

Energy Efficient Windows for Mid- & High-rise Residential Buildings

Energy-efficient windows save heating and cooling energy and improve occupant comfort while allowing for downsized HVAC equipment. Residential-type ENERGY STAR windows are a good choice for saving energy in single family and many multifamily buildings. However, structural, safety and façade design considerations in mid- and high-rise buildings often call for commercial-type windows which are not part of the ENERGY STAR program. Whichever the case, the simple guidelines presented here can help you specify energy efficient options from among the different types of windows used in mid- and high-rise residential applications.



1. Comply with Energy Code Requirements

Most jurisdictions base their building energy code on the International Energy Conservation Code (IECC). Residential buildings higher than three stories are covered by the IECC's commercial chapter, which references ASHRAE Standard 90.1 as a compliance alternative. Both the IECC and Standard 90.1 require that window energy ratings are determined in accordance with NFRC standards. *See "Window Energy Ratings" on the next page.*

2. Look for Well-insulating Windows

In tall buildings, structural and safety considerations are often addressed with metal framing or metal reinforcement. Since this may impact insulating properties, energy codes usually allow some flexibility for window U-factors for residential buildings higher than three stories. Nonetheless, advanced window designs can limit the conductivity of metal frames or boost the strength of non-metal frames—allowing the specification of windows with beyond-average insulating properties while meeting structural and safety requirements. *See next page for U-factor specification recommendations and for an overview of structural performance classes.*

3. Pay Particular Attention to Solar Heat Gain

Solar heat gain is a particular concern for mid- and high-rise buildings where shading is difficult to provide and some units may have their windows only in a single, unfavorable orientation. Building energy codes limit window solar heat gain coefficients (SHGC) in warmer climates. But even in colder climates, you may want to consider low-SHGC windows to prevent overheating, particularly with west-facing windows or large glass areas. Control of window solar heat gain can substantially reduce the required cooling equipment size. *See next page for SHGC specification recommendations.*

4. Limit Air Leakage and Ensure Proper Installation

Air leakage is a particular concern for higher buildings where windows are exposed to greater wind loads. Controlling air leakage requires not only that windows are tested to comply with the energy code's air leakage limit, but also that they are properly installed. Window installation is critical for an airtight fit, to avoid thermal bridging, and to prevent water penetration around the window. Field testing in accordance with ASTM E783 can evaluate both the window assembly and installation details for air leakage. Water penetration can be evaluated in accordance with ASTM E 1105.

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Visit www.efficientwindows.org for more information on the benefits of efficient windows, how windows work, how to select an efficient window, and what manufacturers provide efficient products.



Energy code requirements provide a baseline for energy-efficiency specifications, but various window options are available that can cost-effectively exceed the energy performance prescribed by codes. Below are some recommended specifications that exceed most energy codes but can be met by commonly available windows. These recommendations are based on the ENERGY STAR climate zones (see map on the right).

U-factor Recommendations

These U-factor recommendations differentiate between windows of different structural performance classes. See the text box on the bottom right for a summary of these performance classes. Windows of the R and LC classes often qualify for ENERGY STAR, so a U-factor that matches or exceeds ENERGY STAR criteria is recommended:

U-factor recommendations for R and LC class windows

Northern Zone: Specify ENERGY STAR or U-factor ≤ 0.30
 North-Central Zone: Specify ENERGY STAR or U-factor ≤ 0.32
 South-Central Zone: Specify ENERGY STAR or U-factor ≤ 0.35
 Southern Zone: Specify ENERGY STAR or U-factor ≤ 0.60

Specifications for commercial-grade (CW and AW) windows may have to take into account that structural strength and fire resistance are often achieved at the expense of a somewhat higher U-factor, particularly with metal-framed operable windows:

U-factor recommendations for CW and AW class windows

Northern Zone: Specify U-factor ≤ 0.32 (≤ 0.35 for AW class)
 With operable metal-framed windows, a more realistic goal is U-factor ≤ 0.42 (≤ 0.45 for AW class)
 Central Zones: Specify U-factor ≤ 0.35
 With operable metal-framed windows, a more realistic goal is U-factor ≤ 0.45
 Southern Zone: Specify U-factor ≤ 0.75

Solar Heat Gain Coefficient (SHGC) Recommendations

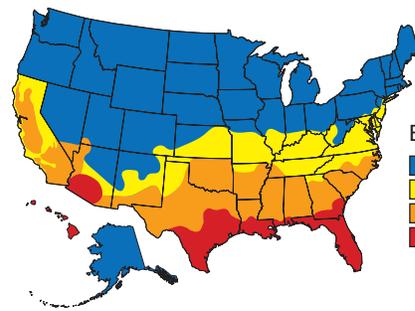
To limit cooling loads, particularly on west-facing façades, specify windows with a low SHGC. If effective shading is provided, somewhat higher SHGC values are also efficient.

SHGC recommendations

Northern Zone: SHGC ≤ 0.40
 Central and Southern Zones: Specify SHGC ≤ 0.25

Air Leakage Recommendations

Specify windows certified to meet the North American Fenestration Standard, which includes air leakage limits (see text box on the right). Where infiltration from severe wind loads is a concern, specify AW class windows, which are tested under higher pressure. Consider field testing in accordance with ASTM E 783 to evaluate the window assembly and installation details for air leakage.



ENERGY STAR Zones

- Northern Climate Zone
- North/Central Climate Zone
- South/Central Climate Zone
- Southern Climate Zone

Window Energy Ratings

U-factor: The rate of non-solar heat transfer through a whole window in Btu/(hr-ft²-°F). The lower the U-factor, the better a window's insulating value.

Solar heat gain coefficient (SHGC): The fraction of incident solar heat admitted through a window.

Visible transmittance (VT): The fraction of visible light transmitted through a window. Most window VT values are between 0.3 and 0.7.

Air leakage (AL): Most windows must have a tested air infiltration rate no higher than 0.3 CFM/ft² to obtain a performance class under the North American Fenestration Standard (NAFS). AW windows are tested at a higher pressure than R, LC and CW class windows.

 World's Best Window Co. Millennium 2000 ⁺ 100% Metal Window Frame Double Glazing - Argon Fill - Low E Product Type: Vertical Slider	
ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./IP)	Solar Heat Gain Coefficient
0.30	0.30
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S./IP)
0.51	0.2
Condensation Resistance	
—	—
<small>Manufacturers should refer these ratings criteria to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined by a test set of environmental conditions and a specific product size. NFRC ratings are not intended to predict or describe the suitability of any product for any specific use. Check manufacturer's literature for other product performance information.</small>	

Specify whole-window energy ratings that are third-party verified and recognized by code officials. Windows should be certified with the National Fenestration Rating Council (NFRC) label. Air infiltration ratings can also be certified in accordance with NAFS.

Structural Performance Classes

The North American Fenestration Standard (AAMA/WDMA/CSA 101/I.S.2/A440) provides a method for structural and air leakage ratings and can be used to show compliance with ASCE 7, the calculation method for wind loads in the International Building Code. Under the 2008 version of this standard, windows can achieve one among four performance classes depending on the stringency of test conditions and the achieved ratings:

R Class: Commonly used in one and two family dwellings.

LC Class: Commonly used in low- and mid-rise multifamily and other buildings where larger sizes and higher wind loading requirements are expected.

CW Class: Commonly used in low- and mid-rise buildings where larger sizes, higher wind loading requirements, limits on deflection, and heavy use are expected.

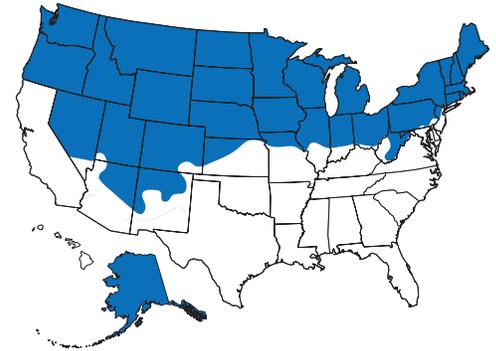
AW Class: Commonly used in mid- and high-rise buildings to meet increased loading requirements and limits on deflection, and in buildings where frequent and extreme use of the fenestration products are expected.

