Bringing Window Innovations To Market: Doubling the Insulating Value of U.S. Windows

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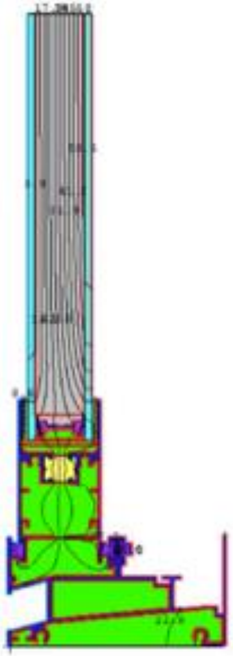
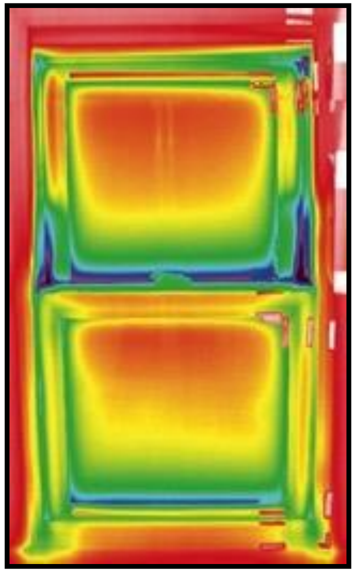
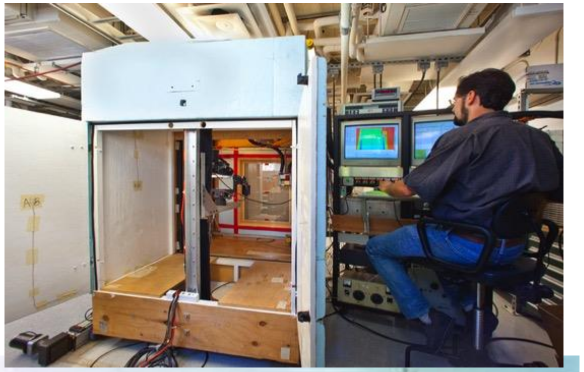
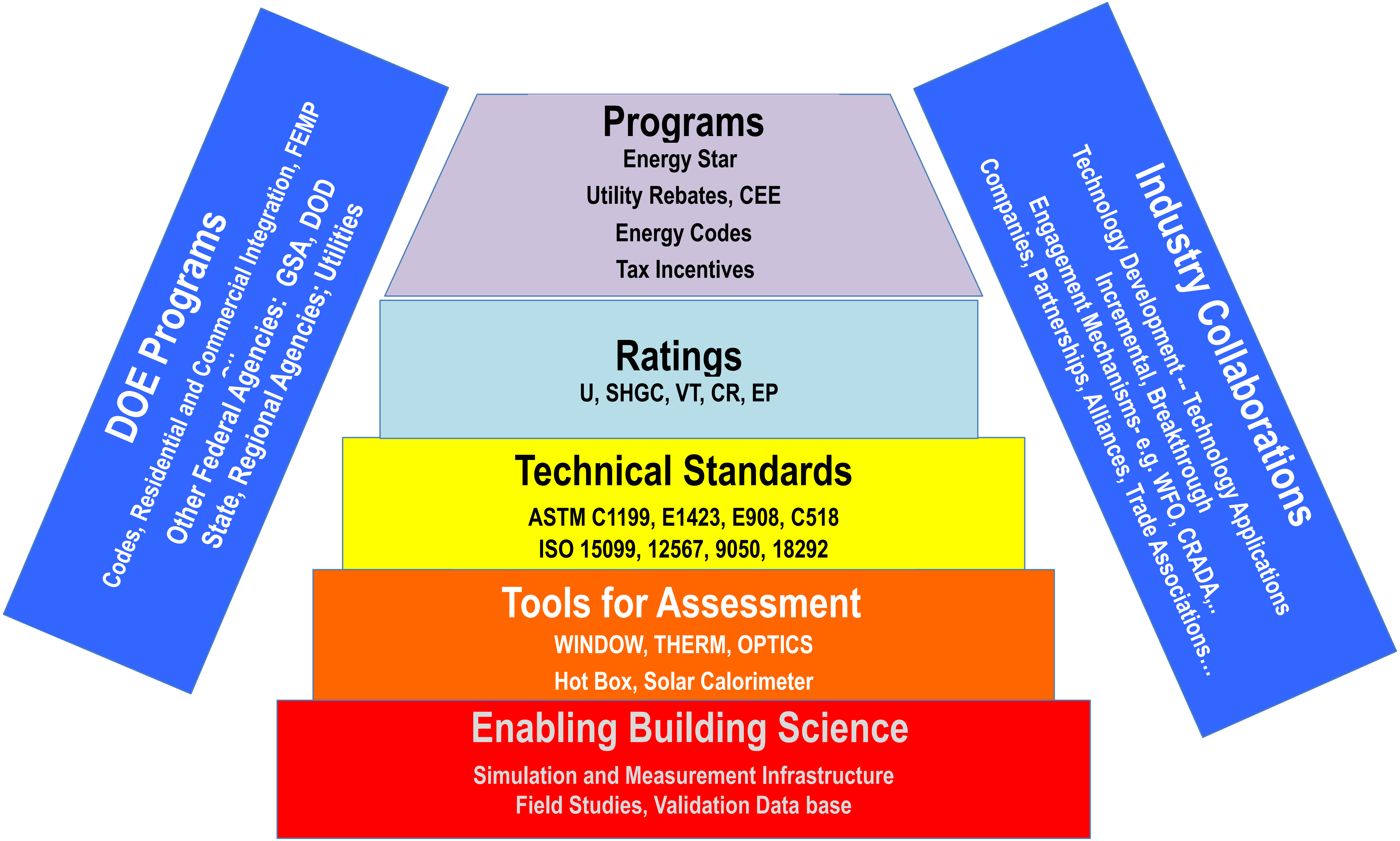






A Platform For Window Innovation



Summary

- Window Energy Overview
- Heat Loss from Windows: $20B/year cost
  - Low-E Market Saturation, Success, but Stalled at R3
  - R6+ Windows -> Net Zero envelope, 2Q Savings
- Create Industry “Alliance” to Advance Near Term, Cost Effective, Scalable Solutions
  - “R8 Thin Glass/IGU” Innovation Platform
  - LBNL has established technical viability
  - 3 year, Public/Private Partnership
- Window industry support across supply chain
- **ENERGYSTAR, Utility Role to Enhance Market Pull**

Energy/Cost Impacts

- Window Impacts
  - **10% of building Energy; 4% of total US Energy; $50B/yr**
  - Energy, Demand, Carbon Impacts
    - **HVAC Energy: ~ 4Q;   Electric Lighting Energy: ~ 1Q**
    - Summer cooling peak, load shape, grid impacts
    - Winter Peak heating impact for electric heating
  - **Occupant: Comfort, View, Daylight, etc**
  - **Owner: Views etc- property values**
- Traditional DOE/EPA/Utility Goals: Reduce Energy Impacts
  - ET Focus-> Technology development goals
  - **Transform Markets to drive impact**
- **Supports Longer Term 2030 Goals**
  - **"Net Zero" Buildings → Net Zero Envelope**

