WAUSAU

WINDOW AND WALL SYSTEMS

# Understanding U-Factors

(An Apogee IFD Presentation)

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## PROGRAM SPECIFICS

**Length:** One hour
**Credits:** 1 learning unit (LU)/HSW/SD
**Cost:** Free - There is no cost to bring this program to your firm or chapter meeting, or to take the online course
**Description:** LEED® ratings and net-zero energy building place high importance on the U-Factor (thermal transmittance) of window systems. This presentation provides an understanding of window assembly U-Factor, component effects, certification and testing methods, and specification language.
**Objective:** Provide design professionals with valuable information on thermal transmittance of fenestration systems.
**Point of Contact:** For more information or to schedule a presentation, contact Wausau at info@wausauwindow.com or call toll-free at 877.678.2983

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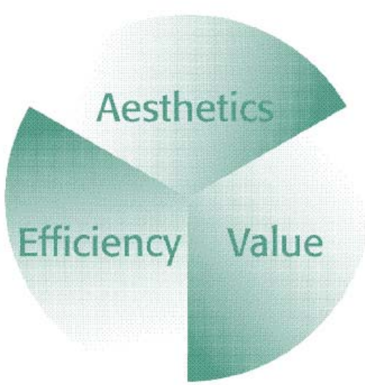
Integrated Façade Design (IFD) recommendations and training draw on the technical expertise of all Apogee architectural business units, to bring balanced and competitive energy solutions to the design community.



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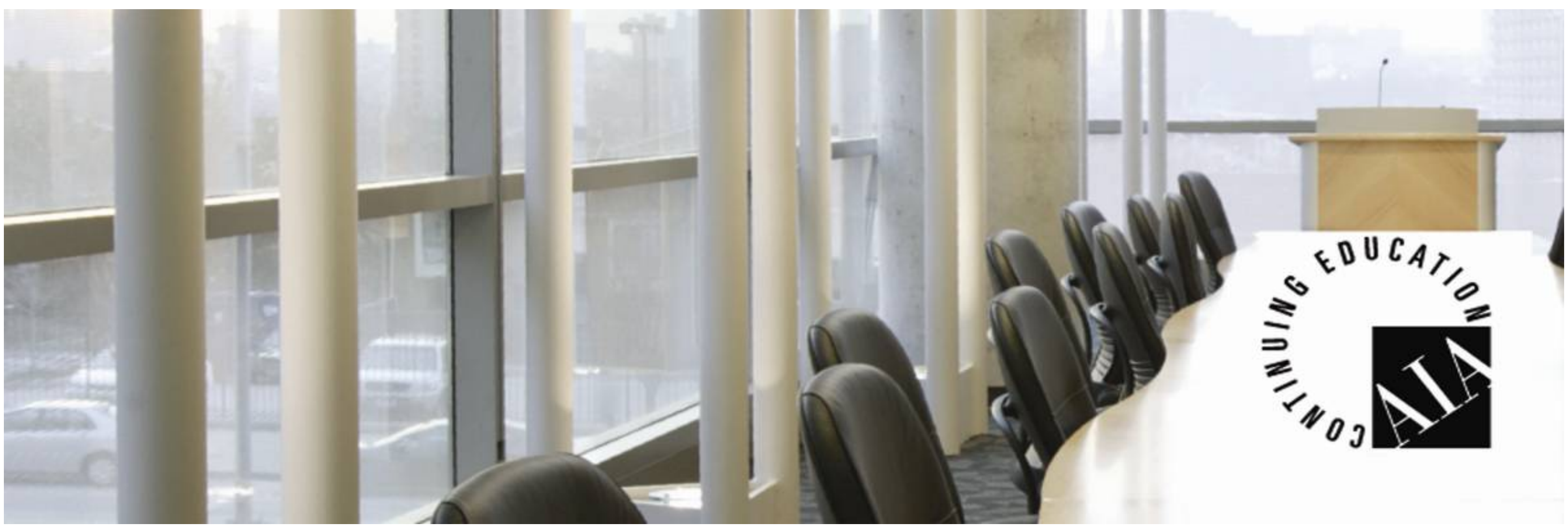
Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Learning Objectives

1. Identify five attributes affecting window U-Factor
2. Employ at least three design options to improve window U-Factor
3. Differentiate between NFRC and AAMA testing and certification processes
4. Draft non-defective specification requirements for U-Factor.
5. Recognize other important energy related window design factors and the importance of a balanced design




Section One

# Introduction to U-Factors

# Model Energy Codes

Model Energy Codes are requiring better performance for many reasons


Building operating costs
HVAC capacity "first cost"
Useable perimeter space
Occupant comfort and productivity
Sanitary conditions and maintenance
View
Need for secondary glare control
Environmental responsibility

Reliance on foreign fossil fuels, as well as an increasing recognition of the societal costs of pollution such as greenhouse gases and acid rain, make rising energy costs a trend not likely to abate in our lifetimes.

Rising energy costs increase building operating costs, and windows in buildings are a key contributor to the country's gross energy consumption.

Better thermal performance renders perimeter areas of buildings more livable. Comfort and natural daylight makes occupants happier and more productive.

Extraneous condensation and moisture build-up are a concern in many occupancy types.
CRF = Condensation Resistance Factor.

# Product Selection Concerns

Single-number rating systems

Level of confidence, accountability for actual results, and uncertainty in energy savings calculations:

This program will help you understand


Understanding energy requirements is an essential starting point, but concerns often arise in the product selection process.

Single-number rating systems can be misleading.  A balanced design approach is strongly recommended.

Energy efficient building designs must comply with codes, **and** meet owner expectations.

Design professionals are increasingly concerned with misrepresentation of energy savings.

Performance assessment must go **beyond "R-Value."**

# Definition of U-Factor

U-Factor (U-Value) is a measure of thermal transmittance, through conduction, convection, and radiation.

U-Factor is the reciprocal of R-Value

$$U = 1/R$$

(R-3 is the same as U = 0.33)

Heat flow per unit area, time, and °F temperature difference (units are BTUs/ $ft^2$-hr-°F or Watts/$m^2$- °K)

**With U-Factor, lower is better**

U-Factor allows the HVAC engineer to calculate peak loads, as well as energy consumption, for any size window, in any climate.

The term "U-Value" is sometimes used to differentiate center-of-glass thermal transmittance, from "whole window" overall U-Factor.

At a basic level, there are three ways heat can transfer.

