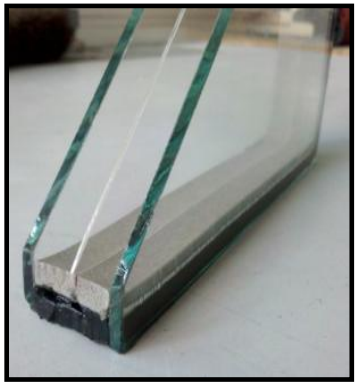
“Thin Triples”: Taking the Pain out of Triple Pane Windows



Rolf Jacobson

Research Fellow, CPHC

Center for Sustainable Building Research

University of Minnesota

Stephen Selkowitz

Retired: Leader, Windows and Envelope Materials

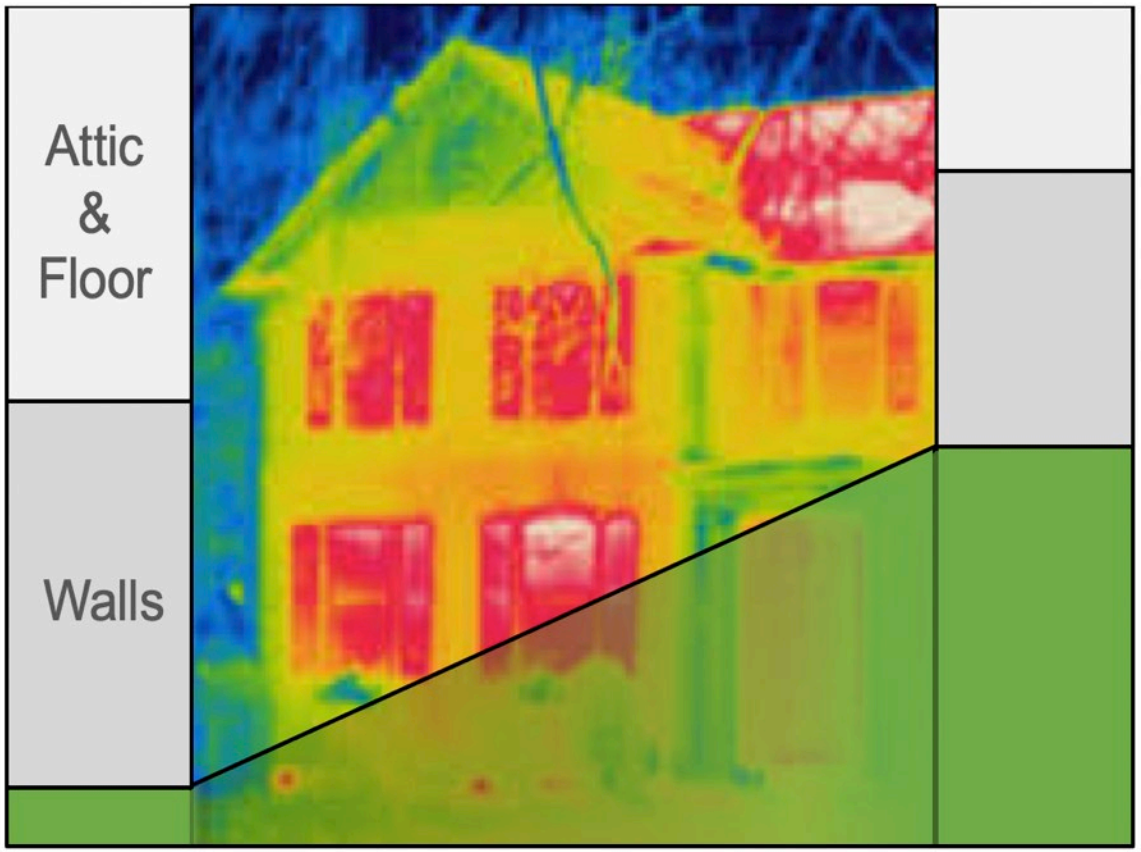
Department Head, Building Technologies

Lawrence Berkeley National Laboratory

PHIUS NAPHC 2019 Washington, D.C. 12/5/2019

Outline

1. Overview of U.S. Market for Energy Efficient Windows
2. “Thin triple” strategy to “Convert” double pane windows to triples
3. Primer on PHIUS Window Requirements
4. How Thin Triples Might Support Passive House Designs



*Based on 2,000 sf 2-story house, IECC 2015

National Energy/Cost Impacts

- **Window Impacts on U.S. Energy Use ~ $50B/yr**
  - **Energy, Electric Demand**
    - **HVAC Energy: ~ 4 Q; Electric Lighting Energy: ~ 1 Q**
    - Summer cooling peak, load shape, grid impacts
    - Winter Peak heating impact for electric heating
  - **Highly Insulating Windows: Large Savings Potential**
    - Residential and Commercial; Heating and Cooling

- **Longer Term 2020+ Goals**
  - **"Net Zero" Buildings → Net Zero Envelope**
  - **Decarbonize: Gas-> Electric heating -> New Challenges**
  - **Resilience: survivability- no power for xx days...**
  - **Daylight: View, Comfort, Wellness,...**

"Recent" Technology Options
Highly insulating, low heat loss glazing

Today: Typical U-value ~ 0.3 Btu/ft^2-hr-F

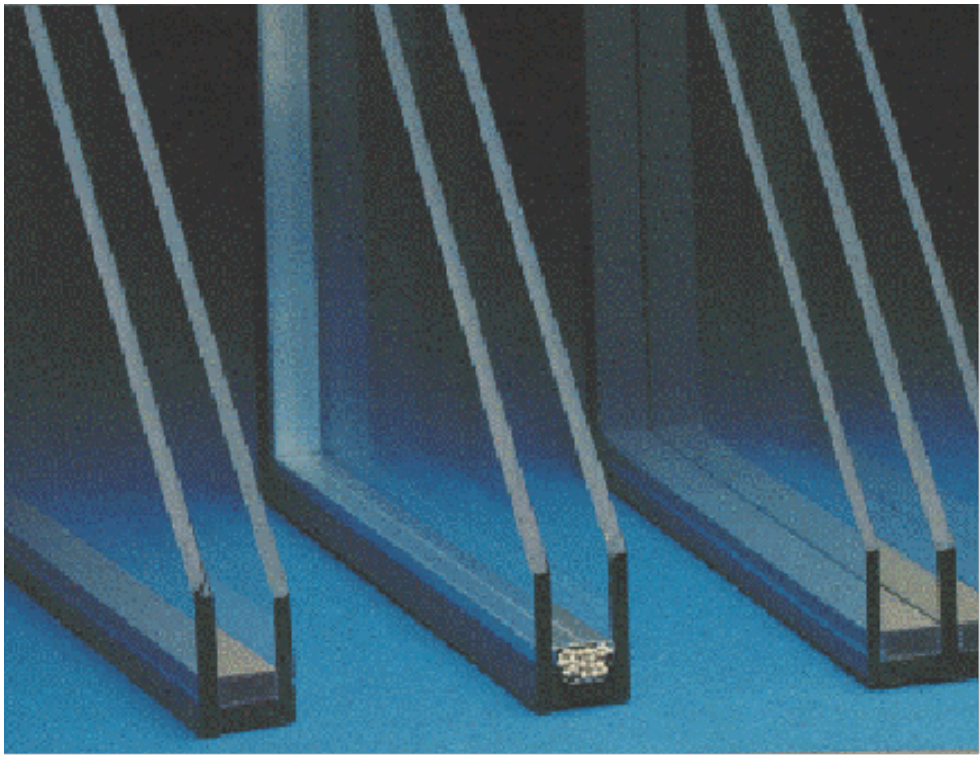
Nearer Term Objective: U-value < 0.2 Btu/ft^2-hr-F

Longer Term Target: U-value < 0.1 Btu/ft^2-hr-F

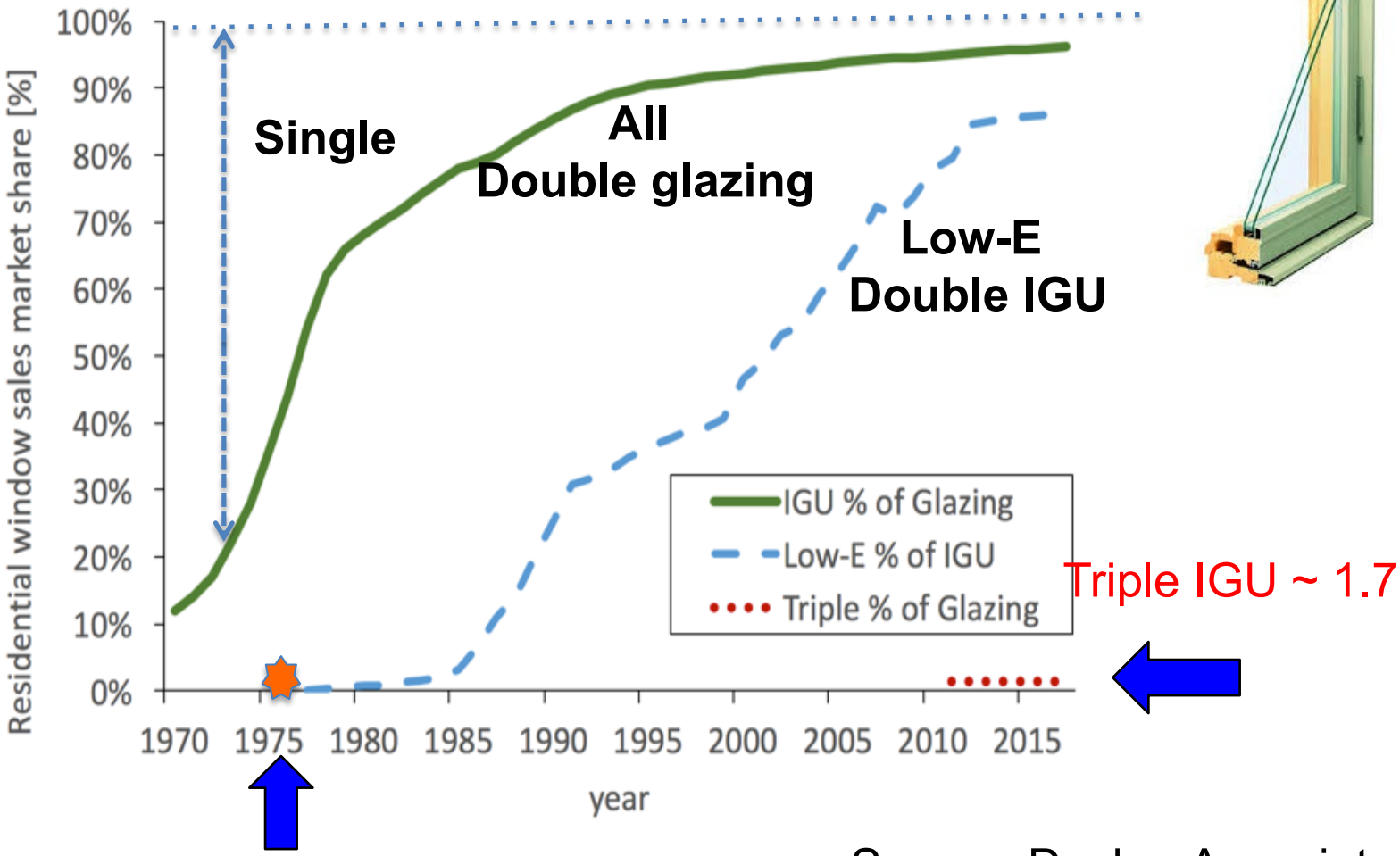
Current Approaches: 30 years

- Low-Emissivity Coatings
- Low Conductance Gas Fills
- "Warm edge" low conductance spacers
- Insulated Frame Systems

New Approaches??



Good News: We've Transformed Markets Before U.S. Residential Glazing Market Share

