A WINDOW on the Future:

The Role of Fenestration in Deep Energy Retrofit Success

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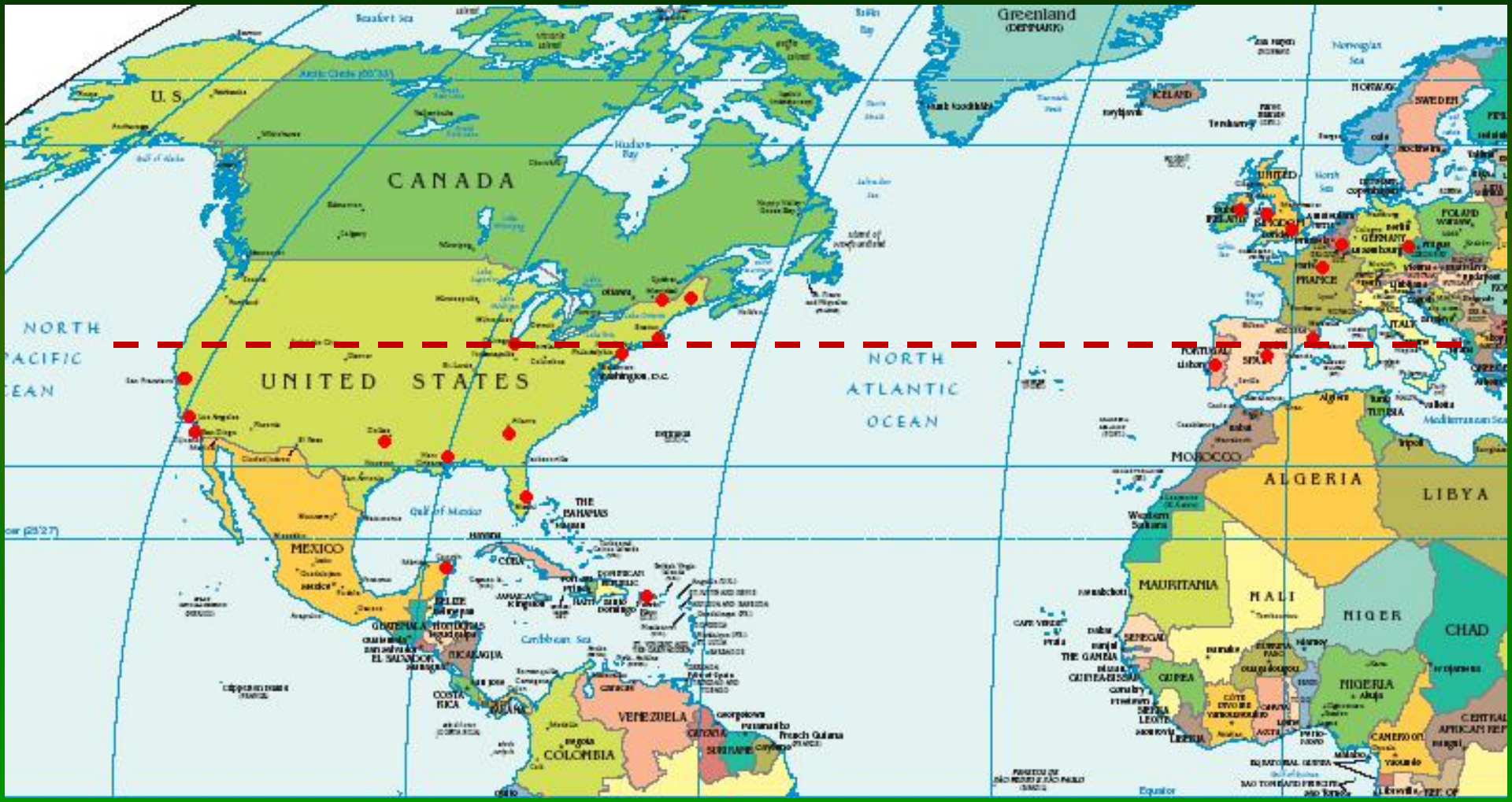
ASHRAE Distinguished Lecturer

The End in Mind

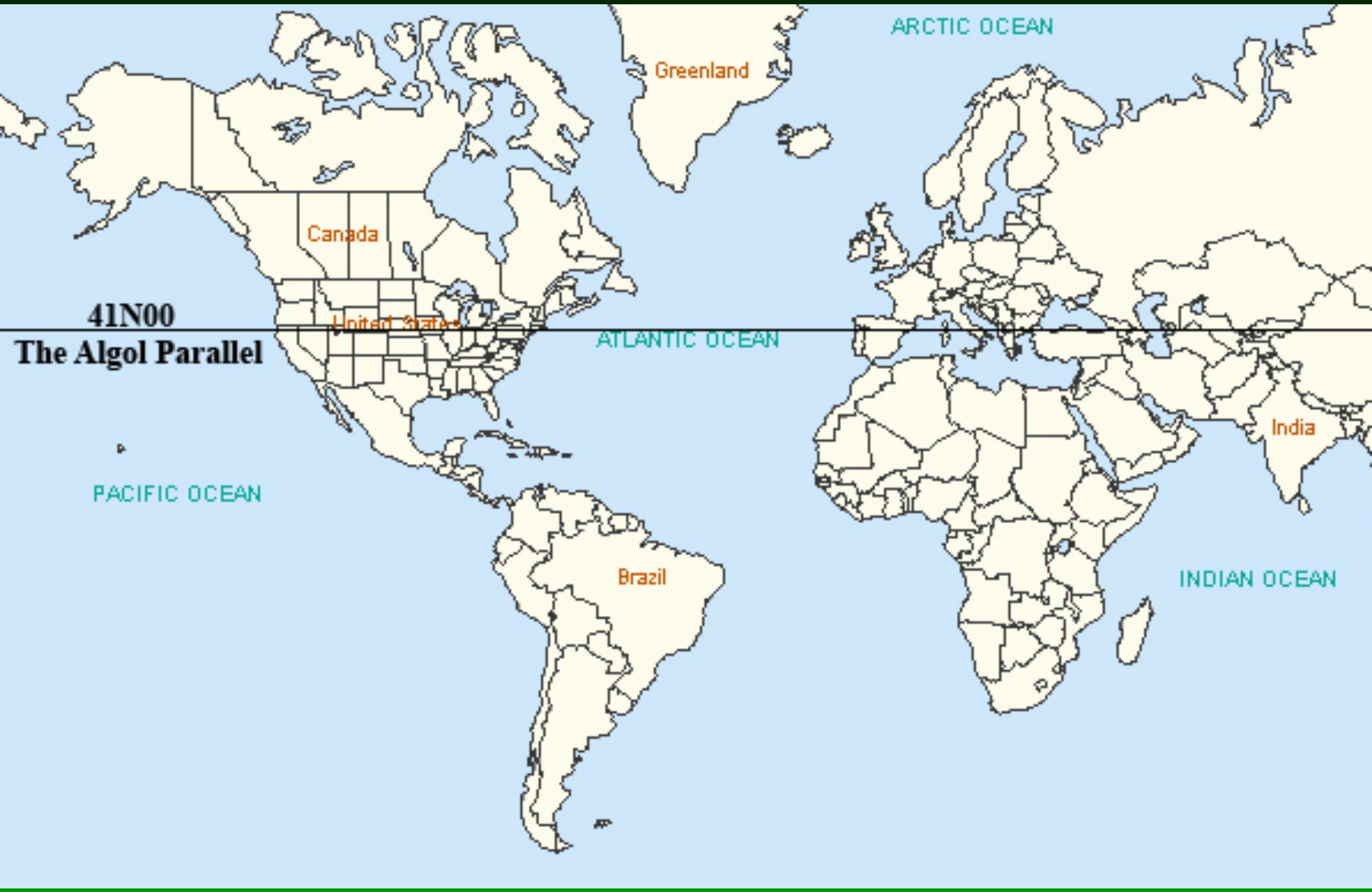
- **The Size of Things…**
  - Scale and implications of fenestration performance
- **Trends in Fenestration Performance**
  - Technological innovation and change
- **Implications for Deep Energy Retrofit Success**
  - Energy
  - Power
  - Comfort
  - Safety

First: Geography Reminder…



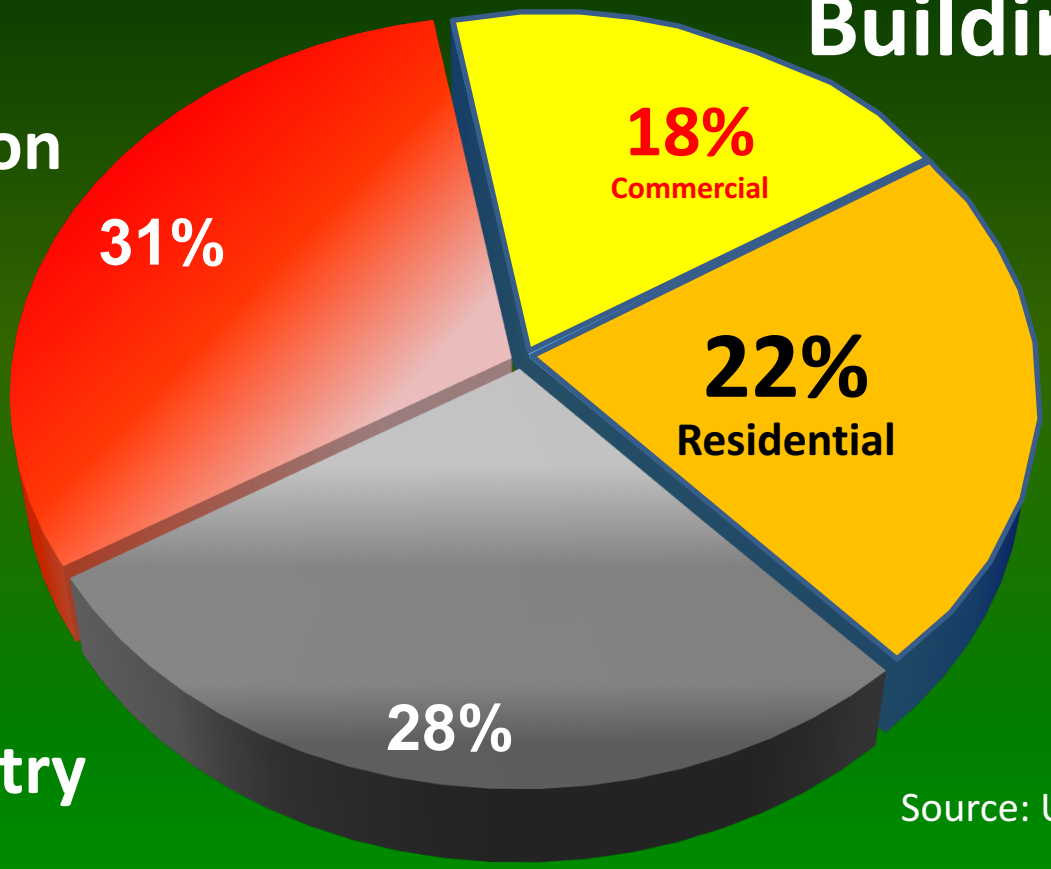
Perspective…

Reminder:


ARCTIC OCEAN
Greenland
Canada
41N00
The Algol Parallel
United States
ATLANTIC OCEAN
India
PACIFIC OCEAN
Brazil
INDIAN OCEAN

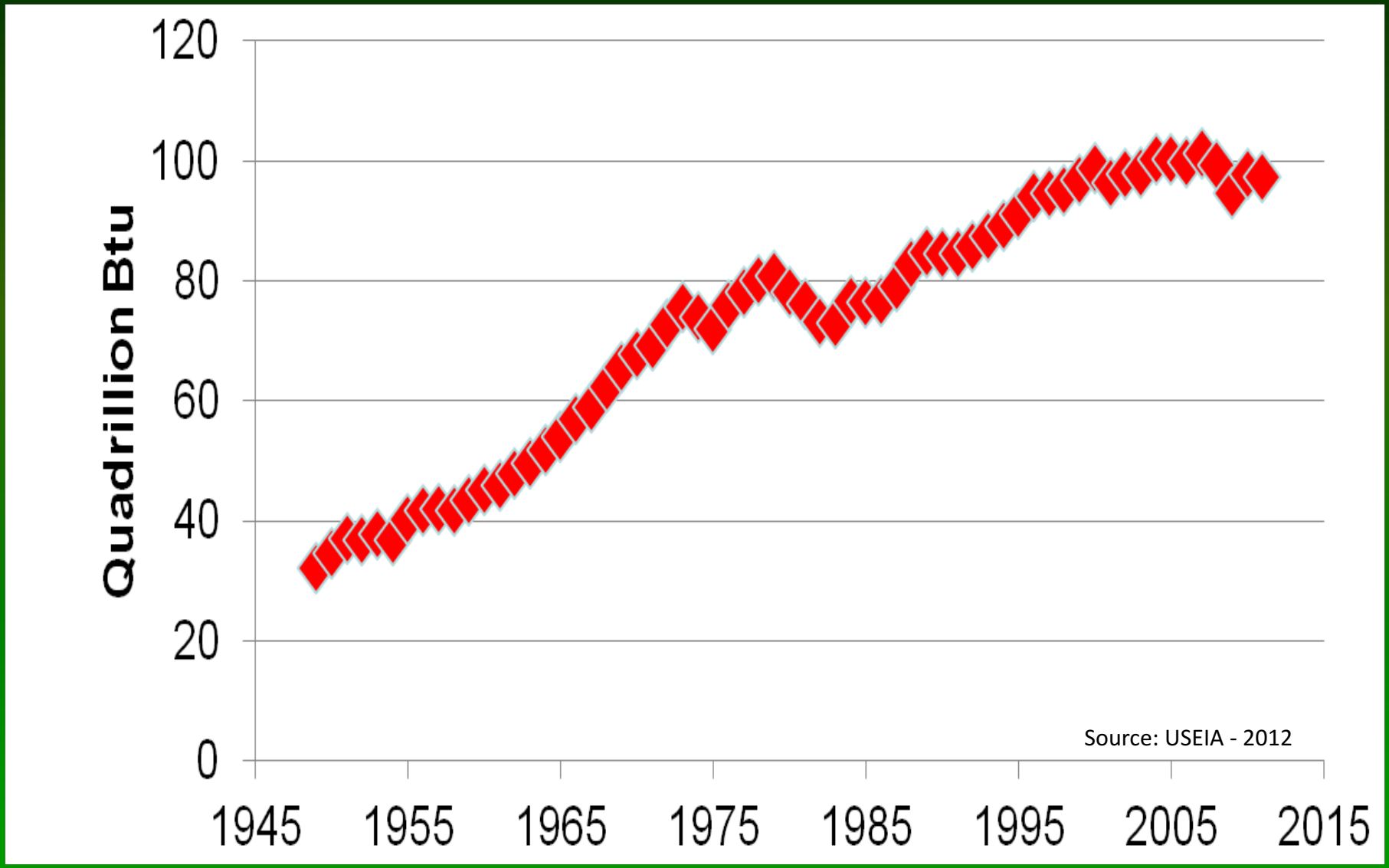
“The Size of Things…”

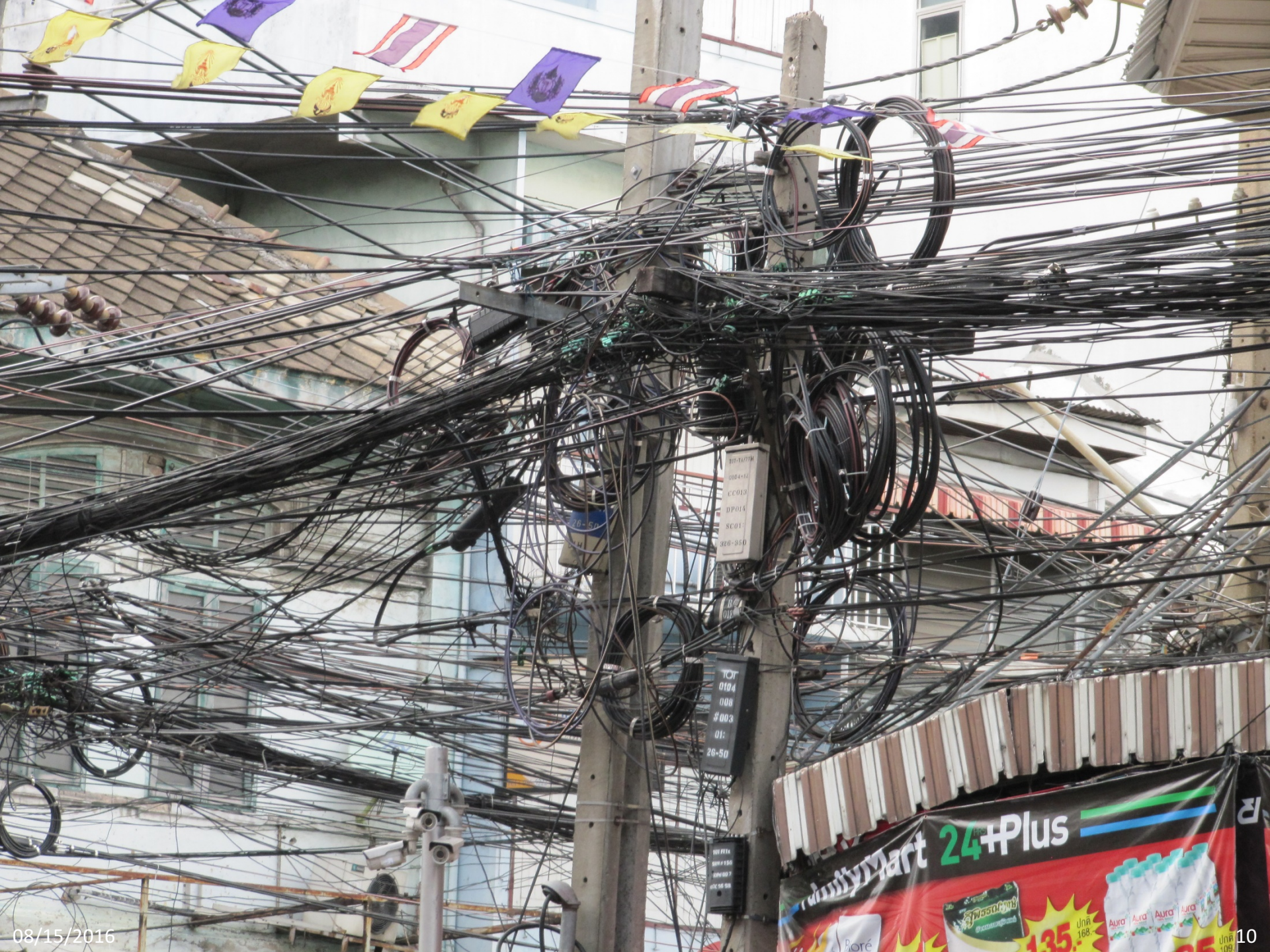
Buildings Matter: US Energy Use



Source: USEIA - 2012

U.S. Energy Consumption




TOT
0104
008
#003
01:
26-50
24+Plus
Aura
Aura
Aura
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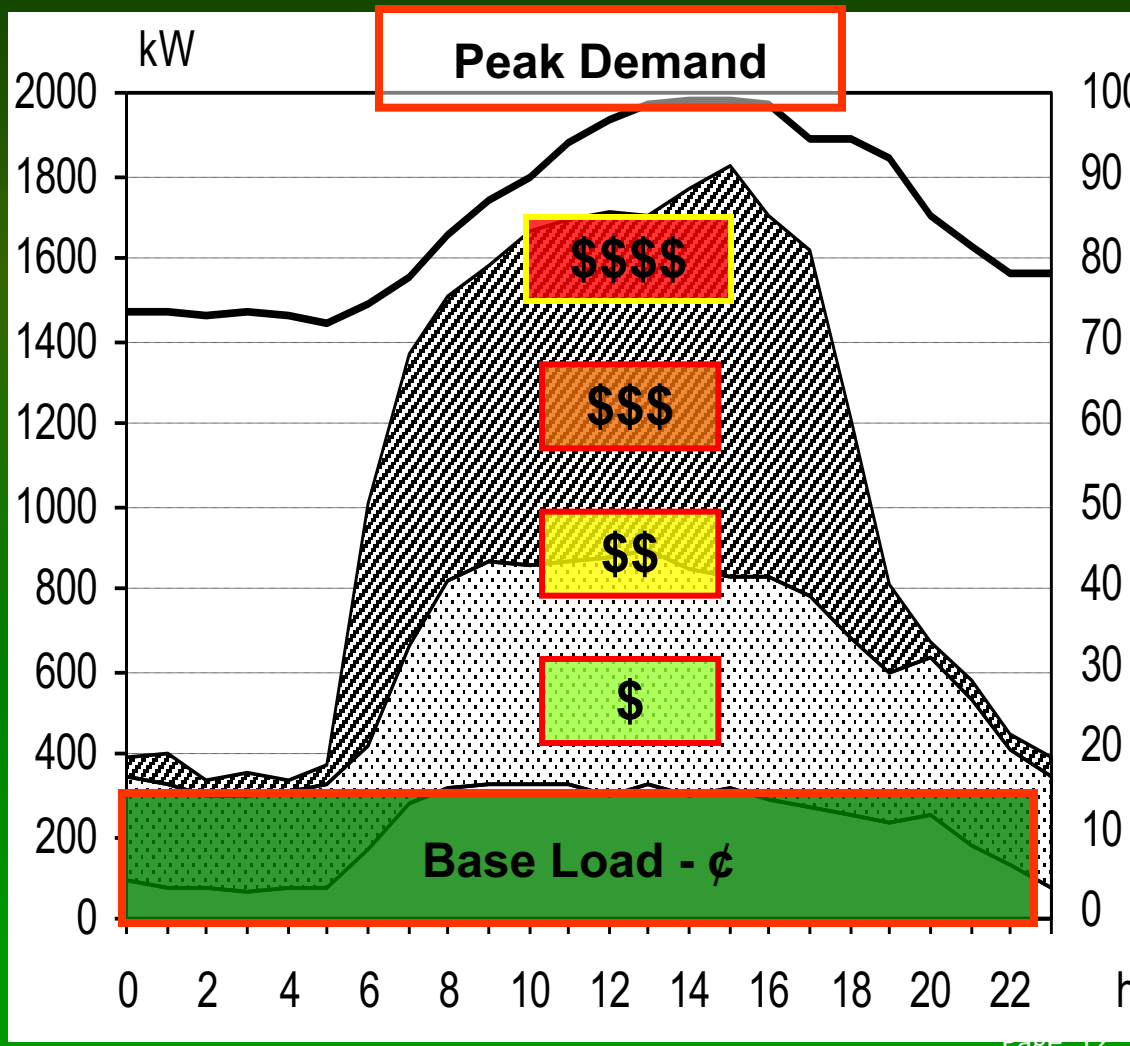
Utility Concerns

