COMFEN
A COMMERCIAL FENESTRATION/FAÇADE DESIGN TOOL

Robert J. Hitchcock[1], Robin Mitchell[1], Mehry Yazdanian[1], Eleanor Lee[1] and Charlie Huizenga[2]
[1]Lawrence Berkeley National Laboratory, Building Technologies Department, Berkeley, CA
[2]University of California, Center for the Built Environment, Berkeley, CA

ABSTRACT

COMFEN is a new tool intended to promote 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. COMFEN version 1.0 provides a simple user interface that focuses attention on key variables in fenestration design. EnergyPlus simulates the effects of these variables on energy consumption, peak energy demand, and thermal and visual comfort. Results are presented in graphical and tabular format to help users move toward optimal fenestration design choices for their project. This paper discusses the objectives in developing COMFEN, the implementation methods used, and plans for future development.

INTRODUCTION

Today's energy-efficient windows can dramatically lower the heating and cooling costs associated with windows while increasing occupant comfort. However, consumers are often confused about how to pick the most efficient window design for a commercial building. Product information typically only offers window properties such as U-factors or R-values, Solar Heat Gain Coefficients or Shading Coefficients. However, the relative importance of these properties depends on site- and building-specific conditions. Furthermore, these properties are based on static evaluation conditions that are very different from the real situation a window will be used in. The real situation includes not only dynamically varying exterior environmental conditions, but also the interactive effects of shading systems, lighting systems, and interior environmental conditions.

Moving toward a goal of net-zero energy buildings requires simulation-based tools that support dynamic analysis of integrated building systems with respect to a variety of performance impacts. The building envelope, and in particular its fenestration systems, must be optimally designed to minimize building loads while achieving desired visual and thermal comfort for building occupants.

COMFEN is a new tool intended to target the issues of high performance fenestration systems. COMFEN version 1.0 (v1.0) provides a simplified Excel™-based user interface that focuses attention on key variables in fenestration design. Under the hood is EnergyPlus (USDOE, 2008), a sophisticated analysis engine that dynamically simulates the effects of these key fenestration variables on energy consumption, peak energy demand, and thermal and visual comfort. The results from the EnergyPlus simulation are presented in graphical and tabular format within the simplified user interface for up to four comparative fenestration design cases to help users move toward optimal fenestration design choices for their project.

BACKGROUND

There are several existing tools with similar objectives and features to COMFEN including EFEN (DesignBuilder, 2008), Daylight1-2-3 (NRC, 2008), SPOT (AEC, 2008), and the MIT Design Advisor (MIT, 2008). EFEN is a tool for evaluating fenestration options in commercial buildings. EFEN uses EnergyPlus and is designed as a user friendly program for quick analysis of fenestration options in early design including whole-building energy use and HVAC equipment sizing predictions. EFEN has a wide variety of sophisticated features and is intended for use by the fenestration industry, code officials, engineers, architects, utilities, and academia. Daylight 1-2-3 (formerly Lightswitch Wizard) predicts the daylighting and energy performance of fenestration options in commercial buildings. The tool is targeted to design professionals with an interest in climate-responsive daylighting design concepts, but without expert knowledge in this area. Daylight 1-2-3 analysis is based on RADIANCE (Ward, 2008) and ESP-r (ESRU, 2008). Daylight 1-2-3 includes an intuitive graphical user interface, 3D presentations of key daylight performance metrics, and monthly charts of energy use and peak load for heating, lighting and cooling. SPOT™ (Sensor Placement and Optimization Tool) is intended to assist a designer in quantifying electric lighting and daylighting characteristics within a lighting zone and identifying the optimal photosensor placement for annual performance and energy savings. SPOT™ is targeted at classroom daylighting, but can be used for all types of spaces. The SPOT™ user interface is Excel and the underlying analysis is based on RADIANCE. The MIT Design Advisor is targeted at building designers to improve occupant comfort and energy performance at the conceptual design stage. The MIT Design Advisor supports quick building input and annual energy simulation without technical experience. The MIT Design Advisor uses independently developed daylight and thermal simulation modules that have been validated against industry-accepted standards. The MIT Design Advisor also includes an optimization module.