Getting to “Net Zero” Windows

Annual Heating Cost simulated for a heating climate

Single Glazed w/Storm, **$1310**

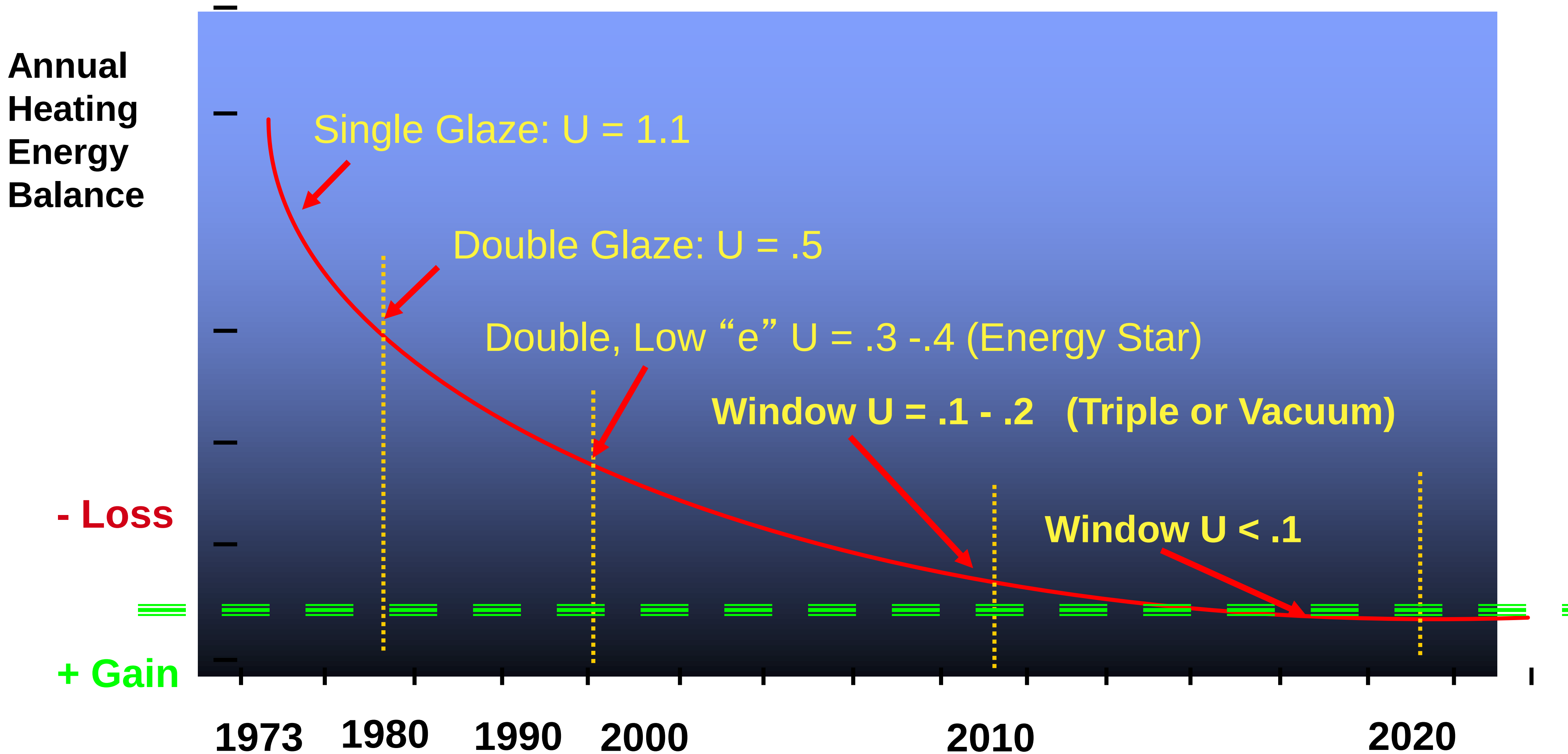
Double Glazed, **$1218**

Double w/Low-E, **$1120**

House with no windows, **$1000**

“SuperWindow”, **$960**

Highly Insulating Windows Can Become Energy Producers in Cold Climates

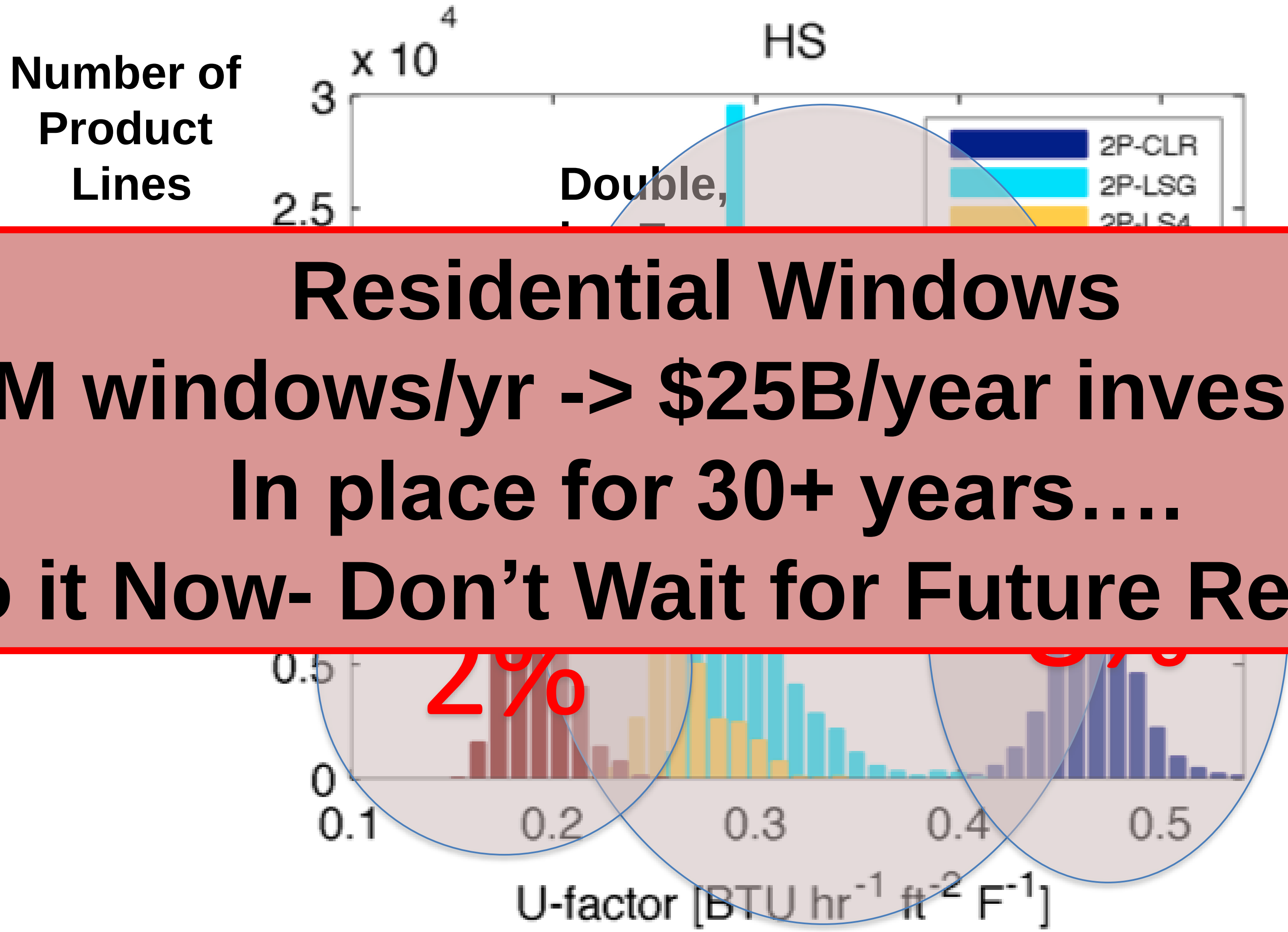


Window Energy Snapshot

- **Good news**:
  - With DOE support, industry transformed markets from single(R1) -> double (R2) -> double, low-E, argon (R4)
  - 90%+ sales of all window are low-E
  - NAHB study: Low-E window most cited Green feature
- **Bad news: little market movement since 1990**
  - Biggest Energy Opportunity- highly insulating glazing for heating dominated climates (~ 1- 2Q at stake)
  - Market “Saturated” at double, low E: 96% Market Share
  - Triple glazing: only 1.7% market share, **unlikely to rise**
    - **too heavy, too wide => too costly to redesign windows**

Market Snapshot
Performance distribution of NFRC-Rated Windows

Source: EPA ENERGYSTAR analysis, Horiz. sliding windows



Residential Windows
60M windows/yr -> $25B/year investment
In place for 30+ years….
Do it Now- Don't Wait for Future Retrofit!

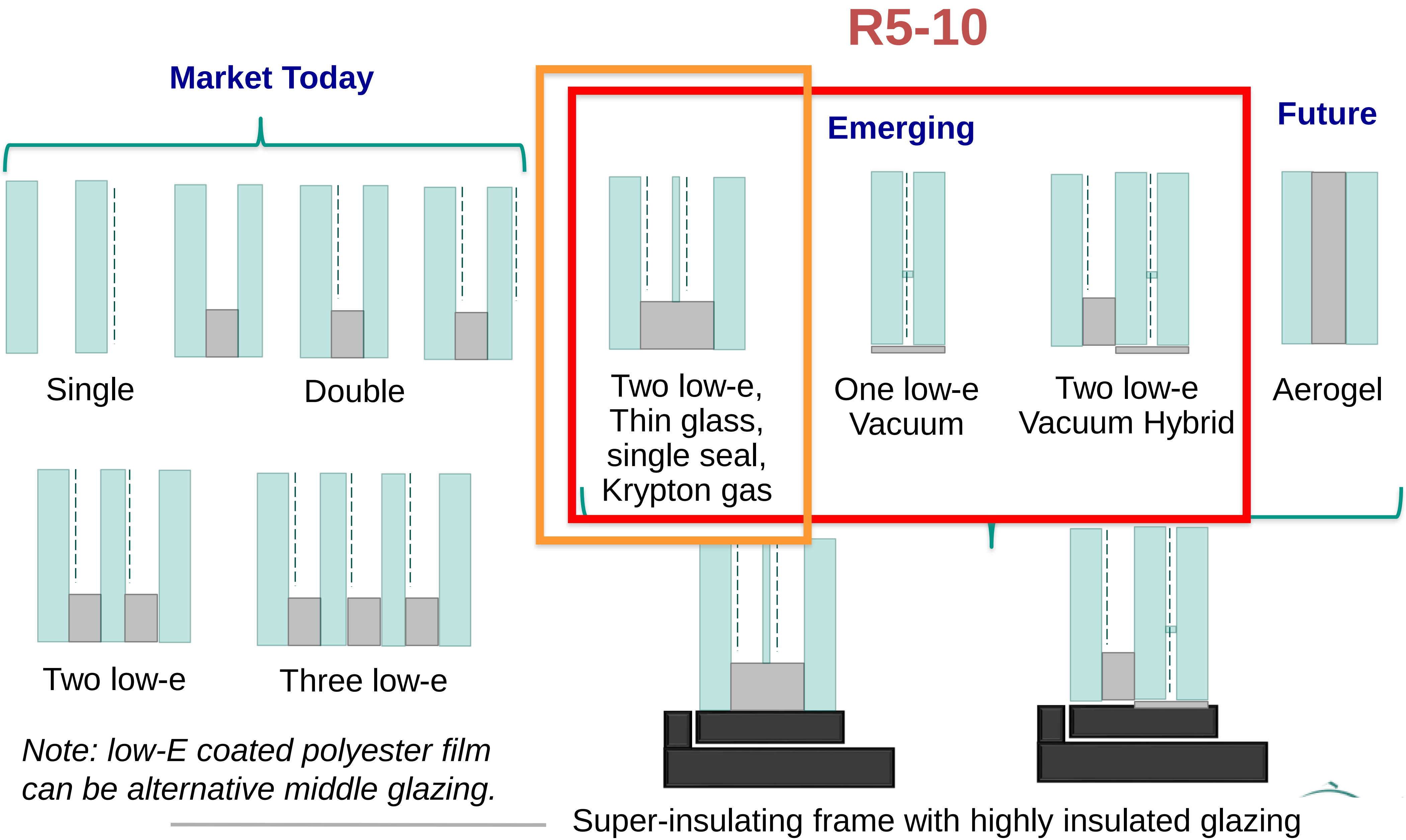
Success of Low-E, Double Glazing: R2 -> R4

- **3 stage "adoption" process to increase market share**
  - Introduction -> ~20% market share: **Innovation push**
  - 20% -> 60% **NFRC Ratings, Energy Star market pull**
  - 60% -> 95%: **Codes and Standards**
- **"Criteria" for Initial rapid adoption: double-> low-E**
  - Leading wood window manufacturers are early adopters
  - Low-E/argon glass package is affordable
  - "Drop-in glass replacement"- no costly redesign of window needed to accommodate the low-E IGU
- **Can We Repeat It?**
- **Biggest Opportunity for National Energy Savings is Reducing Heat Loss from Windows**

