4.401/4.464 Environmental Technologies in Buildings

Christoph Reinhart

L13 Insulation Materials & Windows

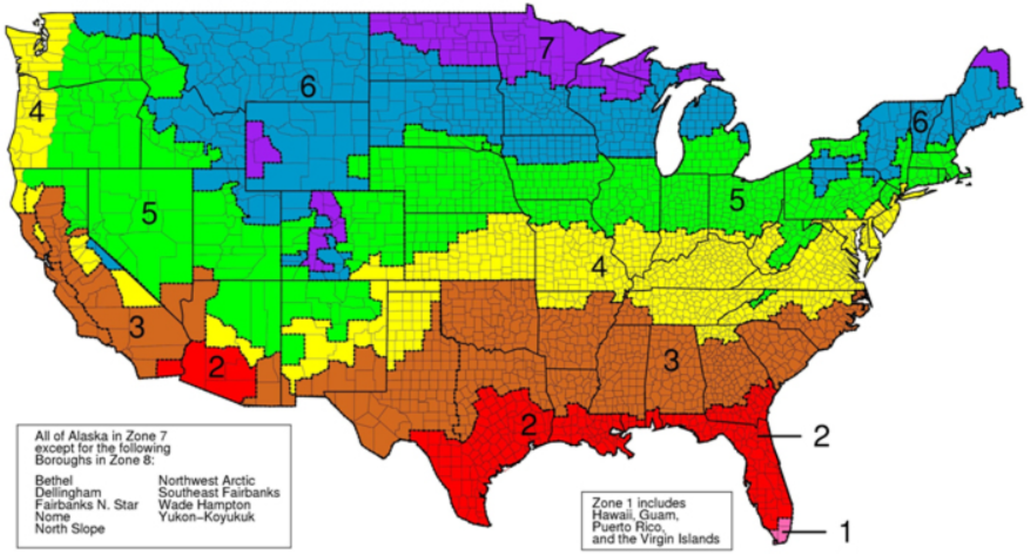
Thermal Module

- ☑ Thermal Mass & Heat Flow
- ❑ Insulating Materials & Window Technologies
- ❑ Shading
- ❑ Ventilation
- ❑ Internal Gains & Load Calculations
- ❑ HVAC for Small Buildings
- ❑ HVAC for Large Buildings
- ❑ Simulation Game

Insulation Materials

Recommended R- values

Recommended insulation levels for retrofitting existing wood-framed buildings



Zone	Add Insulation to Attic		Floor
	Uninsulated Attic	Existing 3–4 Inches of Insulation	
1	R30 to R49	R25 to R30	R13
2	R30 to R60	R25 to R38	R13 to R19
3	R30 to R60	R25 to R38	R19 to R25
4	R38 to R60	R38	R25 to R30
5 to 8	R49 to R60	R38 to R49	R25 to R30

Wall Insulation: ***Whenever exterior siding is removed*** on an

***Uninsulated* wood-frame wall:**

- Drill holes in the sheathing and blow insulation into the empty wall cavity before installing the new siding, and
- Zones 3–4: Add R5 insulative wall sheathing beneath the new siding
- Zones 5–8: Add R5 to R6 insulative wall sheathing beneath the new siding.

***Insulated* wood-frame wall:**

- For Zones 4 to 8: Add R5 insulative sheathing before installing the new siding.

