BERKELEY LAB Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF ENERGY

**ARPA-E**

Philadelphia, November 6, 2014

# Single Pane Windows: Dinosaurs in a Sustainable World ?

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Senior Advisor, Building Technology and Urban Systems

# 1970s Energy Crisis:  Optimal Windows?

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# U.S. Building End Use Energy Consumption

Buildings consume 40% of total U.S. energy

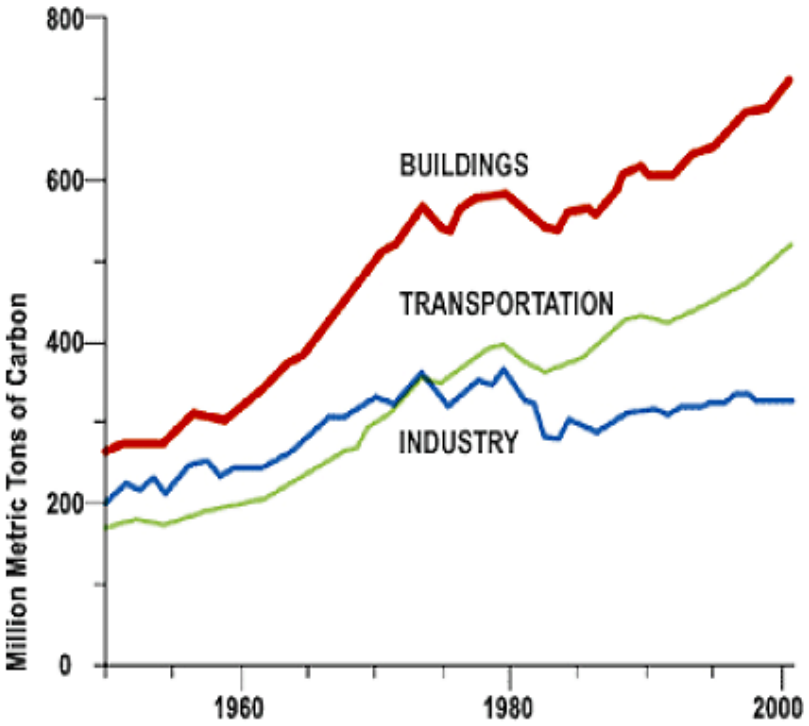
- 71% of electricity
- 54% of natural gas

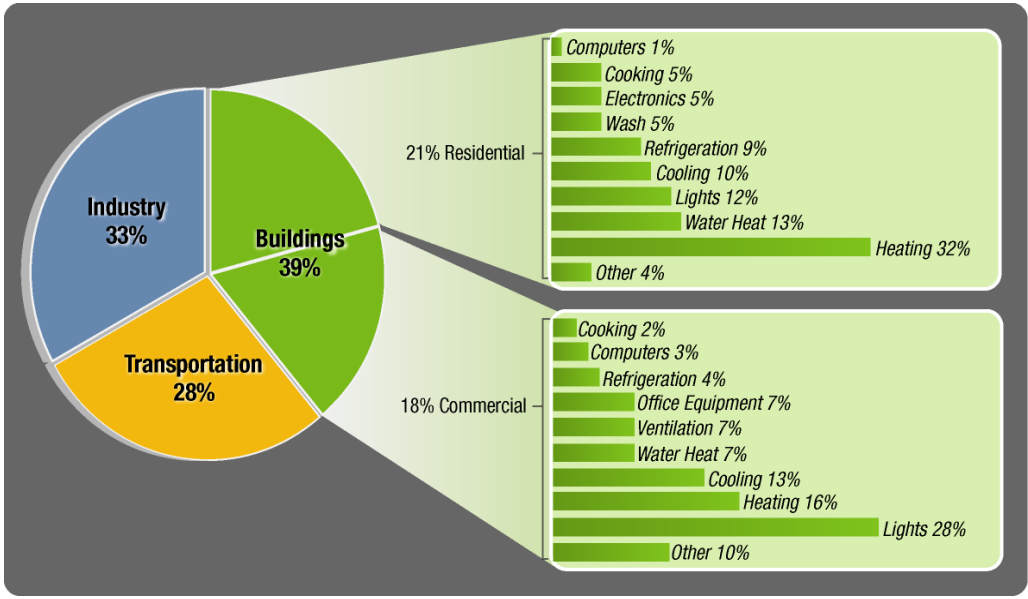
**Windows:**

**~ 10-12 % of Buildings**

**~ 4-5% of Total Energy**

**~ $50 billion/yr**

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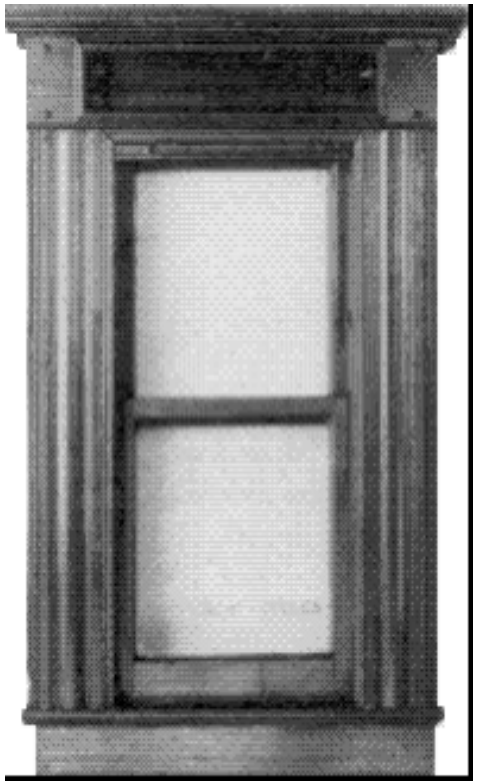
# Window/Glazing Performance Needs

- Comfort
- View/Privacy
- Security
- Acoustics
- Structure
- Recycled Materials

- **Energy**



- Daylight
- Aesthetics
- Weatherproof
- Cleaning
- Maintenance

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# Windows Overview

- **Context**
  - Windows are a ~5Q/yr, ~ $50B/yr cost and opportunity
  - **Vision: change windows from net loss to net supply**
  - **Highly "visible" component- window selection is "complex"**
  - Long-Lived Component- one chance to make the right decision!

Window-Related Energy Consumption
*(Quads)*

| | **Residential** | **Commercial** |
|---|---|---|
| Heating | 1.65 | 0.96 |
| Cooling | 1.02 | 0.52 |
| *Total* | *2.67* | *1.48* |

Daylight: +1 Q

- **Scope, Scale, Impact**
  - Comprehensive program: spans materials science to specific product R&D to systems integration
  - Research – Development – Demonstration – Deployment
  - All Climates, All Building Types, New and Retrofit
  - Significant Industry Collaboration and Cost Share
  - Measurable impact on technology, products, energy savings

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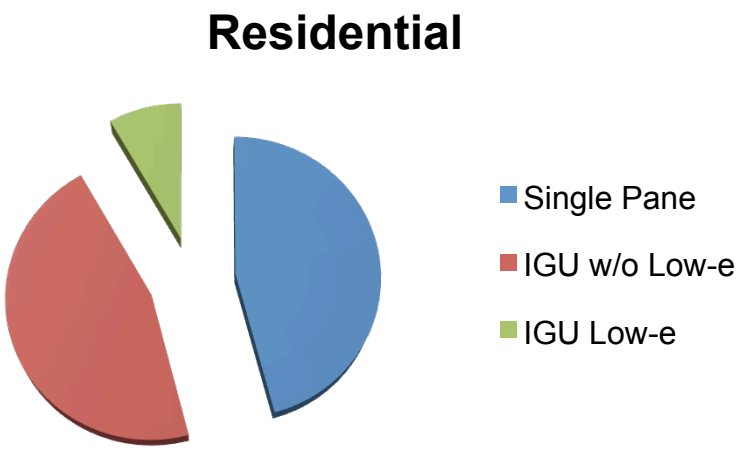
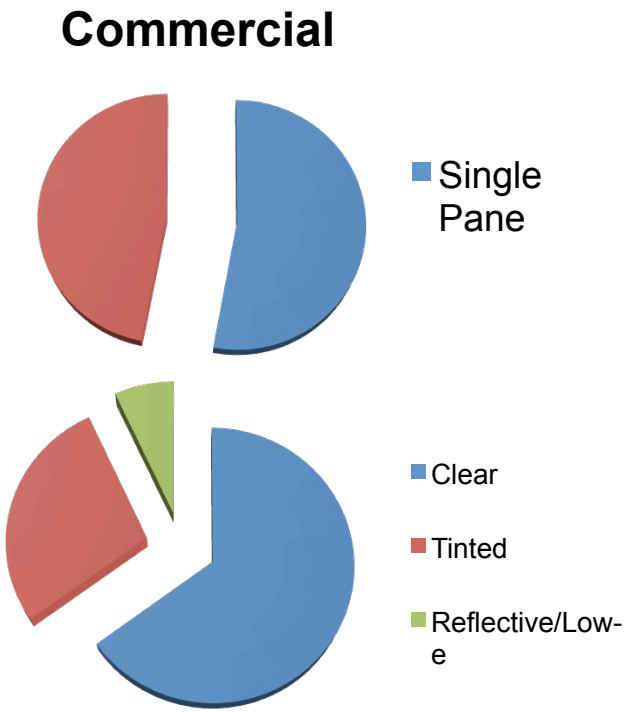
# U.S. Window Stock (based on Ducker 2010)

## *Window Improvement Opportunities*

- Current U.S. window stock has large number of single glazed and/or clear glazing
- Need a range of options in performance and cost
  - –Replace Window When Feasible
  - –Retrofit: a) Window, 2) Glazing, 3) Attachments
- Market Size: ~ 7.6 B sf of single glazed windows




**Existing Window Glazing Distribution for Residential Market**




**Existing Window Glazing Distribution for Commercial Market**

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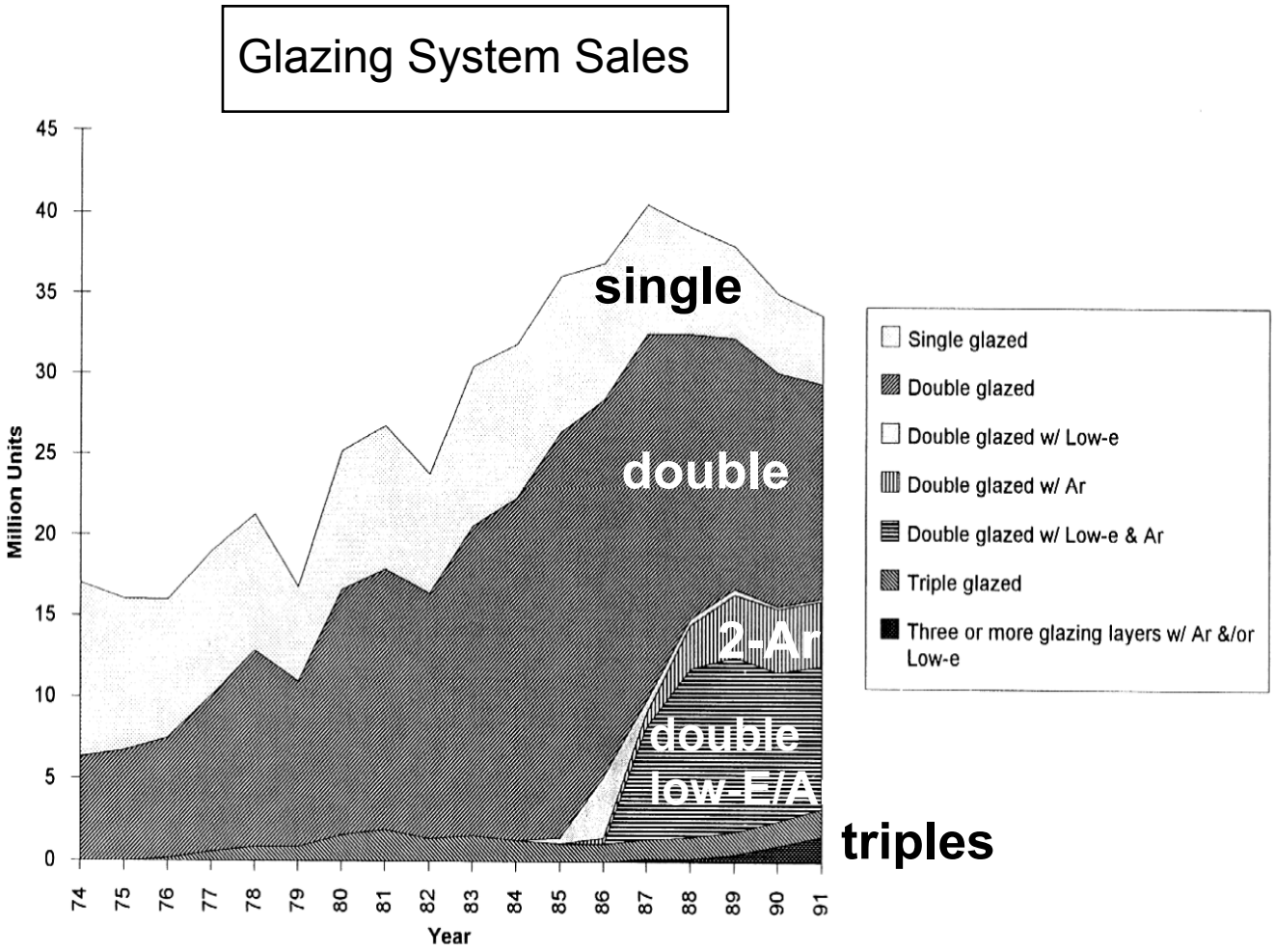
# Glazing System Sales: 1974 – 1996

## Tracking Early Market Penetration of Low-E, a New Glazing Technology

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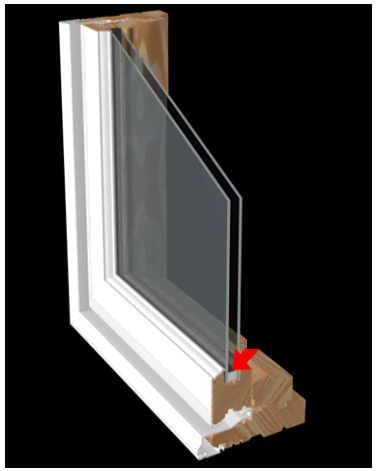
# Progress in U.S. Window Markets

## (Example: Improved Insulating Properties in Residential market)

- **1973: Typical Window:**
  - clear, single glazed,
  - double or storm window in north,
  - $U_{average}$ = 4.8 W/m²-K

- **2003: Typical Window:**
  - 95% double glazed
  - 50% have a low-E coating
  - 30-65% energy savings vs. 1973
  - $U_{average}$ = 2.5 W/m²-K

- **2013: Typical Window:**
  - 97% double glazed
  - 80% have a low-E coating
  - 30-65% energy savings vs. 1973
  - $U_{average}$ = 2.5 W/m²-K



- **2030: Future Window:**
  - Zero net energy use (typical)
    - Net winter gain; 80% cooling savings
  - $U_{average}$ = .6 W/m²-K
  - Dynamic solar control

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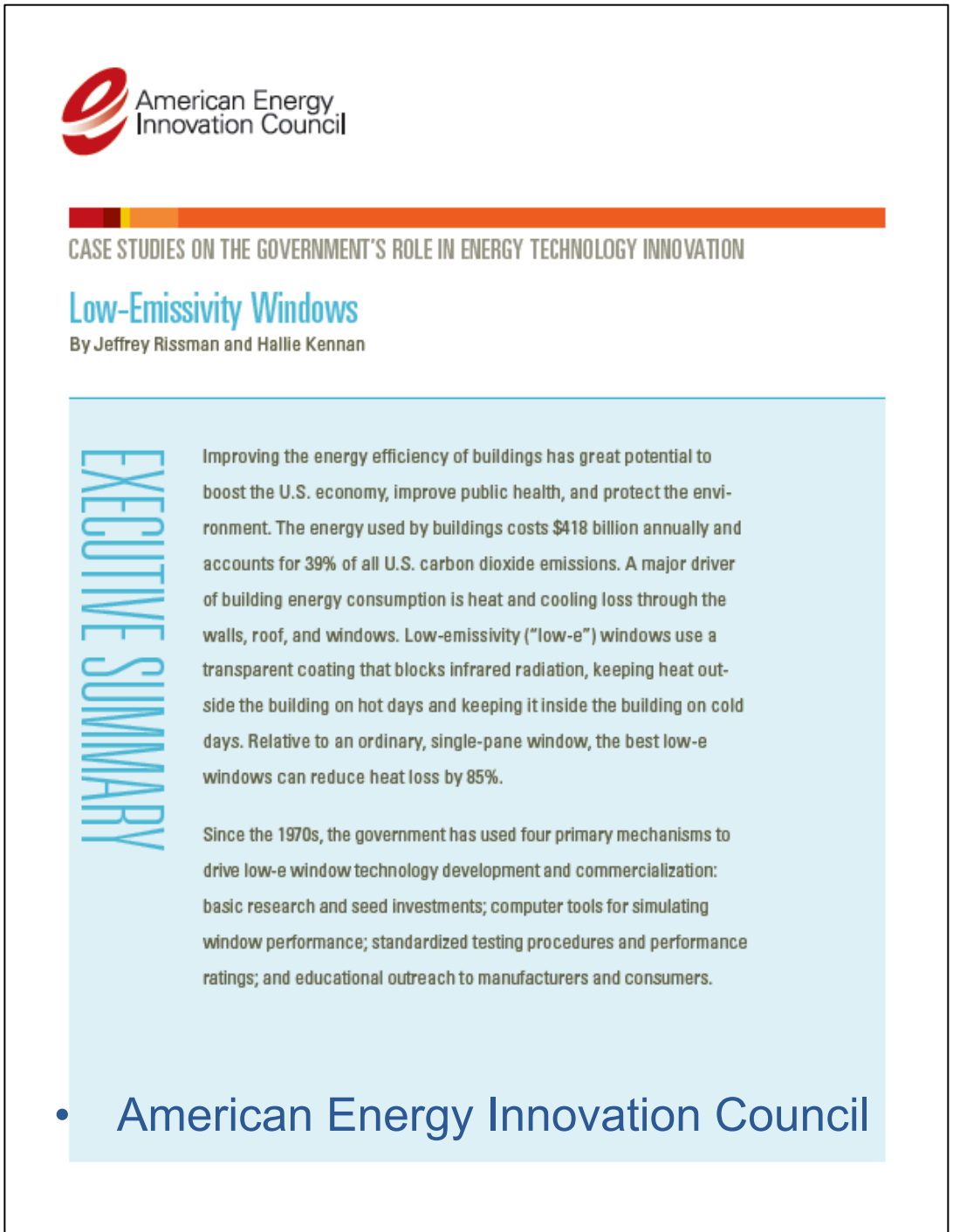
# AEIC Paper:

## *Case Study on the Government's Role in Energy Technology Innovation: Low Emissivity Windows*:

## ….the trek from prototype to 80% market share



American Energy Innovation Council

CASE STUDIES ON THE GOVERNMENT'S ROLE IN ENERGY TECHNOLOGY INNOVATION

Low-Emissivity Windows

By Jeffrey Rissman and Hallie Kennan

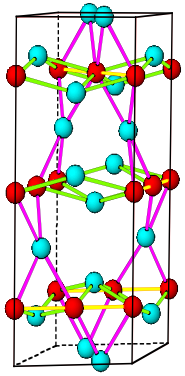
EXECUTIVE SUMMARY

Improving the energy efficiency of buildings has great potential to boost the U.S. economy, improve public health, and protect the environment. The energy used by buildings costs $418 billion annually and accounts for 39% of all U.S. carbon dioxide emissions. A major driver of building energy consumption is heat and cooling loss through the walls, roof, and windows. Low-emissivity ("low-e") windows use a transparent coating that blocks infrared radiation, keeping heat outside the building on hot days and keeping it inside the building on cold days. Relative to an ordinary, single-pane window, the best low-e windows can reduce heat loss by 85%.