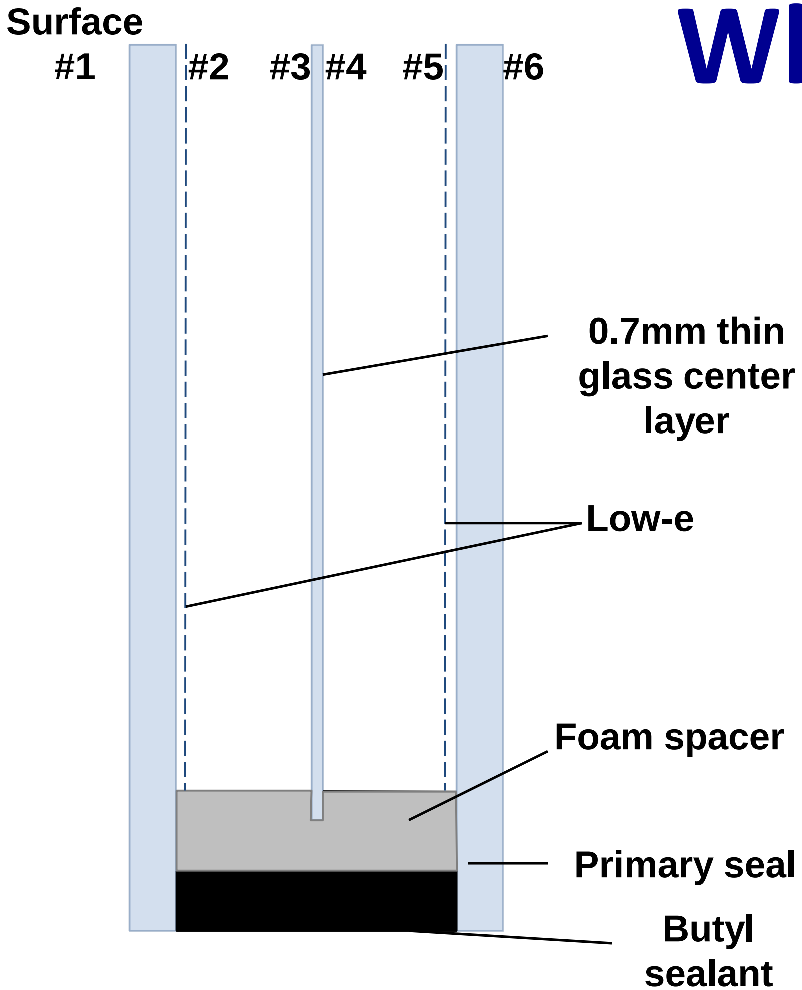
Hi-R Glazing Options

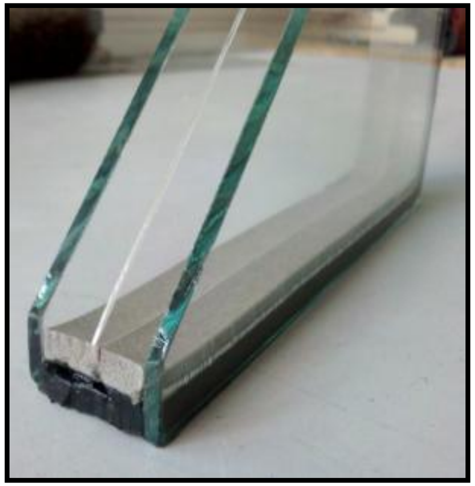
- **Existing Triple Glazing** (w. gas and low-E)
  - Technology elements available (e.g. European triples)
  - Too heavy/too wide -> costly redesign of whole window
- **"New Technology"**
  - **Vacuum glazing**: cost, lifetime, durability, manufacturing capacity all unknowns
  - **Aerogel**- after 30 years still R&D: cost, haze, durability
- **"Thin, Lightweight Triple" w/ low-E and gas fills**
  - **Innovative but affordable, available tech options**
  - **Solvable manufacturing challenges**
  - **Need push/pull strategy and partners**

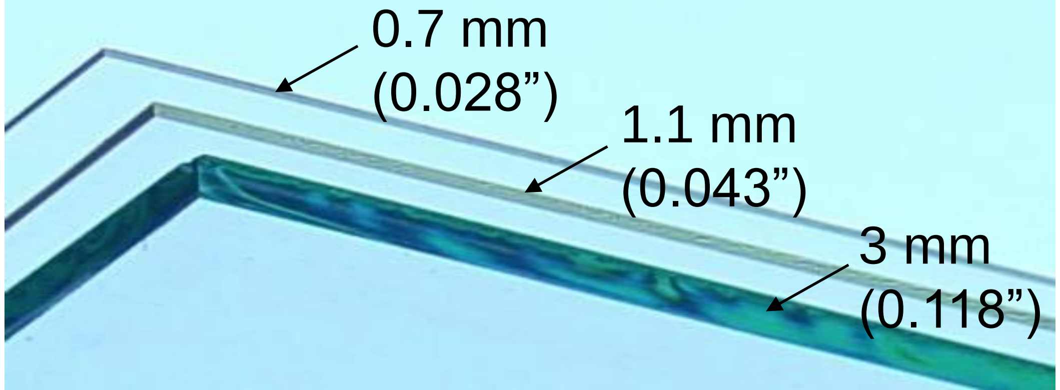
U.S. INSULATING GLAZING Landscape Today:



Why "Thin Glass Triple"?





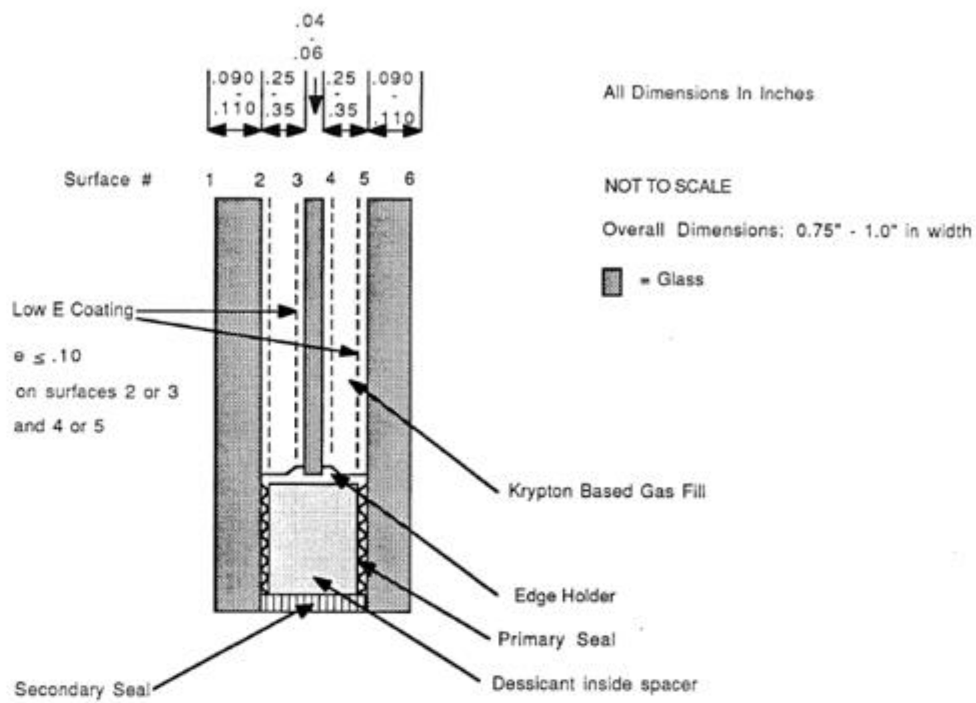


- Platform: R5-R10
- Thin float glass
  - .3, .5, .7, 1.1 mm
- Affordable
- Multiple suppliers
- Low-E coatings
- Krypton gas fill
- Non-structural
  - 2 seals
- Infrastructure exists

Not a New Concept; Thin Glass, Thin Triple Concept Developed "Before its Time"

1991 Design Patent - >

1989 ASME paper



United States Statutory Invention Registration [19]

Selkowitz et al.

[11] **Reg. Number:** **H975**

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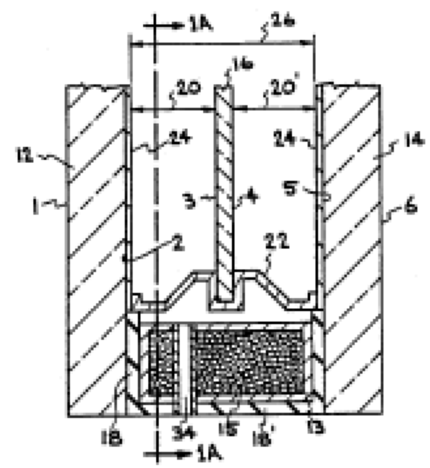
Primary Examiner—Michael J. Carone
Attorney, Agent, or Firm—B. J. Weis; L. E. Carnahan; William R. Moser

[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.

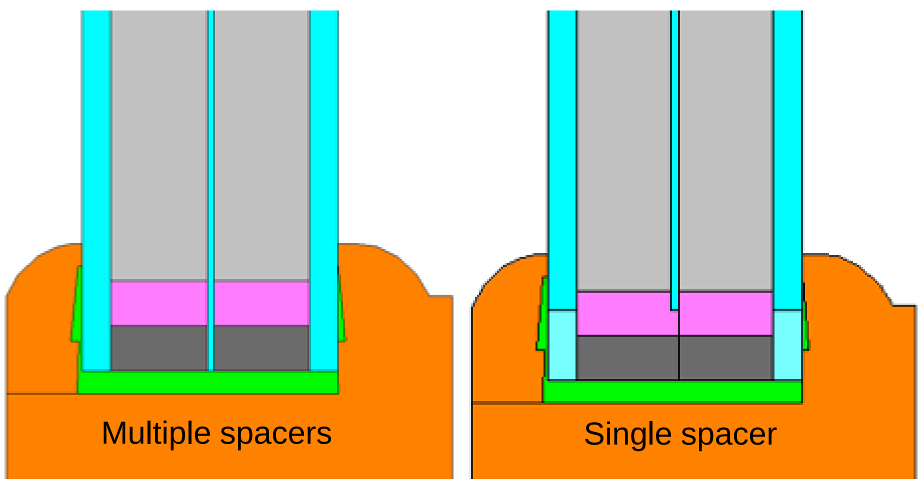
21 Claims, 2 Drawing Sheets

A statutory invention registration is not a patent. It has the defensive attributes of a patent but does not have the enforceable attributes of a patent. No article or advertisement or the like may use the term patent, or any term suggestive of a patent, when referring to a statutory invention registration. For more specific information on the rights associated with a statutory invention registration see 35 U.S.C. 157.

