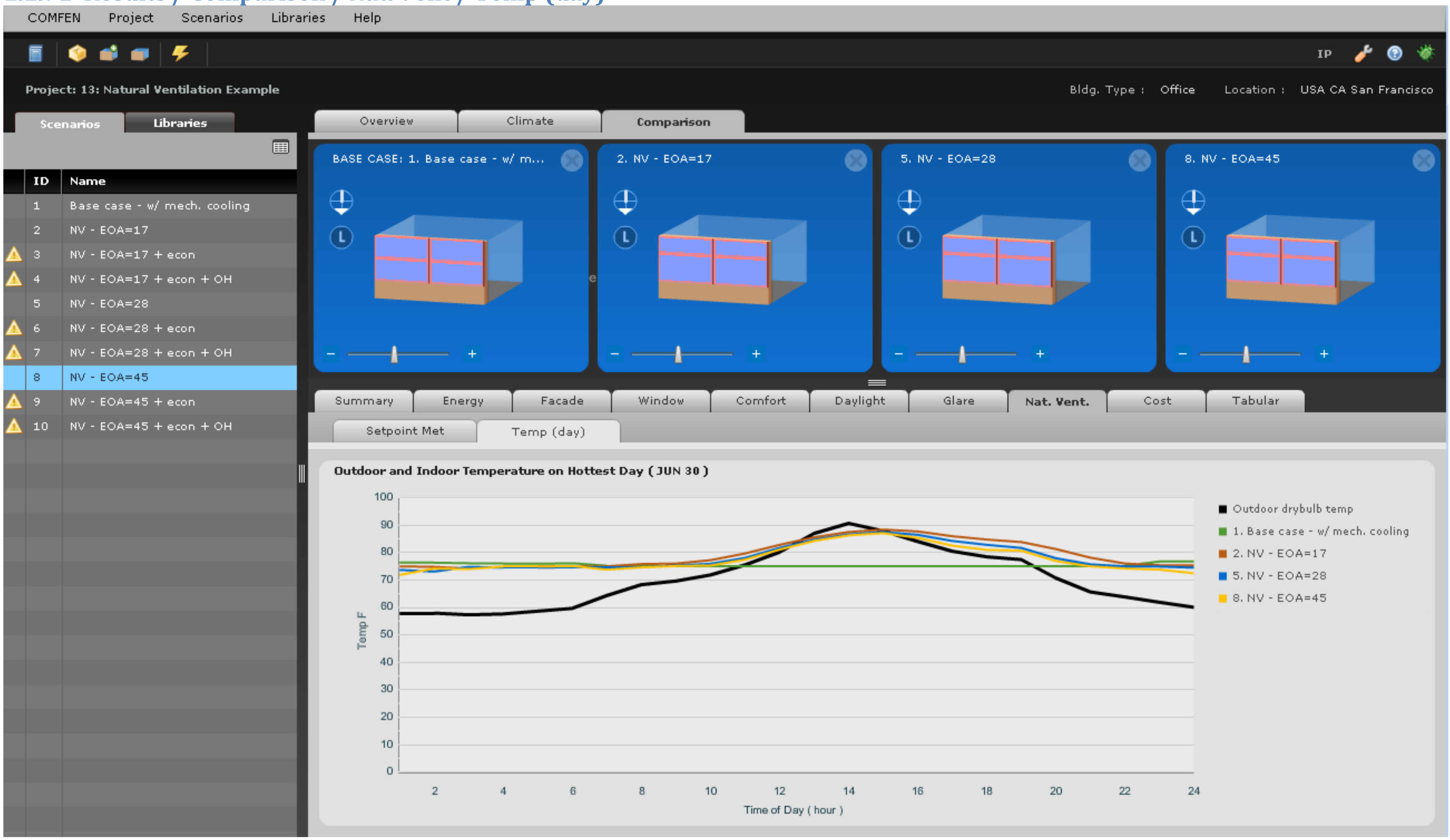
1.1.69 Results / Comparison / Glare / Overcast Sky / False Color