Conversion : $1\ m^2K/W \approx 5.67446\ h\ ft^2 \cdot F\ /Btu$

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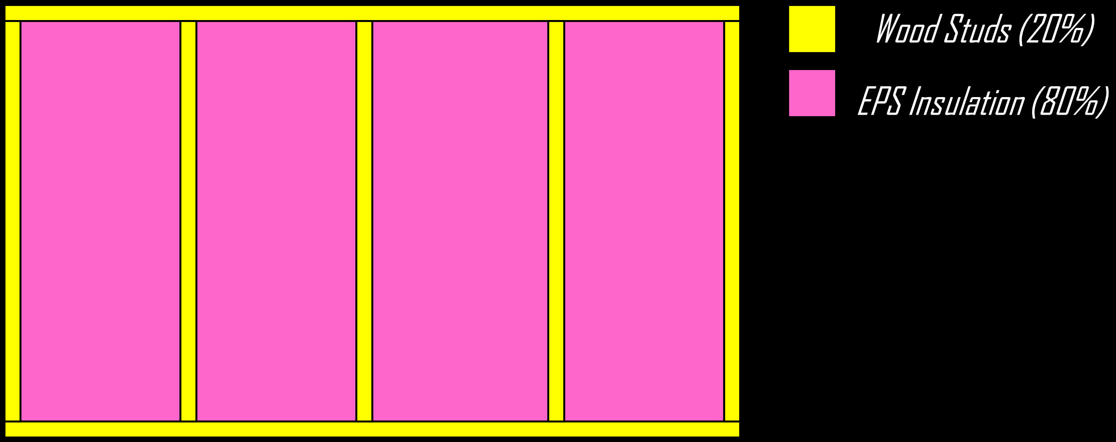
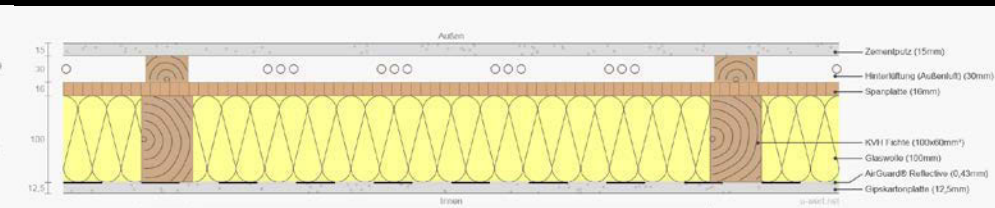
Thermal Bridging

In order to calculate the mean 'R' value of a construction that consists of different types of constructions, i.e. a wood stud construction, one has to calculate the 'R' value for each individual construction and then calculate the area weighted mean as the heat flow through the two constructions goes 'in parallel'.

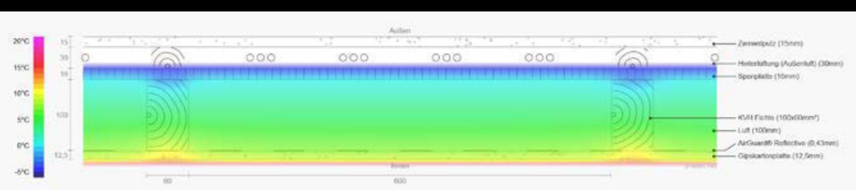


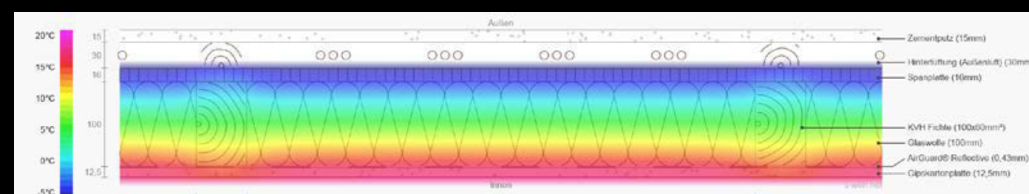
$$1/R_{wall} = 0.2/R_{Wood\ Studs} + 0.8\ /R_{EPS\ Insulation}$$