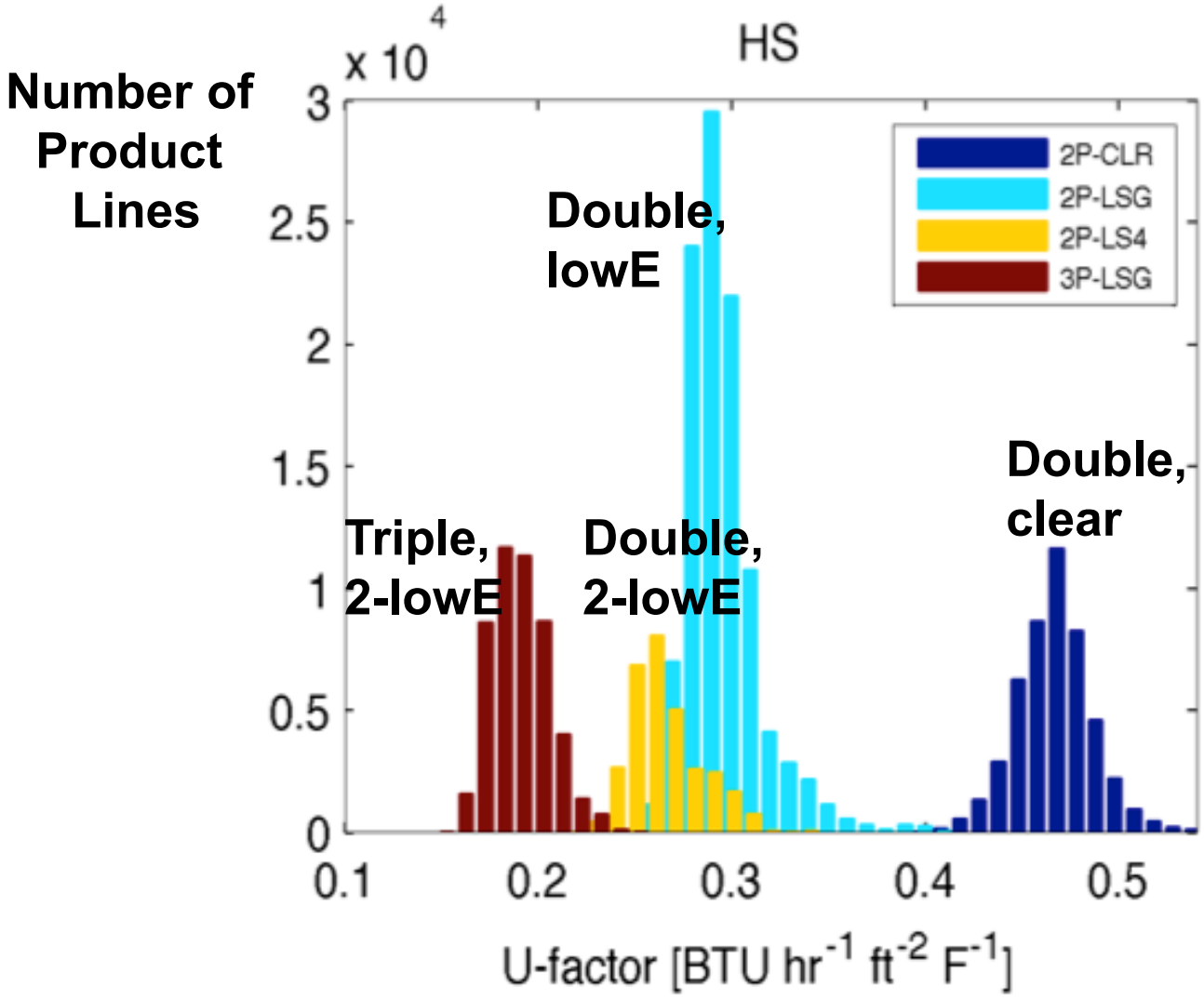


Source: Ducker Associates

U. S. Window Market Snapshot

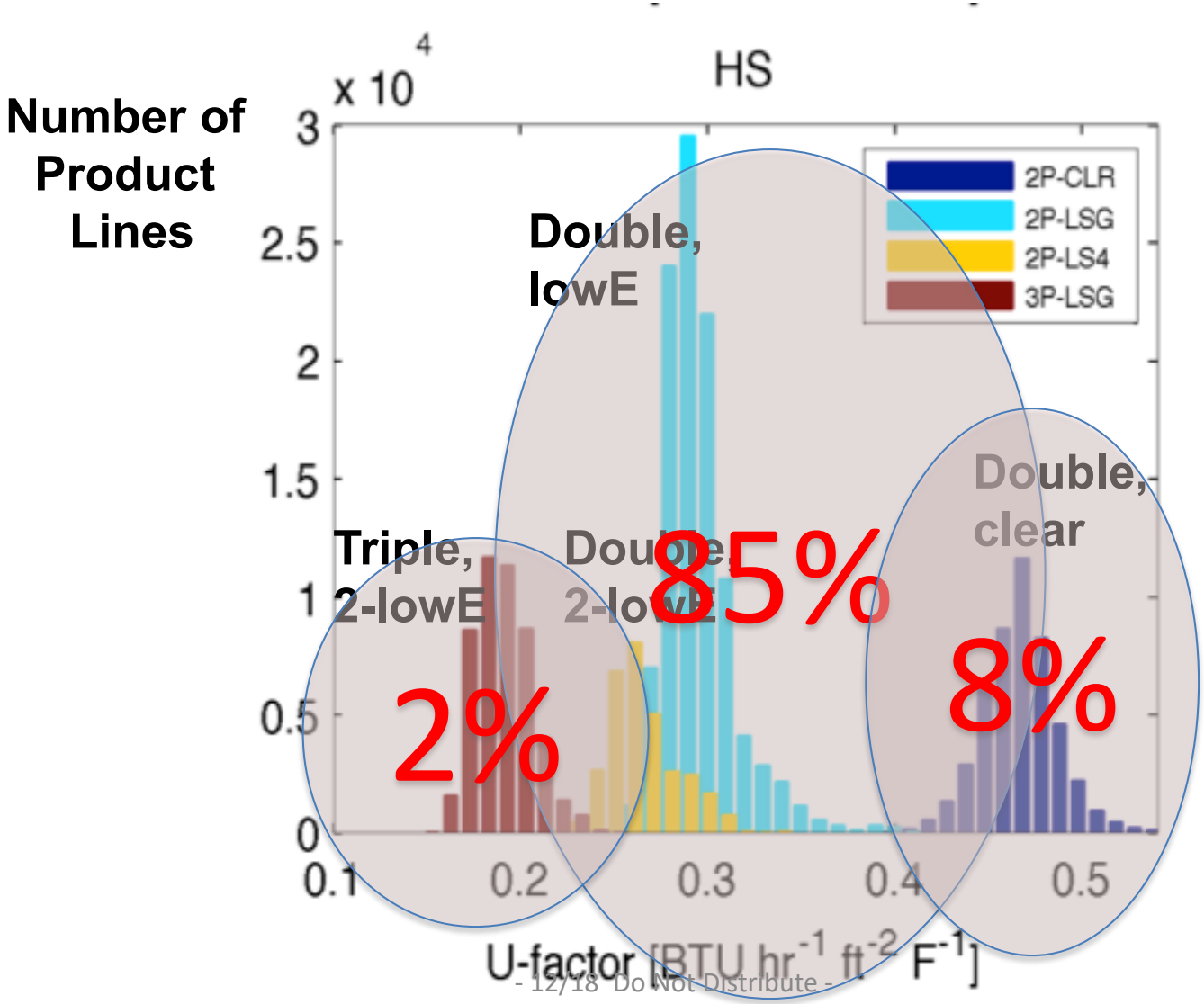
Performance distribution, NFRC-Rated Windows by U

Source: EPA ENERGYSTAR analysis, Horiz. sliding windows



Actual Sales are Very Different from NFRC Listings

Performance distribution, NFRC-Rated Windows by U

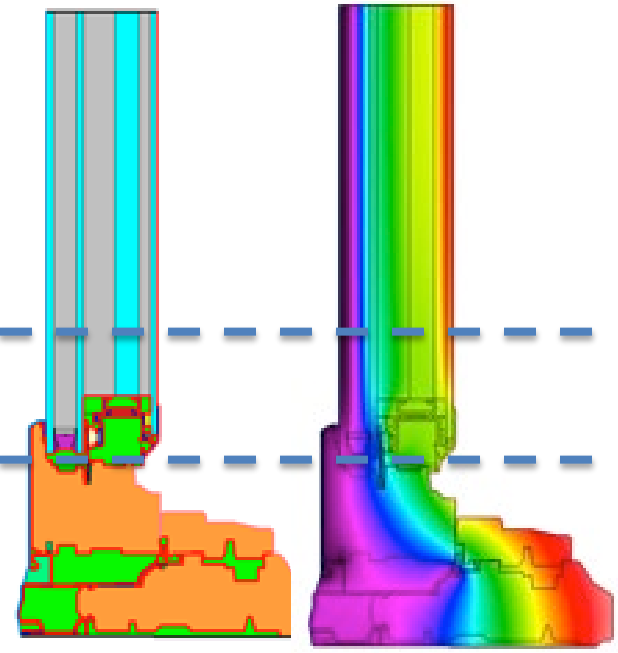


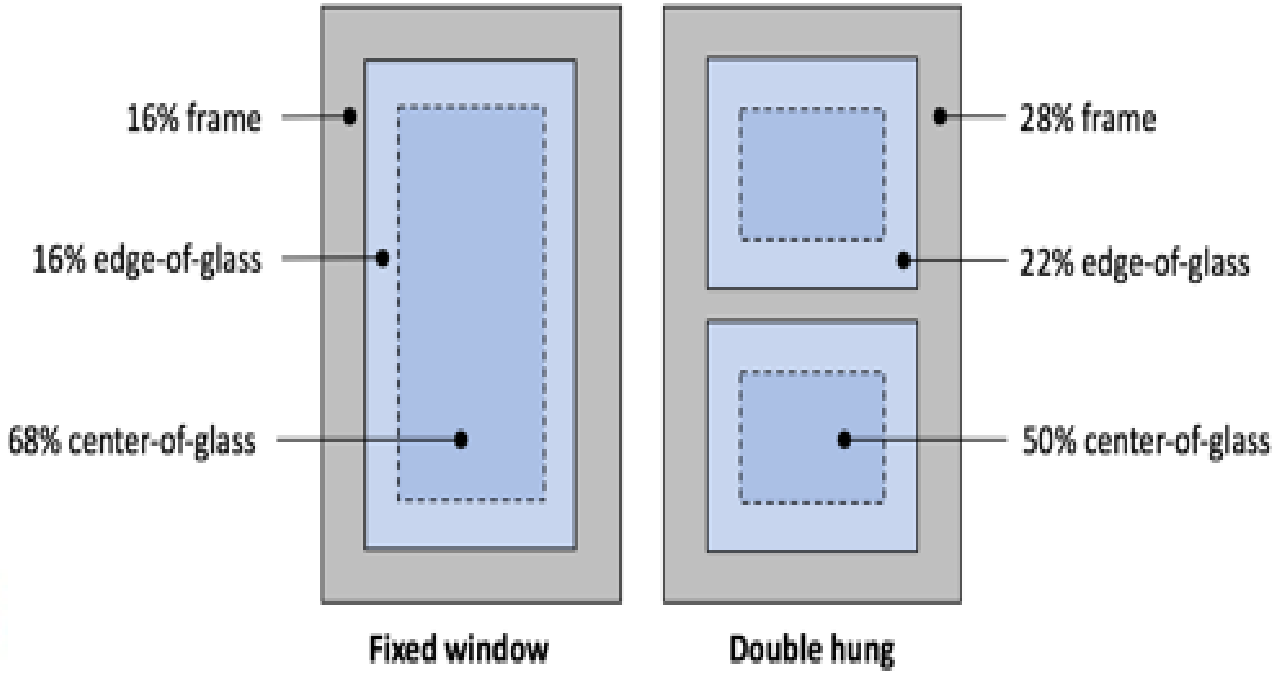
IGU vs Overall Window Properties

The Effect of "edge of glass" and "frame"

- **Total Window** U Properties - worse than Glazing
  - SHGC: ~ 0.4 – 0.6 for cold climates; ~ 0.2 – 0.4 for hot climates
    Future: dynamic glass, variable SHGC: 0.05 → 0.5

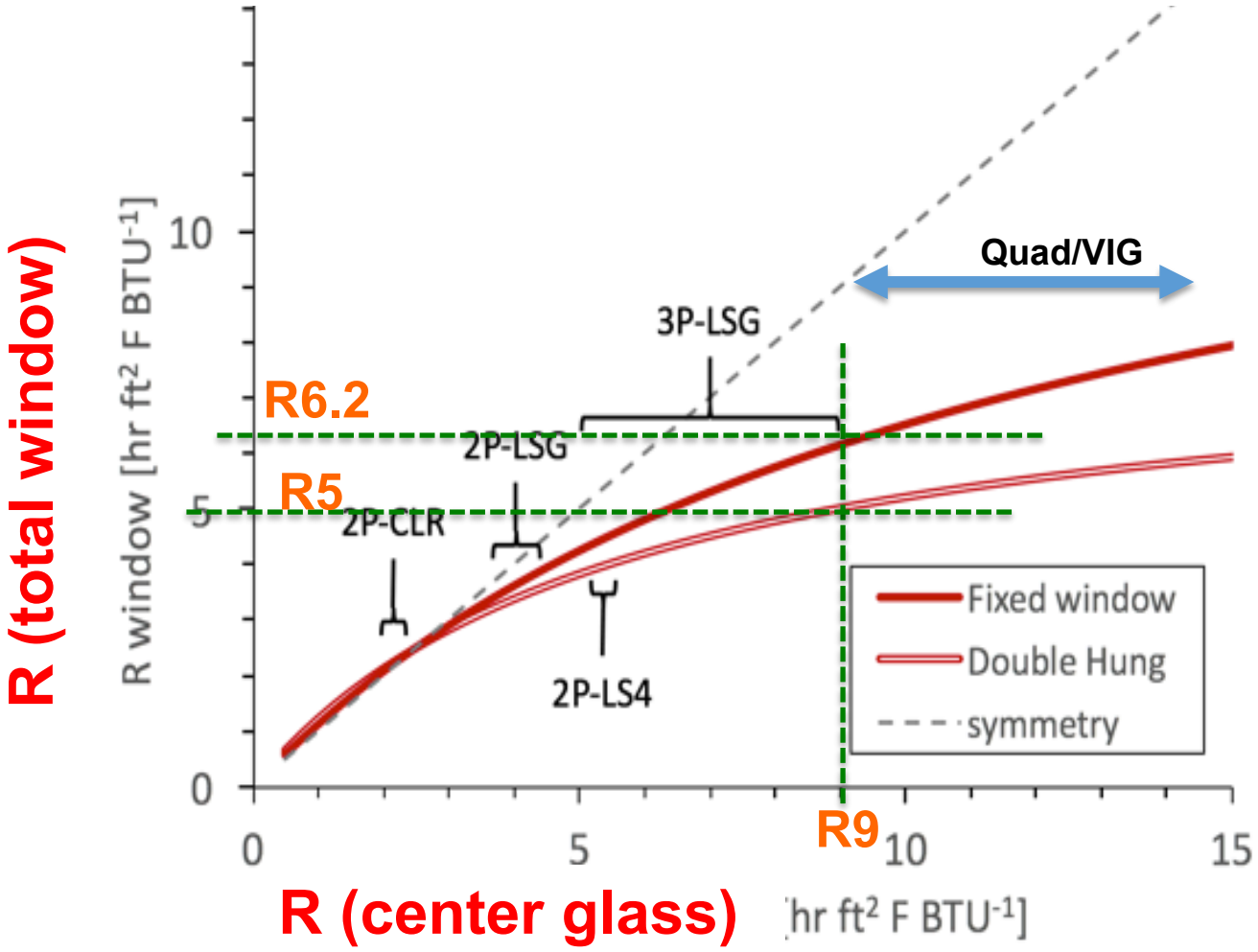
U_{window} = Area-Weighted Average of:
Center of Glass Area, Edge of Glass Area, Frame Area





Thermally Improved Frame Needed for Efficient Windows
Efficient Glass/IGU is not enough
BUT it Gets Us Rapidly on the Path to Better Windows

Total WINDOW R vs GLAZING R: Diminishing Returns



Why Not Make Better Windows Now... ??