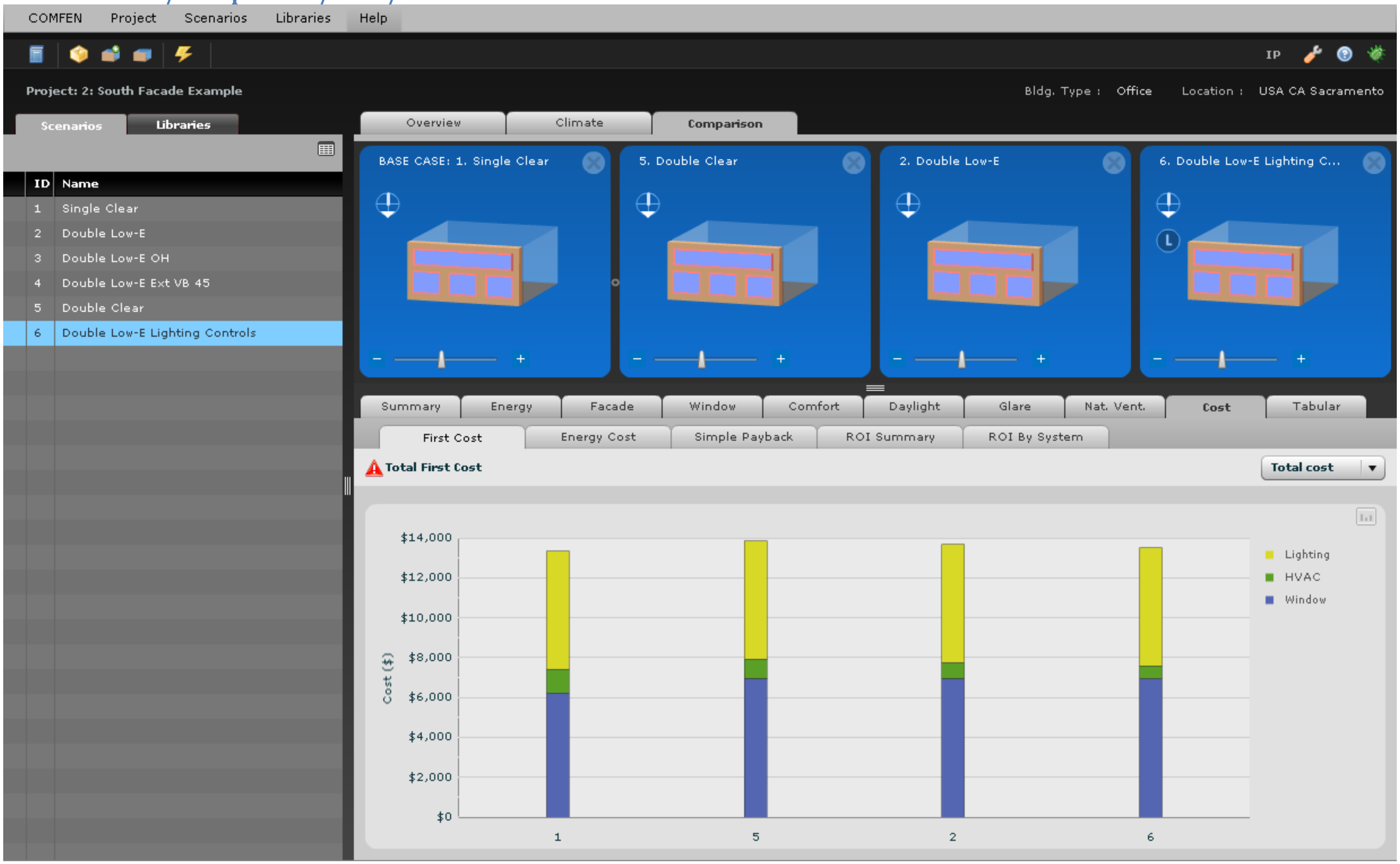
1.1.70 Results / Comparison / Nat. Vent / Setpoint Met



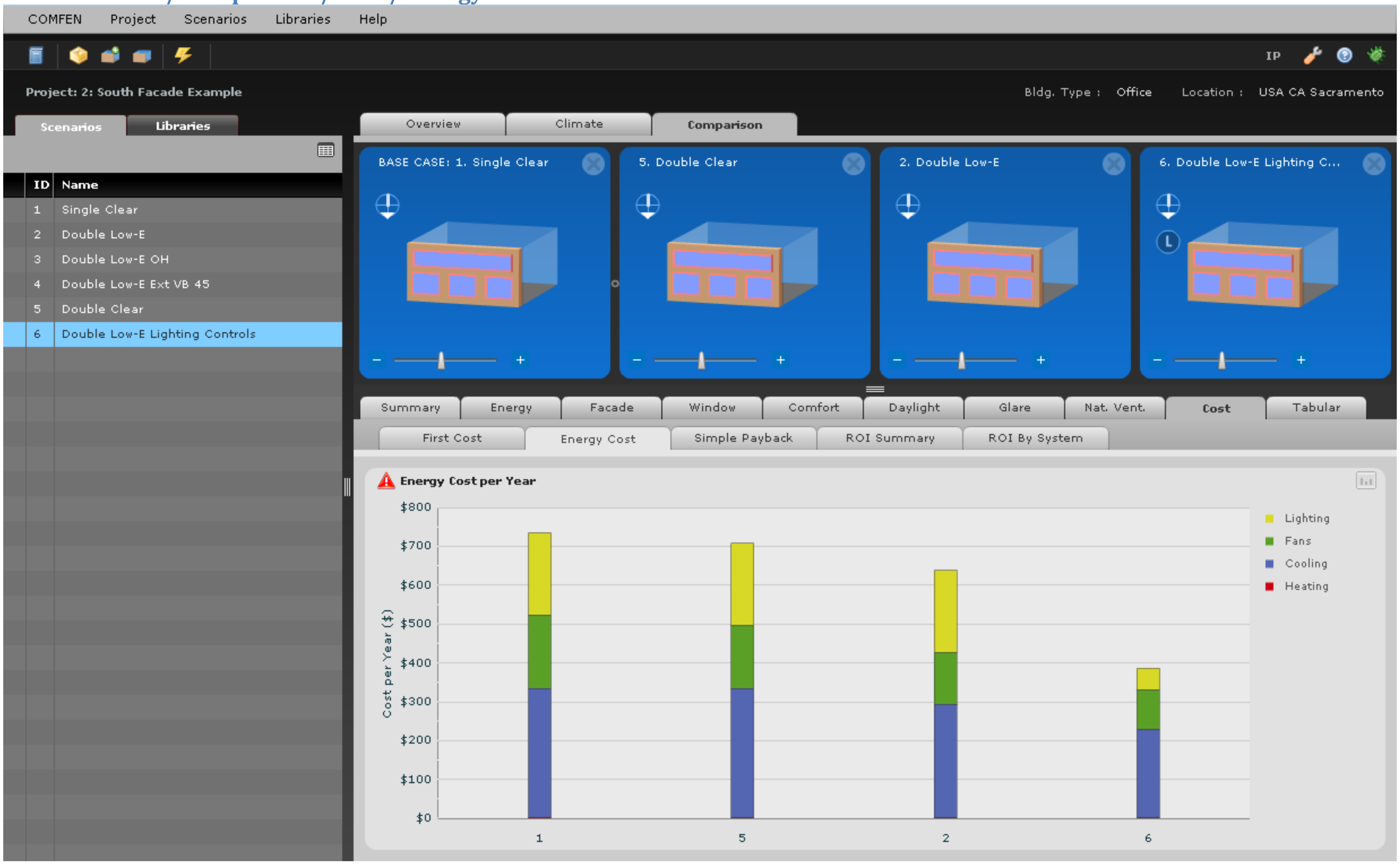
1.1.71 Results / Comparison / Nat. Vent / Temp (day)



