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Recent Advancements in Glazing Technology, Fenestration Performance and Energy Codes

Tom Culp
NGA energy code consultant
Owner, Birch Point Consulting

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Questions will be addressed at the conclusion of the presentation.

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Recent Advancements in Glazing Technology, Fenestration Performance and Energy Codes

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Recent Advancements in Glazing Technology, Fenestration Performance, and Energy Codes

DESCRIPTION

This course is designed to educate architects and designers about the new glazing and fenestration technologies that can be used to address building energy efficiency goals and on-site renewable energy production. It will recommend features that comply with the newest energy codes in each climate zone and will also address technologies that may be used to retrofit existing buildings.

LEARNING OBJECTIVES

At the end of this session, participants will be able to:

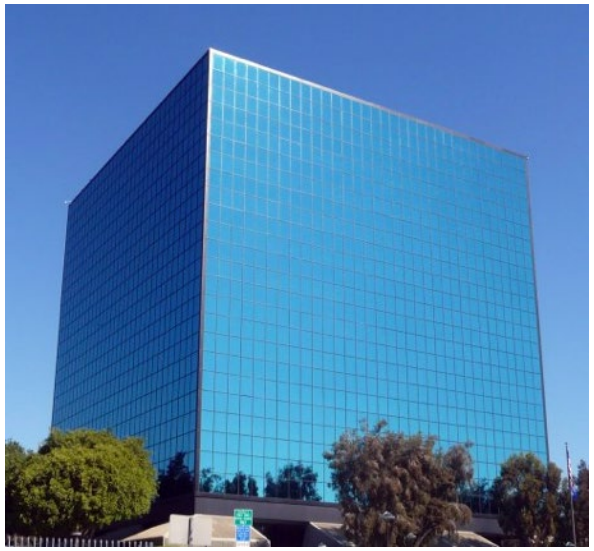
- Describe new glazing and fenestration technologies for building energy efficiency and on-site renewable energy production.
- Classify how different types of fenestration are treated in the energy codes.
- Identify which fenestration component features are required to comply with the newest energy codes in each climate zone.
- Identify the thermal line associated with fenestration installation for thermal bridging considerations.
- Describe new glazing technologies for retrofitting existing buildings.

Windows over time …

1300-1500s
Small windows
No glass or single pane glass

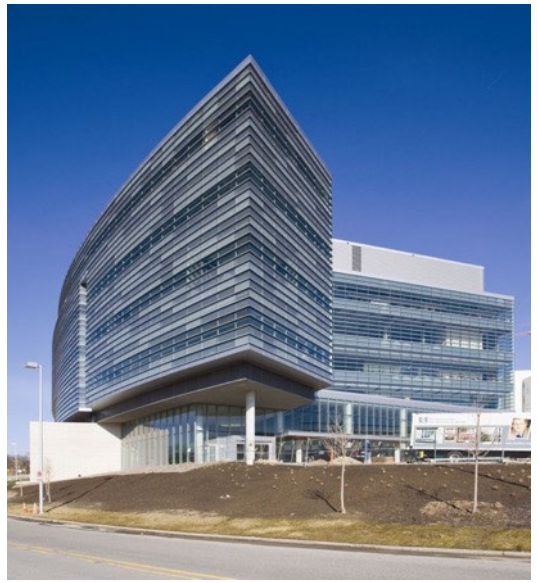
1950-60s
Small window area
Mostly single pane glass
Clear glass or tints

Windows over time …



1970-80s
Large window area
Reflective glass
Mostly single pane
Nonthermal frames

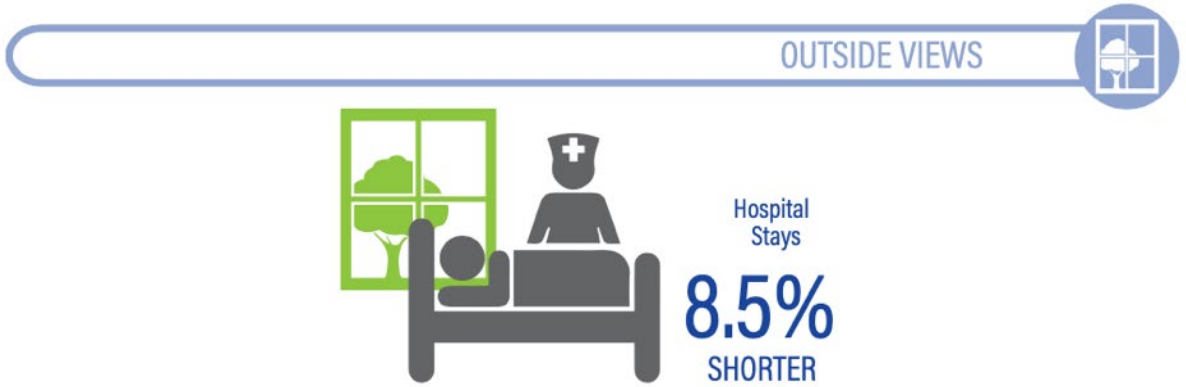
Today
Large window area
Advanced low-e coatings
Double (or triple) glazing
Advanced framing

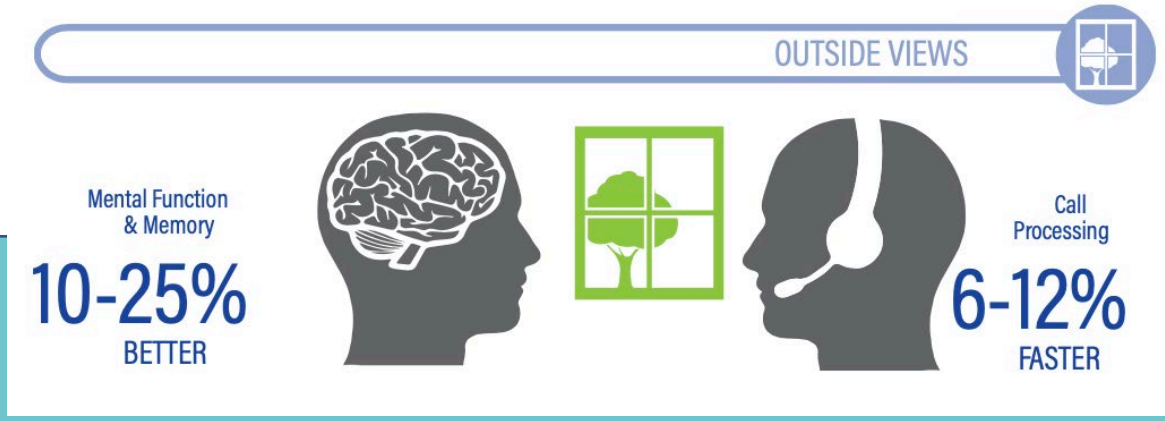


Why do we have windows?

The Human Aspect – Occupant Health and Wellness

Having access to daylighting and quality views provides better learning, faster healing, higher productivity, higher value.





More info at:

https://www.aec.org/page/whitepaper-daylighting

https://www.glass.org/resources/market-intelligence/daylighting

What’s New in Glazing and Fenestration Technology?