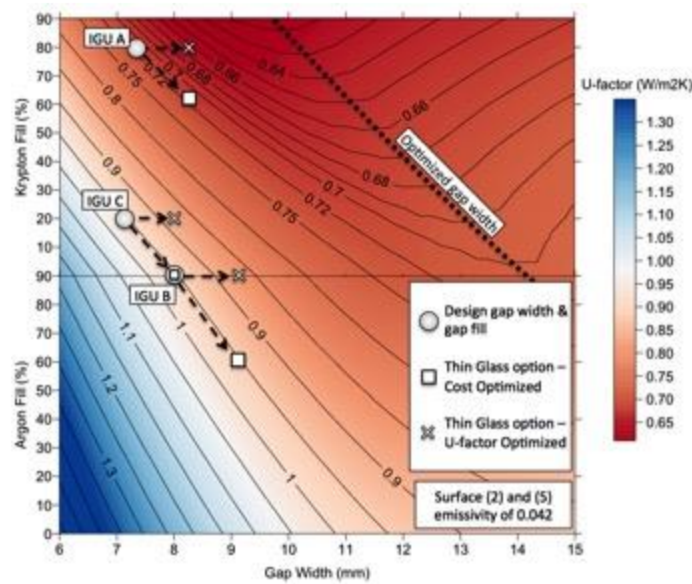


Key Technical, Market Features

- Light Weight: **Thin glass** can be .5-.9 mm vs 3mm
- Single spacer: two leakage paths, not 4
- Glass is Durable: Polymer films have lifetime issues
- **Kr Gas** achieves high R with Thin gap- same IGU dimensions as Double
- **Premature in 1990 -> 2015**
  - **Thin glass and Kr are now market ready and cheaper**



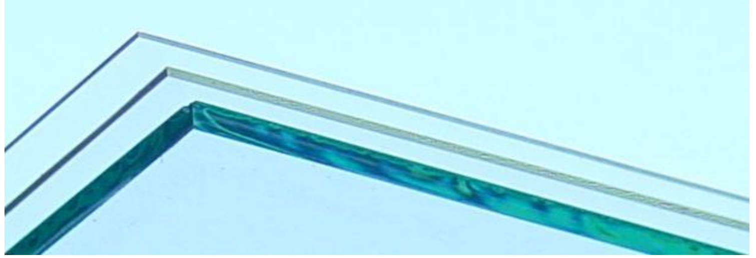
Single spacer



U-factor contour plot of optimization options

Why Will It Work Now? => $$$

- **Thin Glass**:
  - Four years ago: Corning offered glass at $5.00/sf
  - Today: Major float glass suppliers ~ $0.60/sf due to huge demand for large flat screen TVs



- **Krypton Gas**
  - Four years ago: variable demand from other sources kept prices high and volatile; Gas fill process wasted 50% -> Net cost > $2.50/sf
  - Today: Xenon requirements make Kr available; traditional Kr use for halogen lamps has been reduced; suppliers will now sign long term contracts at ~$0.50/ sf
  - New high rate gas fill w/ 10% loss
- **Market Demand:**
  - **Energy Star V7- Potential New Market Pull**
  - **Utility Programs**

IT WORKS!: LBNL Built and Tested Options Validating the Optimization Studies

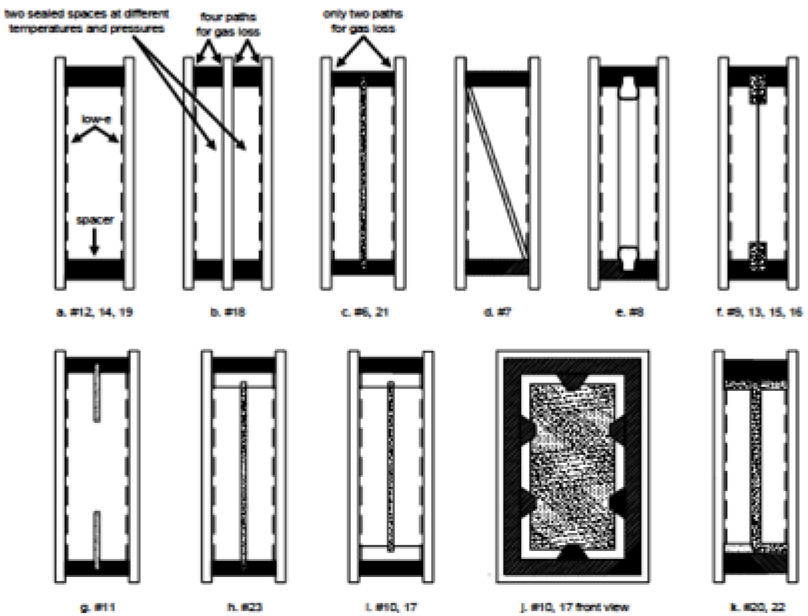


Figure 1(a-k) – Cross-sectional geometry of the prototype insulated glazing units tested. Drawings are not to scale. Refer to Table 1 for dimensions. Specimens 16 and 19 have one low-e despite the

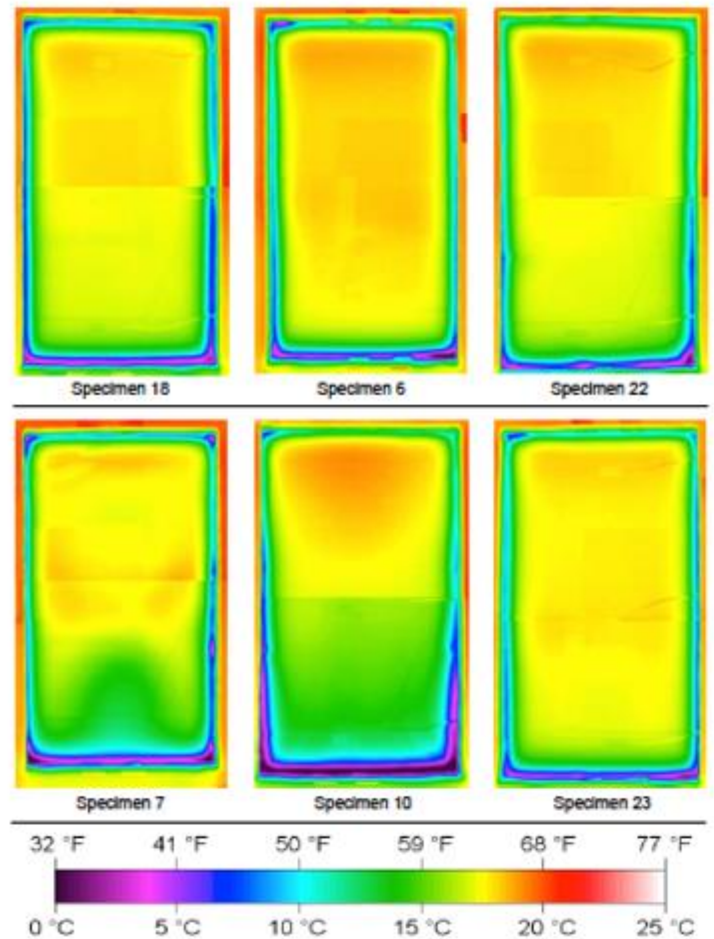
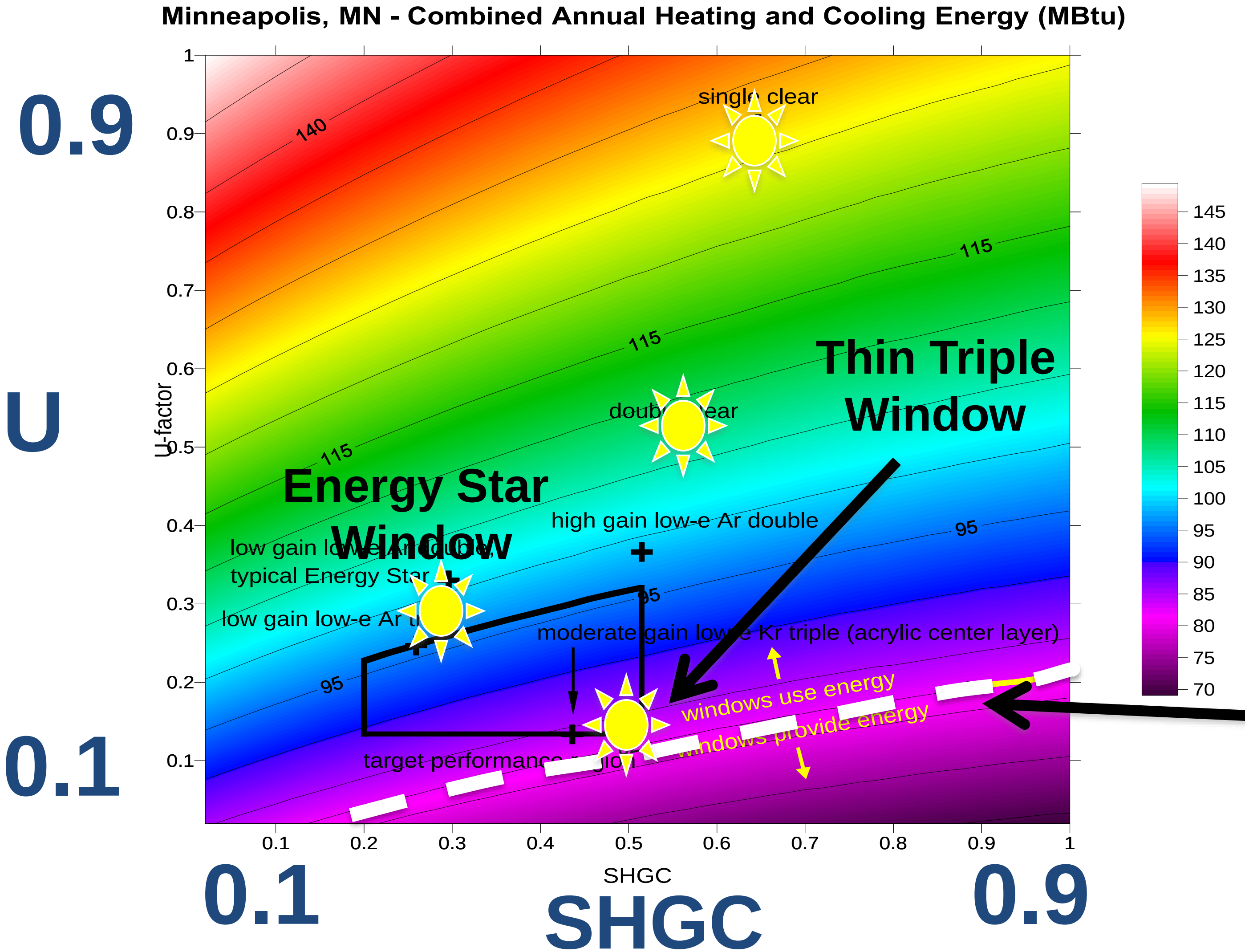