**Conduction** is heat transfer through a solid, liquid, or gaseous material via molecular contact.
Example: Touching a hot stove
**To reduce conduction in windows, add frame thermal barriers.**

**Convection** is the transfer of heat through the movement of liquids or gases.
Example: Facing into a cold north wind
**To reduce convection in windows, add enclosed air spaces.**

**Radiation** is the transfer of heat through space without relying on an intervening medium.
Example: The heat of the sun on your face
**To reduce radiation in windows, add low-e glass coatings.**

Featured Project:

# Boston University Life Sciences

**Location:**
Boston, Massachusetts
Climate Zone 5

**Architect:**
Cannon Design

**Products:**
Triple insulating, argon-fill, low-e glass, warm edge spacer
Multi-level thermal barrier framing

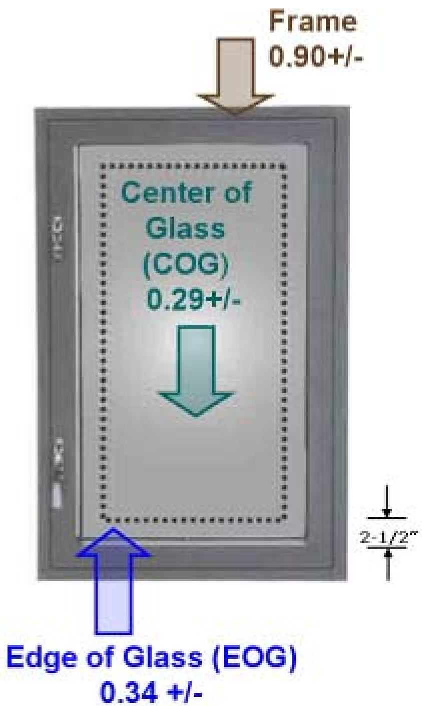
**Performance:**
NFRC U-Factor **0.18** BTU/ $ft^2$-hr-°F
SHGC 0.25 VT 60%
AAMA CRF 83
STC 40, OITC 32

Section Two

# Design Features Affecting U-Factor

# Components and U-Factor

Assembly U-Factor =
The "area weighted" average thermal transmittance of all components




$$\frac{(U_{FRAME} \cdot Area_{FRAME}) + (U_{EOG} \cdot Area_{EOG}) + (U_{COG} \cdot Area_{COG})}{\text{Total Area}}$$

Three components are used to calculate U-Factor:

- **Center-of-glass** (COG)
  Typical value 0.29 BTU/ $ft^2$-hr-°F (low-e IG)

- **Edge of Glass** (EOG)
  Typical value 0.34 BTU/ $ft^2$-hr-°F (aluminum spacer)

- **Frame**
  Typical value 0.90 BTU/ $ft^2$-hr-°F (thermal break)

Frame U-Factor includes heat transfer through surfaces perpendicular to the glass plane.

The center-of-glass is the best-performing component of a non-residential window assembly.

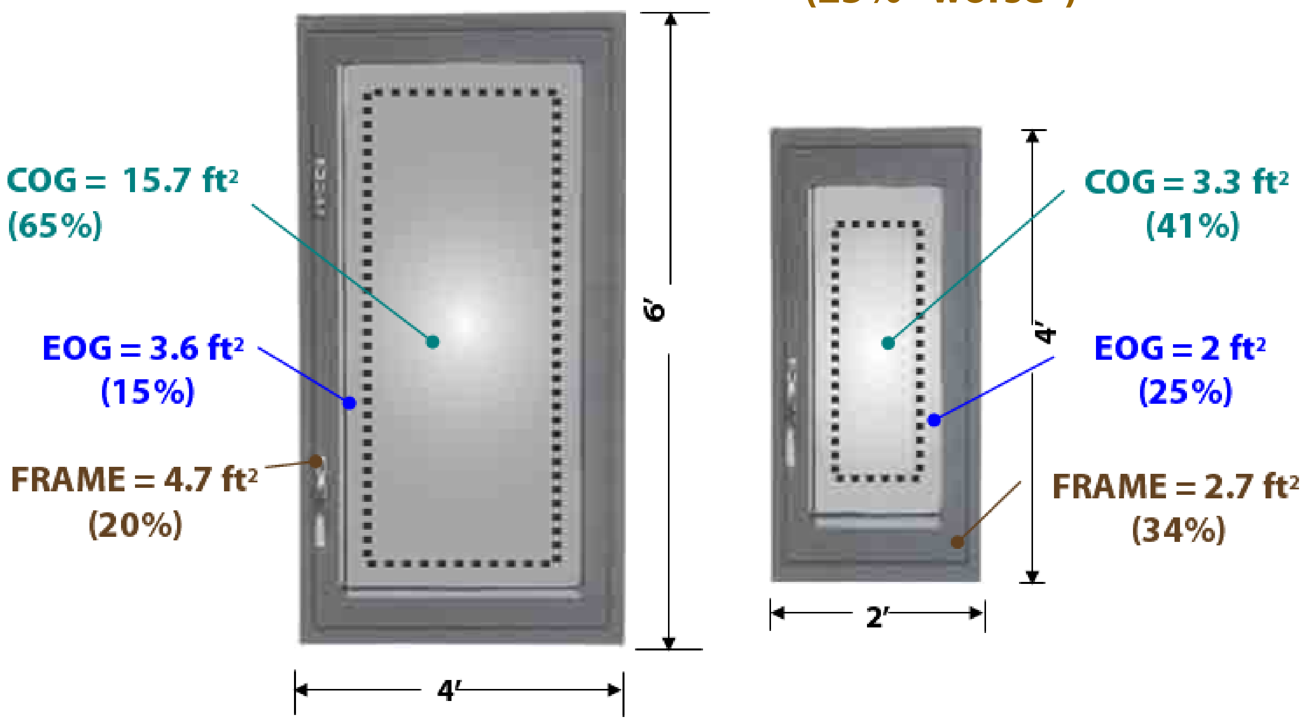
Window area and configuration can significantly affect the overall window assembly U-Factor.

# Area and U-Factor

The windows in this example have identical glass, spacer, and framing components.
The only difference is their **size**.