The MIT Design Advisor and Daylight 1-2-3 are web-based tools. EFEN and SPOT are desktop applications. SPOT focuses on daylighting only, the other three tools analyze both daylighting and thermal aspects of a building. EFEN, the MIT Design Advisor, and Daylight 1-2-3 are targeted to early conceptual design.

Each of these other tools offer features similar to, and some features not available in, COMFEN. COMFEN is currently in its preliminary development, with longer term development plans to extend its usefulness and capabilities without losing its focus (see below).

COMFEN is intended to clearly focus user attention on a limited set of variables specific to façade fenestration design. Some of the above tools offer additional user controlled input (e.g., HVAC type, more complex building form, opaque envelope variations, etc.), and therefore additional analysis variables, beyond COMFEN's focus on comparative analysis of only fenestration alternatives.

At the same time that COMFEN is meant to limit the range of non-fenestration user controlled variables, it is intended to provide rich user control over fenestration-specific variables. Some of the above tools are limited in user control over fenestration variables offering a single glazing system type selection per façade, or limited shading control and frame type options. While COMFEN v1.0 has similar limitations, development plans for later versions of COMFEN, already under implementation, will remove these limitations. The intent is to provide direct links to the most sophisticated fenestration analysis options available through today's simulation tools.

COMFEN OBJECTIVES AND AUDIENCE

The overall objective of COMFEN is 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.

A clear identification of the intended audience of a software tool is critical to identifying and constraining the appropriate functionality of the tool. There may be more than one target audience, with a tailored version of the tool directed to each. Identifying the target audience(s), and clearly defining their needs, helps determine the feature requirements for each version.

One primary audience of COMFEN is architects during early design. This audience is key to designing high performance fenestration systems. Many early design decisions focus on the exterior façade of the building. Aesthetic considerations may be foremost in this decision-making, so it is critical to introduce easy, yet sophisticated, evaluation of design choices with respect to their energy and occupant comfort impacts. What are the impacts of varying opaque and glazed proportions of the façade? What types of glazing are appropriate to meet aesthetic, energy, and occupant comfort goals? What shading devices, if any, are appropriate? Should controllable shading devices be employed to assure occupant visual and thermal comfort? These questions are not intuitively answerable without sophisticated analysis of their interactive impacts. And yet, the early design team does not generally have the resources to undertake this type of sophisticated analysis.

To address this situation, COMFEN must have three high-level features. First, an easy to learn and use interface must focus user attention on the relevant façade design choices, and provide the means to vary these choices within the options available to the project at hand. Second, a sophisticated simulation engine must be hidden from view while being used to analyze the interactive impacts of project-specific design choices. Third, the results of the analysis must be displayed to the user in readily interpretable format to facilitate easy evaluation of the selected design alternatives.

A second primary audience of COMFEN is fenestration manufacturer representatives. This audience is key to promoting the deployment of high performance fenestration components and systems. The high-level features of COMFEN that are needed to address this audience are similar to those above. However, the tool must additionally provide access to emerging fenestration products, and have the ability to analyze these products. The main objective of COMFEN in this respect is to accurately analyze new complex fenestration products in an unbiased manner so that those products that enhance the overall performance of fenestration systems can be promoted to consumers.

These two audiences are focused on the relative impacts of variations in fenestration products and systems. They are most likely less interested in other details of the overall building such as complex space and building geometry, high specificity in opaque materials and construction types, internal loads and scheduling, and HVAC equipment and systems. To minimize the complexity of COMFEN for these users, most non-fenestration details are defaulted and held constant to isolate the relative impacts of fenestration-related details.

Secondary potential audiences for COMFEN include design team members during detailed design, and commercial builders. An important additional feature of COMFEN for these audiences is the ability to access and modify the more detailed types of building information than was available in early design, such as those mentioned above.