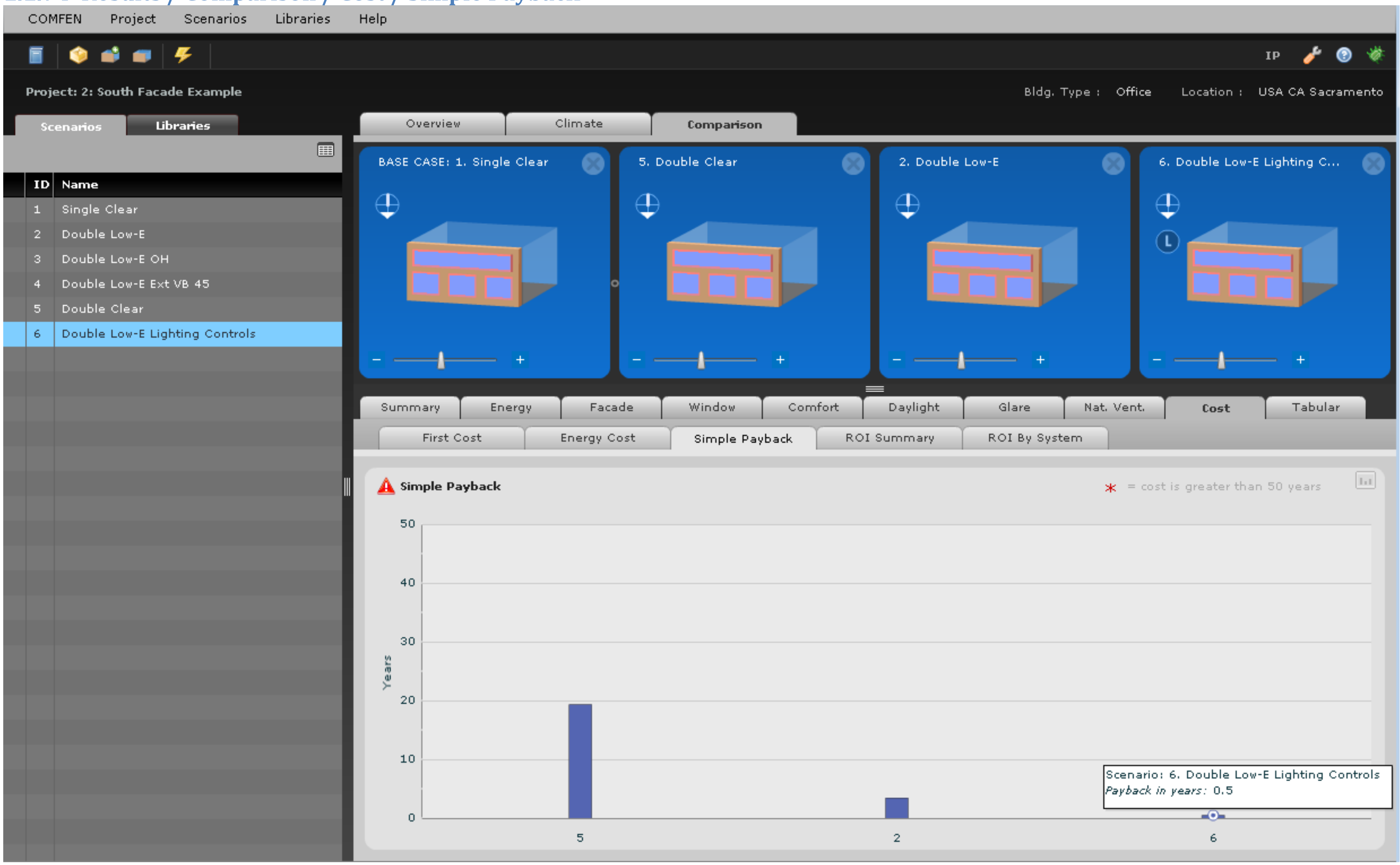
1.1.72 Results / Comparison / Cost / First Cost