**Area** = 24.0 $ft^2$
U-Factor = **0.4** BTU/ ft2-hr-°F

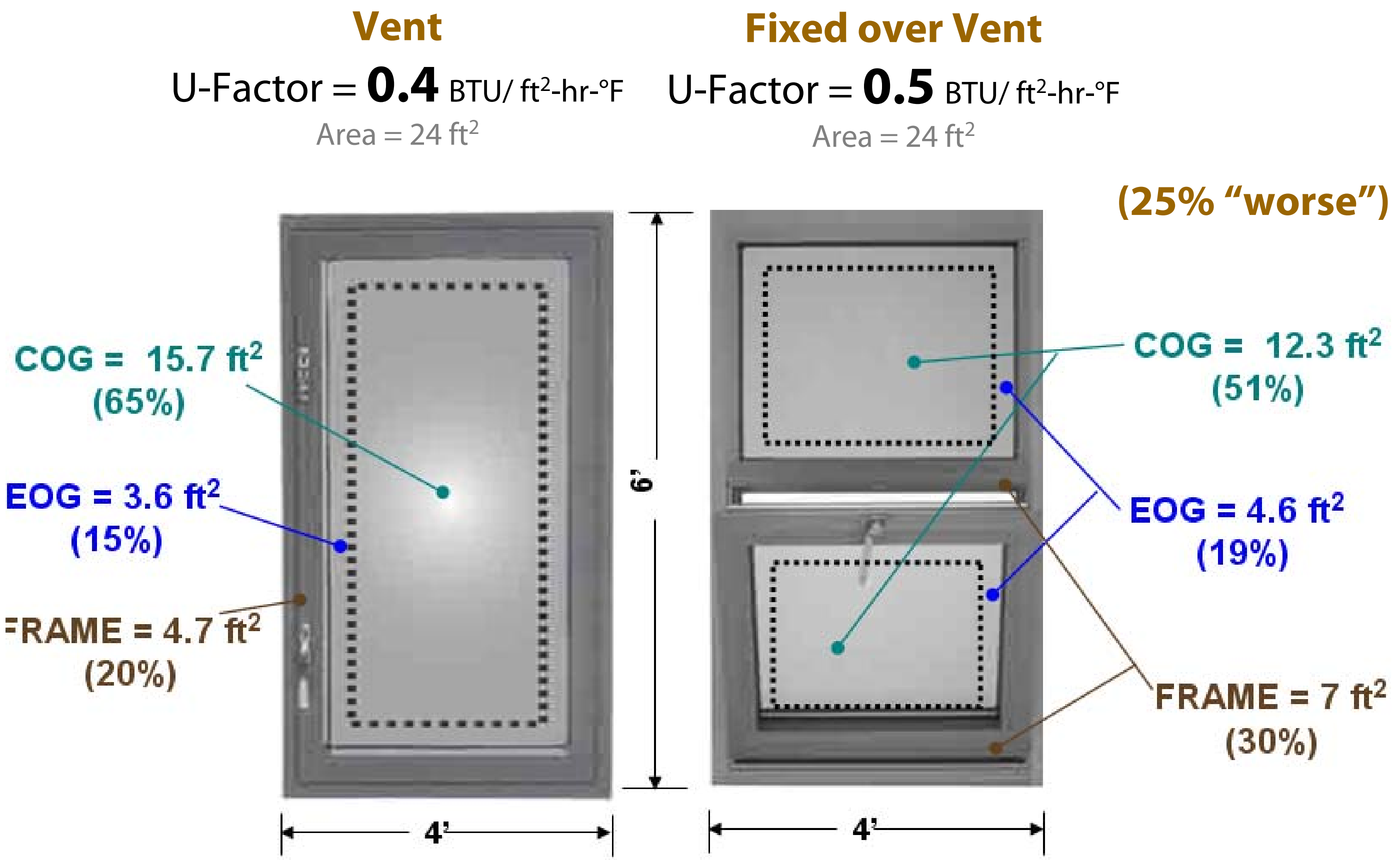
**Area** = 8.0 $ft^2$
U-Factor = **0.5** BTU/ ft2-hr-°F
**(25% "worse")**




For the smaller window shown, the amount of higher-performing COG area decreased from 65% to 41%, and the lower performing frame increased from 20% to 34%.

# Configuration and U-Factor

The windows in this example have identical glass, spacer, and framing components. The only difference is their **configuration**.

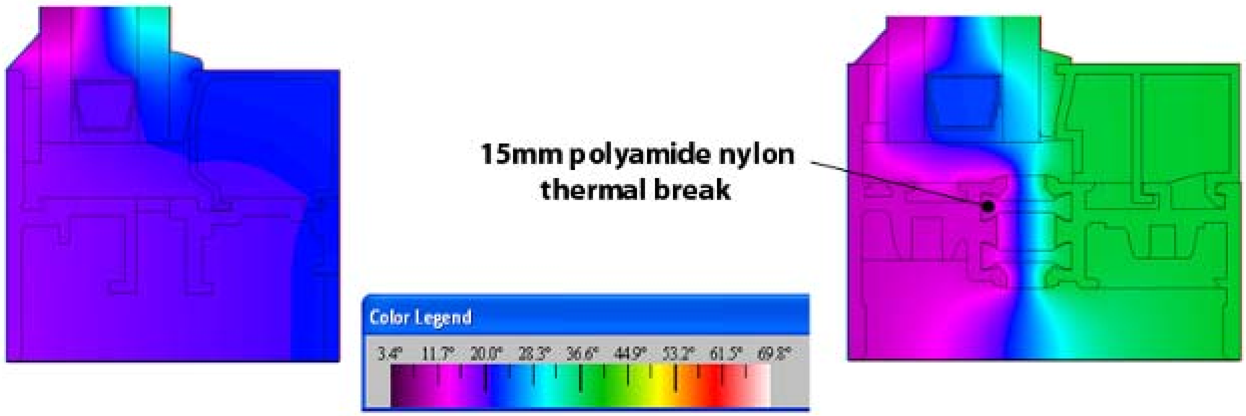



Even though the overall area of the window remained the same, the window on the right has a higher (or worse) U-Factor. Adding a horizontal rail to accommodate the fixed lite decreased the COG area from 65% to 51%, replacing it with frame and EOG area.

# Frame Type and U-Factor

Thermal barriers in frames **also** improve EOG performance

**Non-Thermal** | **Thermal Break**




**Non-Thermal — Local U-Factors**

Frame **1.32** BTU/ $ft^2$-hr-°F

EOG **0.40** BTU/ $ft^2$-hr-°F

COG 0.29 BTU/ $ft^2$-hr-°F

**Thermal Break — Local U-Factors**

Frame **0.85** BTU/ $ft^2$-hr-°F **(36% better)**

EOG **0.37** BTU/ $ft^2$-hr-°F **(8% better)**

COG 0.29 BTU/ $ft^2$-hr-°F

Other frame effects include (in order of their impact on local U-Factor), mullion depth, emissivity of aluminum finish, glass set-back from the exterior, sightline, extrusion wall thickness, and number of frame extrusion webs.

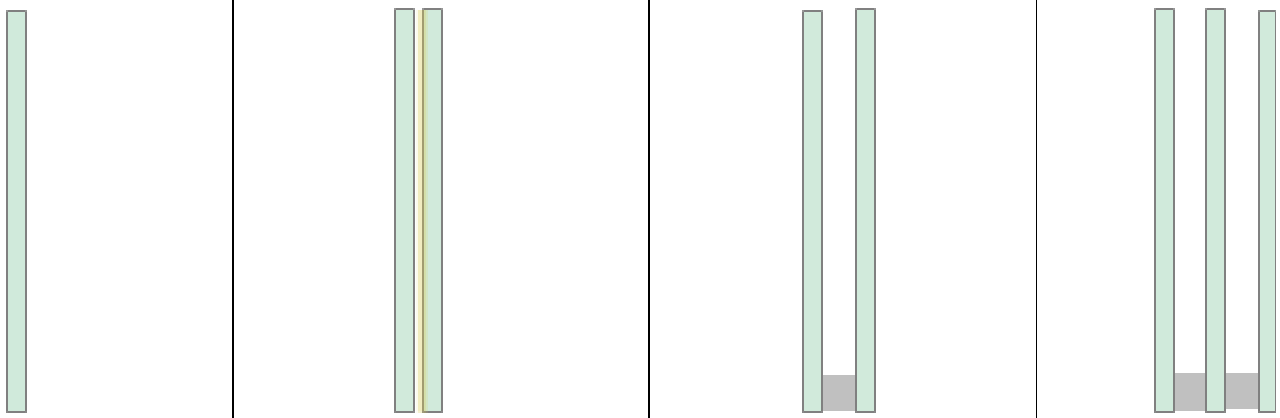

Section Three

# Glass Options

# Glass Makeup and U-Factor

Center-of-glass and edge-of-glass U-factors for uncoated glass vary, based solely on unit makeup.