Nanotechnology … although it’s not actually new

Low-E Coated Glass

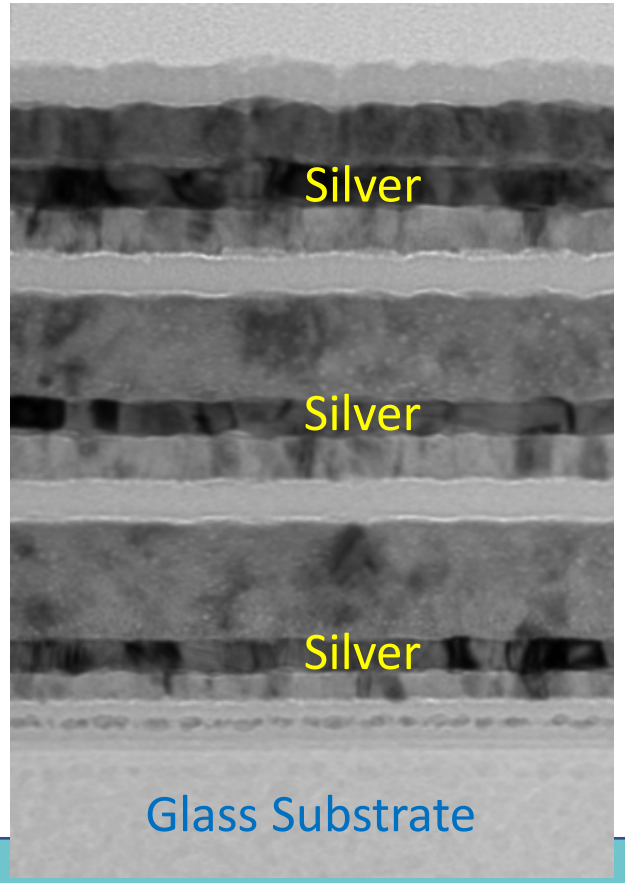
Besides computer chips, one of the first widespread uses of nanotechnology …

Low-E Glass

Low Emissivity coatings

- Transparent, microscopic coating which reflects infrared heat.
- Reduces building energy usage by reducing radiative heat loss.
- Reduces overall U-factor (lower U-factor = more insulating)
- Can be designed to also control solar heat gain.

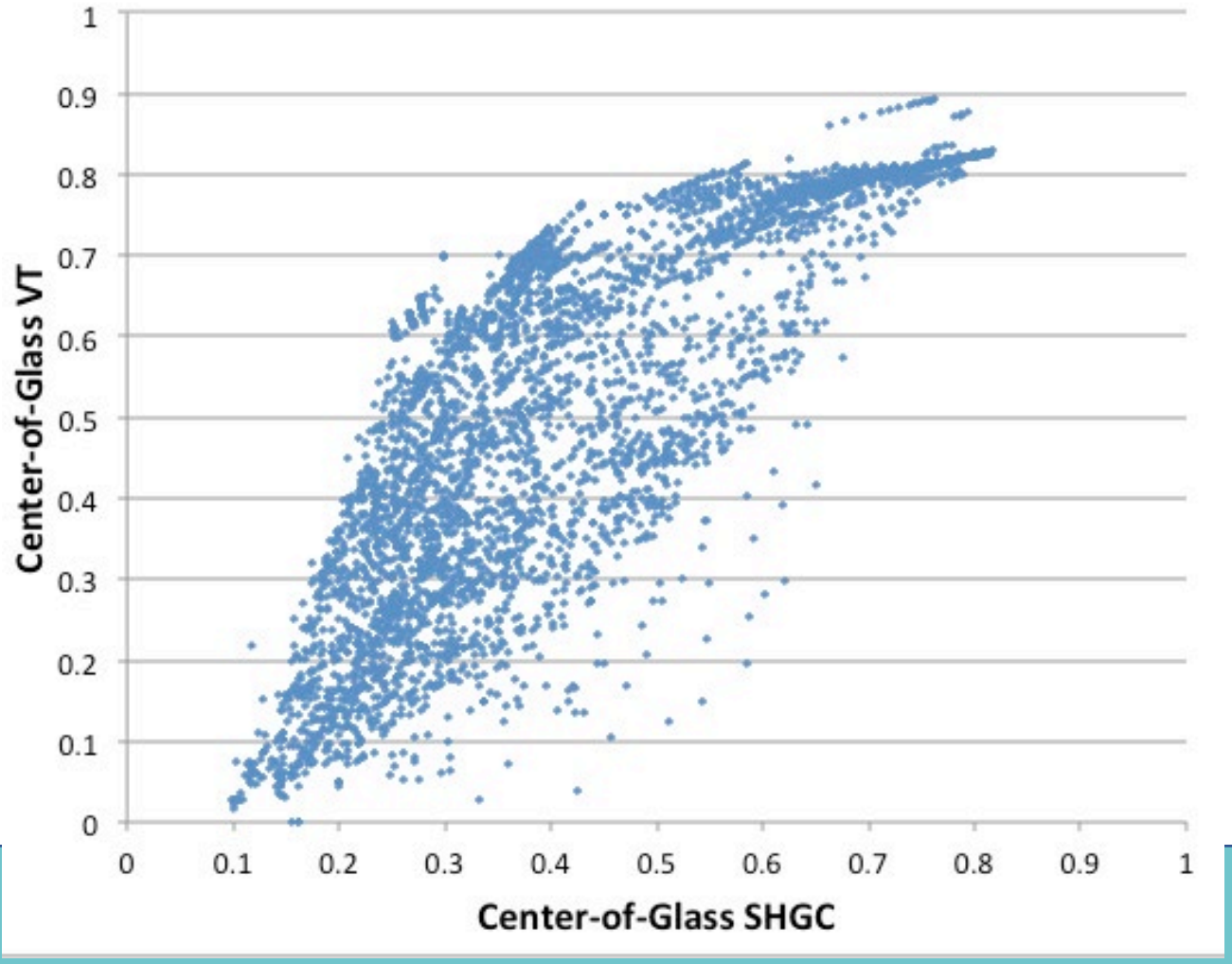
Triple Silver Low-E Coating



↕ 10 nm = 0.00000001 m

How many types glazing products would you guess there are?

Thousands in the International Glazing Database



- Clear, ultraclear (low iron)
- Tints
- Low-e coatings
- Reflective coatings
- Dynamic products
- Laminates
- Films

New Glazing Types

Wider range of low-e coating options

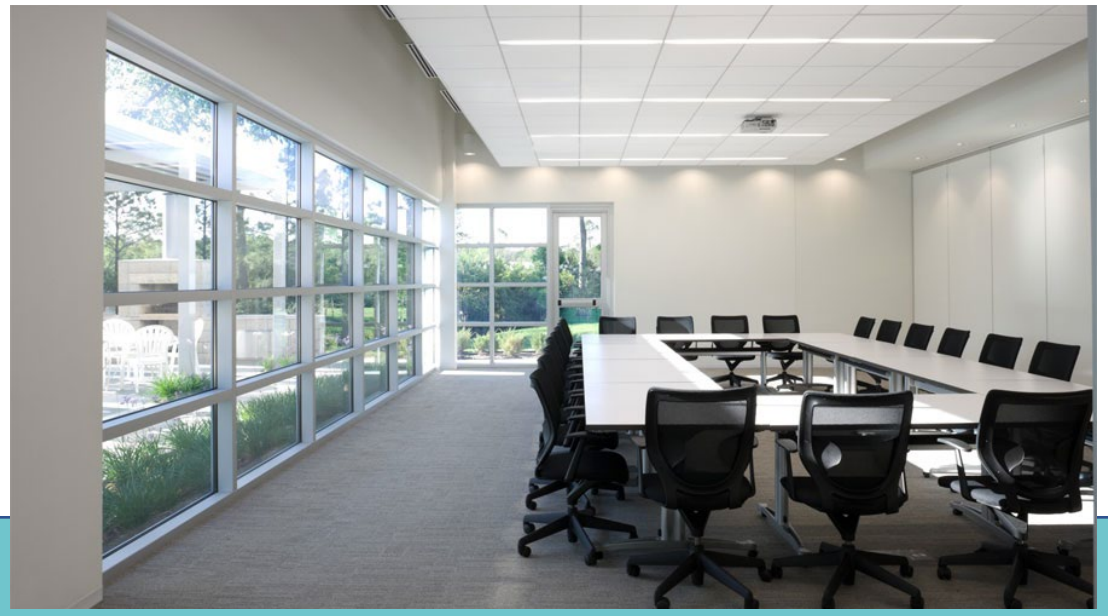
- Low-e in every range of SHGC from high passive solar for cold climates to very low solar control for hot climates.
- 2nd generation triple silver low-e (lower SHGC) for southern climates.
- Colors or color neutral.
- High Transparency or Designed Reflectivity (mild to strong)