Comparing Window Performance in Multifamily Buildings in the Northern Zone

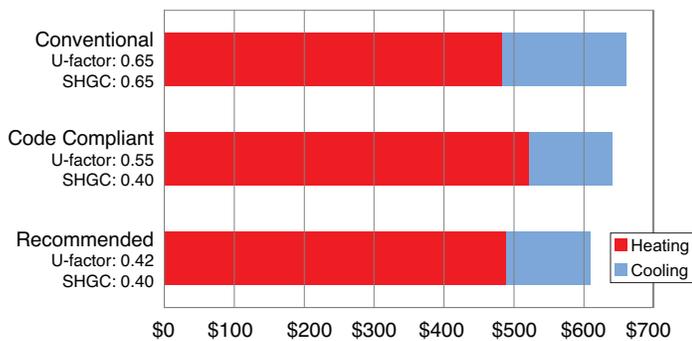
Annual Energy Use in Chicago, Illinois

The annual energy costs shown here assume a typical 950 sq. ft. multifamily unit with 35% window to wall area, using an average of middle and corner units.

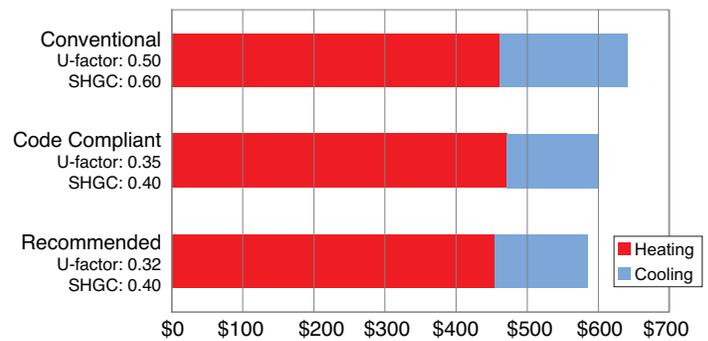
These graphs compare three performance levels for both metal and non-metal frames. Conventional windows are double pane windows without high-performance features, while code compliant windows meet the prescriptive requirements of ASHRAE Standard 90.1-2007. Finally, the bottom windows meet the recommended energy performance levels for CW class windows in a northern climate, as discussed on page 2. Moving from conventional to recommended windows reduces total heating and cooling energy (including all heating and cooling loads) by 10-15%.



Annual Energy Costs in Chicago, Illinois (metal frame)

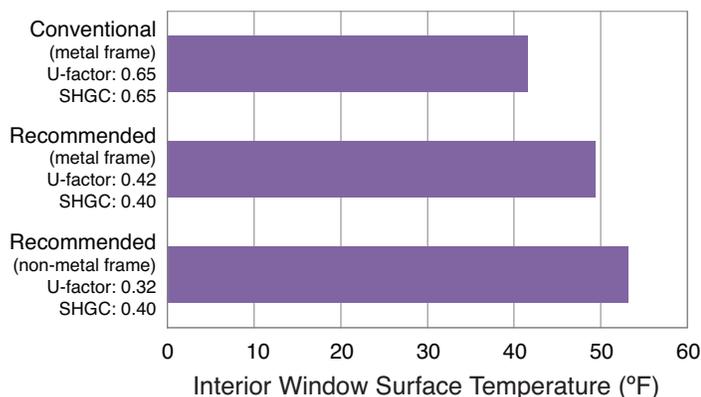


Annual Energy Costs in Chicago, Illinois (non-metal frame)



