Design and Simulation Tools for Window System Energy Performance

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Efficient Windows Collaborative

The Efficient Windows Collaborative is a coalition of window, door, skylight, and component manufacturers, federal, state and local government agencies, research institutions, and others who partner to expand the market for energy efficient window products.

Lead Organizations

- Alliance to Save Energy
- University of Minnesota
- Lawrence Berkeley National Labs
- AZS Consulting
- 160+ Active industry members and affiliates

Acknowledgement and Disclaimer

Acknowledgement: This material is based upon work supported by the Department of Energy, National Energy Technology Laboratory under Award Number DE-FC26-06NT42766.

Why are Windows Important?


Photo: Pella Windows & Doors


Photo: PGT Industries


Photo: Velux-America

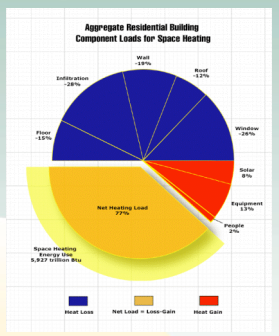

Photo: JELD-WEN


Photo: Associated Materials


Photo: Andersen Corporation

The Impact of Window Performance: A Simple Example

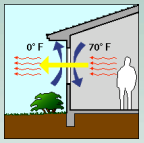
- Typical residential windows area: 1/6 of exterior wall area
- Heat loss per ft² of standard windows (R-2) is easily 6 times the heat loss per ft² of standard wall (R-13)
- With high-performance windows (R-3 to R-5), window heat loss can be cut in half. Similar to doubling wall R-value from 13 to 26.
- *There's more to window performance than heat loss…*

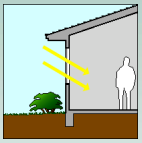


Source: U.S. Department of Energy

Window Energy Parameters

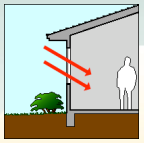
Heat Transfer
U-Factor

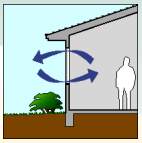




Daylight Access
Visible Transmittance (VT)

Solar Heat Gain
Solar Heat Gain Coefficient (SHGC)





Infiltration
Air Leakage (AL)

The Information Source for Window Energy Properties: The NFRC Label

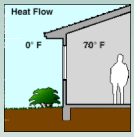
National Fenestration Rating Council

The National Fenestration Rating Council (NFRC) has established a voluntary national energy performance rating and labeling system for fenestration products.

NFRC ratings show the complete aggregated performance of the whole product, including:

- frame
- glazing
- spacer

U-Factor

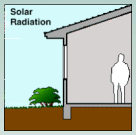


The rate of heat loss is indicated in terms of the U-factor (U-value) of a window assembly. The U-factor is the inverse of the R-value. The lower the U-factor, the greater a window's resistance to heat flow and the better its insulating value.

U-factor is the measure of the rate of non-solar heat loss or gain through a material or assembly. It is expressed in units of Btu/hr-sq ft-°F (W/sq m-°C).

A U-factor of 0.35 (whole window) or less is recommended in cold climates. In warm climates a low U-factor is helpful during hot days or whenever heating is needed, but it is less important than SHGC.

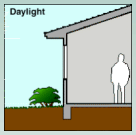
Solar Heat Gain Coefficient (SHGC)



The SHGC is the fraction of incident solar radiation admitted through a window, both directly transmitted and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.

A SHGC of 0.40 or less is recommended in warm climates. In heating-dominated climates, a high SHGC increases passive solar gain for heating, but reduces cooling season performance. A low SHGC improves cooling season performance, but reduces passive solar gain.

Visible Transmittance (VT)



The visible transmittance (VT) is an optical property that indicates the amount of visible light transmitted through the glass. VT is expressed as a number between 0 and 1. The higher the VT, the more daylight is transmitted.

A high VT is desirable to maximize daylight.

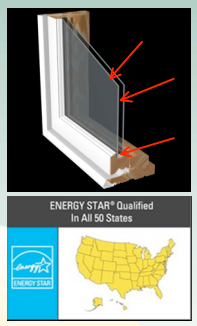
Air Leakage (AL)

Heat loss and gain occur by infiltration through cracks in the window assembly. It is indicated by an air leakage rating (AL) expressed as the equivalent cubic feet of air passing through a square foot of window area. The lower the AL, the less air will pass through cracks in the window assembly.