U-Value Analysis

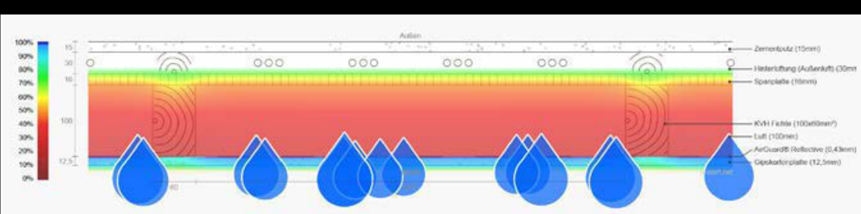


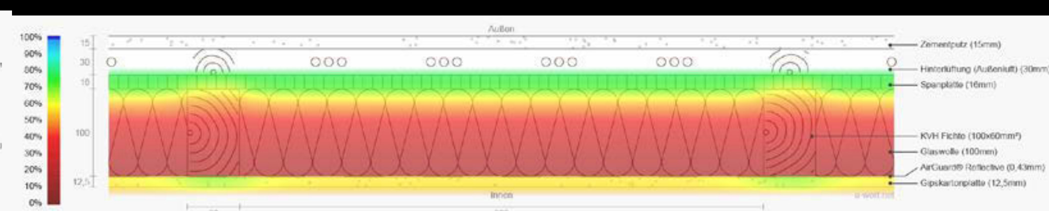
Temperature Profile





Moisture Profile





http://www.u-wert.net/berechnung/u-wert-rechner/

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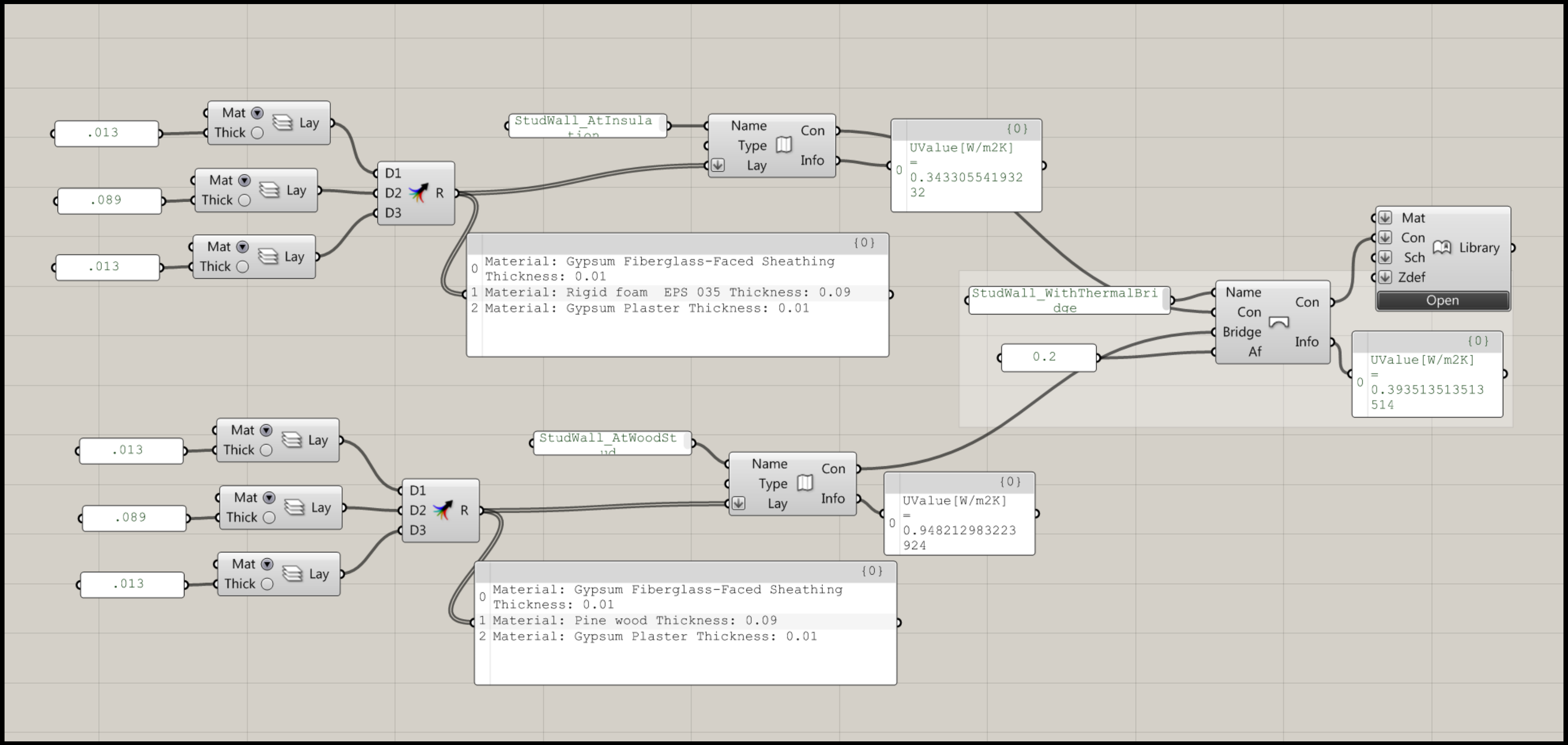
Thermal Bridging in Archsim