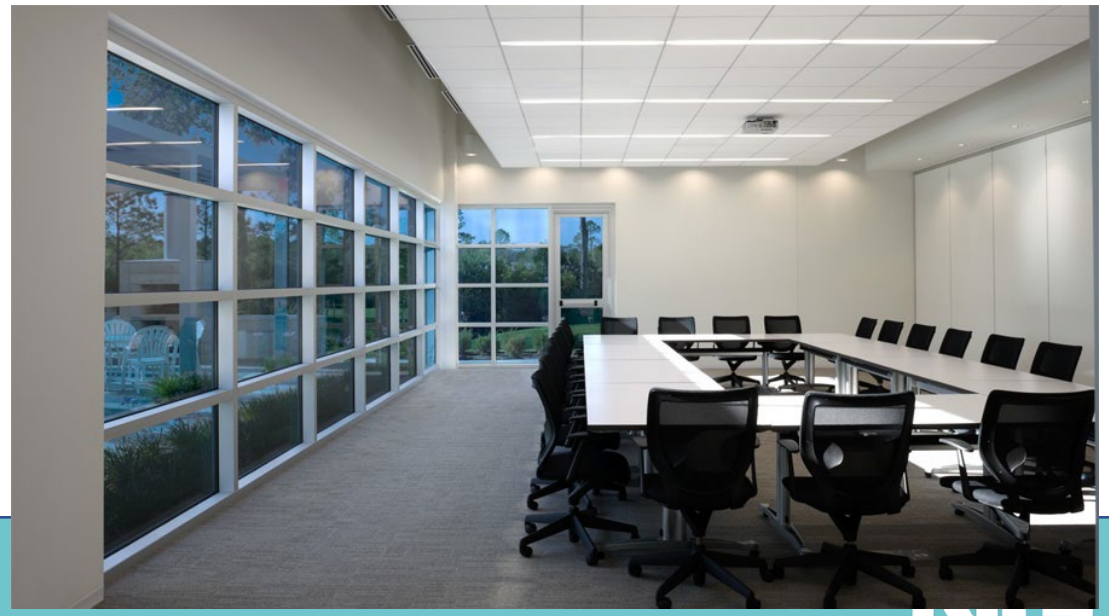
New Glazing Types

Dynamic Glazing

- Electrochromic and thermochromic glazing that can reversibly change its optical properties to optimize energy performance by the hour, day, season.
- SHGC range 0.09 – 0.47, VT range 0.02 – 0.62
- Controls: photosensor, occupancy, time scheduling, manual

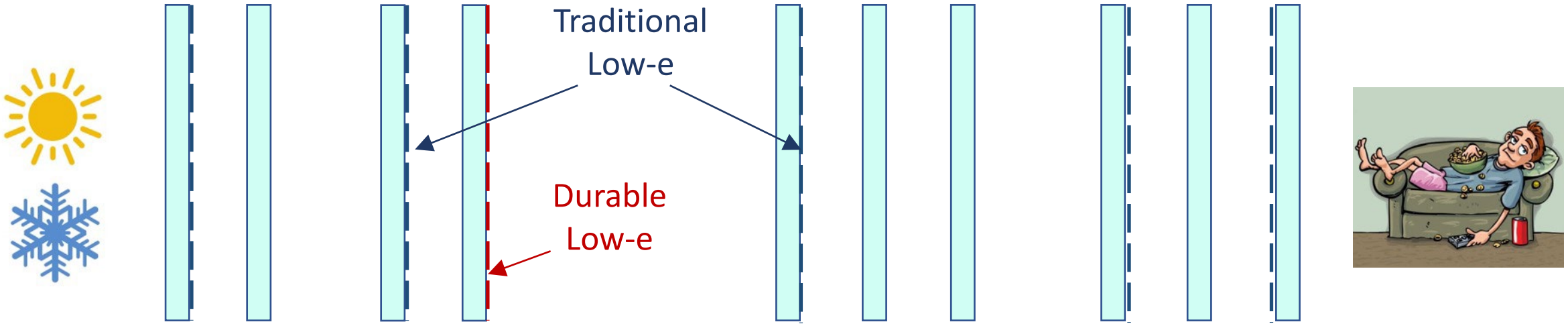
Dynamic Glazing Examples





New Glazing Configurations

- 4th Surface (room-side) low-e in double glazing using a second durable low-e coating as step towards triple glazing.



U_c = 0.24 **U_c = 0.20**

Double pane with argon

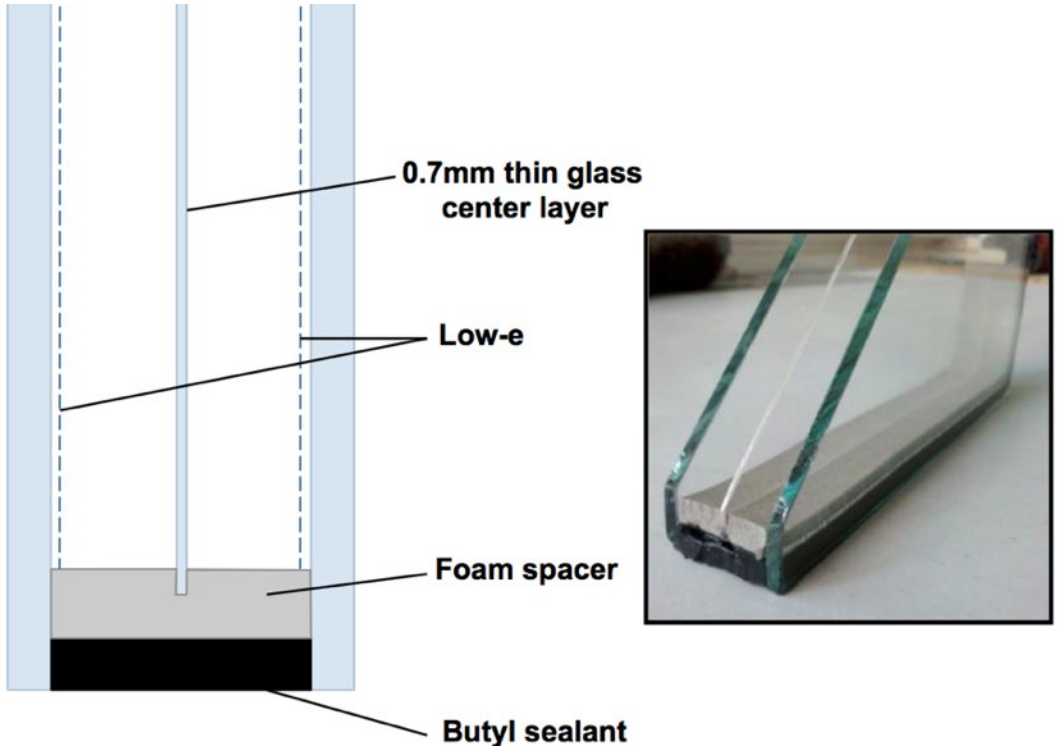
U_c = 0.18 **U_c = 0.12 Btu/hrft^{2}F**

Triple pane with argon

New Glazing Configurations

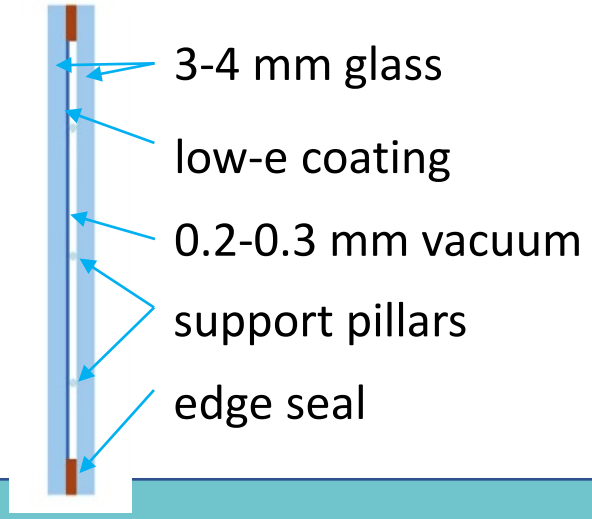
“Thin triples”

- Triple glazing performance with lighter weight from thin middle glass lite.
- Can also use narrower gaps, but use krypton or argon/krypton gas fill mixes to optimize performance with narrower gaps .