Figure 3 – Examples of false color plots showing warm side surface temperature maps from infrared thermography (not accurate in black and white)

Net Zero Windows Are Feasible in Cold Climates:

Minn: Annual energy use vs. window properties



Residential Energy Use (MBTU/yr) vs Window Thermal Properties (U, SHGC)

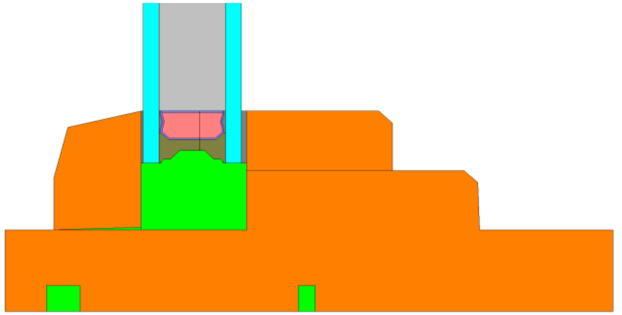
Specific windows plotted on map of iso-energy use

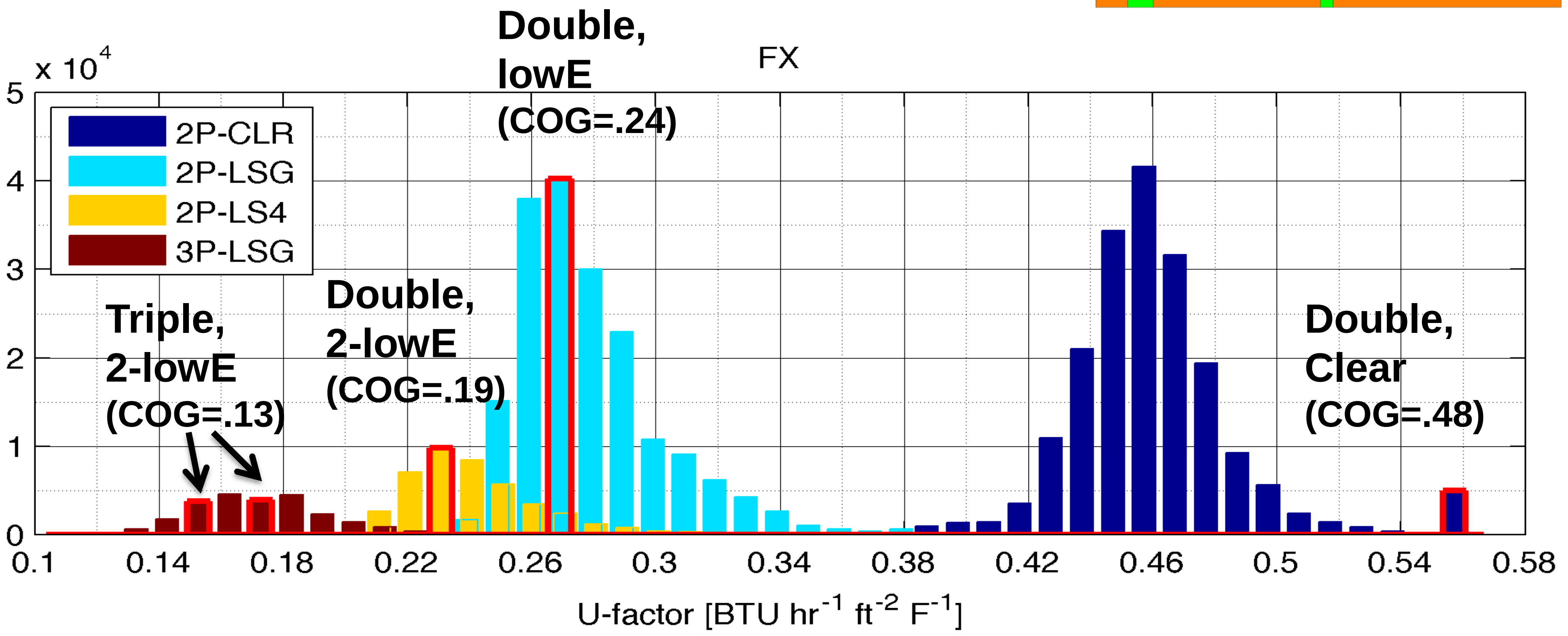
House with no windows uses 82MBTU

~20% savings vs E*

Typical Window U (and Center-of-glass, COG U)

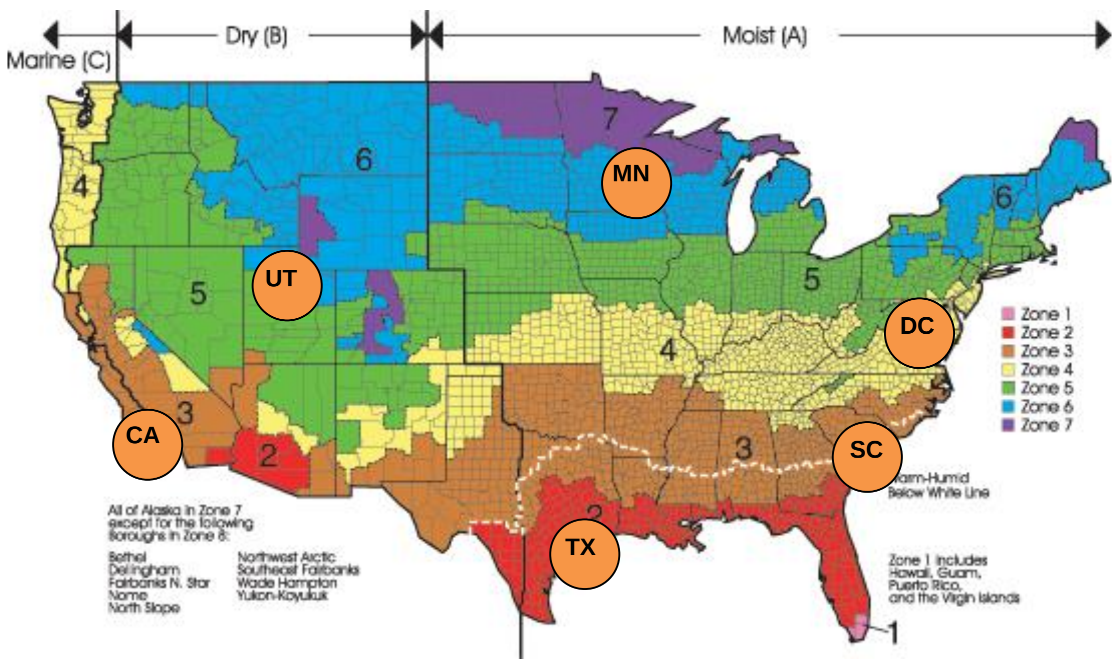
Typical wood frame (clear window is Aluminum)
Stainless steel warm-edge spacer
Low-E to meet IECC 2012 climate zones <=3





Annual Energy Model Locations

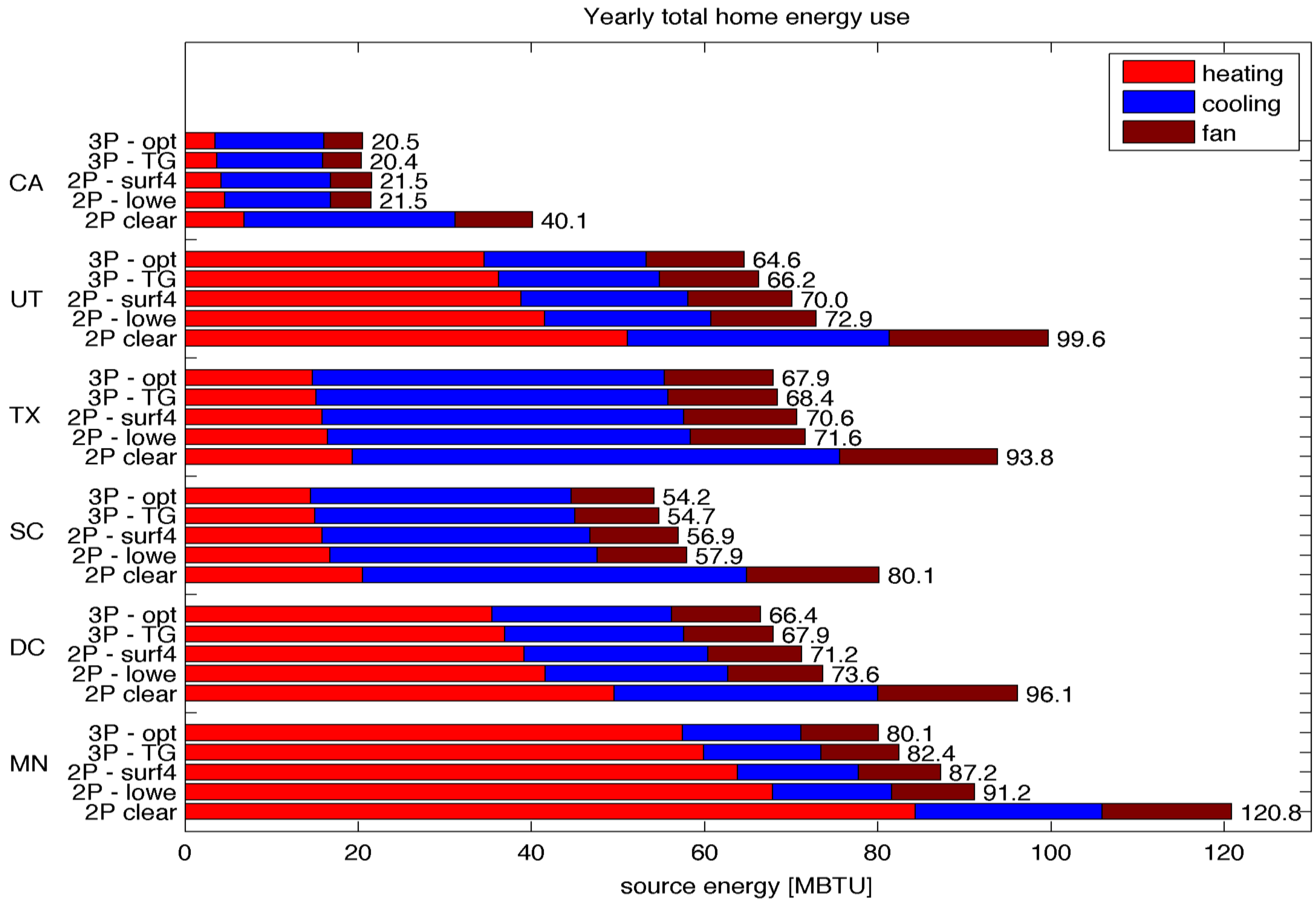
State	City	Climate Zone	Window Requirements			
			IECC 2012 & 2015 [1]Title 24		IECC 2009	
			U-factor	SHGC	U-factor	SHGC
MN	Minneapolis	6	0.32	NR	0.35	NR
DC	Washington	4	0.35	NR	0.35	NR
SC	Charleston	3	0.35	0.25	0.5	0.3
TX	Houston	2	0.4	0.25	0.65	0.3
UT	Salt Lake City	5	0.32	NR	0.35	NR
CA	Los Angeles	3	0.32[1]	0.25	0.5	0.3