- **U.S. Window Manufacturers "could" redesign product lines to offer "conventional" triple glazing - but...**
  - Costly – to manufacturers to retool; → costly to end-users
  - "No Demand" now; uncertain demand at higher price point
- **Europe – Northern countries "mandate" triple glazing**;
  - Base window easily accommodates triple IGU
  - Offered by most suppliers – competitive market
  - Supported by codes, higher energy prices
  - Passive House windows often imported from Europe

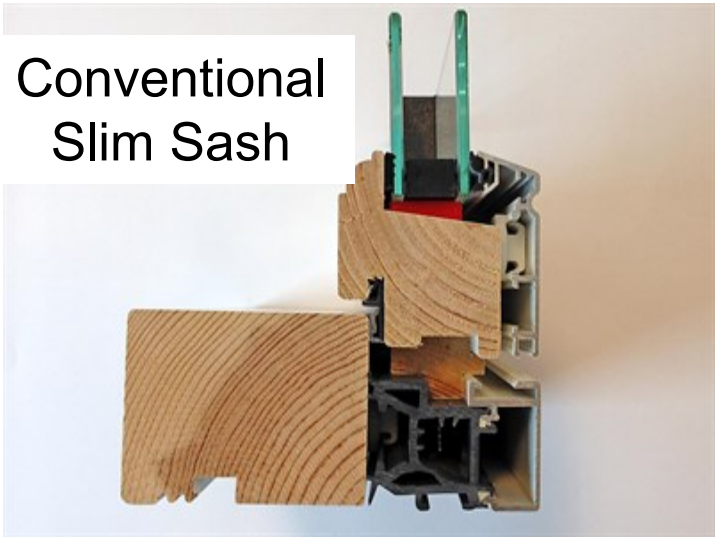
  - But no fundamental "technical" obstacle to adoption here

Sash/Frame and IGU Dimensions

Typical U.S. Window

~80% are sliders

Slim sash/frame



Typical European Window

Most Tilt/Turn or Fixed

Wide sash/frame

too **heavy**

too **wide**

too **expensive**

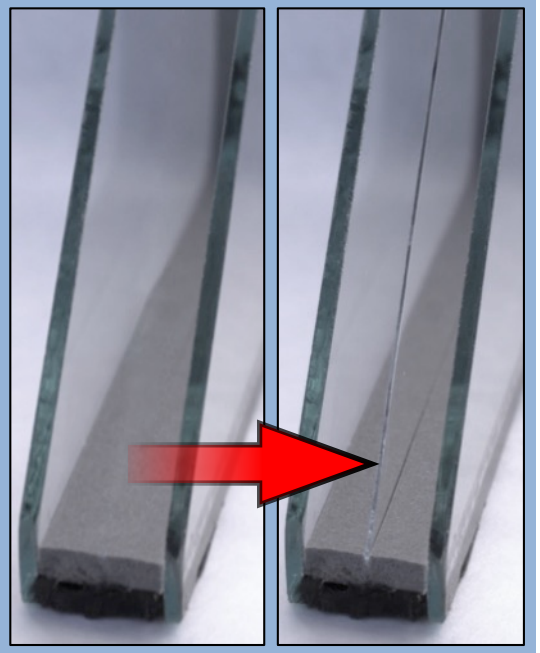
long ROI

Drop-in replacement

low entry **cost**

double performance

minimal weight



Double-pane Thin-triple

LBNL “Thin Triple” Concept and Strategy

Provide a low-cost, low-risk pathway to:

reduce IGU U -> ~0.10-0.14

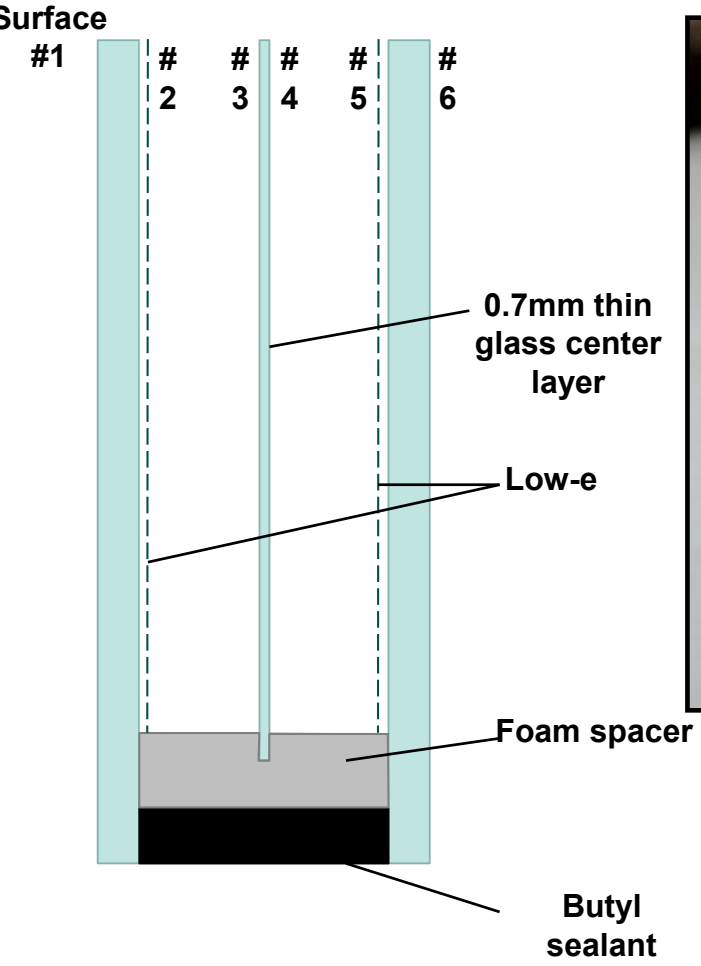
reduce window U -> ~ 0.18-0.21

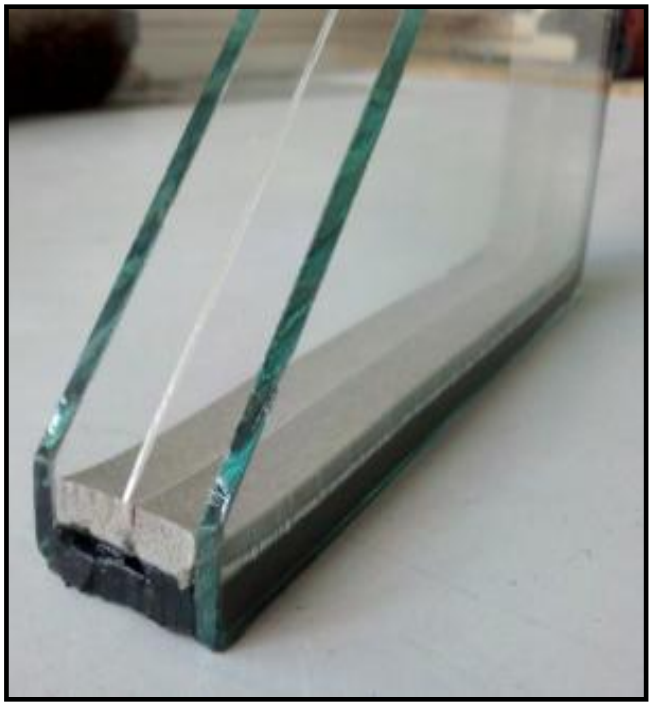
...without window frame redesign

creates a platform for future lower U with improved frames, U -> ~ 0.10-0.16

Drop-In "Thin Lightweight Triple"

"upgrade" all U 0.3 double glazed windows to 0.2 without redesign using new IGU with same width, weight



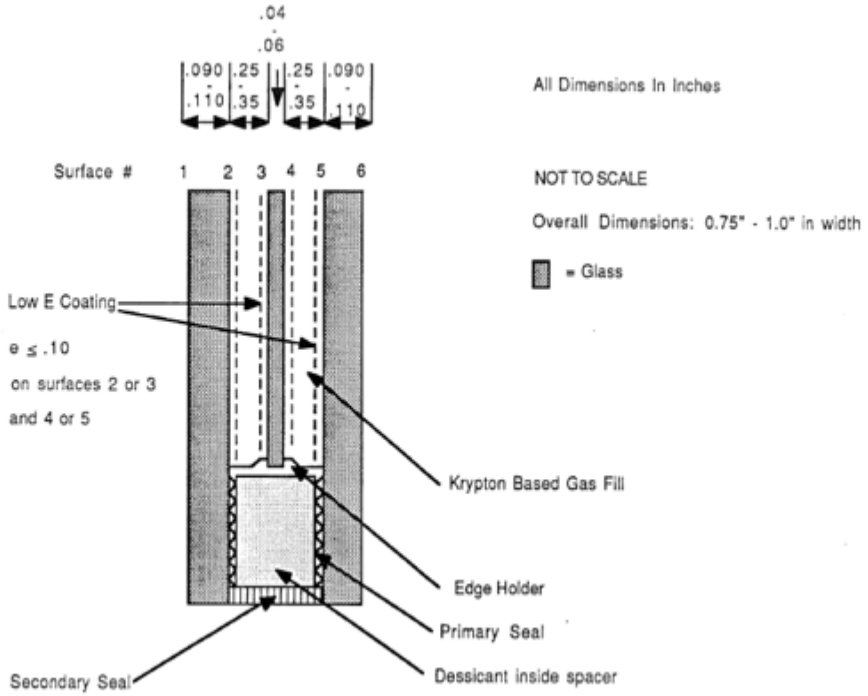


- **Platform: U: ~0.1-0.12**
- **Thin float glass**
  - .3, .5, .7, 1.1 mm
- Multiple suppliers
- **2 Low-E coatings**
- **Krypton gas fill**
- Non-structural center
  - 2 seals, not 4
- Infrastructure exists
- "Affordable"

Not a New Concept;
Thin Glass, Thin Triple
Concept Developed 30 yrs ago

1991 Design Patent -- >

1989 ASME paper



United States Statutory Invention Registration [19]

[11] Reg. Number: H975

Selkowitz et al. [43] Published: Nov. 5, 1991

[54] **THERMAL INSULATED GLAZING UNIT**

[75] Inventors: **Stephen E. Selkowitz**, Piedmont; **Dariush K. Arasteh**, Oakland, both of Calif.; **John L. Hartmann**, Seattle, Wash.

[73] Assignee: **The United States of America as represented by the United States Department of Energy**, Washington, D.C.

[21] Appl. No.: **428,539**

[22] Filed: **Oct. 30, 1989**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 319,871, Mar. 1, 1989, abandoned, which is a continuation of Ser. No. 178,043, Apr. 5, 1988, abandoned.

[51] Int. Cl.[5] E06B 7/12

[52] U.S. Cl. 52/172

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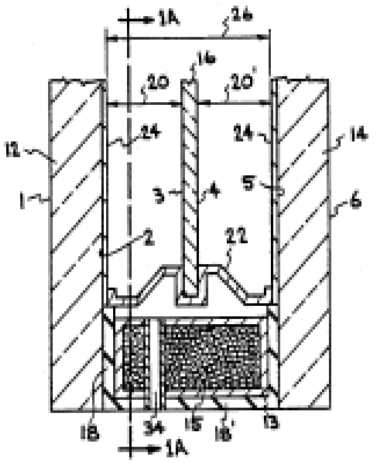
Popular Science, "Superwindows", Elaine Gilmore, 3-1986, pp. 76-77.

Primary Examiner—Michael J. Carone
Attorney, Agent, or Firm—B. J. Weis; L. E. Carnahan; William R. Moser

[57] **ABSTRACT**

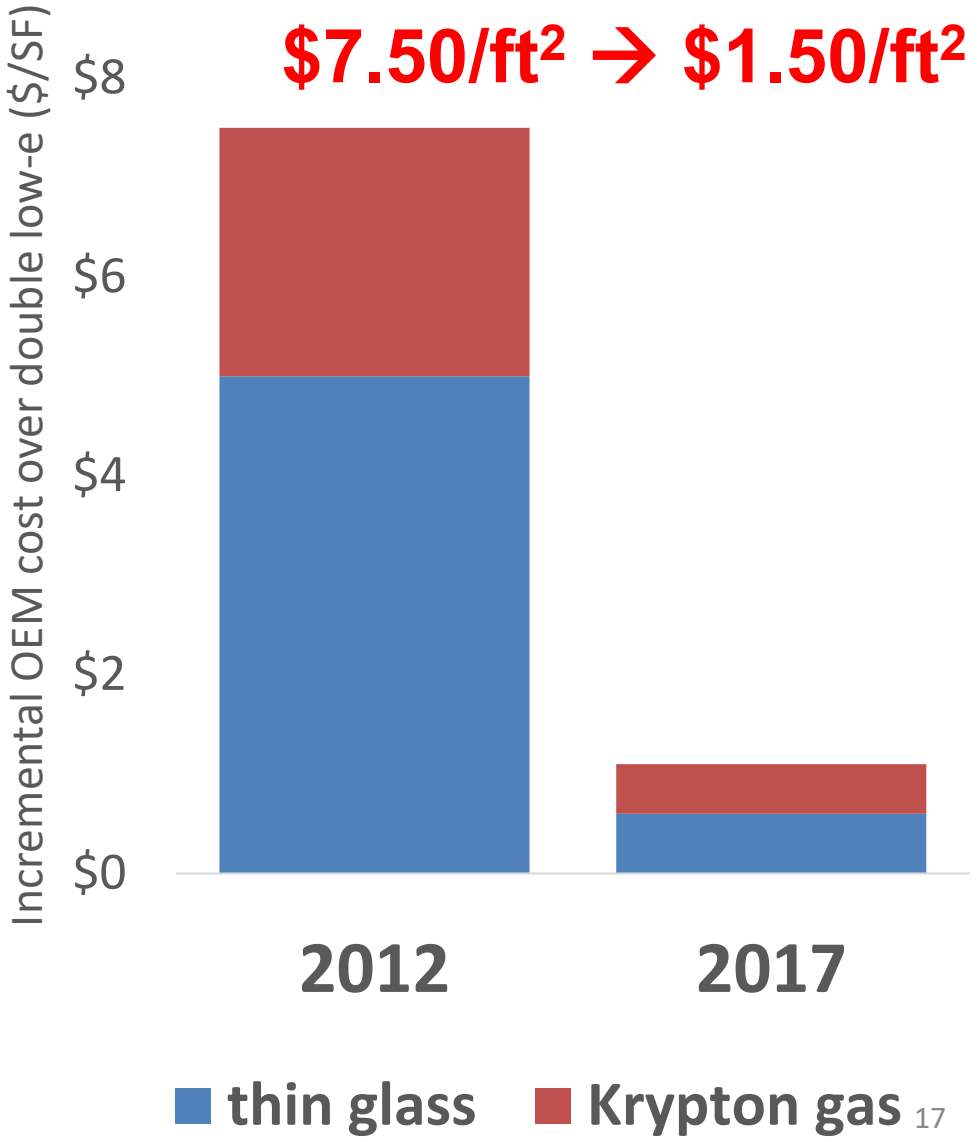
An improved insulated glazing unit is provided which can attain about R5 to about R10 thermal performance at the center of the glass while having dimensions about the same as those of a conventional double glazed insulated glazing unit. An outer glazing and inner glazing are sealed to a spacer to form a gas impermeable space. One or more rigid, non-structural glazings are attached to the inside of the spacer to divide the space between the inner and outer glazings to provide insulating gaps between glazings of from about 0.20 inches to about 0.40 inches. One or more glazing surfaces facing each thermal gap are coated with a low emissivity coating. Finally, the thermal gaps are filled with a low conductance gas such as krypton gas.