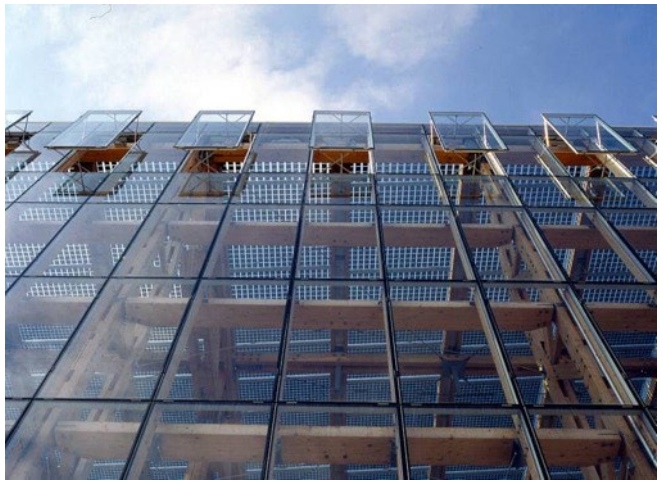
Vacuum Insulating Glazing (VIG)

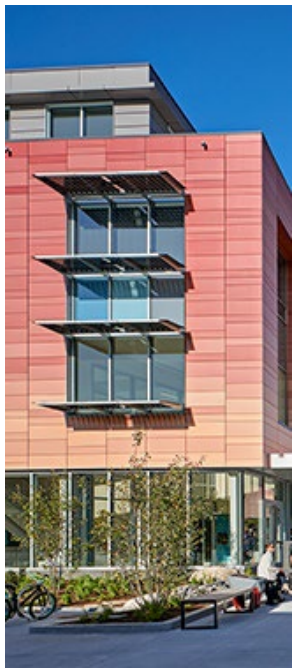
- Uc ≈ 0.10 compared to typical Uc = 0.24 in double glazing low-e argon
- 6.2 – 8.3 mm total thickness - thin enough to replace single glazing. Good option for historic retrofits.
- Even lower U-factor when combined in hybrid unit (use VIG as one of the lites in a traditional IG unit)

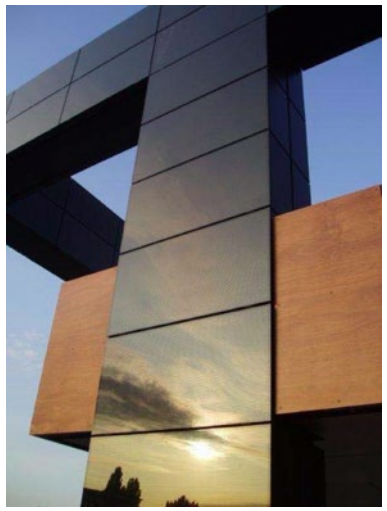


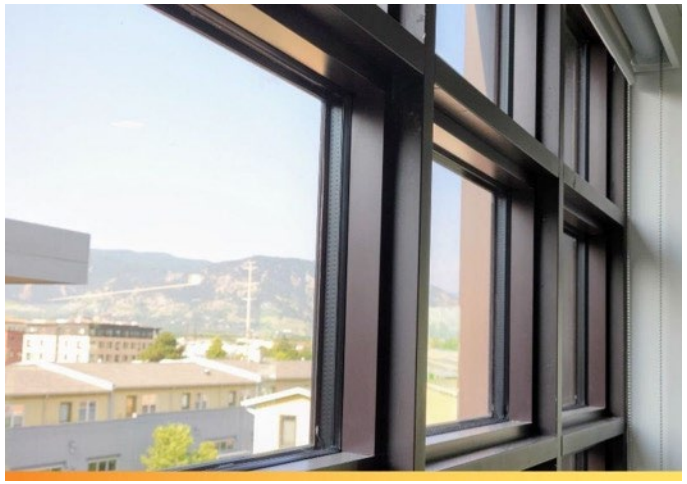
Glazing for On-Site Renewable Energy Production

- **BIPV (Building Integrated Photovoltaics)** in overhead glazing, opaque spandrel, sun shades, and ***now vision glazing!***









Commercial Framing – Thermal Barriers

> 90% of commercial fenestration uses aluminum framing:

- Structural performance
- Durability
- Wide spans with narrow sight lines
- Design flexibility
- Recyclability / sustainability

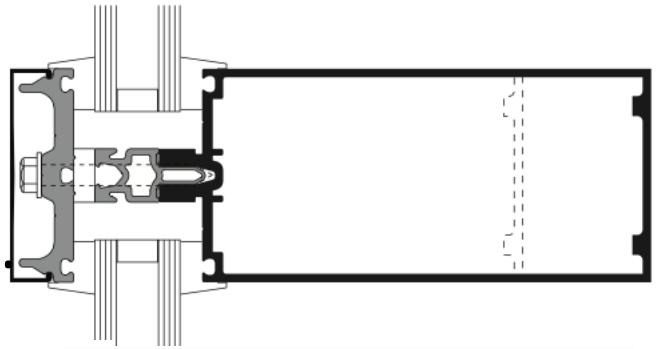
- However, “unbroken” aluminum frames have high thermal conductivity.
- Therefore, use a low conductivity material to break the heat loss path while still maintaining high structural performance: thermal barriers.

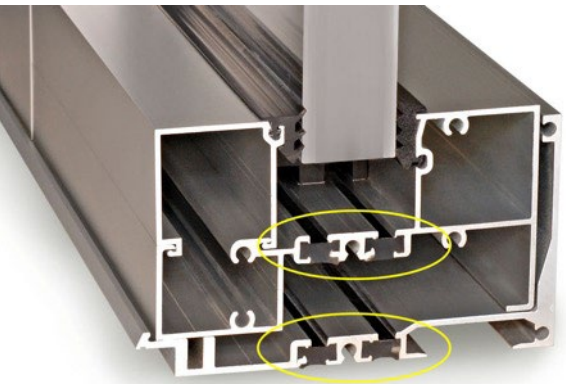
Commercial Framing – Thermal Barriers

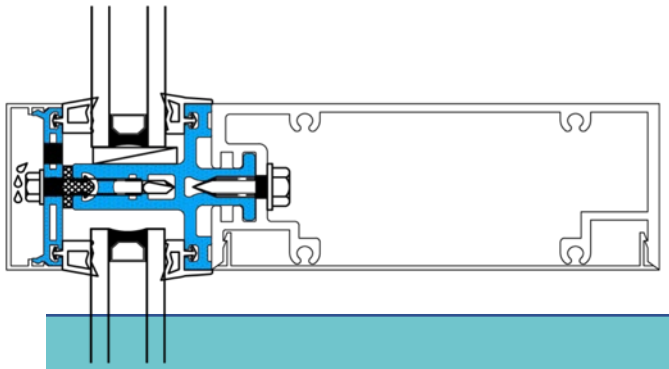
- **“Thermally improved”** or **“thermally separated”**
  - Smaller separation with nonmetal material < ¼”,
    more often seen in older or basic curtain wall and storefront.
- **“Thermally broken”**
  - Wider separation with nonmetal structural material.
  - Terms you might see: polyamide struts, pour-and-debridge polyurethane, fiberglass, double thermal barriers.
  - Can also be combined with nonmetal pressure plates, wider / more complex shaped thermal breaks.

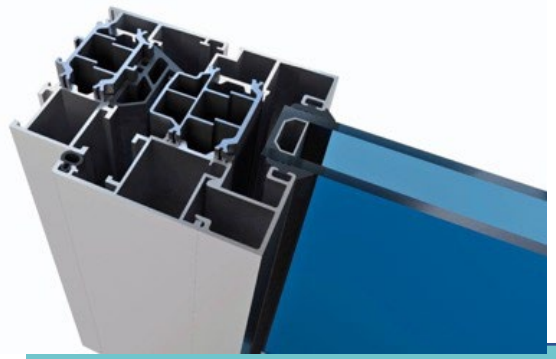
Thermally Broken Frames

- Not just a basic thermal isolator on the bolt or ¼” separators.
  Full thermal break examples:
  Standard performance: single pour-and-debridge polyurethane,
  or basic 12 mm polyamide struts
- *Higher performance:* double pour-and-debridge,
  wider / more complex shape breaks, fiberglass inserts,
  combination with fiberglass or polyamide pressure plates, etc.