(All Winter U-Factors in BTU/hr-ft$^2$-°F)



| | 1/4" Monolithic | 9/16" Laminated | 1" Insulating | 1-3/4" Triple Insulating |
|---|---|---|---|---|
| **COG** | **1.02** | **0.95** | **0.47** | **0.30** |
| EOG | 0.93 | 0.85 | 0.49 | 0.39 |

From left: A 1/4" monolithic glass lite has a COG U-Factor of 1.02.
A 9/16" laminated unit has a COG of 0.95, only a slight improvement.
Adding an airspace to create a 1" insulating unit improves the COG to 0.47.
Adding another airspace to create the 1-3/4" triple insulating unit improves the COG to 0.30.

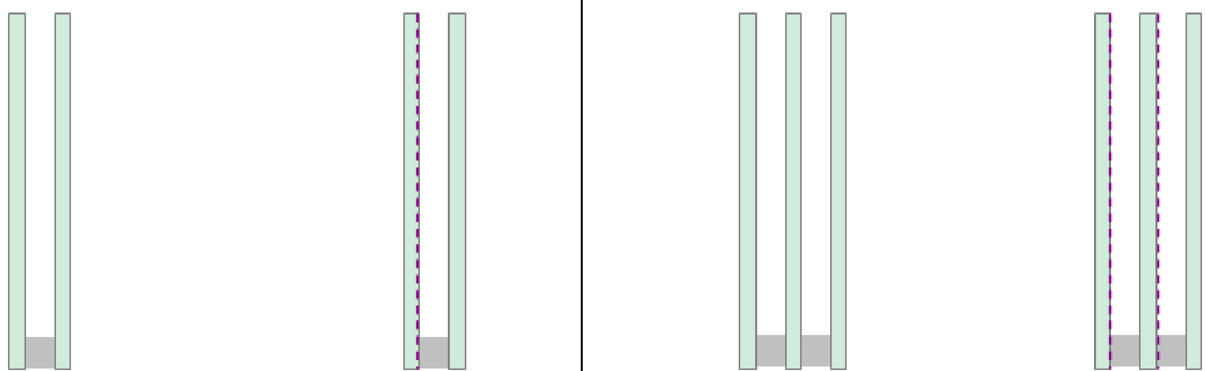
NOTE: EOG U-Factor **also** changes with unit makeup.

# Glass Coatings and U-Factor

Low-e coatings improve both COG and EOG U-Factors.

(All Winter U-Factors in BTU/hr-ft$^2$-°F)

| 1″ Insulating Uncoated | 1″ Insulating Low-e Coated | 1-3/4″ Triple Insulating Uncoated | 1-3/4″ Triple Insulating Double Low-e Coated |
|---|---|---|---|



| | 1″ Insulating Uncoated | 1″ Insulating Low-e Coated | 1-3/4″ Triple Insulating Uncoated | 1-3/4″ Triple Insulating Double Low-e Coated |
|---|---|---|---|---|
| **COG** | **0.47** | **0.29** | **0.30** | **0.16** |
| EOG | 0.49 | 0.37 | 0.39 | 0.27 |
| Frame | 0.86 | 0.85 | 0.71 | 0.69 |
| | | 38% better | | 47% better |

At left: Illustrates the difference between a 1″ uncoated IG unit, and a 1″ IG unit with a Low-e coating on the #2 surface, improving the COG U-Factor by 38%

At right: Illustrates the difference between an uncoated triple IG unit, and a triple IG unit with two Low-E coatings on the #2 and #4 surfaces, improving the COG U-Factor by 47%

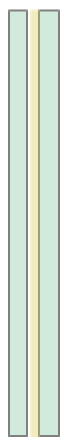
NOTE: EOG U-Factor **also** improves with the use of low-e coatings.

# Glass Coatings and U-Factor (continued)

Coatings added to laminated glass improve SHGC, but without an adjacent air space, **do not** improve COG or EOG U-Factors

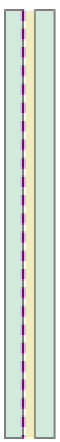
(All Winter U-Factors in BTU/hr-ft$^2$-°F)

**9/16" Laminated Uncoated**



| | |
|---|---|
| **COG** | **0.95** |
| EOG | 0.85 |
| Frame | 1.01 |

**9/16" Laminated Low-e Coated**



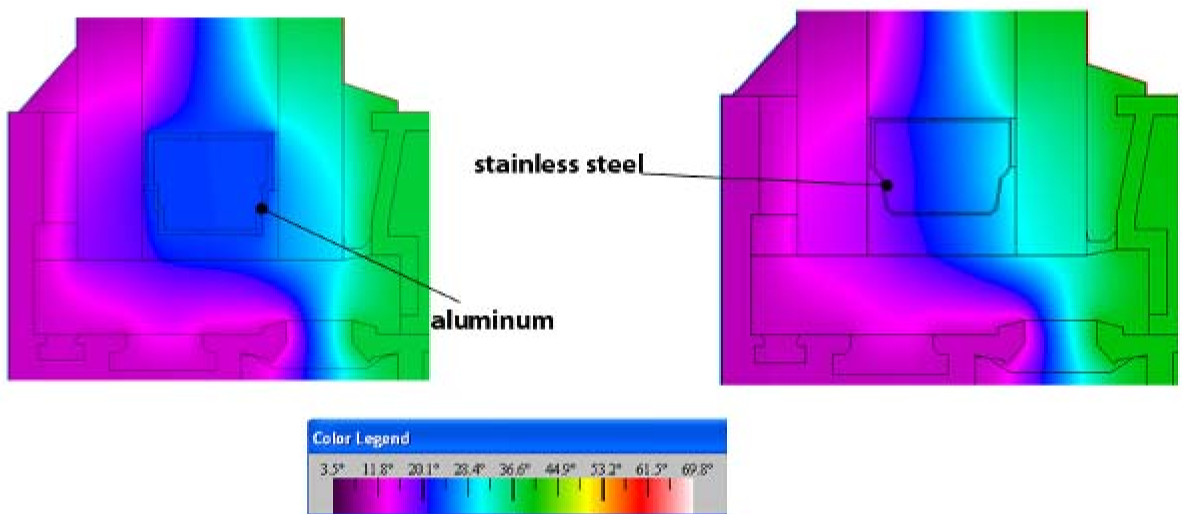
| | |
|---|---|
| **COG** | **0.95** |
| EOG | 0.85 |
| Frame | 1.01 |

NO CHANGE

# Glass Spacer and U-Factor

Surprisingly, insulating glass spacers can affect **frame** U-Factor more than **EOG** U-Factor.

**Standard Aluminum Spacer** | **Stainless Steel "Warm Edge" Spacer**




**Standard Aluminum Spacer**

Local U-Factors

Frame **0.85** BTU/ ft$^2$-hr-°F

EOG **0.37** BTU/ ft$^2$-hr-°F

COG 0.29 BTU/ ft$^2$-hr-°F

**Stainless Steel "Warm Edge" Spacer**

Local U-Factors

Frame **0.79** BTU/ ft$^2$-hr-°F **(7% better)**

EOG **0.35** BTU/ ft$^2$-hr-°F **(5% better)**

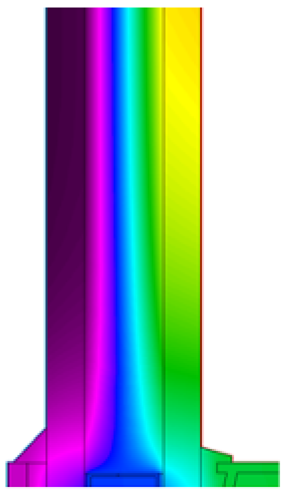
COG 0.29 BTU/ ft$^2$-hr-°F

While difference in U-Factor is relatively minimal, note that surface temperature warms by 3 to 4 °F at standard conditions, forestalling condensation.

