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

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Why are Windows Important?

- Photo: Pella Windows & Doors
- Photo: Associated Materials
- Photo: Andersen Corporation
- Photo: Velux-America
- Photo: JELD-WEN
- Photo: PGT Industries
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…

The Information Source for Window Energy Properties: The NFRC Label

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

Window Energy Parameters

- Heat Transfer
  - U-Factor
- Visible Transmittance (VT)
- Solar Heat Gain
  - Solar Heat Gain Coefficient (SHGC)
- Infiltration
  - Air Leakage (AL)

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?

- Warm-edge spacers
- Gas fill
- Low-E coating

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
- CGDB: Complex Glazing Database
- 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

Help with Sorting Through the Complexities of Window Performance

- Residential Windows Info: www.efficientwindows.org
- Commercial Windows Info: www.commercialwindows.org

Efficient Windows Collaborative

- Residential Tools and Information
  - 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
- Triple Pane, Low-Solar Gain, Low-E, Gas Fill
- Low-E, Gas Fill
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

- Describe by orientation
  - Size of windows (SF or % of floor area)
  - U-factor
  - SHGC
  - Infiltration (CFM/F²)
  - Solar gain reduction
    - Overhangs
    - Interior drapes
    - Neighboring buildings (obstructions)

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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—under development

  • Education and training materials
  • COMFEN

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Decision-making Process

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www.efficientwindows.org

- Toolkit for Builders
- Toolkit for Manufacturers
- Toolkit for Designers

- State Fact Sheets
- Code Information
- Benefits & Technologies
- Window Selection Tool
- Commercial Tools and Information

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### 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.

<table>
<thead>
<tr>
<th>Lighting System</th>
<th>Energy Use</th>
<th>Peak Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Daylight Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Daylight Controls</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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
Façade Design Tool

- Windows for high performance commercial buildings
- Tools to Determine Window Performance
  - Developed by: Lawrence Berkeley National Lab
  - CGDB (Complex Glazing Database)
  - IGDB (Specular Glass Data Source)
  - COMFEN (Whole Building Commercial)
  - RESFEN (Whole Building Residential)

Tools to Determine Window Performance

- OPTICS: Analysis of window visual properties
- IGDB (International Glazing Database)
- CGDB (Complex Glazing Database)
- 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 commercial buildings

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
  - CO2 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

Daylighting Results

COMFEN: Daylighting Results

Daylight levels for July 4

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 EnergyPlus?
  - 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

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

Window Library: Define the geometry of the window.

Window Library: Specify the glazing system for the window.

Window Library: Specify the frame for the window.
COMFEN 3 – The Next Version
Window Library: Specify the Shading System for the window

Sources and Links

Alliance to Save Energy
www.ase.org

Center for Sustainable Building Research
www.csb.berkeley.edu

COMFEN
windows.lbl.gov/software/comfen/

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
Window Management Guide by Joseph W. Lstiburek
www.ase.org

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

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

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