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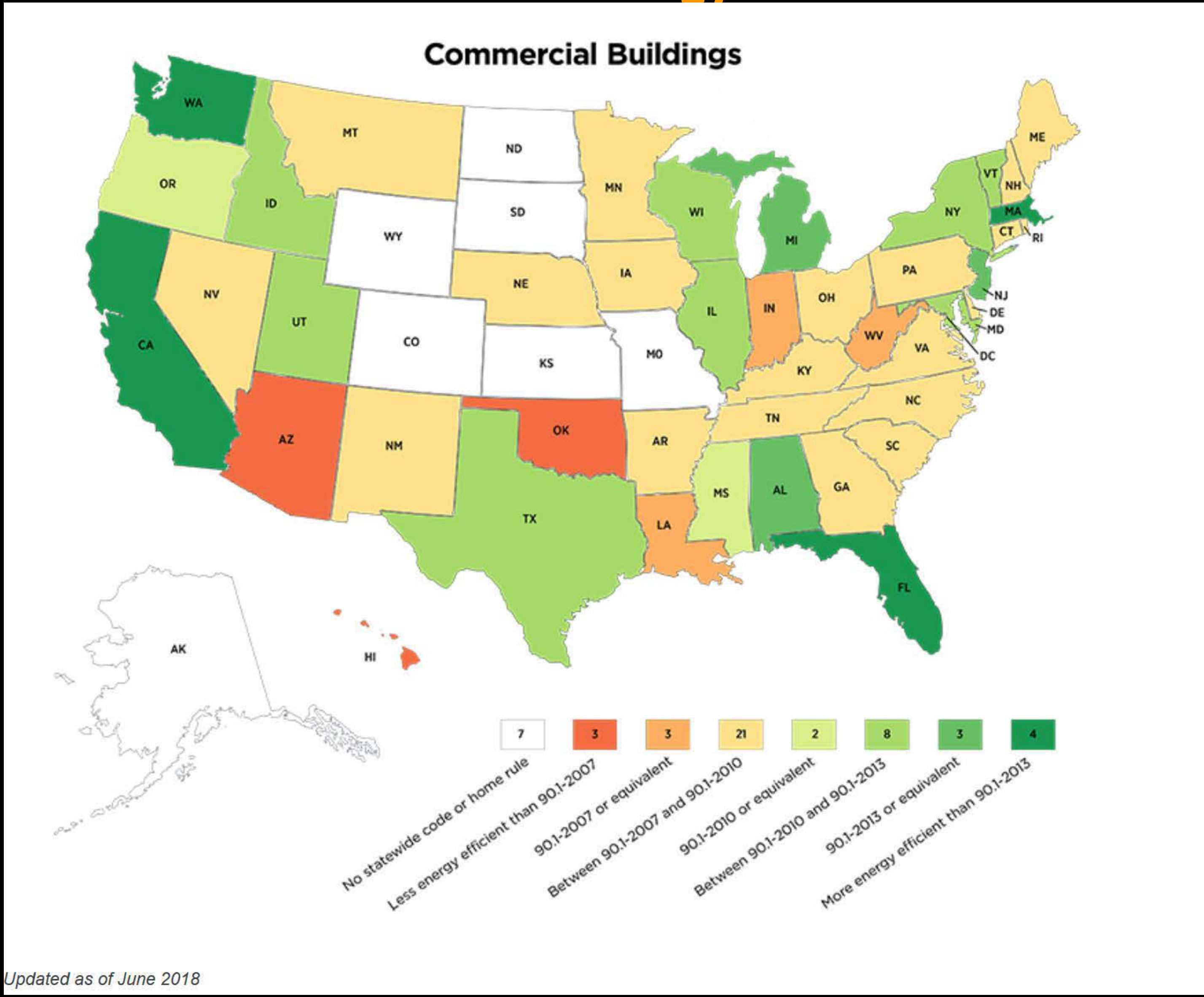