COMFEN VERSION 1.0

COMFEN v1.0 was designed as an example tool targeting the two primary audience applications of early design and product promotion. To focus user attention on fenestration variations while minimizing attention to other building details, analysis projects are based on comparative analysis of individual room (thermal zone) modules. Each module consists of a single exterior façade wall attached to an interior rectangular thermal zone served by a packaged single zone HVAC system that is properly sized for each façade module. Up to four such modules can be included in an analysis project to compare variations in their façade walls.

This comparative module approach is central to the intent of COMFEN v1.0. Eliminating the effects of interactive variations in whole-building designs (e.g., thermal exchange between adjacent thermal zones and varying HVAC components and systems) highlights relative impacts from façade variations. This approach is targeted to early design exploration. Later detailed design would need to consider whole-building issues as well.

Façade Library Input Screen

The COMFEN v1.0 user interface consists of two basic worksheets. The first of these worksheets is the Façade Library screen, shown in Figure 1. This screen supports the definition of new façade modules, and the viewing and editing of existing façade modules in the library. The Façade Layout portion of this screen presents two-dimensional elevation, plan, and section views of a façade wall. Up to four separate windows can be located and sized on each wall using the edit boxes at the bottom of this screen, and will be displayed in the two-dimensional views. A different glazing system and frame type can be selected for each window. Rectangular overhangs and fins can be located and sized using the edit boxes on the right of the screen and will also be displayed in the 2-D views. The upper portion of this screen allows simple rectangular geometry and internal loads to be defined for the modular thermal zone attached to each façade wall.

COMFEN Project Input Screen

The second worksheet is the main Project screen, shown in Figure 2. Multiple projects can be created and stored in each copy of COMFEN. Each project is defined by a user name, location, building type, vintage, project orientation, and analysis run period. The project location identifies the weather data used for analysis. Building type is limited to small office in COMFEN v1.0, but will be extended in future versions (see Future Development Plans below). Vintage is limited to new ASHRAE 90.1-2004, but may also be extended in the future. Project orientation allows the user to rotate the complete set of comparative module cases.

Each project consists of up to four comparative module cases that are selected in the Façade Design Comparison portion of the Project screen. For each case, the user selects a Façade Design Name from the Façade Library. Each case can be individually oriented and daylighting controls can be set to none, continuous, or stepped. Using this approach, the user can explore a range of façade design issues. What are the relative impacts of changing orientation for the same façade design? What are the relative impacts of various window configurations, glazing systems, frames, shading surfaces, and daylighting control options?

COMFEN Project Analysis and Output

Having selected a set of comparative cases, the user clicks on the *Calculate* button to perform an analysis. An EnergyPlus input data file is automatically generated and simulated, and the results are retrieved for graphical and tabular display. Details of this automated process are given in the following section.

The top section of the Results portion of the Project screen displays bar charts comparing all cases with respect to annual energy consumption (heating, cooling, fans, and lighting), peak energy, and CO_2 emissions. Lower portions of this screen (not shown) display tabular comparisons of average daylight illuminance, discomfort glare, and thermal comfort, and bar charts of monthly energy use and peak energy, and percent thermal comfort distributions. Still more detailed charts of hourly daylight illuminance and discomfort glare, and thermal comfort distributions are also accessible.

IMPLEMENTATION METHODS

COMFEN User Interface

As discussed above, COMFEN v1.0 has been developed within the Microsoft Excel™ environment, to provide a simplified user interface for input and graphical display of output. Excel is a familiar environment for many potential users and provides built-in capabilities for organizing user input and graphically displaying analysis results. The Visual Basic macro programming facilities within Excel have been used to customize input and output display features described in the previous section.