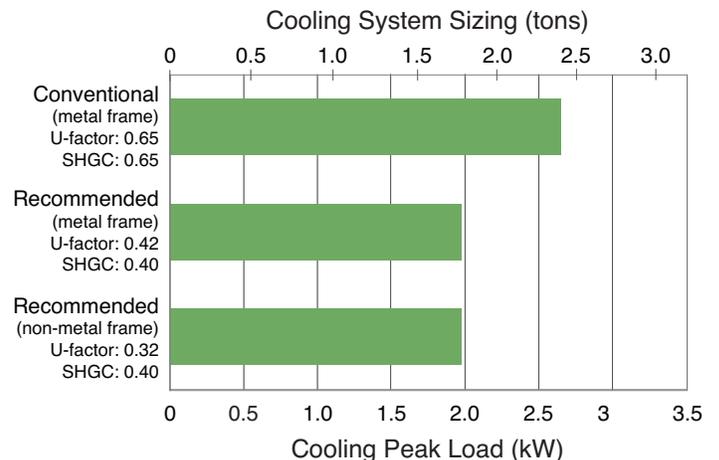
Winter Comfort and Interior Temperature

A significant benefit of energy-efficient windows is improved winter comfort due to warmer interior window surfaces. The figure below shows the area-weighted interior surface temperature of a window when the outside air temperature is 0° Fahrenheit. Windows with low surface temperature feel uncomfortable because more heat is radiated from a person's body to the window.



Cooling Peak Load

Windows with solar control glazing reduce peak cooling loads, which allows for downsized mechanical equipment. Lower peak cooling loads typically also improve summer comfort. The following example shows the estimated peak cooling load for a typical 950 square foot unit on the southwest corner of a multifamily building.



Note: The annual energy performance figures shown here were generated using modified energy simulations of the DOE Commercial Reference Building (www1.eere.energy.gov/buildings/commercial_initiative/reference_buildings.html) for post 1980 multifamily buildings. Heating and cooling energy of the entire building was divided by the number of 950 square foot housing units in the building, creating an average heating and cooling demand for the combination of top, middle and bottom units as well as all orientations. Whole building window to wall area was 35%, with corner units having a greater total window area than center units. A national average cost of natural gas of \$1.20 per therm and average cost of electricity of \$0.12 were used.

Comparing Window Performance in Multifamily Buildings in the North Central Zone

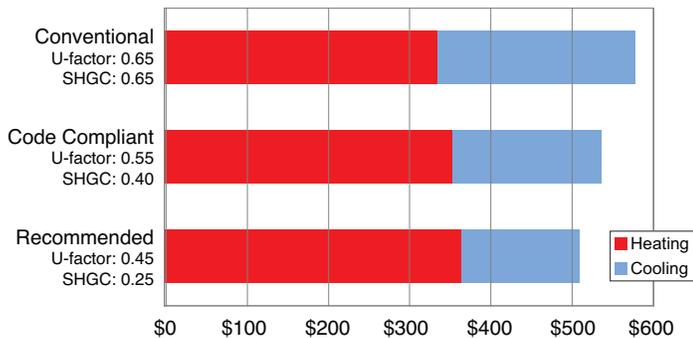
Annual Energy Use in Baltimore, Maryland

The annual energy costs shown here assume a typical 950 sq. ft. multifamily unit with 35% window to wall area, using an average of middle and corner units.

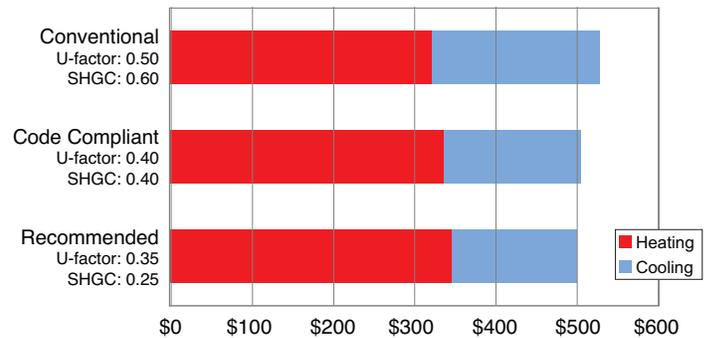
These graphs compare three performance levels for both metal and non-metal frames. Conventional windows are double pane windows without high-performance features, while code compliant windows meet the prescriptive requirements of ASHRAE Standard 90.1-2007. Finally, the bottom windows meet the recommended energy performance levels for CW class windows in a central climate, as discussed on page 2. Moving from conventional to recommended windows reduces total heating and cooling energy (including all heating and cooling loads) by 5-10%.