An air leakage rating (AL) of 0.30 cfm/sq ft or less (whole window) is recommended.

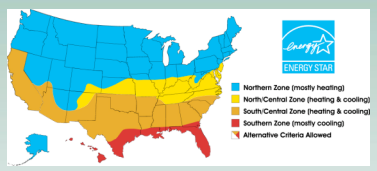
What Makes an Energy-Efficient Window?

U-factor: 0.49
SHGC: 0.56



Window Energy Performance also Depends on…

- **Climate**



- **Building Type**

- **Orientation, etc.**

Tools to Determine Window Performance

Developed by: Lawrence Berkeley National Lab

Optics
Analyze glazing optical properties

IGDB (International Glazing Database)
Database of glazing materials

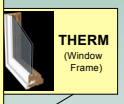
CGDB (Complex Glazing Database)
Database of complex glazing materials

THERM
Analyze two-dimensional heat transfer through building products

WINDOW
Analyze window thermal and optical performance

RESFEN
Calculate the heating and cooling energy use of windows in residential buildings

COMFEN
Calculate the heating and cooling energy use of windows in commercial buildings, as well as evaluating daylighting and thermal comfort



Design / Simulation To
DOE-2, EnergyPl
Radiance

RESFEN
(Whole Building
Residential)

Help with Sorting Through the Complexities of Window Performance

Efficient Windows *Collaborative*

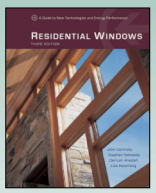
Residential Windows Info

www.efficientwindows.org

Commercial Windows Info

www.commercialwindows.org

Efficient Windows Collaborative



Residential Tools and Information

- 3rd edition of book: *"Residential Windows: A Guide to New Technology and Energy Performance"*
- EWC web site: *www.efficientwindows.org*
- Fact sheets for 100 cities
- Education and training materials
- Window Selection Tool
- RESFEN

The Window Selection Process

1. Look for the ENERGY STAR

   Look for a product that qualifies for the Energy Star in your area.

2. Look for Energy Efficient Window Properties on the NFRC Label

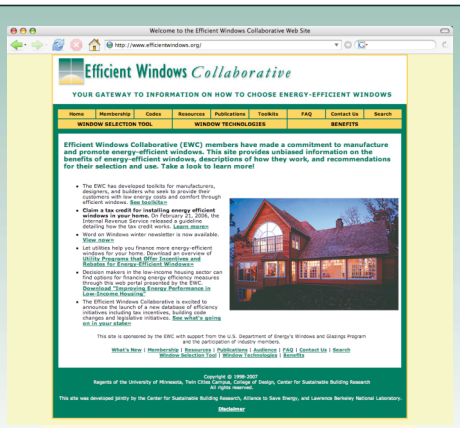
The key window properties are U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT). The NFRC label provides the only reliable way to determine the window properties and to compare products.

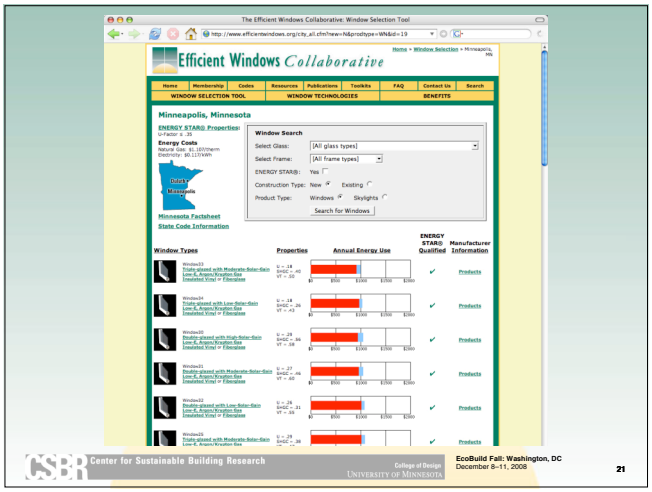
3. Compare Annual Energy Costs for a Typical House

The annual energy use from computer simulations for a typical 2000-square-foot house in your region can be compared for different window options.

4. Estimate and Compare Annual Energy Costs for Your House

Using a computer program such as RESFEN to compare window options is the only method of obtaining reasonable estimates of the heating and cooling costs for your climate, house design, and utility rates.