Links to EnergyPlus

Links to EnergyPlus as the analysis engine make use of both Excel and EnergyPlus macro capabilities. A number of hidden worksheets within the Excel spreadsheet are used for calculating and storing parameter values required for the EnergyPlus input models. For example, the geometry of the façade walls and other zone surfaces for each façade module are calculated on hidden worksheets from user input on the Façade Library worksheet. This geometry is then passed to parameterized include files (i.e., pre-defined ASCII files with EnergyPlus macros) to generate an EnergyPlus input macro file (IMF). Similarly, input related to selected glazing systems, frames, shading surfaces, daylighting options, and location are passed from Excel worksheets to EnergyPlus as part of the generated IMF for a particular COMFEN Project set of comparative cases.

An Excel macro script is then used to set up and execute a batch file that manages an EnergyPlus simulation run for the current COMFEN project. Following successful completion of the simulation run, the EnergyPlus output results are processed using another batch file. These results are then automatically imported into the spreadsheet to populate other hidden worksheets, and displayed on the user-viewable worksheets in graphs and tables. To avoid ballooning the Excel file size beyond limits, only the most recently simulated COMFEN project results are stored in the spreadsheet. At this time, to compare results from multiple projects, separate copies of the COMFEN spreadsheet must be created.

FUTURE DEVELOPMENT PLANS

COMFEN v1.0 was developed to be both a useful tool as it stands and a concept demonstration to elicit user feedback for future development. There are a number of limitations in the current version. Available glazing system and frame type selections are limited to non-extendable lists. Available project locations are limited to a non-extendable weather library. Dynamic shading options are not currently available. Internal load and schedule defaults are currently implemented only for small office buildings and are not user customizable.

Plans for future development and enhancement of COMFEN are being defined. Near-term enhancements are being identified from early user feedback and will be implemented with currently available resources. Longer term development plans are also being defined.

Near Term Enhancement Plans

In the near term, we plan to enhance COMFEN by adding richer and more flexible selections of glazing systems, frame types, and shading options. Links to the International Glazing Database (IGDB 2007) will be implemented to support user-defined glazing systems built from the over 2300 glazing products currently in the IGDB. These glazing systems will be input to EnergyPlus as material layer objects using full spectral data sets to maximize analysis accuracy. Additional frame types will be added to support the exploration of very high-performance window systems using highly insulated frames. A more flexible method of adding new locations (i.e., weather and design data) will be implemented. The ability to select a variety of shading options such as venetian blinds or translucent shades, located inside, outside, or between layers of each window will be added. This will include the ability to select from a variety of shading control options (e.g., based on exterior incident solar or interior daylight illuminance levels).

As these enhancements are being implemented, we also plan to improve the separation of the methods for EnergyPlus input generation and results extraction so that they are not so tightly wedded to the Excel environment. We will also look into separate data visualization and project data archival methods. These enhancements are intended to improve the maintainability of the overall program, and to support longer term development outside of the Excel environment.

Longer Term Development Plans

Development plans for COMFEN over the longer term include changing the development and user interface environment, adding more complex fenestration system options, and addressing more detailed design requirements.

Alternative user interface environments will be evaluated for improving the flexibility of user input. For example, Google SketchUp™ provides an easy to learn and use environment for inputting building façade geometry, and potentially for selecting fenestration products (e.g., windows, blinds, shades) from online catalogs (e.g., see SpecifiCAD™ 2008).

A more CAD-like user environment could also provide the ability to carry forward modular façade designs to the whole-building detailed design phase. Façade walls or complete modules could be duplicated and built up into buildings, adding additional geometric detail at the same time.

Account for HVAC system right-sizing for façade variations

The next generation of energy-saving and energy-producing window technologies will be characterized with detailed bidirectional scattering (i.e., transmitting and reflecting) distribution properties. As the ability to analyze these more optically complex glazing and shading materials becomes more widely available in tools such as WINDOW (2007) and EnergyPlus, this ability will be added to COMFEN. Very high performance fenestration systems of the future, necessary to achieve net-zero energy buildings, will likely require the use of these optically complex non-specular materials. Selecting amongst these new window technologies in an optimal manner for a specific building project will require the type of tool that COMFEN has been designed to be.