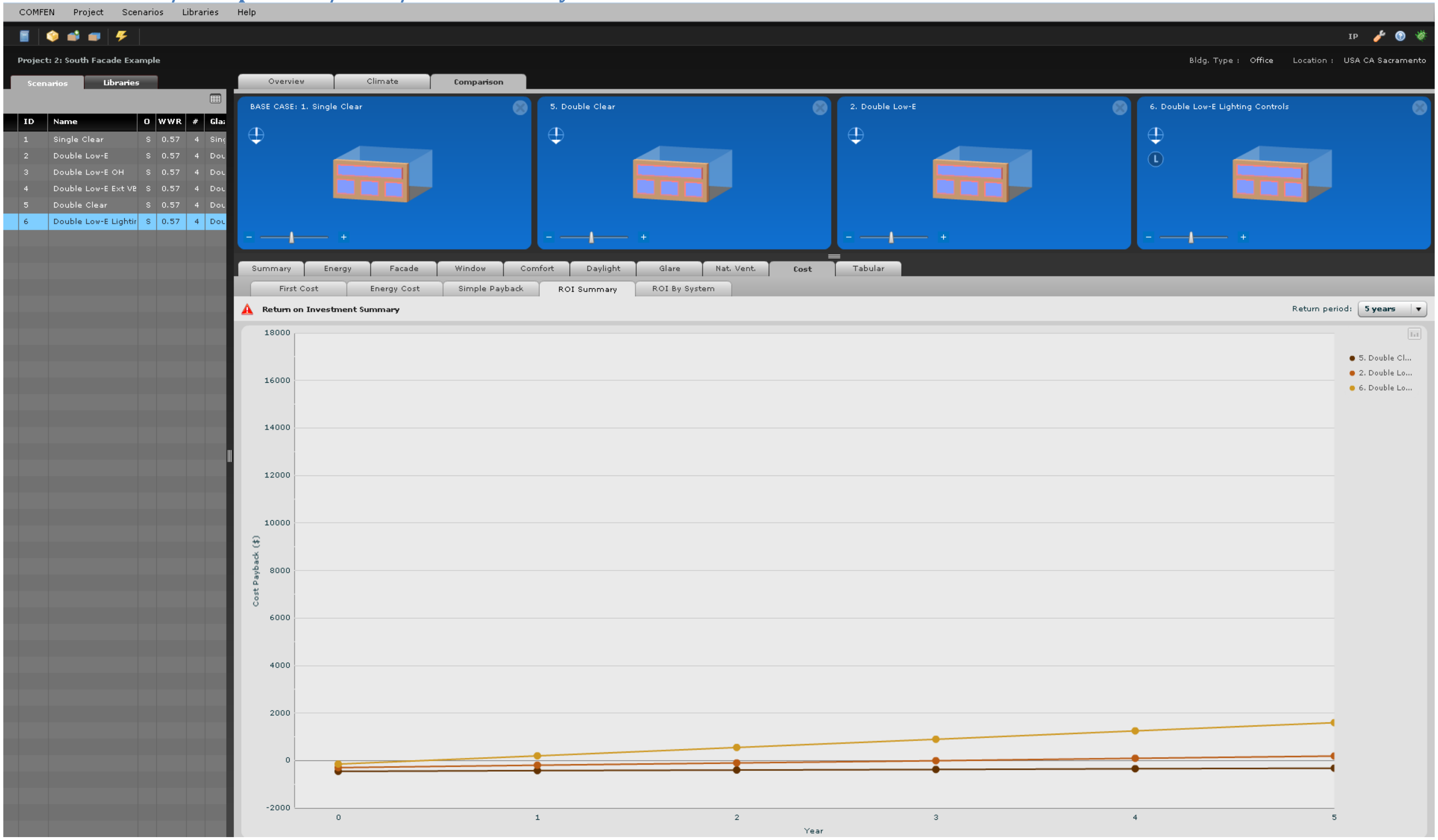
1.1.73 Results / Comparison / Cost / Energy Cost



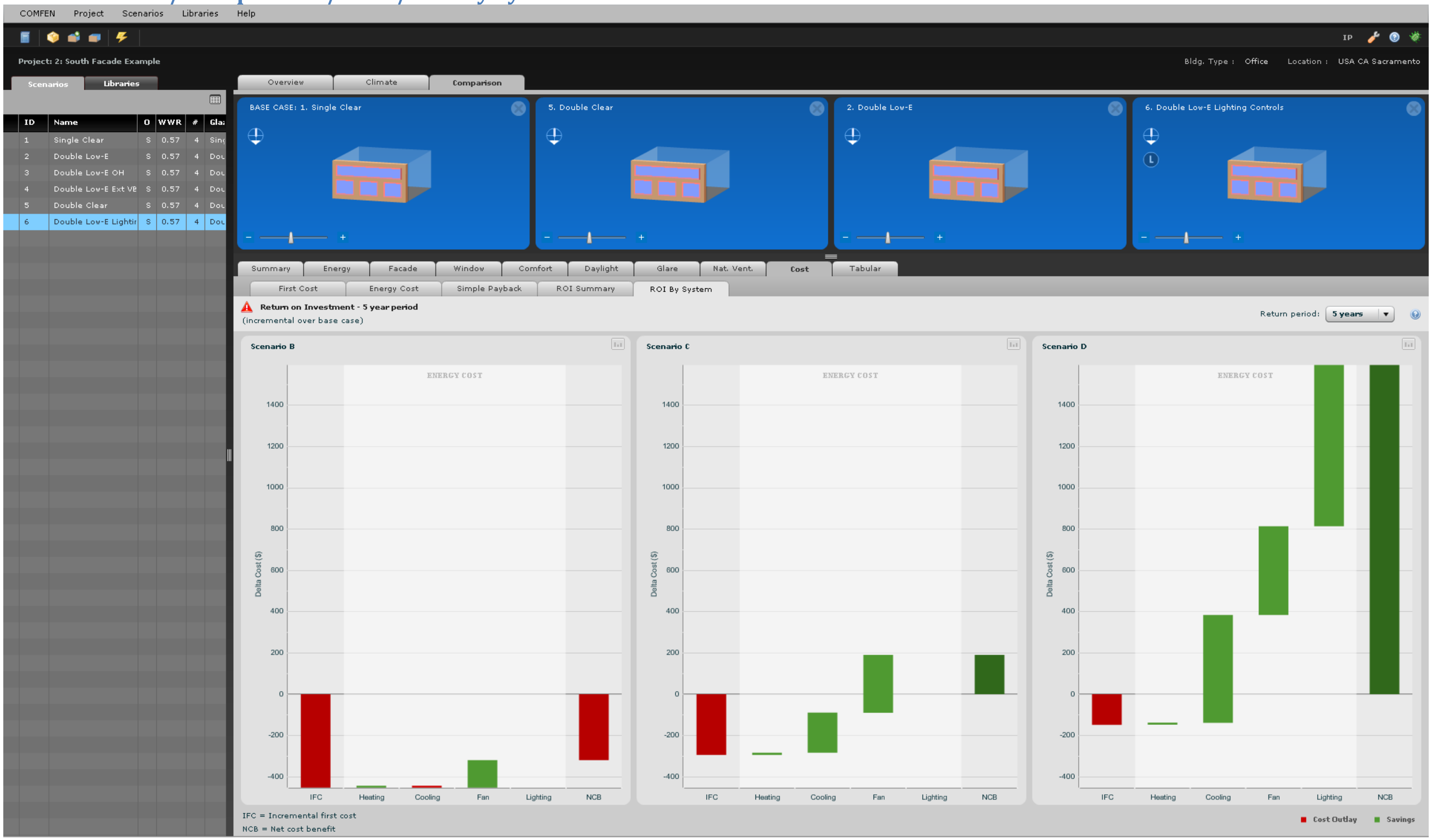
1.1.74 Results / Comparison / Cost / Simple Payback