Annual Energy Costs in Baltimore, Maryland (metal frame)

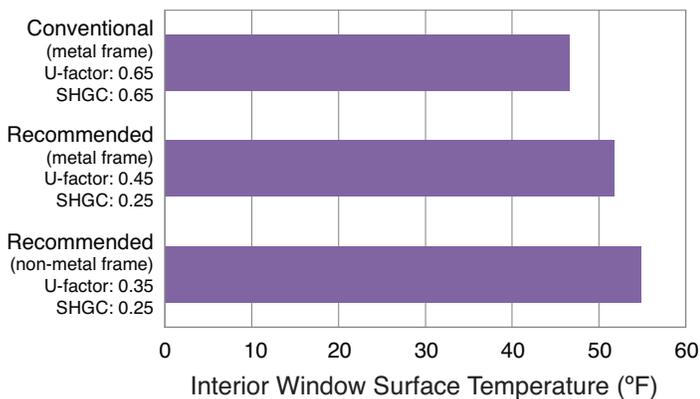


Annual Energy Costs in Baltimore, Maryland (non-metal frame)



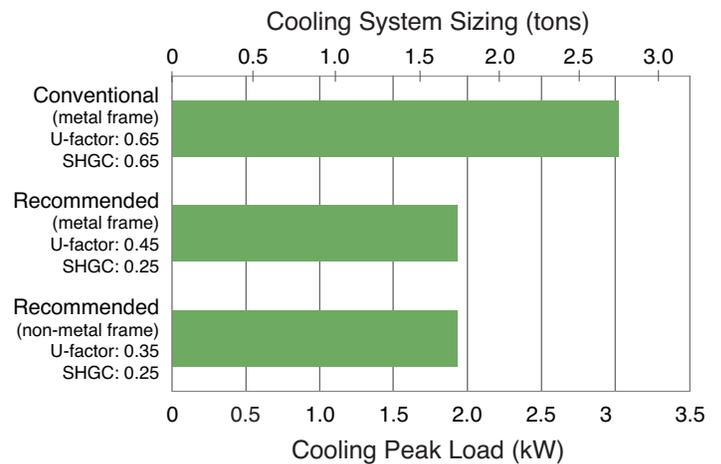
Winter Comfort and Interior Temperature

A significant benefit of energy-efficient windows is improved winter comfort due to warmer interior window surfaces. The figure below shows the area-weighted interior surface temperature of a window when the outside air temperature is 20° Fahrenheit. Windows with low surface temperature feel uncomfortable because more heat is radiated from a person's body to the window.



Cooling Peak Load

Windows with solar control glazing reduce peak cooling loads, which allows for downsized mechanical equipment. Lower peak cooling loads typically also improve summer comfort. The following example shows the estimated peak cooling load for a typical 950 square foot unit on the southwest corner of a multifamily building.