Annual Source Energy Use

5 Alternative Window Designs

End use multipliers: Elec=3.167,Gas=1.084

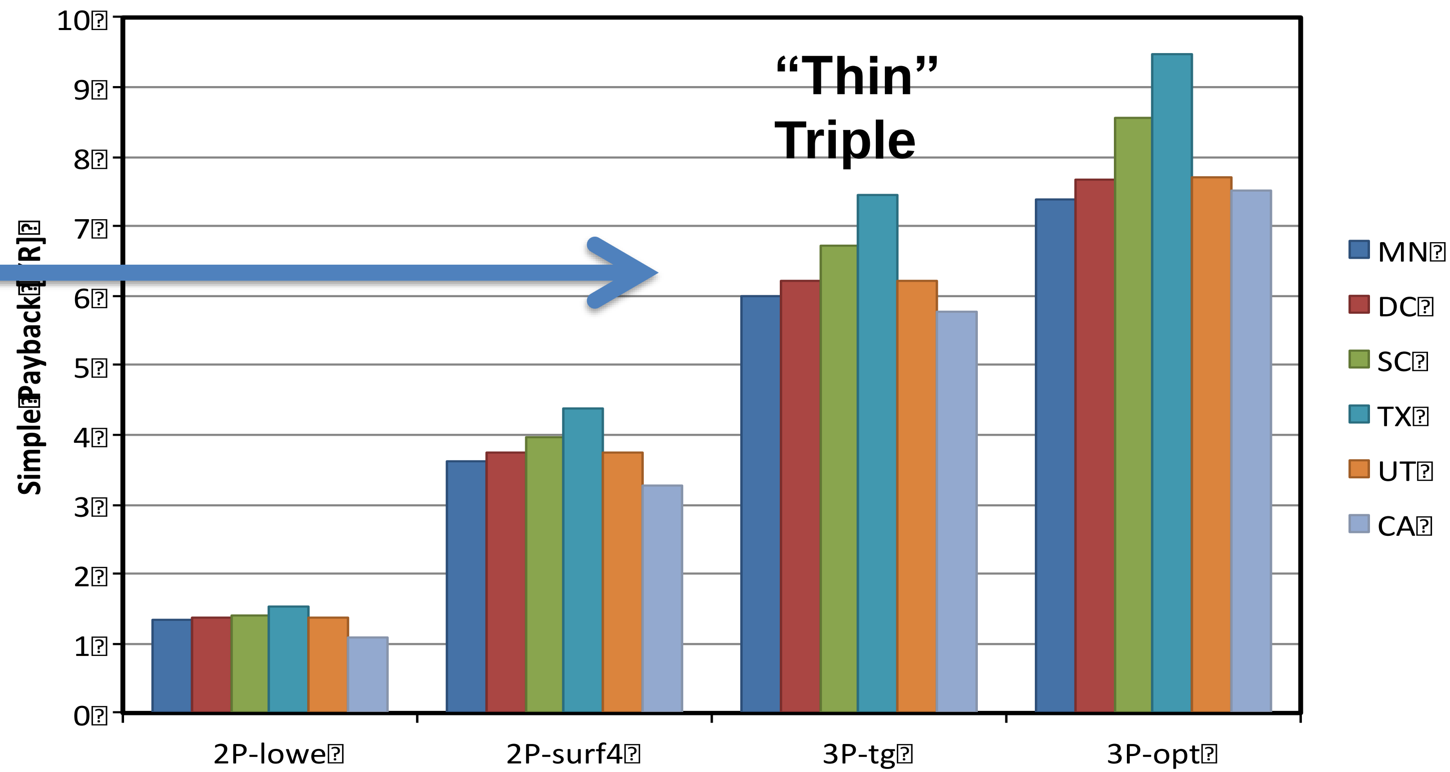


Energy Cost and Payback in 6 Climates: 5-7 years (Similar in All Climates (?))

Vs Existing Window; House w/357 SF window (15% of wall area)

					IGU cost per SF					Window savings per SF MN	
Window #	# Panes	Glass Type	Gas	IG width (in) DS glass	Glass	Gas	Assembly and Spacers	total	Incremental Markup (1.9x)	Energy cost savings	Simple Payback (YR)
1	2	clear	Air	0.74	$1.00	$0.00	$2.00	$3.00	$5.70		
2	2	low solar gain (#2)	Argon	0.74	$1.50	$0.01	$2.00	$3.51	$0.96	$0.72	1.3
3	2	low solar gain (#2) high solar gain (#4)	Argon	0.74	$2.50	$0.01	$2.00	$4.51	$2.86	$0.79	3.6
4	3 TG	low solar gain (#2, #5)	Krypton	0.74	$3.00	$0.31	$2.50	$5.81	$5.34	$0.89	6.0
5	3 opt	low solar gain (#2, #5)	Krypton	1.05	$2.50	$0.81	$3.33	$6.64	$6.92	$0.94	7.4

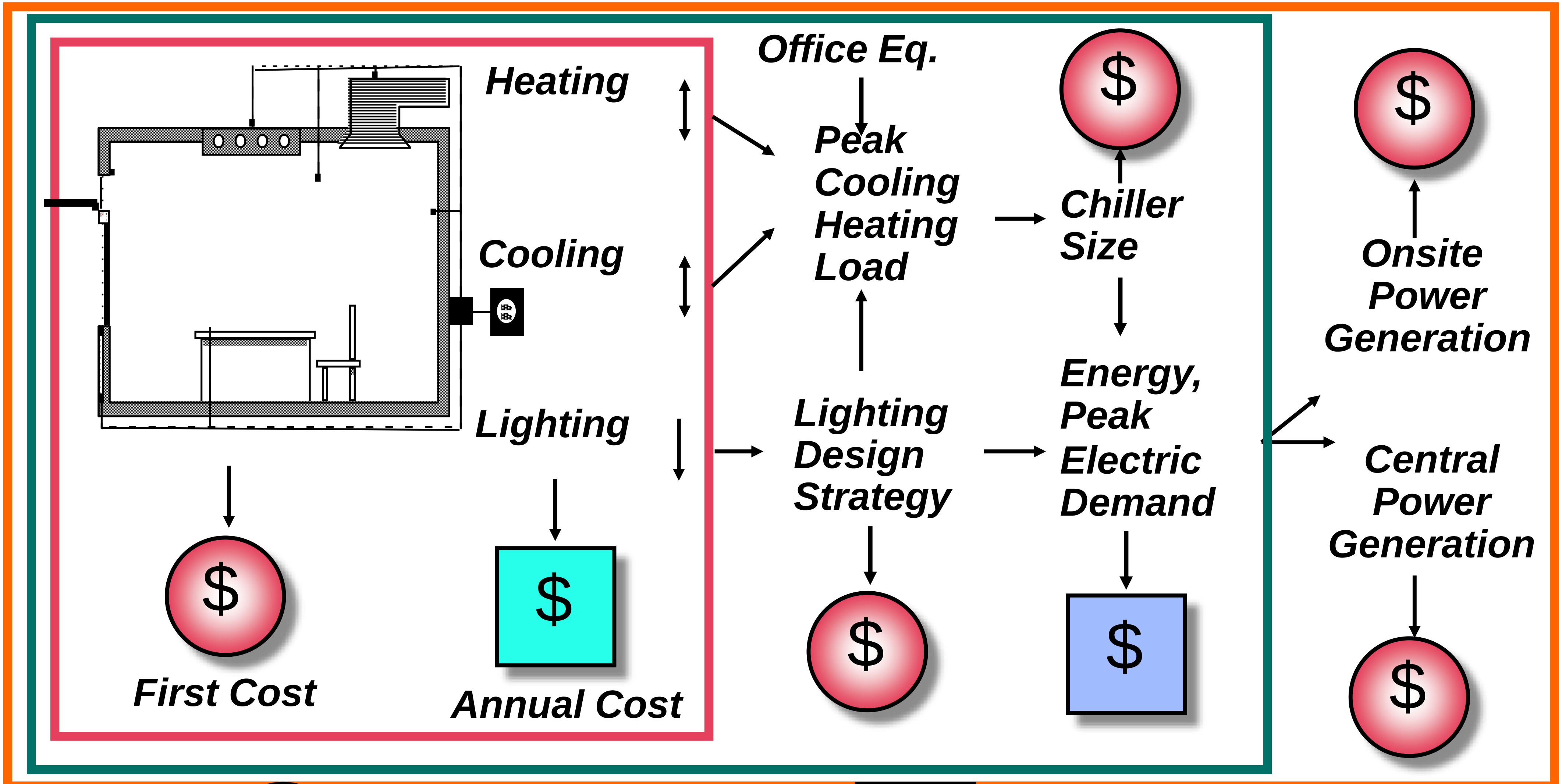
Payback 5-7 years



“Real World” Market Drivers

- **Owner:**
  - Comfort, Condensation
  - Resilience
- **Builder/Developer:**
  - Larger View Windows Meet Code
  - Downsize HVAC (= cost savings)
- **Utility**
  - Energy (new “service” offering?)
  - Peak heating and cooling
  - Resilience