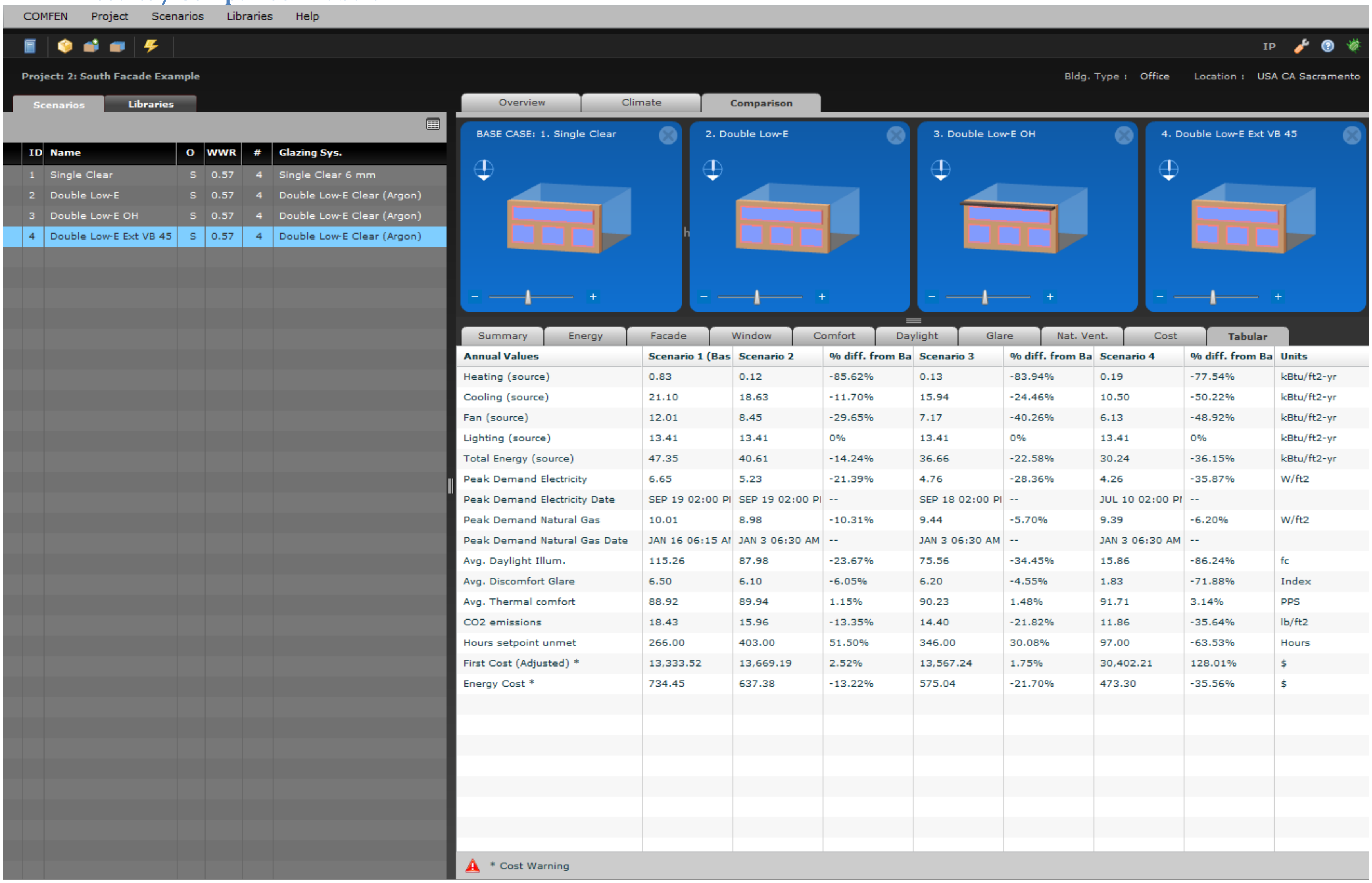
1.1.75 Results / Comparison / Cost / ROI Summary