# Gas Fill and U-Factor

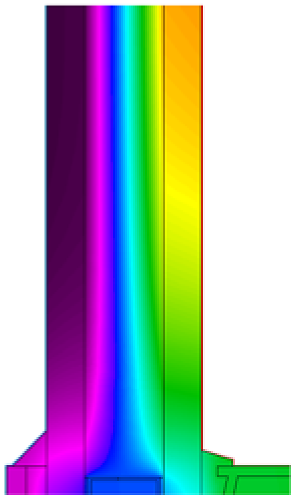
Gas fill affects **COG** U-Factor much more than EOG U-Factor.

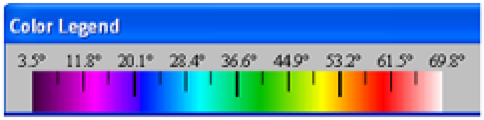
**Air space in IG**



1" Insulating low-E coated

**Argon-filled space in IG**






Local U-Factors

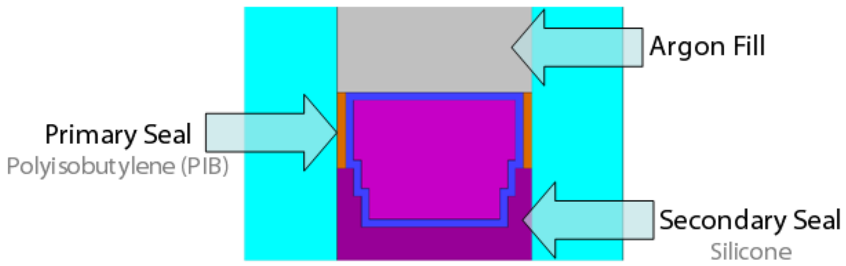
COG **0.29** BTU/ ft$^2$-hr-°F
EOG **0.37** BTU/ ft$^2$-hr-°F
Frame 0.85 BTU/ ft$^2$-hr-°F

Local U-Factors

COG **0.24** BTU/ ft$^2$-hr-°F **(17% better)**
EOG **0.34** BTU/ ft$^2$-hr-°F **(8% better)**
Frame 0.84 BTU/ ft$^2$-hr-°F

# Argon Retention

Over time, argon gas will dissipate from an insulating glass unit. The rate at which this occurs depends upon the type of edge seal, the quality of materials, and manufacturing assembly processes.




In the absence of a formal U.S. standard, the industry has accepted a dissipation rate of 1% per year.

Select an insulating glass manufacturer that is IGCC-certified for argon, and uses PIB primary seals, with silicone secondary seals.

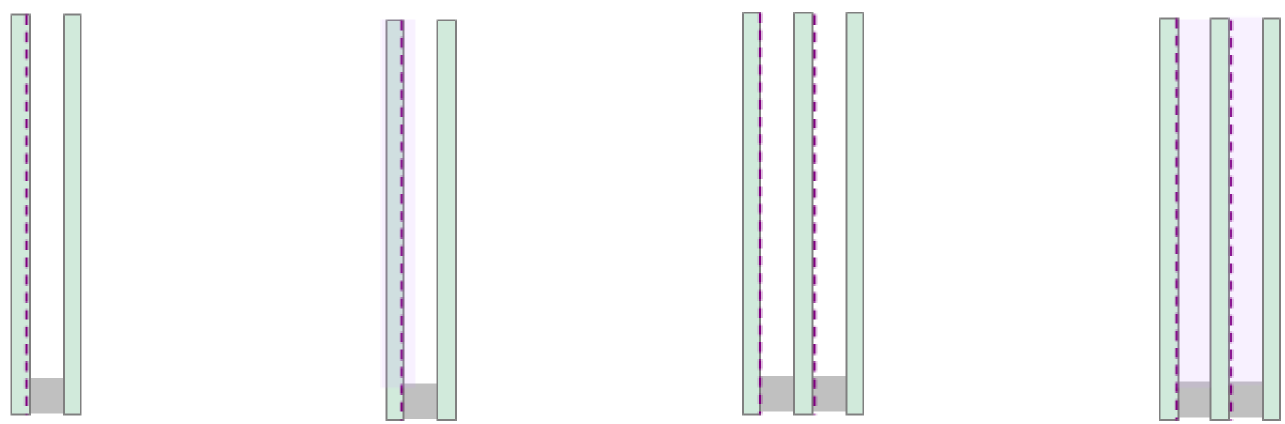
Relative sealant permeability:

| Sealant | Oxygen | Argon |
|---|---|---|
| PIB | 0.7 | 1 |
| Polysulfide | 5 | 4 |
| Polyurethane | 50 | 45 |
| Silicone | 750 | 650 |

# Combined Effects

## on U-Factor

In this comparison, the same thermal barrier frame was used for all glass types.



| | 1" Insulating Low-e Coated, Air, Alum Spacer | 1" Insulating Low-e Coated Argon, Stainless Steel Spacer | 1-3/4" Triple Insulating Double Low-e Coated, Air, Alum Spacer | 1-3/4" Triple Insulating Double Low-e Coated, Argon, Stainless Steel Spacer |
|---|---|---|---|---|
| COG | 0.29 | 0.24 | 0.16 | 0.12 |
| EOG | 0.37 | 0.32 | 0.27 | 0.22 |
| Frame | 0.85 | 0.80 | 0.69 | 0.64 |

GOOD → BEST

Featured Project:

# Syracuse Newhouse Center

**Location:**

Syracuse, New York

Climate Zone 5

**Architect:**

Polshek and Partners

**Products:**

Unitized four-side silicone curtainwall

1" low-e insulating glass

**Performance:**

NFRC U-Factor **0.39** BTU/ $ft^2$-hr-°F

SHGC 0.38 VT 70%

AAMA CRF 63

STC 35, OITC 30

Section Four

# Manufacturers' Claims

# Testing and Rating Protocols

U-Factor Claims

# Watch for…

Many times, residential products are used as a basis for U-Factor claims.

Few residential systems are appropriate for commercial buildings.

For a given glass type, frame sightline, and thermal barrier, there is little that can be done to lower U-Factor.

Sizes larger than NFRC test size may not be acceptable per local code

Residential 1/8” (3 mm) glass **thickness** can result in pillowing, roller wave distortion, size limits, few coating options, and increased breakage during glazing.

Verify sightline, color, radius corners, structural glazing, size, and availability of residential **“warm edge”** spacer systems.

If the window is designed “inside-out”, U-Factor can be improved, but with outside-glazed vision glass, lower CRF, different appearance.