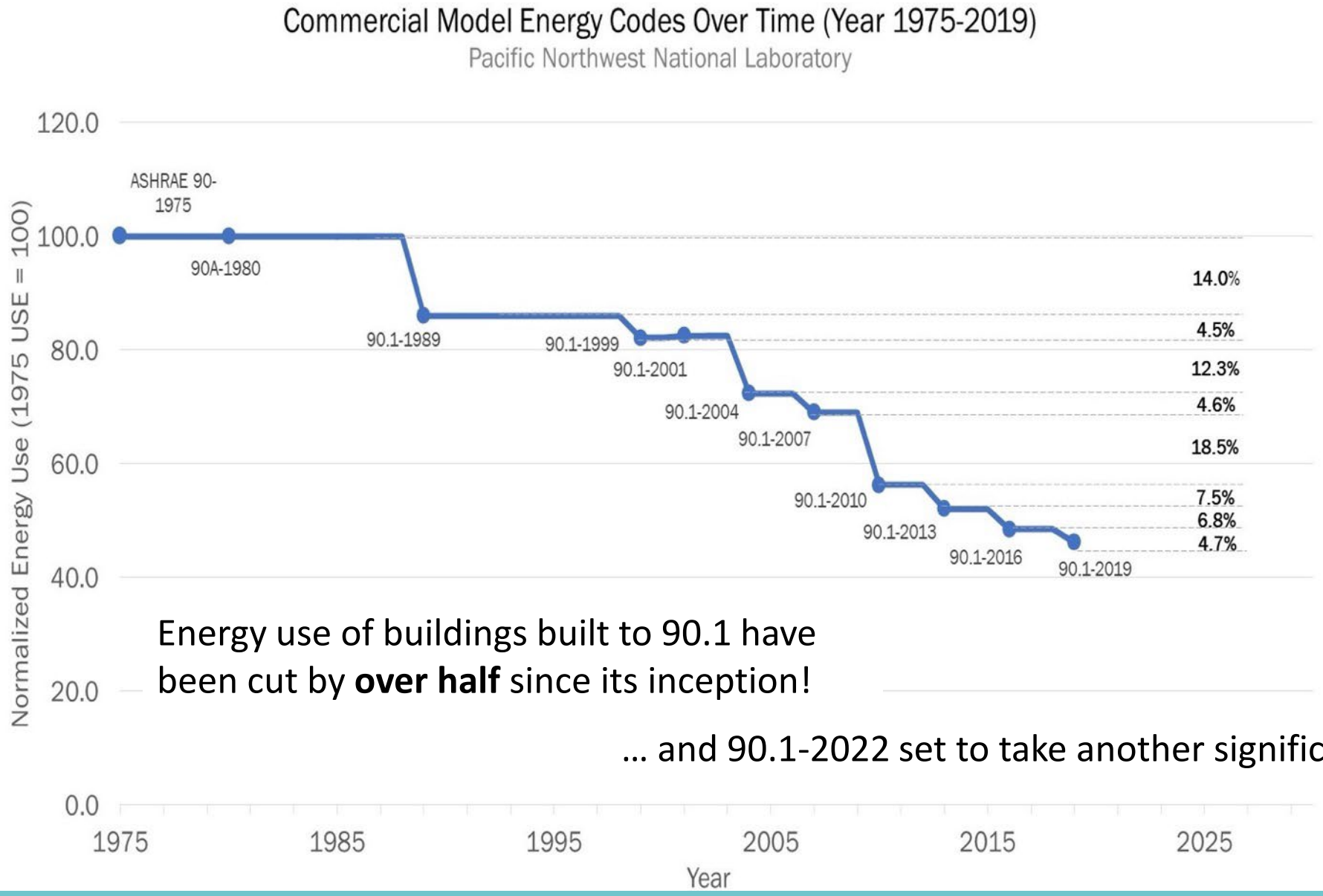






What's New for Fenestration in the Energy Codes?

Overall Trend in Energy Code Stringency – ASHRAE 90.1



Energy use of buildings built to 90.1 have been cut by **over half** since its inception!

… and 90.1-2022 set to take another significant step

Increased Stringency for Windows

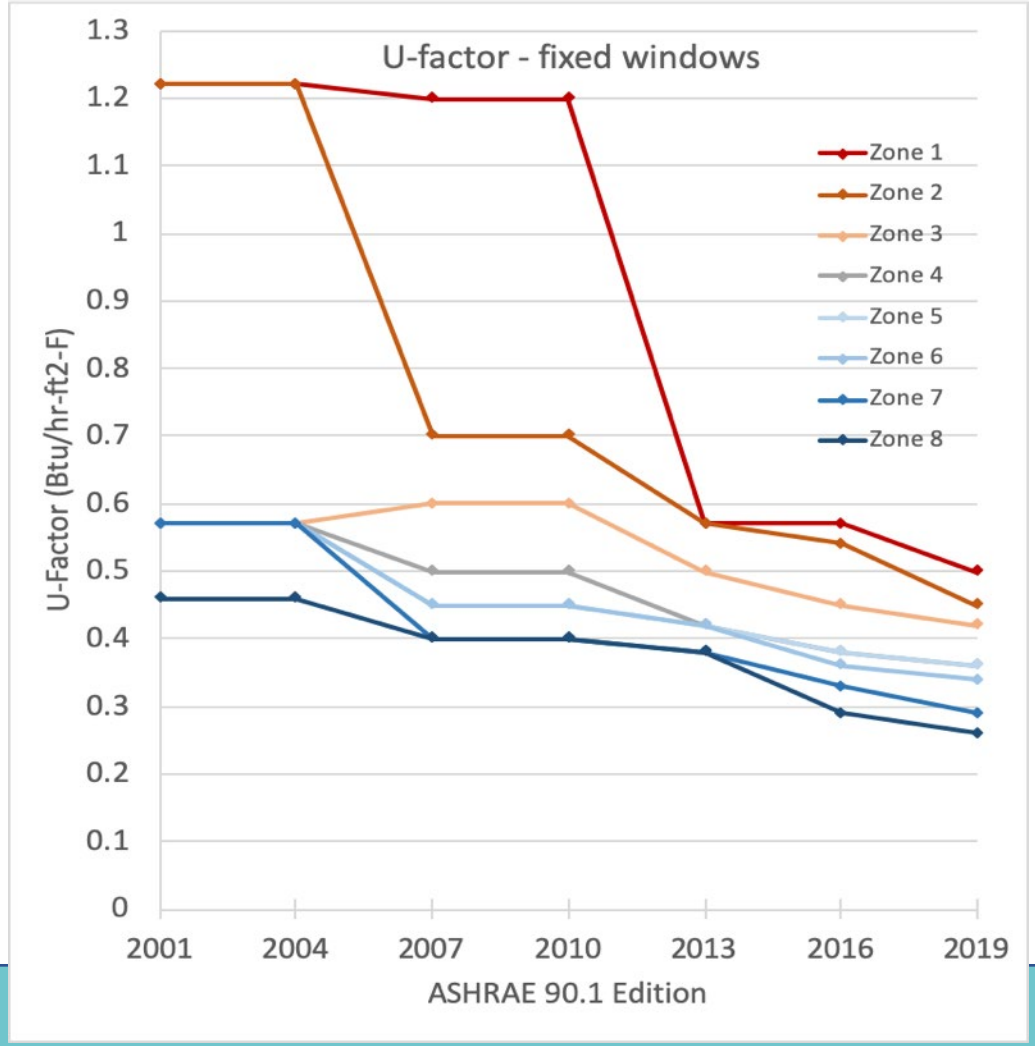
Stringency for commercial windows has also increased:

Over last 15 years,

20-60% reduction in U-factor

Smaller changes in SHGC

Note: All U-factors are *whole assembly* including the framing, not just center-of-glass.



Before we get into the detailed code requirements … *what is fenestration* (and what is not) in the energy code?