Since the 1970s, the government has used four primary mechanisms to drive low-e window technology development and commercialization: basic research and seed investments; computer tools for simulating window performance; standardized testing procedures and performance ratings; and educational outreach to manufacturers and consumers.

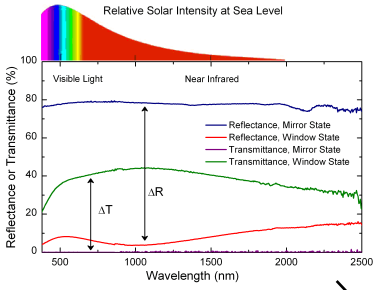
- American Energy Innovation Council

# New Glazing Solutions: From R&D to Market Ready and Market Share



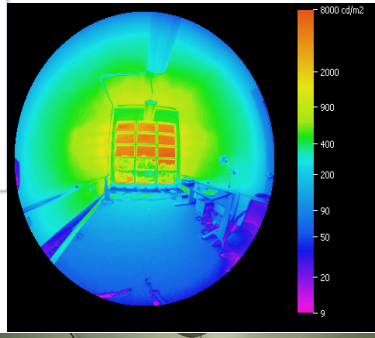
$Mg_2Ni$

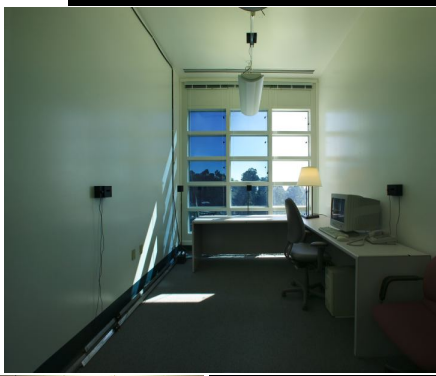
**Invent New Materials**




**Characterize Coating Performance**

**Integrate Technology into Window**



**Assess Human Factors**

**Assess Savings**

**Invent Innovative Manufacturing Process**

**Field Test Installed Systems**

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# How “Efficient” Can A Window Be??

# Is our goal an R100 Window?

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# Vision: "Net Zero-Energy Window"
# Energy Losers --> Neutral --> Net Suppliers

- **Heating climates**
  - Reduce heat losses so that ambient solar energy balances and exceeds loss
  - Need lower heat loss technologies
- **Cooling climates**
  - Reduce cooling loads
  - Natural ventilation
  - Static control -> dynamic control
- **All climates**
  - Replace electric lighting with daylight
- **Electricity supply options**
  - Photovoltaics-building skin as power source

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# Savings from Better 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

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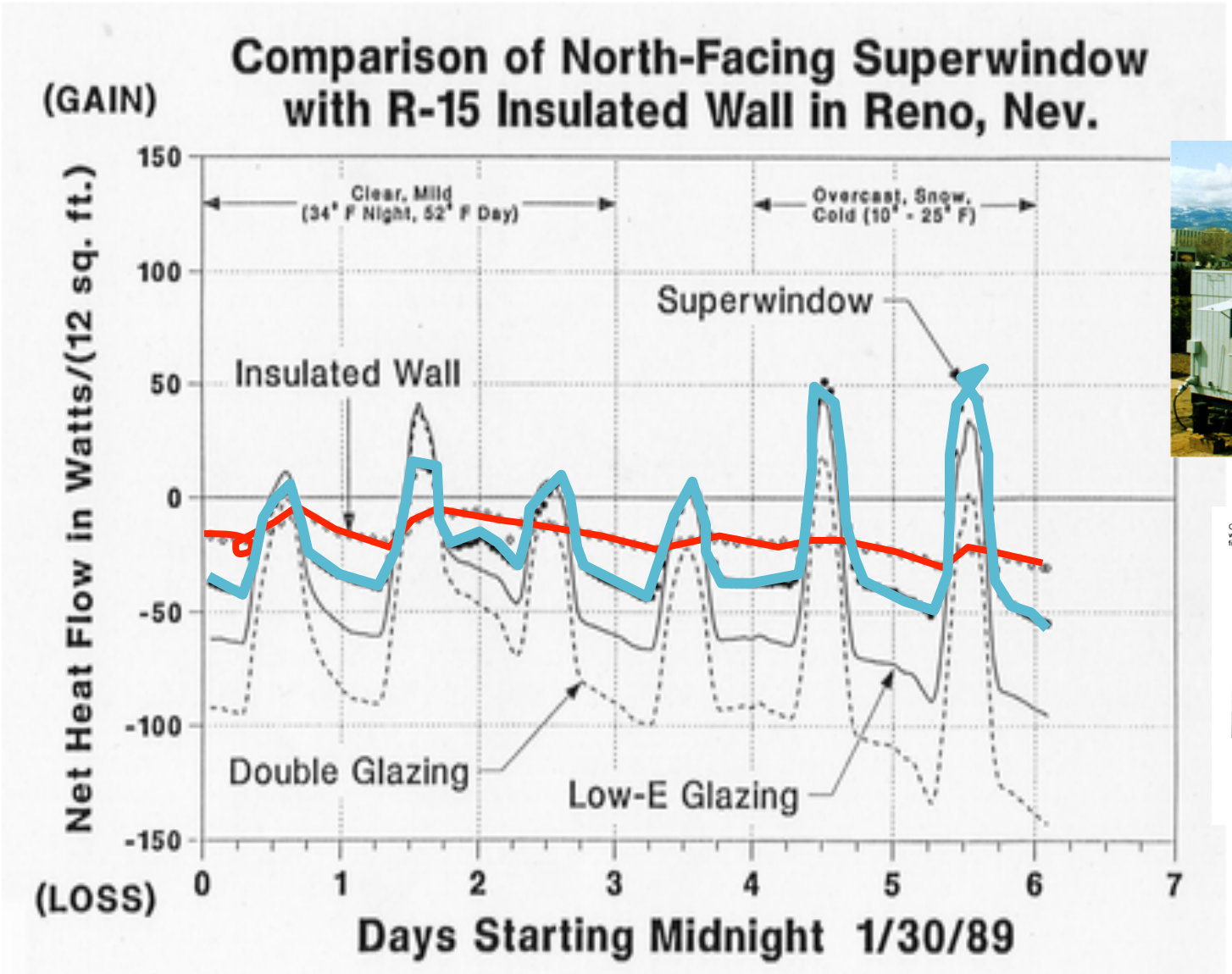
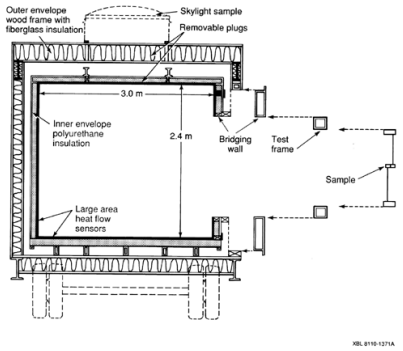
# NEWSFLASH (from 1989!):

## ”North-facing Windows Outperform Insulated Walls during winter heating season”





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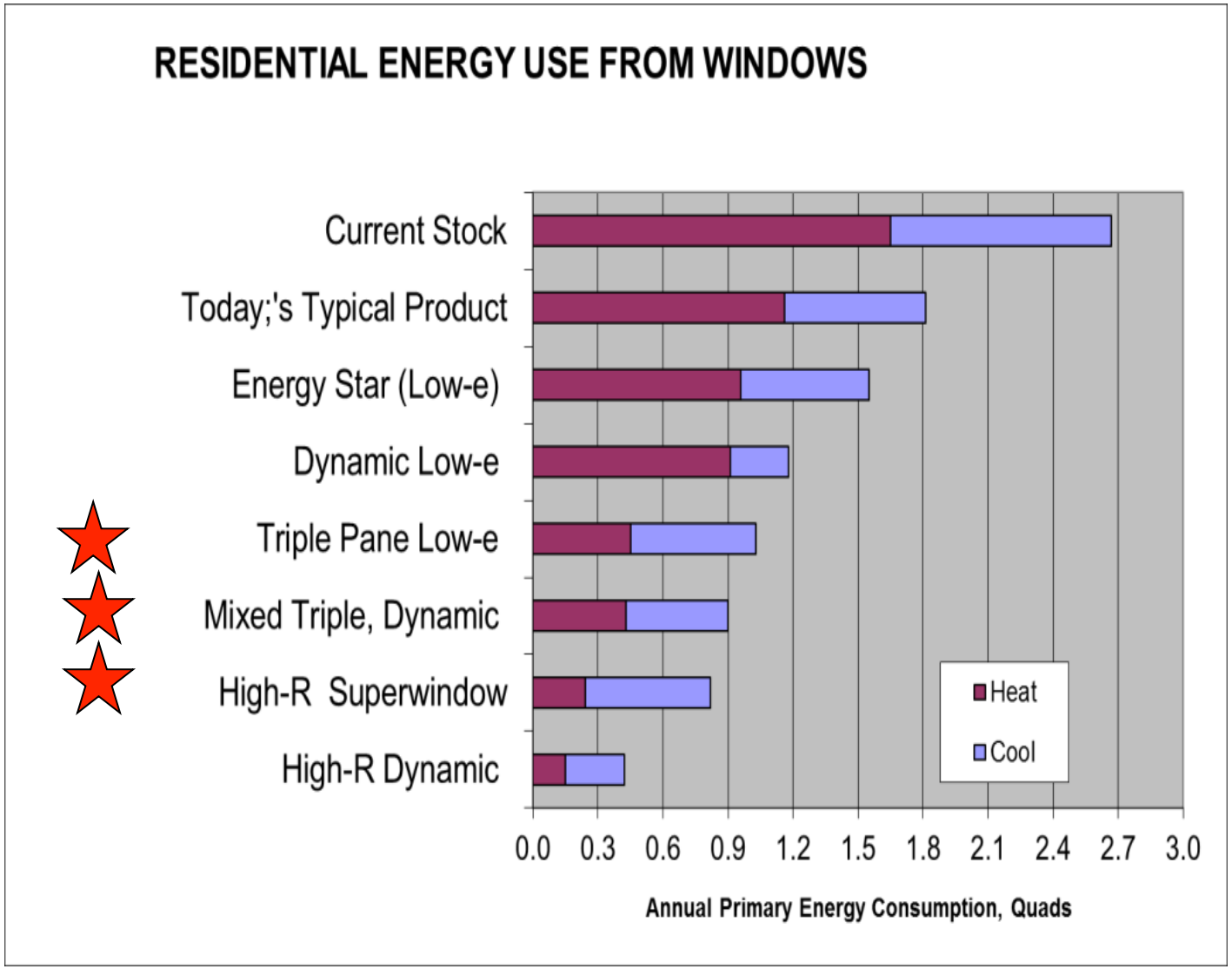
# How Would We Get to This "Net +" Goal?




*Current Energy Use Based on US Energy Information Administration, BTP Data*

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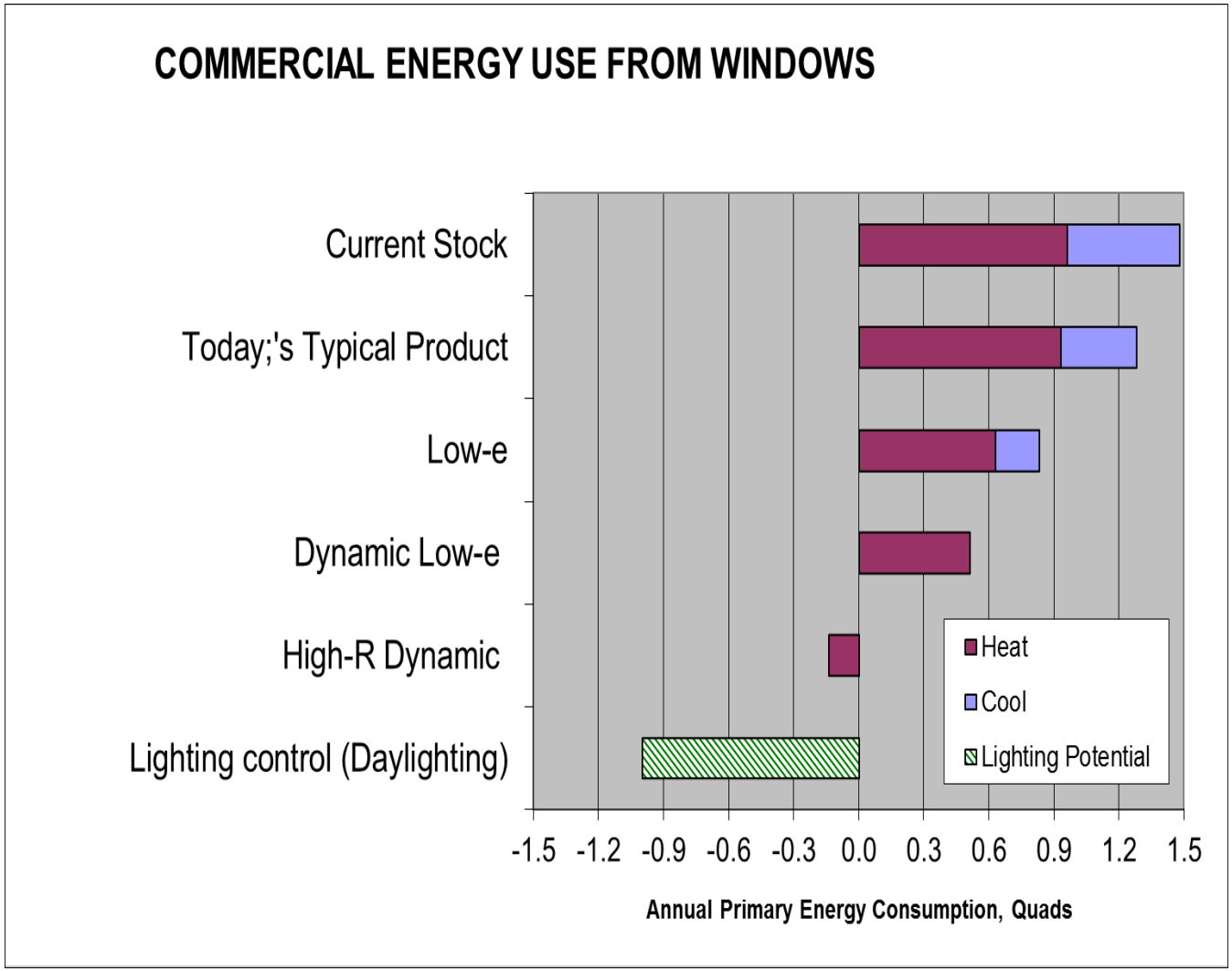
# Commercial windows?

## Commercial Sector – w/ Lighting Impacts




*Current Energy Use Based on US Energy Information Administration, BTP Data*

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# Where are the Game Changers?

- Double/triple the insulating value of new IGU/window
- **High performance retrofits**
  - **Add-on for existing glazing/windows**
  - **Window attachments**

- Independent control of U and SHGC
- Dynamic control of SHGC and Tv
- Daylight control, glare free, daylight redirection
- Air flow management – natural ventilation

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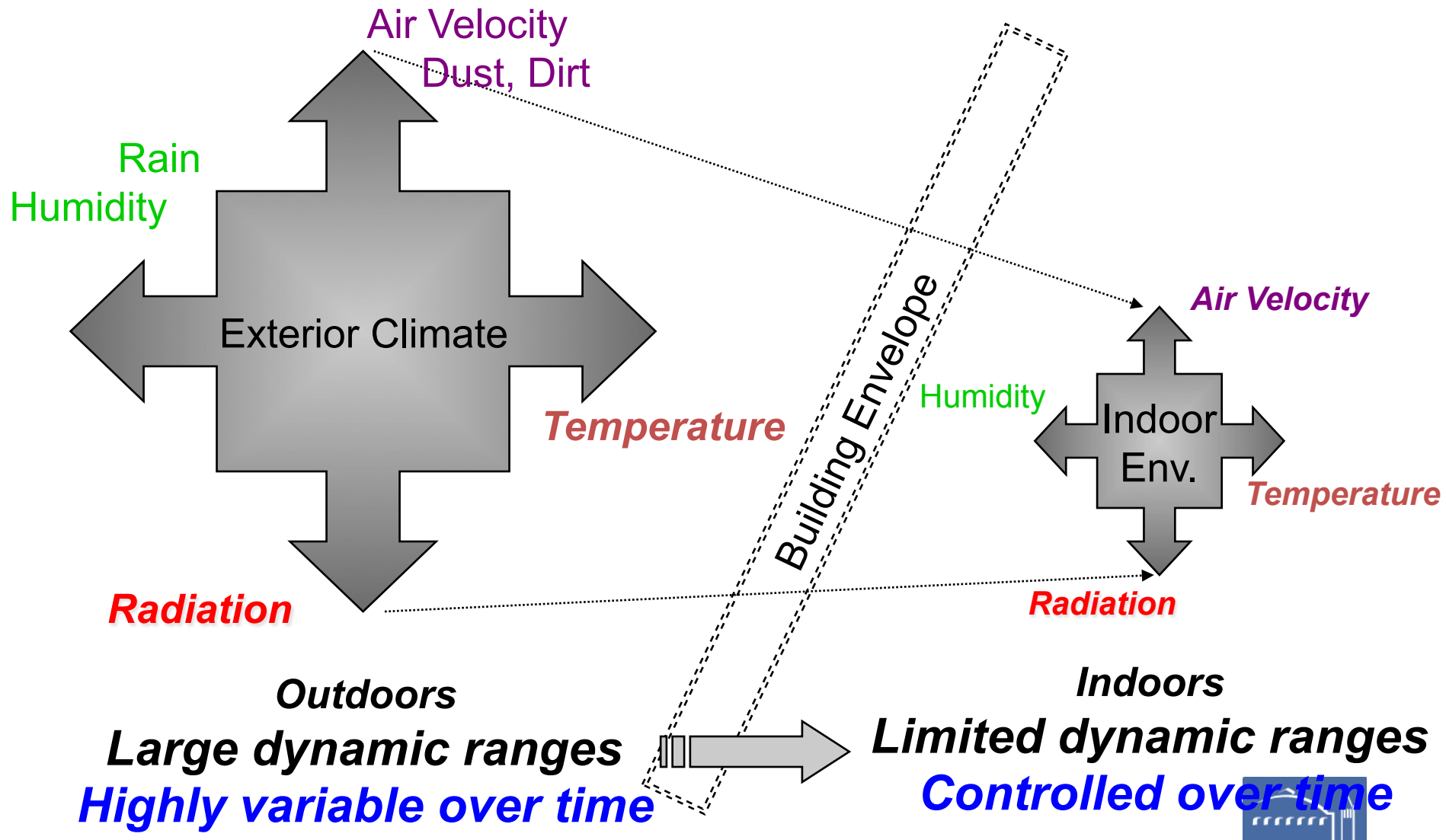
# Building Envelope as Dynamic Filter