1.1.76 Results / Comparison / Cost / ROI By System

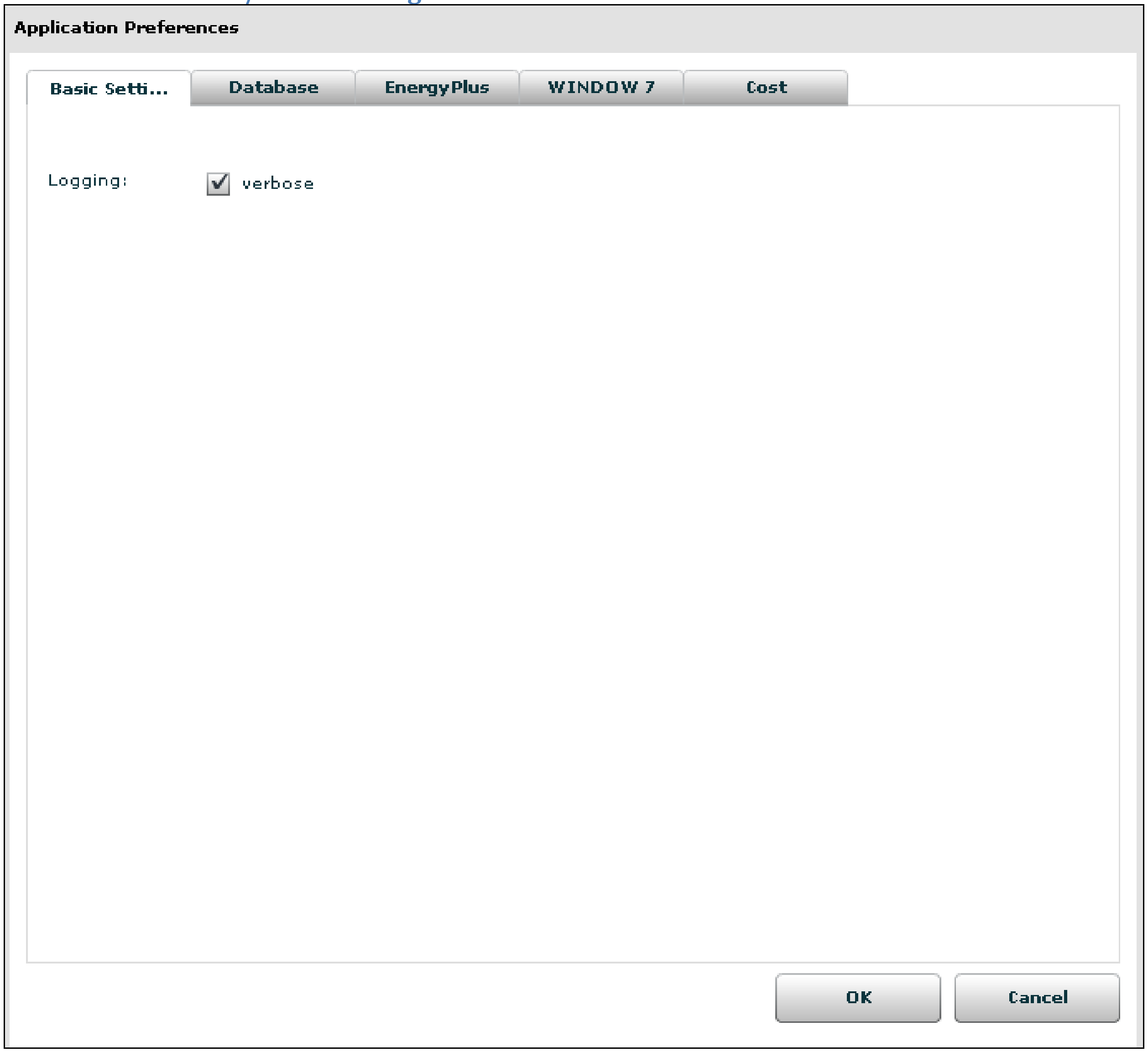


1.1.77 Results / Comparison Tabular

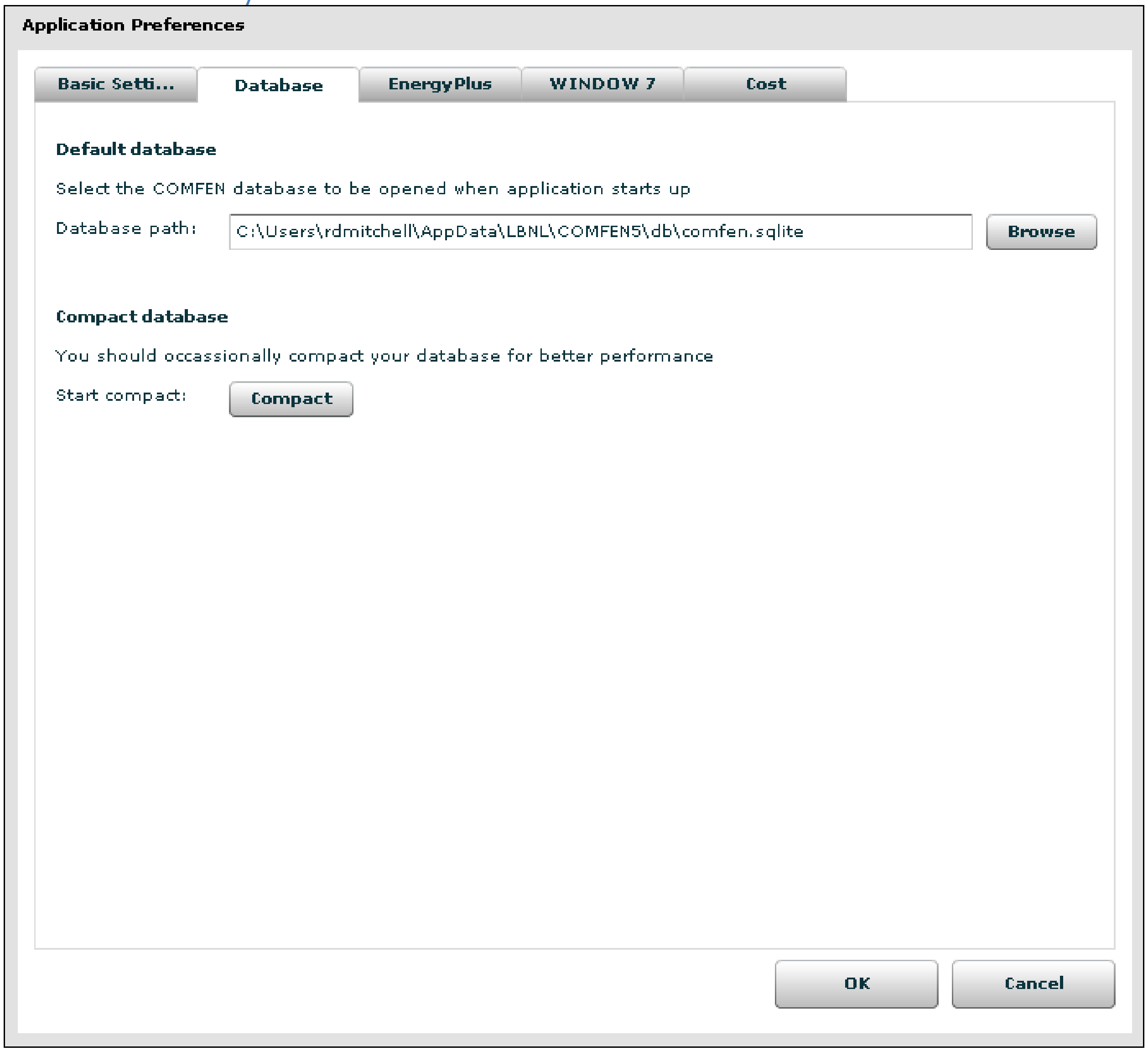


Annual Values	Scenario 1 (Bas	Scenario 2	% diff. from Ba	Scenario 3	% diff. from Ba	Scenario 4	% diff. from Ba	Units
Heating (source)	0.83	0.12	-85.62%	0.13	-83.94%	0.19	-77.54%	kBtu/ft2-yr
Cooling (source)	21.10	18.63	-11.70%	15.94	-24.46%	10.50	-50.22%	kBtu/ft2-yr
Fan (source)	12.01	8.45	-29.65%	7.17	-40.26%	6.13	-48.92%	kBtu/ft2-yr
Lighting (source)	13.41	13.41	0%	13.41	0%	13.41	0%	kBtu/ft2-yr
Total Energy (source)	47.35	40.61	-14.24%	36.66	-22.58%	30.24	-36.15%	kBtu/ft2-yr
Peak Demand Electricity	6.65	5.23	-21.39%	4.76	-28.36%	4.26	-35.87%	W/ft2