21 Claims, 2 Drawing Sheets



80+% reductions in glass/Kr cost in 5 yrs

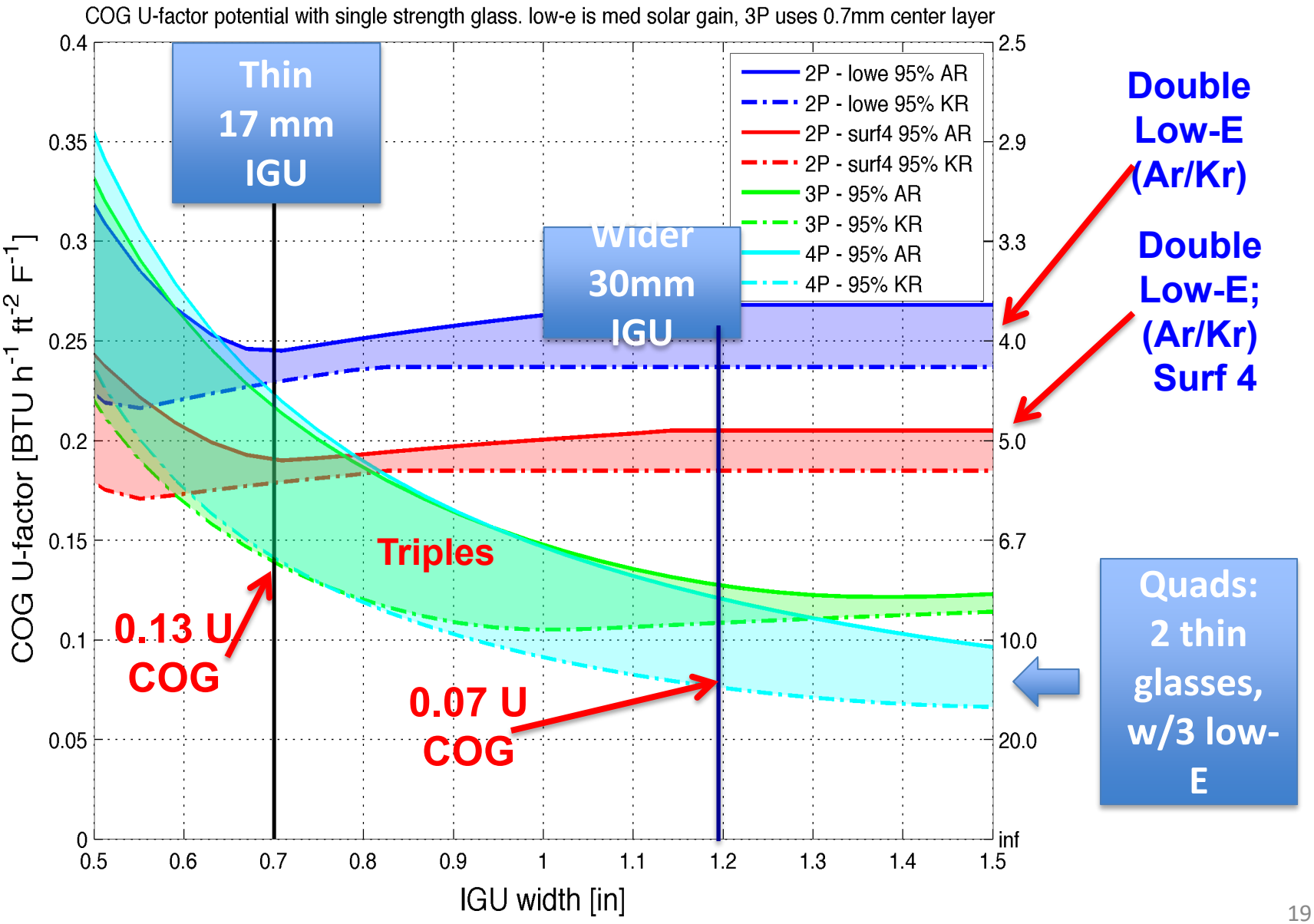
(thanks to flat screen TVs, satellite thrusters, LEDs)

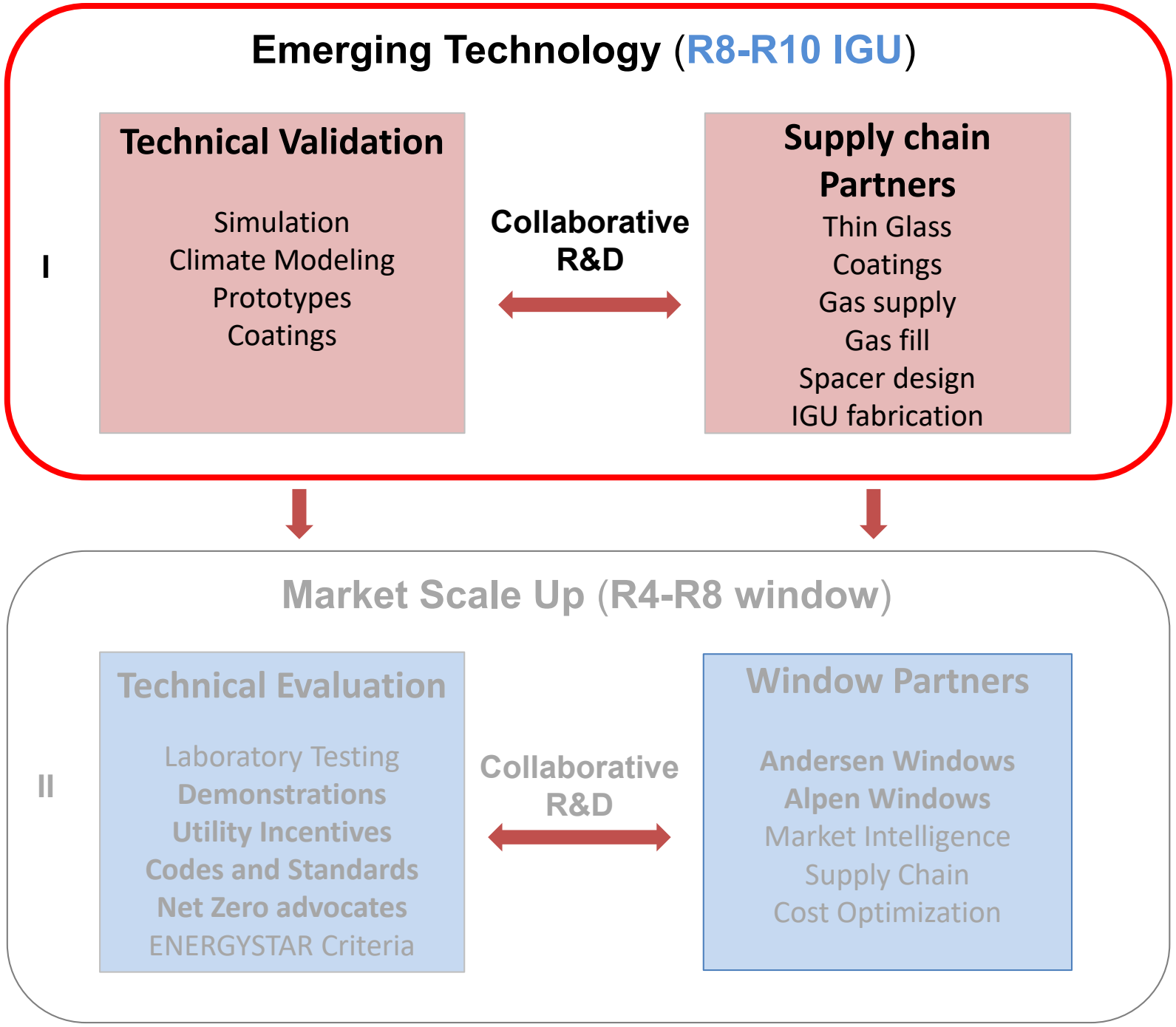


Optimizing and Validating Thermal Properties

Early Prototypes with Window Industry Partners

Thin Lightweight Triple → Thin Quad: R15

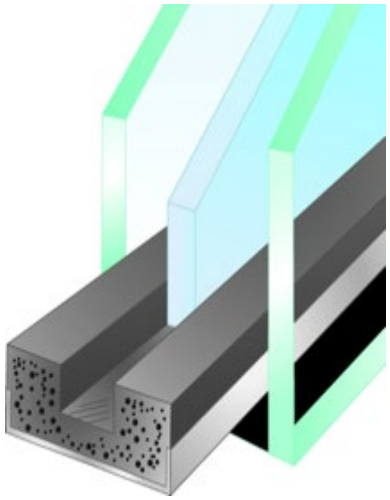



Emerging Technology (R8-R10 IGU)
I
Technical Validation
Simulation
Climate Modeling
Prototypes
Coatings
Collaborative R&D
Supply chain Partners
Thin Glass
Coatings
Gas supply
Gas fill
Spacer design
IGU fabrication
Market Scale Up (R4-R8 window)
II
Technical Evaluation
Laboratory Testing
Demonstrations
Utility Incentives
Codes and Standards
Net Zero advocates
ENERGYSTAR Criteria
Collaborative R&D
Window Partners
Andersen Windows
Alpen Windows
Market Intelligence
Supply Chain
Cost Optimization

Thin-glass spacer - Single spacer, dual seal systems

(or use conventional two spacer system)

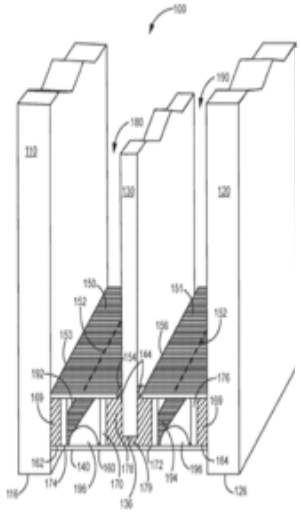
Examples: Products are already entering the market!



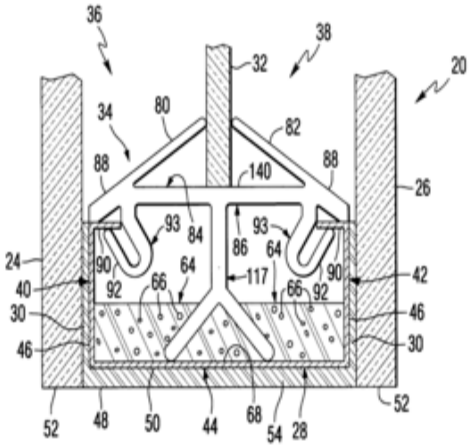
Edgetech

Swisspacer

SORA



Guardian: US 9,677,321 B2

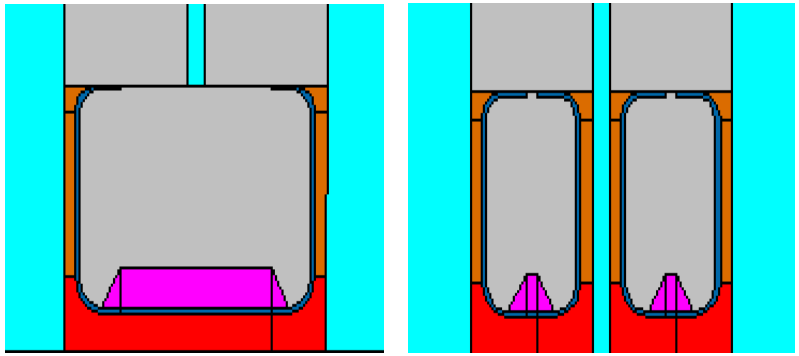


PPG: US6289641B1

Long Term Durability/Reliability

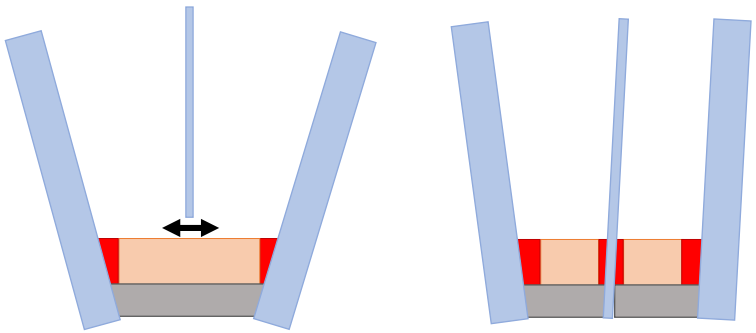
Two sealant paths in place of four:

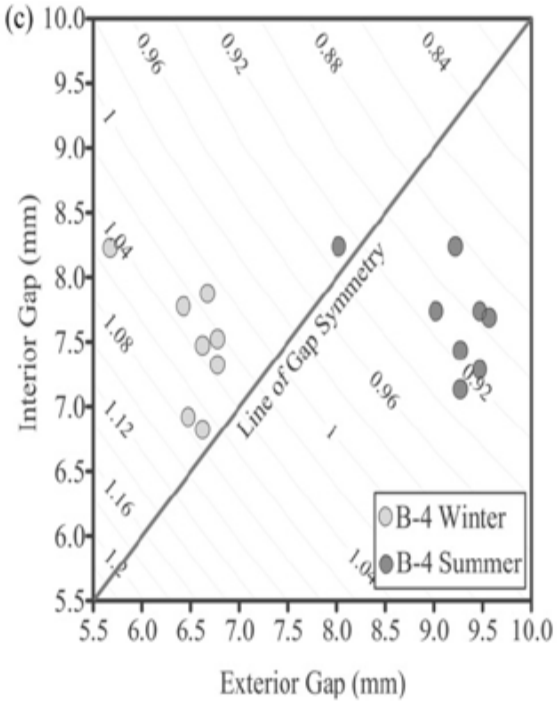
- Fewer sealant paths
- Removes center layer from structural load share



