Decision-making Methodology & Selection Tools for High-performance Window Systems in U.S. Climates

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www.efficientwindows.org / www.commercialwindows.org
Why are Windows Important?

Integrated Design

Integrated design is important in achieving the energy-efficient goals of a building and the comfort and health of its occupants.

• Fenestration options play an important role.

• Window system design and orientation will have an impact on energy use and the environment.

• Window system design and orientation will have an impact on occupant’s comfort and health.

• Complex and inter-related building performance issues such as daylighting strategies, HVAC design and sizing, and shading options must be considered in the early design stages.
What Makes an Energy-Efficient Window?

Characteristics of Low-E Coatings

- Long-wave radiant heat is reflected, giving an improved U-factor and reduced winter heat loss.
- Higher temperatures on the interior glass surface contribute to greater comfort and less condensation in winter.
- Visible transmittance is only slightly affected.
- With high-solar-gain coatings, solar heat is transmitted.
- With low-solar-gain coatings, solar radiation is reflected back toward the exterior.

Characteristics of Gas Fills

- Thermal resistance is increased with argon and krypton gas fills, reducing winter heat loss and summer heat gain through conduction.
- Higher temperatures in winter on the interior glass surface contribute to greater comfort and less condensation.
- Visible transmittance is not affected.

Characteristics of Thermally Improved Spacers

- Overall U-factor is improved because heat loss at the glass edges is reduced.
- Higher temperatures on the glass edges produce less condensation.

• Low-E coating
• Gas fill
• Warm-edge spacers
Residential Energy Savings
What’s a Ton of AC Worth?

- Saving 1 ton of AC per house
  - 1 ton = 12,000 Btu/hr
  - 13 SEER = 13,000 Btu/kWh
  - Using “Joe Math” – ~1 kW per house
  - 110 million existing homes, assume about half have AC
  - ~50 million X 1 kW = 50 million kW

Roughly the equivalent of 100 new coal-fired power plants

Slide courtesy of Chris Mathis, Mathis Consulting and Jim Larsen, Cardinal Glass
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: windows.lbl.gov/software
Residential: 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.
Residential: Selecting the Right Window

Impact of window glazing area on annual energy use for a typical house in Minneapolis, Minnesota. The better performance of the window — the less of an impact of the glazing area.

![Annual Energy Costs Chart](chart.png)
Residential: Selecting the Right Window

Impact of shading on annual energy use for a typical house in Phoenix, Arizona. The better performance of the window — the less of an impact of shading devices.
www.efficientwindows.org
Window Selection Tool

Compare how different window or skylight types affect annual energy cost simulated for a typical house in your location. This tool also links to products from specific manufacturers that correspond to the listed window or skylight types.

Select a condition:
- New Construction
- Existing Construction

Select a type:
- Windows
- Skylights

Select a city:
- AK Anchorage

Compare Energy Costs

When selecting windows or skylights:
- Look for properties on the NERG Label.
- Look for the ENERGY STAR®.
- Perform simulations using RESFEN.

Design Variations:
- Glazing Area
- Shading
- Orientation

Multiple Benefits Fact Sheet:
This fact sheet combines several measurable attributes (annual energy cost, peak demand, winter and summer thermal comfort, and condensation) to assist in the selection process.

American Architectural Manufacturers Association (AAMA):
AAMA is the premier source for performance standards, product certification and educational programs. AAMA's over 350 members represent both the residential and commercial window, door and skylight industry. The AAMA online Certified Products Directory is the best resource available for locating products to achieve air, water, structural and forced entry resistance code compliance.

Window & Door Manufacturers Association (WDMA):
WDMA is a trade association representing approximately 145 U.S. and Canadian manufacturers and suppliers of windows and doors for the domestic and export markets. WDMA members manufacture high performance products designed and built to performance-based standards.

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Disclaimer
## Minneapolis, Minnesota

**Window 28**
- Triple-glazed, High-solar-gain Low-E Glass
- Argon/Krypton Gas
- Non-metal, Thermally Improved
- **U** = 0.20
- **SHGC** = 0.26-0.40
- **VT** = 0.41-0.50

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<th>Manufacturer</th>
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**Disclaimer:** Manufacturers have agreed that products listed here meet the energy performance requirements of the Efficient Windows Collaborative and have been tested and certified according to NFRC standards.

The Efficient Windows Collaborative does not provide any guarantees of service or usability for products or services purchased from these merchants.

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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
  - 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
- Air Leakage (Infiltration)
- Solar Gain Reduction (shading)
  - Overhangs
  - Interior drapes
  - Neighboring buildings (obstructions)

```
Window Data

<table>
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<tr>
<th>Window Type</th>
<th>Area ft2</th>
<th>U-factor Btu/h•ft2•F</th>
<th>SHGC</th>
<th>Air Leakage cfm/ft2</th>
<th>Solar Gain Reduction</th>
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<td>Skylight</td>
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<td>None</td>
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</tbody>
</table>

Total Window Area: 240 ft²  9.6% of floor area
```
Recent research estimates that windows are responsible for 39% of commercial heating energy use and 28% of commercial cooling energy use—34% of all commercial space conditioning energy use. This is equivalent to 1.48 quads of space conditioning energy use—almost 1.5% of the total U.S. energy consumption.