Peak Demand Electricity Date	SEP 19 02:00 PI	SEP 19 02:00 PI	--	SEP 18 02:00 PI	--	JUL 10 02:00 PI	--	
Peak Demand Natural Gas	10.01	8.98	-10.31%	9.44	-5.70%	9.39	-6.20%	W/ft2
Peak Demand Natural Gas Date	JAN 16 06:15 AI	JAN 3 06:30 AM	--	JAN 3 06:30 AM	--	JAN 3 06:30 AM	--	
Avg. Daylight Illum.	115.26	87.98	-23.67%	75.56	-34.45%	15.86	-86.24%	fc
Avg. Discomfort Glare	6.50	6.10	-6.05%	6.20	-4.55%	1.83	-71.88%	Index
Avg. Thermal comfort	88.92	89.94	1.15%	90.23	1.48%	91.71	3.14%	PPS
CO2 emissions	18.43	15.96	-13.35%	14.40	-21.82%	11.86	-35.64%	lb/ft2
Hours setpoint unmet	266.00	403.00	51.50%	346.00	30.08%	97.00	-63.53%	Hours
First Cost (Adjusted) *	13,333.52	13,669.19	2.52%	13,567.24	1.75%	30,402.21	128.01%	$
Energy Cost *	734.45	637.38	-13.22%	575.04	-21.70%	473.30	-35.56%	$