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Comparing Window Performance in Multifamily Buildings in the South Central Zone

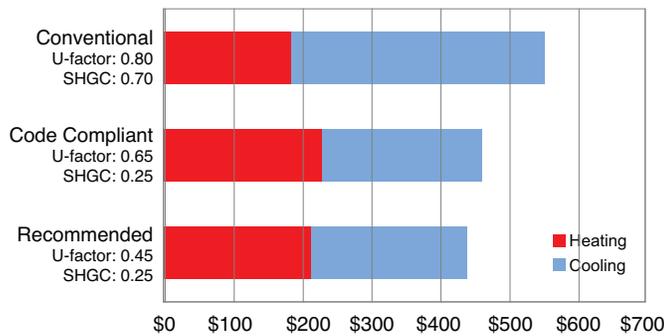
Annual Energy Use in Atlanta, Georgia

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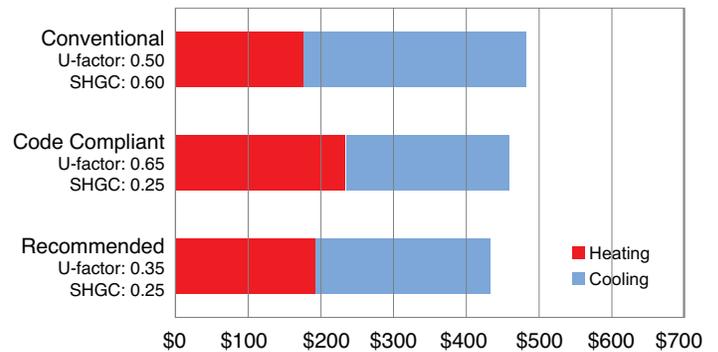
These graphs compare three performance levels for both metal and non-metal frames. Conventional windows are double pane windows without high-performance features, while code compliant windows meet the prescriptive requirements of ASHRAE Standard 90.1-2007. Finally, the bottom windows meet the recommended energy performance levels for CW class windows in a central climate, as discussed on page 2. Moving from conventional to recommended windows reduces total heating and cooling energy (including all heating and cooling loads) by 12-20%.



Annual Energy Costs in Atlanta, Georgia (metal frame)

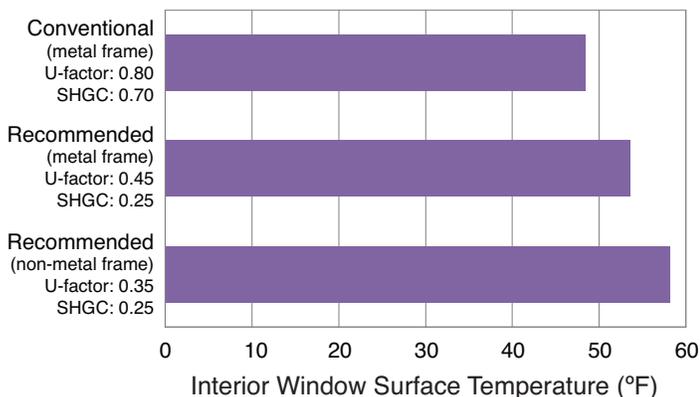


Annual Energy Costs in Atlanta, Georgia (non-metal frame)



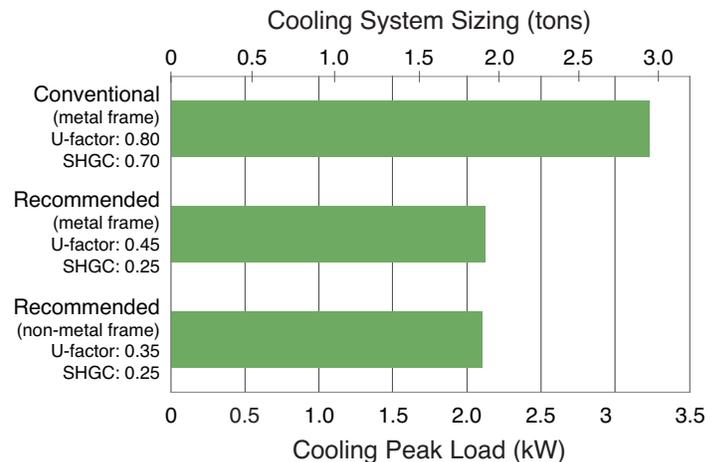
Winter Comfort and Interior Temperature

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Comparing Window Performance in Multifamily Buildings in the Southern Zone