**Krypton** as gas fill offers a favorable cost versus benefit only for air spaces ¼” wide or less.

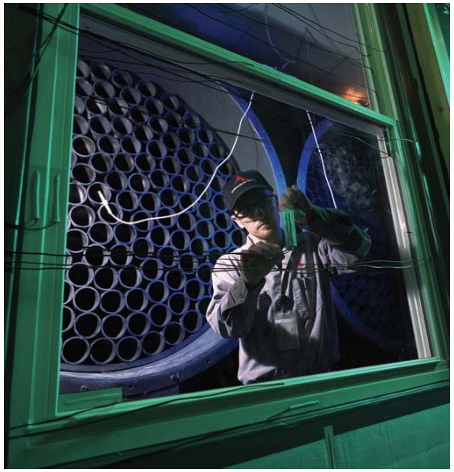
**Suspended films** can introduce concerns with wrinkles, corrosion, warranty, and replacement cost.

# Thermal Ratings
## and Testing

There are two U.S. thermal testing protocols.

**AAMA**
American Architectural Manufacturers Association

**NFRC**
National Fenestration Ratings Council



The two programs yield similar, but not identical, thermal performance results.

Aluminum remains the framing material of choice for non-residential applications, when all design requirements are considered in balance.

Of course, there are many vinyl and fiberglass residential windows vying for market share, some making unrealistic claims regarding R-Value, and applicability to commercial and institutional projects.  Consider ALL factors - from structural integrity to longevity to stiffness to heat build-up - before deciding on alternative materials.

Systems using conventional thermal barrier aluminum window and curtainwall frames can achieve overall U-Factors below 0.20 (R-5), meeting needs for best-in-class envelope performance in any Climate Zone.

## Testing and Rating
# AAMA

AAMA established in 1936 to develop standards providing third-party validation of product performance and quality

Uses physical testing per AAMA 1503.1, to measure window assembly U-Factor and CRF, but not glass SHGC

In 2009, changed single-lite fixed and operable sizes in AAMA 1503 to be the same as NFRC

Offers combination fixed and operable non-residential configurations

The AAMA 507 rating system is applicable to storefront, curtainwall, window wall and other fenestration products for commercial buildings, not just windows.


Performance rating is building-specific

AAMA 507 accounts for vision area and spandrel area, size variation, and the effect of any type of architectural glass.

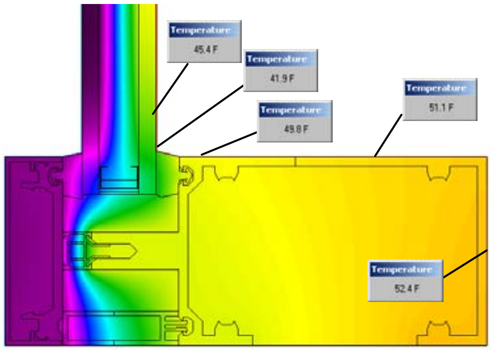
Code acceptance varies

# Testing and Rating

# NFRC

Established in 1989 - A joint effort of government, residential window manufacturers and other stakeholders.

Uses physical testing (NFRC 102) and thermal modeling, to determine Window Assembly U-Factor (NFRC 100) and SHGC (NFRC 200)




Recently implemented the new Component Modeling Approach (CMA) for non-residential projects.

NFRC labeling is currently referenced in Model Energy Codes as a compliance option.

The NFRC Certified Products Directory lists all products that can be labeled

Certified Products Directory Search

<< Back

**Manufacturer:** Wausau Window and Wall Systems
**Series Name:** 2250
**Operator Type:** Casement

Key:
1) 2 values for U-Factor, SHGC, and VT indicate Res/Non-Res ratings.
2) ' indicates that certified SHGC/VT values are available from the manufacturer.

Fact Sheet

View NFRC Code Listing

| CPD Number | Manufacturer Product Code | Frame and Sash Type | U-Factor | SHGC | VT | Condensation Resistance | Glazing Layers | Low-E/Internal Film (Surface) | Gap Width(s) | Spacer | Fill | Grids | Divide |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WAU-A-2-00001 | | Aluminum w/ Thermal Breaks - All Members, Aluminum w/ Thermal Breaks - All Members | 0.61 | 0.47 | 0.50 | 34 | 2 | | 0.500 | A1-D | Air | N | |
| WAU-A-2-00002 | | Aluminum w/ Thermal Breaks - All Members, Aluminum w/ Thermal Breaks - All Members | 0.51 | 0.26 | 0.45 | 35 | 2 | 0.040 (2) | 0.500 | A1-D | Air | N | |
| WAU-A-2-00003 | | Aluminum w/ Thermal Breaks - All Members, Aluminum w/ Thermal Breaks - All Members | 0.48 | 0.26 | 0.45 | 35 | 2 | 0.040 (2) | 0.500 | A1-D | Argon | N | |
| WAU-A-2-00004 | | Aluminum w/ Thermal Breaks - All Members, Aluminum w/ Thermal Breaks - All Members | 0.54 | 0.42 | 0.47 | 34 | 2 | 0.215 (2) | 0.500 | A1-D | Air | N | |
| WAU-A-2-00005 | | Aluminum w/ Thermal Breaks - All Members, Aluminum w/ Thermal Breaks - All Members | 0.47 | 0.26 | 0.45 | 37 | 2 | 0.040 (2) | 0.500 | SS-D | Argon | N | |

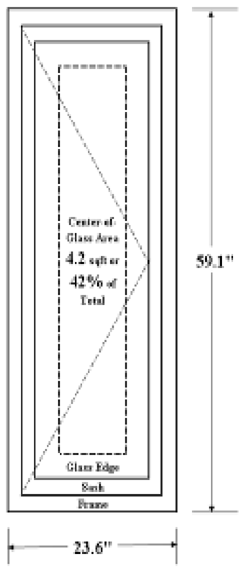
In general, aluminum windows can be made in larger sizes than PVC, wood, or fiberglass, and exhibit superior durability, finish, longevity, and strength. These attributes are not yet recognized by NFRC

# NFRC Test Sizes

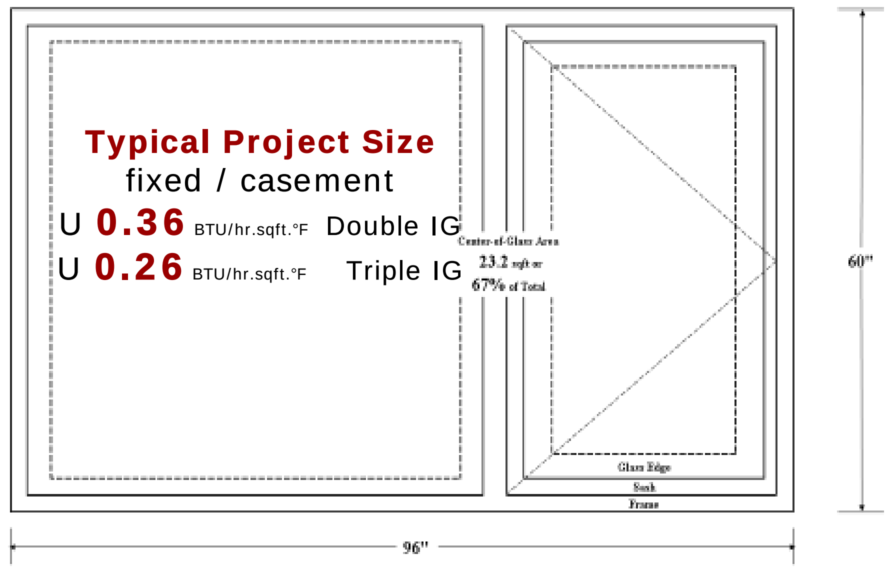
As shown in the diagram below, even when using the same frame and glass, **test size** can matter… a lot.