# Glazing and Window Technology Landscape: Changing "Scale" and Function for R&D

| "1μ" coating | "1mm" glass | "1m" Window, shading |
|---|---|---|
| + Numerous options | + Numerous options | + Numerous options |
| + Minimal mass | + Low Maintenance | + Versatile |
| + Versatile | + Cost | + Operable |
| + Low Maintenance | + Durability | - Maintenance |
| +/- Cost | | - Cost |
| +/- Durability | | +/- Durability |
| +/- Operable | | |

Intelligent Control of Dynamic Conditions, Properties:

Thermal flows: U value

Daylight/Solar Gain: SHGC, G, Tv

- Intensity
- Spectral content, color
- Directional

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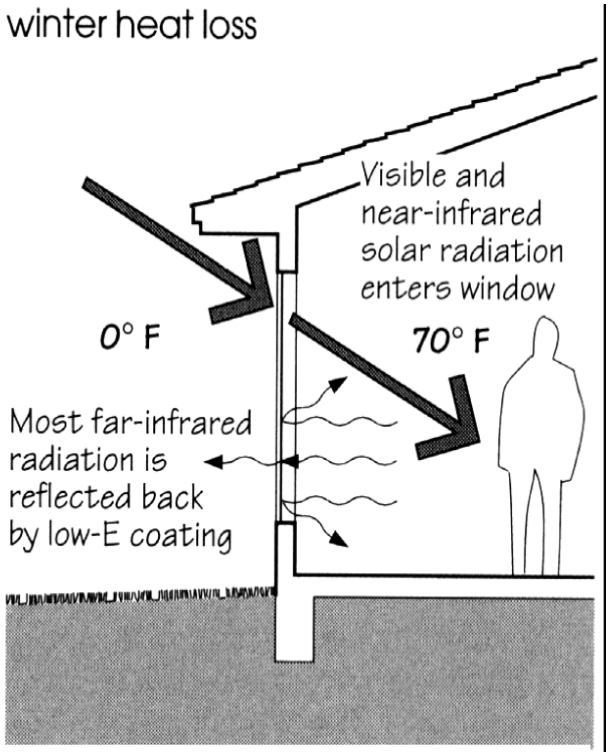
# Winter Heat Loss Control

- **Minimize conductive heat transfe (low U)**
- **Minimize air leakage**
- **Maximize useful solar gain (high SHGC)**

- **Actual Energy Use influenced by:**
  - **Climate**
  - **Orientation**
  - **House Design Features**




High Transmission low-E glass provides solar heat gain and reduces winter heat loss.

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# R and U values: a reminder….

- **R-value** = thermal resistance
  - SI unit $K \cdot m^2/W$, IP unit $ft^2 \cdot °F \cdot h/Btu$
  - 1 $K \cdot m^2/W$ = 5.675 $ft^2 \cdot °F \cdot h/Btu$
- 1/R = thermal conductance
- **U-value** = thermal transmittance
  - **U=1/R** if convection and thermal radiation can be neglected
  - more general, U-value contains all forms of energy transfer: thermal conductance + convection + radiation
  - SI unit $W/K\ m^2$, non-Si unit $Btu/ft^2\ °F \cdot h$
- **Heat Loss, $$ Saved ~ U, not R**

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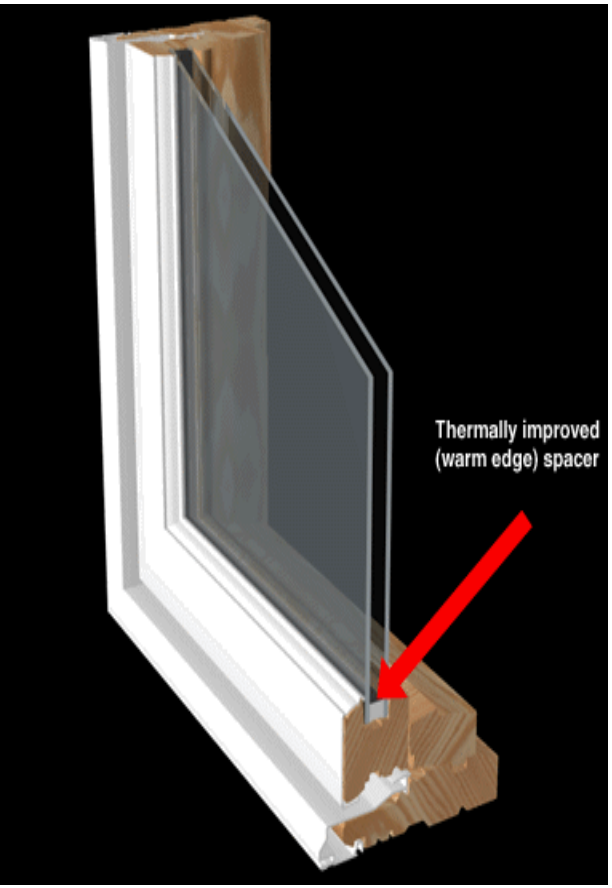
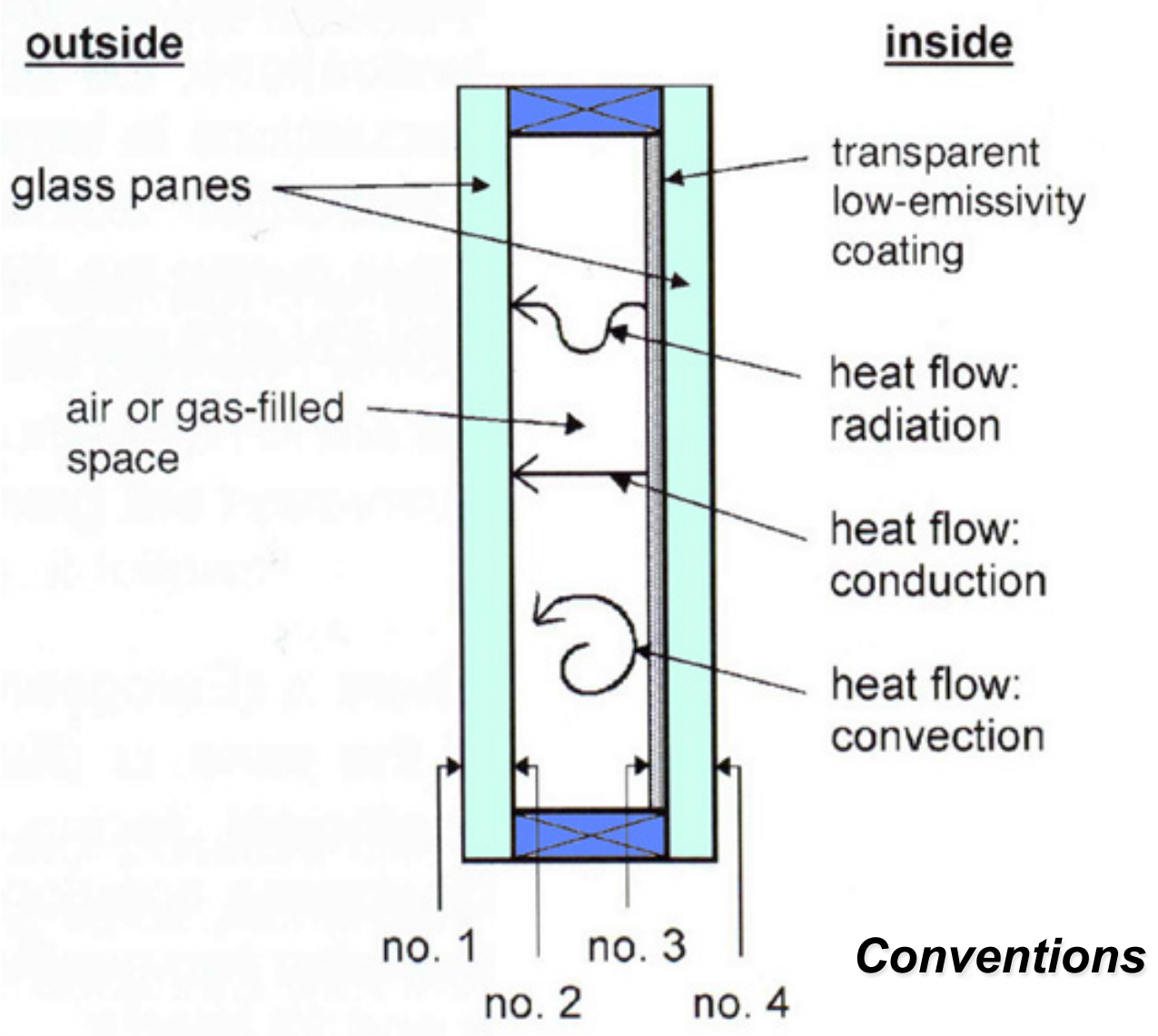
# Adding Low-E Coating to Insulated Glass Unit – IGU (keep track of heat transfer mechanisms)




***Conventions***

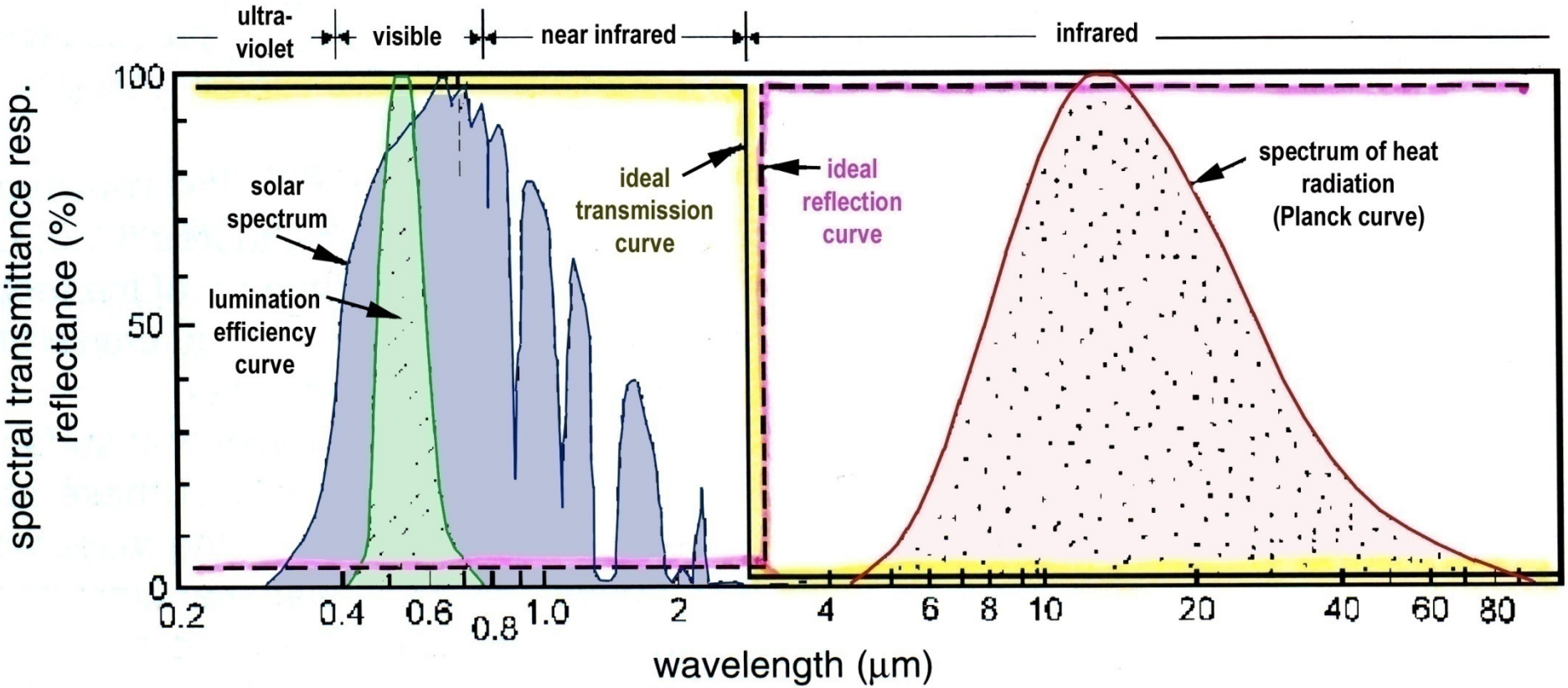
# Glazing "Systems" Ecosystem

- Glass: Monolithic <--> Multiple pane
  - Glass thickness: historically > 3mm….
  - Now .1mm glass options
  - Multilayer: Gas fills
- Clear – Body Tinted – Coated
  - On line, off-line, retrofit
- Processed: Laminated, Tempered
- Multipane: Low conductance Spacers
- Vacuum glazings
- Aerogel, Transparent insulators,...
- Polymeric glazings
  - Plastic films - suspended and glue-on
  - Extruded and ribbed polymers
  - Fiberglass panels
  - Prismatic glazings

# Radiation and the Ideal Energy-Saving Window:

Solar Radiation:
cooling vs lighting

Long Wave IR:
thermal transfer

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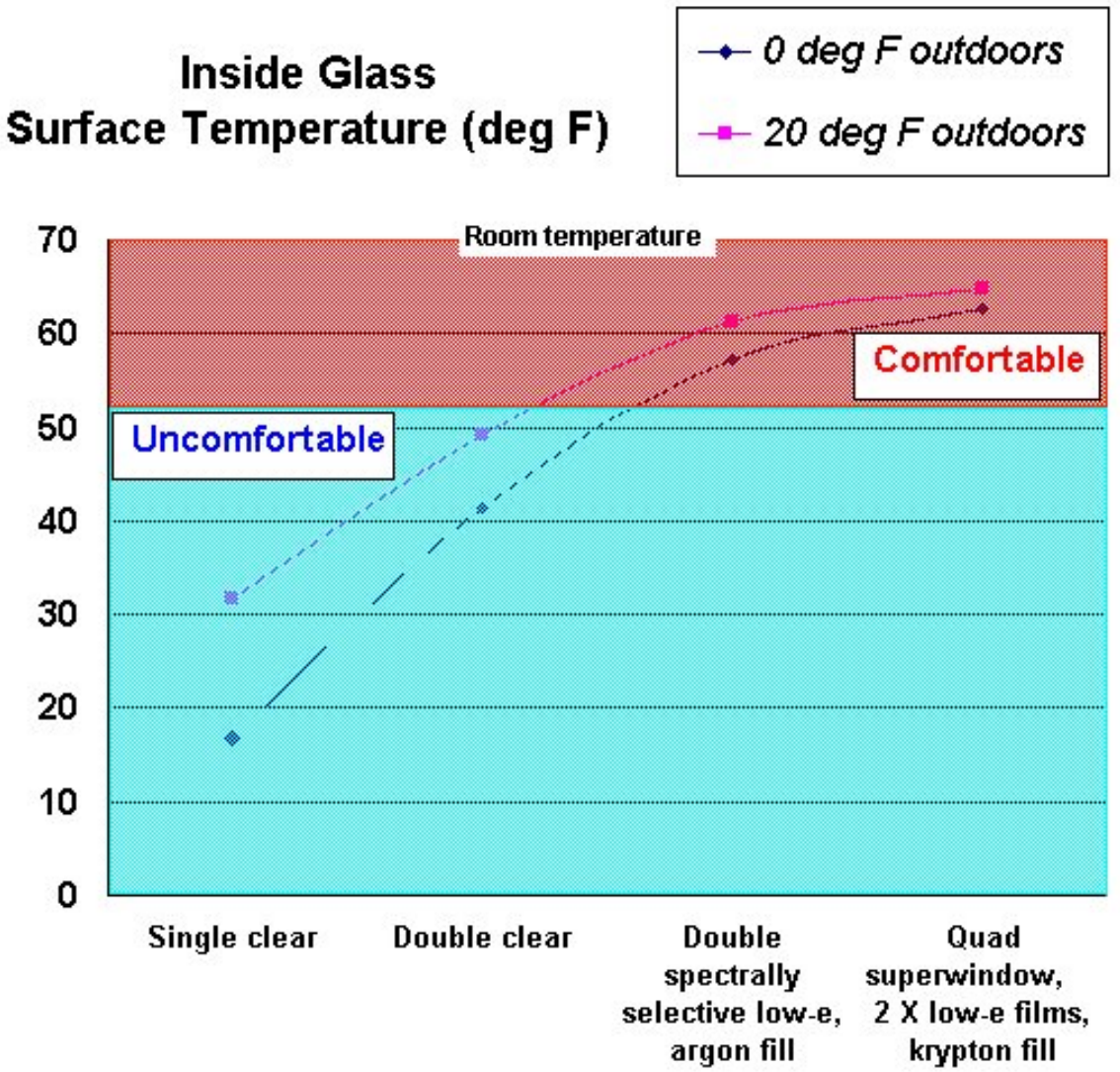
# Thermal Comfort – Interior Glass Temp

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# Technology Trends/Opportunities