Fenestration

(Common sense says all windows, doors, skylights, but …)

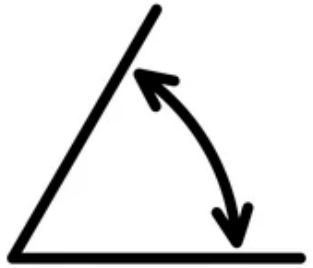
“Vertical Fenestration” ≥ 60 degrees

Windows

Doors

Opaque Doors
≤ 50% glazed

Glazed Doors
> 50% glazed



“Skylights” < 60 degrees

Unit skylights

TDDs (tubular daylighting devices)

Sloped glazing

Vertical and Sloped Glazing

Note that **International Building Code (IBC)** and **ASHRAE 90.1 / IECC** use different angles!

IBC: overhead glazing **> 15 degrees** from vertical must be laminated or have screens.

IECC and 90.1: < 60 degrees from horizontal considered a skylight.

This is *vertical fenestration* in the IECC, and a *skylight / sloped glazing* in the IBC.

Actually, makes sense because two purposes – energy efficiency & heat flow vs. safety

Vertical Fenestration and Spandrel

- Spandrel area is treated as an opaque wall in the energy code.
- Must be insulated according to R-value table, meet opaque wall U-factor, or use trade-off options.

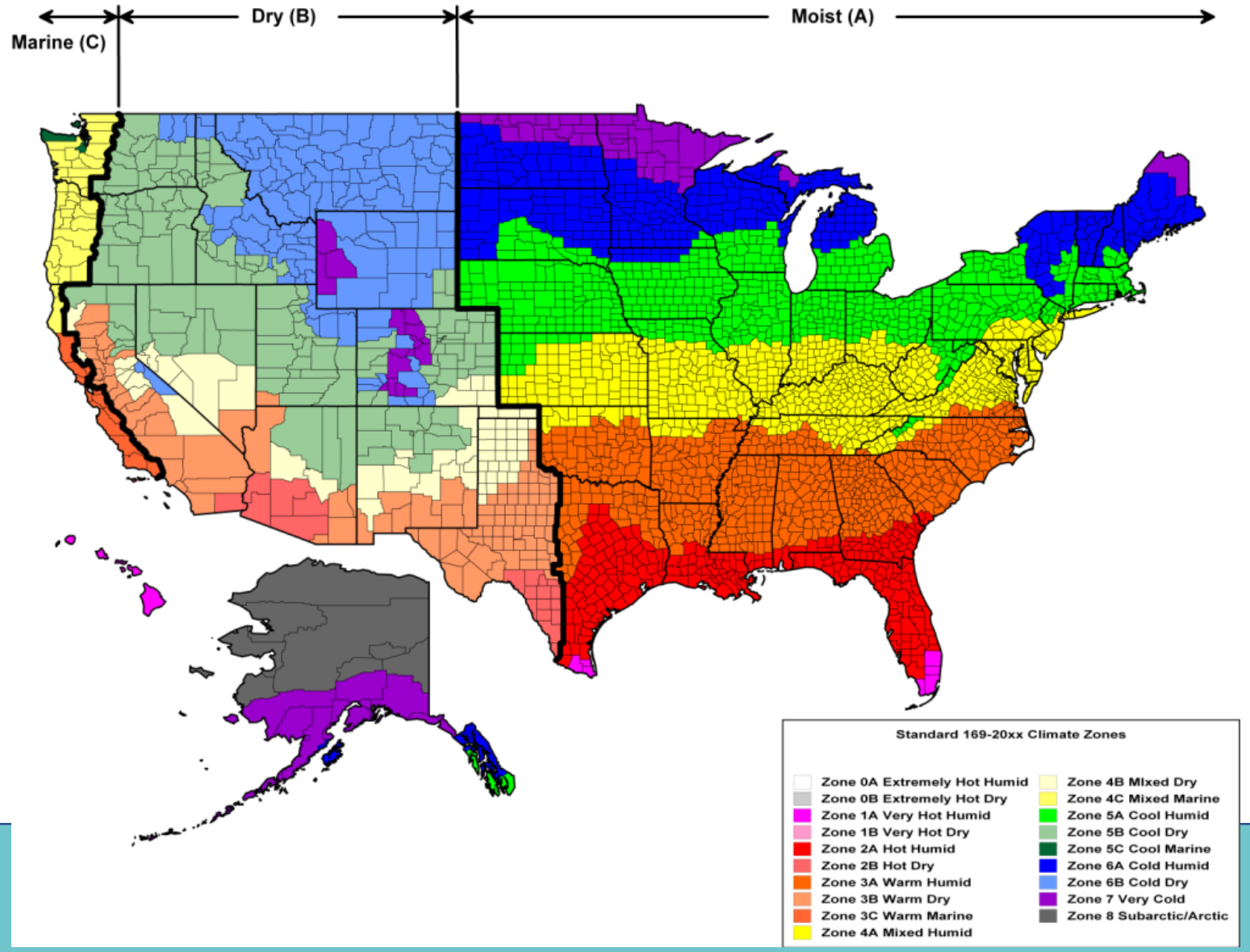
Vertical Fenestration

NOT Vertical Fenestration

Side comment:
Spandrel is not addressed well in the code. U-factors are set for steel-stud walls, and not very realistic for spandrel. Charles Pankow Foundation, with DOE support, is sponsoring ongoing research to better characterize spandrel.

***New:* spandrel is a good area to include building-integrated photovoltaics (BIPV)!**

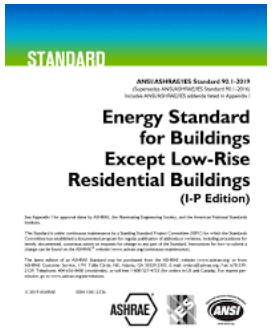
Climate Zone Map (ASHRAE 90.1-2016, 2019 and 2021 IECC)



Commercial Vertical Fenestration U-factors (2009 – 2021)

Values for metal framed products shown.
There were separate values for nonmetal framing in 2006-2009 IECC and ASHRAE 90.1-2007 to 2016 (not shown here)

Climate Zone	0	1	2	3	4	5	6	7	8	
Fixed		1.20	0.70	0.60	0.50	0.45	0.45	0.40	0.40	90.1-2010, 2009 IECC
	0.50	0.57	0.57	0.50	0.42	0.42	0.42	0.38	0.38	90.1-2013
	0.50	0.57	0.54	0.45/0.49	0.38	0.38	0.36	0.33	0.29	90.1-2016
		0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29	2012, '15, '18 IECC
	0.50	0.50	0.45	0.42	0.36	0.36	0.34	0.29	0.26	90.1-2019, 2021 IECC
Operable		1.20	0.75	0.65	0.55	0.55	0.55	0.45	0.45	90.1-2010, 2009 IECC
	0.65	0.65	0.65	0.60	0.50	0.50	0.50	0.40	0.40	90.1-2013
	0.65	0.65	0.65	0.60	0.46	0.46	0.45	0.40	0.35	90.1-2016
		0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37	2012, '15, '18 IECC
	0.62	0.62	0.60	0.54	0.45	0.45	0.42	0.36	0.32	90.1-2019, 2021 IECC
Entrance door		1.20	1.10	0.90	0.85	0.80	0.80	0.80	0.80	90.1-2010, 2009 IECC
	0.83	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77	90.1-2013
	0.83	1.10	0.83	0.77	0.68	0.68	0.68	0.68	0.68	90.1-2016
		1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77	2012, '15, '18 IECC
	0.83	0.83	0.77	0.68	0.63	0.63	0.63	0.63	0.63	90.1-2019, 2021 IECC



Example of increasing stringency

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ROUGHLY what is needed to meet U-factor for ASHRAE 90.1-2019, 2021 IECC?

General guideline.
Do not use for code compliance.

- **Zone 0:** Low-e double glazing + lower 0.22 SHGC
- **Zone 1:** Low-e double glazing + lower 0.23 SHGC
- **Zone 2:** Low-e double glazing, thermally broken frame + air
  or 'thermally improved' frame (not full thermal break) + argon
- **Zone 3:** Low-e double glazing, thermally broken frame
- **Zone 4:** Low-e double glazing, thermally broken frame and ***pick 2***:
- **Zone 5:** Low-e double glazing, thermally broken frame and ***pick 2***:
- **Zone 6:** Low-e double glazing, thermally broken frame and ***pick 3***:
- **Zone 7:** Low-e double glazing, thermally broken frame and ***pick 4***:

… or go to triple glazing

Pick list

- argon
- warm edge spacer
- high performance thermal break (see slide 20)
- two low-e coatings (#2 / #4)

- **Zone 8:** Triple glazing with multiple low-e (#2 / #5), thermally broken frame, and pick 2 out of the 3 top items from above.