Commercial: Decision-making Process

**Orientation**
- If climate and building type are known, determine orientation
  - North
  - East
  - South
  - West

**Daylight Controls**
- If other conditions are known, determine daylight control strategy
  - None
  - Continuous Dimming

**Window Area** (window-to-wall ratio)
- If orientation is known, determine window area
  - 0.15
  - 0.30
  - 0.45
  - 0.60

**Shading Condition**
- If orientation and area are known, determine shading condition
  - None
  - Interior
  - Overhang
  - Fins
  - Overhang and Fins

**Window Type**
- If other conditions are known, determine window type
  - A single clear
  - B double clear
  - C double bronze tint
  - D double reflective
  - E double bronze tint low-E
  - F double spectrally selective tint low-E
  - G double clear low-E
  - H triple clear low-E
  - I quadruple clear low-E
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: windows.lbl.gov/software
Windows Systems for High-Performance Buildings

A sustainable design process is intended to produce high-performance buildings that are energy-efficient, healthy, economical in the long run, and use resources wisely to minimize the impact on the environment. Properly designed windows play an important role in achieving these energy and environmental goals and contribute to the comfort, satisfaction, and productivity of building occupants as well.

The challenge in designing facades and selecting windows in commercial buildings is balancing many issues and criteria. This web site provides critical information and performance data on the energy efficiency, interior environment, and technical considerations that drive window design decisions.

This web site is sponsored by the U.S. Department of Energy's Windows and Glazings Program.
Façade Design Tool

Welcome to the Facade Design Tool

The Facade Design Tool lets you choose the design conditions of a window and rank and compare the performance data in terms of annual energy, peak demand, carbon, daylight illuminance, glare, and thermal comfort.

1. First select a location.
2. Then select a building type.
3. After a location and type have been selected, you have the choice to Rank or Compare the performance data of window design options that you define in terms of orientation, window area, daylight controls, interior shades, exterior shades, and window type. If you need more information regarding the design conditions, click here.

Location: MA Boston

Building Type: Office

Rank
Set design conditions and see a ranking of performance information in Boston, MA.

Compare
Set design conditions and compare performance information between four options in Boston, MA.
# Façade Design Tool

![Facade Design Tool: Compare Performance Options in Boston, Massachusetts](image)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Orientation</th>
<th>Window Area</th>
<th>Daylight Controls</th>
<th>Interior Shades</th>
<th>Exterior Shades</th>
<th>Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>None</td>
<td>None</td>
<td>Double Low-E Clear</td>
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<tr>
<td>2</td>
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<td>30%</td>
<td>No Controls</td>
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<td>None</td>
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<td>3</td>
<td>South</td>
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<tr>
<td>4</td>
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<td>No Controls</td>
<td>No</td>
<td>Shallow Overhang</td>
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**How to Perform a Comparison**

1. Choose the design conditions for each of the 4 scenarios in which to compare.
2. If you need more information regarding the design conditions, [click here](#).
3. Click the Compare Design Conditions button to see the results for annual energy, peak demand, carbon, daylight illuminance, glare, and thermal comfort.
4. Once the results are displayed, you can modify the design conditions to view other comparisons.

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# Façade Design Tool

![Facade Design Tool: Compare Performance Options in Boston, Massachusetts](image)

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<tr>
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<td>No Controls</td>
<td>No</td>
<td>None</td>
<td>Double Low-E Clear</td>
</tr>
</tbody>
</table>

- **Annual Energy (kBTU/ft²-yr)**
  - Lower Limit
  - Upper Limit
- **Peak (W/ft²)**
  - Lower Limit
  - Upper Limit
- **Carbon (lb/ft²-yr)**
  - Lower Limit
  - Upper Limit
- **Daylight Illuminance (footcandles)**
  - Lower Limit
  - Upper Limit
- **Glare**
  - Impeccable
  - Acceptable
  - Unacceptable
- **Thermal Comfort (PPD)**
  - Acceptable
  - Unacceptable

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COMFEN 3

- Façade design tool for conceptual / preliminary building design
- For architects, engineers, building industry professionals
- Provides comparative results between façade design options
- Multiple glazing and shading options on each façade
- EnergyPlus simulation engine
- Graphical Output
  - Energy Consumption
  - Peak Demand
  - CO$_2$ Emissions
  - Daylighting Illuminance
  - Visual and Thermal Comfort Indices

windows.lbl.gov/software/comfen/comfen.html
COMFEN 3: Steps for modeling

- Create Façade Scenarios
  - room size
  - window geometry
  - overhang / fin geometry
  - Shading system (from Shading System Library)
  - Glazing system (from Glazing System Library)
  - Frame