## Highly Insulating
## Solar Gain Management
## U – SHGC tradeoffs

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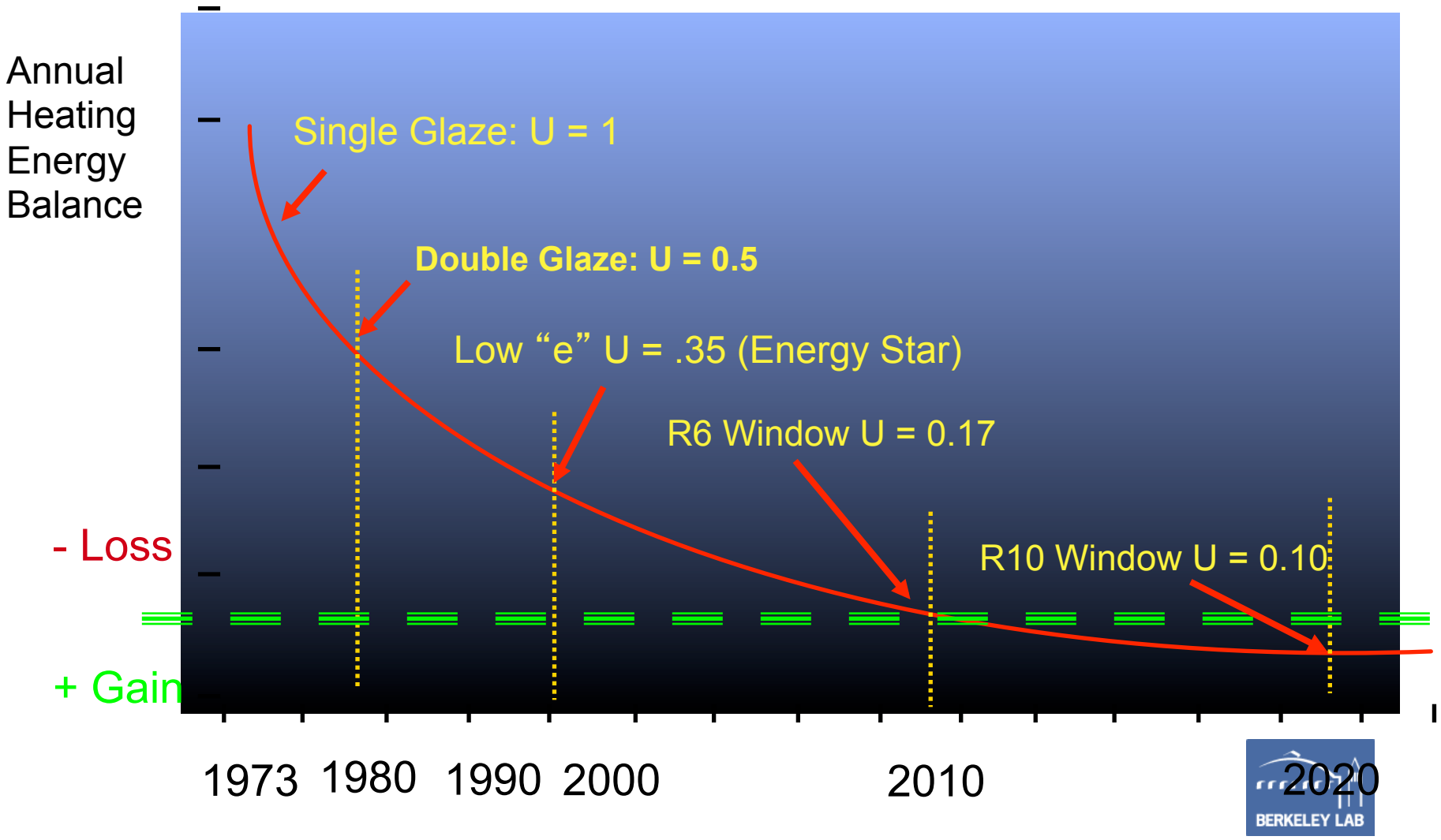
# Windows Can Become Net Energy Producers as R > ~5:
## Caution: Balance of loss and gain in cold climates

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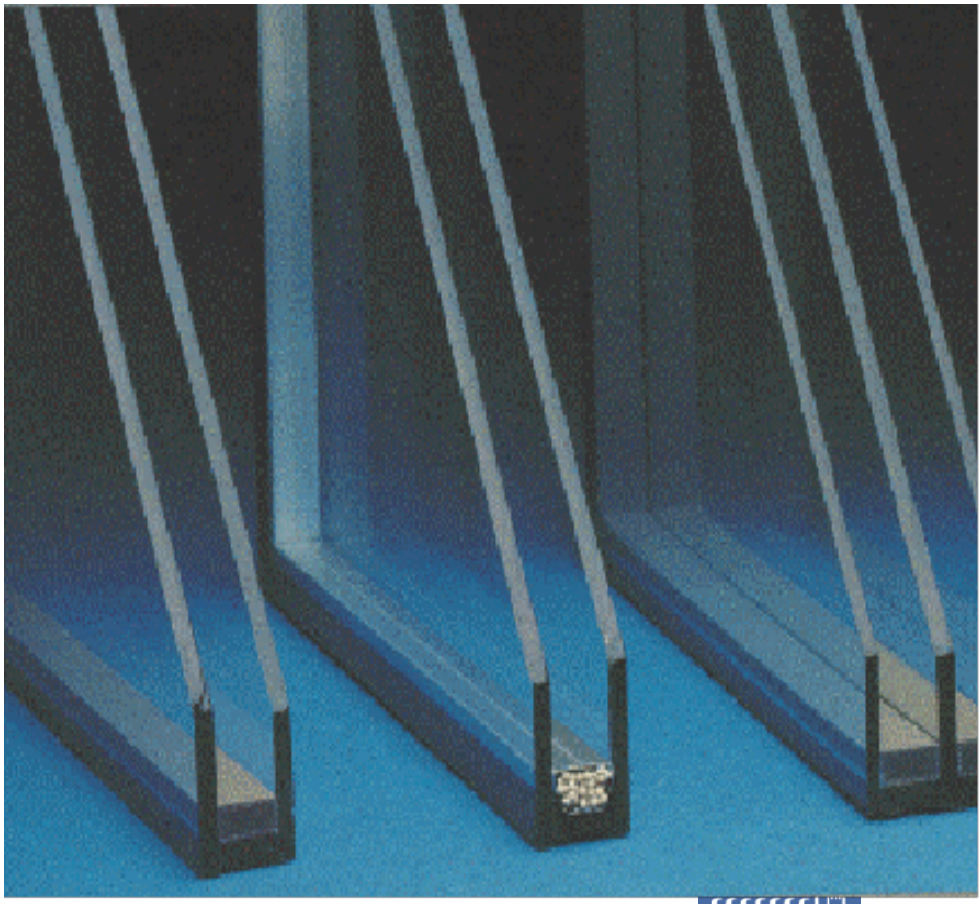
# Highly Insulating Window Strategies

Nearer Term Objective: U-value < 0.25 Btu/sf-hr-F

Longer Term Target: U-value < 0.15 Btu/sf-hr-F

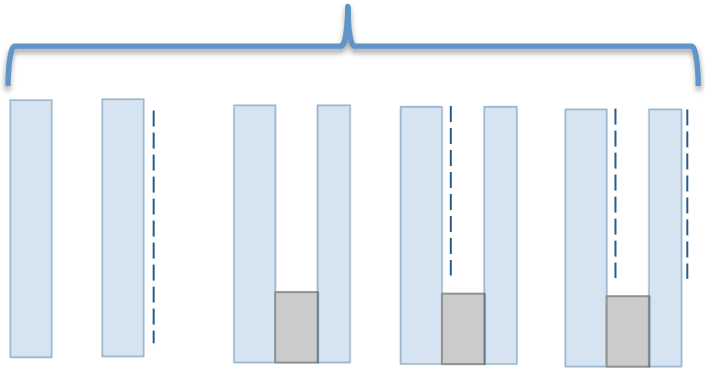
**New Window Approaches:**

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



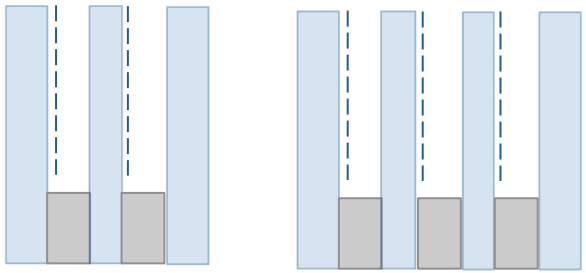
# GLAZING SOLUTIONS: U ~ .1BTU/h-ft$^2$-F

Market Today



Single

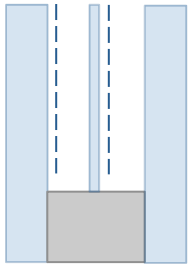
Double



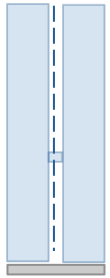
Two low-e

Three low-e

FY12-FY15

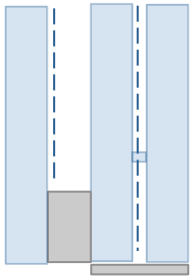


Two low-e
Thin glass
single seal
Krypton

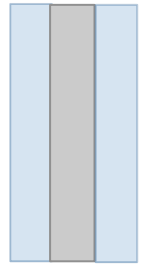


One low-e
Vacuum

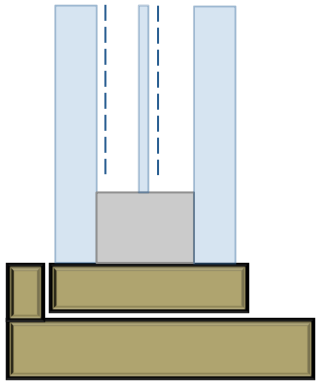
> FY15

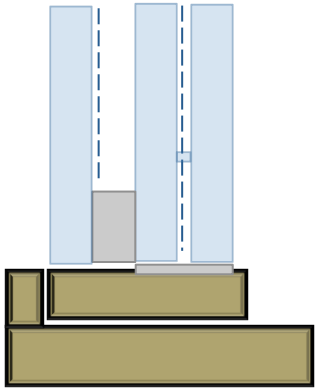


Two low-e
Vacuum Hybrid



Aerogel





*Note: low-E coated polyester film can be alternative middle glazing.*

Super-insulating frame with highly insulated glazing

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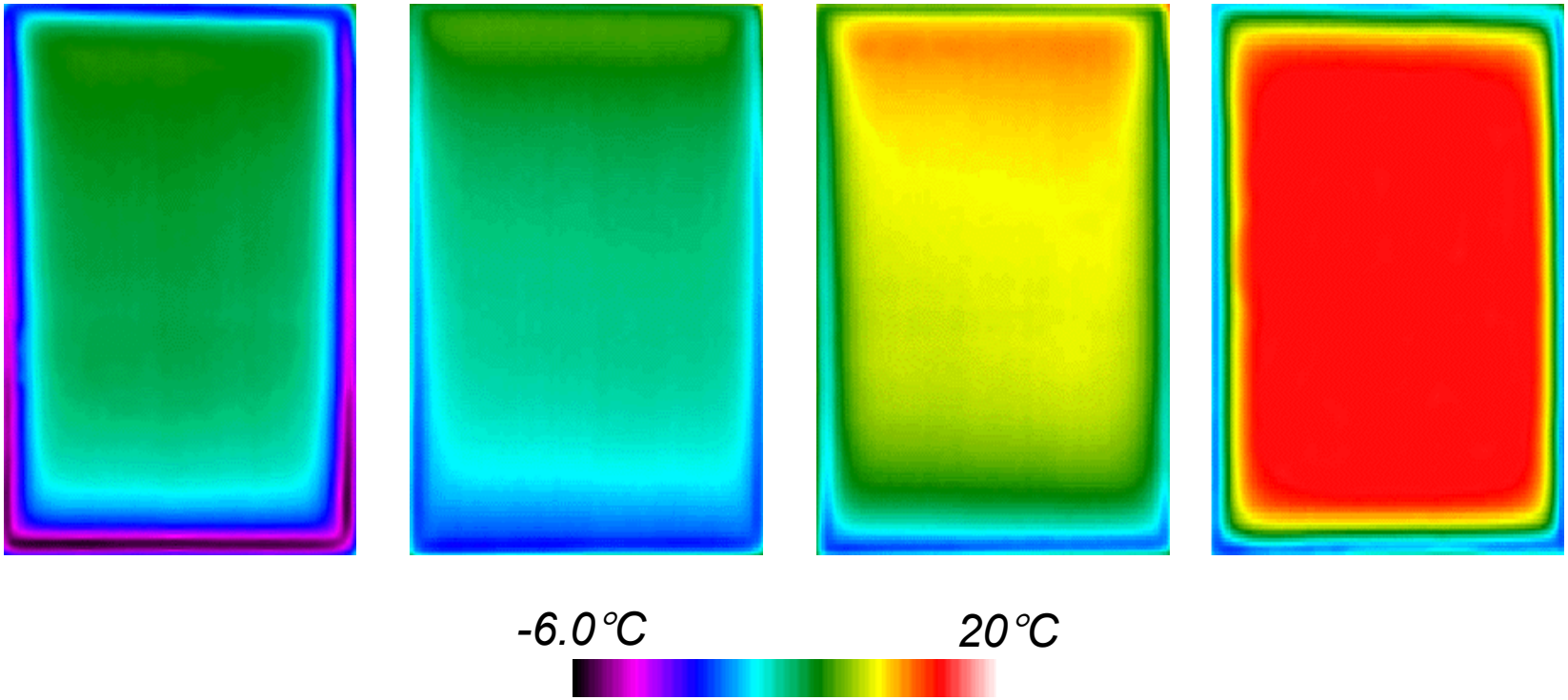
# Technologies to Reduce Heat Loss
# Glass, Glass Edge

*Dual, Clear, Alum. spacer*

*Dual, Clear, Foam spacer*

*Dual, Low-e, Foam spacer*

*Superwindow, 4-lites, low-e, Kr*




*Images from LBNL Infrared Thermography Lab showing glass edge/spacer effects and convective loops in IGUs*

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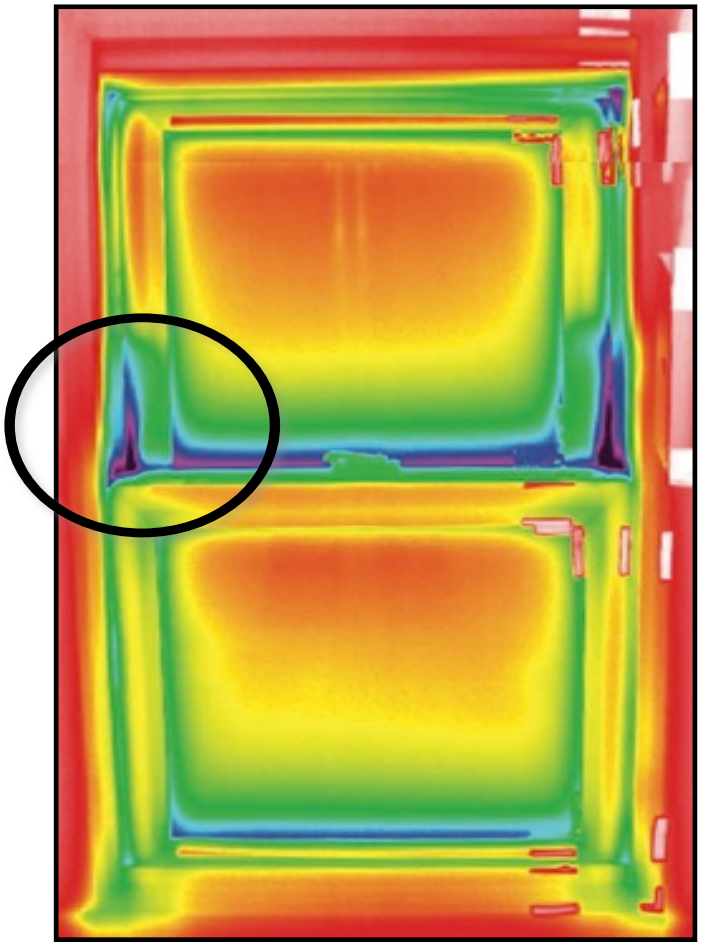
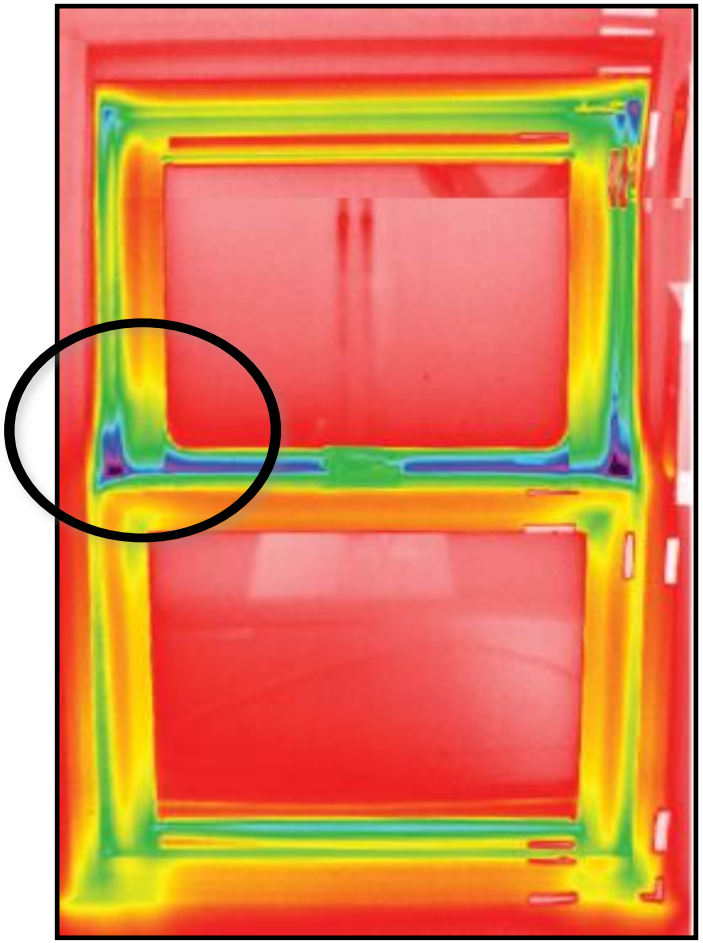
# Measurement: LBNL IR Thermography Lab

## Quantitative Analysis

## Lab cold chamber and Field Tests





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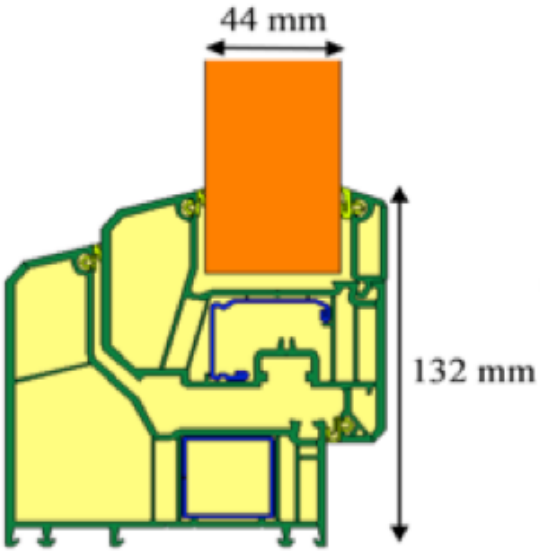
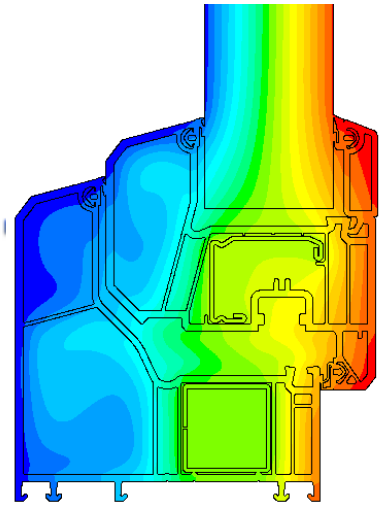
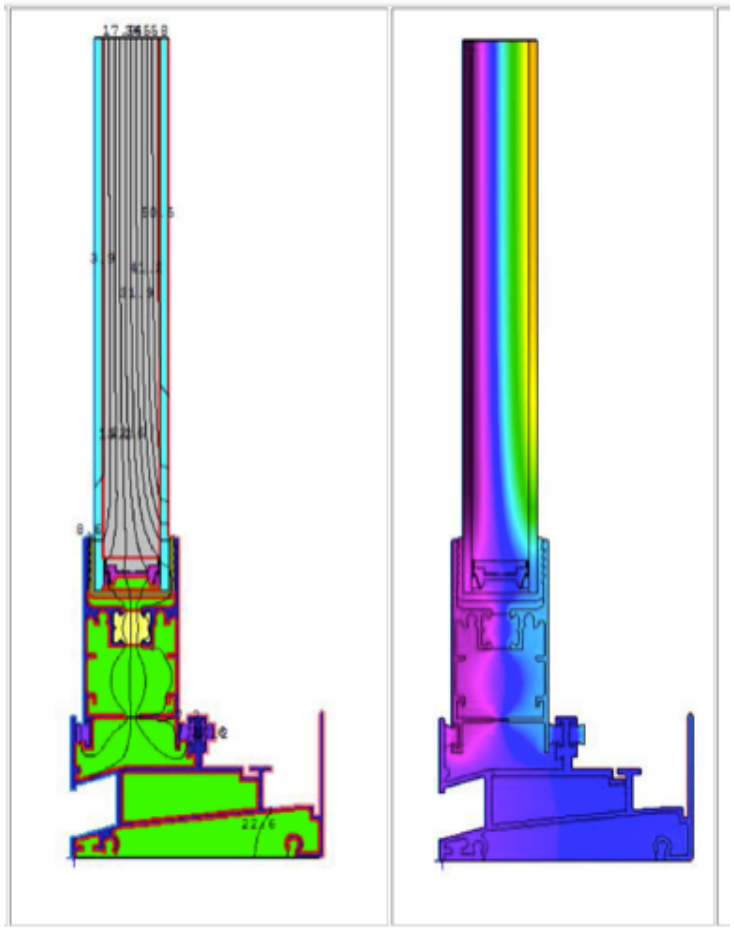
# THERM: Heat Transfer in Glass Edge and Window Frames