- **The "Timing" of our Demand**
  - Cooling Driven
  - Lighting Driven

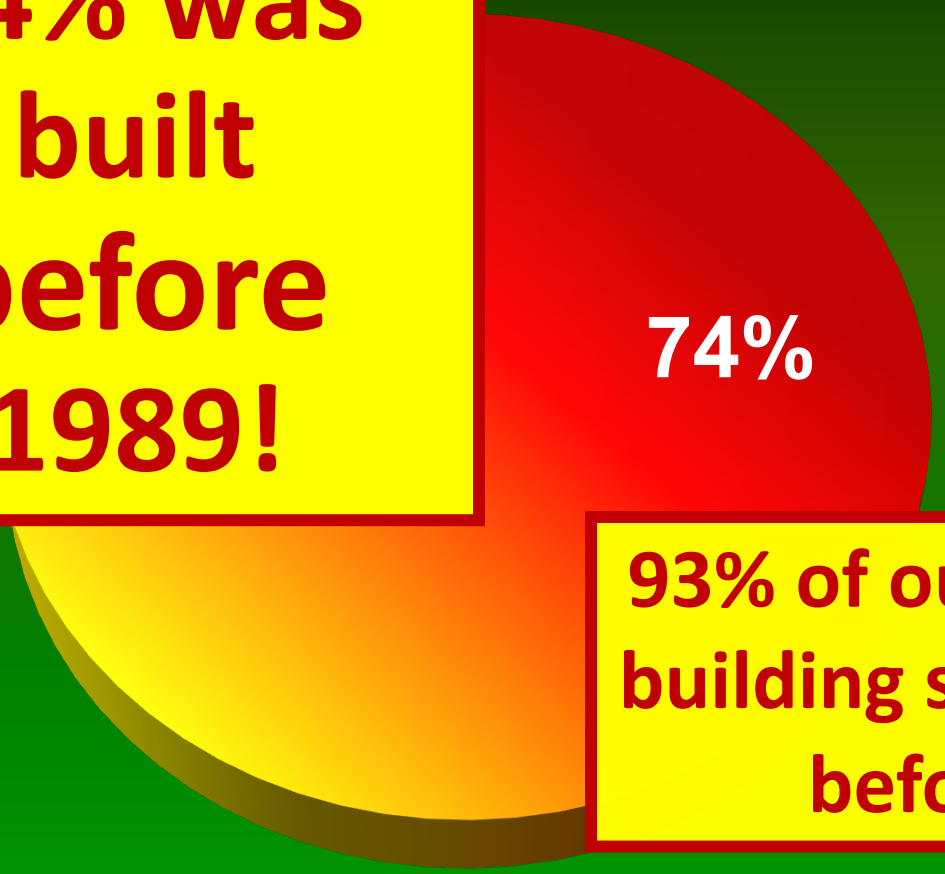


The Energy Megatrend

- Increasing demand
- Supply challenges
- Peak power
- Energy security
- Economic security

US Commercial Buildings

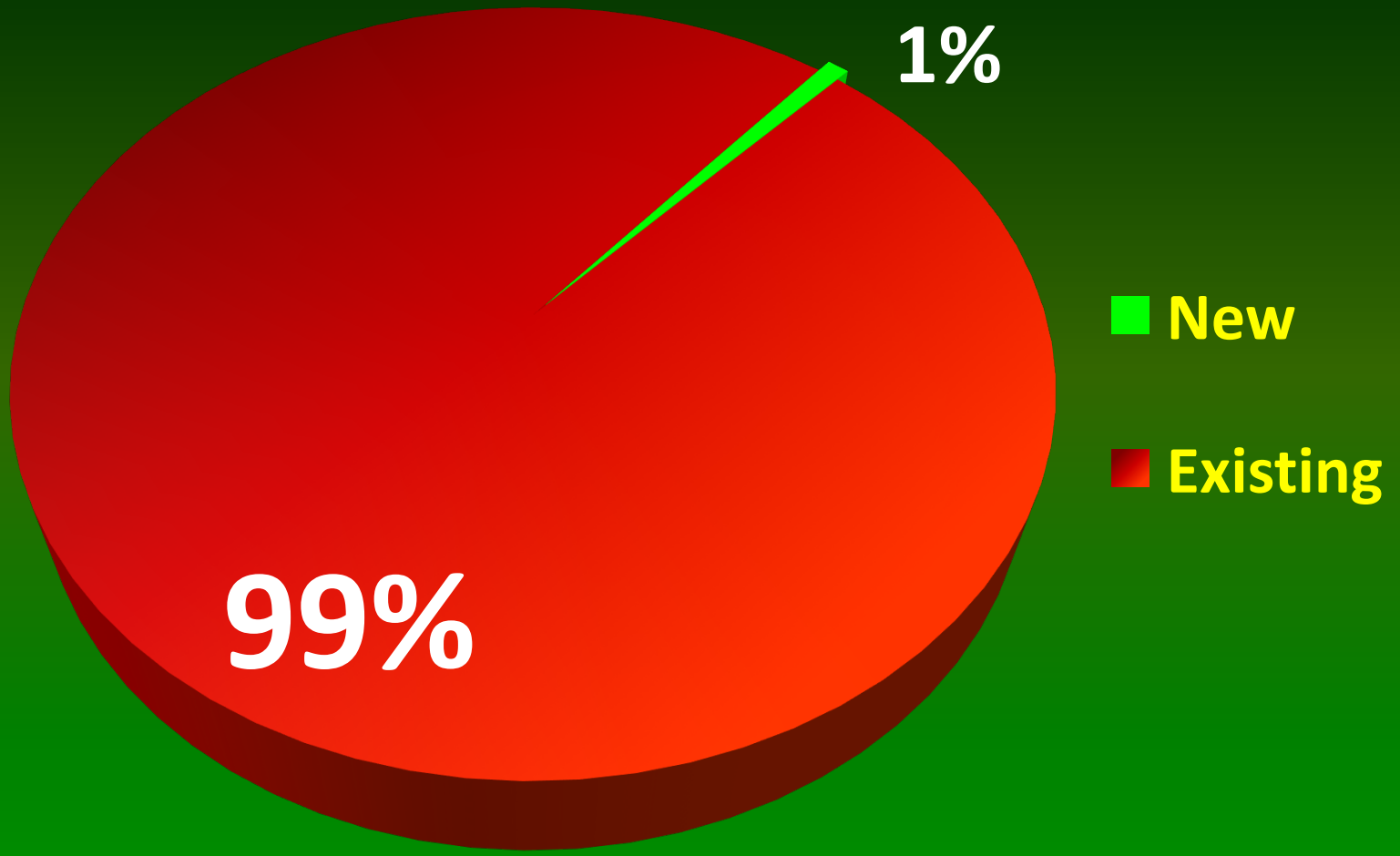
74% was built before 1989!



93% of our commercial building stock was built before 2003!

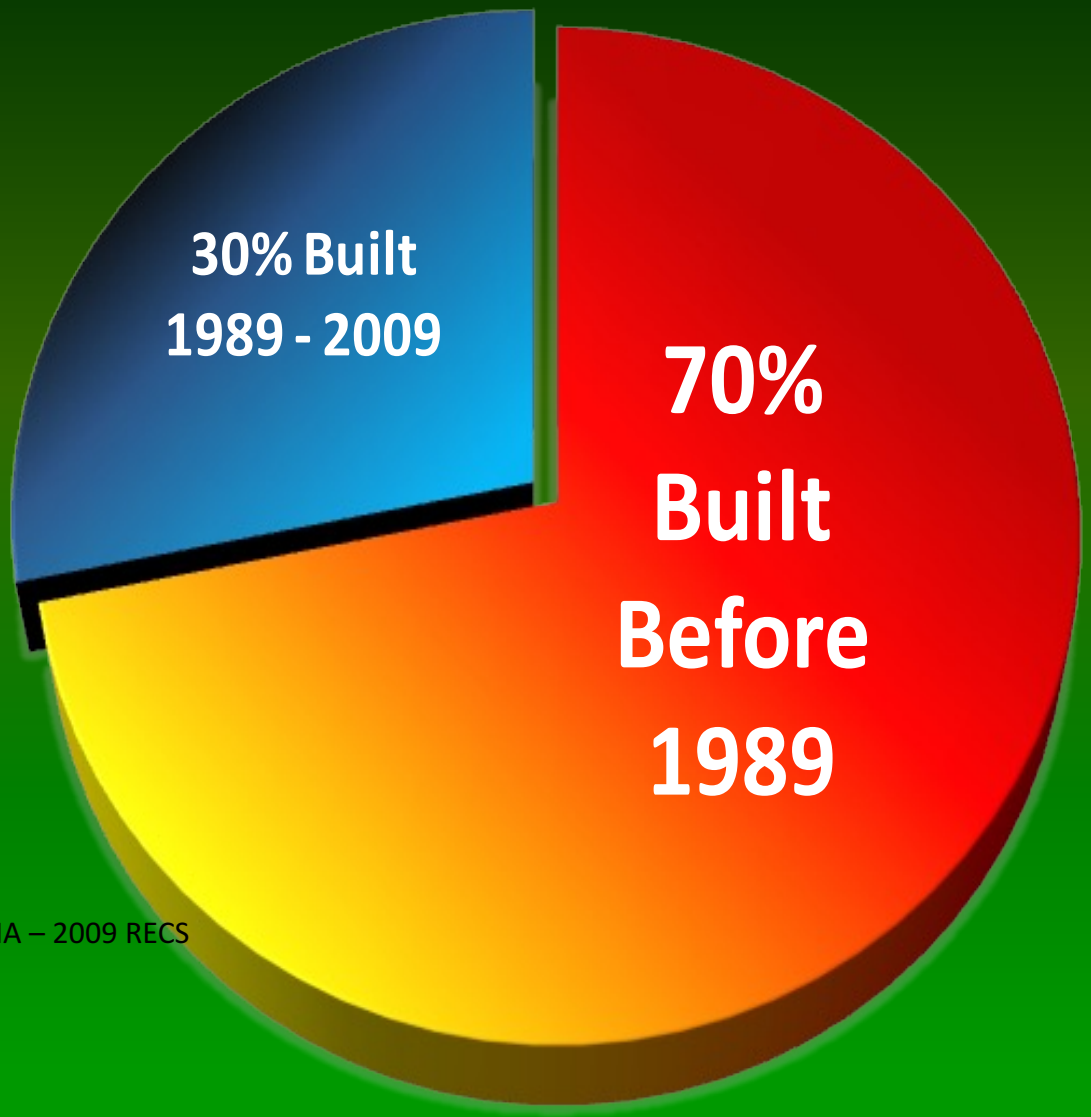
Source: USEIA , 2003 CBECS

U.S. Residential Buildings

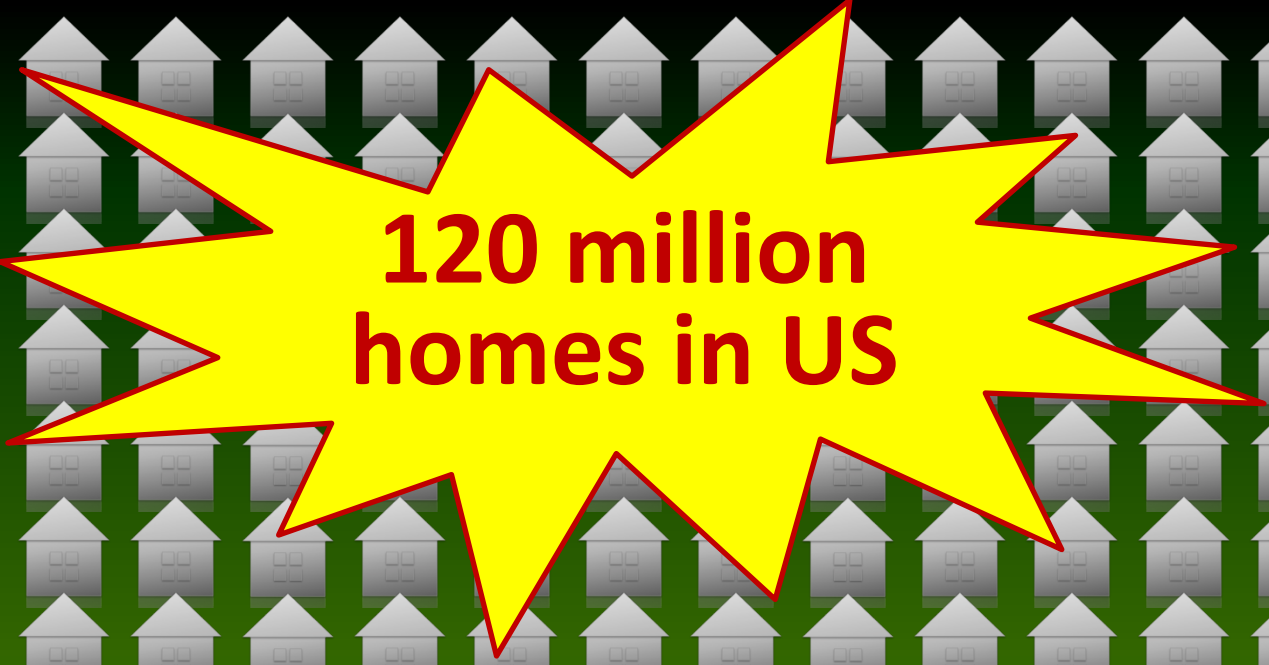


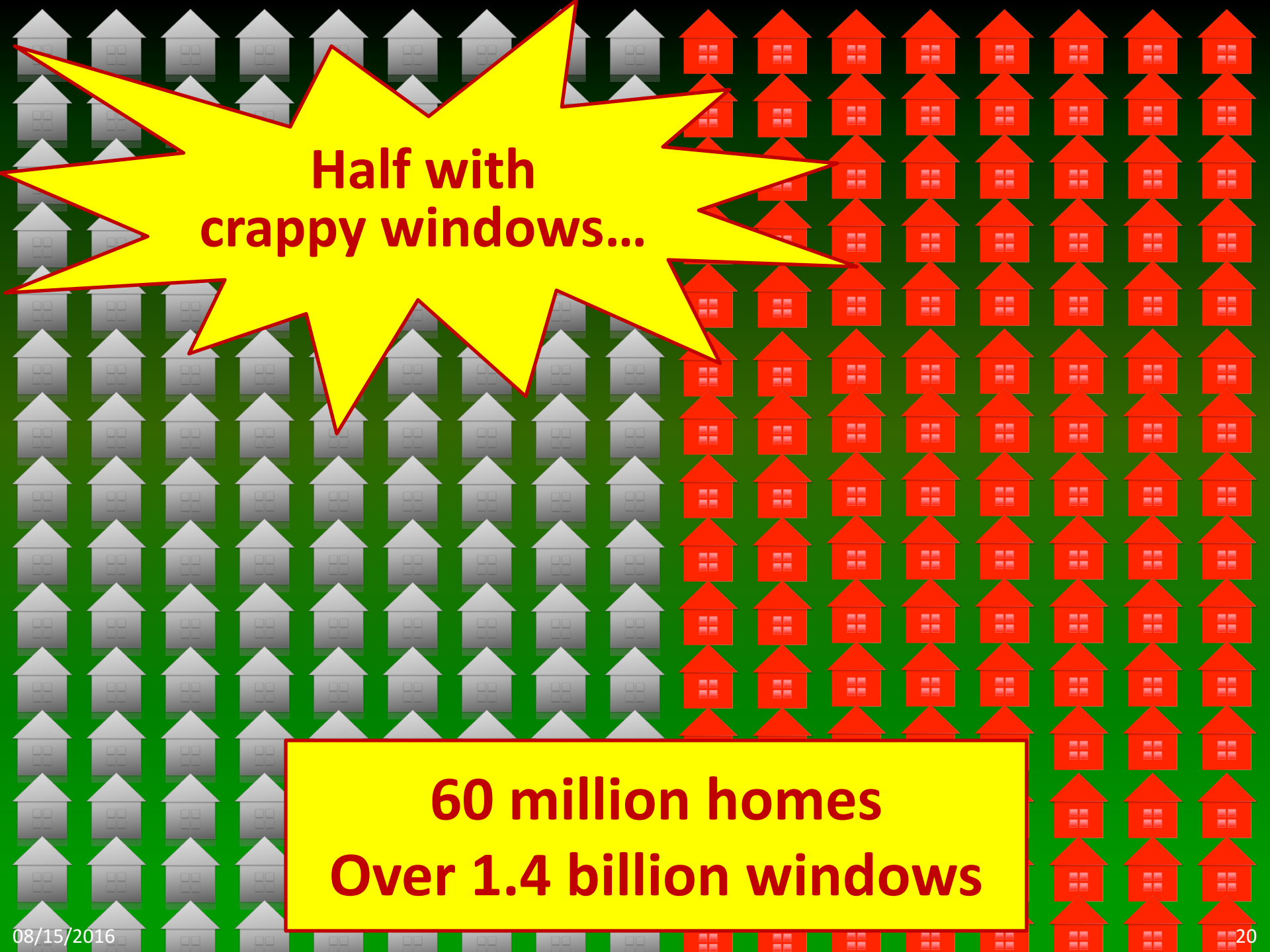
Source: USEIA – 2009 RECS

Age of U.S. Homes…



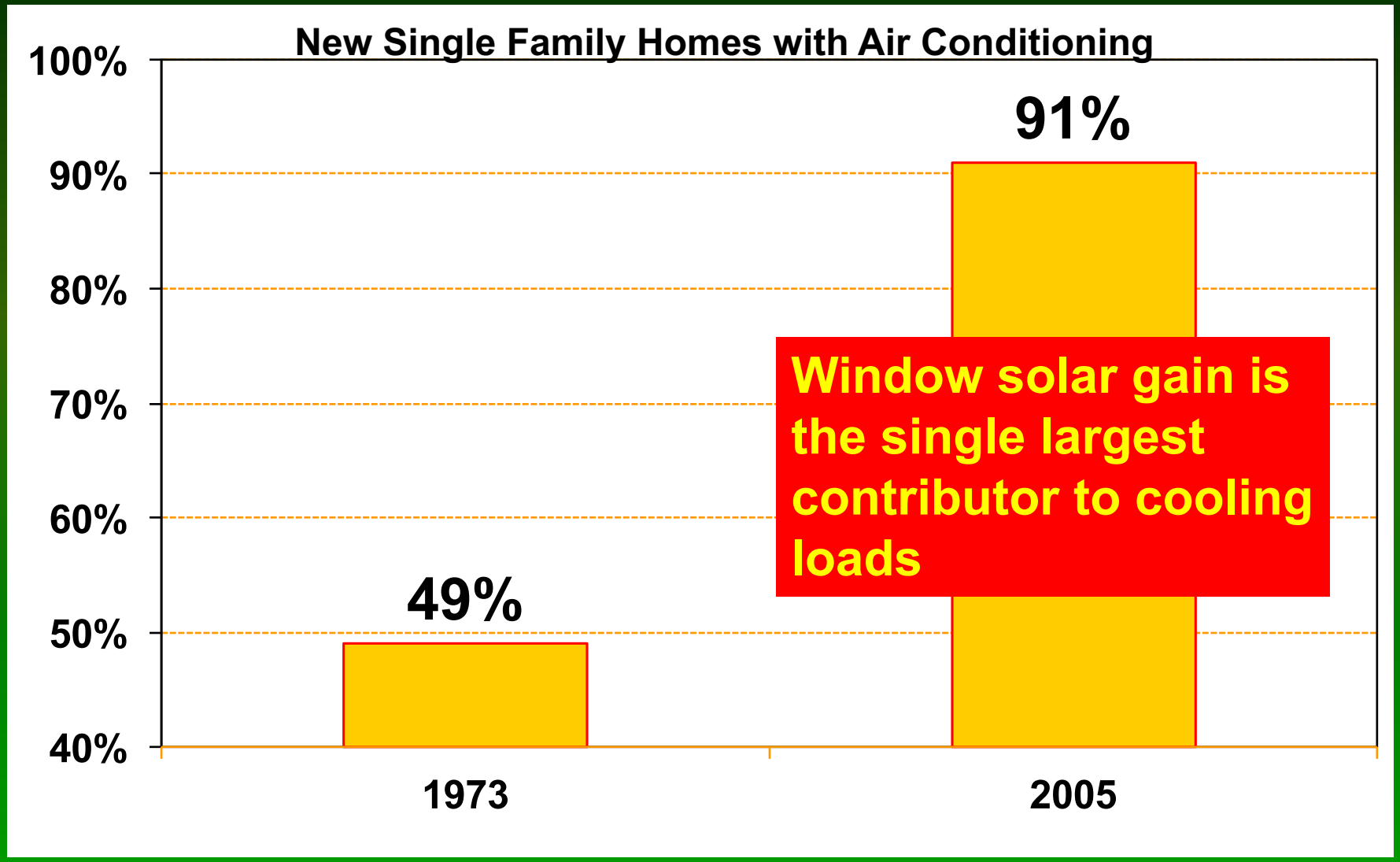
Source: USEIA – 2009 RECS


120 million
homes in US

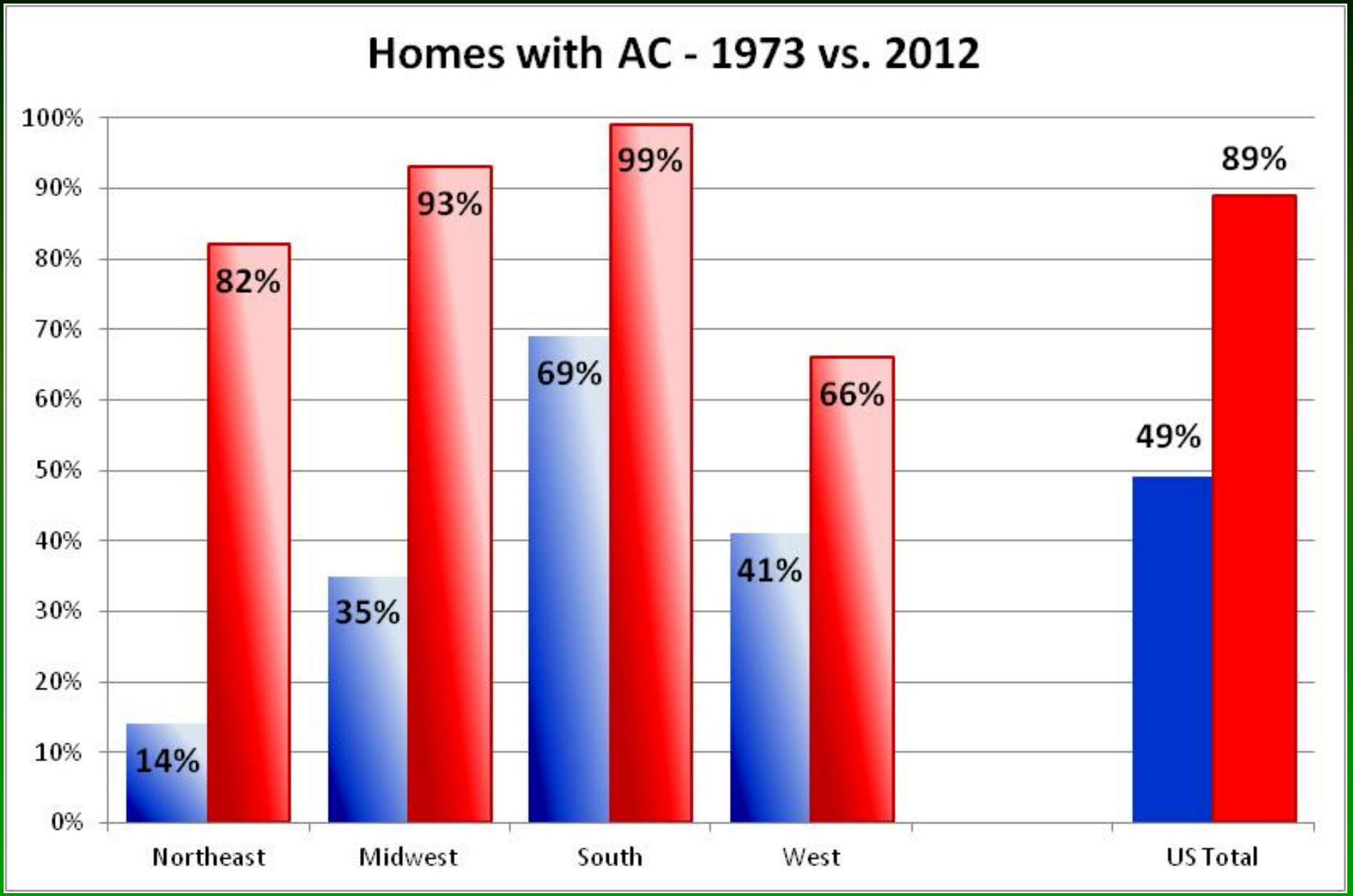

Half with
crappy windows…
60 million homes
Over 1.4 billion windows

What If We Replaced Windows?