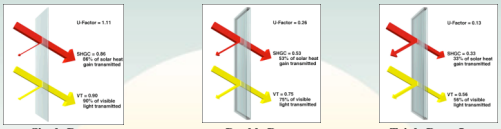


Examples of Frame and Glazing Options

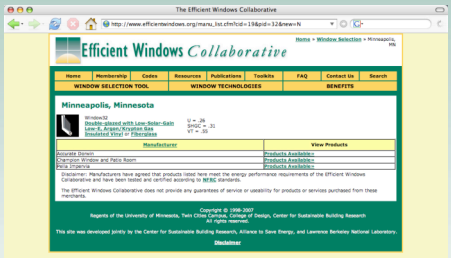
Frame Types

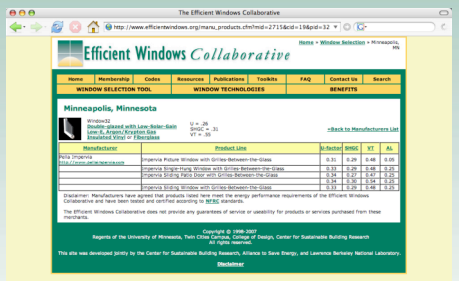
Aluminum | Wood | Vinyl | Fiberglass

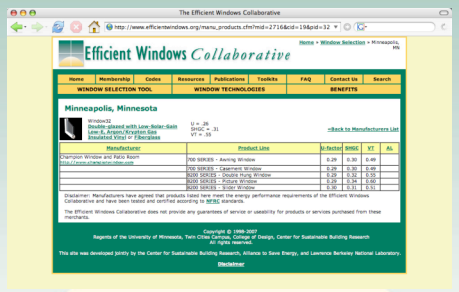
Glazing Types



Single Pane | Double Pane, Moderate-Solar-Gain Low-E, Gas Fill | Triple Pane, Low-Solar-Gain Low-E, Gas Fill







RESFEN

for Calculating the Heating and Cooling Energy Use of Windows in Residential Buildings

RESFEN can be used to run performance comparisons of different window and skylight options and to calculate annual energy use, peak heating and cooling loads, and costs.

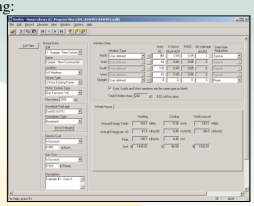
Calculates the heating and cooling energy use of a building:

- –for a specific house
- –in a specific location
- –with specific window products

Compares different window options

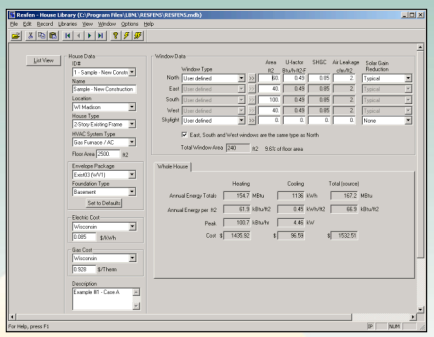
Helps select energy-efficient windows

windows.lbl.gov/software/resfen/resfen.html



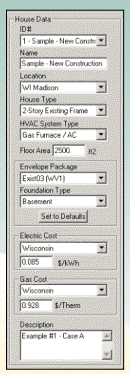
RESFEN

- Location
- House Description
- Window Description



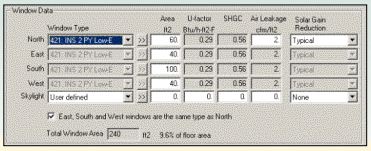
RESFEN

- Location
  - 250+ cities
- Number of stories
  - 1 or 2
- Construction
  - Frame
  - Masonry
- Foundation type
  - Slab
  - Crawlspace
  - Basement
- HVAC System
  - Furnace
  - Heat Pump
- Floor area
- Utility costs
  - defaults by location
  - can be edited