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Commercial Vertical Fenestration SHGC, 2009 - 2021

Climate Zone	0	1	2	3	4	5	6	7	8	
SHGC		0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45	90.1-2007 2009 IECC 90.1-2010 2012 IECC 90.1-2013 2015 IECC
	0.22	0.25	0.25	0.25	0.36	0.38	0.40	0.45	0.45	90.1-2016 2018 IECC
Fixed:	0.22	**0.23**	0.25	0.25	0.36	0.38	0.38	0.40	0.40	90.1-2019 2021 IECC
Operable:	0.20	**0.21**	0.23	0.23	0.33	0.33	0.34	0.36	0.36	

- These are the main SHGC requirements for the overall building, but there are variations based on *external shading* and *orientation*. Credit for overhangs, sun shades.
- New SHGC requirements in 90.1-2019 and 2021 IECC have separate SHGC for fixed vs. operable products, similar to U-factor.
  - In reality, changes are small, as both require the *same glazing type* – it is just accounting for the higher frame-to-glass ratio in operable products.
- Only real change is zone 1, where 0.23/0.21 SHGC will require new lower SHGC triple silver products and/or tint with low-e.

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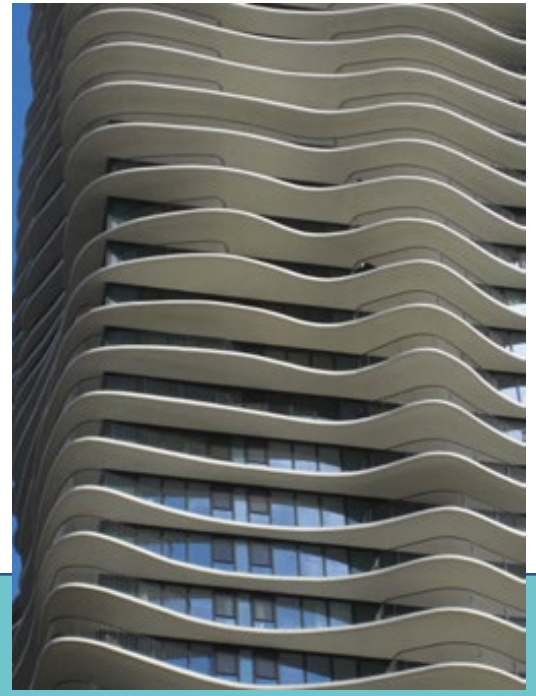
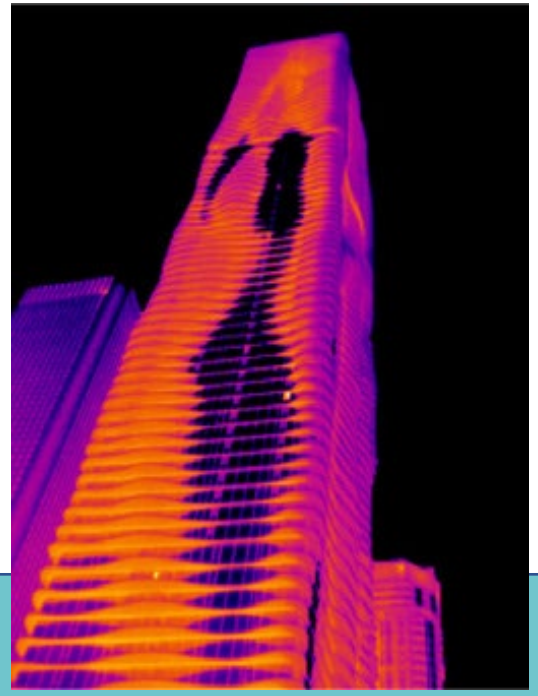
What is Coming in 90.1-2022 for Fenestration?

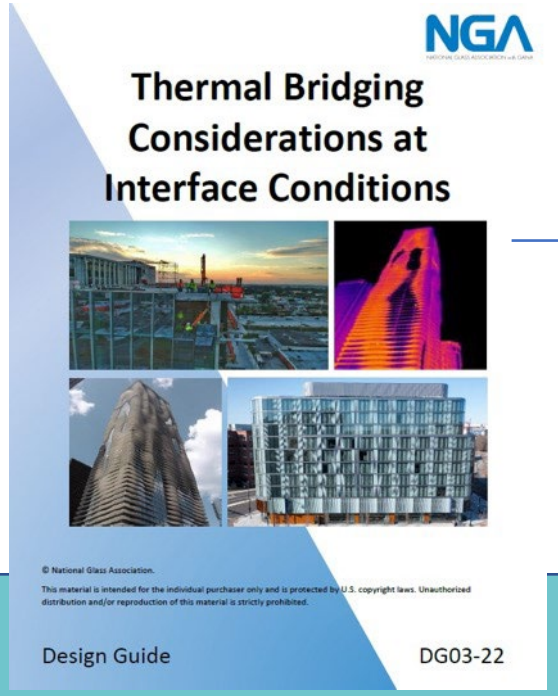
- New **thermal bridging** requirements (more on this next …)
- New **envelope backstop**, limiting how much overall envelope performance can be traded off in performance path.
- New **“additional energy credits”** section that requires designer to choose additional items on top of the main code.
  - Options to earn points include **higher performance fenestration**, **shading**, **daylighting**, **on-site renewable energy**.
- New **on-site renewable energy** requirement for new buildings, strongly pushing PV, BIPV.
- Tighter **air leakage** criteria and increased testing.

Thermal Bridging

- Reduce bypassing of insulation – parapets, balconies, brick shelf angles, etc.
- For fenestration, affects installation details at wall / window interface and sun shade attachment.
- Control water, air, *and* thermal lines.
- Requirements set for zones 4-8.