## Impact of low conductance warm edge spacers and thermal breaks in window frames

(THERM software downloads from windows.lbl.gov/software/)





Sample Isotherm Results (Aluminum Slider Window Frame)

Sample Color Infrared Results (Aluminum Slider Window Frame)

# Solar-Optical Properties of Glazing

## Tvis, Solar Heat Gain Coefficient SHGC

- **Highly Transparent**
  - View, Daylight
  - Passive solar gain in winter
- **Solar Protection**
  - Reduce Cooling energy
  - Minimize cooling system size and cost
  - Manage Glare
- **Energy Control Options:**
  - Spectrum
  - Intensity
  - Transmission: specular vs diffuse

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# Capturing Useful Solar Gain in Winter (to balance winter heat loss)

- **Goal- net energy improvement:** what happens when insulation improvements also reduce solar gain?
- Most strategies to reduce U (extra glazing layers and coatings) will also reduce SHGC
- Lower U may NOT have better annual performance, if solar gain is lost

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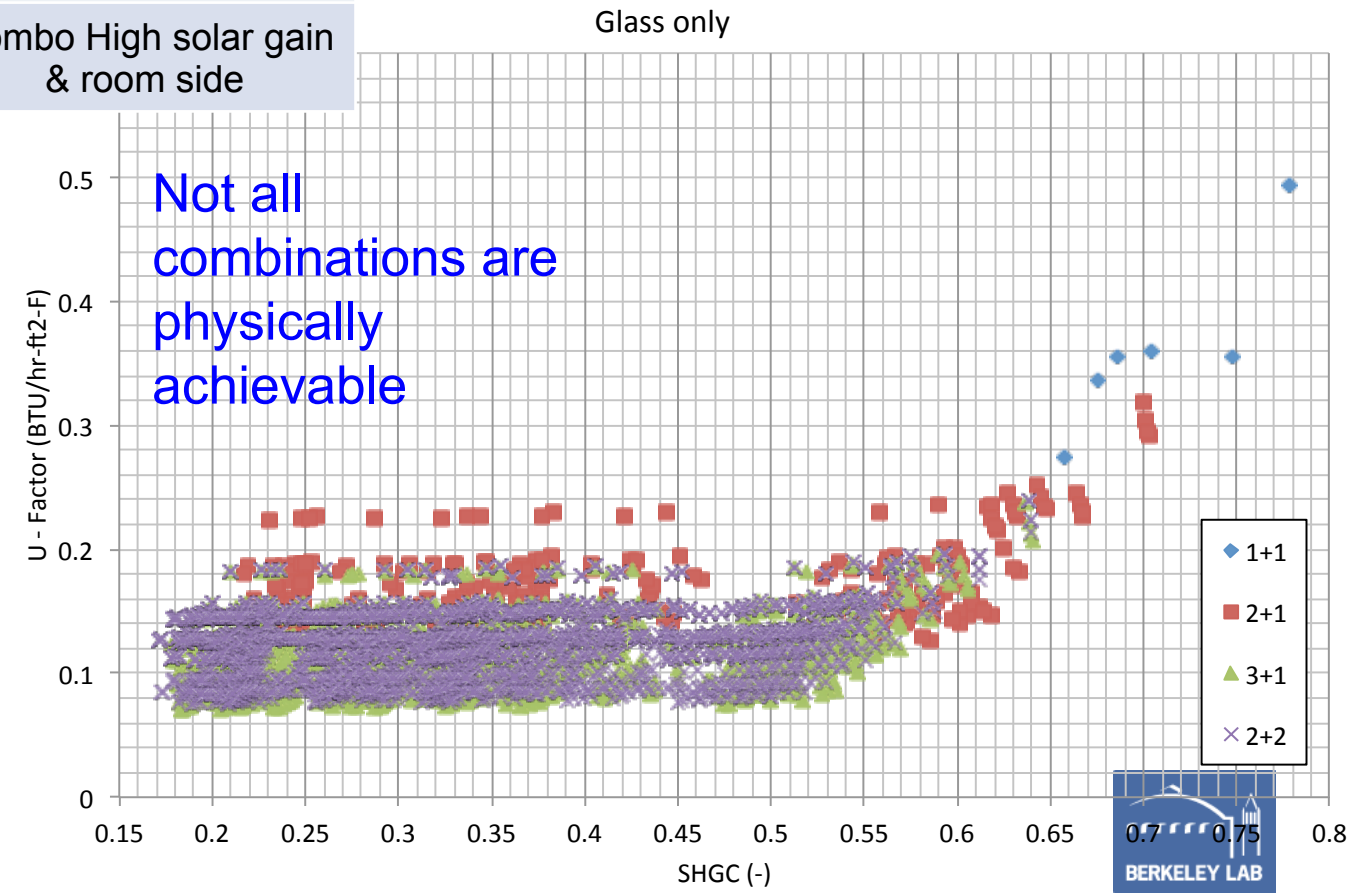
| NFRC ID | NAME | TYPE |
|---|---|---|
| 2001 | clear | Clear |
| 2011 | Low-e$^2$ 272 | Moderate solar gain |
| 2154 | Low-e$^3$ 366 | Solar control |
| 2159 | Low-e i89 | Room side low-e |
| 2191 | Low-e 180 | High solar gain |
| 5001 | Starphire (PPG) | Low iron |
| * | Low-e i89/180 | Combo High solar gain & room side |

| GAS FILL |
|---|
| Air |
| Argon (90%) |
| Krypton (50%) / Argon (45%) |
| Krypton (90%) |

# Goal: Find the U/SHGC properties that minimize annual energy

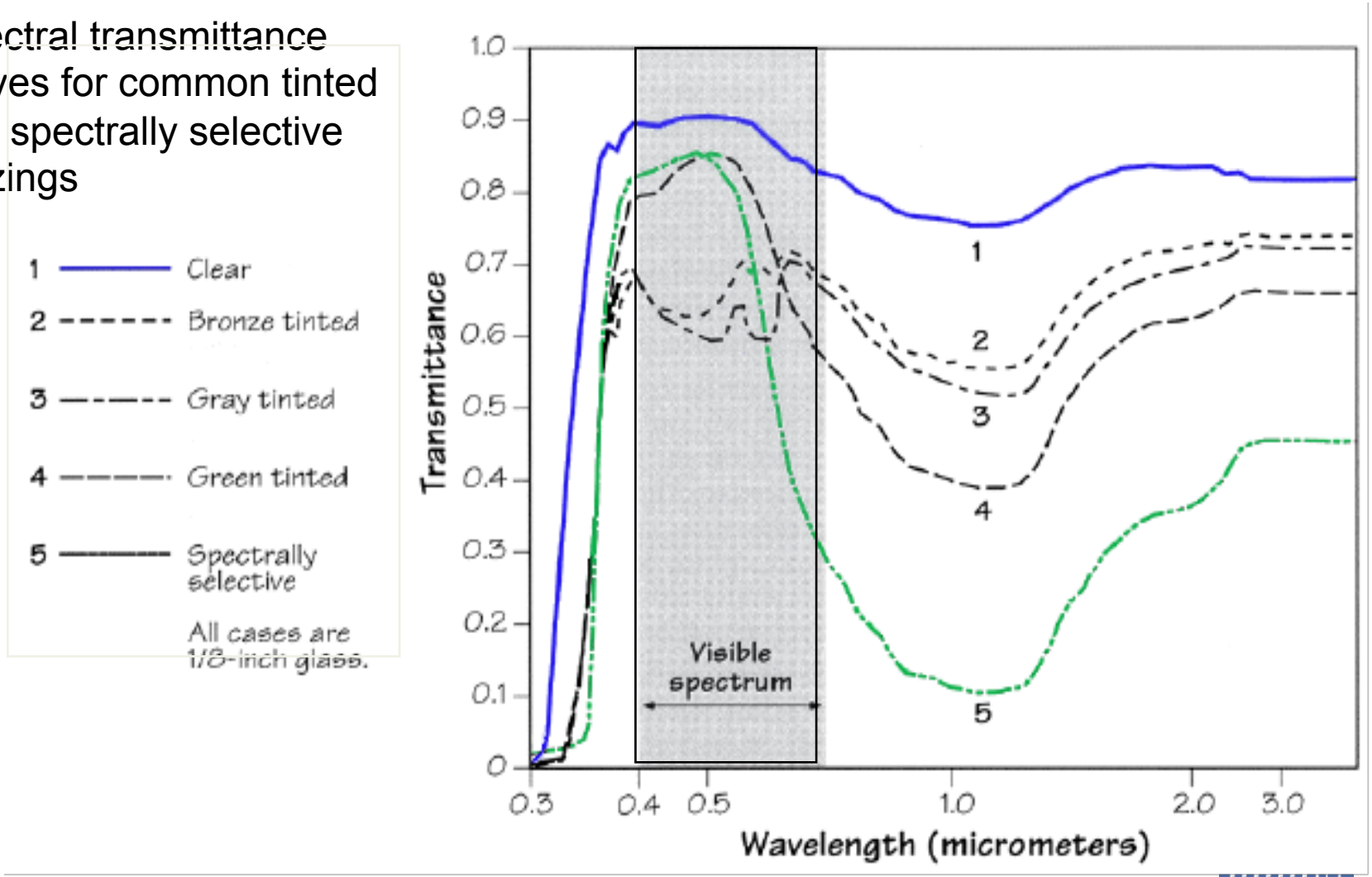
6213 total combinations

# Finding a Needle in a Haystack: 6,000 Glazing, coating, gas combinations **U vs SHGC**



# Spectrally Selective "Cool" Glazings:
## Providing daylight with minimal solar gain
## (All are low-E as well)

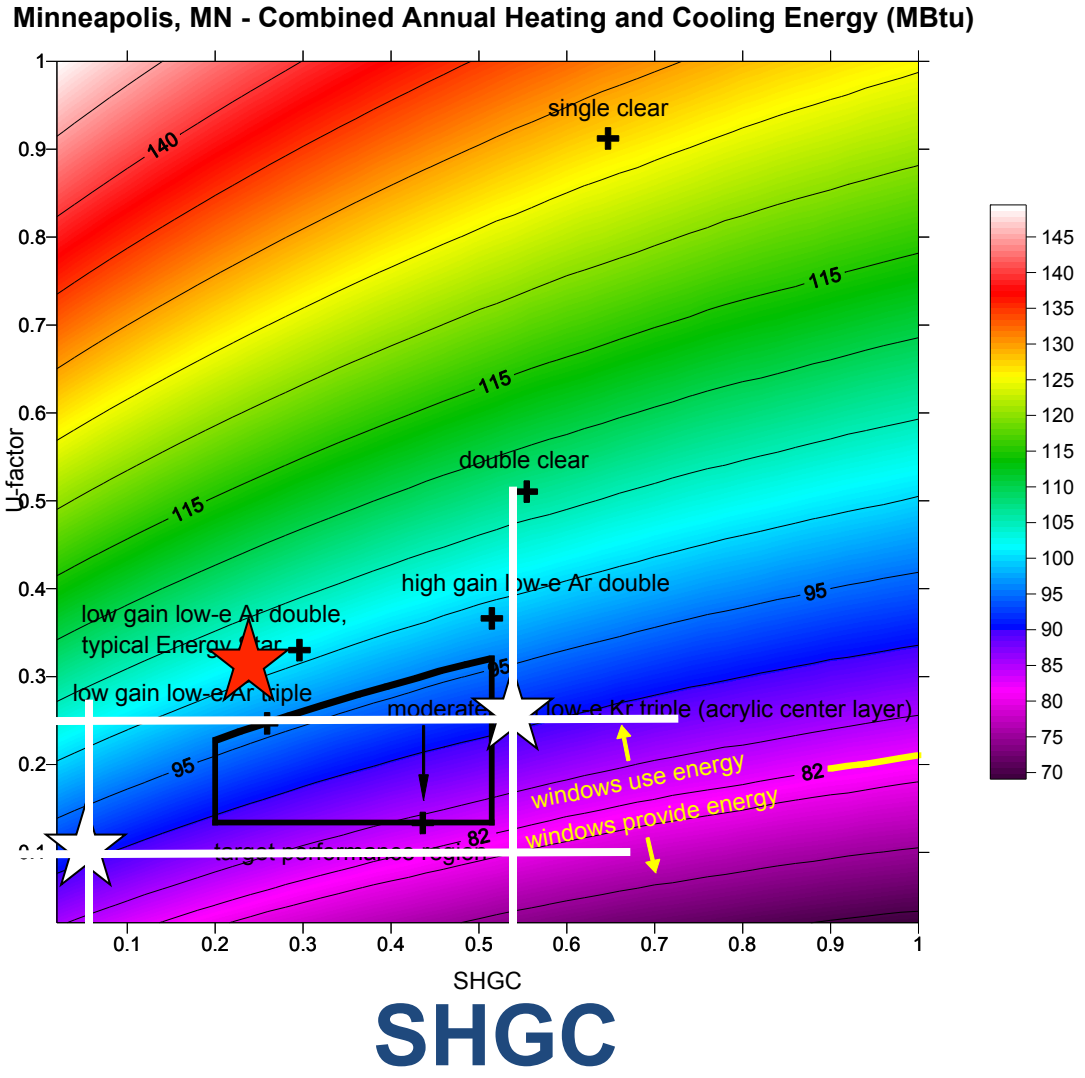
Spectral transmittance curves for common tinted and spectrally selective glazings



# Minneapolis: Heating Climate:

## static high solar, hi-R (U=0.1 Btu/h-ft2-F) can meet ZEH goals
## Tradeoffs possible between U and SHGC for "equal energy"

### Annual energy use vs. window properties




U

SHGC

Red star: Energy Star window

White star: two high perf windows with equal energy use

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

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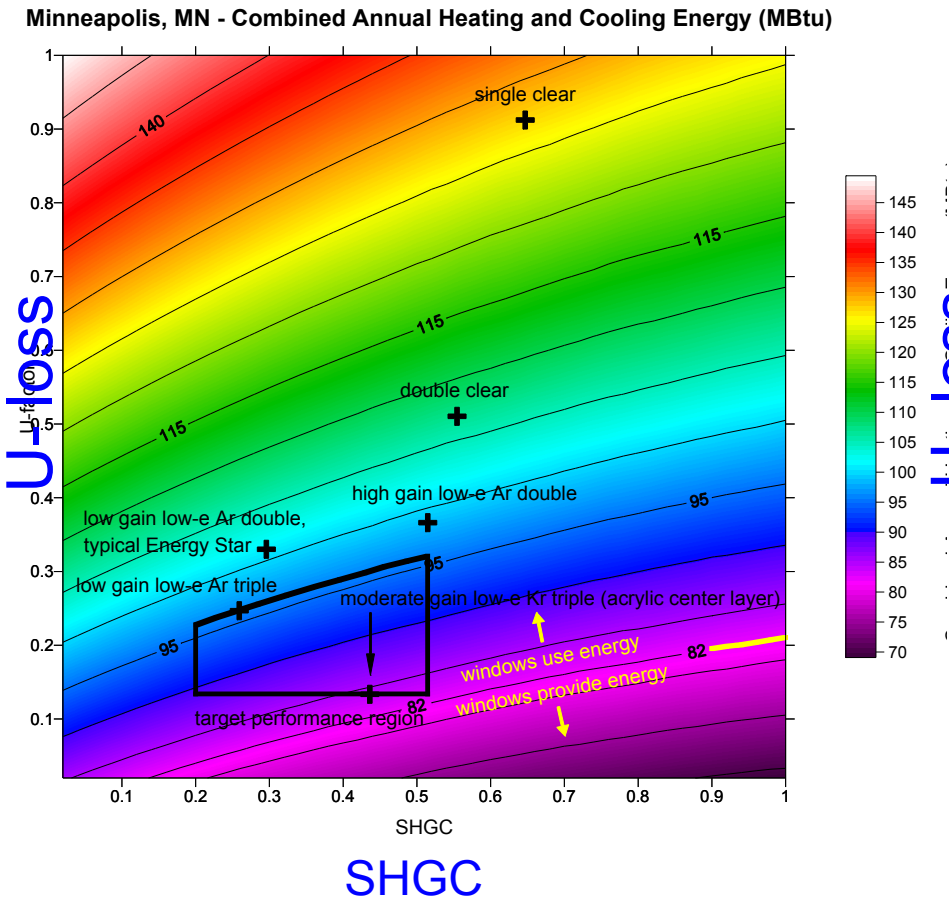
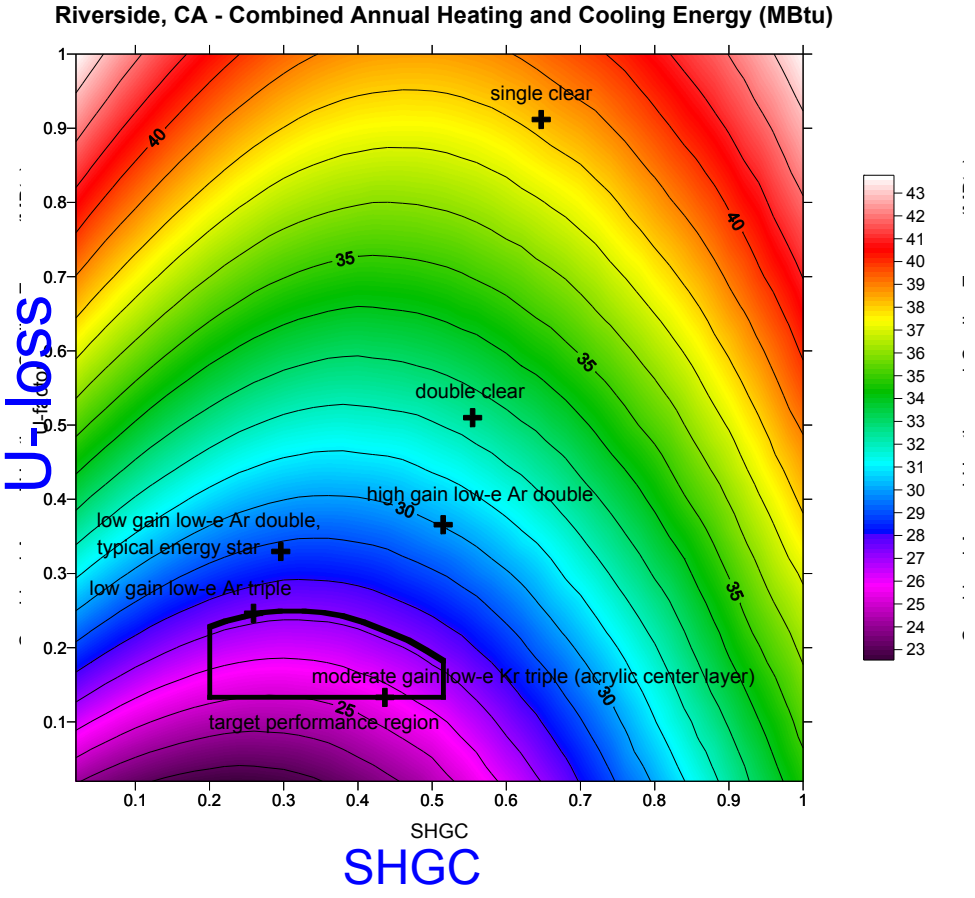
# Darwin's Finchs: Adapting to Climate?
# Minneapolis MN vs Riverside CA
## (plots of equal energy use differ dramatically by climate)