RESFEN

- Describe by orientation
  - Size of windows (SF or % of Floor area)
  - U-factor
  - SHGC
  - Infiltration (CFM/Ft²)
  - Solar Gain Reduction
    - Overhangs
    - Interior drapes
    - Neighboring buildings (obstructions)



www.efficientwindows.org

Toolkit for Builders

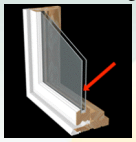
Toolkit for Manufacturers

Toolkit for Designers

Window Selection Tool

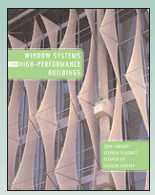
State Fact Sheets

Benefits & Technologies



Code Information

Efficient Windows Collaborative



Commercial Tools and Information

•Book: *"Window Systems for High Performance Buildings"*

•Web site

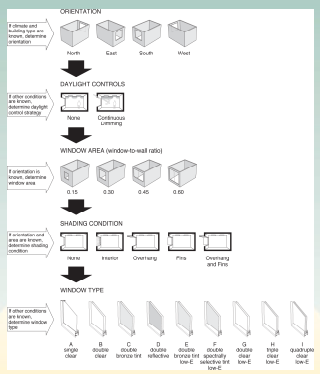
www.commercialwindows.umn.edu
2006 Crystal Achievement Award from *Glass Magazine*

www.commercialwindows.org
Prototype—in development

•Education and training materials

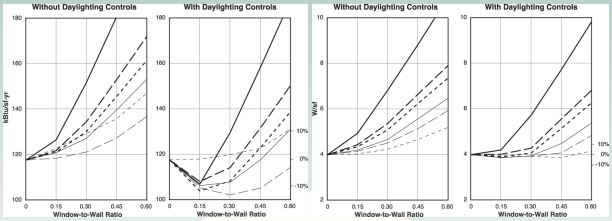
•COMFEN

Decision-making Process



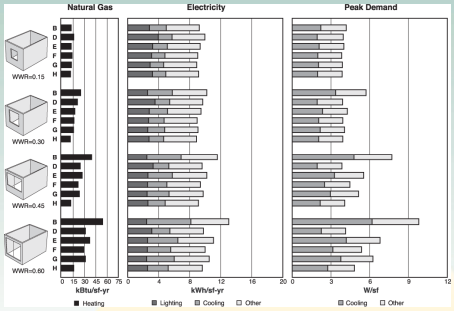
Energy-related Issues

Annual energy use and peak demand comparison by lighting system
All cases are in Chicago and south-facing and no shading. Numbers are expressed per sf within a 15 foot deep perimeter zone.



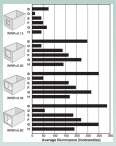
Energy-related Issues

Annual energy use and peak demand comparison by window area
All cases are in Chicago and south-facing with no shading and daylighting controls. Numbers are expressed per sf within a 15 foot deep perimeter zone.

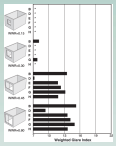


B Clear glazing
D Reflective coating
E Low-E, bronze tint
F Spec. selective low-E tint
G Spec. selective low-E clear
H Triple glazing, low-E clear

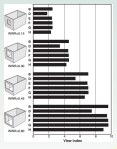
Human Factor Issues



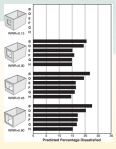
Average Daylight Illuminance
Average daylight illuminance is calculated at a point 10 feet from the window. All cases are in Chicago and south-facing with no shading.



Weighted Glare Index
Glare index is calculated at a point 5 feet from the window for a person facing the side wall A lower index is better. All cases are in Chicago and south-facing with no shading.

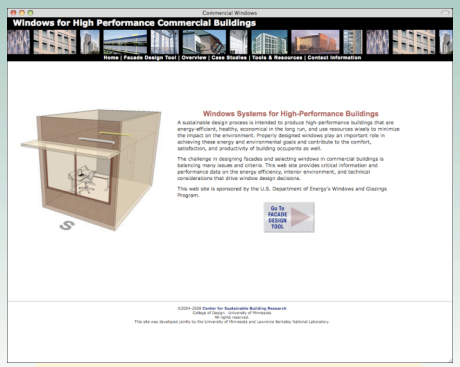


View Index
View index is calculated at a point 10 feet from the window. A higher index is better. All cases are in Chicago and south-facing with no shading.