**NFRC Size**
casement
U **0.44** BTU/hr.sqft.°F Double
U **0.36** BTU/hr.sqft.°F Triple

**Up to 40% higher!**




**Typical Project Size**
fixed / casement
U **0.36** BTU/hr.sqft.°F Double IG
U **0.26** BTU/hr.sqft.°F Triple IG

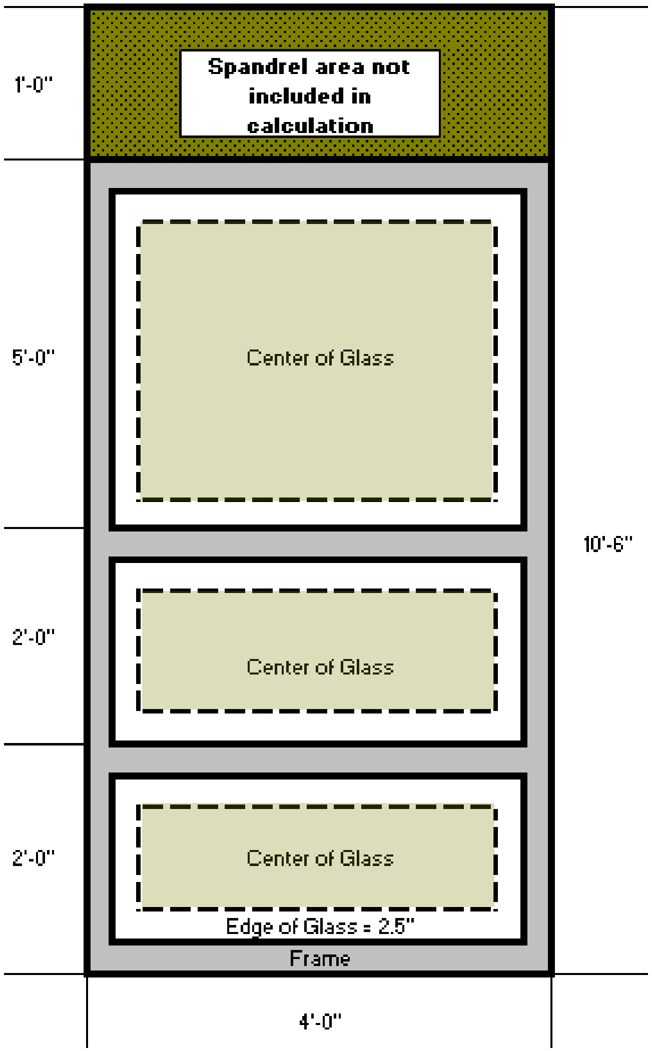



NFRC was residentially-oriented, so NFRC **operable** window test sizes are small.
Small NFRC test sizes make a huge difference in U-Factor for aluminum windows
(…but not for PVC, wood, or fiberglass).

Fixed window and curtainwall test sizes are more representative,
so U-Factors are much lower, even though frame performance is worse!

# Comparing AAMA and NFRC

## Thermal Test Results




NFRC 100 U-Factors are about **10% LOWER** than AAMA 1503 U-Factors

Spandrel areas don't "count", only vision glass and adjacent framing

Can't use thermal models for labeling of products with between-glass blinds

Thermal models are fairly accurate for U-Factor, but NOT necessarily for surface temperatures (CRF)

Featured Project:

# University of Illinois

## Business Instructional Facility

LEED® Platinum

**Location:**

Champaign, Illinois
Climate Zone 5

**Architect:**

Pelli Clark Pelli Associates

**Products:**

Two-side silicone-glazed curtainwall
1" low-e insulating glass

Triple-glazed operable thermal barrier windows with between-glass blinds

**Performance:** (Curtainwall)

NFRC U-Factor **0.36** BTU/ $ft^2$-hr-°F
SHGC 0.38 VT 70%
AAMA CRF 71
STC 31, OITC 25

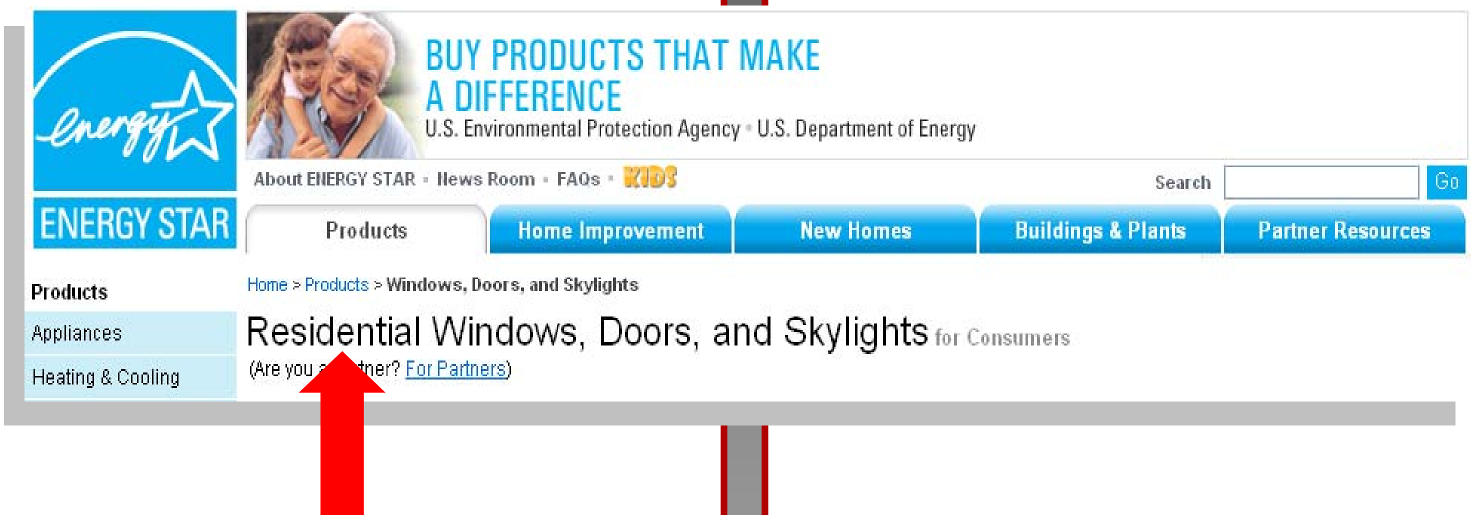

Section Five

# Writing Valid Specifications

# Integrated Façade Design

# Energy Star®

Specifying Energy Star® for Windows in a commercial building is a misapplication of a great idea.




The EPA's Energy Star for Windows is a **residential** program.