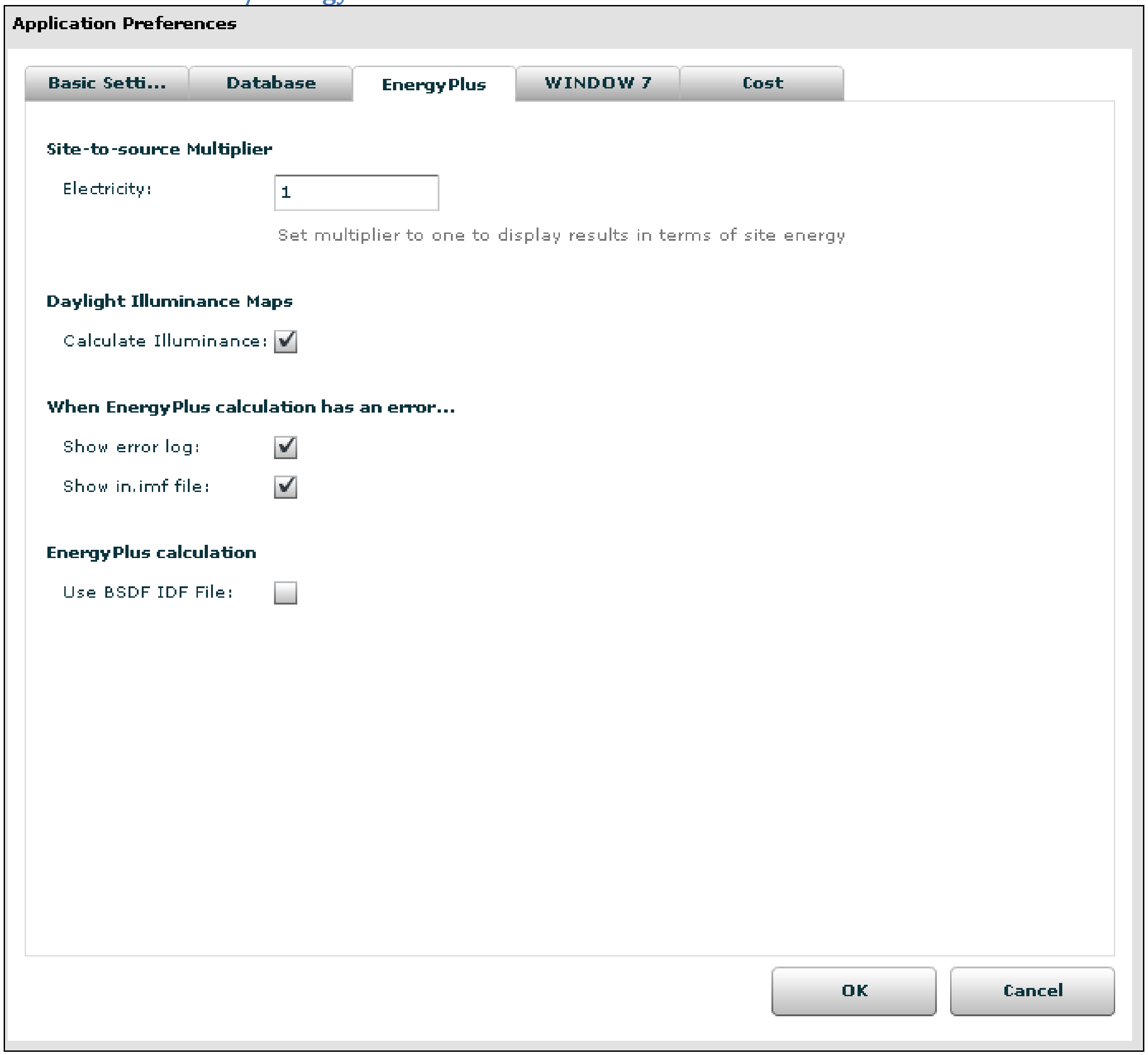
1.1.78 Preferences / Basic Settings



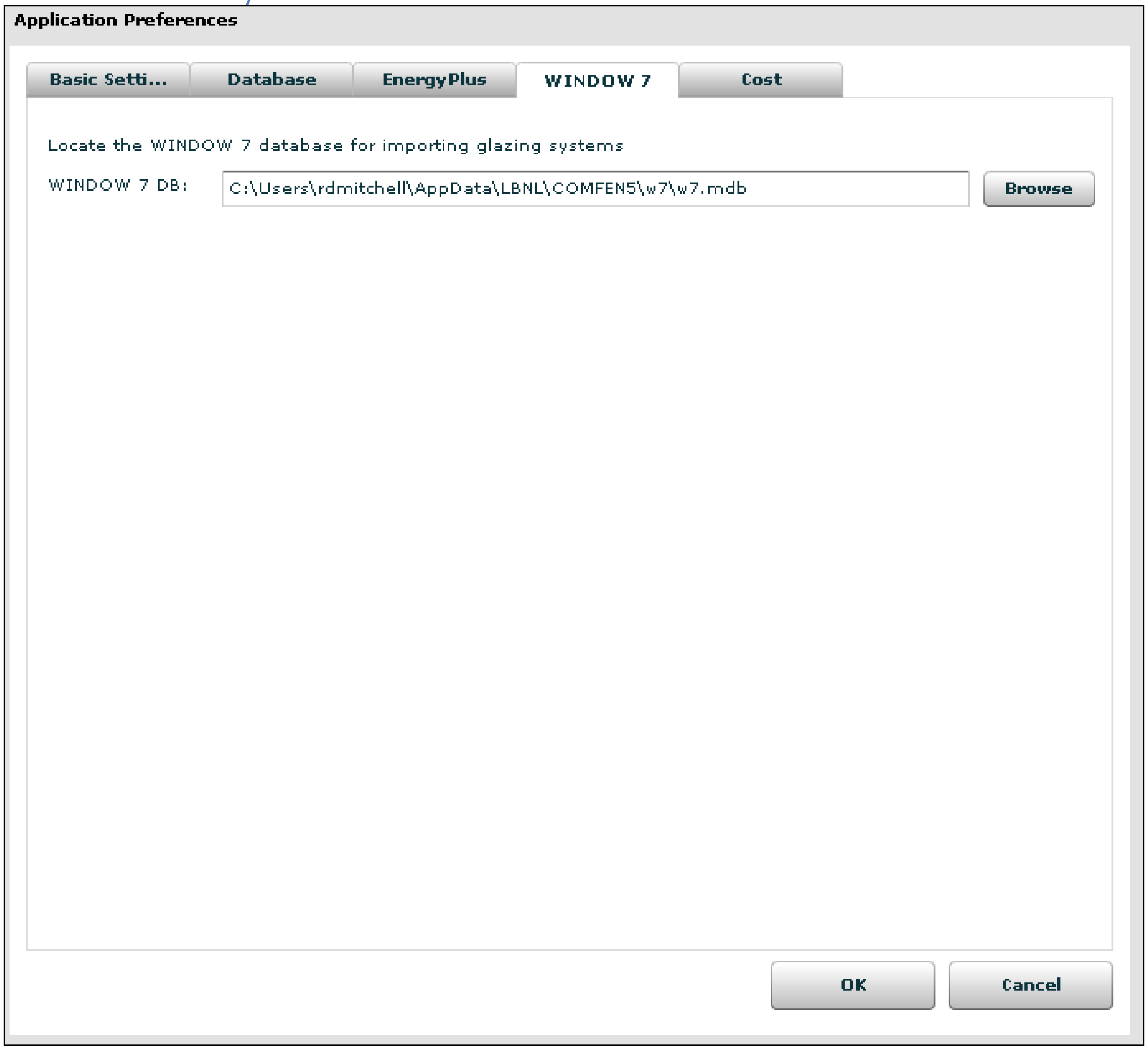
1.1.79 Preferences / Database



1.1.80 Preferences / Energy Plus



1.1.81 Preferences / WINDOW 7



1.1.82 Preferences / Cost