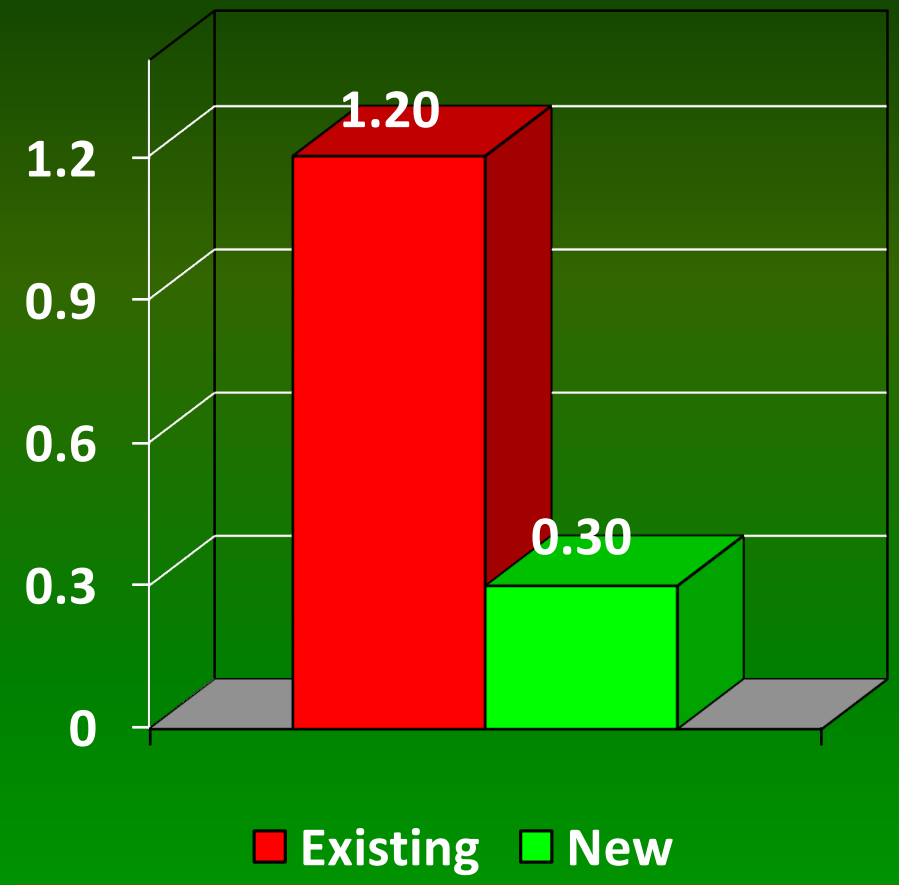
Homes Have Changed



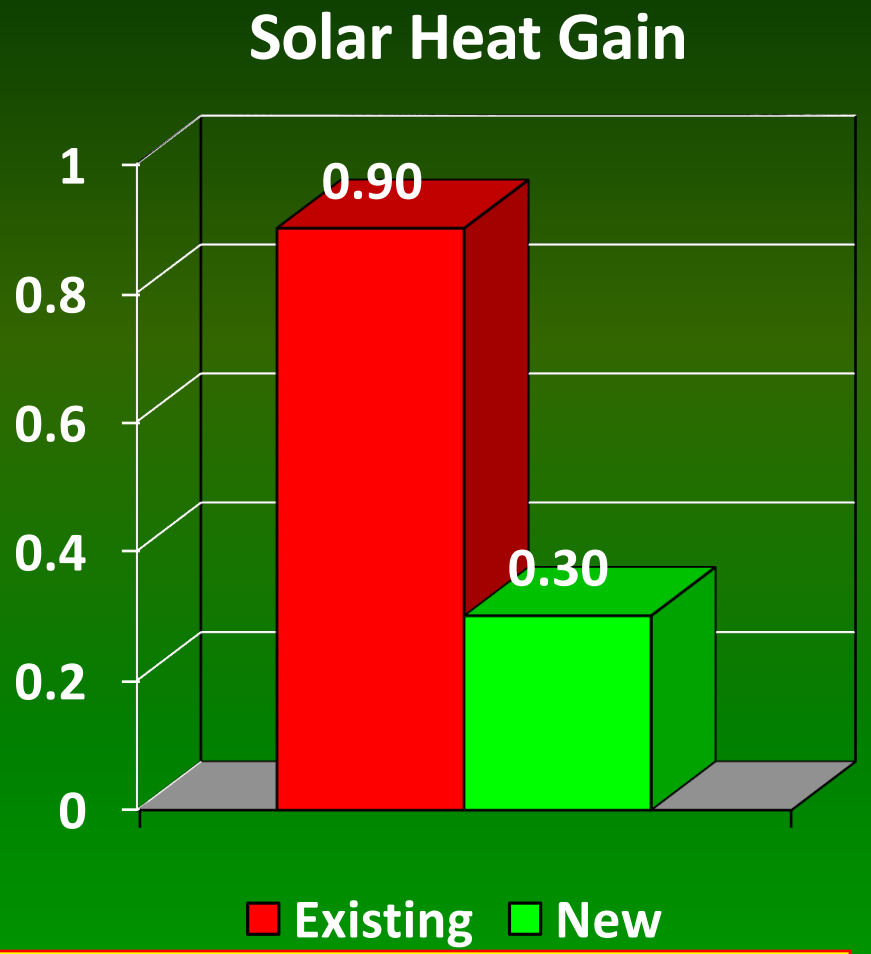
Source: US Census 2005


Homes with AC - 1973 vs. 2012
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
14%
82%
35%
93%
69%
99%
41%
66%
49%
89%
Northeast
Midwest
South
West
US Total

Heat Loss (winter)



Heat Gain (summer)



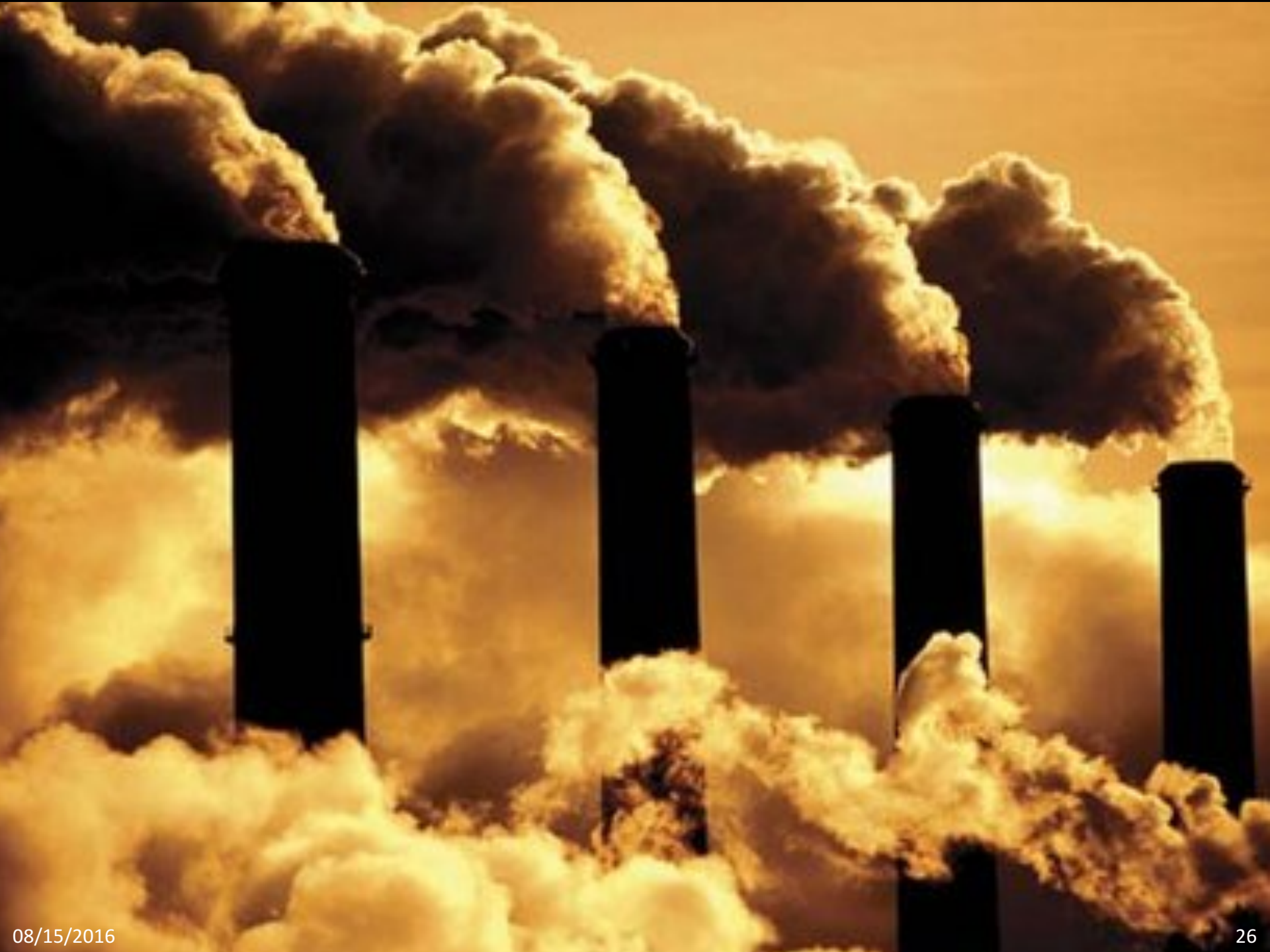
Use the "Worst" Code-Compliant Window

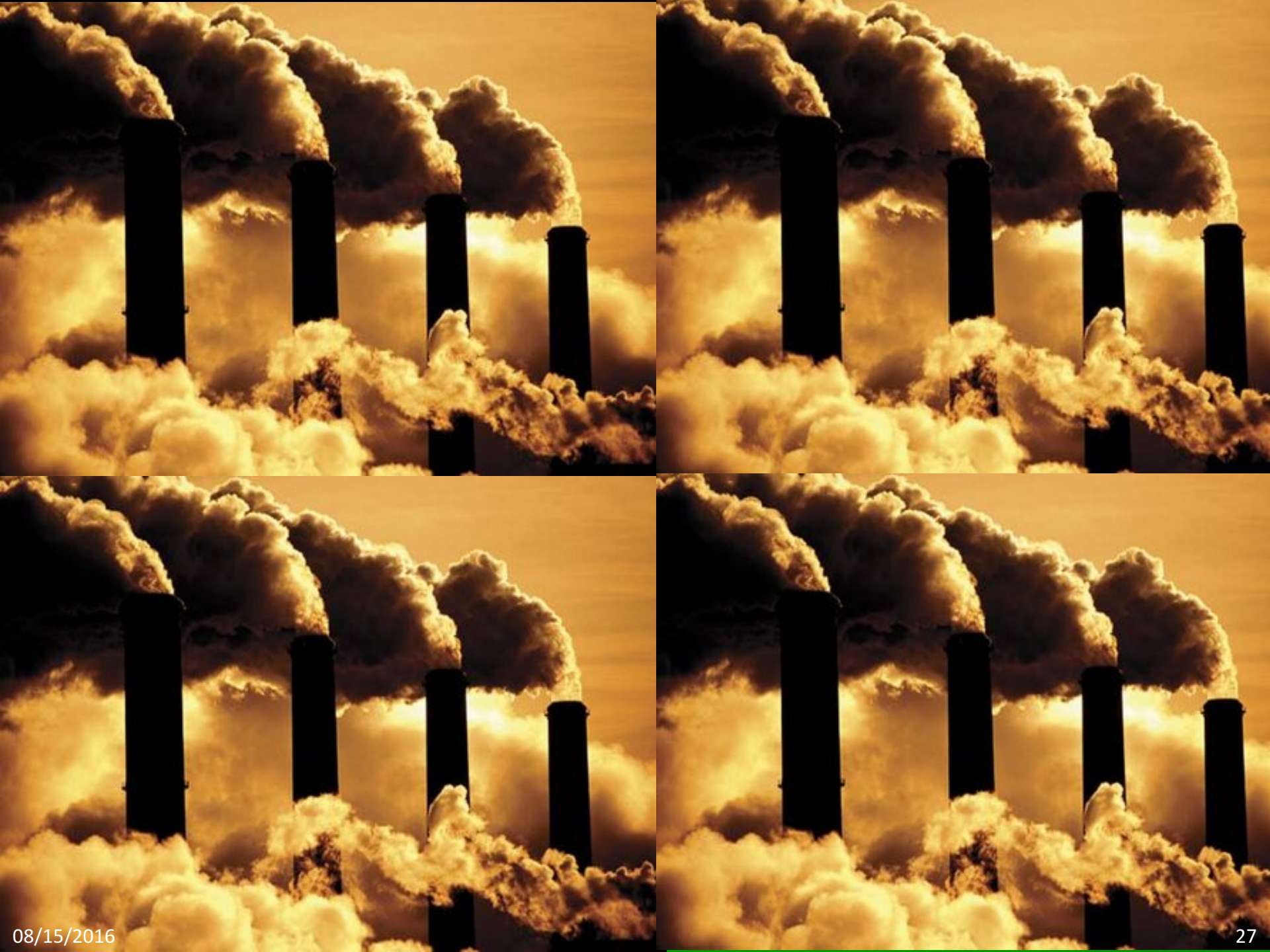
What Would We Save?

- 1 to 3 Tons of Air Conditioning per house
  - Depending on size, location, leakiness, etc.
- 1 ton = 12,000 Btu/hr
- 13 S
- ~1 k

What is 60 million kW?

- ~120 million existing homes
  - About half have lousy windows
- ~60 million * 1 ton * 1 kW/ton = 60 million kW





60 Million kW?

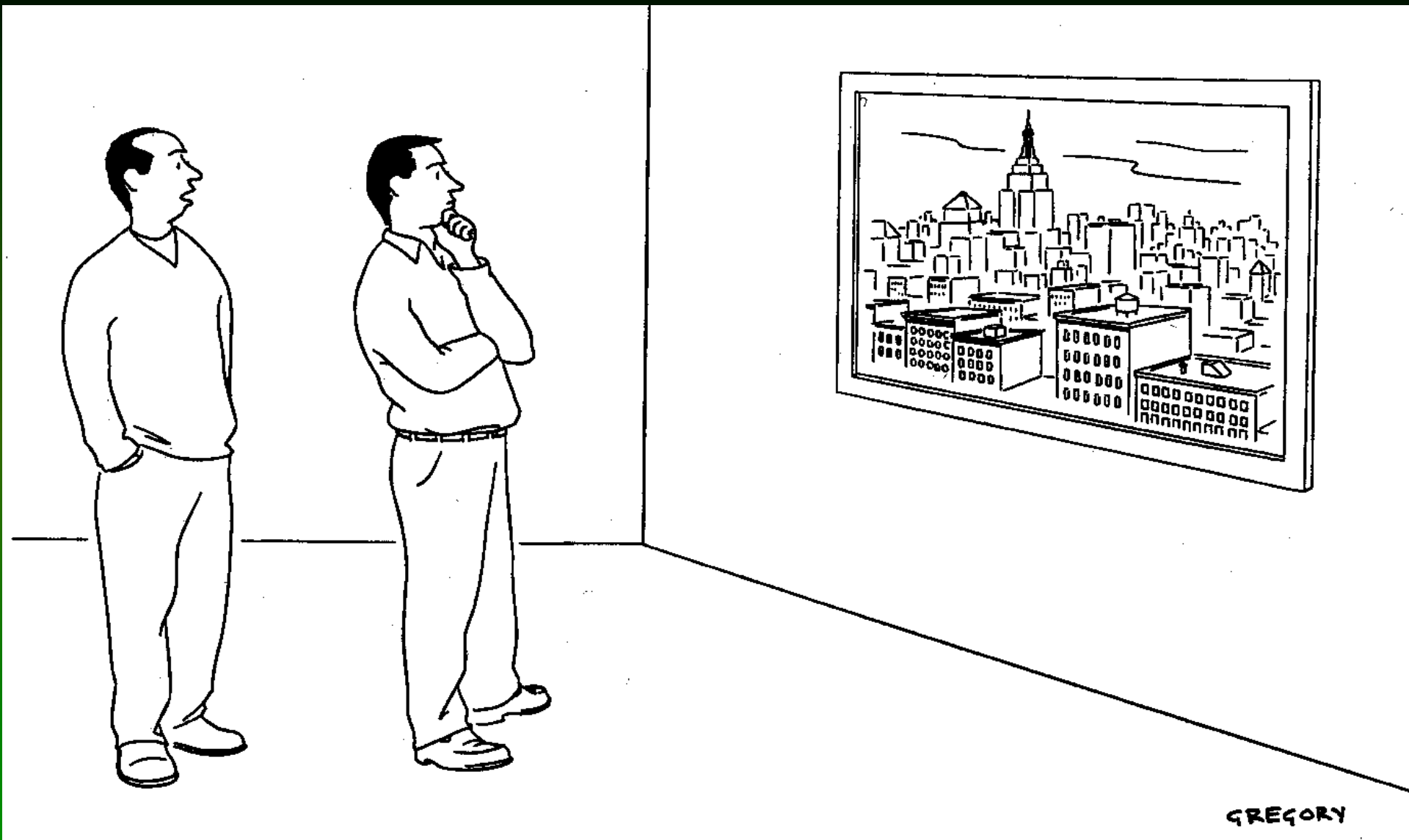
Over 300 coal-fired power plants….

What if…

Lessons from the 70's…

THIS is the DER Perspective

- **Understand and quantify the impacts of the individual elements**
  - Windows, Insulation, Equipment, Etc.
- **Understand the life cycle of each element**
  - Some last a long time…
- **Understand the combinatorial impacts!**
  - Energy
  - Peak Power
  - Carbon
  - Comfort
  - Productivity



"It's not high-definition anything. It's a window."

Review
Fenestration Performance Basics

“Relationship” Issues

- Too cold in winter
- Too hot in summer
- Too much air leakage
- High energy costs
  - Heating
  - Cooling
- Loss of comfort
- Acoustics
- Other performance issues

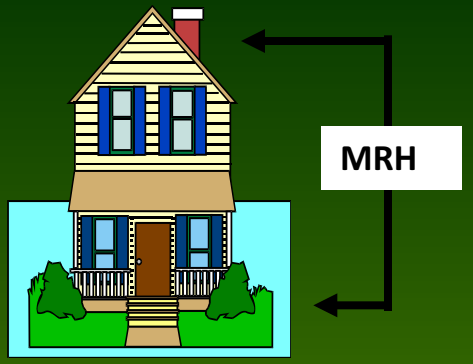
How Do We Pick a Window?

- Aesthetics
- Cost
- Heat Loss
- Heat Gain
- Air Leakage
- Water Penetration
- Wind Load Resistance
- Sound Transmission
- Fabric Fading Potential
- Condensation Resistance
- Visible Light Transmission
- Daylighting
- Ventilation Efficiency
- Operating Characteristics
- Maintenance & Durability
- Code Compliance
- Warranty Considerations
- Other Issues…

Design Pressure Elements

Wind Speed

Unit Size

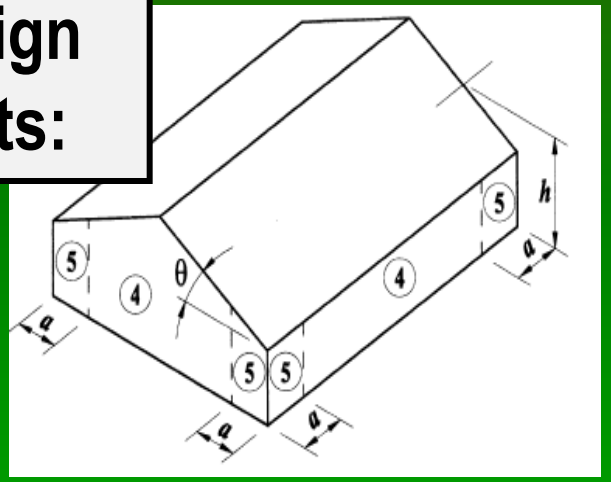


Mean Roof Height

Exposure

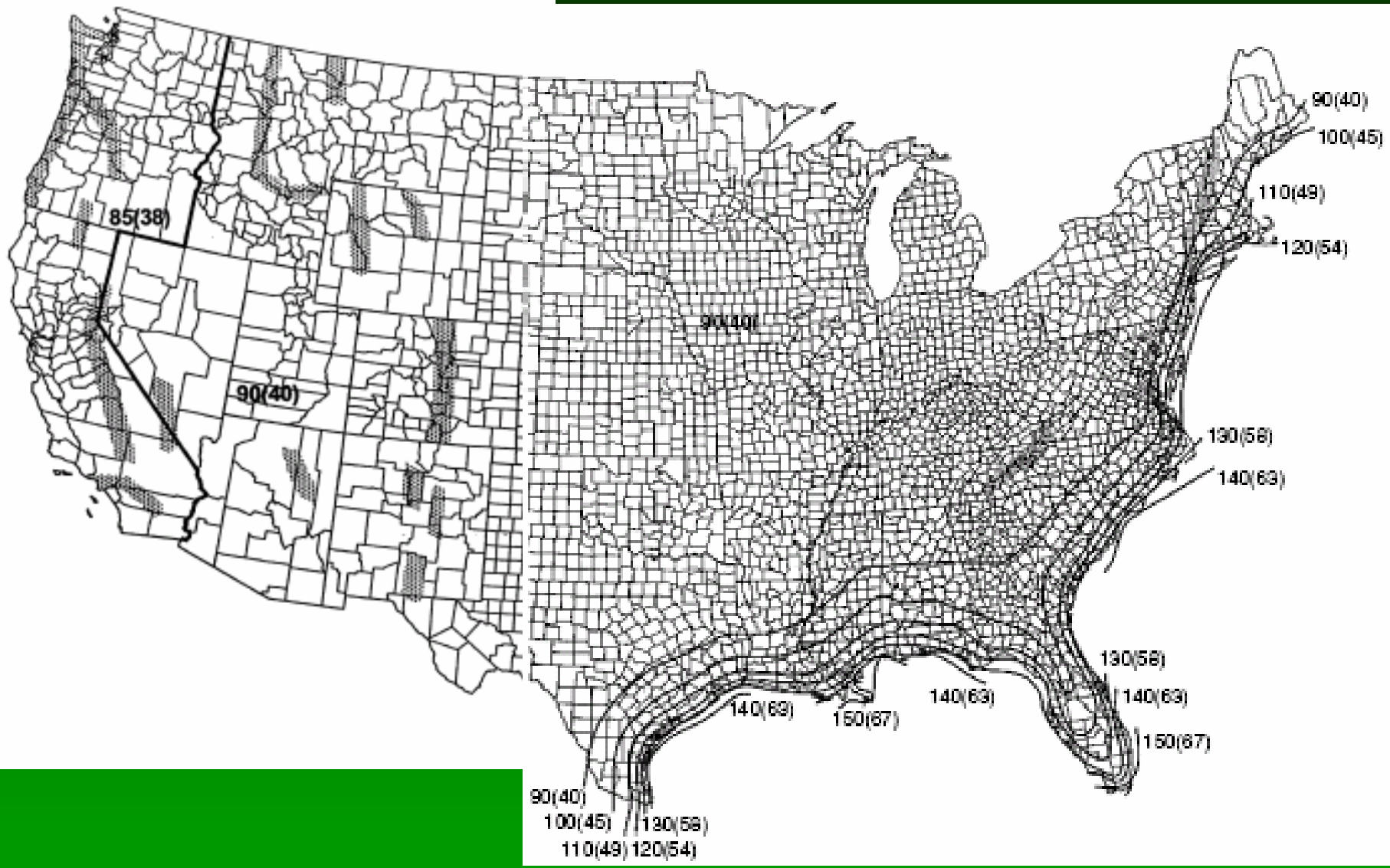
Six basic elements are used to calculate design pressure requirements:

Importance factor



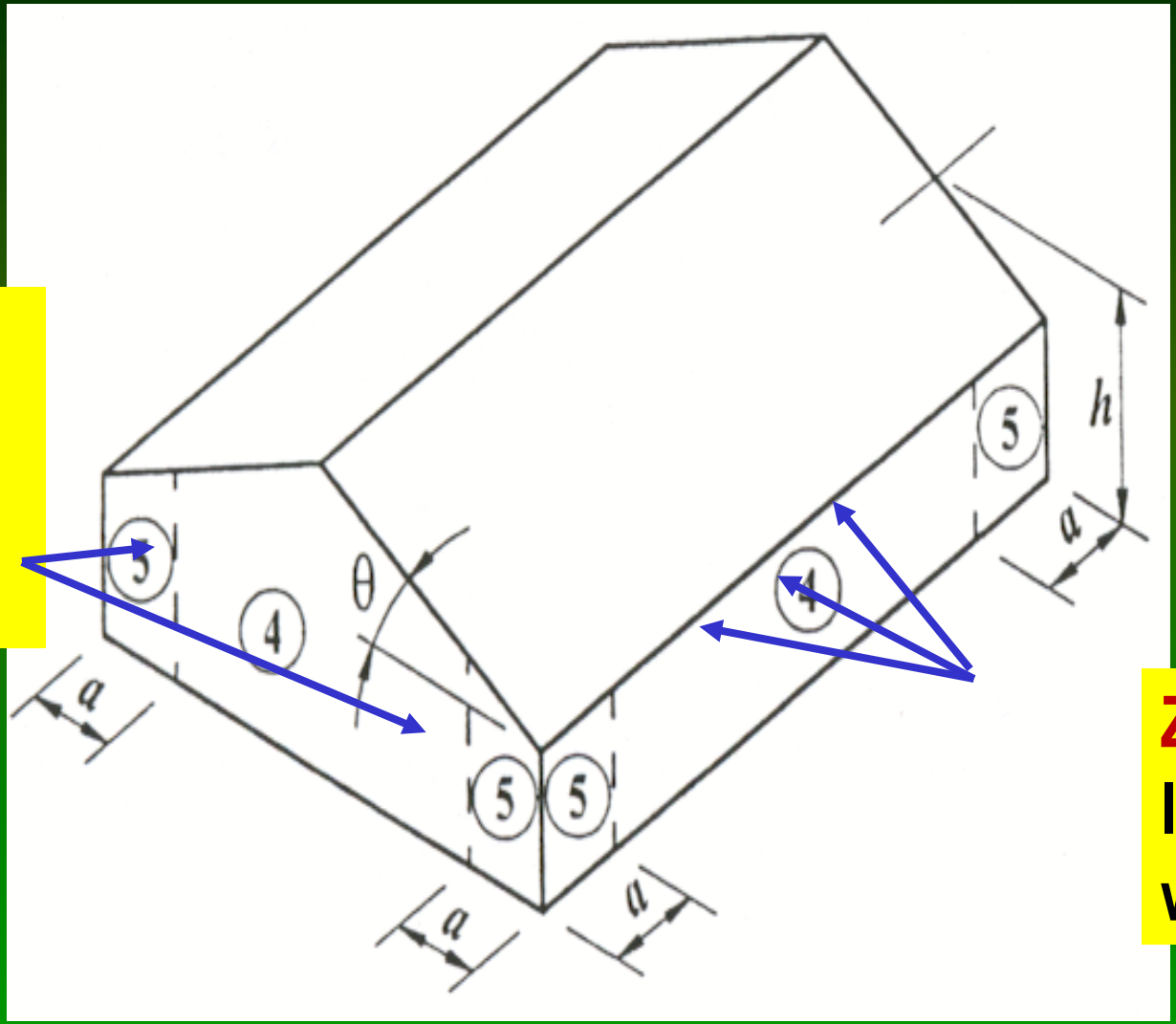
Location in Wall

Know Your Local Wind Speed!



Know Where & What Size

Zone 5
Within four feet of a corner



Zone 4
Interior wall area

Know Your Exposure

Exposure B

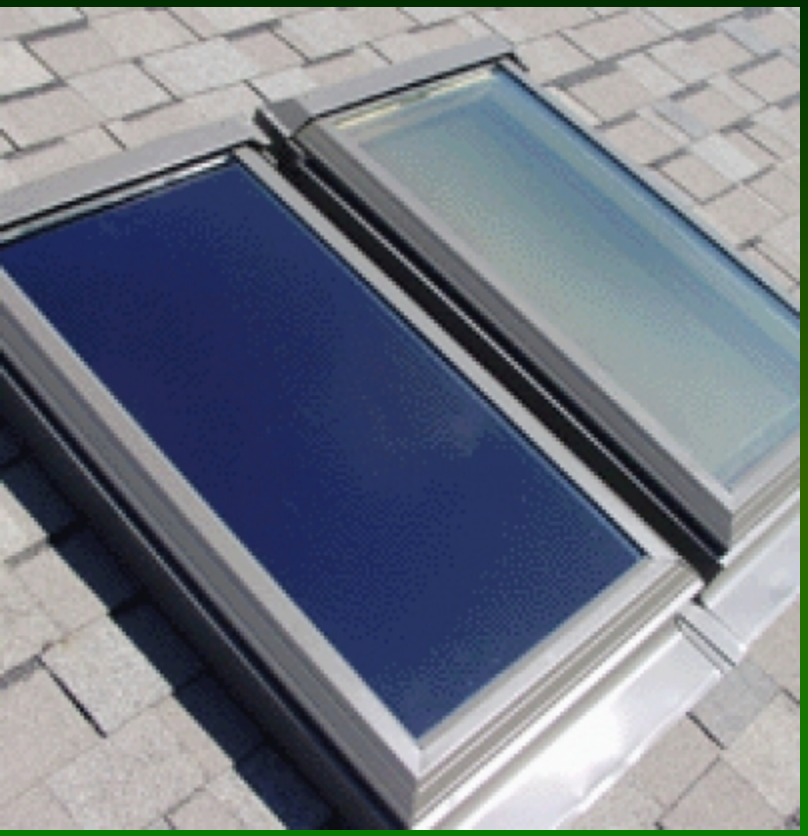
Areas with numerous closely spaced obstructions such as trees and houses

Exposure C

Areas with scattered obstructions such as a coast line or open land

Review
Recent Innovations in Fenestration Performance

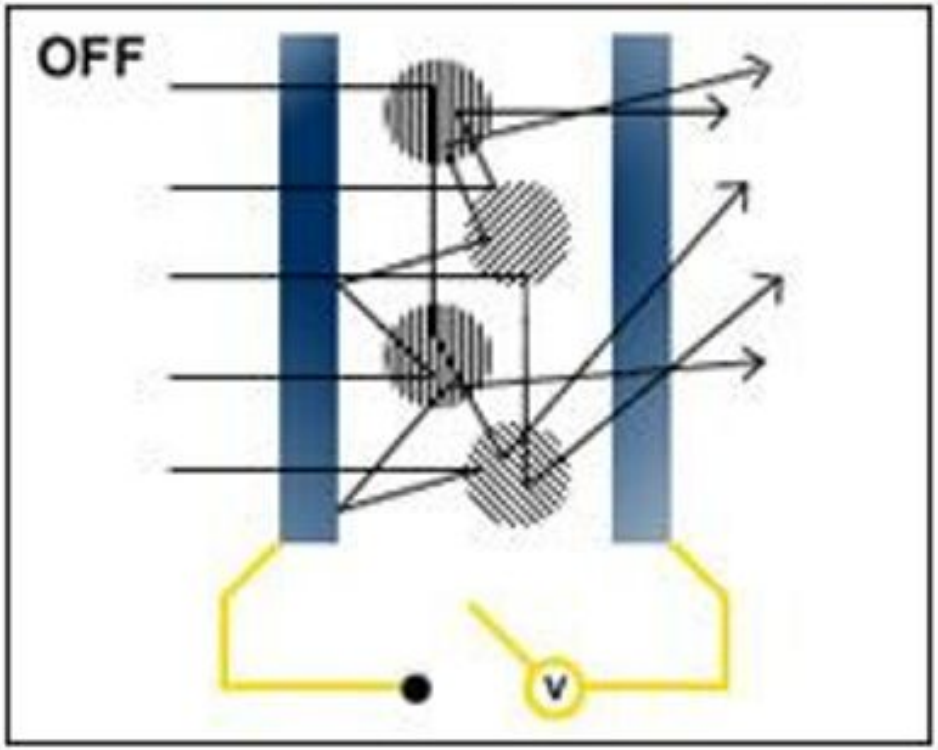
Windows Have Changed

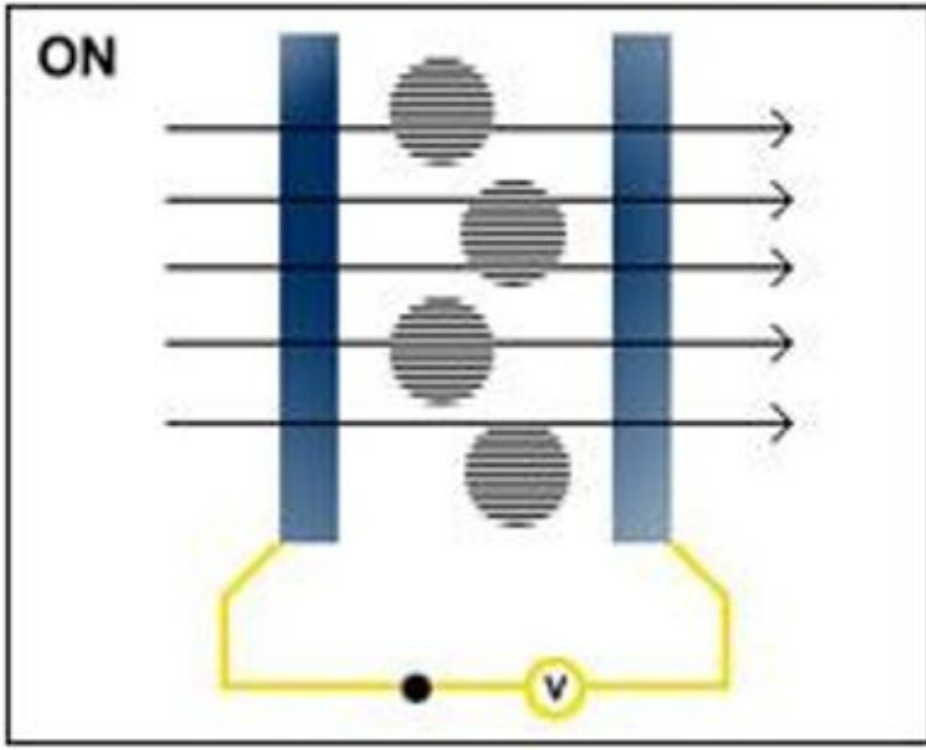


Switchable Glazings


OFF

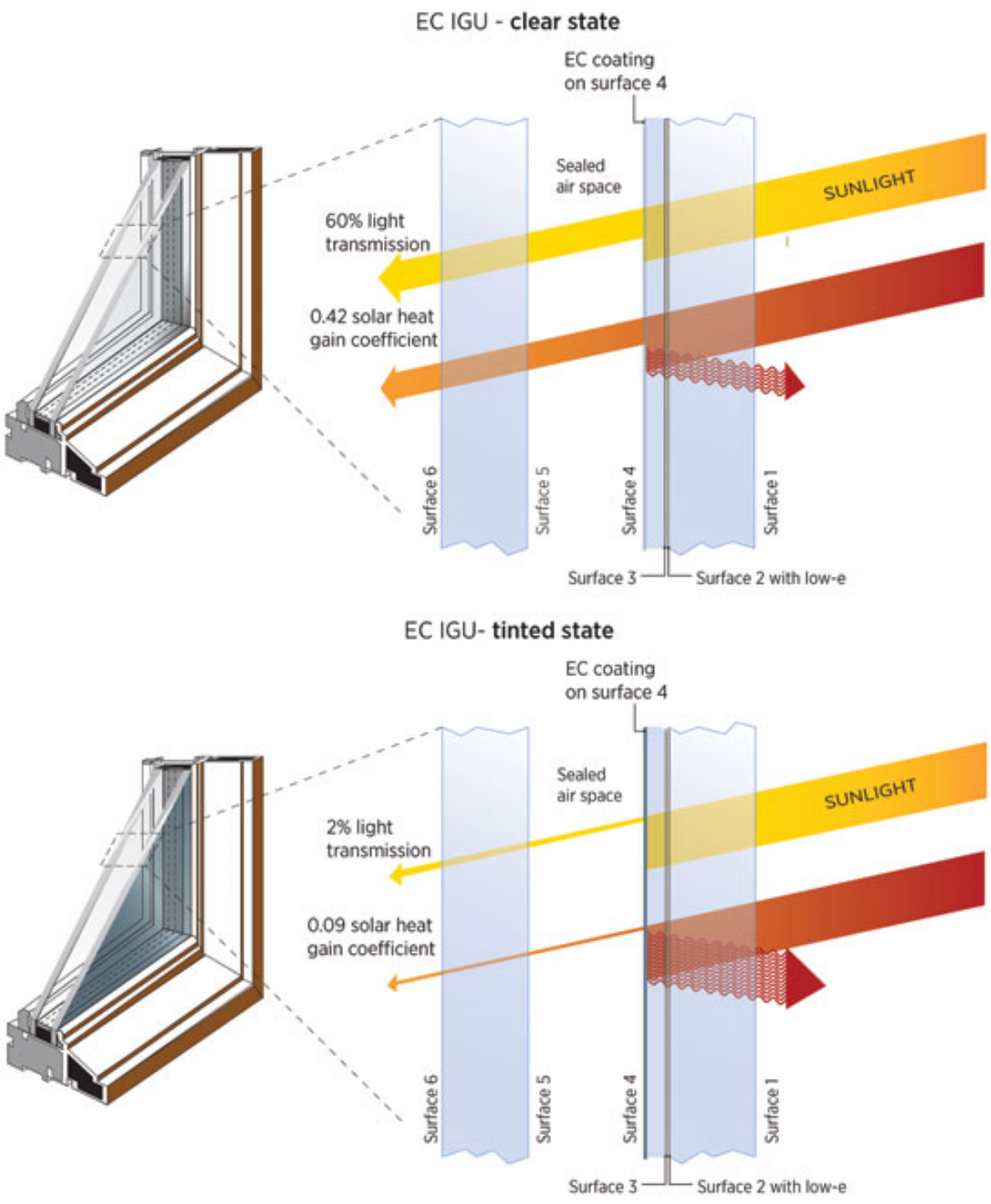

ON


OFF
V


ON
V

Electrochromics

- Switchable transmission
- Range of solar control
- Major implications for utilities and peak loads
- Commercial applications first

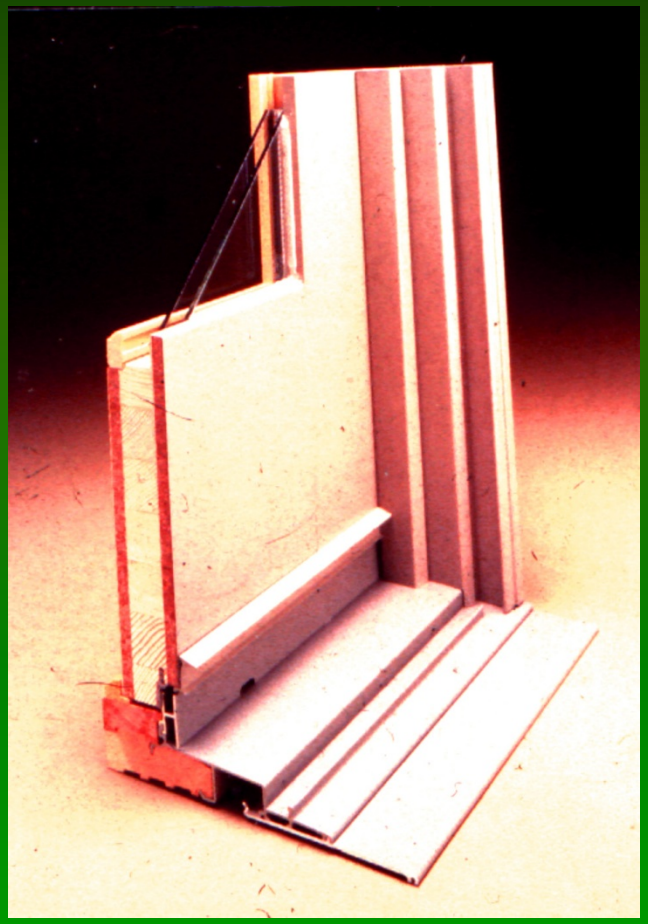

EC IGU - clear state
EC coating
on surface 4
Sealed
air space
SUNLIGHT
60% light
transmission
0.42 solar heat
gain coefficient
Surface 6
Surface 5
Surface 4
Surface 1
Surface 3
Surface 2 with low-e
EC IGU- tinted state
EC coating
on surface 4
Sealed
air space
SUNLIGHT
2% light
transmission
0.09 solar heat
gain coefficient
Surface 6
Surface 5
Surface 4
Surface 1
Surface 3
Surface 2 with low-e

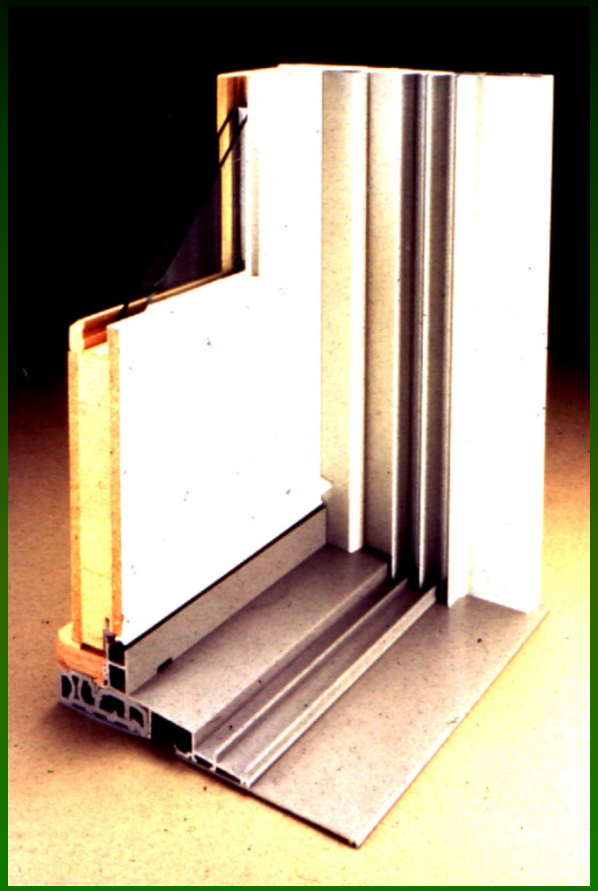
Aerogels

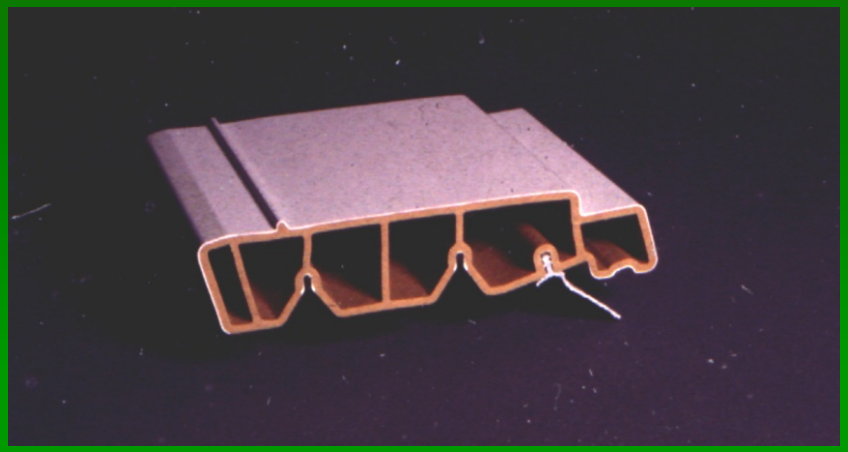
- “Foamed glass”
- Highly insulative
- Over R-20 per inch
- Fragility is current challenge.
- Many advancements in this area.
- Lots of research underway.
- Already in use in piping insulation.