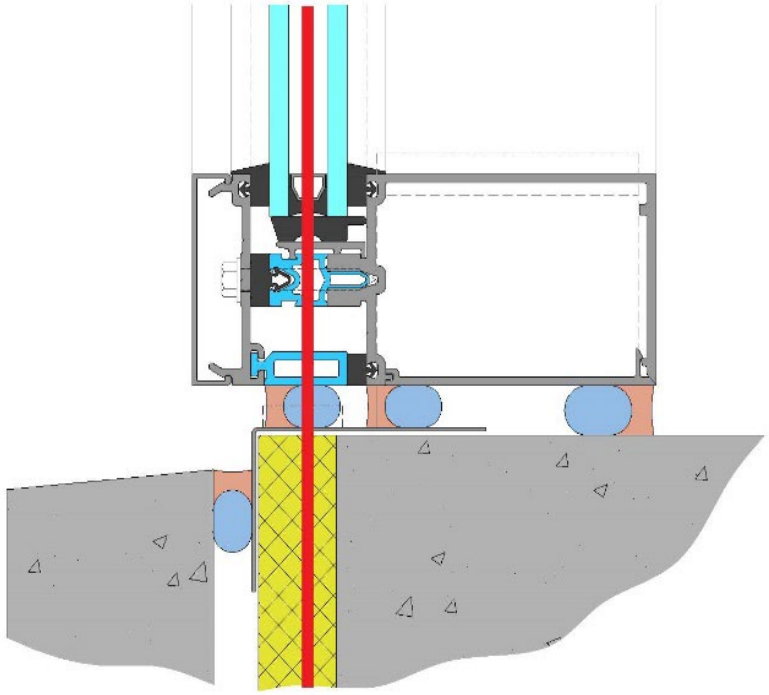




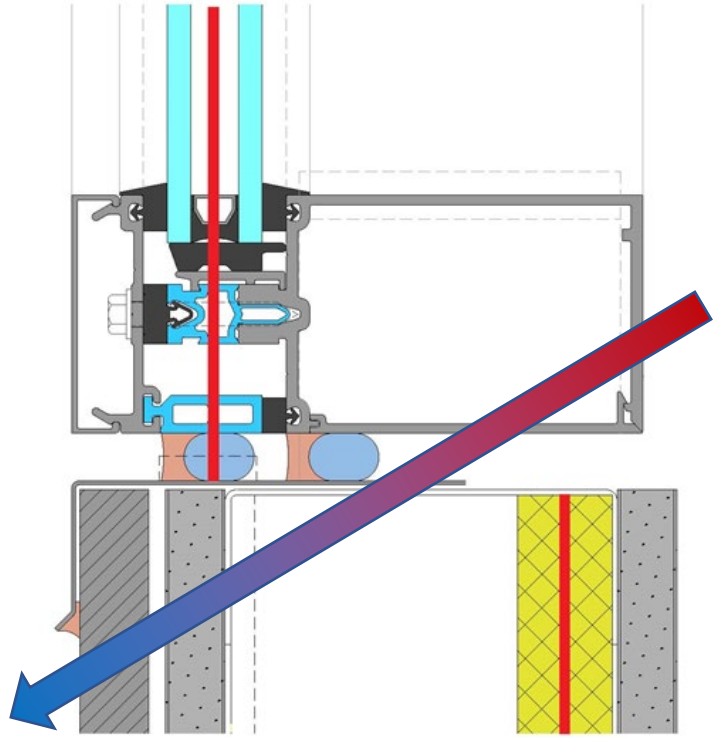
Download Design Guide

Thermal Bridging

Control water, air, *and* thermal lines.



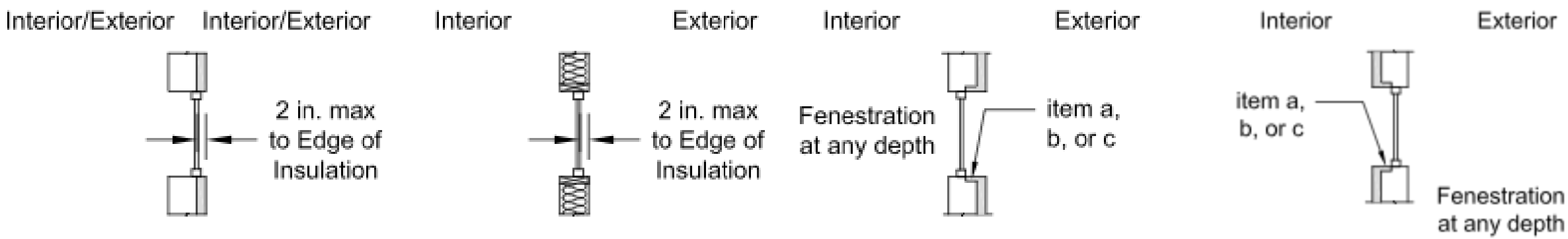
Efficient: Well aligned glazing without conductive bypasses (thermal line illustrated in red)



Poor: Cavity-insulated and conductive bypasses (thermal line illustrated in red)

Thermal Bridging

- This is more of a design issue for architects than an issue for manufacturers, but window / wall interface requirements of 90.1-2022 are pretty easy.
  - Align the glazing with the insulation layer.
  - For recessed windows, wrap the insulation or use a wood buck.



  - Purposely simplified - can also do psi-factor calculation for detailed design.

- For sun shade attachment through insulation, allowed as many point connections as need with each <= 3 in^2 carbon steel, or <= 9 in^2 stainless steel.

What about Existing Buildings?

Existing Building – Retrofit Opportunities

We work very hard on new building technology and codes,
yet often overlook the vast amount of energy used in ***existing buildings****.*

- DOE estimates there is still:
  - 2 billion ft^2 of single pane glazing in commercial buildings
  - 47 million homes with single glazing
  - 46 million homes with less efficient double pane clear (no low-e)
- To increase the focus on existing buildings, many locations have enacted ***building energy disclosure laws***.
  - Buildings over a certain size must publicly report their annual utility bills.
  - Transparency to help identify the energy stars and energy hogs.
- Many are now taking the next step towards ***building performance standards*** – actual energy use limits and fines / taxes.

Building Performance Standards
expanding rapidly!

New local action to address climate change by setting **energy use limits on existing buildings** on top of new building codes.

- Building Performance Standards have been enacted in:
  - New York City (carbon limits starting 2024)
  - St. Louis (energy use limits starting 2025)
  - Boston (carbon limits starting 2025)
  - Washington State (energy use limits starting 2026)
  - District of Columbia (energy use limits starting 2026)
  - Colorado (limits still in development, but targeting 2025)

Replacement glazing
Replacement windows
Secondary glazing
Low-e storm windows

Fines start 2025-2026 … but building owners have already started planning

Large incentive to upgrade existing buildings; improves economics of envelope retrofits

National Building Performance Standards Coalition

- This is expanding rapidly.
- Every location here has joined the National BPS Coalition and committed to passing a building performance policy by Earth Day 2024.

Institute for
Market Transformation
imt.org

Fenestration Upgrades in Existing Buildings

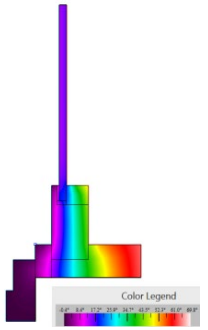
There is great technology for replacement glazing and windows.

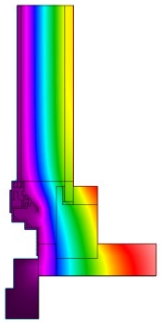
In addition, there are also new options for when:

- Rip-out and replacement of existing windows is *impractical* or *cost prohibitive*
- Not allowed or don't want to replace existing windows in *historic buildings*

Low-E Secondary Windows, Storm Windows, and Insulating Panels

- Upgrade existing windows by adding an additional low-e glazing layer(s) and air space over existing glazing
- Operable or fixed
- Interior or Exterior
- Cost can be 1/4 to 1/3 of the cost of full window replacement



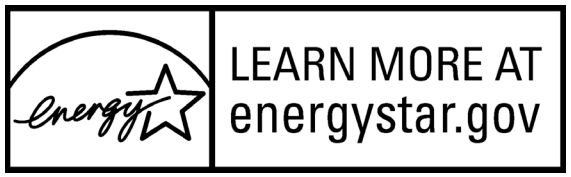


With exterior low-e panel

- Insulation *and* air sealing measure
- Improved comfort, acoustics
- U-factor decreased 43-64% depending on existing window

Secondary Window Product Performance Information

- **EPA Energy Star®** program for exterior and interior storm windows
- https://www.energystar.gov/productfinder/product/certified-storm-windows/



- **Attachments Energy Rating Council** (AERC) certification program for storm windows and commercial secondary windows.
- https://aercenergyrating.org/product-search/

Recap of Learning Objectives

At the end of this session, participants will be able to:

- Describe new glazing and fenestration technologies for building energy efficiency and on-site renewable energy production.
- Classify how different types of fenestration are treated in the energy codes.
- Identify which fenestration component features are required to comply with the newest energy codes in each climate zone.
- Identify the thermal line associated with fenestration installation for thermal bridging considerations.
- Describe new glazing technologies for retrofitting existing buildings.

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thirsty
THURSDAY
Quench your thirst for knowledge!

Questions?

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Additional NGA Resources

Thermal Bridging Considerations at Interface Conditions
Design Guide

Alignment in U.S. Energy Conservation Codes
Glass Technical Paper

Building Energy Performance Criteria Terms
Glass Technical Paper

Products for Energy Applications
Glass Technical Paper

Browse glass.org/resources/publications/glass-informational-bulletins-technical-papers for additional tools

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SAVE the DATE

NGA Glass Conference: Miramar Beach
Jan 24-26, 2023 | Hotel Effie Sandestin

BEC Conference *25th Anniversary*
Mar 5-7, 2023 | Caesars Palace, Las Vegas

NGA Glass & Glazing Advocacy Days
March 2023 | Washington, DC

NGA Glass Conference: Tacoma, WA
Jul 24-27, 2023 | Marriott Tacoma Downtown

glass.org/ondemand-webinars

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