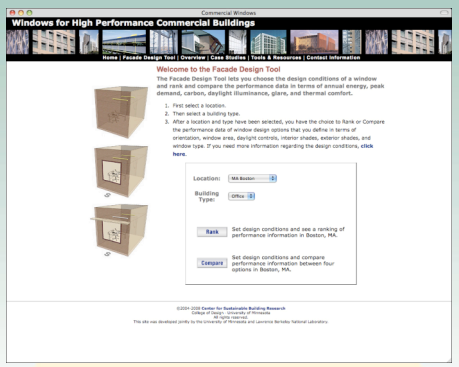


Thermal Comfort
Thermal comfort is calculated at a point 5 feet from the window. A lower PPD is better. All cases are in Chicago and south-facing with no shading.

www.commercialwindows.org



Façade Design Tool



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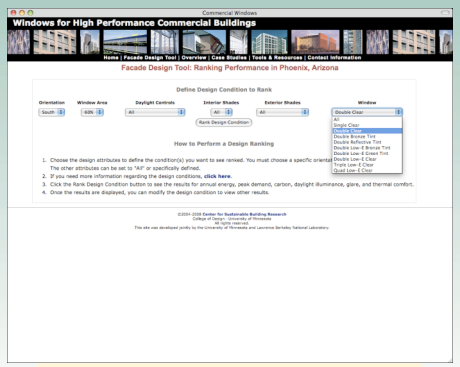

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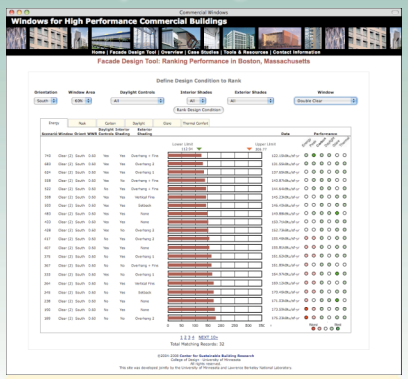

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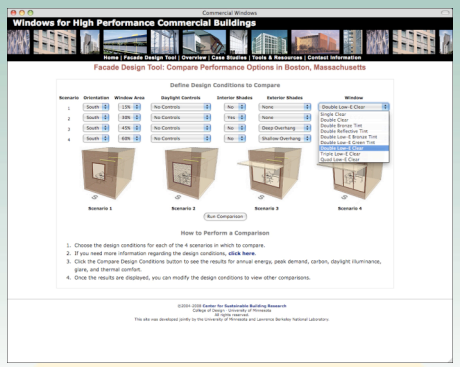

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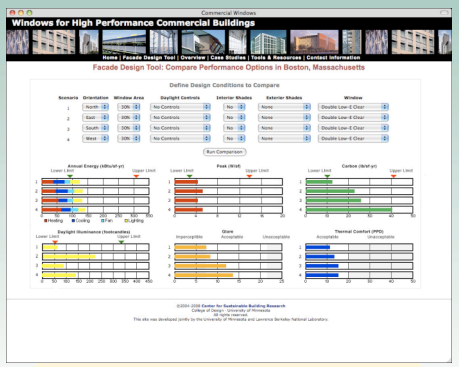

Tools to Determine Window Performance

Developed by: Lawrence Berkeley National Lab

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RESFEN
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COMFEN
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THERM
(Window Frame)

RESFEN
(Whole Building Residential)

Design / Simulation To
DOE-2, EnergyPl
Radiance

COMFEN Version 1

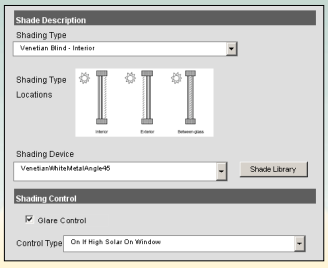
A Computer Tool to Optimize Commercial Building Façade Design

- Up to four comparative façade cases
- Multiple glazing and exterior shading options on each façade
- EnergyPlus simulation engine
- Graphical Output
  - Energy Consumption (Heating/Cooling/Fans/Lighting)
  - Peak Demand
  - CO_2 Emissions
  - Daylighting Illuminance
  - Visual and Thermal Comfort Indices