Layers versus Weight…

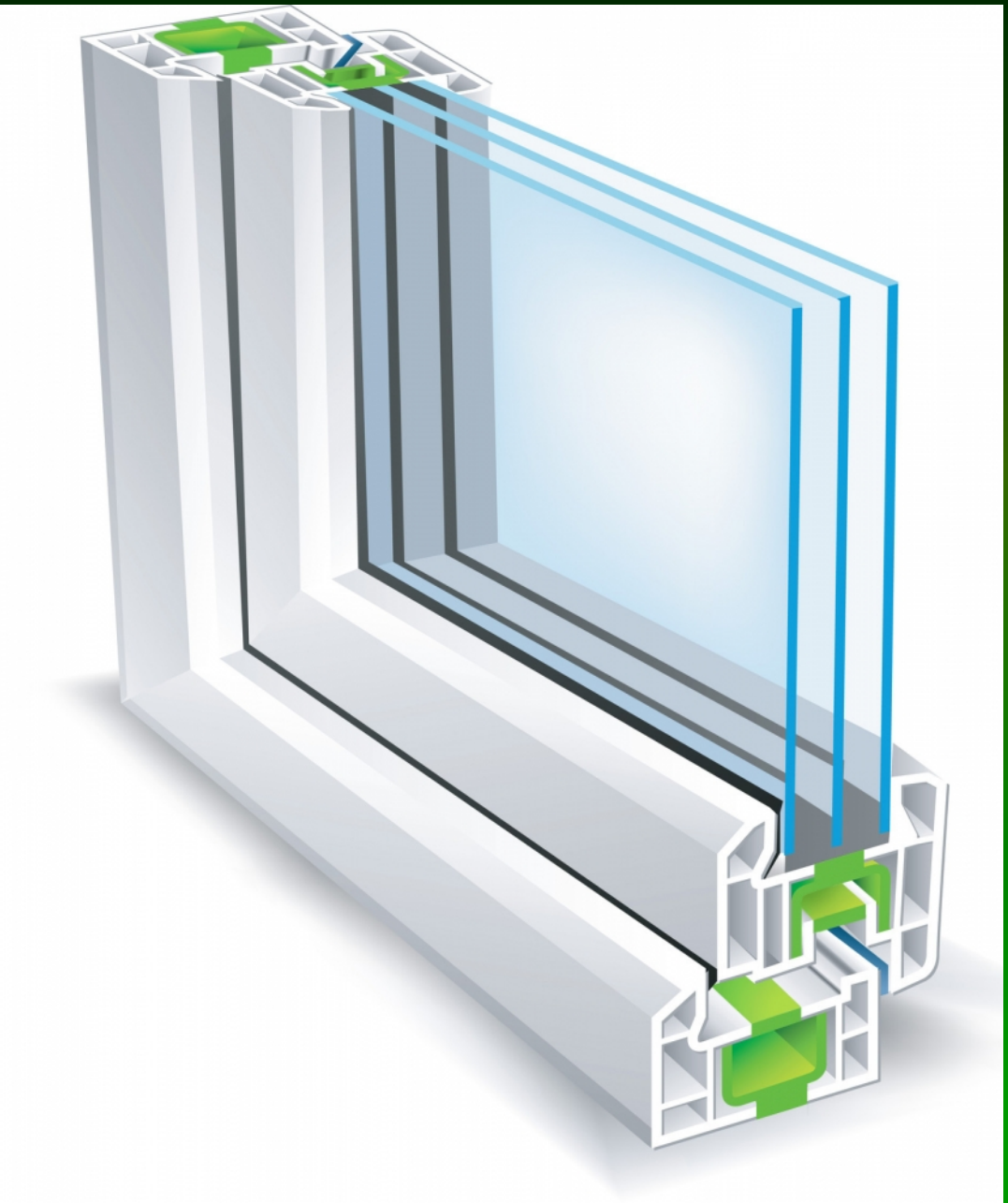
Frame Material Innovations



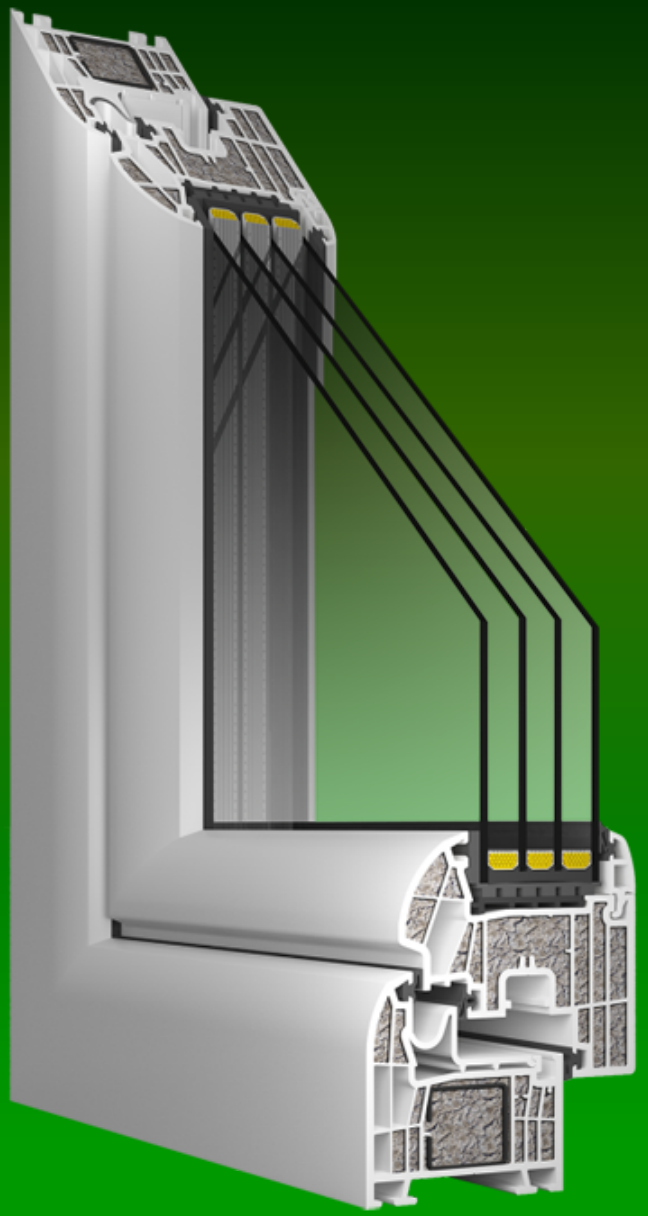




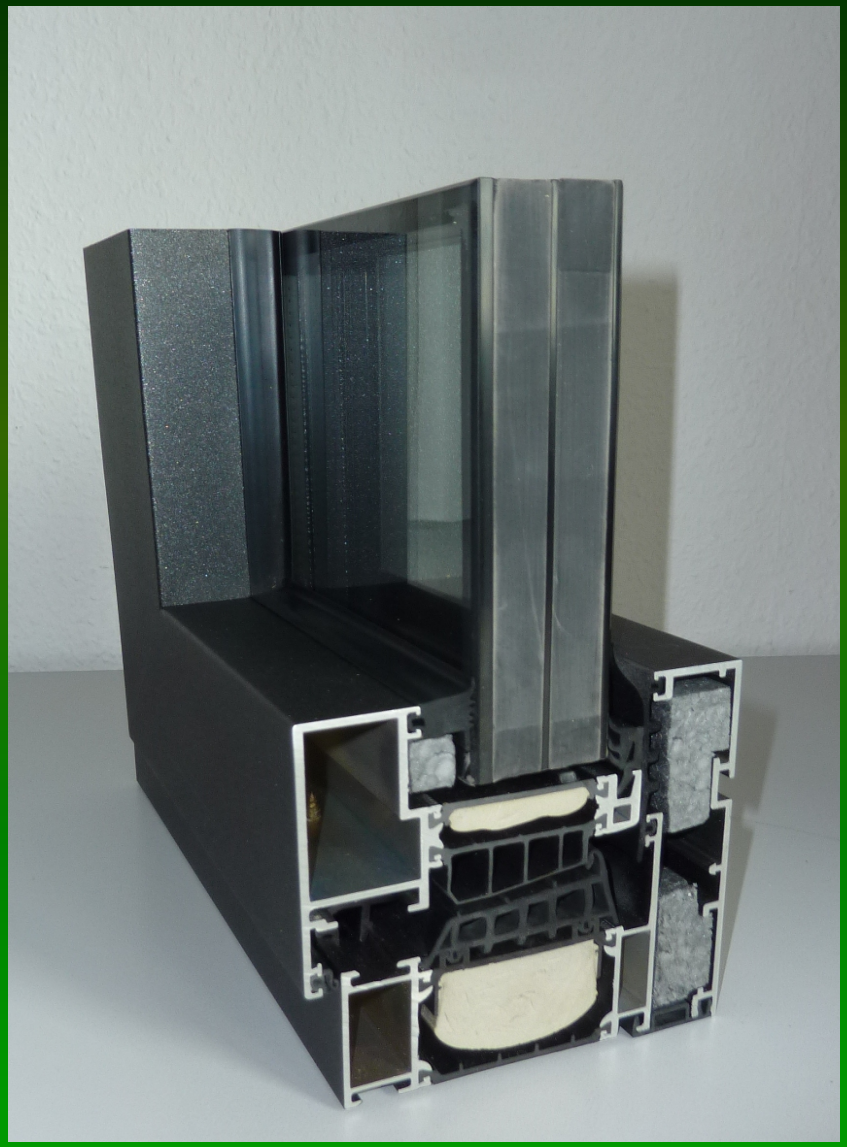
Improved Thermal Breaks

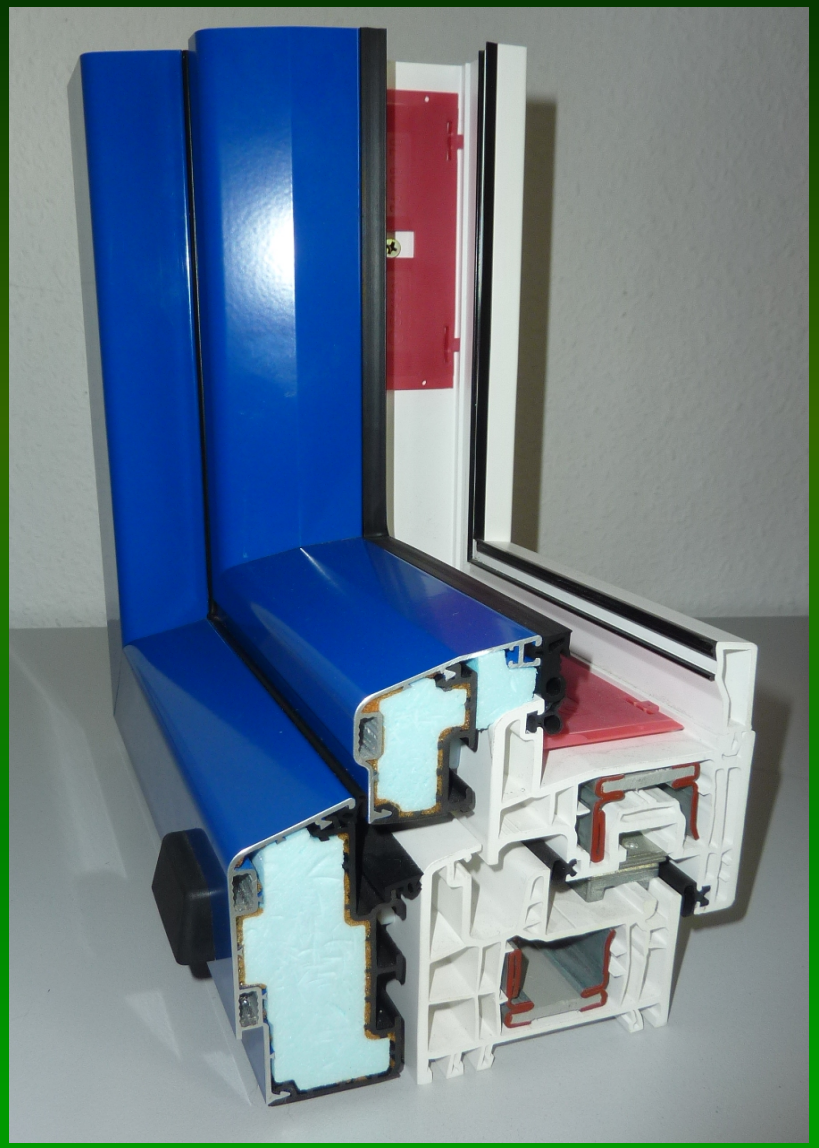


High R-value Frame Innovations



Improved Frames



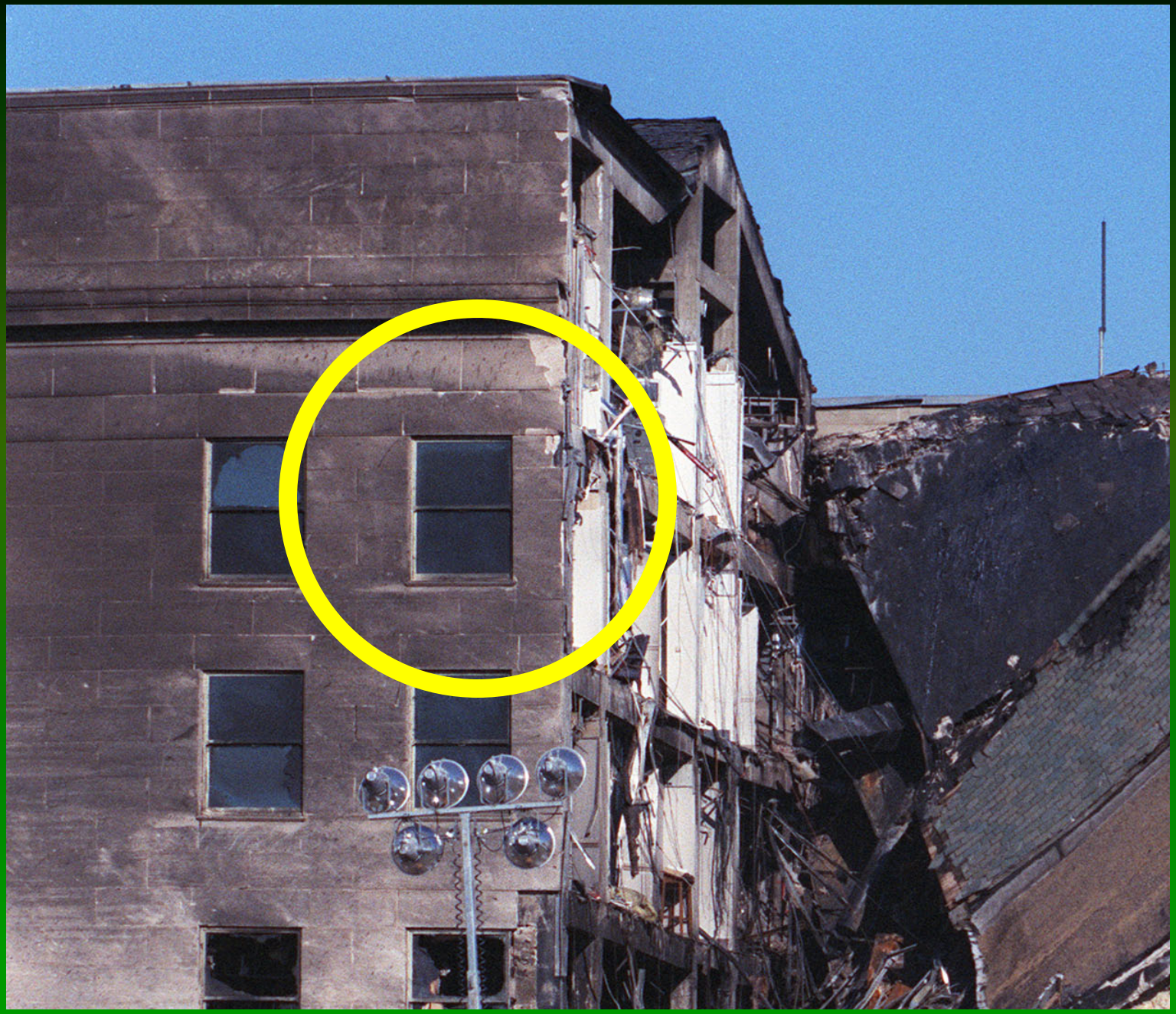


Other Window/Glass Considerations

- **Privacy**
- **Acoustics**
- **Safety Glazing Needs**
  - Hurricane, Blast, Impact Protection
- **Limitations**
  - Temperature, Altitude, Comfort
- **Durability/Longevity**
- **Shapes**

- **Cost**


COUNTY
OF
FAIRFAX
INGERSOLL-RAND



Energy Performance Fundamentals

- U-factor
- Solar Heat Gain Coefficient
- Visible Transmittance
- Air Leakage

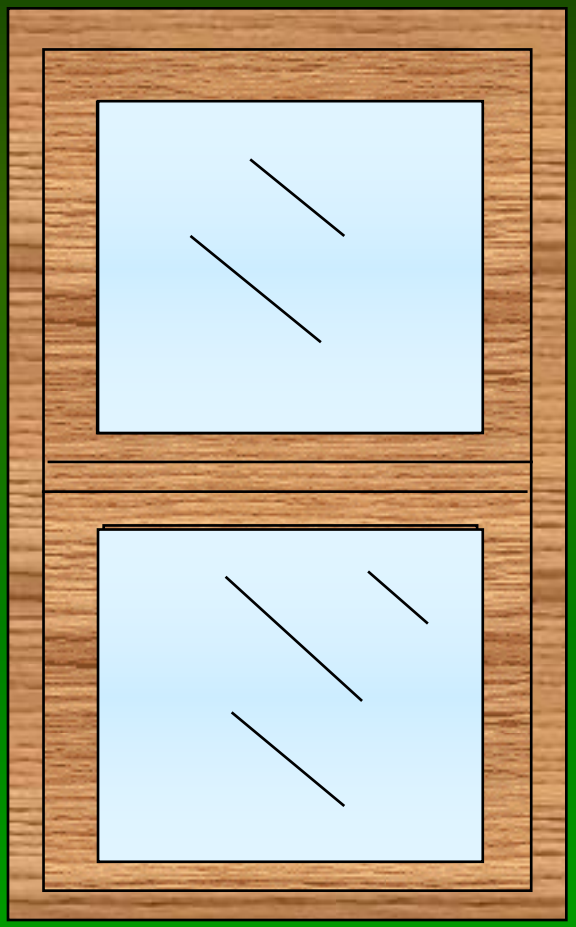
But before we go TOO far...

Chris's Rule # 1

"Specify and Compare WHOLE PRODUCT Performance Values"

Comparing Performance

Whole Product vs. Center of Glass Performance



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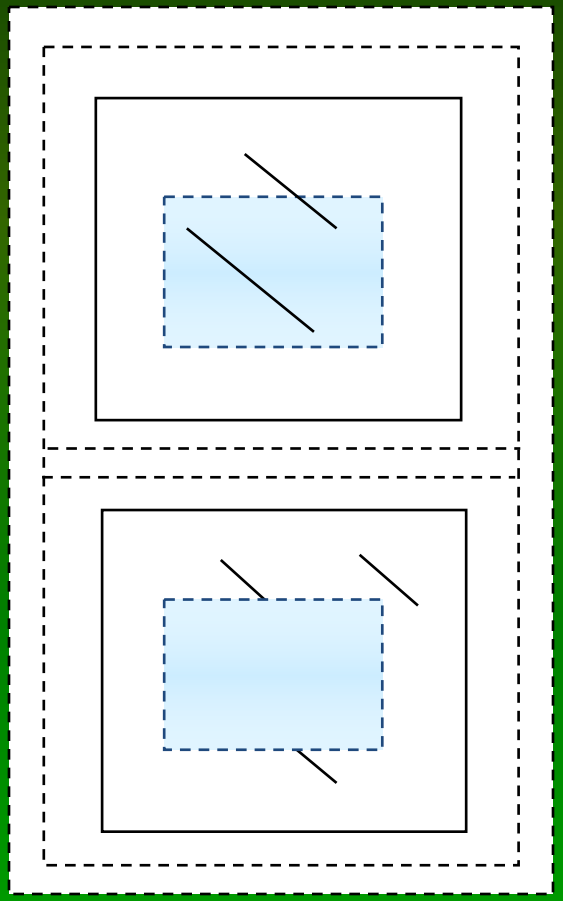
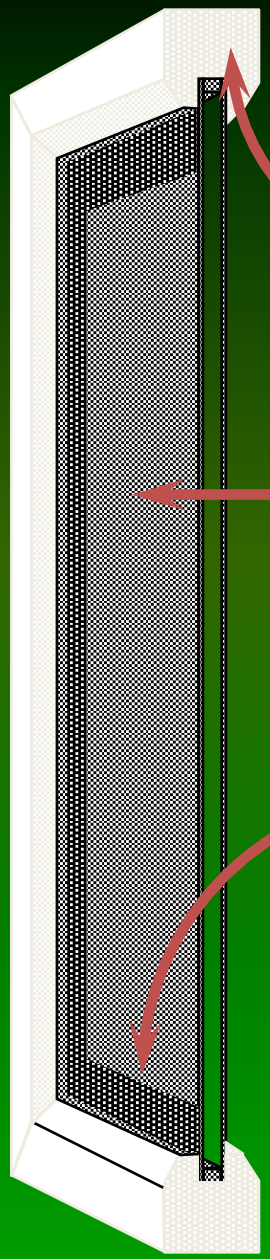


Different Materials:

- Wood
- Vinyl
- Aluminum
- Glass
- Steel
- Sealants
- Gases
- Laminates
- Coatings
- etc.



Frame area

Center-of-glass area

Edge-of-glass area

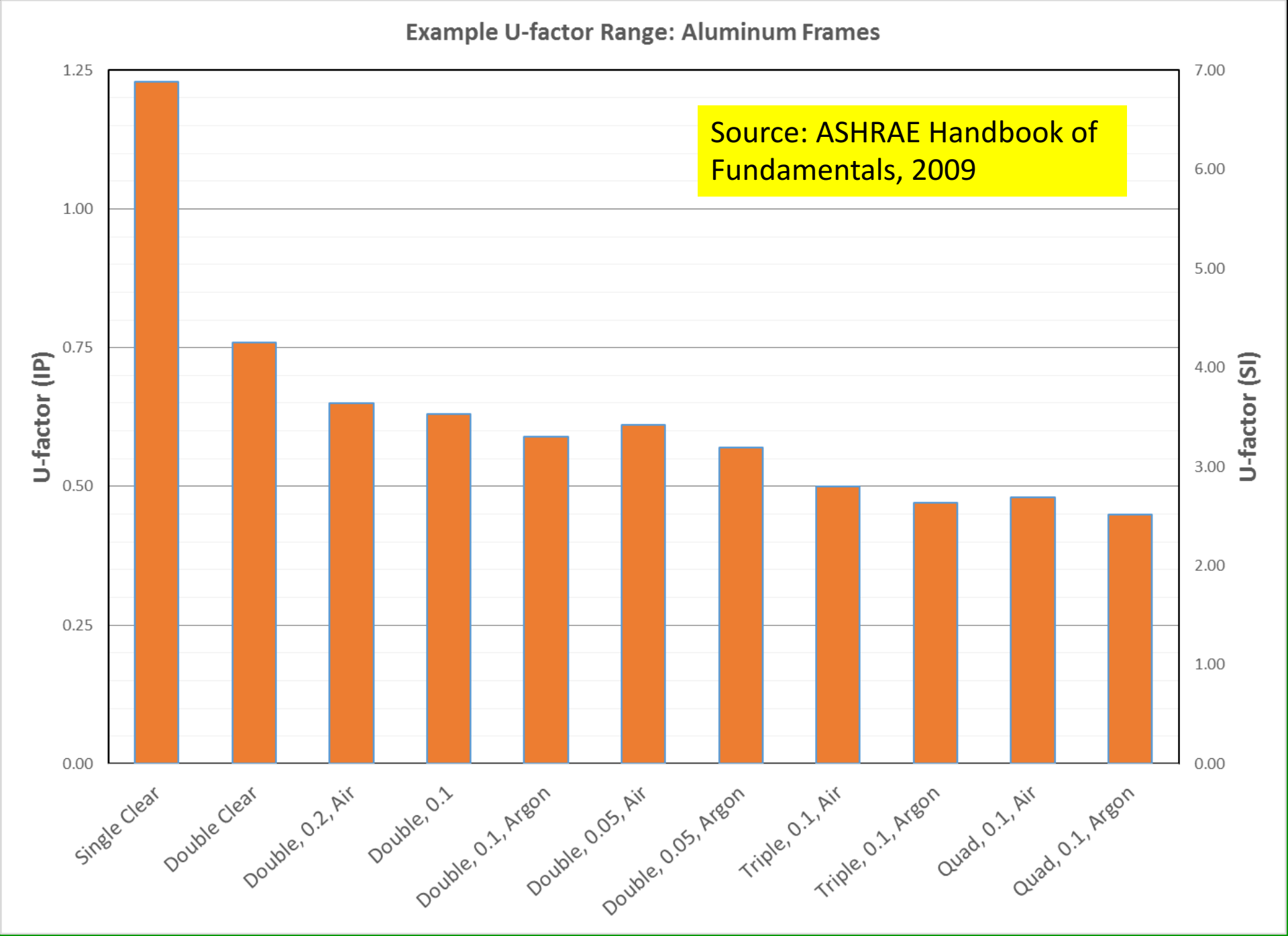
Specification Basics: Energy

Four Energy Basics

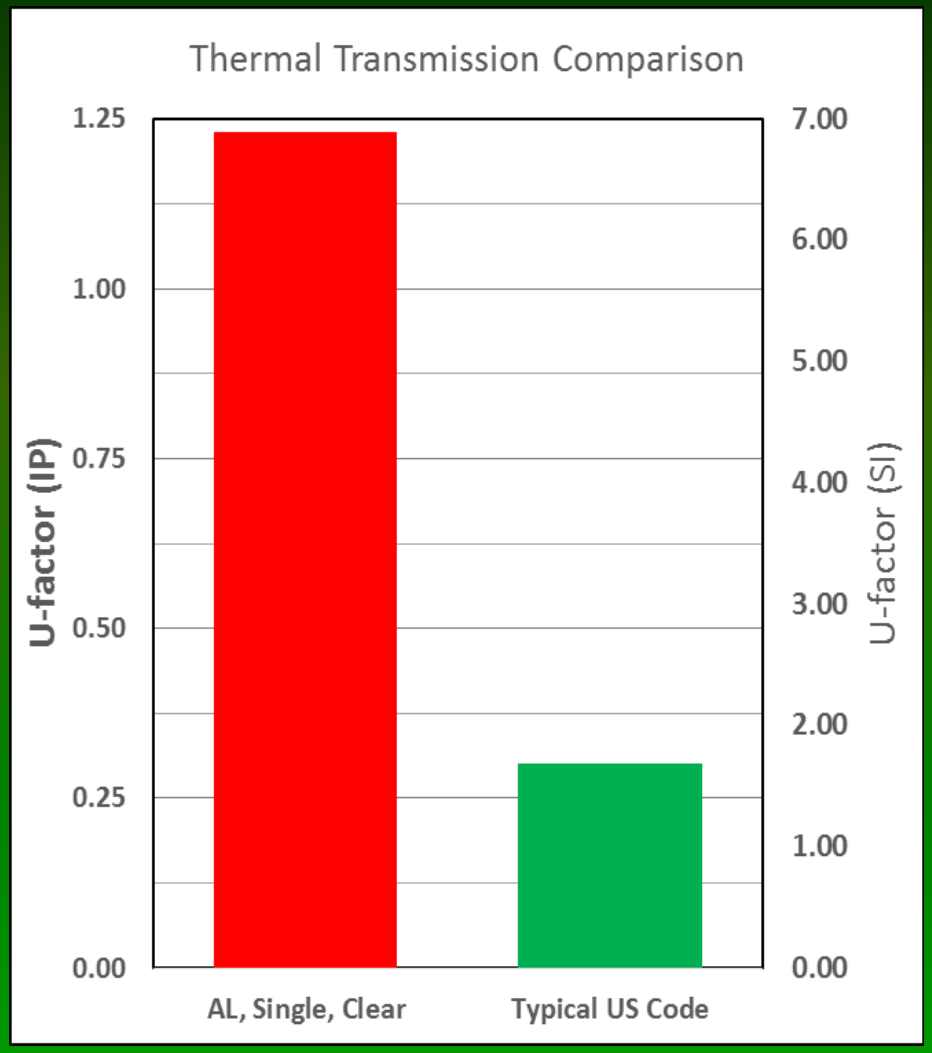
- U-factor
- Solar Heat Gain Coefficient
- Visible Transmittance
- Air Leakage