Using Energy Star® window requirements for commercial buildings will result in a significantly sub-optimal design

Energy Star® for Buildings uses utility data versus nationwide benchmarks

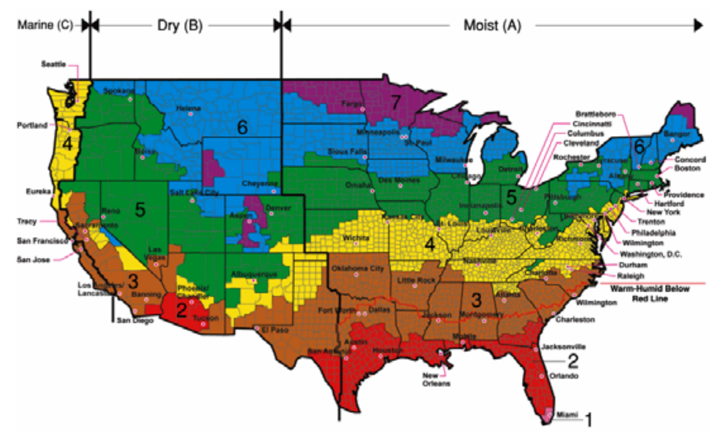
For commercial window design, Model Energy Codes like ASHRAE 90.1 and IECC reflect best practices, updated for every three-year code cycle.

# Specification Checklist

- ✓ Don't use **<u>any</u>** single performance criteria to select a system.
- ✓ Don't confuse COG U-Factor with "whole window" U-Factor
- ✓ U-Factor and CRF are very different

- ✓ For windows, cite U-Factor rather than R-Value
- ✓ If using published product NFRC U-Factors, be sure to review the project sizes and configurations

- ✓ Be consistent with SHGC and SC
- ✓ Know your Climate Zone and local energy codes




- ✓ Make sure Division 8 Metal Windows specifications for U-Factor and SHGC match the Glass and Glazing specifications, and both match code requirements and building permit values.

# Balanced Design


Window selection and design should be based on **all** applicable criteria, not on any specific single number rating system.

Selection and design criteria almost always include:

Code Compliance
Structural Integrity
Weather-ability
**Energy Efficiency**
Condensation Resistance
Building Movements
Ventilation and Cleaning Access
Sustainable Design
Durability
Cost
**Aesthetics**

…and on some projects, also:

Emergency Egress
Hurricane Impact
Psychiatric Detention
Blast Hazard Mitigation
Noise Control
Seismic Movements
Smoke Evacuation

# Balanced Design
(Continued)

Second decimal place U-Factor comparisons should be reserved for components only, and not overall window assembly U-Factors.

Princeton Ellipse Dorm

Considerable variability can occur between product types, lab-to-lab testing and modeling.

Apply common sense to product comparisons.

Thermal testing and modeling is **not** that precise. When comparing manufacturer's products, the second decimal place is usually immaterial.

Statistically, U = 0.39 $BTU/hr.ft^2.°F$ can be essentially equal to U 0.36 $BTU/hr.ft^2.°F$ .

For energy efficient designs, also consider daylighting, natural ventilation, LSG, shading devices, and air infiltration.

Conductive heat loss can actually reduce demand in swing seasons.

Most commercial buildings are cooling mode-dominated, even in cold climates. For these buildings, solar heat gain control is of primary importance.

Featured Project:

# 1800 Larimer

LEED® Platinum

**Location:**
Denver, Colorado
Climate Zone 6

**Architect:**
RNL Design

**Products:**
Unitized four-side silicone curtainwall
Thermal barrier window wall
1” low-e insulating glass

**Performance:**
NFRC U-Factor **0.50** BTU/ ft²-hr-°F
SHGC 0.19 VT 20%
AAMA CRF 65
STC 35, OITC 30


Richmond Federal Courthouse

Section Six

# Summary

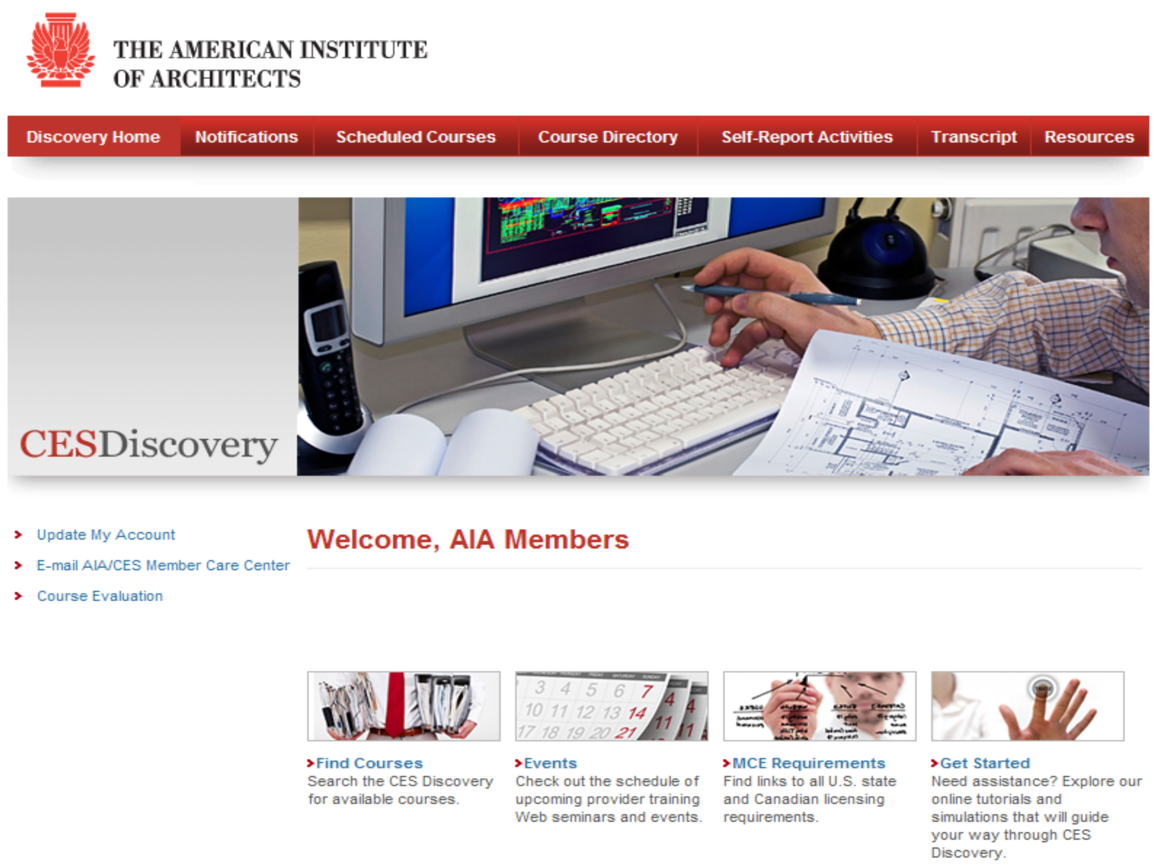
# Learning Objectives

1. Identify five attributes affecting window U-Factor
2. Employ at least three design options to improve window U-Factor
3. Differentiate between NFRC and AAMA testing and certification processes
4. Draft non-defective specification requirements for U-Factor.
5. Recognize other important energy related window design factors and the importance of a balanced design

For buildings using windows or curtainwall as design elements, it is important to consult with an experienced manufacturer early in the process. Teamed with a reputable, local glazing subcontractor, manufacturers can provide design input, budget pricing, sequencing, and schedule information that will prove invaluable to the design team.

# Course Evaluations

In order to maintain high-quality learning experiences, please access the evaluation for this course by logging into CES Discovery and clicking on the Course Evaluation link on the left side of the page.



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