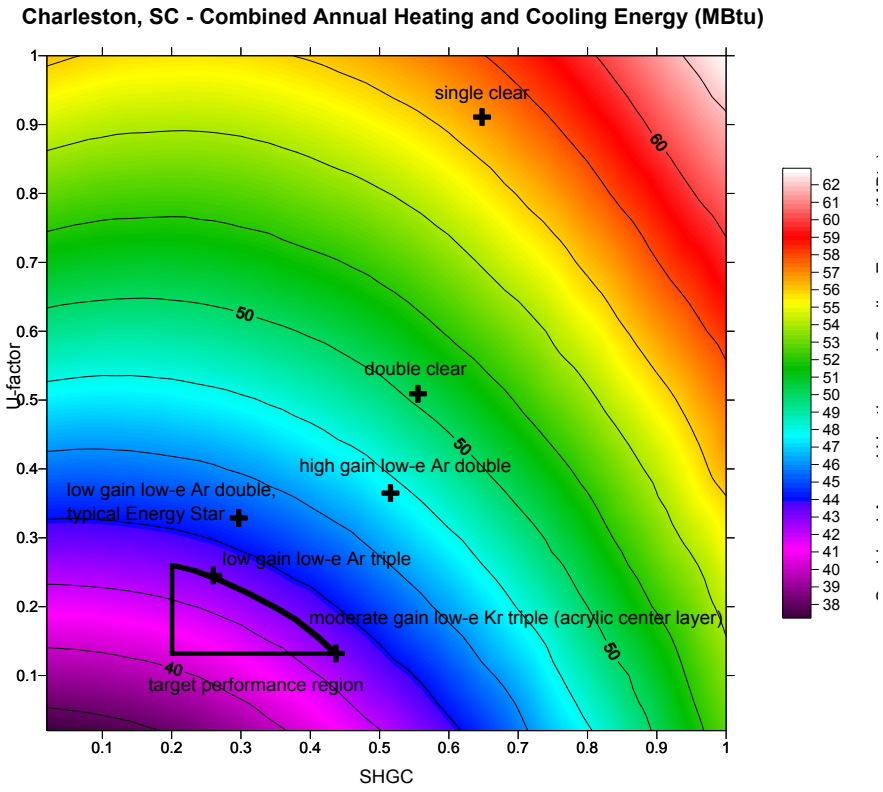


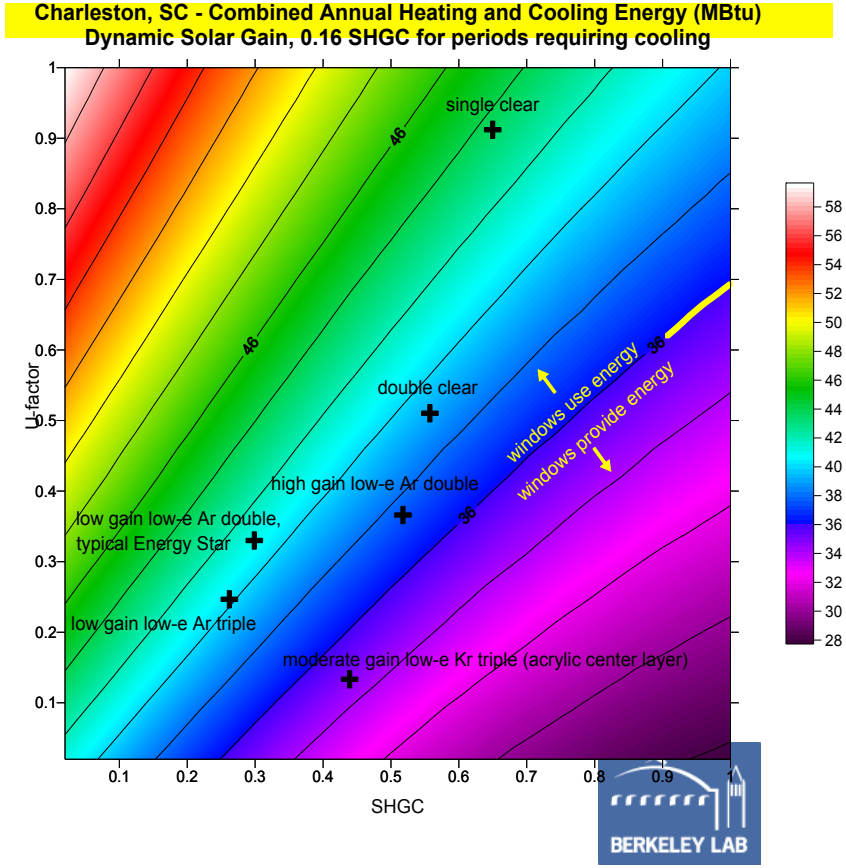



# Static vs Dynamic Solar Control Create Dramatically Different Energy Profiles: Charleston, SC - Cooling Climates:

## Left: Conventional Static Window

## Right: Dynamic or ultra-low-solar, hi-R (U=0.1-0.3 Btu/h-ft2-F) approaches ZEH goals



# **Impact of Incremental Insulation Improvements:** Reductions with Alternate Glazing Improvements to 3 Base Windows

## % Reduction in Heat Loss by Adding Rx to Base Window $$ Savings Associated with Each

| Added R-> Base Window | R1 | R2 | R3 | R5 | R8 | Initial Value |
|---|---|---|---|---|---|---|
| Single U= 1.1 | 50% | 67% | 75% | 85% | 90% | $1.00 |
| Double Clear U= .5 | 33% | 50% | 60% | 72% | 80% | $0.50 |
| Double Low-E U= .25 | 20% | 33% | 42% | 55% | 67% | $0.25 |

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# Single Glazing "Add-on" Issues

- Where to intervene:
  - Glass, Sash, Window
  - Modify window or "add-on" **attachments**
  - Different impacts of each
- Business Models for Retrofit
- New Technology Options
- Tool for parametric analysis of properties and energy impacts

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# WINDOW ATTACHMENTS

***Window attachments (coverings) are products added to existing windows to:***

- improve energy performance, comfort, glare, privacy, security, or enhance the appearance of a home.
- The primary energy impact from the attachments is ability **to reduce U, manage SHGC and Tv and/or reduce air leakage**

- **Exterior attachments:**


Low-e Storm Window


Fixed Awning

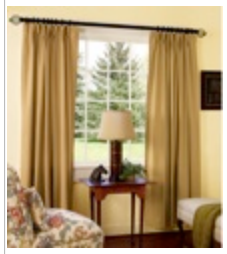

Dynamic Awning

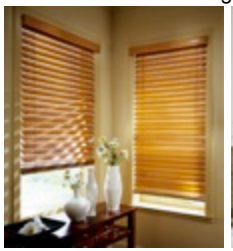

Roller Shutter - Window


Roller shade

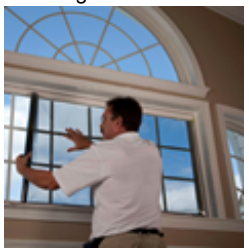

Solar screen

- **Interior attachments:**


Drapes

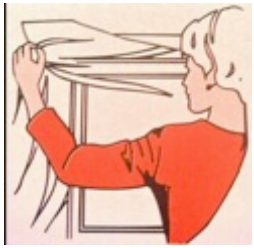

Louvered blinds


Roller shades


Surface applied film

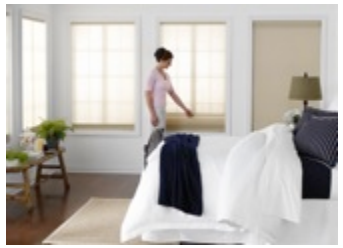

Cellular shade

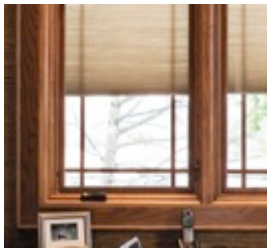

Window quilt


Seasonal film kit

- **Between Glass (applies to non-sealed glazing systems only – applied as a retrofit option):**


Louvered blinds


Roller shades


Cellular shades


Solar screens


Surface applied films

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# Existing Models for Single Glass Retrofit?

# Window Film Industry

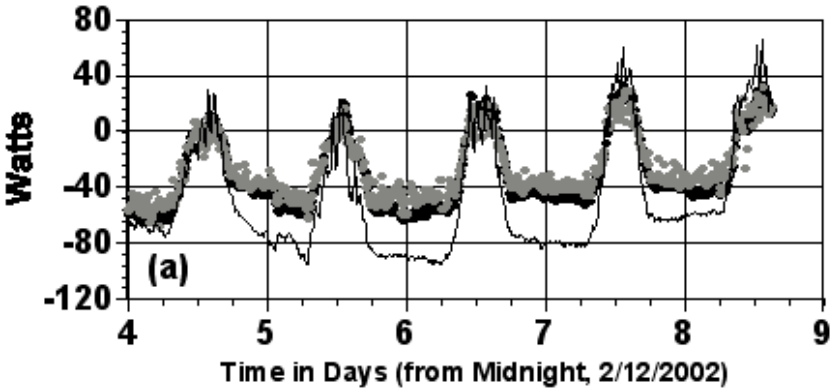
- Historical focus on solar control, (blast)
- New: Low-E options
  - E < .05
- Future:
  - Smart Coating
  - Insulating coatings

## Issues

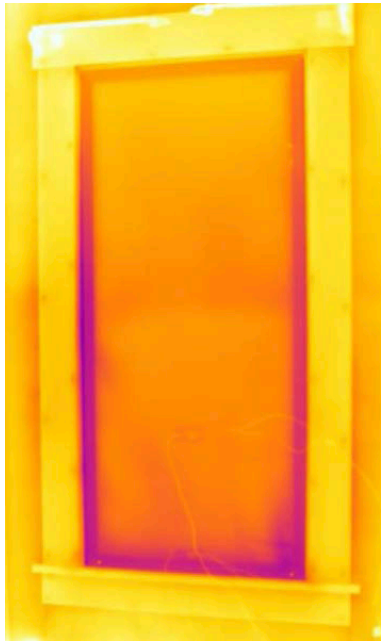
- Service models/costs:
  - On site “sizing”
  - Labor
- Cleaning
- Lifetime

# Existing Business Models: Storm Panels
## (interior and exterior low-E storms work well)
## (DOE Projects, Building America Webinar)

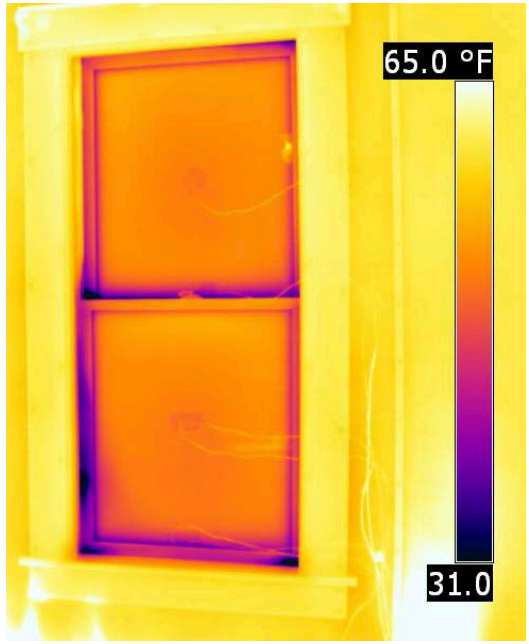
**2000: LBNL Field Testing - MoWiTT**
**Low-E Storms Added to Single Prime**
**~ = New Double Low-E**




**2011: LBNL Field IR Testing in Vermont**
**Interior Low-E Panels**



Interior Low-E Retrofit Panel




Low-E Sash Replacement

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# Existing Business Models: DIY

Home Energy Solutions

Products | Resources | Where To Buy | Contact

United States > All 3M Products > Home and Leisure > Home Energy Solutions > Home Energy Solutions > 3M™ Indoor Window Insulator Kit, 2 Windows

## 3M™ Indoor Window Insulator Kit, 2 Windows

Print Share


Available in a variety of indoor and outdoor window sizes, 3M™ Window Insulator Kits keep cold drafts out and warm air in through heat shrink window film and Scotch® Window Film Mounting Tape. Easy to install, 3M™ window kits have the clearest film and stay up all season long with Scotch® tape technology.

- Clearest window film available
- Scotch® double sided tape holds firmly between films and surfaces
- Saves energy and reduces heating costs

**Need Help?**

**Questions?** We can help
Contact Us

Save

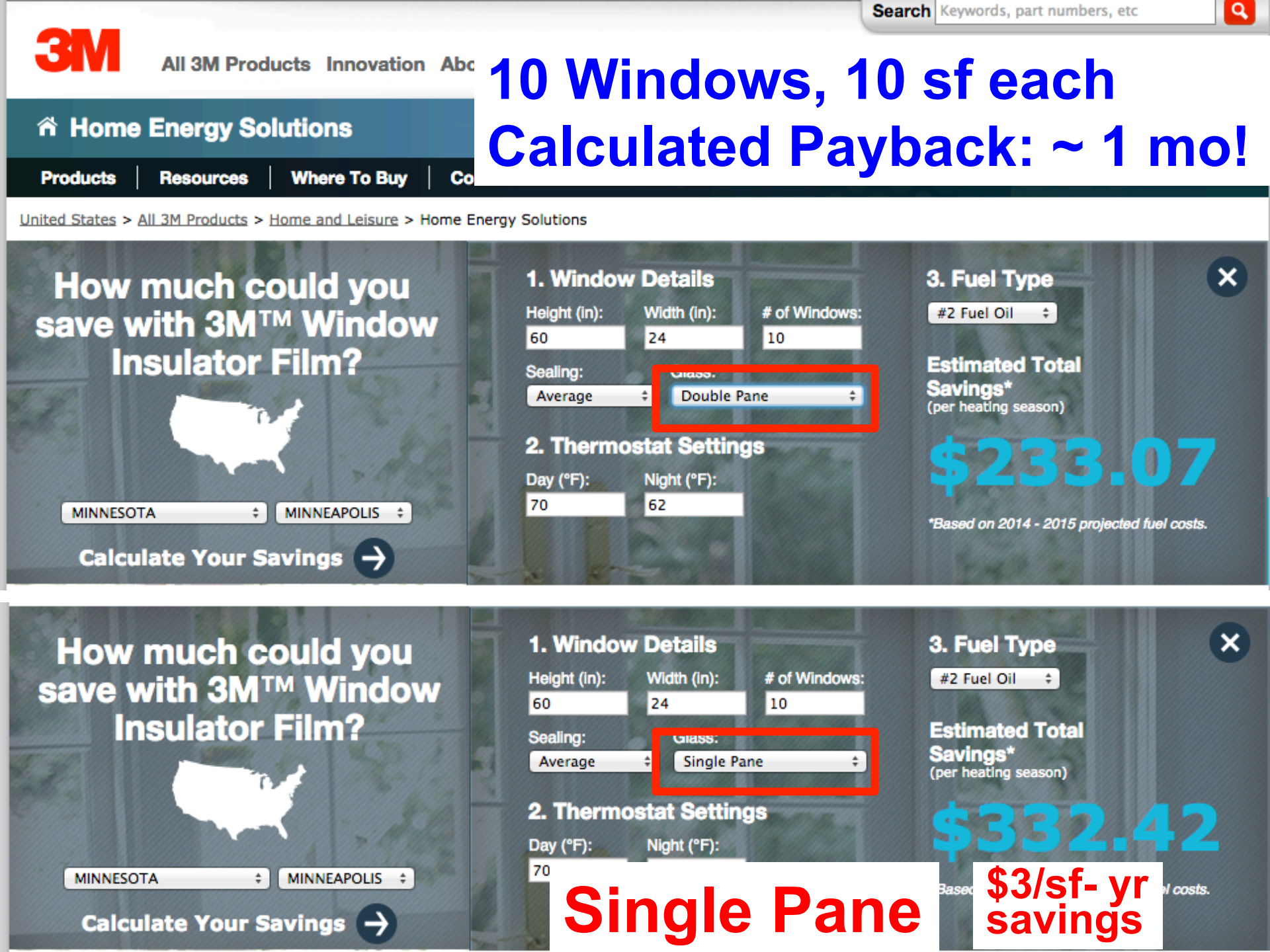
Overview | Related Products | Reviews


3M Indoor Window Insulator Kit, 5-Window
by 3M

$12.99 $22.54 Prime
Get it by Friday, Nov 7

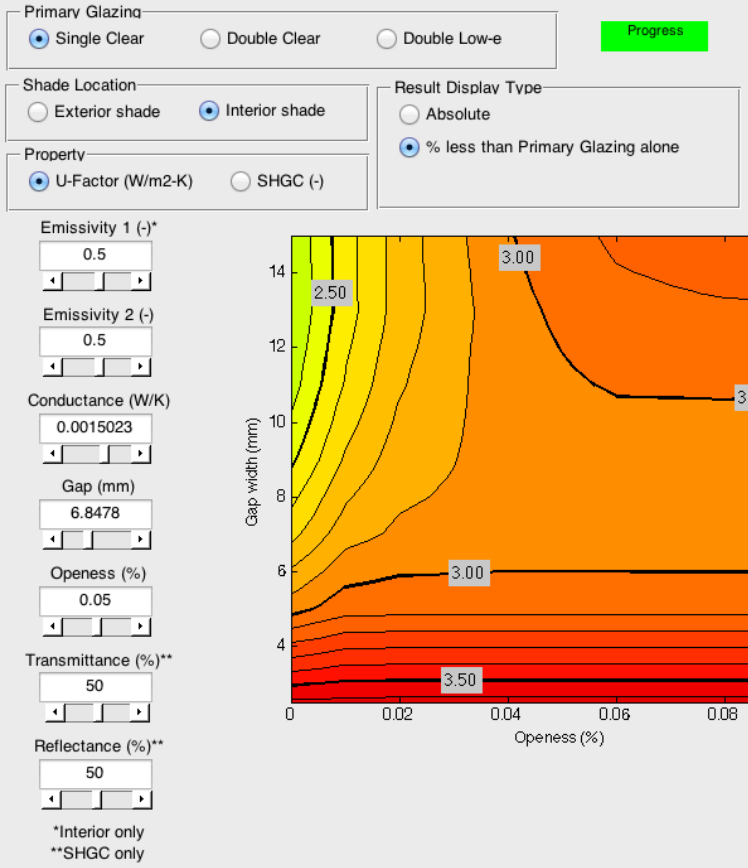
More Buying Choices
$12.85 new (49 offers)
$12.08 used (1 offer)