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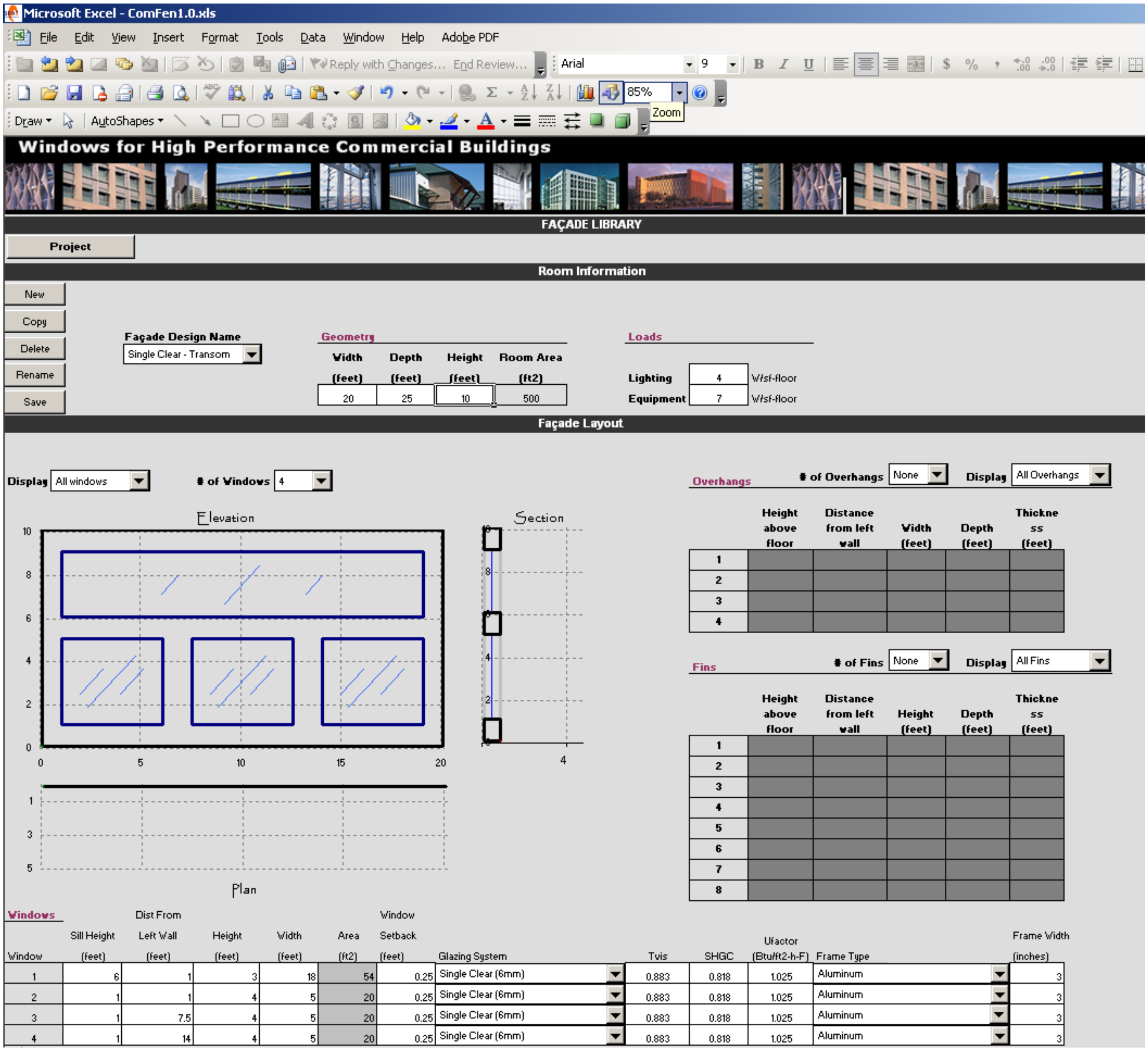

Figure 1 The COMFEN Façade Library screen allows definition of custom façade designs.