- Current Cyclic Durability Testing

Better pressure equalization = less optical distortion





Field Studies- IGU Deflection

IGU MANUFACTURING CHALLENGES

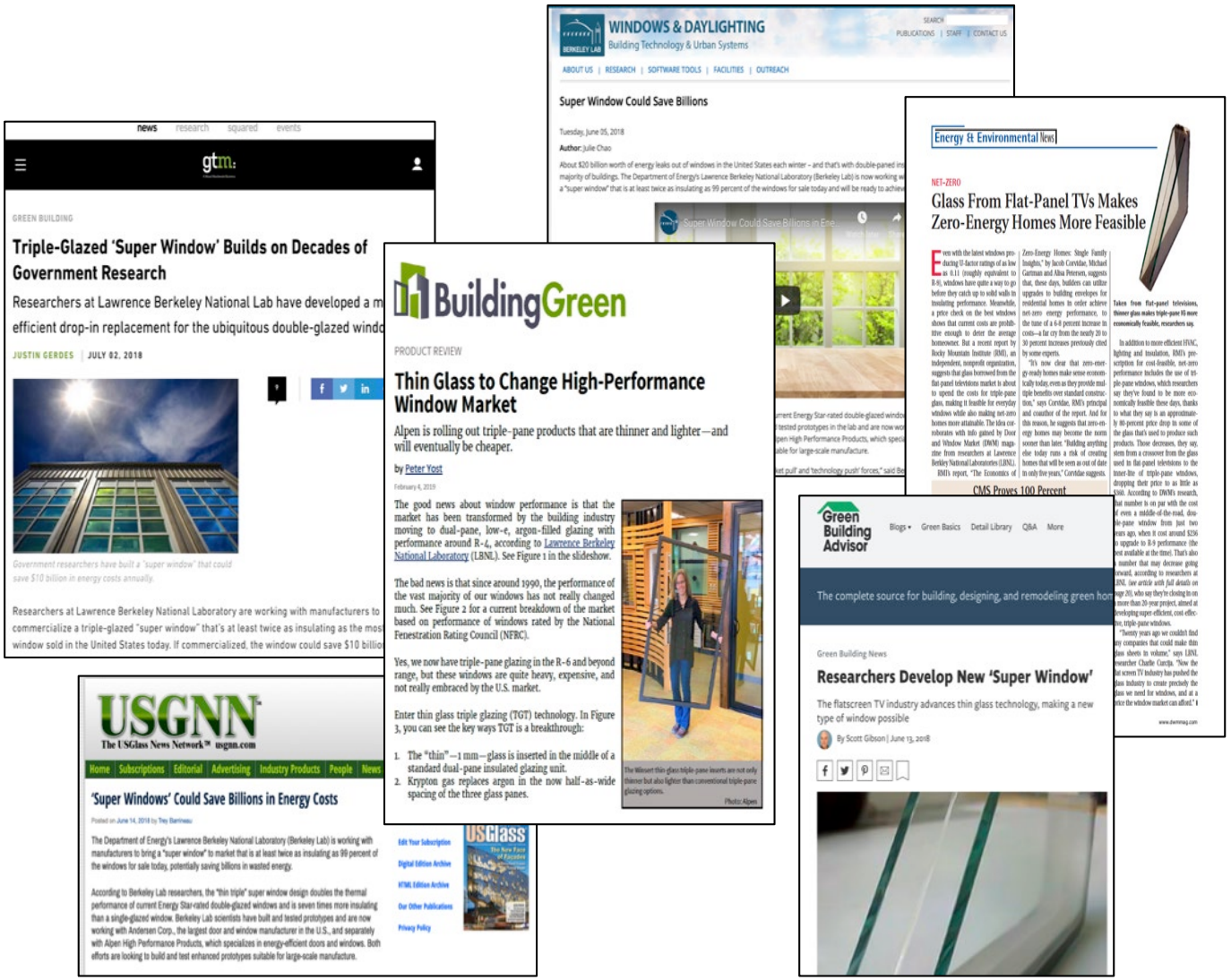
Thin-glass cutting

Thin-glass handling

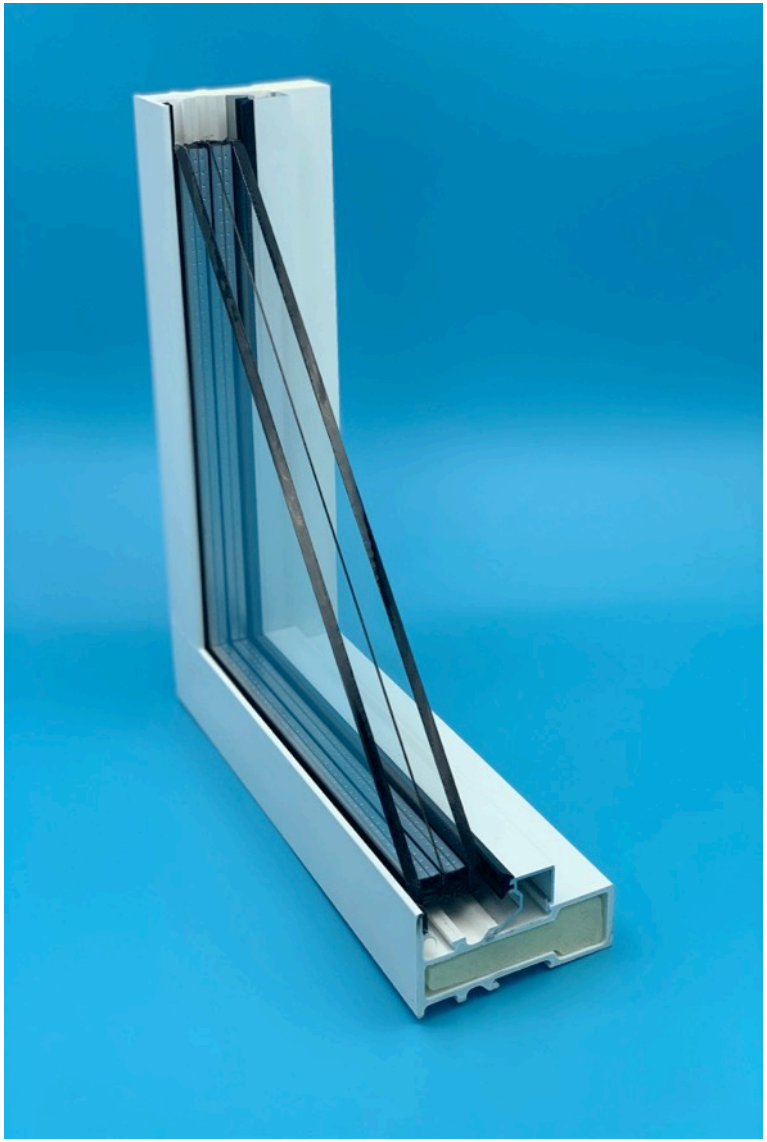
Low loss Krypton gas fill

Automation: 1000 units/day

Increased U.S. Industry Interest and Collaboration

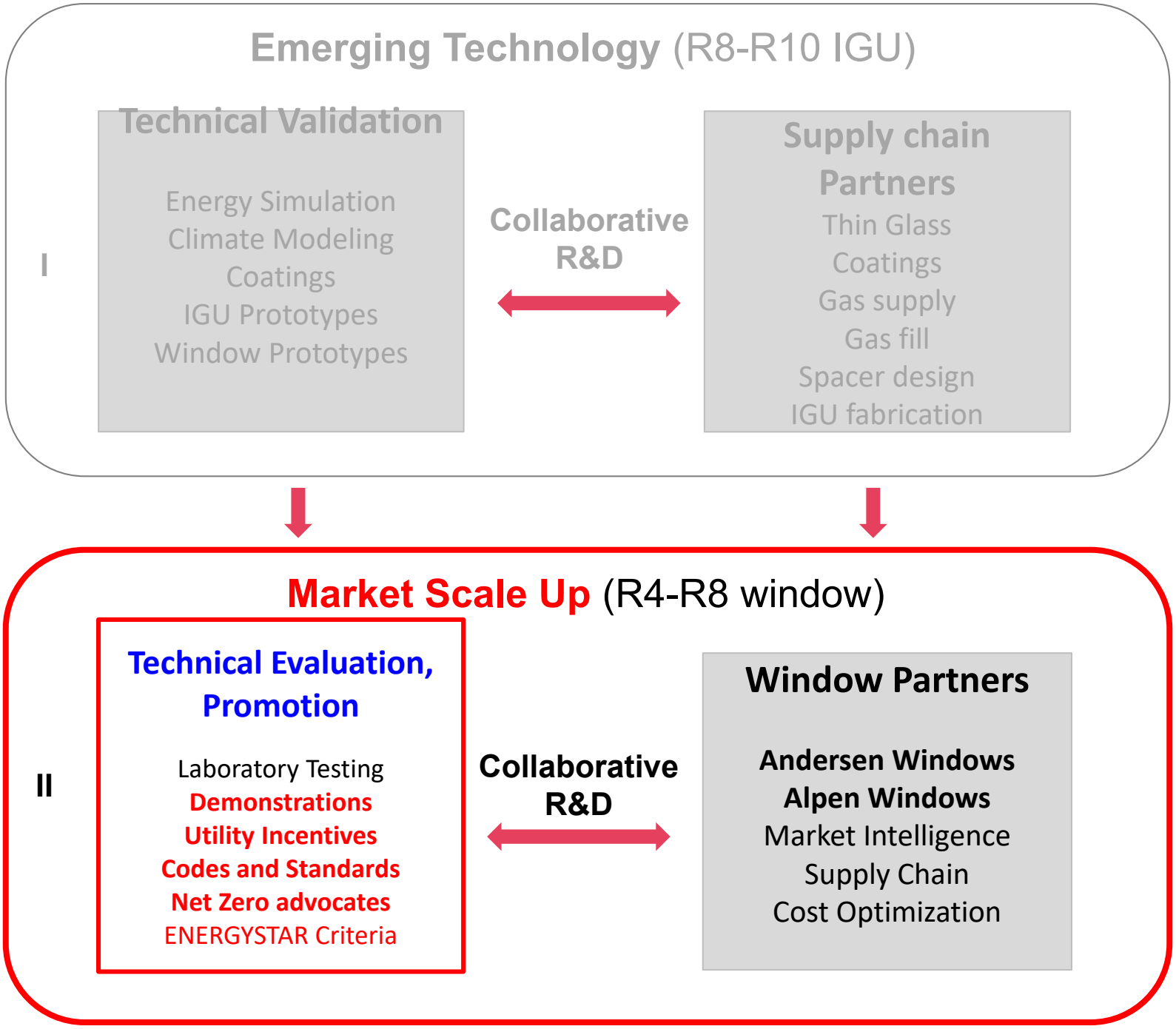


Alpen: Triple and Quad Thin Glass Windows



Creating More Demand:

Market Pull and Transformation


Emerging Technology (R8-R10 IGU)
I
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Supply chain Partners
Thin Glass
Coatings
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Gas fill
Spacer design
IGU fabrication
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Technical Evaluation, Promotion
Laboratory Testing
Demonstrations
Utility Incentives
Codes and Standards
Net Zero advocates
ENERGYSTAR Criteria
Collaborative R&D
Window Partners
Andersen Windows
Alpen Windows
Market Intelligence
Supply Chain
Cost Optimization

Market Drivers: Who Wants This? Needs This?

- **Building Owners**
  - Energy/$$ Savings
  - Thermal comfort
  - Larger window area
  - **Early Adopters**
    - **Passive House designers/buyers**
    - **Zero Net Energy Home buyers**

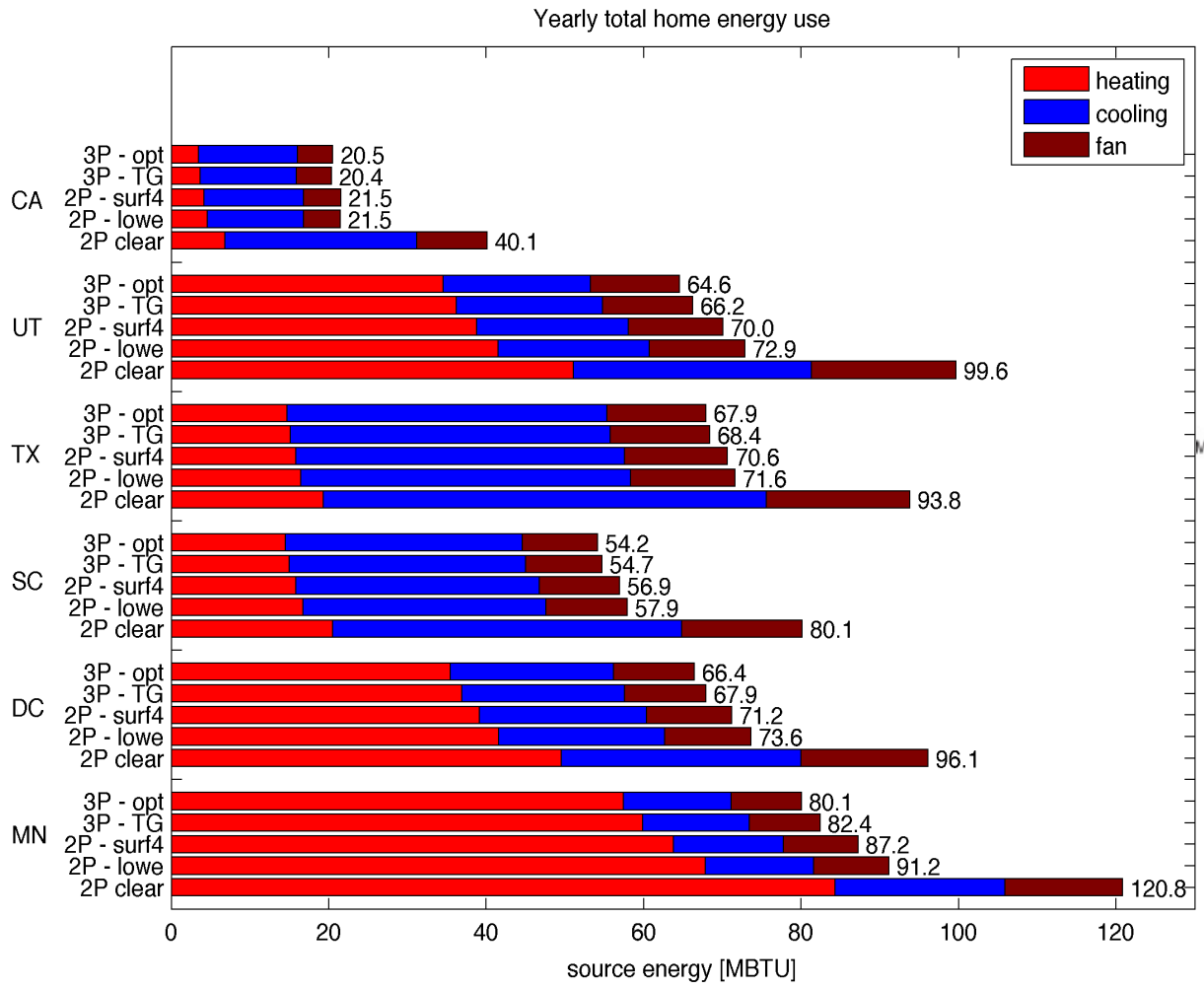
- **Architects/Engineers**
  - Builders- first cost dominated-
    - Emerging early adopters
  - Comfort/Daylight
  - "Justifying" larger window area
  - HVAC system
    - first cost savings- reduced size
    - Duct system reductions, distributed/zonal HVAC

Annual Energy Cost/Savings (6 U.S. Cities)

5 Alternative Window Designs

6 U.S. Climates

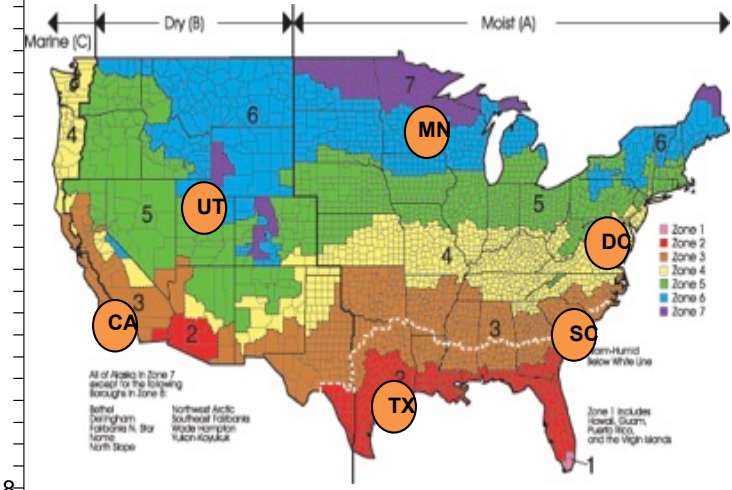
End use multipliers: Elec=3.167,Gas=1.084



Payback:

Varies with climate and utility rate

Different U.S. Climate Zon



Mass-Market Adoption of Triple-Pane Windows

CA Demo Program:
High performance windows installed at **no incremental cost** to builder

Deployment collaborators

- California Partnership for Advanced Windows (C-PAW)
  - Lawrence Berkeley National Lab
  - California Energy Commission
  - CONSOL
  - CBIA
  - And many more…

Development collaborators

- Lawrence Berkeley National Lab
- Andersen Windows
- Alpen HPP
- Ply-Gem
- Guardian
- Bystronic
- Nippon Sheet Glass (NSG)
- And many more…

Additional incentives for installing advanced thin center glass triple-pane windows are now available for participants of the California Advanced Homes Program (CAHP) and California Multifamily New Homes (CMFNH) Program.