**Cost: $3/window ~$.30/sf**


Search
Keywords, part numbers, etc
3M
All 3M Products
Innovation
Abc
10 Windows, 10 sf each
Calculated Payback: ~ 1 mo!
Home Energy Solutions
Products
Resources
Where To Buy
United States > All 3M Products > Home and Leisure > Home Energy Solutions
How much could you save with 3M™ Window Insulator Film?
MINNESOTA
MINNEAPOLIS
Calculate Your Savings
1. Window Details
Height (in):
Width (in):
# of Windows:
60
24
10
Sealing:
Average
Glass:
Double Pane
2. Thermostat Settings
Day (°F):
Night (°F):
70
62
3. Fuel Type
#2 Fuel Oil
Estimated Total Savings*
(per heating season)
$233.07
*Based on 2014 - 2015 projected fuel costs.
How much could you save with 3M™ Window Insulator Film?
MINNESOTA
MINNEAPOLIS
Calculate Your Savings
1. Window Details
Height (in):
Width (in):
# of Windows:
60
24
10
Sealing:
Average
Glass:
Single Pane
2. Thermostat Settings
Day (°F):
Night (°F):
70
3. Fuel Type
#2 Fuel Oil
Estimated Total Savings*
(per heating season)
$332.42
Single Pane
$3/sf- yr savings

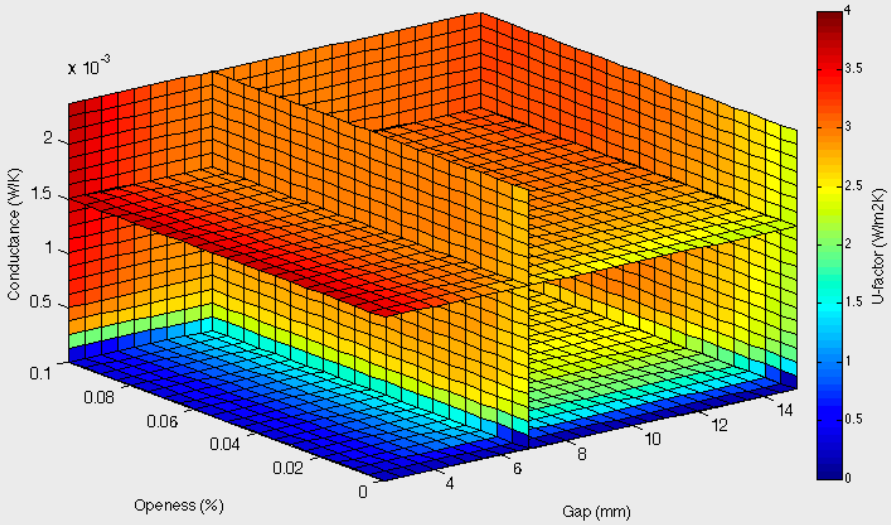
# New Designs/Materials - What is Possible?

## Prototype MATLAB Tool to Assess Window System Properties as a function of “Window Add-on Parameters”









# What's Possible?

Representative Conductance values

| Materials | C (W/m2K) | R (m2K/W) |
|---|---|---|
| 2.5 mm air | 12.2 | 0.082 |
| 3mm glass | 333.3 | 0.003 |
| 1mm Aerogel* | 17.0 | 0.059 |
| 1mm ev Aerogel** | 8.0 | 0.125 |
| 10mm Aerogel* | 1.7 | 0.588 |
| 10mm ev Aerogel** | 0.8 | 1.250 |
| 100mm Aerogel* | 0.2 | 5.882 |
| 100mm ev Aerogel** | 0.1 | 12.500 |

*typical aerogel 0.017W/mK

**evacuated aerogel 0.008 W/mK

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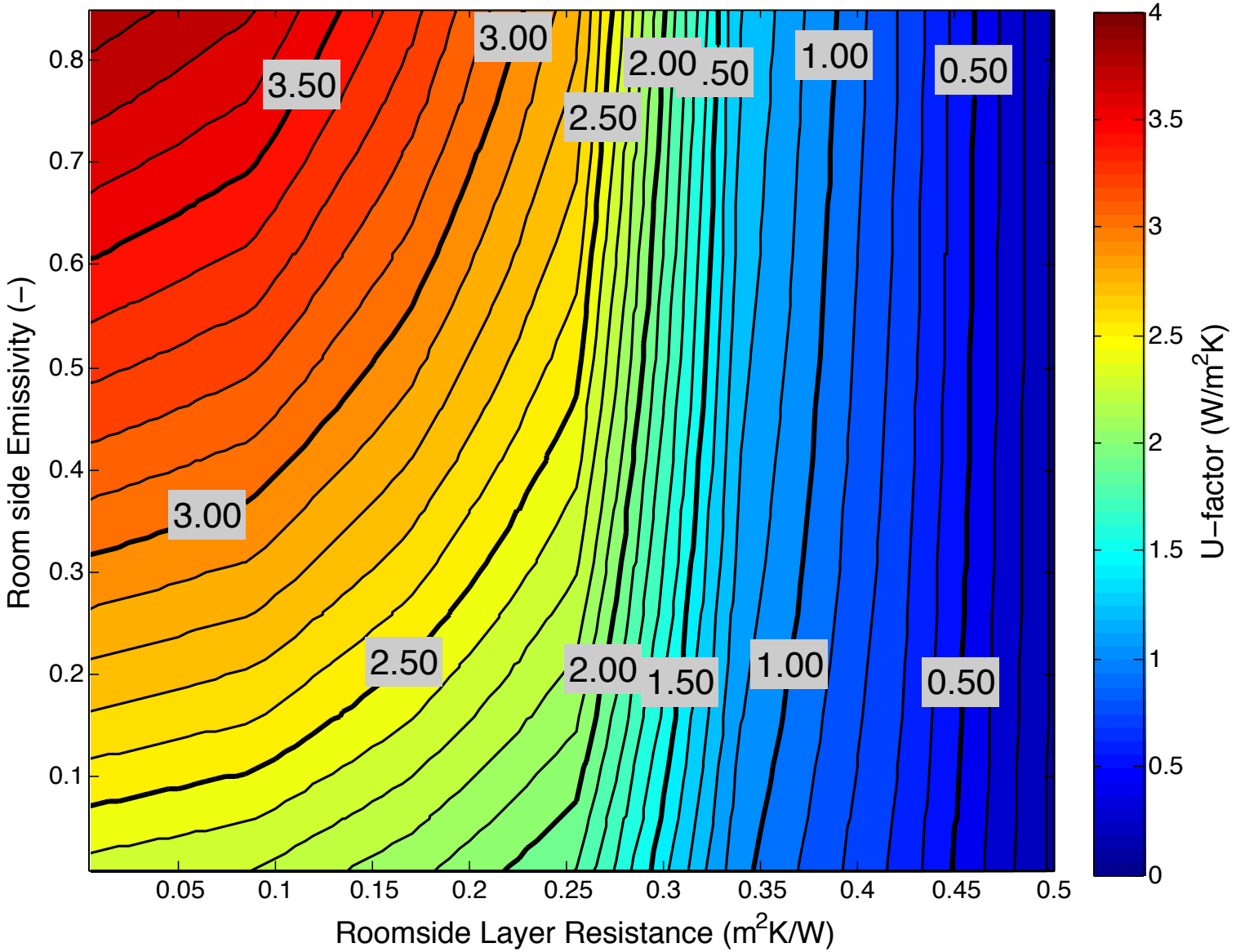
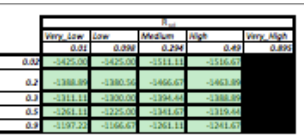
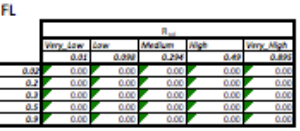
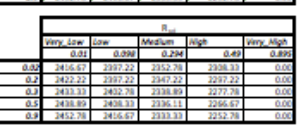
# Overall U as a function of added layer thermal resistance and room side emissivity

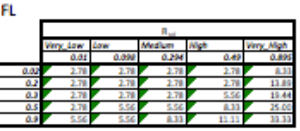


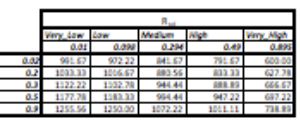
# Examples: Maps of Annual Energy Use vs Thermal Properties (U, E, SHGC)

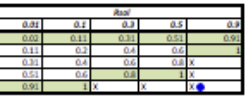


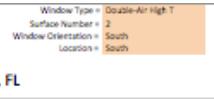


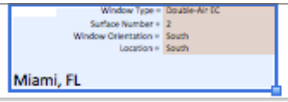


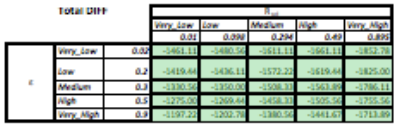


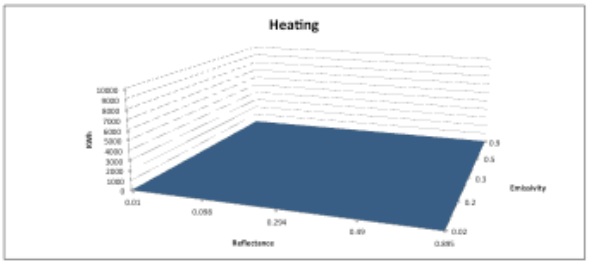


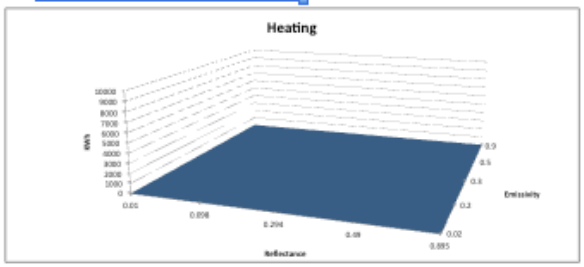


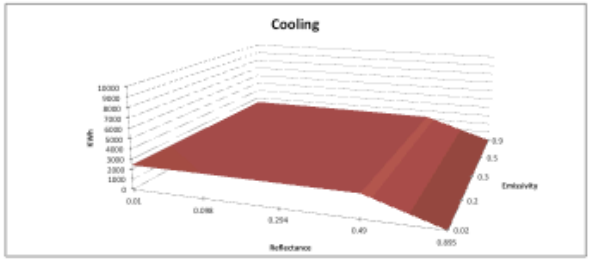


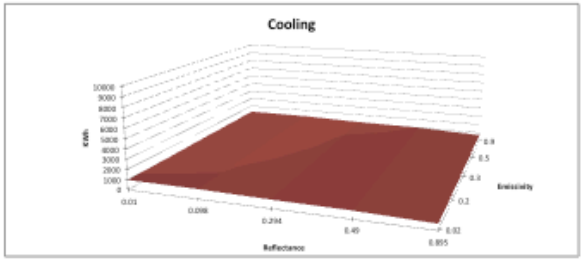


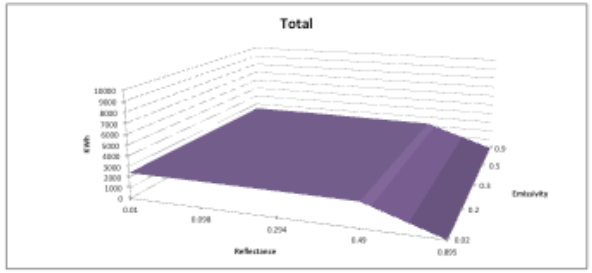


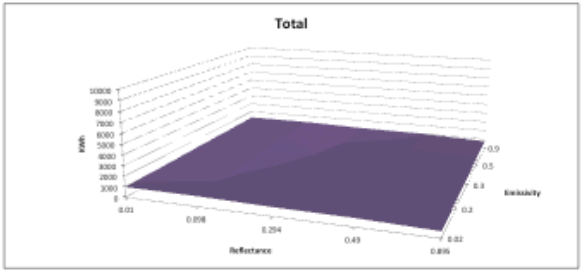


# Requirements for High Performance Insulating "Glazing" Layers

**Table 1.** Proposed requirements of the future high performance thermal insulation materials and solutions.

| Property | Requirements |
|---|---|
| Thermal conductivity – pristine | <4 mW/(mK) |
| Thermal conductivity – after 100 years | <5 mW/(mK) |
| Thermal conductivity – after modest perforation | <4 mW/(mK) |
| Perforation vulnerability | Not to be influenced significantly |
| Possible to cut for adaption at building site | Yes |
| Mechanical strength (e.g. compression and tensile) | May vary |
| Fire protection | May vary, depends on other protection |
| Fume emission during fire | Any toxic gases to be identified |
| Climate aging durability | Resistant |
| Freezing/thawing cycles | Resistant |
| Water | Resistant |
| Dynamic thermal insulation | Desirable as an ultimate goal |
| Costs vs other thermal insulation materials | Competitive |
| Environmental impact (including energy and material use in production, emission of polluting agents and recycling issues) | Low negative impact |

Jelle et al, *Journal of Building Physics* 2010 34: 99

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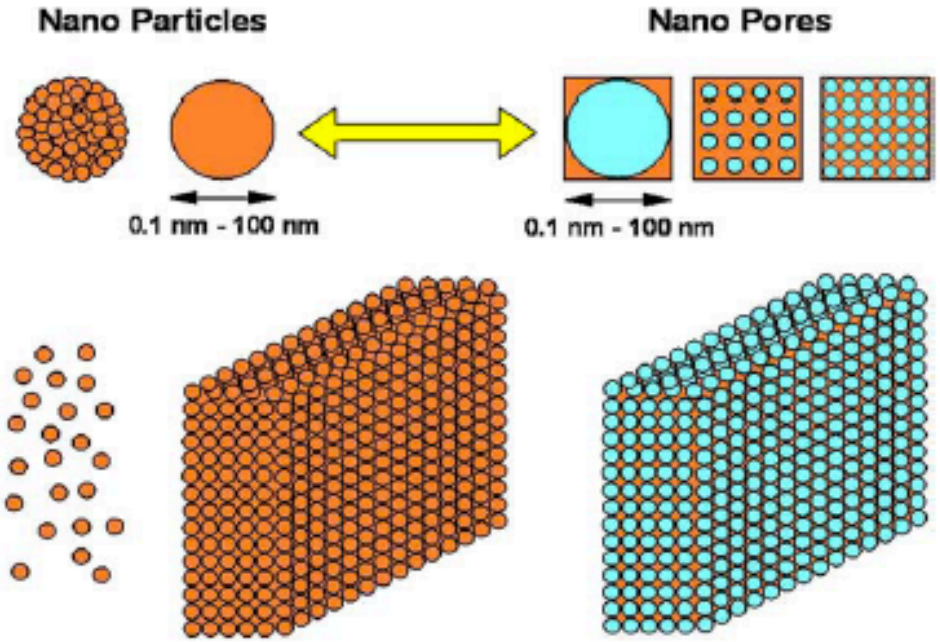
# Nano- Insulating Materials

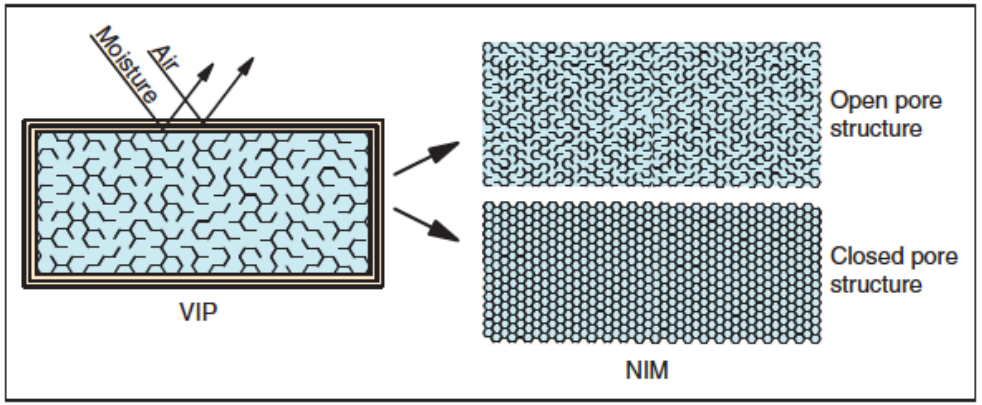
B.P. Jelle / Energy and Buildings 43 (2011) 2549–2563

**Nanotechnology:**
**Technology for controlling matter of dimensions between 0.1 nm - 100 nm.**


For comparison: Solar radiation: 300 nm - 3000 nm
Atomic diameters: Hydrogen: 0.16 nm
Carbon: 0.18 nm
Gold: 0.36 nm
Molecular length: Stearic Acid: 2.48 nm
($C_{17}H_{35}COOH$)

**Nanotechnology:**
**Technology for controlling matter at an atomic and molecular scale.**

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# Comparative Performance of Insulating "Glazing" Layers

| Thermal insulation materials and solutions | Low pristine thermal conductivity | Low long-term thermal conductivity | Perforation robustness | Possible building site adaption cutting | A thermal insulation material and solution of tomorrow? |
|---|---|---|---|---|---|
| *Traditional* | | | | | |
| Mineral wool and polystyrene | No | No | Yes | Yes | No |
| *Today's state-of-the-art* | | | | | |
| Vacuum insulation panels | Yes | Maybe | No | No | Today and near future |
| Gas-filled panels | Maybe | Maybe | No | No | Probably not, near future |
| Aerogels | Maybe | Maybe | Yes | Yes | Maybe |
| Phase change materials | – | – | – | – | Heat storage and release |
| *Beyond state-of-the-art – advanced insulation materials* | | | | | |
| Vacuum insulation materials | Yes | Maybe | Yes | Yes | Yes |
| Gas insulation materials | Yes | Maybe | Yes | Yes | Maybe |
| Nano insulation materials | Yes | Yes | Yes, excellent | Yes, excellent | Yes, excellent |
| Dynamic insulation materials | Maybe | Maybe | Not known | Not known | Yes, excellent |
| Others? | – | – | – | – | Maybe |

Table 2 from Jelle et al, *Journal of Building Physics* 2010 34: 99

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# How Can Simulation Tools Help Inform the Search for Solutions?