Reliable System integration → First Cost tradeoffs
Improved Façade = Lower HVAC System Cost



$ = First Cost

$ = Annual Cost

Comfort Considerations

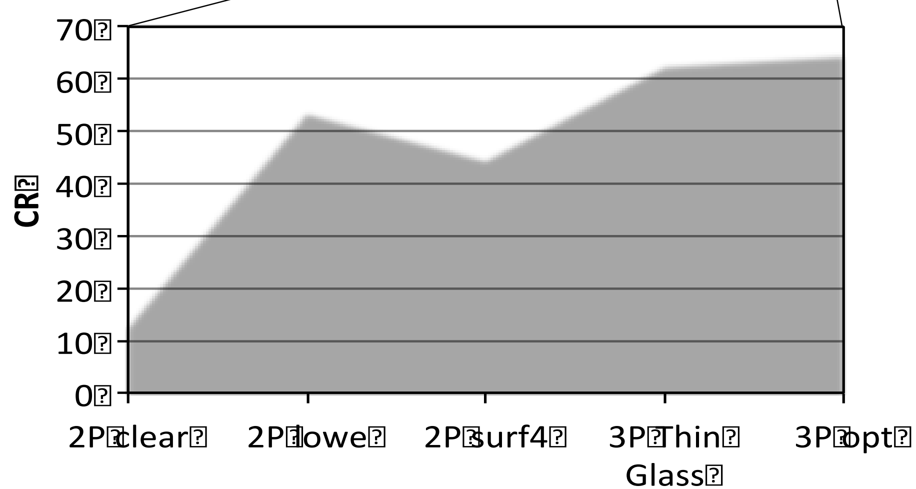
- Condensation Resistance

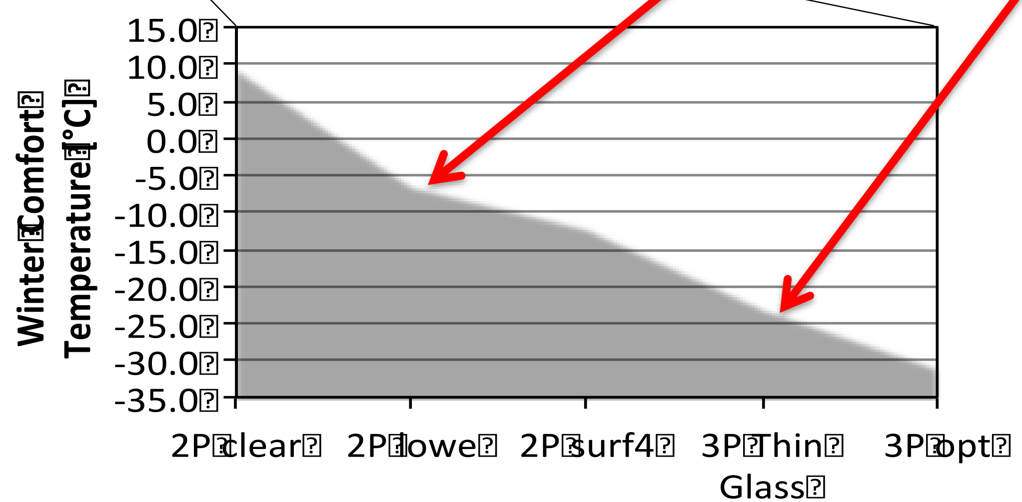
- Winter Outdoor Comfort Temperature

	Glazing Type	Condensation Resistance [CR]	Winter Comfort Temperature [°C]	Acoustic	Security
1	2P clear	13	9.7		
2	2P lowe	54	-6.1		3 panes
3	2P surf4	45	-11.8	?	>
4	3P Thin Glass	63	-22.6		2 Panes
5	3P opt	65	-30.6		

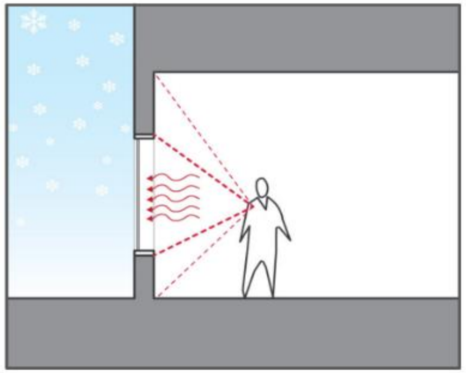
Double Low-E: -6C

Triple - 24C

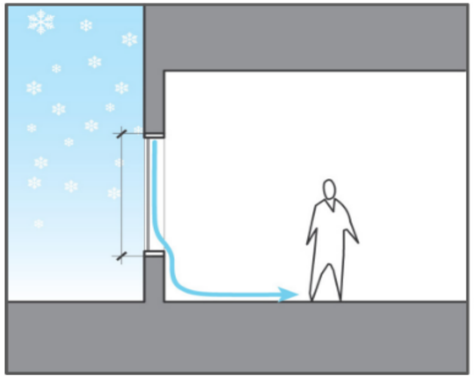




Commercial Buildings
Recapturing Perimeter Floor Space



Radiant Discomfort (Full-body Discomfort)

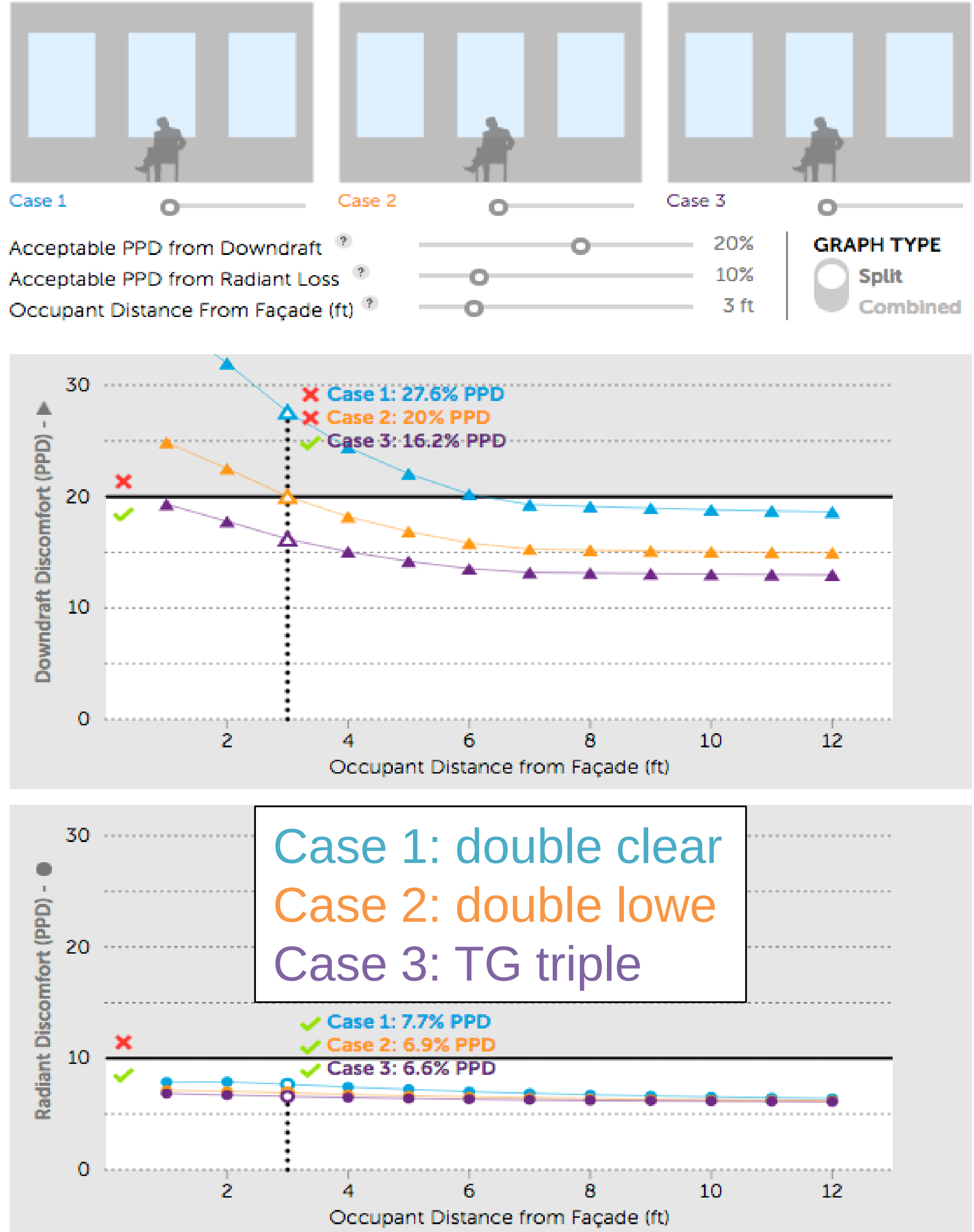


Draft Discomfort (Ankle Discomfort)