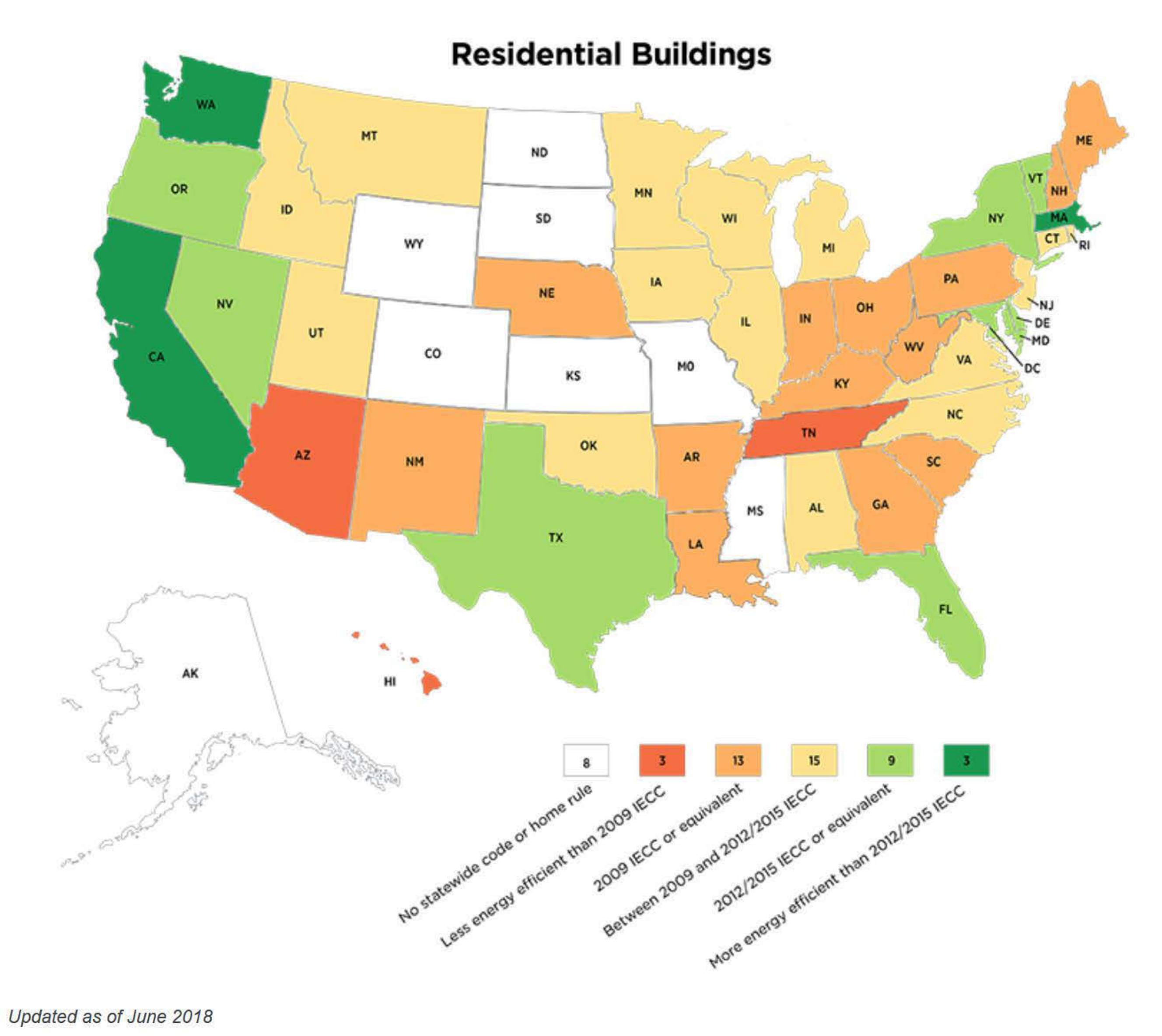
Status of Commercial Energy Codes