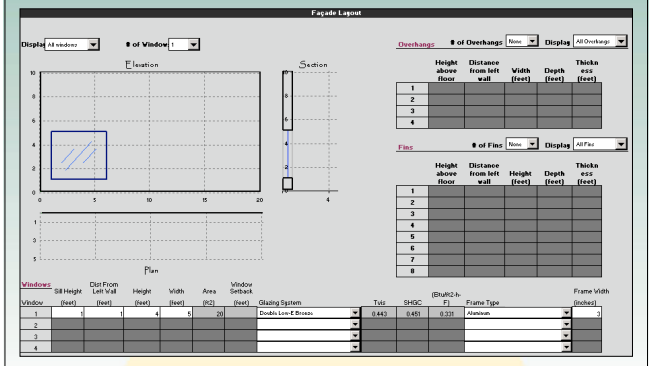
windows.lbl.gov/software/comfen/1/

COMFEN Version 2

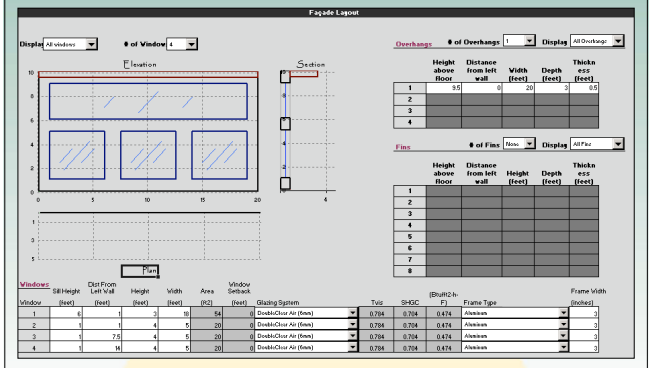
New Features:
Location Library – can add new cities
Glazing System Library – create custom glazing systems
Shading Systems – create custom shading systems



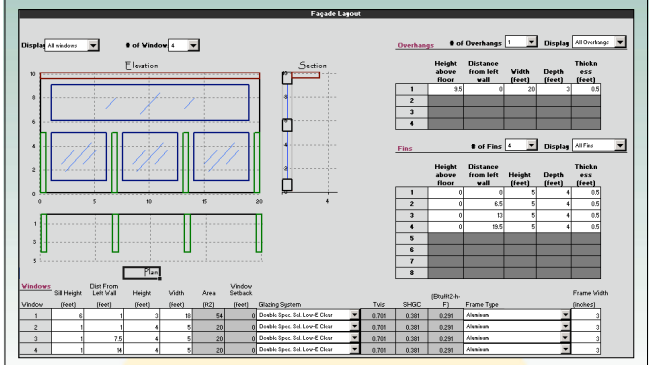
COMFEN: Façade Library–Add Windows



COMFEN: Façade Library–Add Overhangs

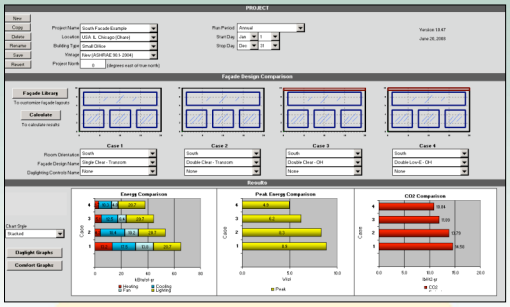


COMFEN: Façade Library–Add Fins



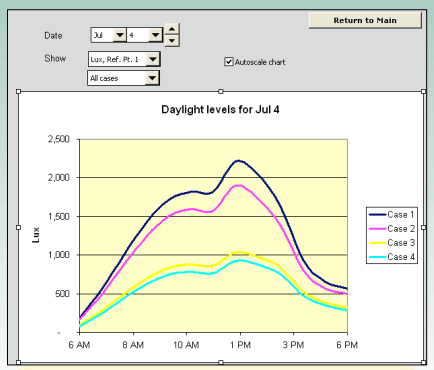
COMFEN: Glazing and Shading Example

- Location = Chicago
- Results show decrease in Annual Energy Consumption based on high efficiency glazing and overhangs