- **Project specific**
  - High rise? Low-rise?
  - Residential? Industrial?
  - Office? School?
- **Climate specific**
  - Hot? Cold? Mixed?
  - Dry? Humid?
  - Sandy? Snowy?
  - Altitude?
- **Microclimate specific**
  - Orientation
  - End Use

Primary Window Performance Elements


Example U-factor Range: Aluminum Frames
Source: ASHRAE Handbook of Fundamentals, 2009
U-factor (IP)
U-factor (SI)
1.25
1.00
0.75
0.50
0.25
0.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Single Clear
Double Clear
Double, 0.2, Air
Double, 0.1
Double, 0.1, Argon
Double, 0.05, Air
Double, 0.05, Argon
Triple, 0.1, Air
Triple, 0.1, Argon
Quad, 0.1, Air
Quad, 0.1, Argon

Heat Loss Comparison



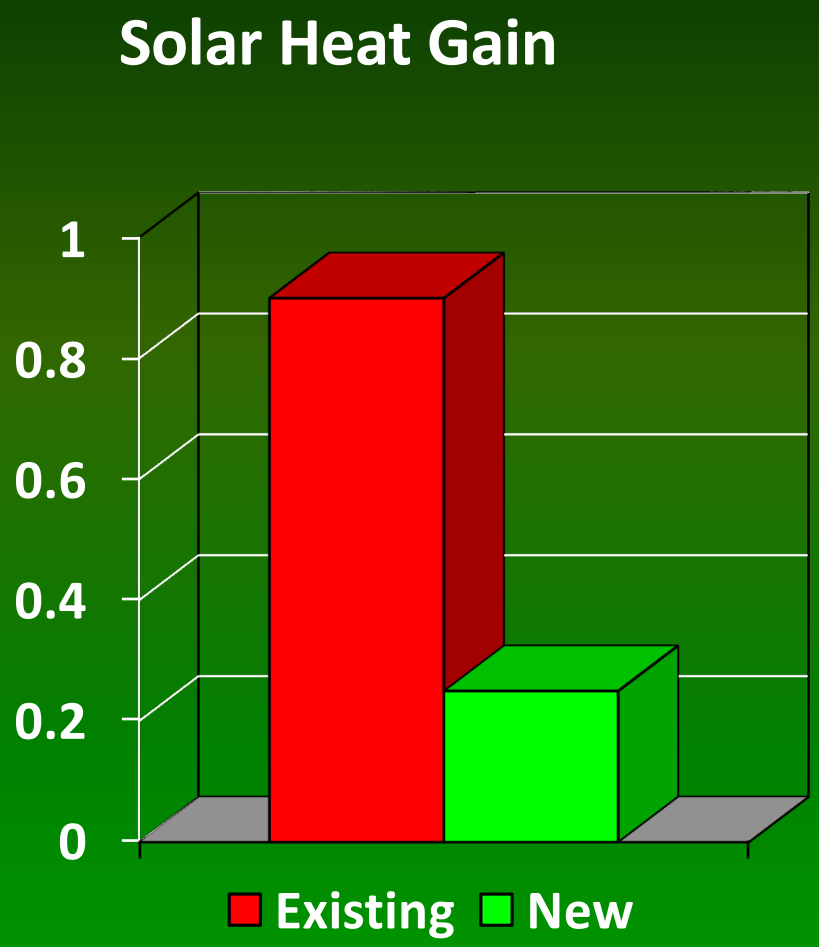
- Common aluminum-framed, single glazed windows **lose 3 to 4 times** more heat in winter than today's most basic energy efficient technologies
- Cold glass surfaces with recurring condensation
- BIG impact on comfort
- BIG impact on heating costs

"U-Factor"

- **Amount of heat transmitted through the window due to a temperature difference between inside and out.**
  - Includes Conduction, Convection and Radiation heat transfer through the unit
- **The lower the value, the less heat is lost through the window in the winter**
- **Simple Rule for heating climates:**
  - **Look for products with a U-factor < 0.30**
  - Severe heating climates: U < 0.24
    - (Will be likely triple glazed with today's technology)

Now, let's talk about heat gain...

Heat Gain Comparison



- Air conditioning energy is very expensive
- New window technologies are **over three times** more efficient at blocking unwanted heat gain than common aluminum-framed, single glazed windows
- Windows generally drive the air conditioning load (residential)
- Windows generally determine the perimeter load (commercial)

“Solar Heat Gain Coefficient”

- **The fraction of the incident solar radiation that is actually transmitted through the window in the form of heat gain**
- **The lower the value, the less solar heat gain into the space**
- Simple rule for cooling climates:
  - **Look for SHGC values < 0.25**
  - Severe cooling climates: SHGC < 0.20
    - (But will have visible color and loss of optical transmission)

Two “Low-E” Windows

Message:

They may LOOK the same - but can perform very differently.

Two Solar Control Options

Message:

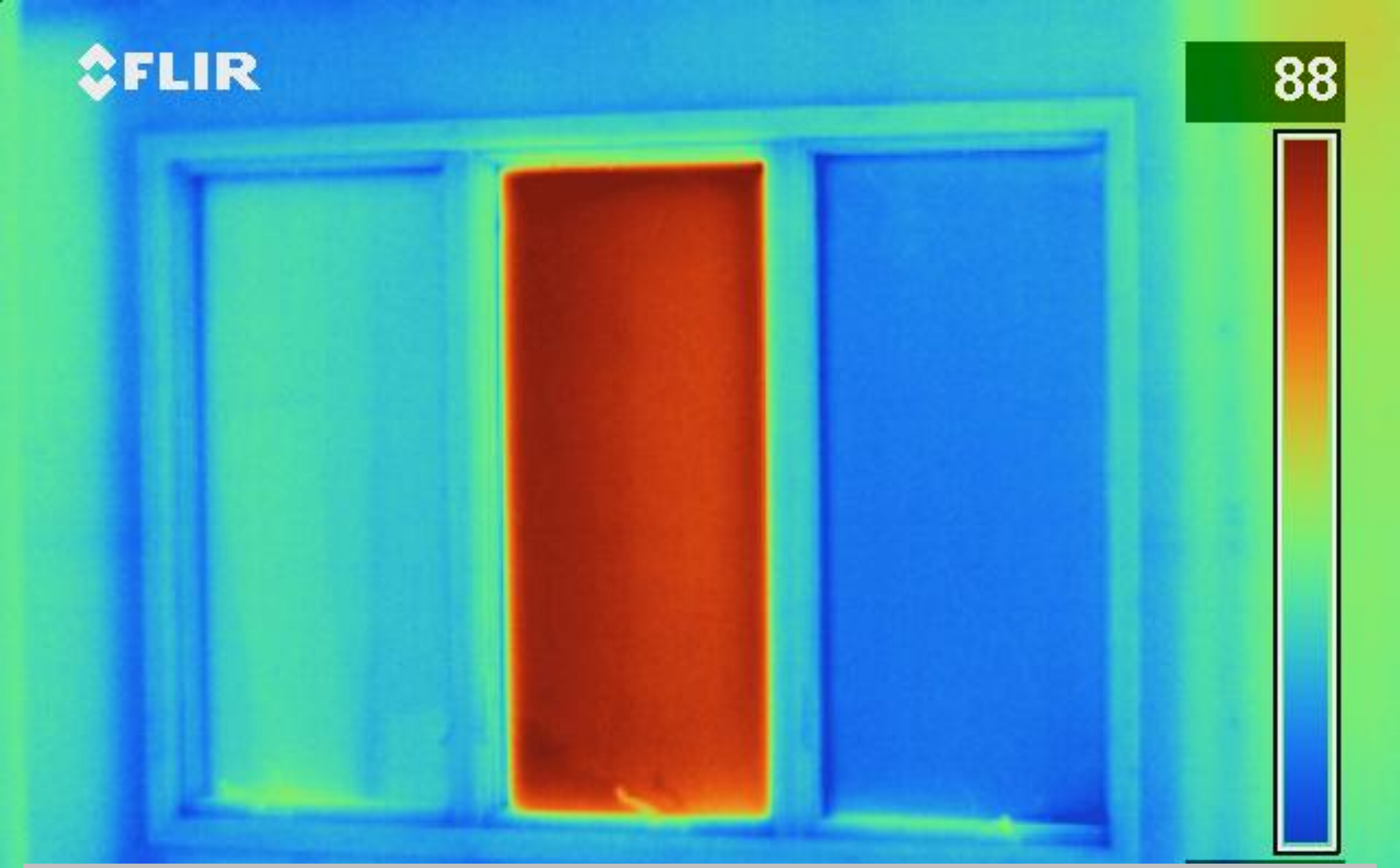
They may LOOK different - but can perform the same!

Chris's Rule # 2

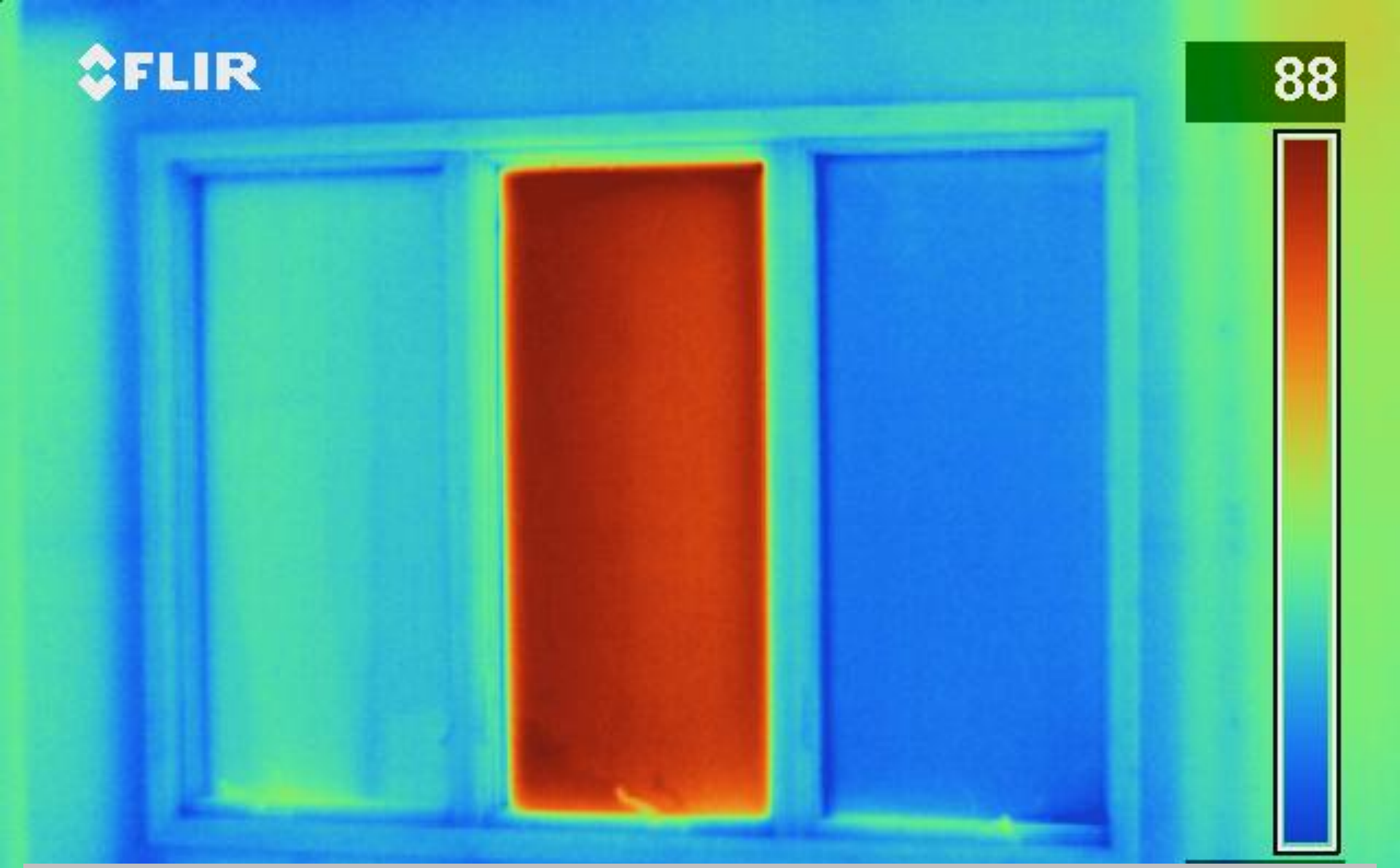
Don't Trust Your Eyes!

- Can look the same, but perform differently;
- Can look different, but perform the same.


| Low-E | Clear Glass
Med Solar | High Solar



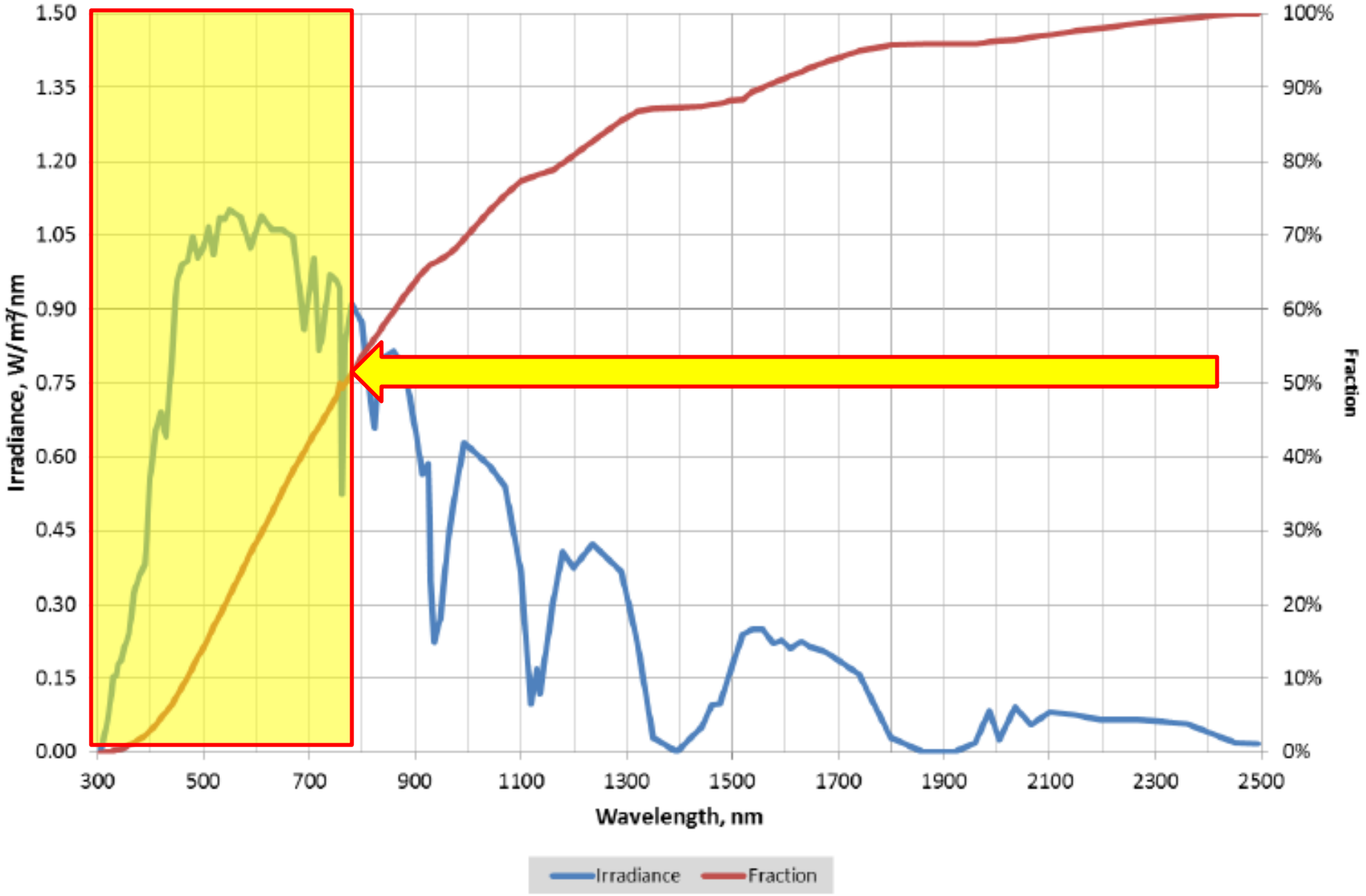
High solar gain low-E is hot in sunlight



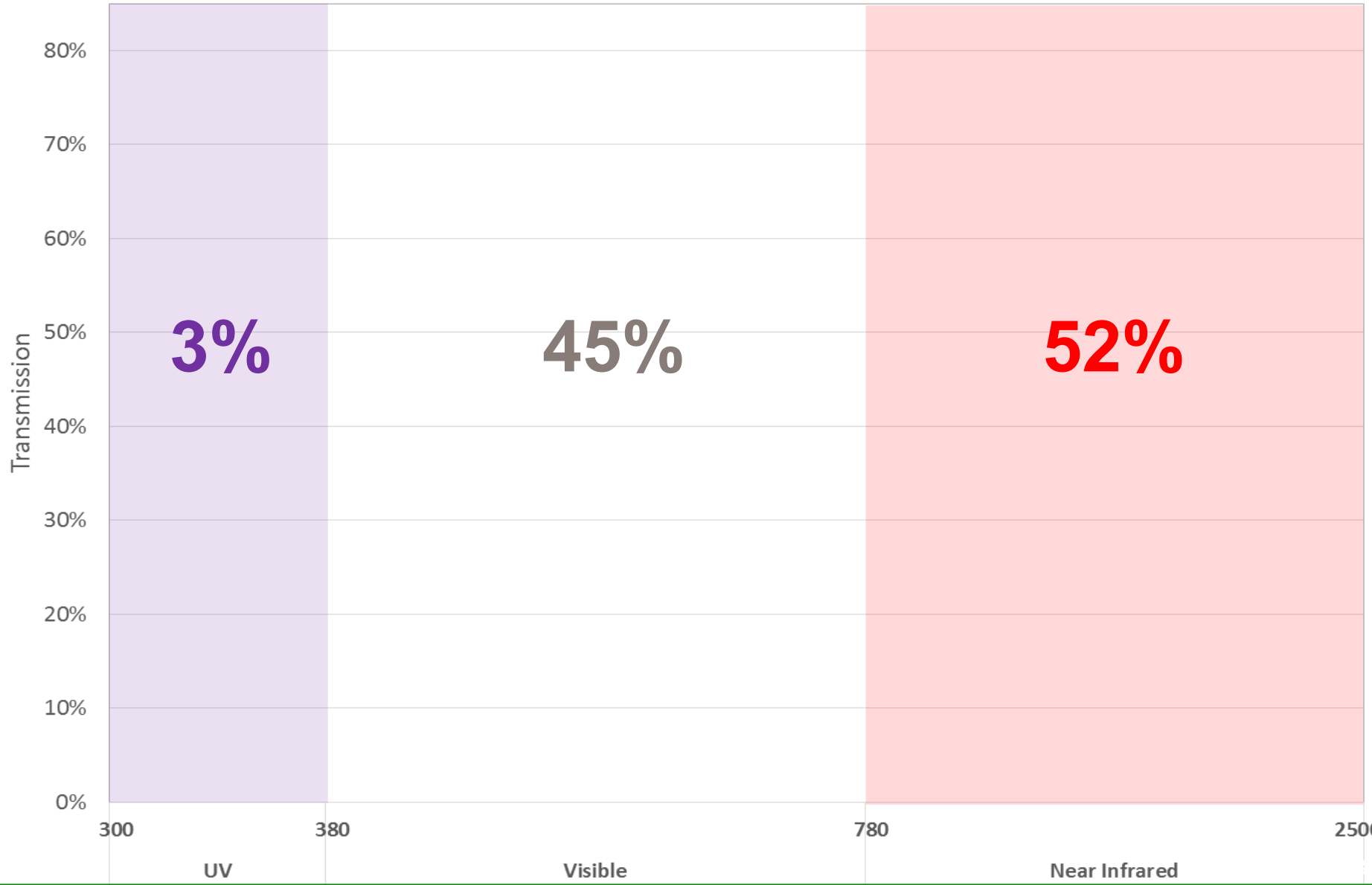
If entire house was glazed with HSLE, cooling thermostat would have to be lowered by 4-5°F for equal comfort