- Project level
  - Location
  - Compare Façade Results
COMFEN 3: Façade Scenarios

Façade Scenario Comparisons
COMFEN 3: Façade Design

Draw the **geometry** of the windows, fins, overhangs
Define room dimensions, room loads
COMFEN 3: Window Library
Assign Glazing Systems, Shading Systems, and Frames to a window

Window Name: 2x2 double Low Solar LowE w/Int VB 45
Description: 
Default Height: 2 ft
Default Width: 2 ft
Default Setback: 0 ft
Total Area: 4 ft²
COMFEN 3: Window Library

Assign Glazing Systems, Shading Systems, and Frames to a window
COMFEN 3: Glazing System Library

Define Glazing Systems

Can import from WINDOW 6

Drag glass or gas layer to create glazing system.
## COMFEN 3: Glass Library

Update Glass Library from IGDB Releases

![Glass Library Update](file://image.png)

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<td>0.54</td>
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<td>SLCL603.SWT</td>
<td>Select Clear on Clear</td>
<td>0.22</td>
<td>IGDB v1.4</td>
<td>0.32</td>
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</tr>
</tbody>
</table>

**Center for Sustainable Building Research**

**University of Minnesota**

**BEST2 Conference**

Portland • April 2010
COMFEN 3: Shading System Library
Define venetian blinds, shades/drapes, exterior screens
COMFEN 3: Façade Design

Assign a Glazing System to the windows

Drag glazing system onto window
COMFEN 3: Annual Energy Results
COMFEN 3: Monthly Results

Energy Use Intensity (by month):

- Single Clear
- Double Clear Low-E
- Dbl Clr Low-E Interior VB
- Dbl Clr Low-E Between VI
- Dbl Clr Low-E Exterior VB

Month: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC

Energy Use Intensity: 0 to 32 kBu/ft²
COMFEN 3: Thermal Comfort Results
COMFEN 3: Average Annual Daylighting Results
# COMFEN 3: Tabular Results

Can be exported to CSV file

<table>
<thead>
<tr>
<th>Results Summary</th>
<th>Energy (Monthly)</th>
<th>Comfort</th>
<th>Daylight Avg.</th>
<th>Daylight Hourly</th>
<th>Tabular Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Values</td>
<td>Units</td>
<td>Scenario 1</td>
<td>Scenario 2</td>
<td>% diff. from</td>
<td>Scenario 5</td>
</tr>
<tr>
<td>Heating</td>
<td>kBtu/ft²·yr</td>
<td>20.95</td>
<td>5.32</td>
<td>-74.56%</td>
<td>6.57</td>
</tr>
<tr>
<td>Cooling (source)</td>
<td>kBtu/ft²·yr</td>
<td>82.02</td>
<td>70.29</td>
<td>-14.29%</td>
<td>56.88</td>
</tr>
<tr>
<td>Fan (source)</td>
<td>kBtu/ft²·yr</td>
<td>147.60</td>
<td>77.86</td>
<td>-47.24%</td>
<td>64.31</td>
</tr>
<tr>
<td>Lighting (source)</td>
<td>kBtu/ft²·yr</td>
<td>52.36</td>
<td>52.36</td>
<td>0%</td>
<td>52.36</td>
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<tr>
<td>Total Energy (source)</td>
<td>kBtu/ft²·yr</td>
<td>302.94</td>
<td>205.85</td>
<td>-32.04%</td>
<td>180.14</td>
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<tr>
<td>Peak Demand</td>
<td>W/ft²</td>
<td>21.03</td>
<td>14.34</td>
<td>-31.82%</td>
<td>12.30</td>
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<tr>
<td>Avg. Daylight Illum.</td>
<td>fc</td>
<td>76.29</td>
<td>59.16</td>
<td>-22.44%</td>
<td>5.38</td>
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<tr>
<td>Avg. Discomfort Glare</td>
<td>Index</td>
<td>7.47</td>
<td>7.24</td>
<td>-3.16%</td>
<td>4.35</td>
</tr>
<tr>
<td>Avg. Thermal comfort</td>
<td>PPD</td>
<td>43.25</td>
<td>35.28</td>
<td>-18.43%</td>
<td>28.69</td>
</tr>
</tbody>
</table>
Software Tools for Energy Performance Evaluation

- **WINDOW** (Whole Building)
- **Optics** (Window Glass)
- **THERM** (Window Frame)
- **IGDB** (Specular Glass Data Source)
- **CG DB** (Complex Glazing Data)

**Design / Simulation Tools**
DOE-2, EnergyPlus, Radiance

**Software Tools for Energy Performance Evaluation**

- **COMFEN** (Whole Building Commercial)
- **RESFEN** (Whole Building Residential)
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/3/

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.org