Thin-glass, triple-pane windows can be installed in the same window openings as double-pane windows, are significantly more energy efficient, and reduce the energy needed to maintain a comfortable temperature.

california advanced homes

CALIFORNIA MULTIFAMILY NEW HOMES

CAHP Incentives

- High Performance Fenestration (HPF) cash bonus **doubles to $400/home**
- Each home receives an additional **$6 per square foot of glazing***

CMFNH Incentives

- High Performance Fenestration (HPF) cash bonus **doubles to $150/unit**
- Each unit receives an additional **$6 per square foot of glazing***

INCENTIVE REQUIREMENTS

To qualify for these additional incentives, the programs will require:

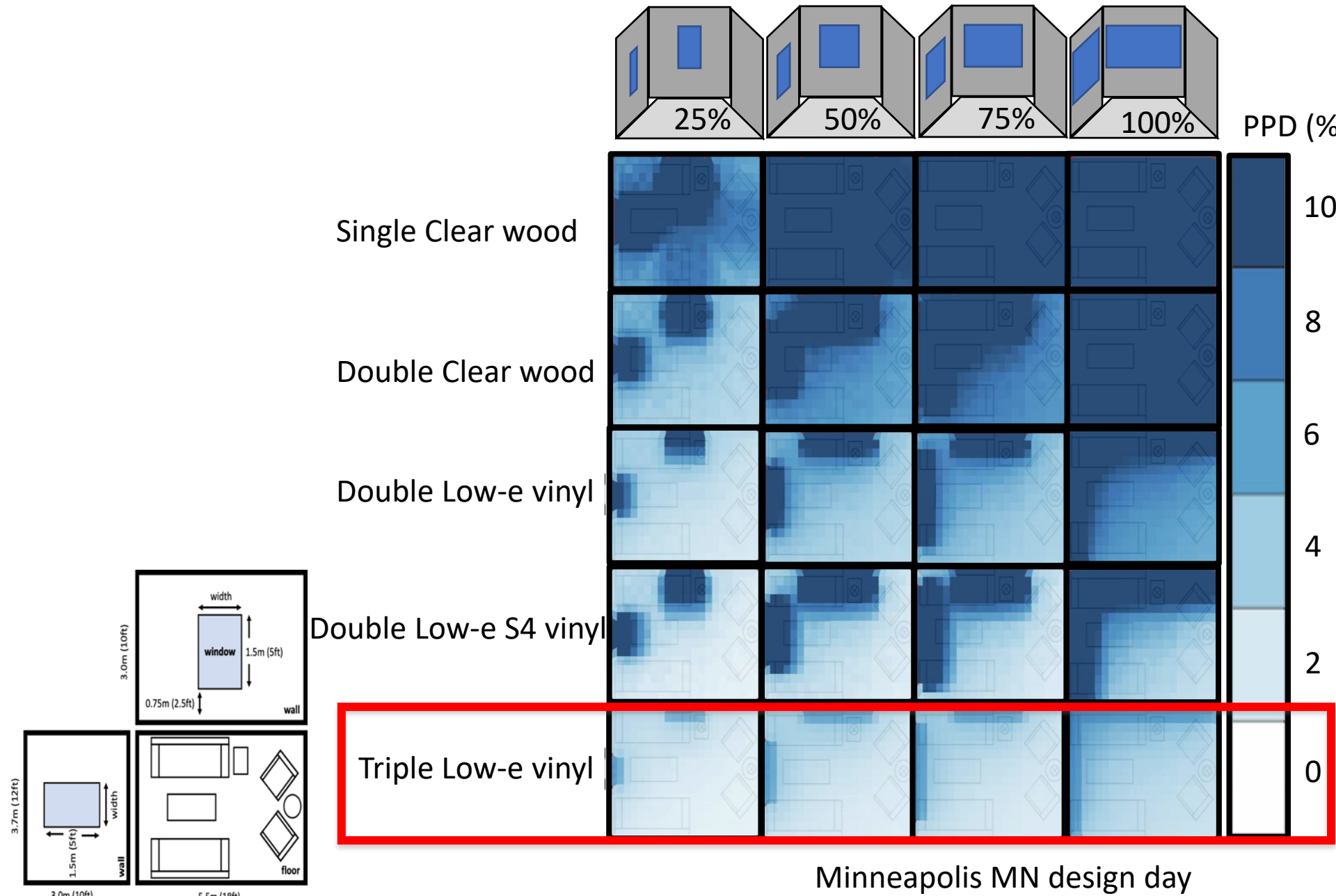
- ✓ All buildings permit to 2016 Title 24 code
- ✓ All buildings participate in CAHP or CMFNH
- ✓ All buildings must be built in climate zones 11, 12, or 13**
- ✓ PG&E or a PG&E representative must observe the installation
- ✓ Access to incremental costs data with copies of applicable invoices (material and labor)
- ✓ Release to use collected data in case studies or marketing materials as appropriate
- ✓ Compliance with program-approved thin-glass, triple-pane window: a Krypton-filled, triple-pane window with a thin center pane of glass (≤ 2mm thick), fitting into a typical double-pane window frame with an NFRC-rated U-factor ≤ 0.22 and SHGC as per Title 24 code*

*Includes windows only. Doors, sliding glass doors, and skylights are excluded from program requirements.
**No more than ten (10) homes from any one builder in any one climate zone. Projects not meeting these requirements may be eligible but require program approval prior to enrollment.

ACT NOW: NEW INCENTIVES ARE AVAILABLE FOR A LIMITED TIME

Contact us to learn more and for assistance with sourcing
866-352-7457 | cahp@TRCcompanies.com | info@cmfnh.com

Thermal Comfort vs Window Size and Type



Design Flexibility to Meet More Stringent Codes

Office Building

Make the case to **architects**, **engineers**, and **builders, early adopters**

Increase window **size**
Decrease perimeter **HVAC**

Condensation resistance
Comfort

Triple glazing eliminates need for perimeter heating coil;
Heating Coil Savings Pays for the Glass

	Cost/ft2 Window
Upgrade Double to Triple Pane	$5.47
Add Perimeter Heat to Double	$53.20

*image credit and cost data: Chris Mackey at Payette Architects

Market Acceleration Programs: Creating Demand for Better Windows

- Window Manufacturers – Training, Promotion
- Education and Training – Architects, Engineers
- Voluntary Programs – ENERGY STAR
- Utility Rebates and Incentives
  - Midstream, Upstream?
- **Pilot Programs, Field Demonstration, Test Houses**

Research Project Goals and Design

Major project partners:

1) PNNL – pilot/field demonstration project lead
2) LBNL – window technology/supply chain lead
3) University of Minnesota – research and field testing
4) Funding from U.S. Dept. of Energy

Goals:

1) Increase uptake of the technology in the US market
2) Perform field testing to validate energy, comfort, condensation, and sound performance

Research Project Goals and Design

Image from Easy Science For Kids, https://easyscienceforkids.com

1) Technology uptake –
   Developing a "Push-Pull" Strategy

   a) Supply Push
      - LBNL leads efforts with manufacturers
      - LBNL facilitates testing and provision of glass and IGU information for IGDB (International Glazing Database) and NFRC + Energy Star certification

   b) Demand Pull
      - PNNL leads validation studies and outreach efforts (conferences, webinars, in-the-field demonstrations, etc) to encourage implementation of higher performance residential windows

   c) Window manufacturer involvement to date
      - Alpen windows: thin triple IGU development and supply
      - Kensington (Pennsylvania): frame and window assembly
      - Paradigm (Maine): frame and window assembly
      - Looking for additional window manufacturers

Field Test/Demonstration Project Goals and Design

2) Validation testing

a) 8 to 16 new residential or retrofit projects in different climates around US.

- Retrofit projects (before and after monitoring)
- New construction projects
- Looking for additional “case study” projects

b) Validating performance from occupant’s perspective:

- HVAC savings (energy consumption, peak loads)
- condensation performance
- acoustic performance
- comfort improvement
- subjective occupant experience

c) Validating performance from installer/builder perspective:

- window costs compared to double glaze options
- ease of installation/labor
- supply chain (availability)

Habitat for Humanity field test project - Minneapolis, MN

Passive House Designers are Key Potential Partners

1. Passive House designs require high performance, low U windows
2. Product availability is limited today and costly
3. New low U window products are needed but manufacturers want to see the demand before investing in new low U products

We are exploring how new thin triple IGUs can enhance window product offerings to meet needs for Passive House Projects

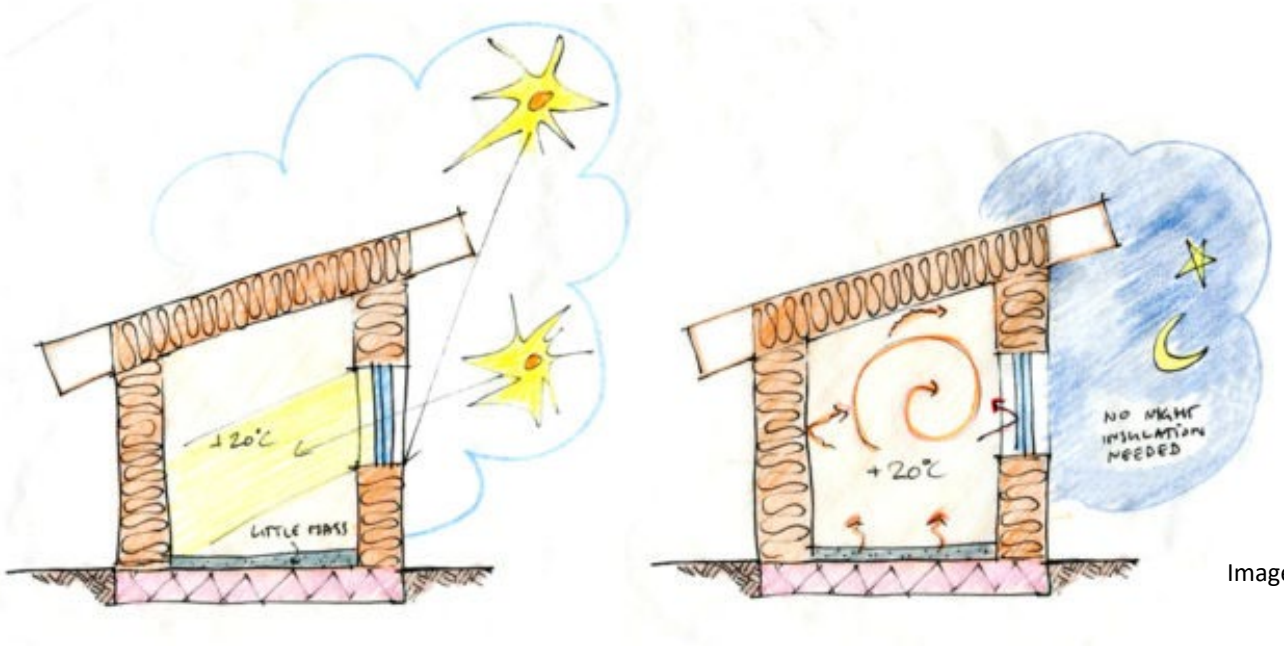


Image from jhmrad.com

PHIUS window requirements

PHIUS measures window performance differently than NFRC:

U_g = U-value of glass (value for center of glass)

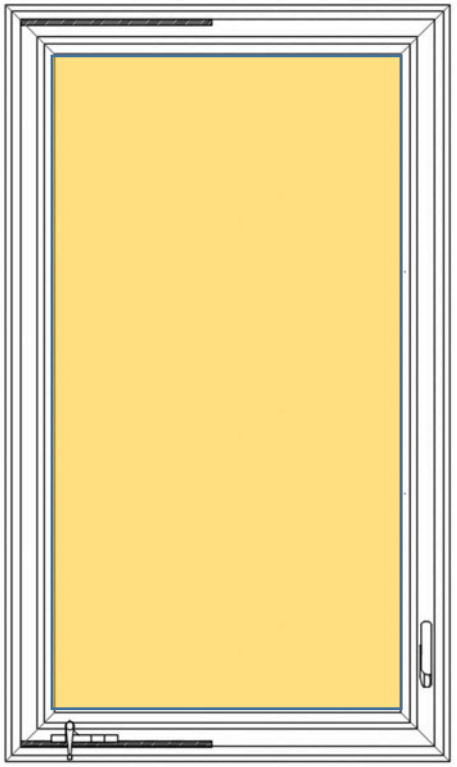


Image from Windows Professional, windowsprofessional.net

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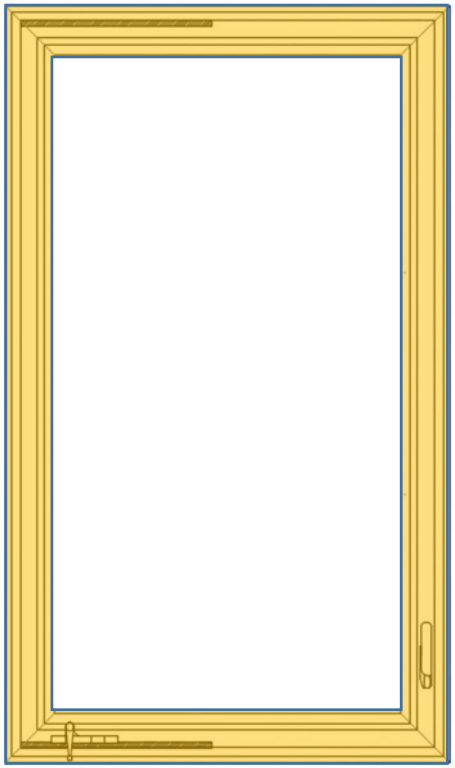
U_g = U-value of glass

U_f = U-value of frame



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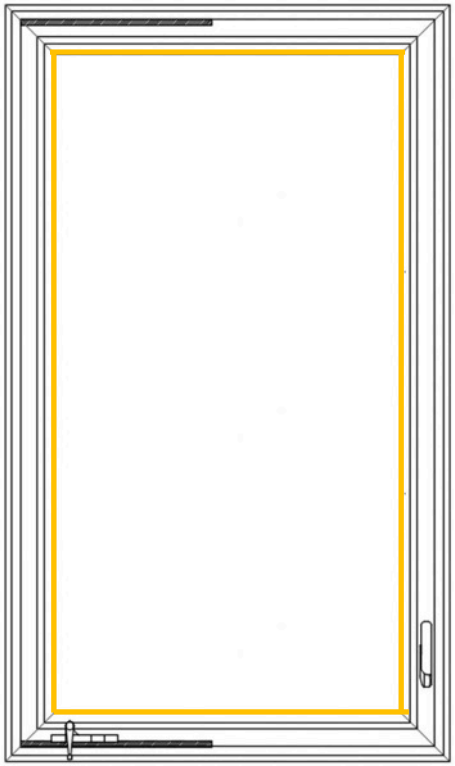
PHIUS window requirements

PHIUS measures window performance differently than NFRC:

U_g = U-value of glass

U_f = U-value of frame

Ψ_{spacer} = heat loss through spacer
(accounts for edge-of-glass effects)



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PHIUS window requirements

PHIUS measures window performance differently than NFRC:

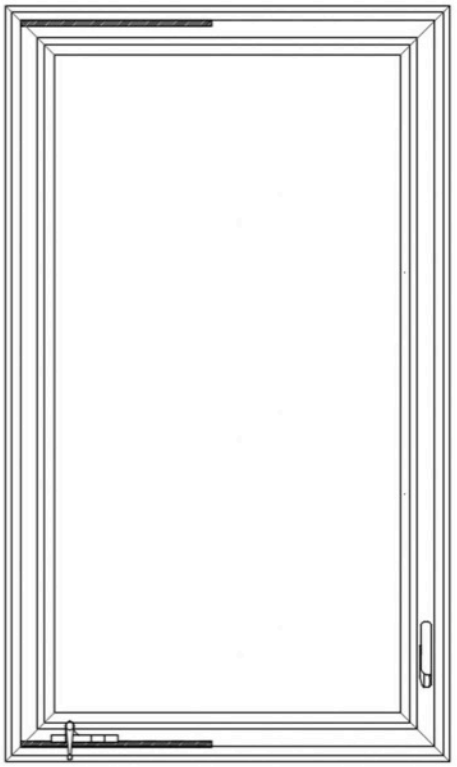
U_g = U-value of glass

U_f = U-value of frame

Ψ_{spacer} = heat loss through spacer
(accounts for edge-of-glass effects)

$$U_w = \frac{U_g \times A_g + U_f \times A_f + \Psi_{spacer} \times L_{spacer}}{A_g + A_f}$$

Window U-value is used to compare window performance.