Review
Glass Performance Fundamentals

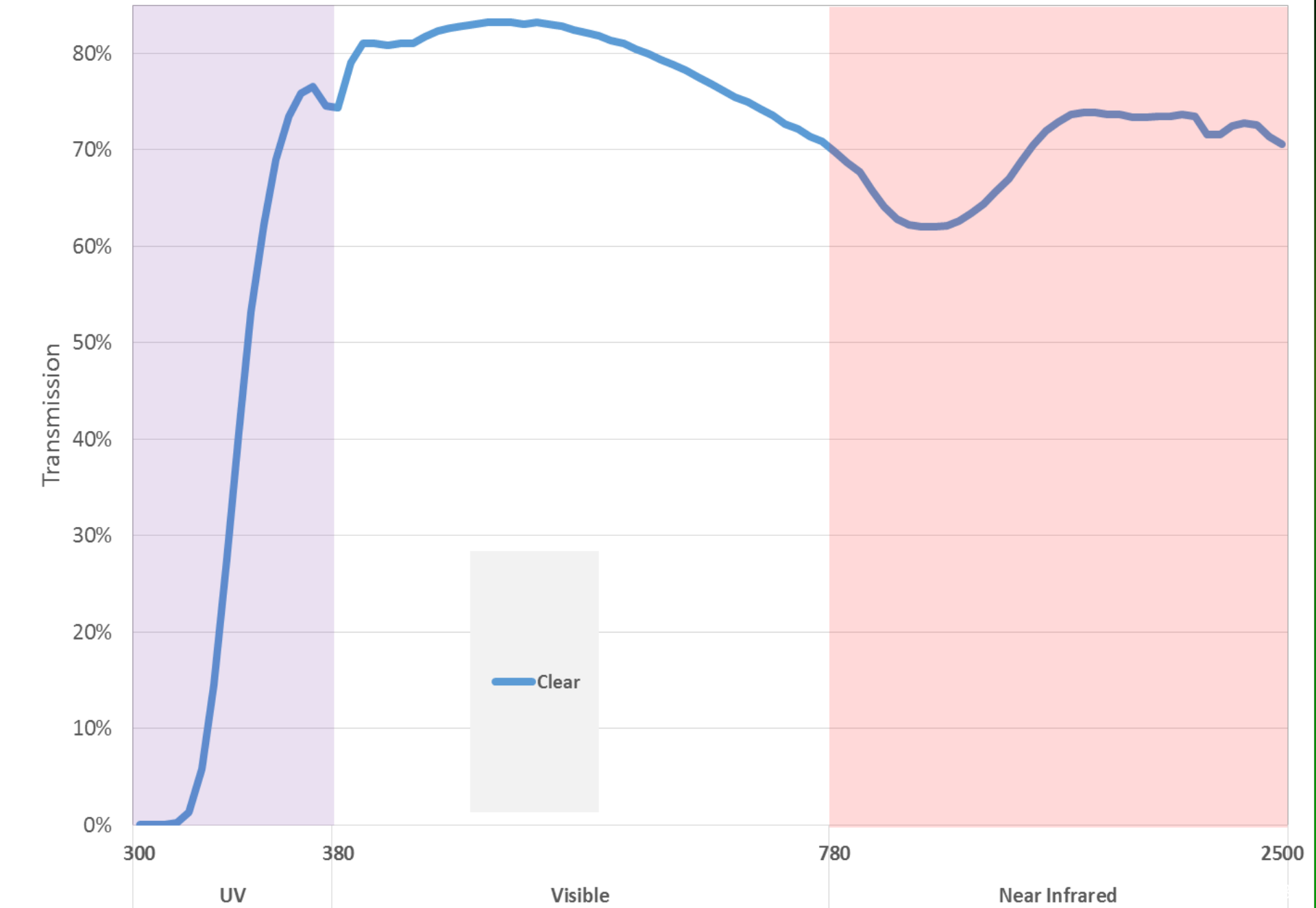
E891/G159/ISO 9845



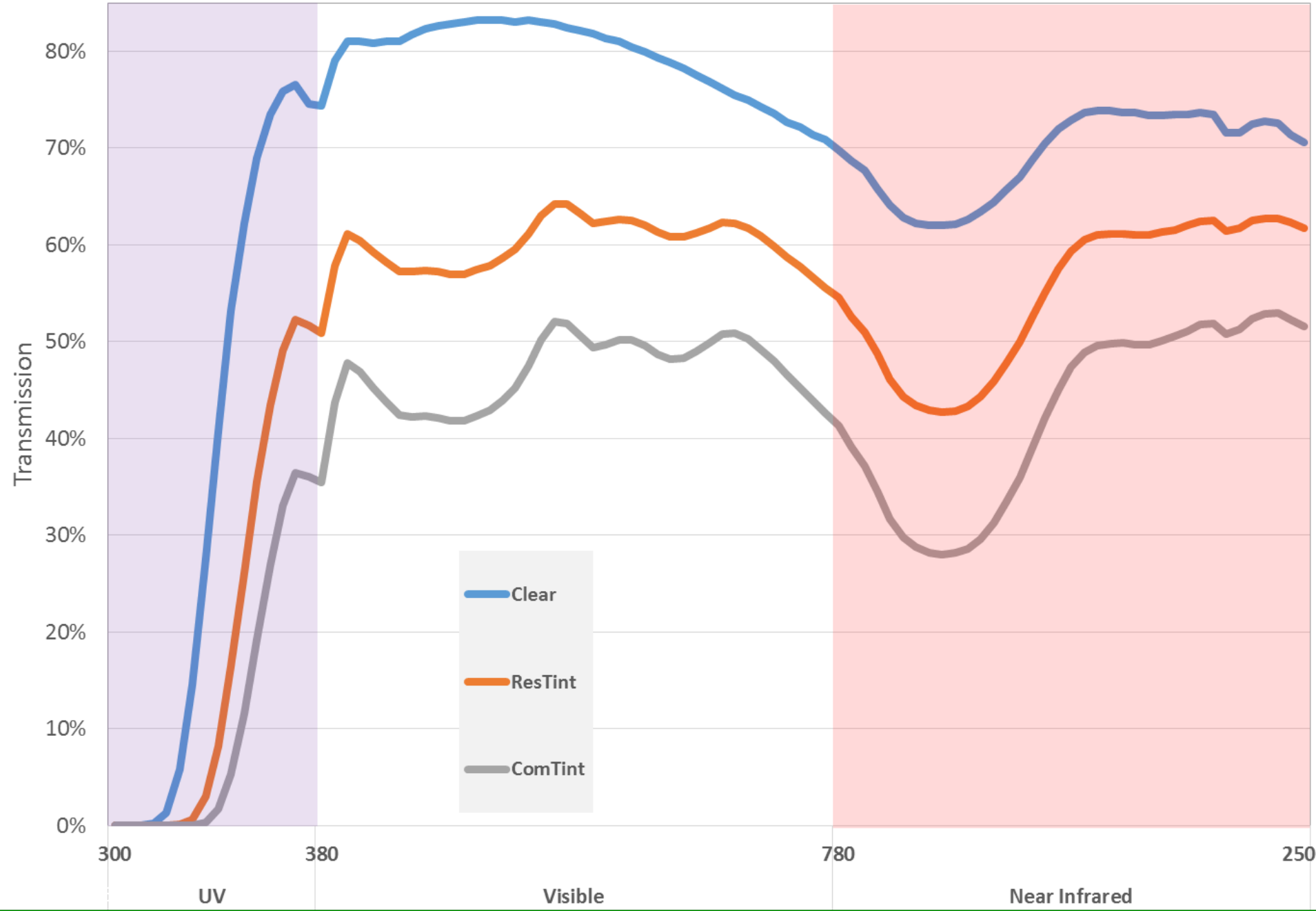
The Solar Spectrum



Clear Double Pane Glass SHGC ~ 0.75



Tinted Double Pane Glass SHGC 0.65 – 0.55



Today's Options for Solar Control

Tinted Glass

- Adds color to "body" of glass
- Absorbs sunlight and re-radiates to exterior

Reflective Glass

- Mirror appearance
- Reflects sunlight out

Spectrally Selective (~1990)

- Clear glass appearance with solar control
- Reflects solar infrared (invisible to human eye)

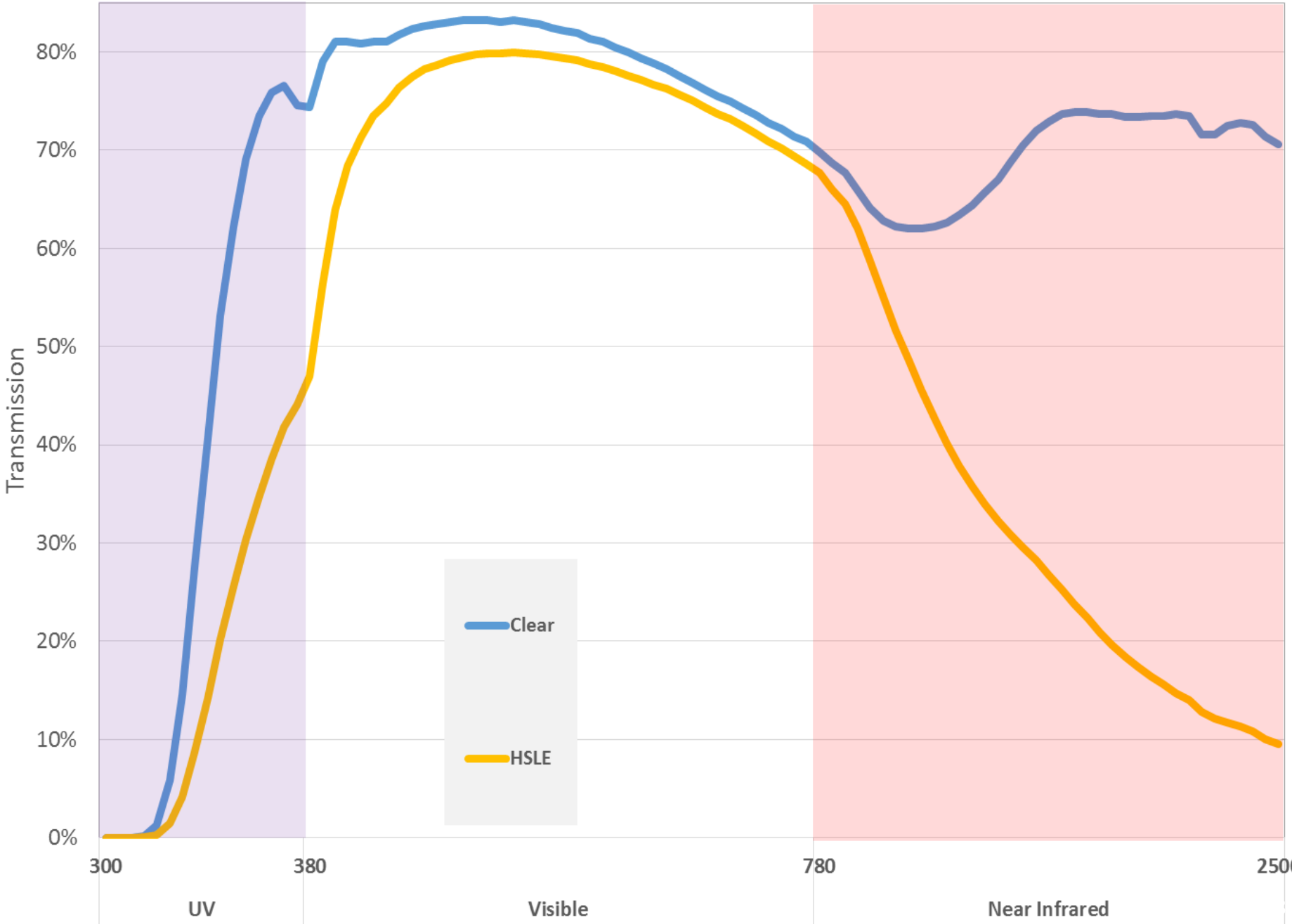
“Clear” Low-E Solar Options

High Solar Gain (HSLE)

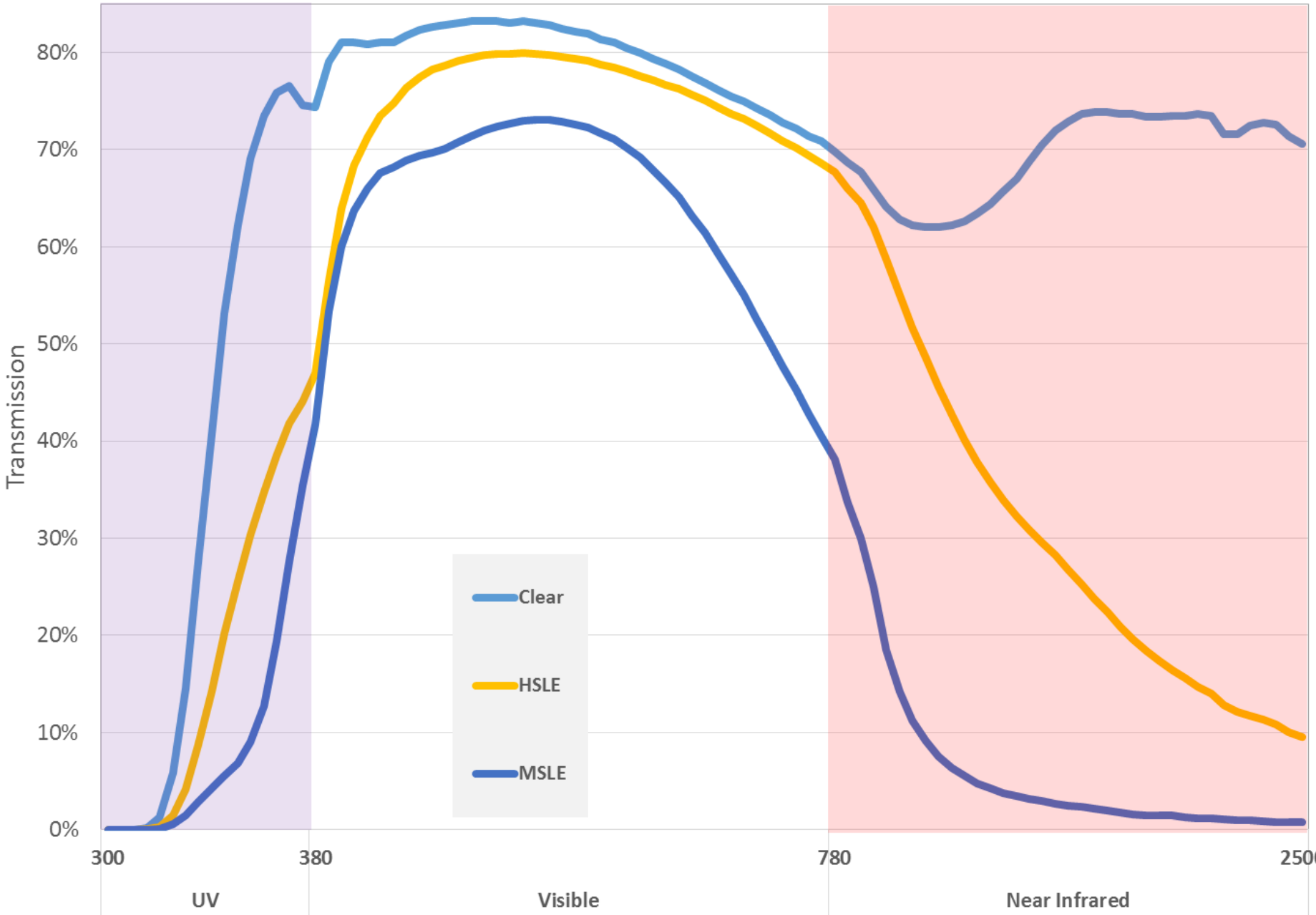
- VT ~ 80%
- Glass SHGC ~ 0.65

- **This was the 1st generation low-E introduced in the early 1980s. (heating energy savings focus)**
- **Even though it was promoted as a “northern” glazing and backed up by energy simulations that credit passive solar gain, the consumer response was extremely negative due to year-round overheat.**

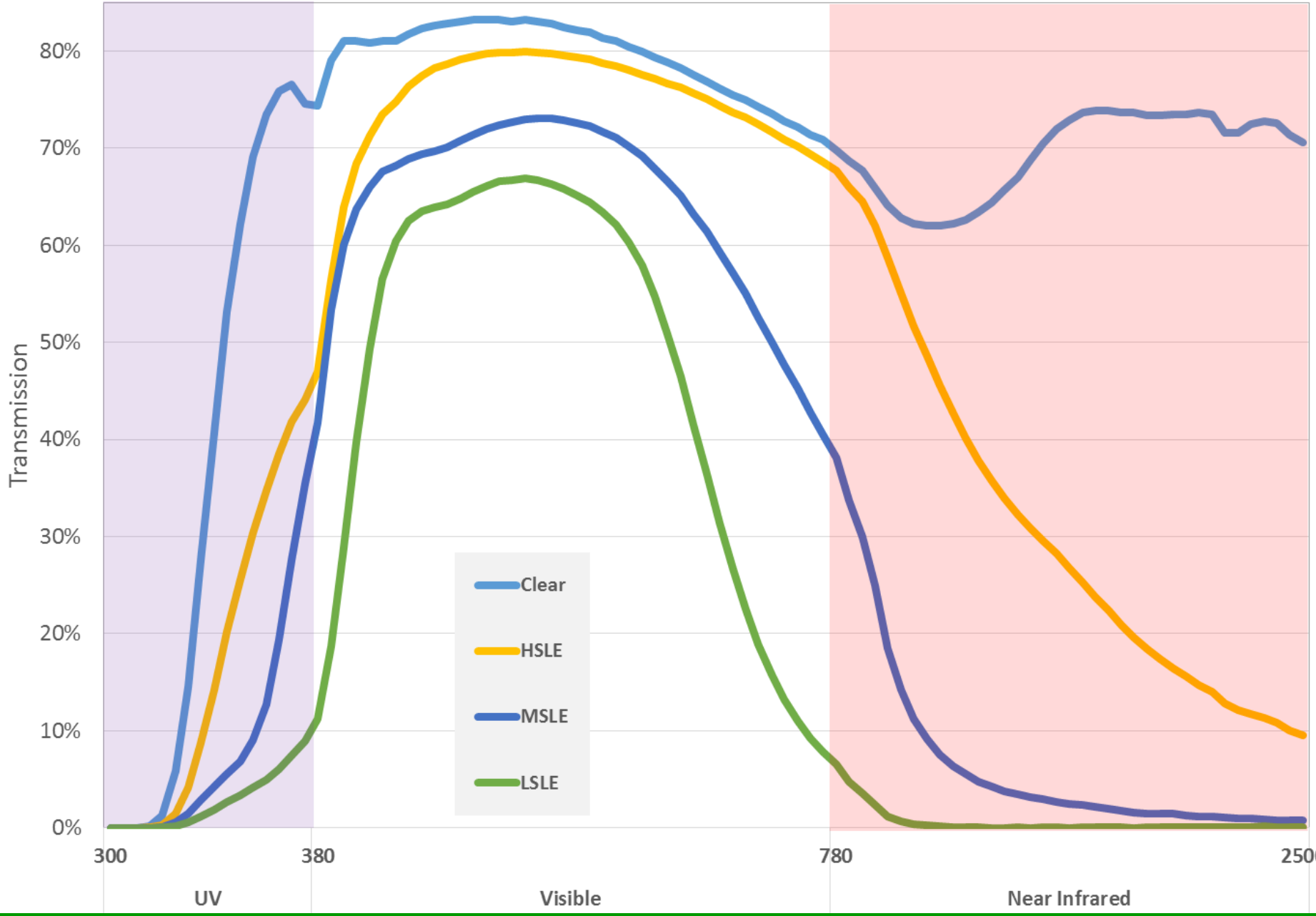
High Solar Gain Low-E: Glass SHGC ~ 0.65



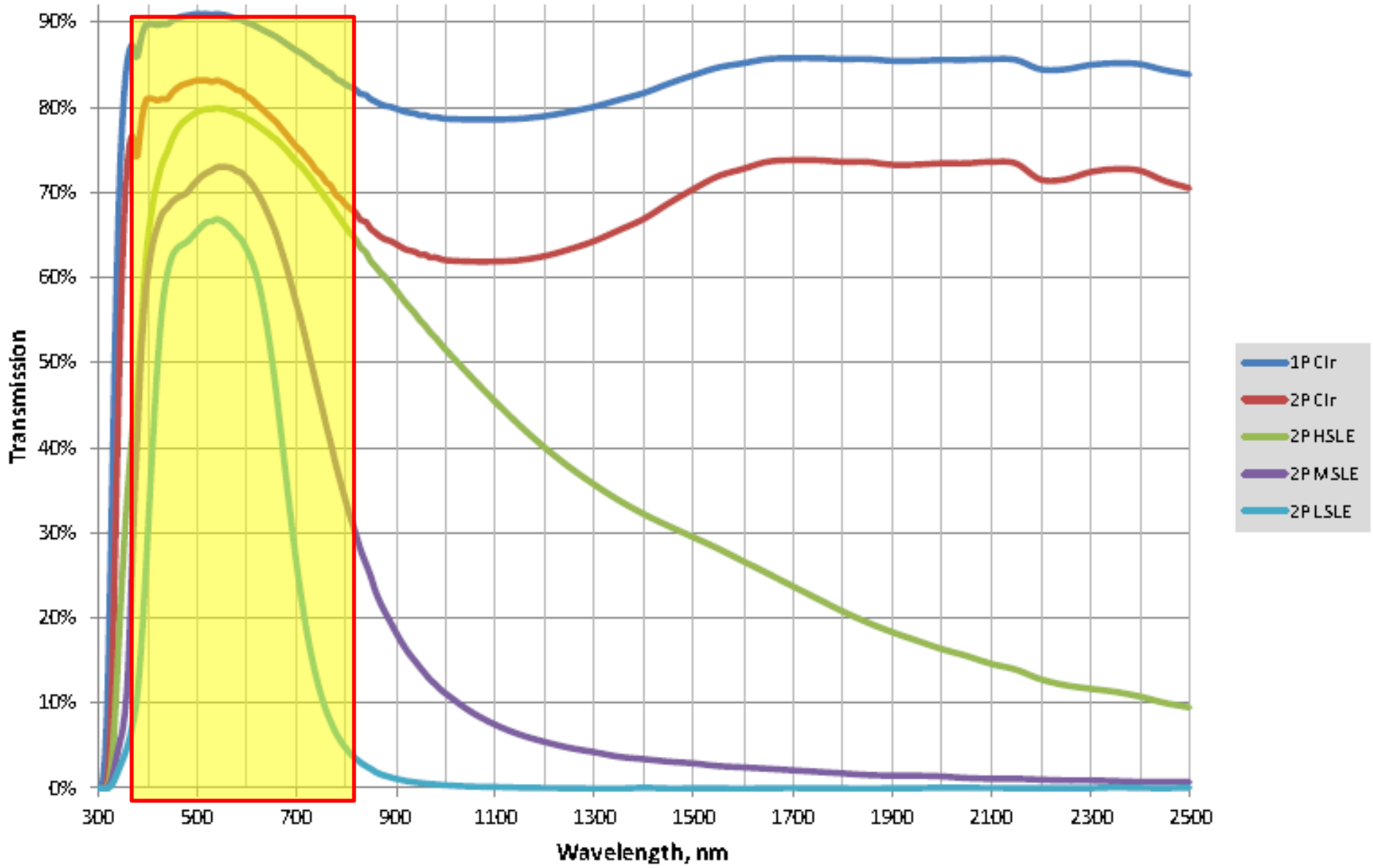
Medium Solar Gain Low-E: Glass SHGC ~ 0.40