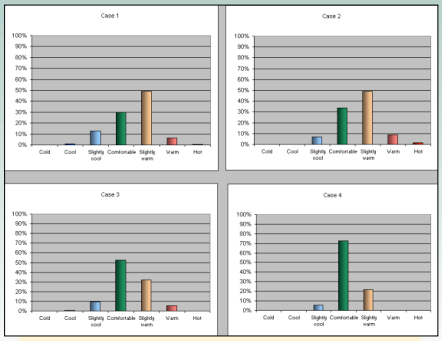
COMFEN: Monthly Results

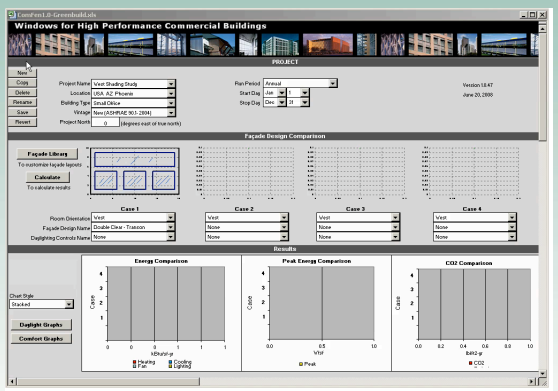
COMFEN: Daylighting Results



COMFEN: Thermal Comfort Results

- Highest comfort rating results from high efficiency glazing with exterior overhang (Case 4)



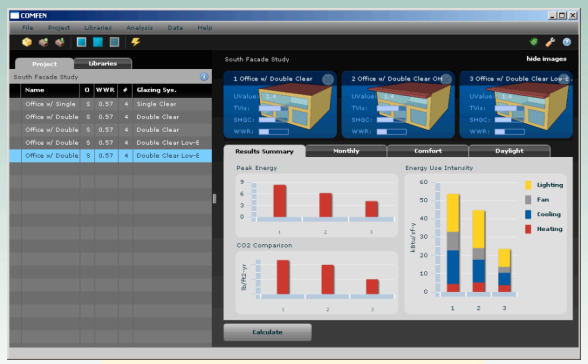


COMFEN 3 – The Next Version

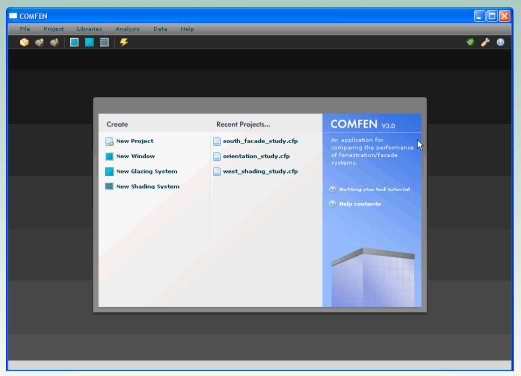
'Sketching' with Simulation?

- What if building performance analysis took the lead from architects?
  - Don't make early design performance sketches with limited sketching 'tools'
  - Use the best performance analysis 'tools'
- To sketch with Radiance or Energy+?
  - The simulation model is a 'sketch' / idealisation of the building itself – to explore an idea
  - Rapid turnaround of performance analysis ideas using validated, trustable performance calculation engines
- Improved, stand-alone GUI interface
- Uses a project and scenario paradigm for use pattern
  - A 'project' might be School X in City A or Office Y in City B
  - A 'scenario' is a combination of window, glazing and shading in the School or Office

COMFEN 3 – The Next Version



COMFEN 3 – The Next Version



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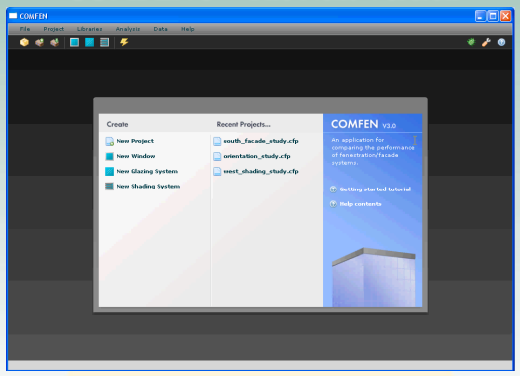
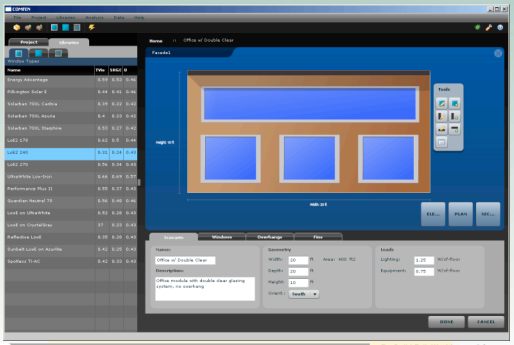