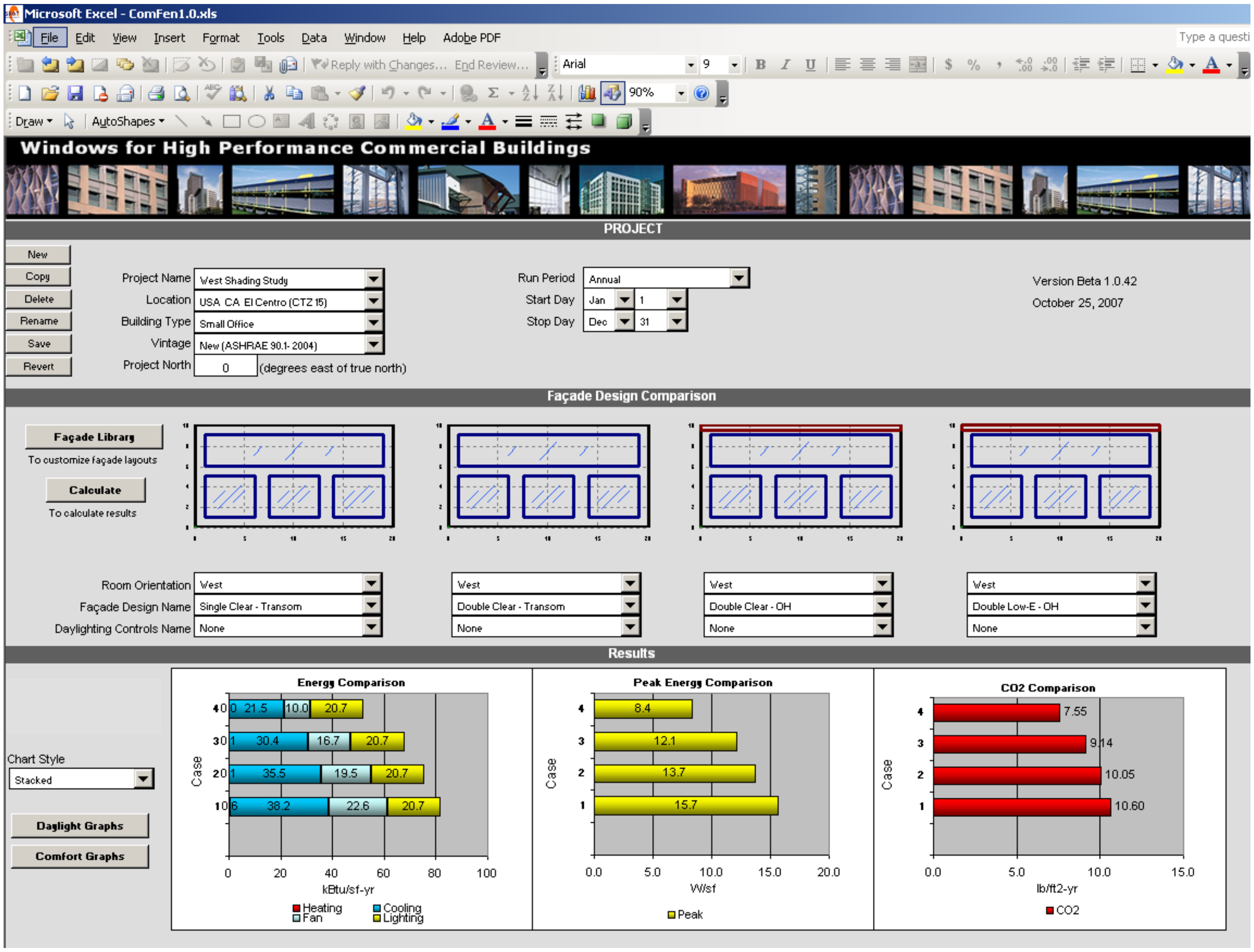

Figure 2 The COMFEN Project screen allows comparison of four different façade designs.