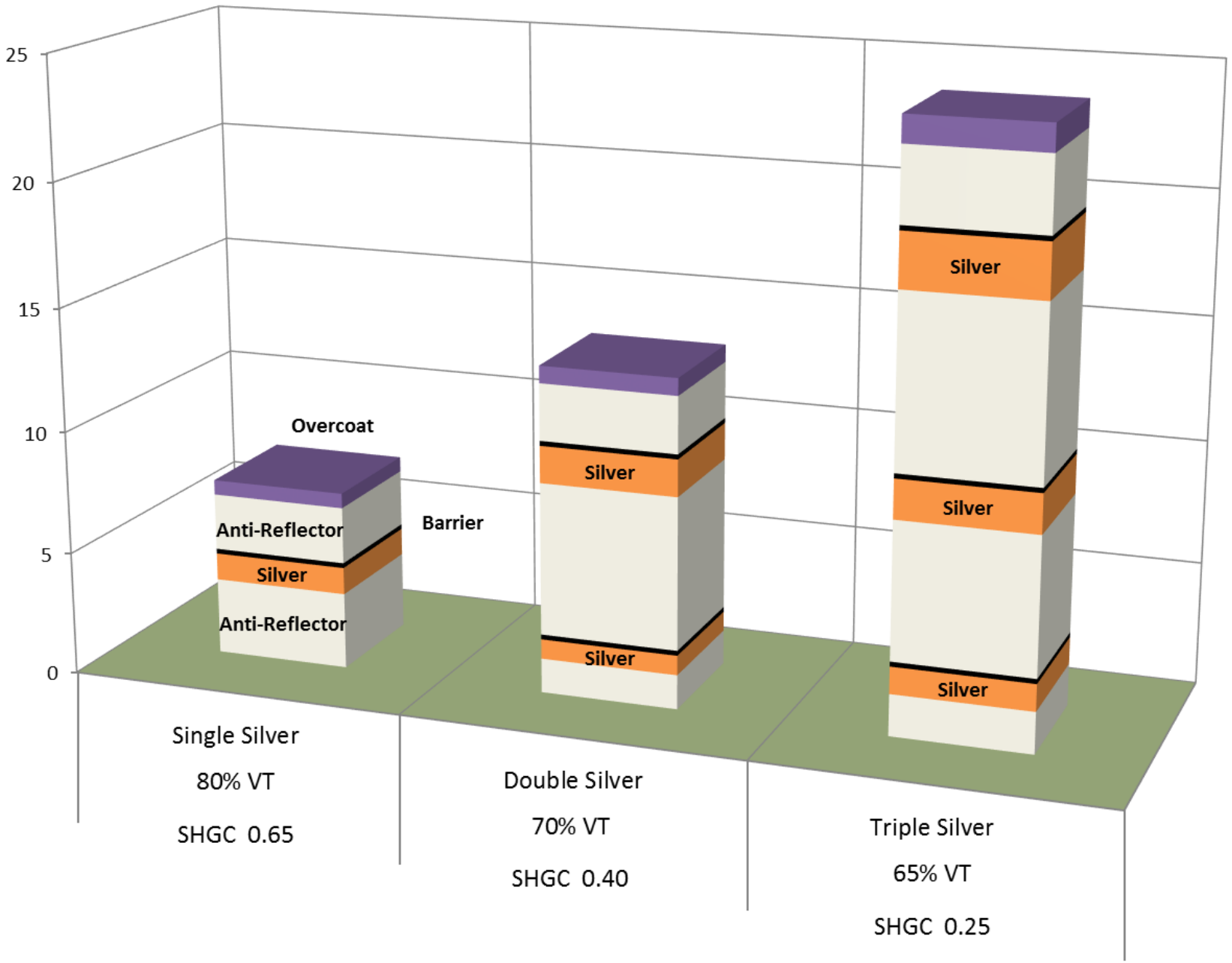
Low Solar Gain Low-E: Glass SHGC ~ 0.25



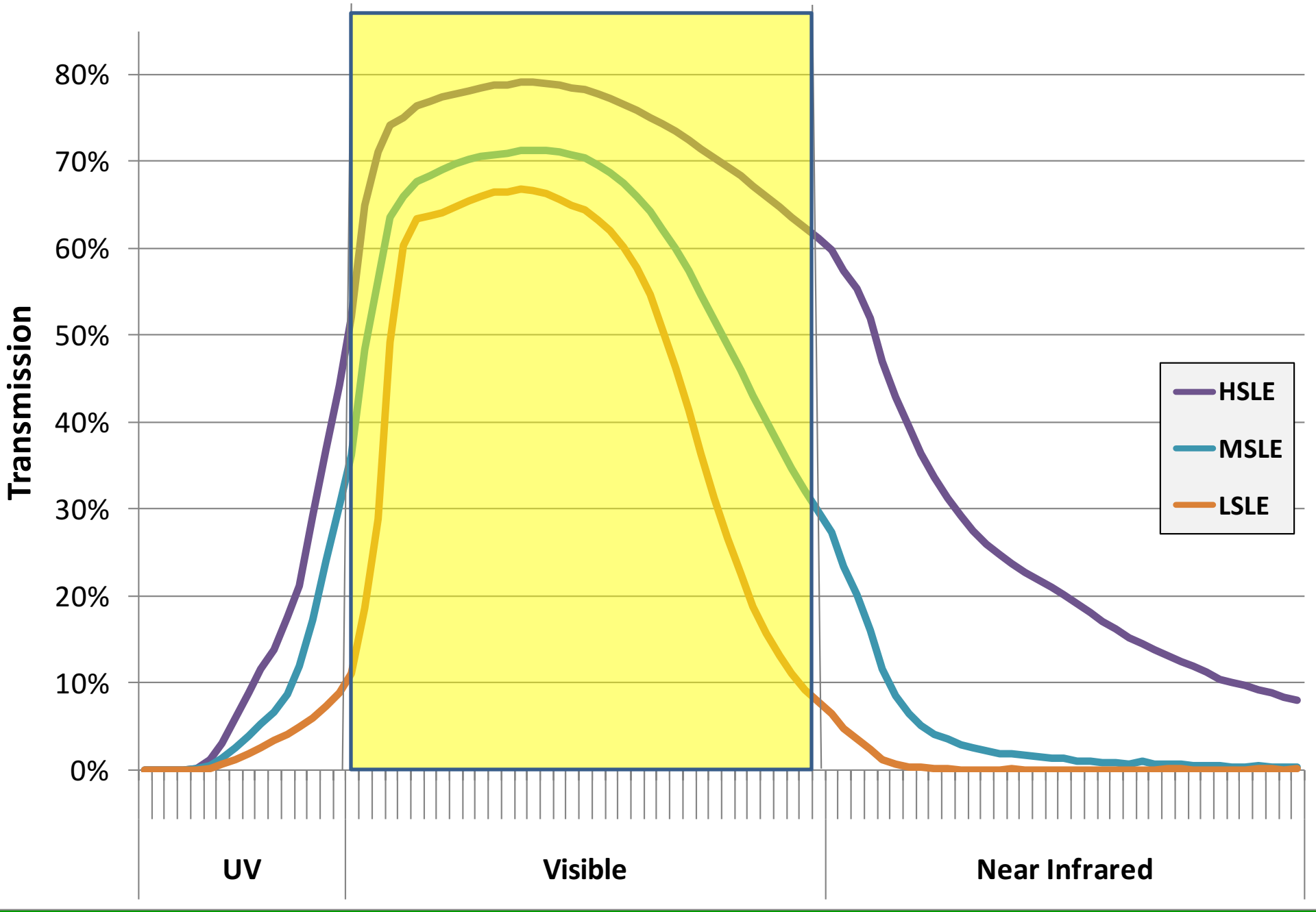
Full Spectrum Width



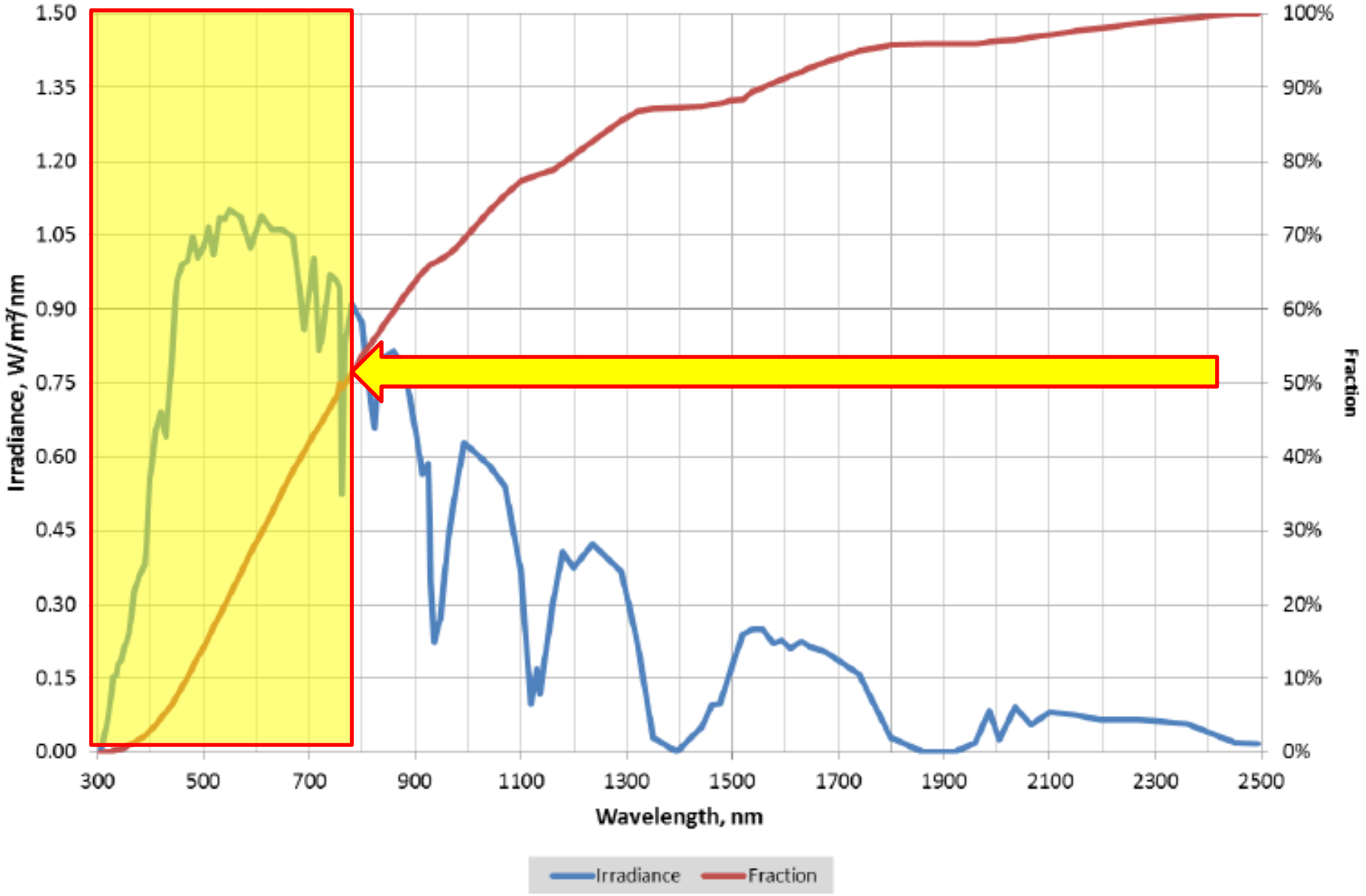
Low-E Coating Structure

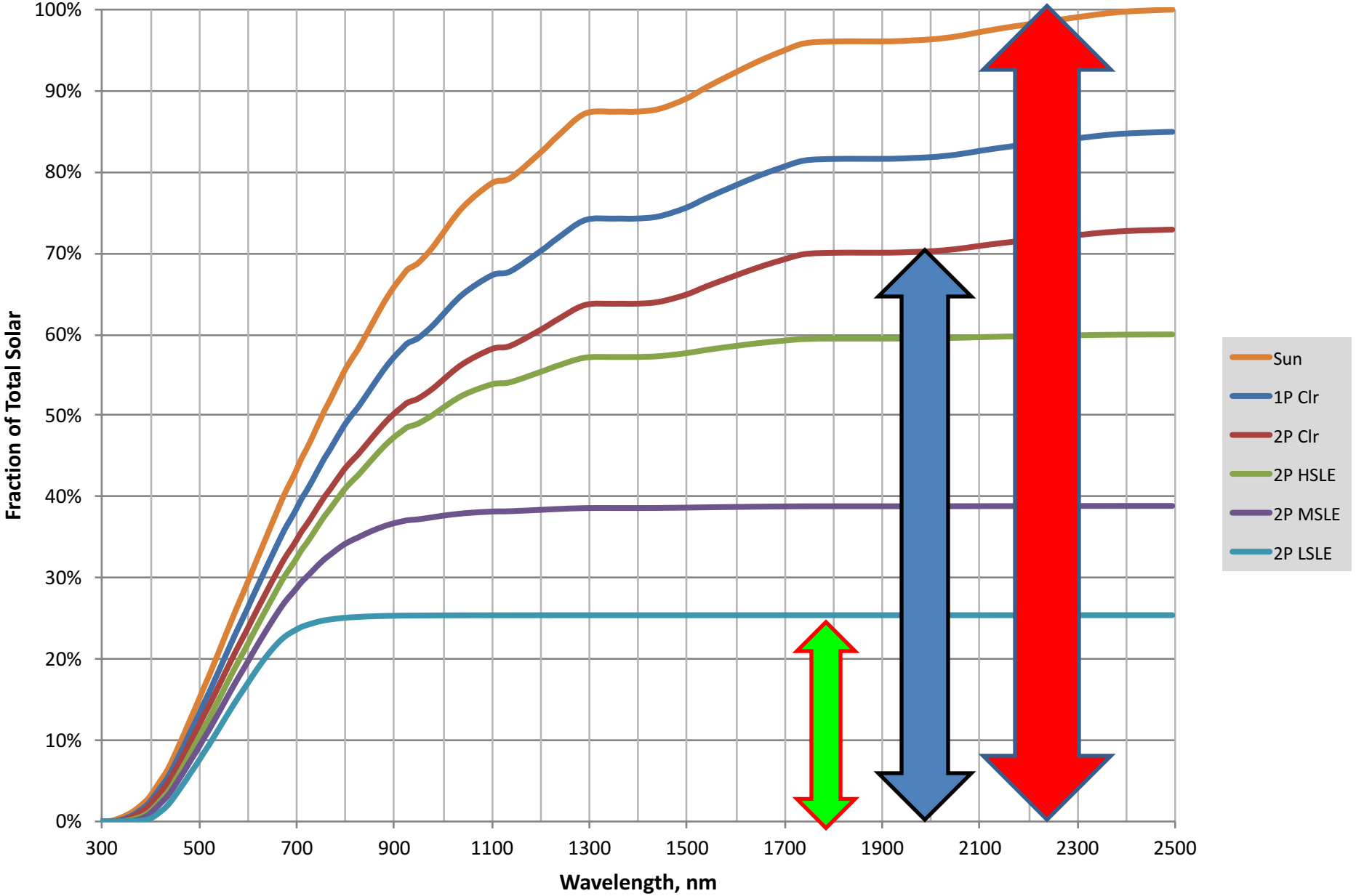


"Clear" LowE Options: High, Medium, Low Solar Gain

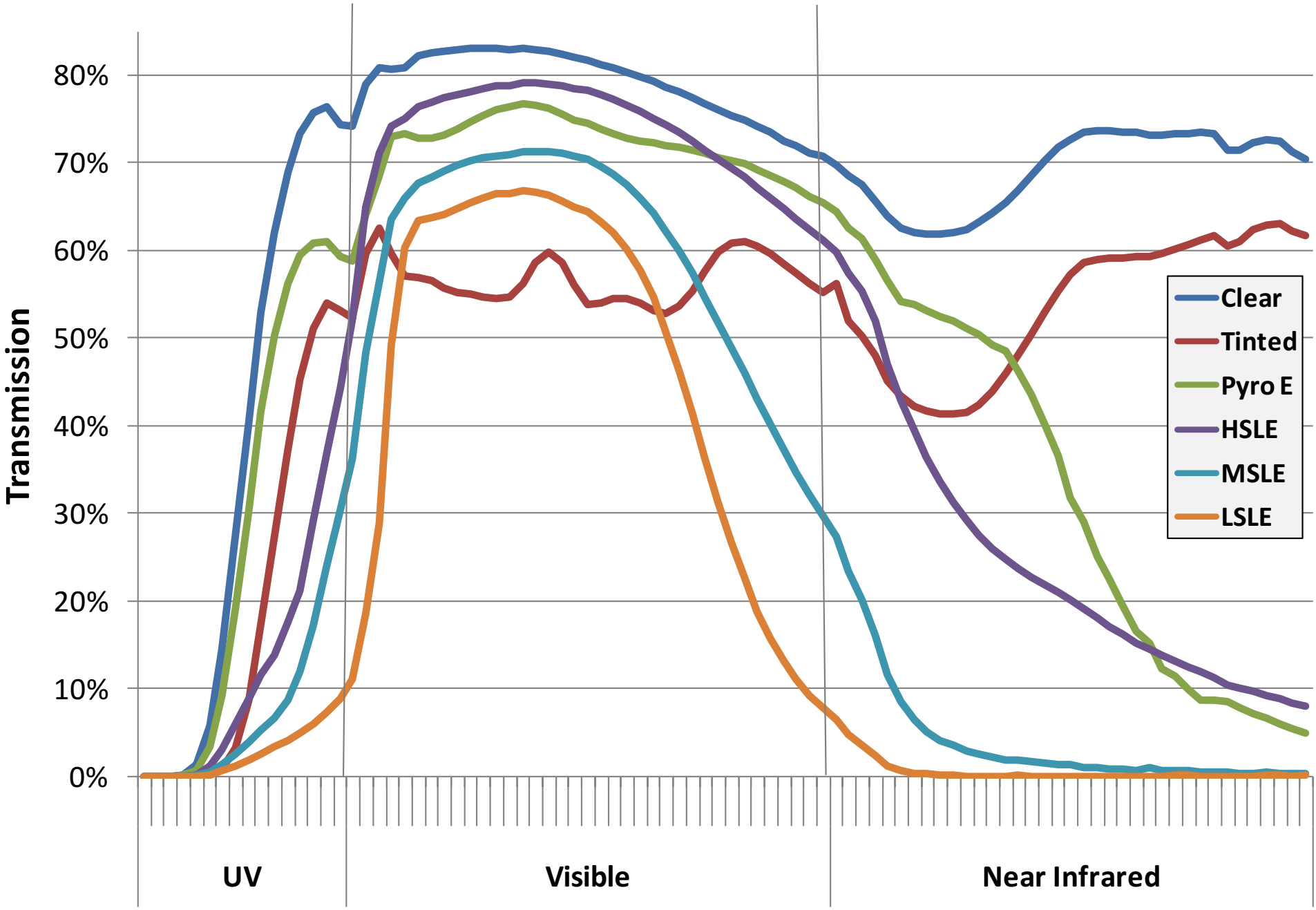


E891/G159/ISO 9845



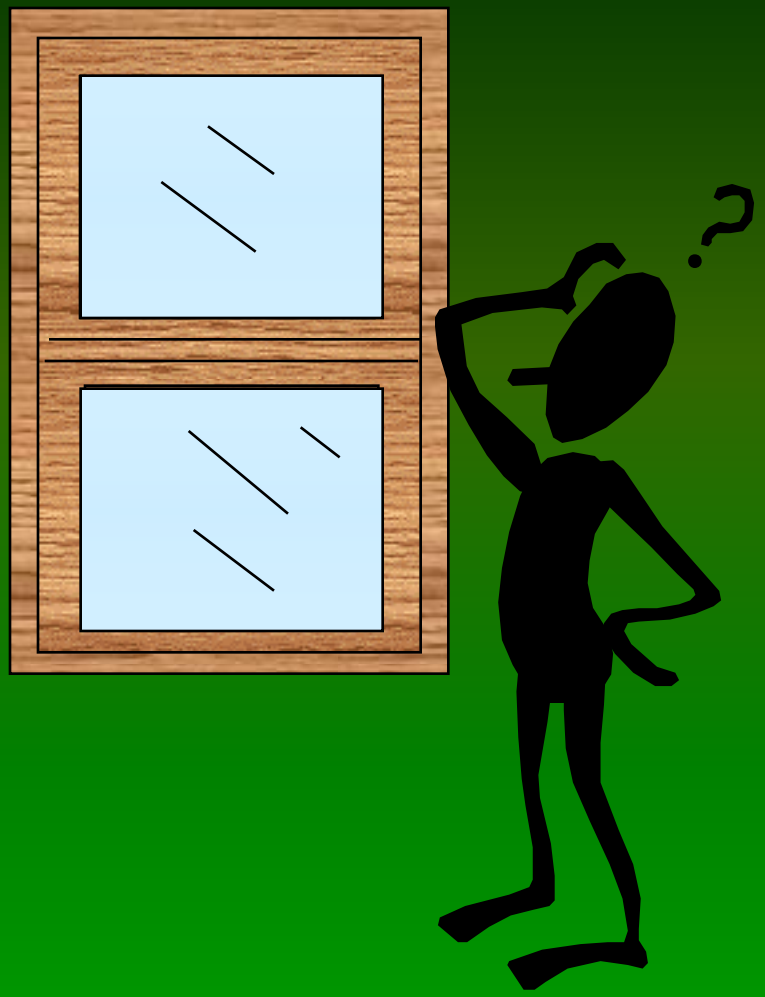

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fraction of Total Solar
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
Wavelength, nm
Sun
1P Clr
2P Clr
2P HSLE
2P MSLE
2P LSLE

What Flavor is Your Glass? Read the Label!



Is the Performance Certified & Labeled?

- **Does it have…**
  - Low-E coatings?
    - Which one?
  - Gas fills? Which one?
  - Low-conductivity spacers?
- **Does it meet…**
  - Local codes?
  - Performance expectations?
  - Comfort expectations?
- **Known Impact on HVAC Sizing Calculations?**

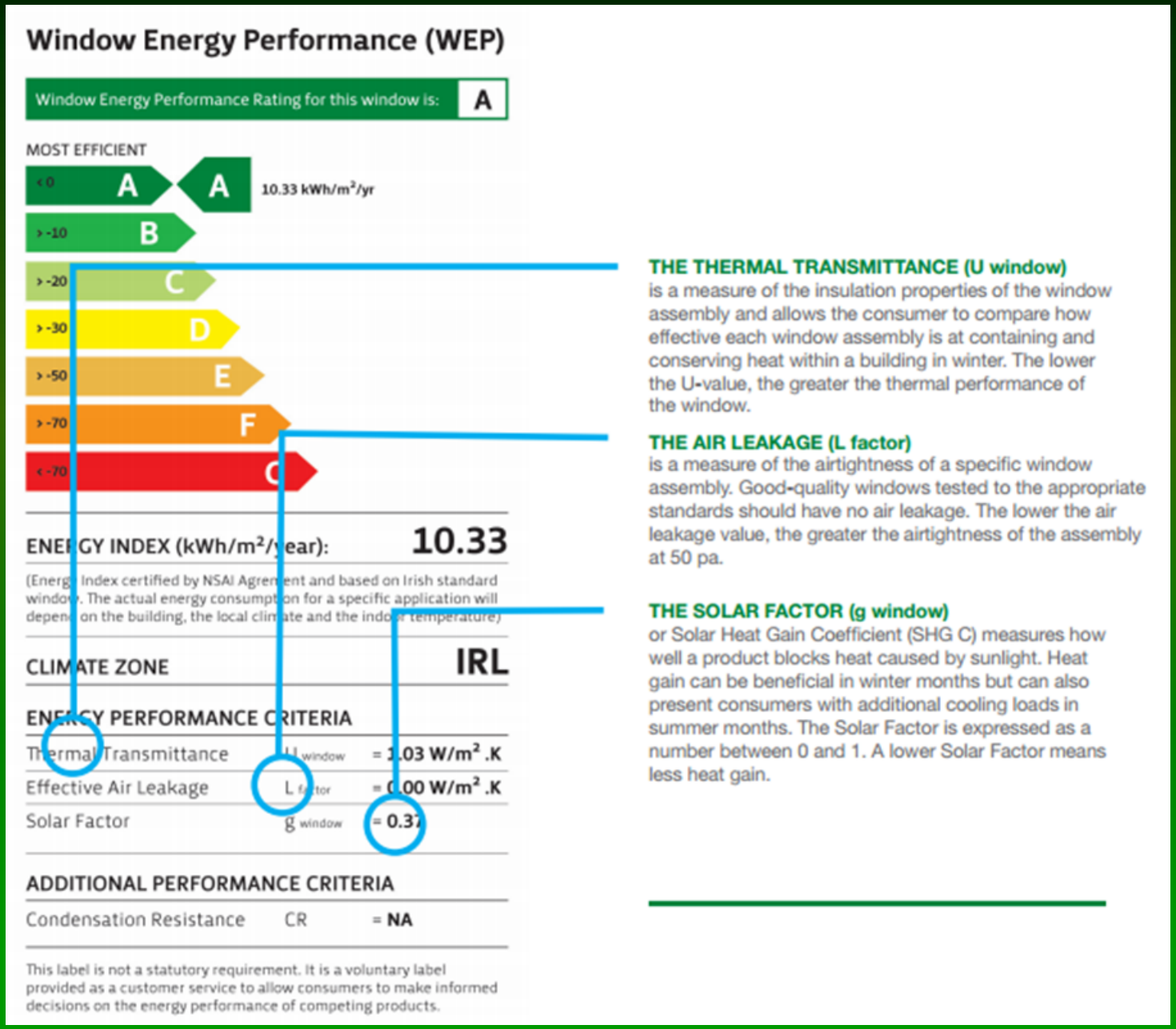


Certification Matters?

Chris's Rule #3

- **If the properties are not certified, don't buy it.**
  - No way to know critical properties by visual inspection
    - Air
    - Water
    - Structural
    - Impact
    - U-factor
    - SHGC
    - Visible Transmittance

Energy Certification in Europe: Critical



Installation and Integration

- **The DER Annex contains important guidance concerning proper replacement window installation, including information on:**
  - Proper integration with the wall's water management system
  - Air leakage minimization and control
  - Anchoring and loads
  - Etc.

- **Investments in energy efficient fenestration can be lost without proper installation**
  - We want performance that lasts!

The End in Mind

- **The Size of Things…**
  - Scale and implications of fenestration performance
- **Trends in Fenestration Performance**
  - Technological innovation and change
- **Implications for Deep Energy Retrofit Success**
  - Energy
  - Power
  - Comfort
  - Safety

Some of the messages are pretty simple…

Thank You!

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