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PHIUS window requirements

PHIUS measures window performance differently than NFRC:

U_g = U-value of glass

U_f = U-value of frame

Ψ_{spacer} = heat loss through spacer
(accounts for edge-of-glass effects)

$\Psi_{install}$ = heat loss through joint between frame and wall
(accounts for installation effects)

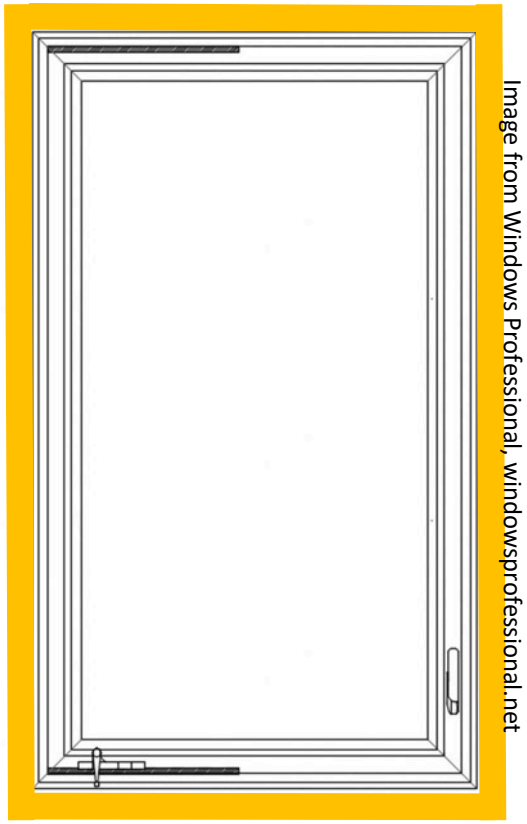


Image from Windows Professional, windowsprofessional.net

PHIUS window requirements

PHIUS measures window performance differently than NFRC:

U_g = U-value of glass

U_f = U-value of frame

Ψ_{spacer} = heat loss through spacer
(accounts for edge-of-glass effects)

$\Psi_{install}$ = heat loss through joint between frame and wall
(accounts for installation effects)

$$U_{w\ installed} = \frac{U_g \times A_g + U_f \times A_f + \Psi_{spacer} \times L_{spacer} + \Psi_{install} \times L_{install}}{A_g + A_f}$$

Installed window U-value is used to calculate window heat loss in the energy model.

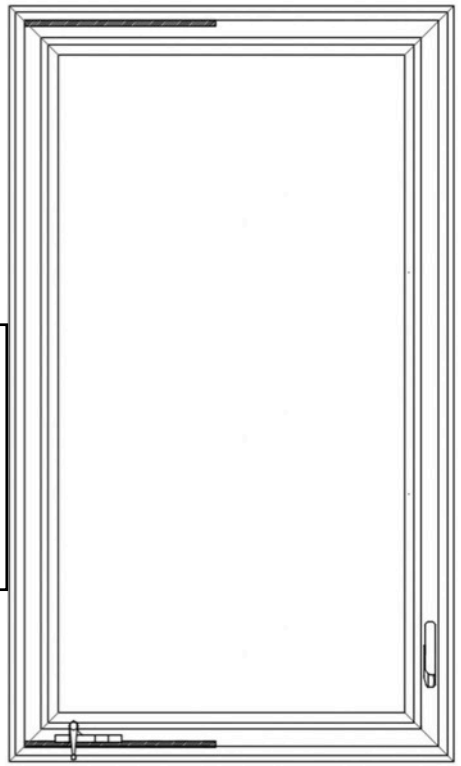


Image from Windows Professional, windowsprofessional.net

PHIUS window requirements

PHIUS climate zone **recommendations**:

ASHRAE/IECC/DOE North American Climate Zone	Overall installed window U-value Btu/h.ft2.F ($U_{w\ installed}$)	Center-of-glass U-value Btu/h.ft2.F (U_g)	SHGC - South	SHGC - North, East, West
8	≤0.11	≤0.10	≥0.50	Any
7	≤0.12	≤0.11	≥0.50	Any
6	≤0.13	≤0.12	≥0.50	Any
5	≤0.14	≤0.13	≥0.50	Any
4	≤0.15	≤0.14	≥0.50	≤0.40
Marine North	≤0.16	≤0.15	≥0.50	≤0.40
Marine South	≤0.22	≤0.20	≤0.50	≤0.30
3	≤0.18	≤0.16	≤0.50	≤0.30
2 West	≤0.18	≤0.16	≤0.30	≤0.30
2 East	≤0.20	≤0.18	≤0.30	≤0.30

PHIUS window requirements

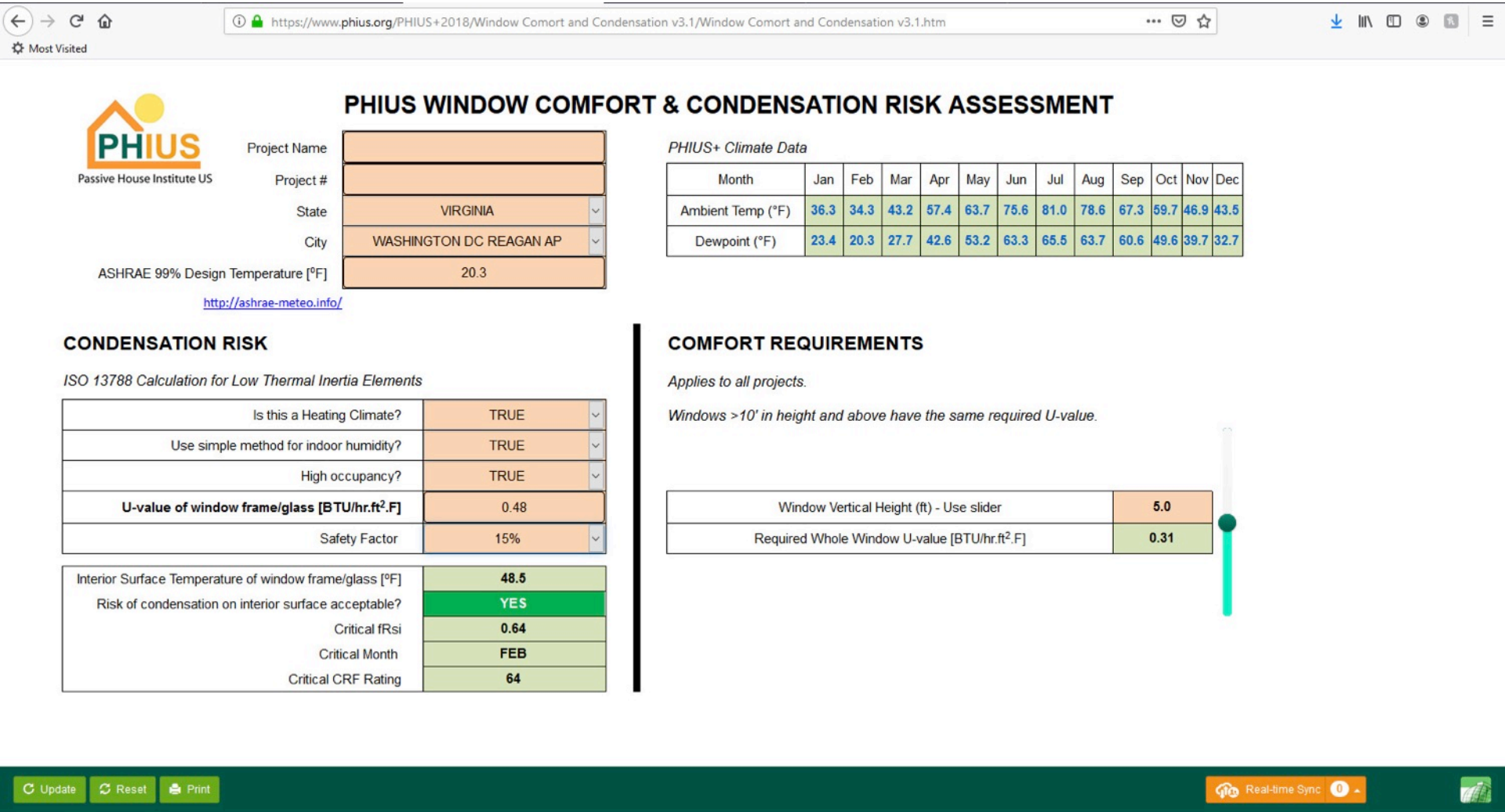
PHIUS climate zone **recommendations**: The recommended performance for even the warmest climate zones is well beyond what double-glazed windows can provide.

ASHRAE/IECC/DOE North American Climate Zone	Overall installed window U-value Btu/h.ft2.F	Center-of-glass U-value Btu/h.ft2.F	SHGC - South	SHGC - North, East, West
8	≤0.11	≤0.10	≥0.50	Any
7	≤0.12	≤0.11	≥0.50	Any
6	≤0.13	≤0.12	≥0.50	Any
5	≤0.14	≤0.13	≥0.50	Any
4	≤0.15	≤0.14	≥0.50	≤0.40
Marine North	≤0.16	≤0.15	≥0.50	≤0.40
Marine South	≤0.22	≤0.20	≤0.50	≤0.30
3	≤0.18	≤0.16	≤0.50	≤0.30
2 West	≤0.18	≤0.16	≤0.30	≤0.30
2 East	≤0.20	≤0.18	≤0.30	≤0.30

PHIUS window requirements

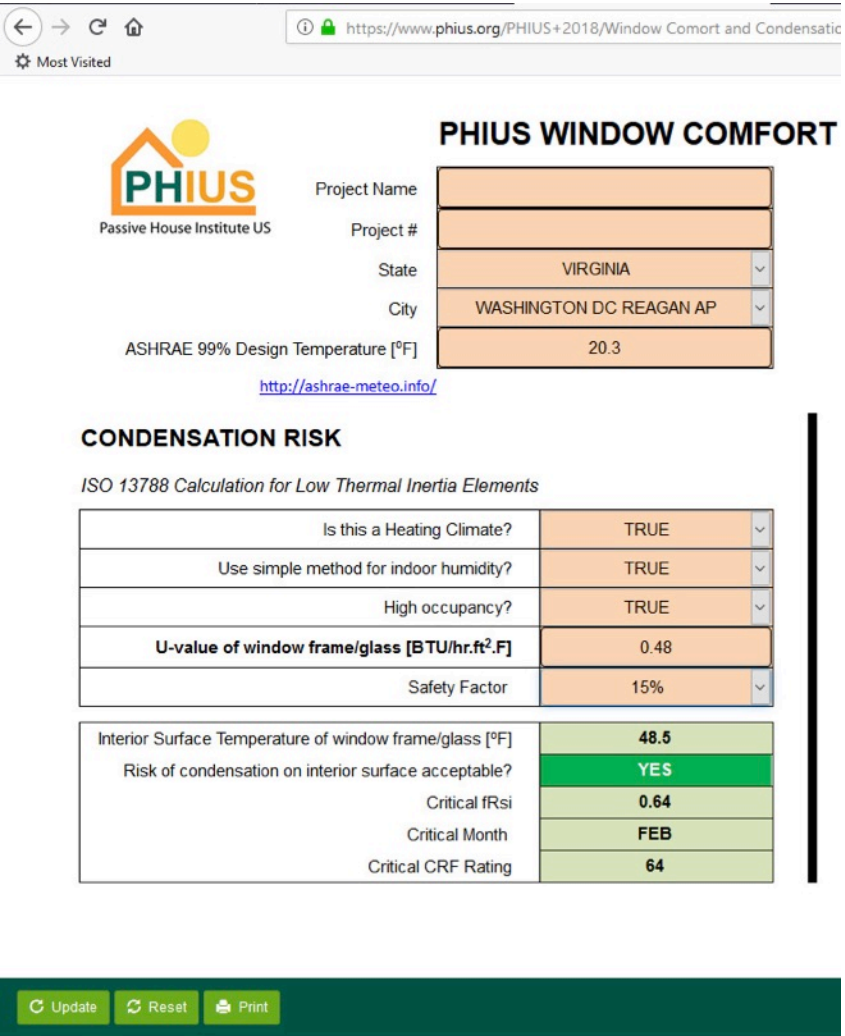
While window *energy* performance values are recommendations, PHIUS does have hard requirements for window condensation and comfort performance.

PHIUS has created a calculator to assist in determining compliance.