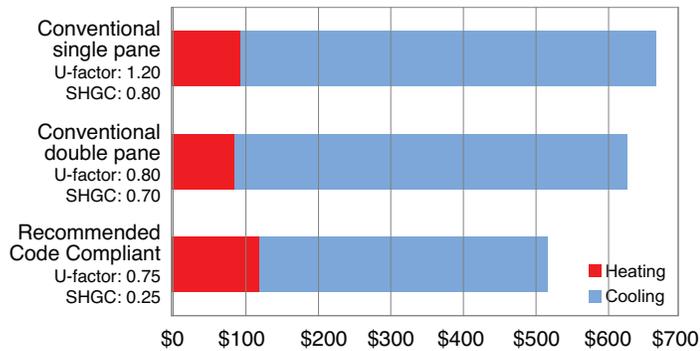
Annual Energy Use in Houston, Texas

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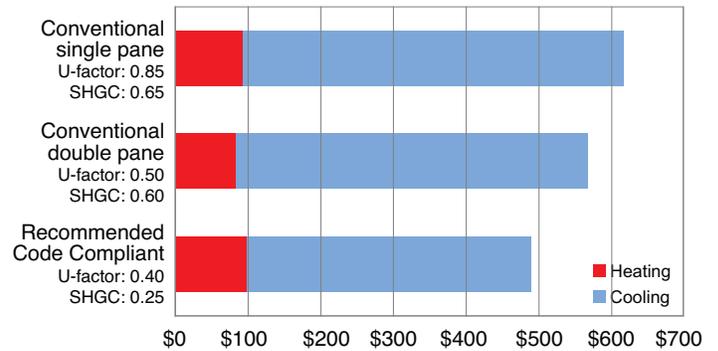
These graphs compare three performance levels for both metal and non-metal frames. Conventional single-pane and double-pane windows without high-performance features are shown, while the bottom windows meet the recommended energy performance levels for CW class windows in a southern climate, as discussed on page 2. Moving from conventional to recommended windows reduces total heating and cooling energy (including all heating and cooling loads) by 20-25%.



Annual Energy Costs in Houston, Texas
(metal frame)

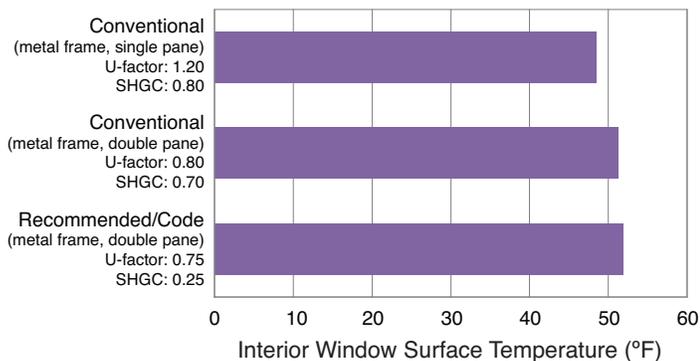


Annual Energy Costs in Houston, Texas
(non-metal frame)



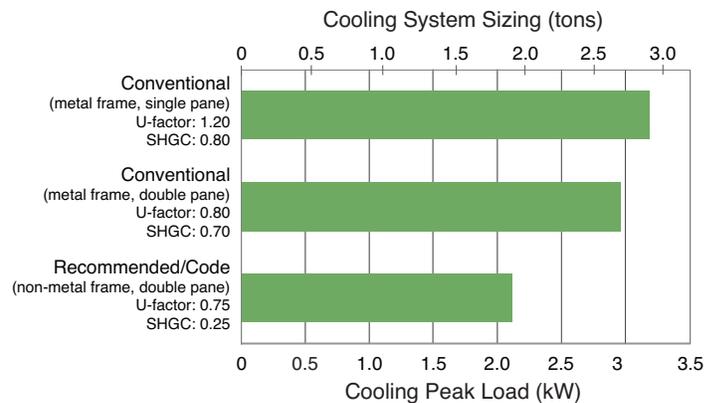
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