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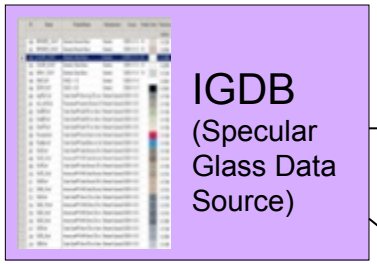
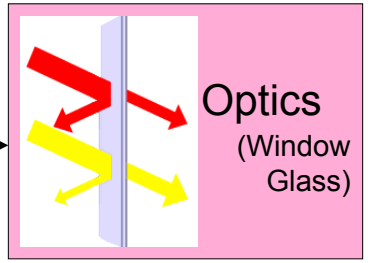
# Tools for Glazing Window and Façade Decision

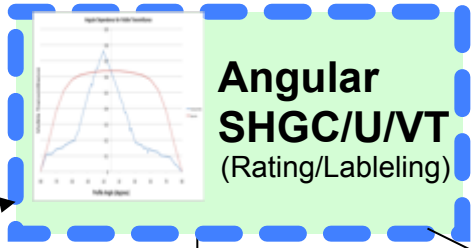
**Download http://windows.lbl.gov/software/ FY13 ~ 40,000 Downloads; ~2000 uses/day**



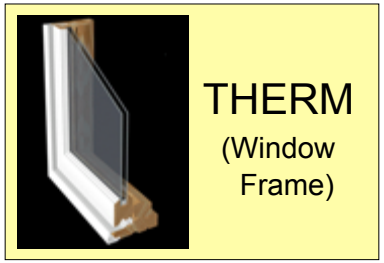
IGDB
(Specular Glass Data Source)



Optics
(Window Glass)

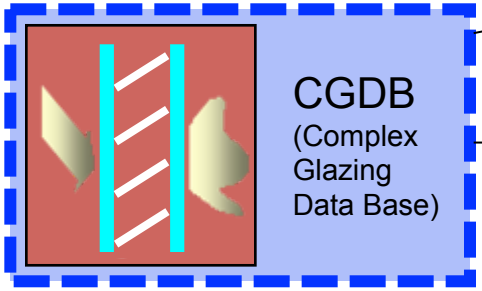


**Angular SHGC/U/VT**
(Rating/Labeling)



THERM
(Window Frame)

?



CGDB
(Complex Glazing Data Base)

WINDOW
+
Shading Systems
(Whole Window)

**NFRC Ratings and Labels**

**Energy Star**

Radiance
Lighting /Daylighting

COMFEN
(Whole Building Commercial)

RESFEN
(Whole Building Residential)

Commercial Windows Website Efficient Windows Website

**Design /Simulation Tools**

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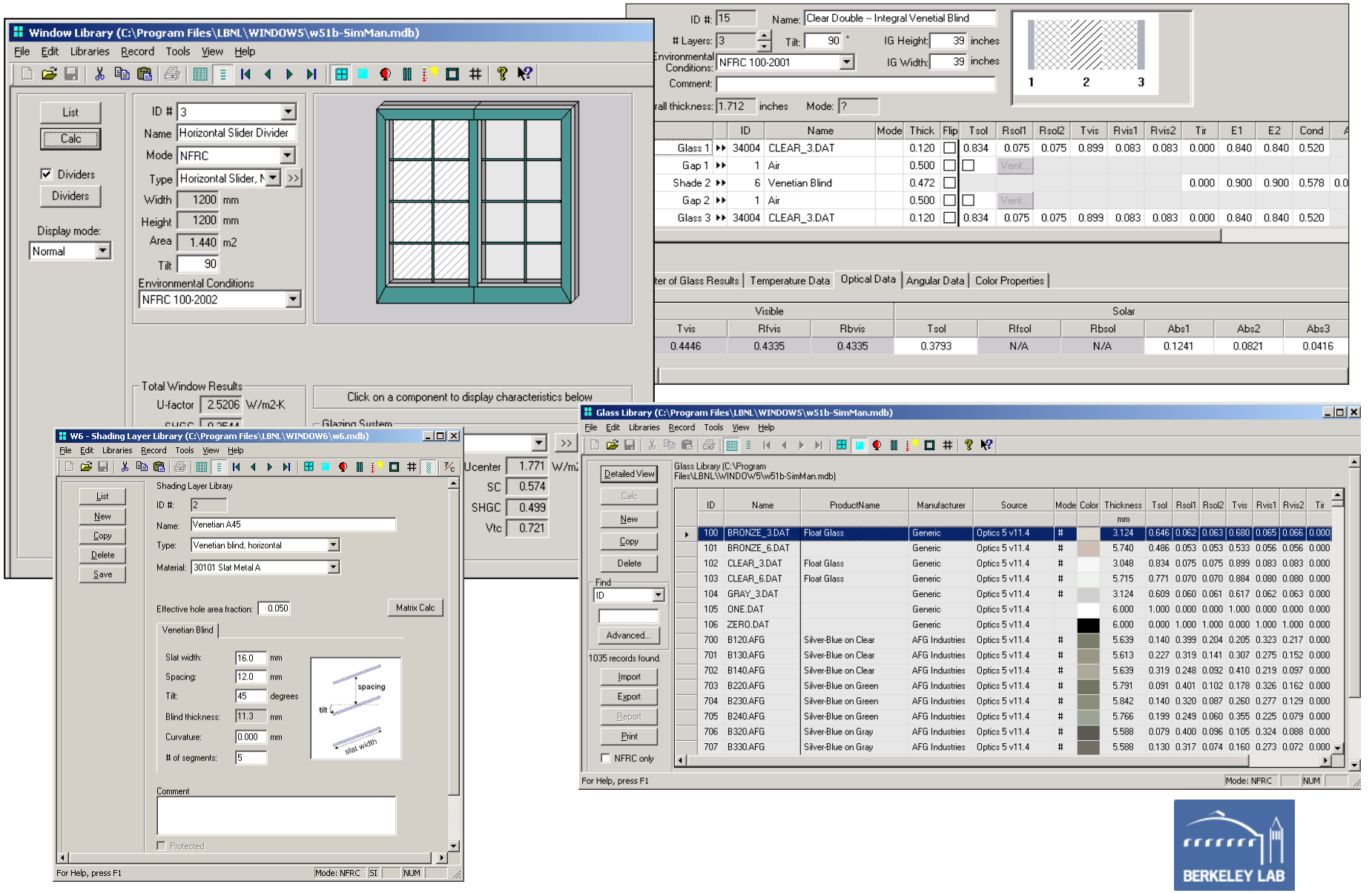
# WINDOW: Glazing System and Whole Product Tool

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# Ultimately Any "Product" will Need NFRC Data and Ratings….


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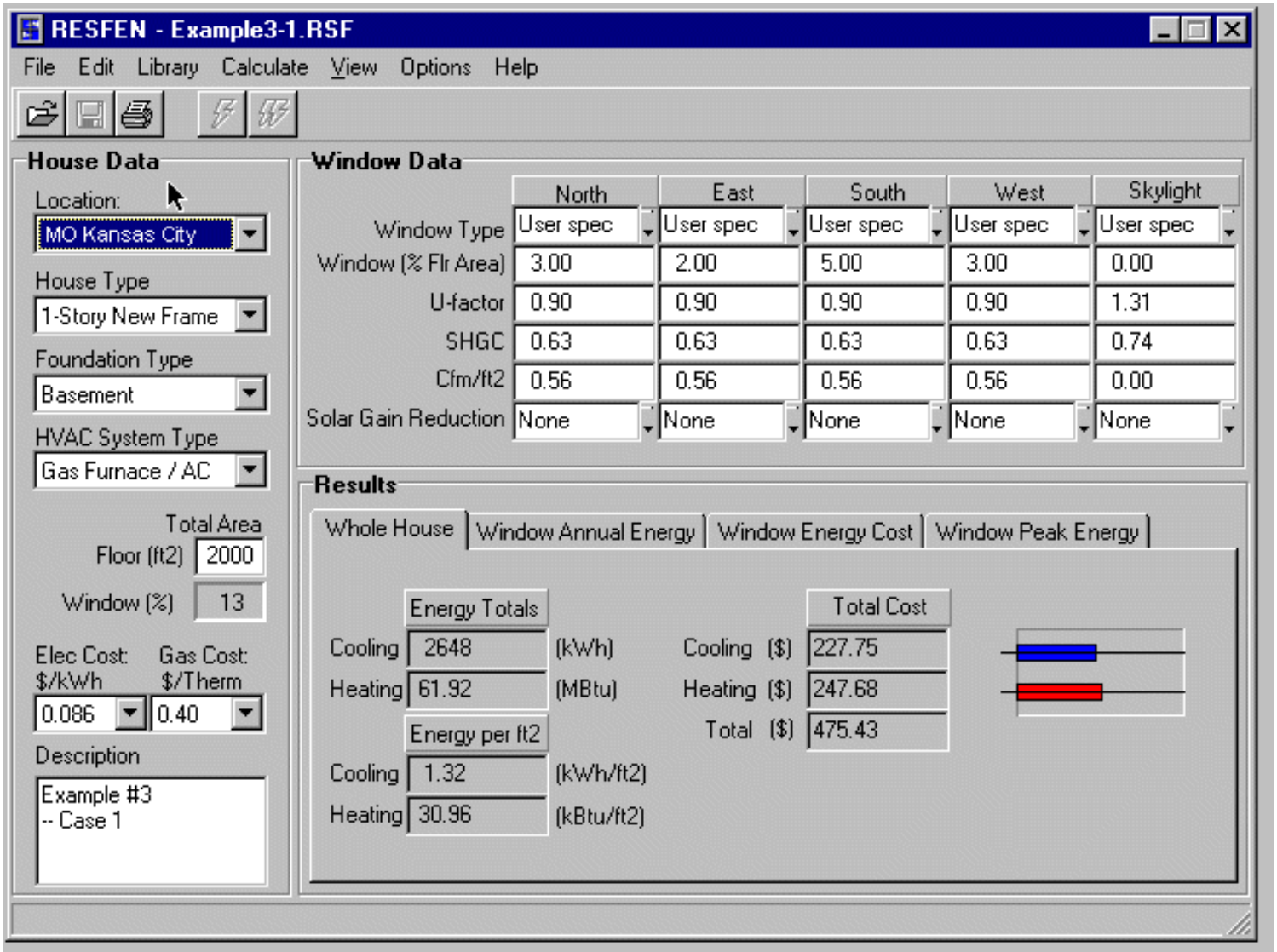
# RESFEN Window Selection Tool: Annual Energy Calculator

Annual energy vs properties, location, orientation, shading, house type, etc

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# RESIDENTIAL EFFICIENT WINDOWS COLLABORATIVE
# www.efficientwindows.org

Efficient Windows Collaborative

Home » Window Selection

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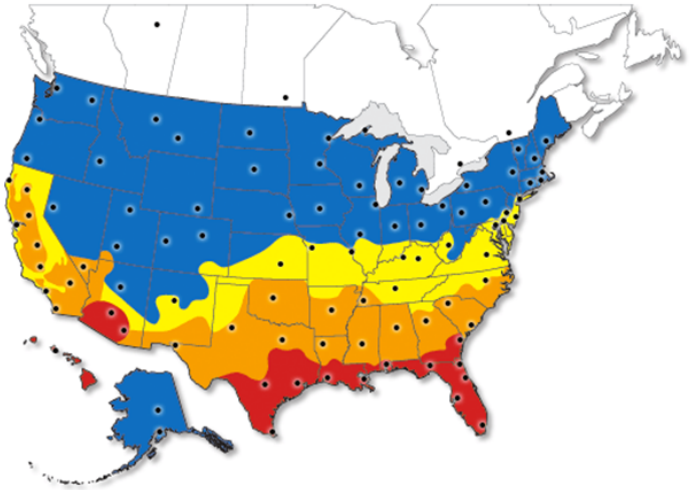
WINDOW SELECTION TOOL | WINDOW TECHNOLOGIES | BENEFITS

## Window Selection Tool

**Compare Annual Energy Cost**

- Compare how various window or skylight types affect estimated energy cost for a typical house in your location;
- Find manufacturers who offer windows and skylights within the categories shown;
- Learn more about manufacturers' specific product options.

These comparisons assume average conditions. The effect of windows on your specific home's heating and cooling costs may vary depending on glazing area, shading, and orientation, but also on thermostat setpoints, equipment efficiency, etc.



**Other Factors to Consider**

In addition to energy use, you may also want to consider the non-energy benefits of

**Select a condition:**
(•) New Construction
( ) Existing Construction

**Select a type:**
(•) Windows
( ) Skylights

**Select a city:**
MN Minneapolis

Compare Energy Costs

**American Architectural Manufactu Association (AAMA):**
AAMA is the premier source for performance standards, product certification and educational programs AAMA's over 250 members represent both the residential and commercial window, door and skylight industry. T AAMA online Certified Products Directory is a resource for locating products to achieve air, water, struct and forced entry resistance code compliance.

AAMA

**Window & Door Manufacturers Association (WDMA):**
WDMA is a trade association

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Home » Window Selection » Minneapolis, MN

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WINDOW SELECTION TOOL | WINDOW TECHNOLOGIES | BENEFITS

## Minneapolis , Minnesota

**Energy Costs**
Natural Gas: $0.991/therm
Electricity: $0.097/kWh


Minnesota Factsheet
State Code Information

**Window Search**

Select Glass: [All glass types]
Select Frame: [All frame types]
ENERGY STAR®: Yes
Construction Type: New (•) Existing ( )
Product Type: Windows (•) Skylights ( )
Search for Windows

| Window Types | Properties | Annual Energy Use | Manufacturer Information | ENERGY STAR® Qualified |
|---|---|---|---|---|
| Window 28 Triple-glazed, Medium-solar-gain Low-E Glass, Argon/Krypton Gas Non-metal Frame, Thermally Improved | U = ≤0.20 SHGC = 0.26-0.40 VT = 0.41-0.50 | $0 $300 $600 $900 $1200 | Products | yes |
| Window 29 Triple-glazed, Low-Solar-Gain Low-E Glass, Argon/Krypton Gas Non-metal Frame, Thermally Improved | U = ≤0.20 SHGC = ≤0.25 VT = ≤0.40 | $0 $300 $600 $900 $1200 | Products | yes |
| Window 23 Triple-glazed, Medium-solar-gain Low-E Glass, Argon/Krypton Gas Non-metal Frame | U = 0.21-0.25 SHGC = 0.26-0.40 VT = 0.41-0.50 | $0 $300 $600 $900 $1200 | Products | yes |
| Window 24 Triple-glazed, Low-Solar-Gain Low-E Glass, Argon/Krypton Gas Non-metal Frame | U = 0.21-0.25 SHGC = ≤0.25 VT = ≤0.40 | $0 $300 $600 $900 $1200 | Products | yes |

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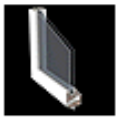
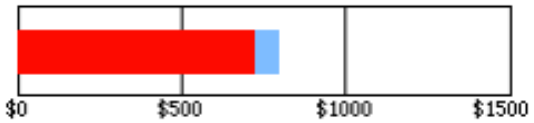
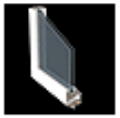
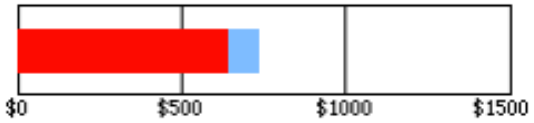
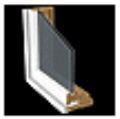
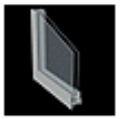
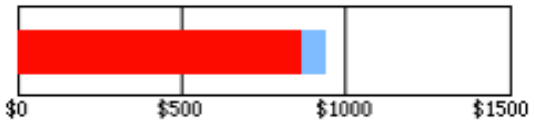
# WEB-BASED QUANTITATIVE PRODUCT SELECTION TOOL

- Example of Window Selection Tool (efficientwindows.org)

| Window Types | | Properties | Annual Energy Use |
|---|---|---|---|
|  | Window 27<br>Double-glazed, Low-solar-gain<br>Low-E Glass, Argon/Krypton Gas<br>Non-metal Frame, Thermally Improved | U = 0.26-0.30<br>SHGC = ≤0.25<br>VT = 0.41-0.50 |  |
|  | Window 22<br>Double-glazed, Low-solar-gain<br>Low-E Glass, Argon/Krypton Gas<br>Non-metal Frame | U = 0.31-0.40<br>SHGC = ≤0.25<br>VT = 0.41-0.50 |  |
|  | Window 29<br>Triple-glazed, Low-Solar-Gain<br>Low-E Glass, Argon/Krypton Gas<br>Non-metal Frame, Thermally Improved | U = ≤0.20<br>SHGC = ≤0.25<br>VT = ≤0.40 |  |
|  | Window 24<br>Triple-glazed, Low-Solar-Gain<br>Low-E Glass, Argon/Krypton Gas<br>Non-metal Frame | U = 0.21-0.25<br>SHGC = ≤0.25<br>VT = ≤0.40 |  |
|  | Window 14<br>Double-glazed, Low-solar-gain<br>Low-E Glass, Argon/Krypton Gas<br>Metal Frame with Thermal Break | U = 0.41-0.55<br>SHGC = ≤0.25<br>VT = 0.51-0.60 |  |

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# Summary: Trends and Needs….

- **Tremendous energy savings potential with single glazing retrofits**
- **Challenging markets-**
  - must balance technical performance vs cost, installation, aesthetics, view, Tv clarity, comfort, durability, house ownership, etc vs climate, orientation
  - Cost is a major limitation; product OEM cost <-> Installed cost
- **Applications Targets**:
  - Glass focus, but consider sash +/or frame
  - Interior or exterior "attachments"
  - Existing products and markets: int/ext retrofit panels; glue-on films
  - Sunbelt challenge: dynamic solar control
- **Technical challenges/opportunities**
  - H**eat Loss in cold climates** – minimize heat loss, but manage SHGC; optimal option might not be the lowest U
    - Increase of "only" R2-3 at low cost might be good starting option
    - New high R, transparent materials and coating options
  - **Solar Gain control in southern climates –** minimize solar gain
    - Static solutions exist
    - New Low Cost Dynamic control options?
  - All Climates: Higher cost options need higher performance to justify cost
    - Or- provide other important market value, e.g comfort, security

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# Benefits of with High Performance Windows

Improve Occupant Comfort, Satisfaction and Performance

Occupant

Add Value, Reduce Operating Costs

Building Owner

Reduce Energy, Greenhouse Gas Emissions

Planet

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# Available Information Resources

**Stephen Selkowitz**
**Building Technologies Department**
Lawrence Berkeley National Laboratory
Building 90-3111
Berkeley, CA 94720 USA
**E-mail:** SESelkowitz@lbl.gov

**More Info:**

**http://wem.lbl.gov**

**http:/facades.lbl.gov**

**Software Tools**
**http://windows.lbl.gov/software/**

http://windows.lbl.gov/resources/LBNLresources.pdf

Download a 7 page collection of 50 reports and websites at the URL above or scan with your smart phone below to get the PDF

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