PHIUS window requirements

Condensation Risk: In general, the easier of the two requirements to meet. Must be met for both frame and glass, U_f and U_g



Inputs ask for:

- ASHRAE 99% design temperature
- Information about the indoor humidity
- Safety factor
- U-values of frame and glass: U_f , U_g

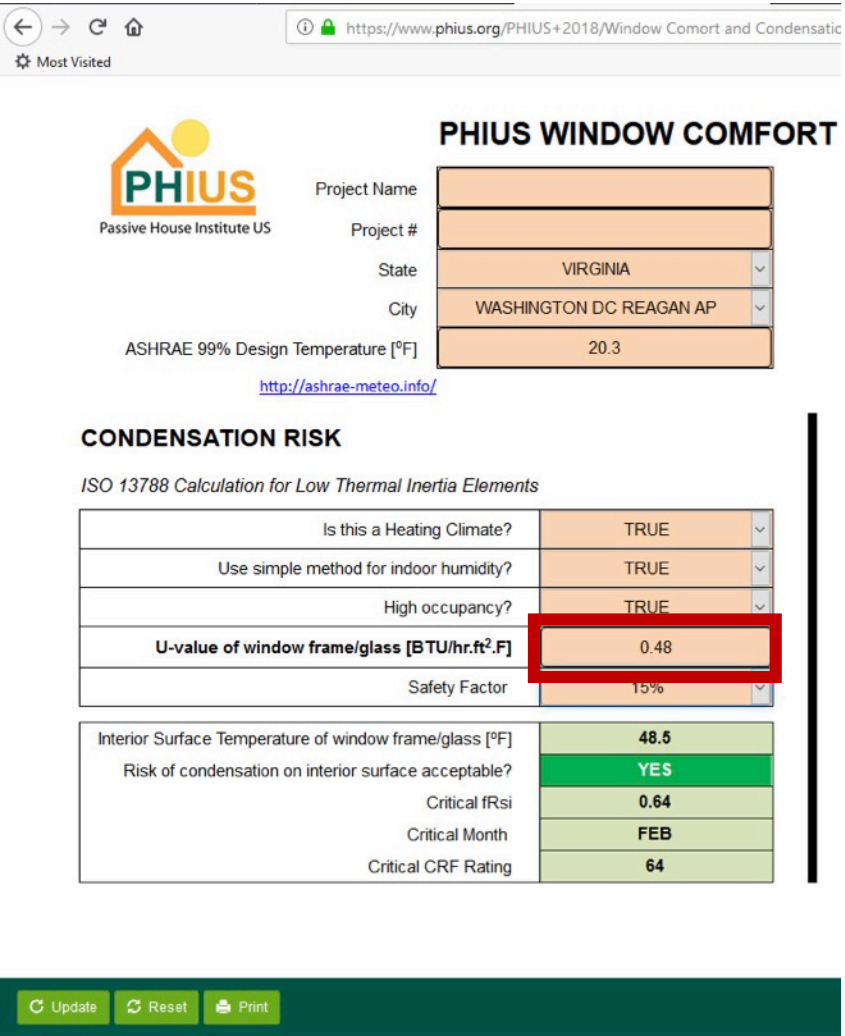
Outputs calculate:

- Interior surface temperature of frame and glass at design temp (using 0.74 (IP) surface film resistance)
- Dewpoint based on indoor humidity
- A check whether the interior surface temperature is above the dewpoint

- Can also meet this criterion using an F_{rsi} or CRF calculation based on the coldest month average temp

PHIUS window requirements

Condensation Risk: In general, the easier of the two requirements to meet. Must be met for both frame and glass, U_f and U_g



Required window frame or glass U-value to meet condensation requirement is only U-0.48 for Washington D.C.

(with high occupancy and 15% safety factor specified)

PHIUS window requirements

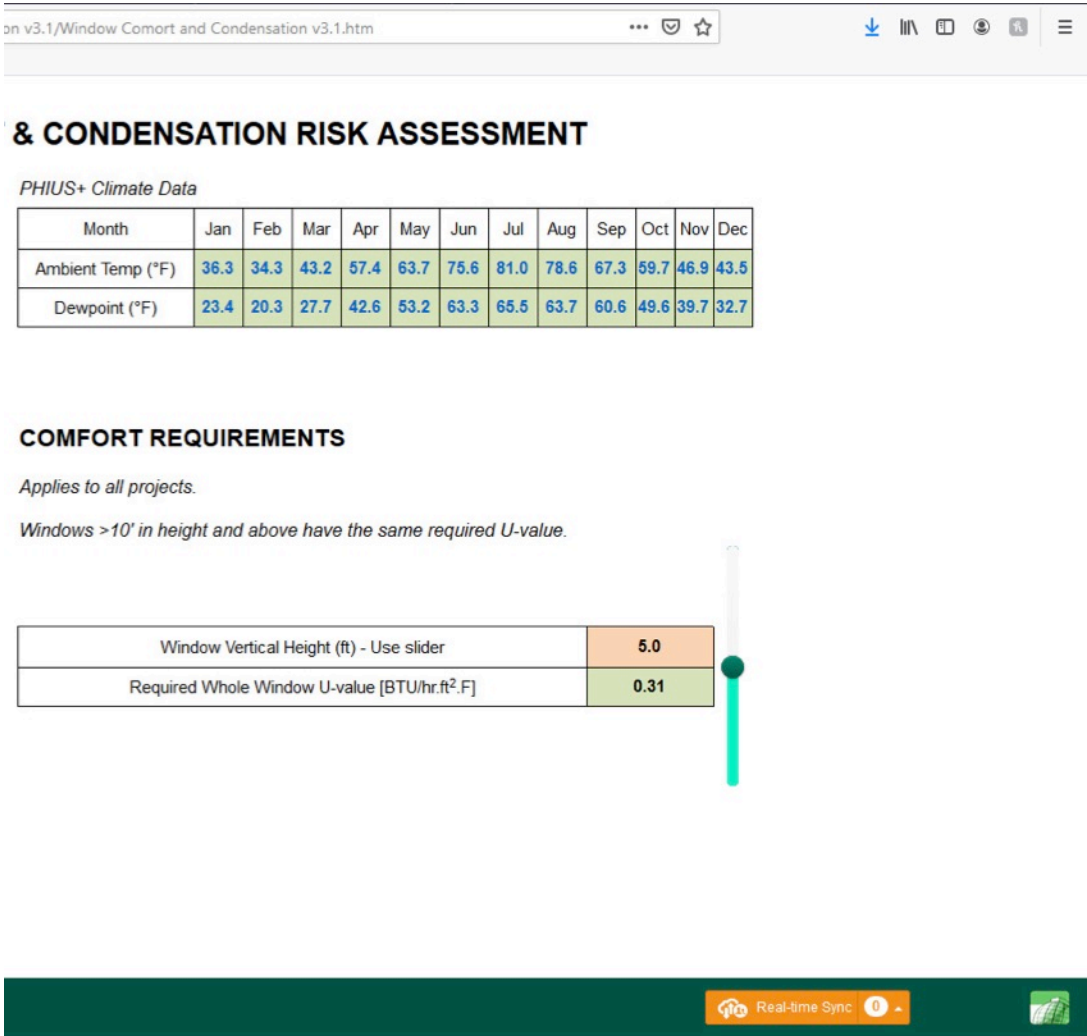
Comfort Assessment: In general, the harder of the two requirements to meet. The assessment specifies the required whole-window U-value, U_w

Inputs ask for:

- ASHRAE 99% design temperature
- Window vertical height (ft) (to account for convection effects)

Outputs calculate:

- The max ΔT (between indoor air temp and interior glass surface temp) allowed to meet requirements, generally between 6˚F and 13.3 ˚F depending on window height
- Then provides the required window U-value (U_w) to pass max ΔT at ASHRAE 99% design temp

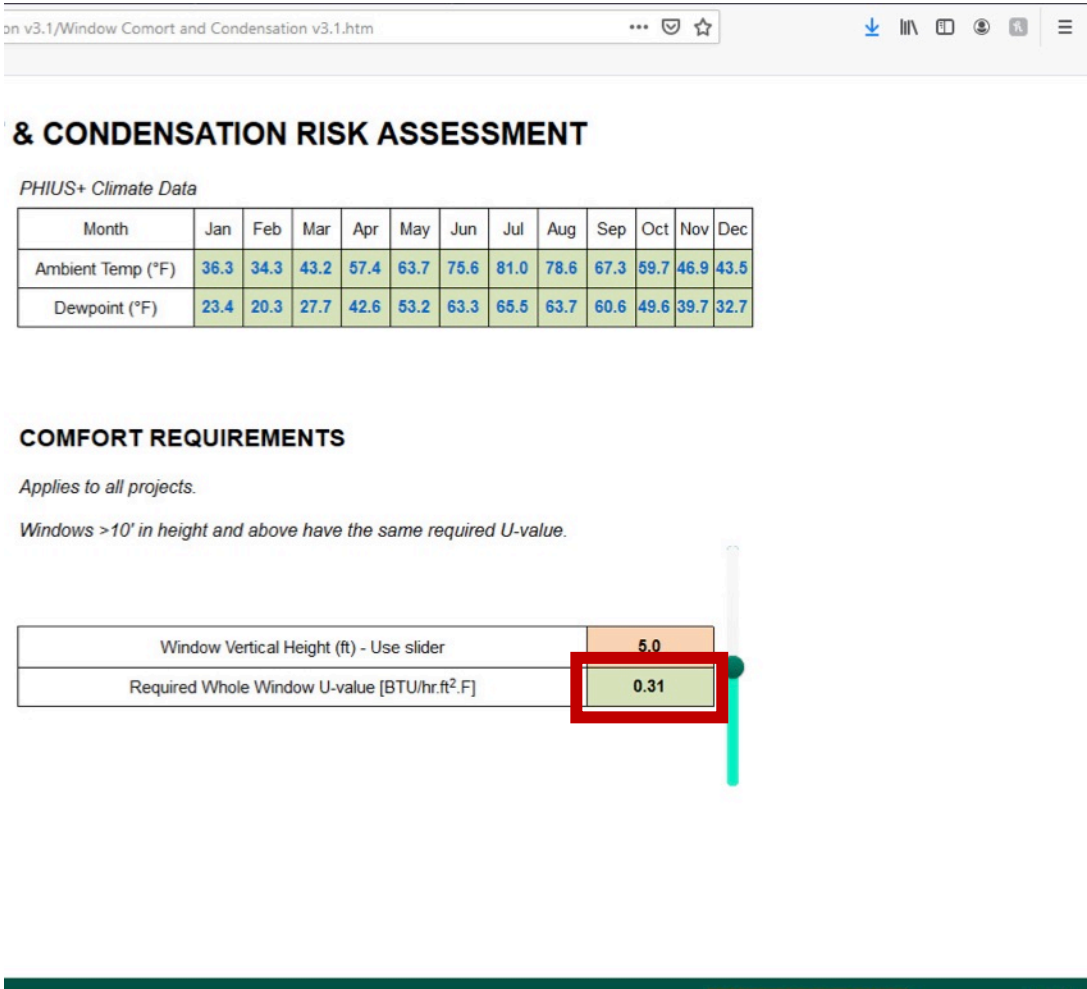


PHIUS window requirements

Comfort Assessment: In general, the harder of the two requirements to meet. The assessment specifies the required whole-window U-value, U_w

Required whole-window U-value to meet comfort requirement is U-0.31 for Washington, D.C.

(for a 5 foot high window)



Thin Triple Fit with PHIUS Requirements

What range of performance is possible for thin-triples given current window frame and spacer technology?

	Window Product	U-frame	U-cog (center of glass)	Uw (whole window) [1]	Uw (installed)[2]
Upper Range	Tilt/Turn w thin Quad IGU IGU = 1 3/8 in. thick (Ex: Alpen Tyrol window)	0.143	0.078 - 0.085	0.107 - 0.113	0.120
Middle	Casement w thin Triple IGU IGU = 7/8 in. thick (Ex: Alpen 725 Series)	0.15	0.106	0.125	0.138
Lower Range	Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.13	0.19 - 0.20	0.223

1) Includes psi-spacer: Ψ-0.0117 for Alpen Tyrol and 725 Series, Ψ-0.034 industry standard
2) Includes psi-install: Ψ-0.0145 for all windows
3) PHIUS climate zone recommendations are based on installed window U-value and SHGC

Thin Triple Fit with PHIUS Requirements

What range of performance is possible for thin-triples given current window frame and spacer technology?

How does this match up to PHIUS climate zone recommendations?

	Window Product	**U-frame**	**U-cog (center of glass)**	**Uw (whole window) [1]**	**Uw (installed)[2]**	**PHIUS Climate Zone Recommendation [3]**
Upper Range	Tilt/Turn w thin Quad IGU IGU = 1 3/8 in. thick (Ex: Alpen Tyrol window)	0.143	0.078 - 0.085	0.107 - 0.113	0.120	Climate Zone 7
Middle	Casement w thin Triple IGU IGU = 7/8 in. thick (Ex: Alpen 725 Series)	0.15	0.106	0.125	0.138	Climate Zone 4-5
Lower Range	Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.13	0.19 - 0.20	0.223	Climate Zone 3 Marine South only (i.e. southern CA)

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2) Includes psi-install: Ψ-0.0145 for all windows
3) PHIUS climate zone recommendations are based on installed window U-value and SHGC

But these are recommendations only. Windows in the lower range of performance could still be used in colder climates provided the building meets energy requirements and the windows meet condensation and comfort requirements.

Thin Triple Fit with PHIUS Requirements

How does this range of performance align with PHIUS condensation requirements?

	Condensation risk[4]	
	Washington, D.C.	Minneapolis, MN
PHIUS+ 2018 maximum U-value	0.48	0.39
Tilt/Turn w thin Quad IGU IGU = 1 3/8 in. thick (Ex: Alpen Tyrol window)	0.143	0.143
Casement w thin Triple IGU IGU = 7/8 in. thick (Ex: Alpen 725 Series)	0.15	0.15
Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.40
	--evaluated for frame U-value--	

Color coding: Green – meets requirements, Yellow – possibly meets requirements, Red – does not meet requirements

Thin Triple Fit with PHIUS Requirements

How does this range of performance align with PHIUS condensation requirements?

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Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.40
	--evaluated for frame U-value--	

In general, even a standard industry frame (R-2.5) can pass condensation requirements in cold climates like Minneapolis.

As long as the glass is a thin triple IGU, such windows could be used throughout most of the country in multifamily buildings or other building types where enclosure performance is less critical for the energy balance.

Color coding: Green – meets requirements, Yellow – possibly meets requirements, Red – does not meet requirements

Thin Triple Fit with PHIUS Requirements

How does this range of performance align with PHIUS comfort requirements?

	Condensation risk[4]		**Comfort Requirement[5]**			
	Washington, D.C.	Minneapolis, MN	Washington, D.C. (5' high)	Washington, D.C. (10' high)	Minneapolis, MN (5' high)	Minneapolis, MN (10' high)
PHIUS+ 2018 maximum U-value	0.48	0.39	0.31	0.21	0.20	0.13
Tilt/Turn w thin Quad IGU IGU = 1 3/8 in. thick (Ex: Alpen Tyrol window)	0.143	0.143	0.113	0.113	0.113	0.113
Casement w thin Triple IGU IGU = 7/8 in. thick (Ex: Alpen 725 Series)	0.15	0.15	0.125	0.125	0.125	0.125
Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.40	0.20	0.20	0.20	0.20
	--evaluated for frame U-value--		---------- evaluated for whole-window U-value ----------			

Thin Triple Fit with PHIUS Requirements

How does this range of performance align with PHIUS comfort requirements?

	Condensation risk[4]		Comfort Requirement[5]			
	Washington, D.C.	Minneapolis, MN	Washington, D.C. (5' high)	Washington, D.C. (10' high)	Minneapolis, MN (5' high)	Minneapolis, MN (10' high)
PHIUS+ 2018 maximum U-value	0.48	0.39	0.31	0.21	0.20	0.13
Tilt/Turn w thin Quad IGU IGU = 1 3/8 in. thick (Ex: Alpen Tyrol window)	0.143	0.143	0.113	0.113	0.113	0.113
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Industry standard frame w thin triple IGU = 3/4 in. thick	0.40	0.40	0.20	0.20	0.20	0.20
	--evaluated for frame U-value--		---------- evaluated for whole-window U-value ----------			

Comfort requirements are more challenging, but even an industry standard frame with a thin triple IGU could be used throughout the country in buildings where the enclosure is less critical for the energy balance. Window heights might be restricted.

Collaborate with Us

- Your Market Views/Feedback
  - Are adequate low U products available?
  - At Reasonable cost? Delivery times ?
  - What size, operator types are you looking for?

- What added information/data/tools on window performance do you need?

- Do you have projects suitable for use as potential test houses?

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