If this were well insulated

We wouldn't need this

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



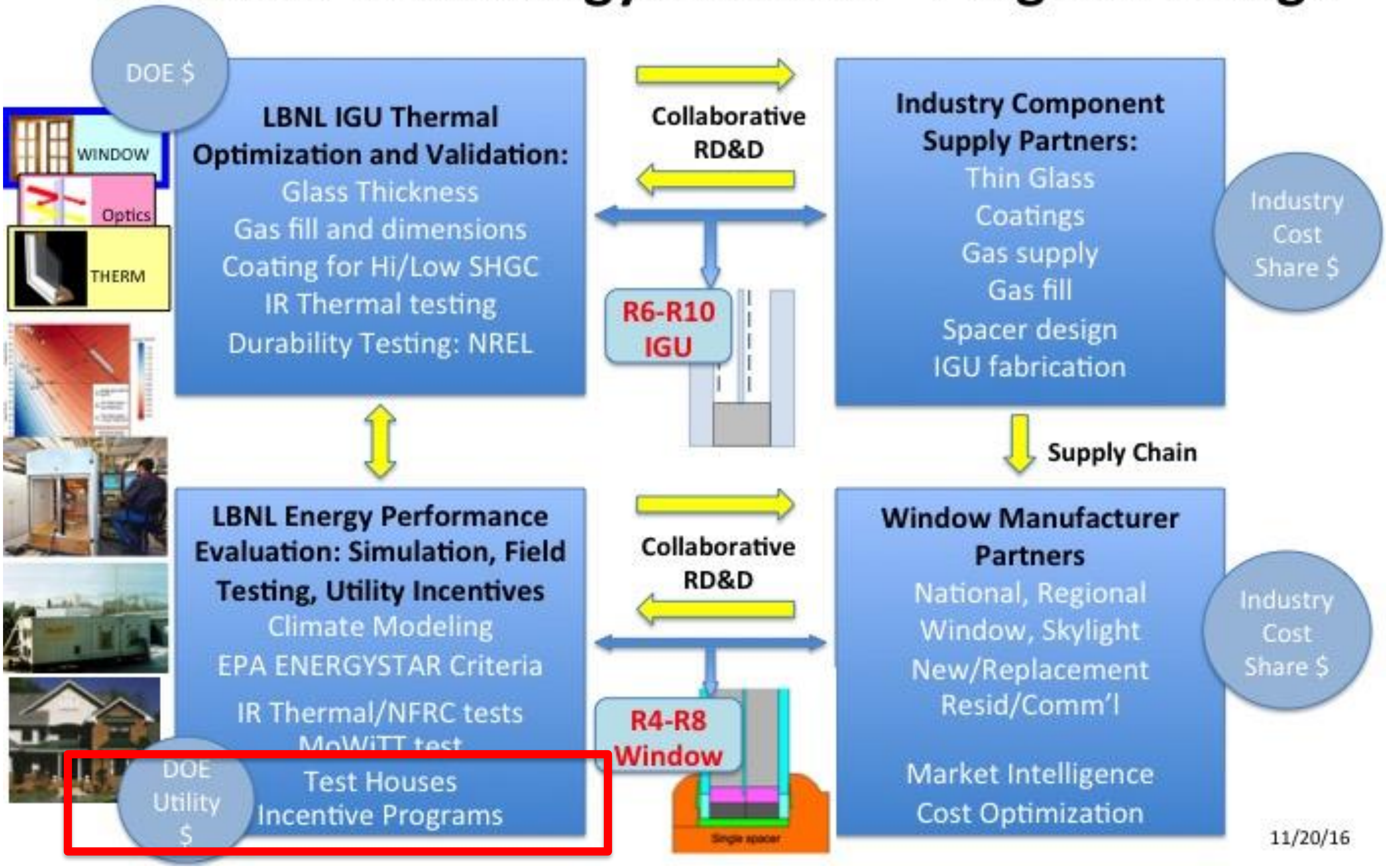
*Slide credit and cost numbers: Chris Mackey Payette Architects

Next Steps Forward

- **Propose an Enhanced "Industry Partnership" to:**
  - **Engage Broader Crossection of Window Industry**
  - **Biggest Concern: Market Demand!**
  - **Accelerate Process- ~2 years to initial market entry**
- **Supply Side**: Focus on manufacturing and cost issues
- **Demand Side**: Engage Window manufacturers with new Energy Star criteria to differentiate products, and **Utility Programs for Early Market Launch**

- Launch Coordinated **Technical** and **Business** Program

"Hi-R IGU Technology Platform" Program Design



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Utility Partner Roles

- Demonstration programs
- Local “Cost effectiveness” calculations
- Incentive Program Design
- Supply chain market impact: upstream, downstream
- Timing
- Load management- winter peak management
- Climate optimization- cooling impacts

CONTACT US!

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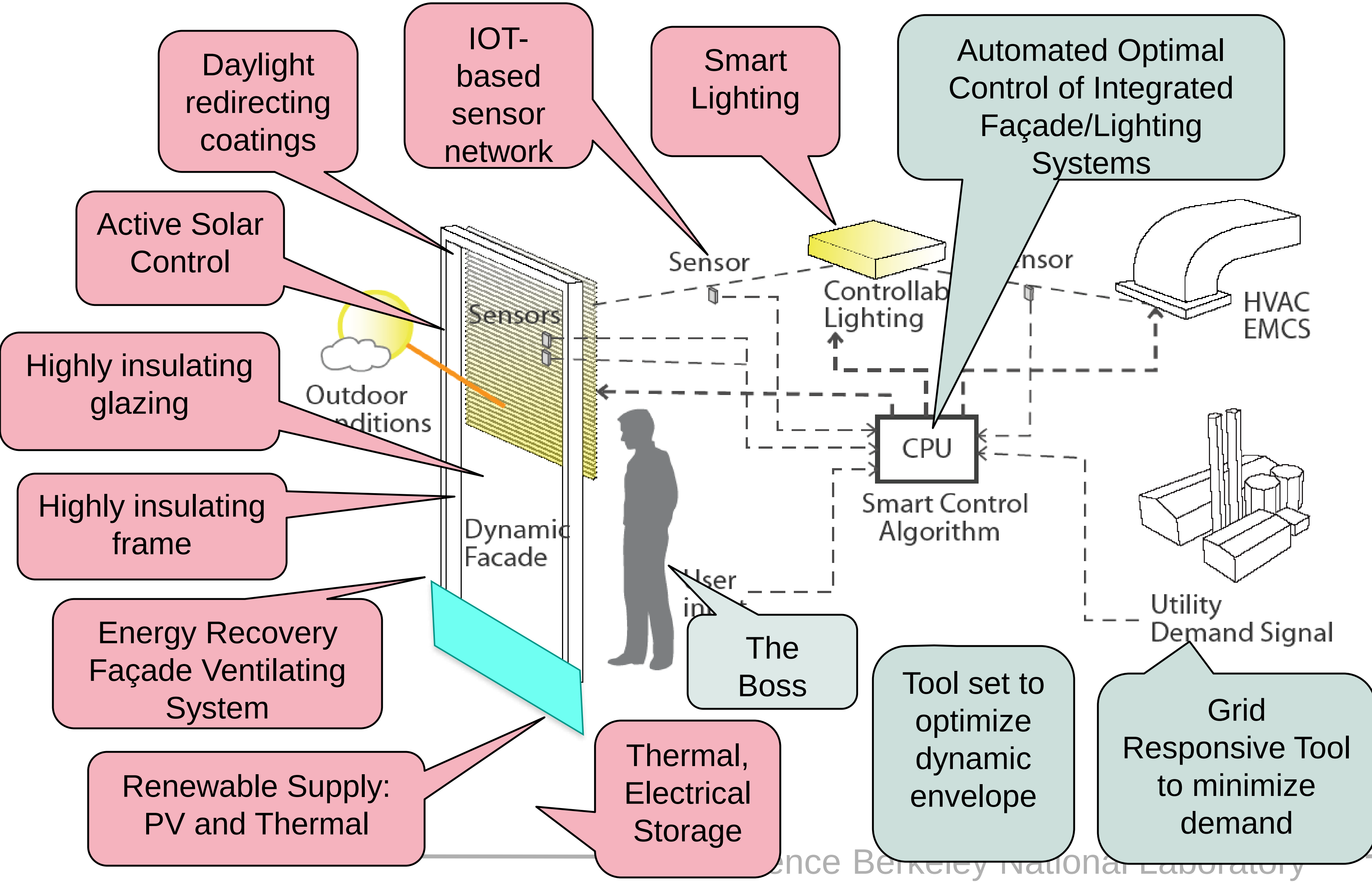
Framework for Facades as “integrated building systems” –

managing light, glare, solar gain, heat transfer, ventilation, power generation, energy storage,



Relative Cost and Complexity?

VS

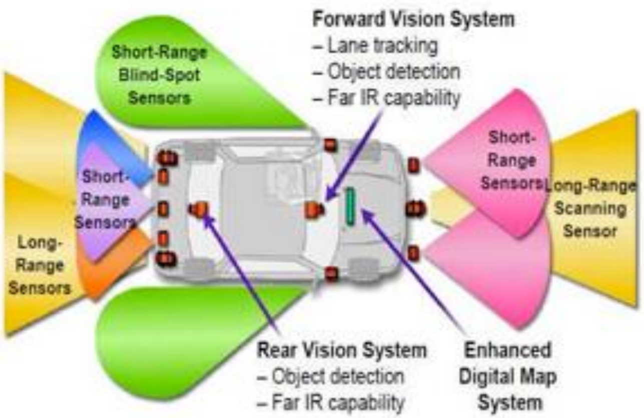
Heating savings from High R Window

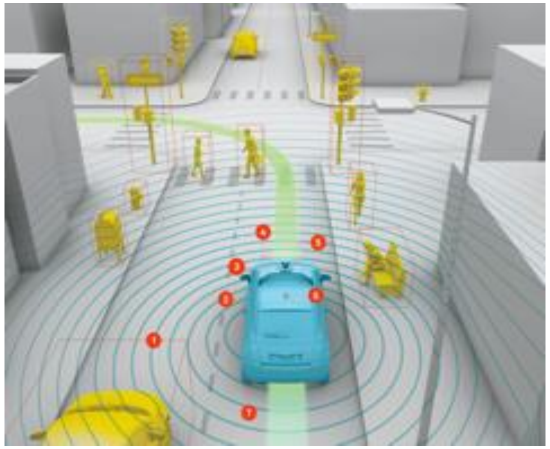
Cooling Savings from Automated Shade

Electricity from Nuclear power plant
For Heat, Cooling and Light

Relative Cost and Complexity?
A Story of Two $500B/yr Industries

INDUSTRY "A"





Integrated System:
Autonomous Car w/ Smart Sensors

VS

INDUSTRY "B"

Integrated System:
Sensor-Driven
Automated Shade or EC
w/ Daylight Dimming

"B": Façade Design-Delivery Ecosystem
Who's In Charge? Who Delivers Complete Solutions?