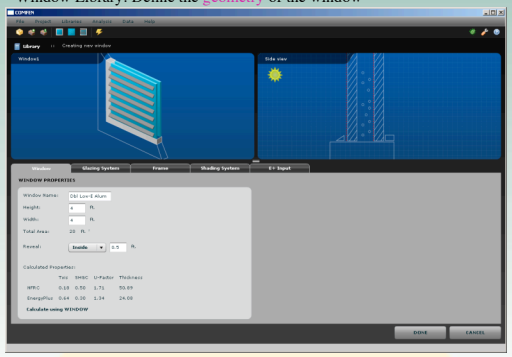
COMFEN 3 – The Next Version

Façade Design: Drag and drop library selection for windows, glazing systems, and shading systems



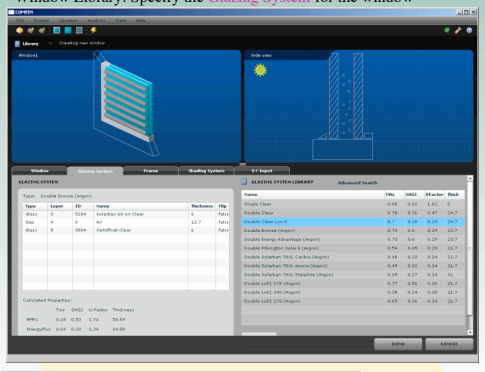
COMFEN 3 – The Next Version

Window Library: Define the geometry of the window



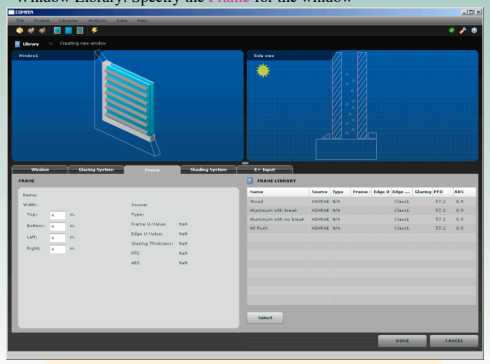
COMFEN 3 – The Next Version

Window Library: Specify the Glazing System for the window



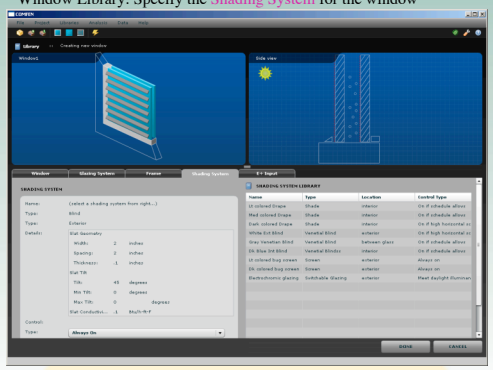
COMFEN 3 – The Next Version

Window Library: Specify the Frame for the window



COMFEN 3 – The Next Version

Window Library: Specify the Shading System for the window



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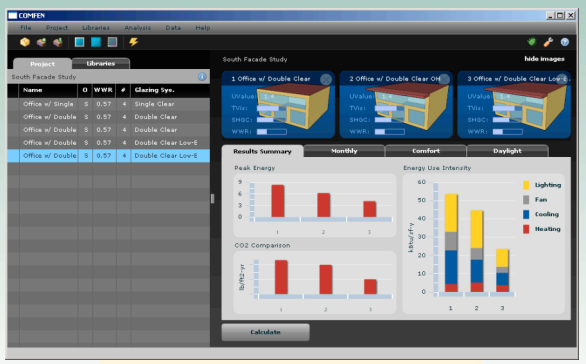

Sources and Links

Alliance to Save Energy
www.ase.org

Center for Sustainable Building Research
www.csbr.umn.edu

Center for the Built Environment
www.cbe.berkeley.edu

COMFEN
windows.lbl.gov/software/comfen/1/

Efficient Windows Collaborative (EWC)
Window Selection Tool
www.efficientwindows.org

ENERGY STAR
www.energystar.gov

National Fenestration Rating Council (NFRC)
www.nfrc.org

RESFEN
windows.lbl.gov/software/resfen/resfen.html

US Department of Energy
Energy Efficiency and Renewable Energy
www.eere.energy.gov

Window Installation
Water Management Guide by Joseph W. Lstiburek
www.eeba.org

Windows and Daylighting
Lawrence Berkeley National Laboratory
windows.lbl.gov

Windows for High Performance Commercial Buildings
Façade Design Tool
www.commercialwindows.umn.edu
www.commercialwindows.org

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