http://www.energycodes.gov/status-state-energy-code-adoption Public domain image courtesy of the US Department of Energy.

Status of Residential Energy Codes



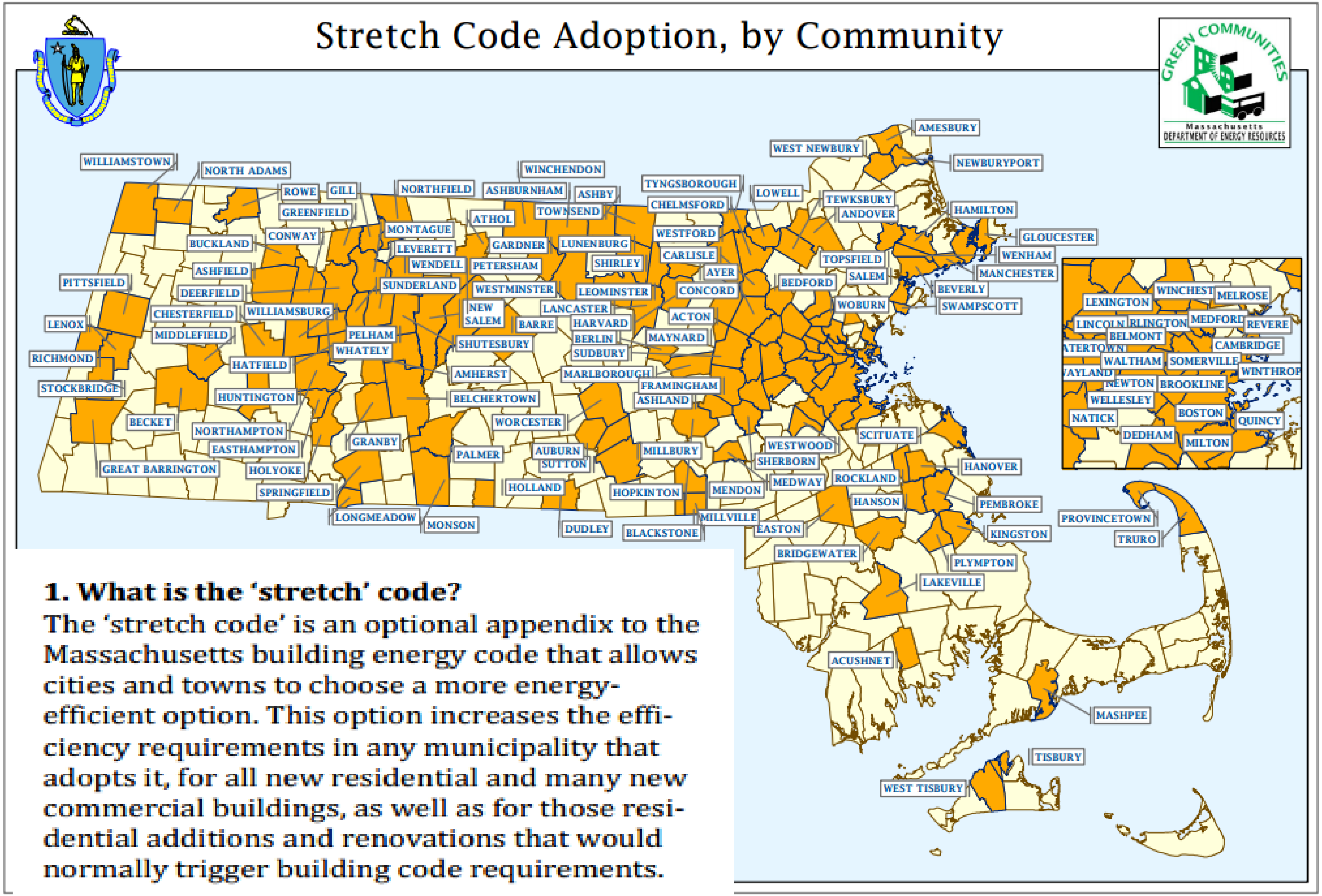
http://www.energycodes.gov/status-state-energy-code-adoption

IECC = International Energy Conservation Code

Public domain image courtesy of the US Department of Energy.

DLAB

Massachusetts Stretch Code



1. What is the 'stretch' code?

The 'stretch code' is an optional appendix to the Massachusetts building energy code that allows cities and towns to choose a more energy-efficient option. This option increases the efficiency requirements in any municipality that adopts it, for all new residential and many new commercial buildings, as well as for those residential additions and renovations that would normally trigger building code requirements.

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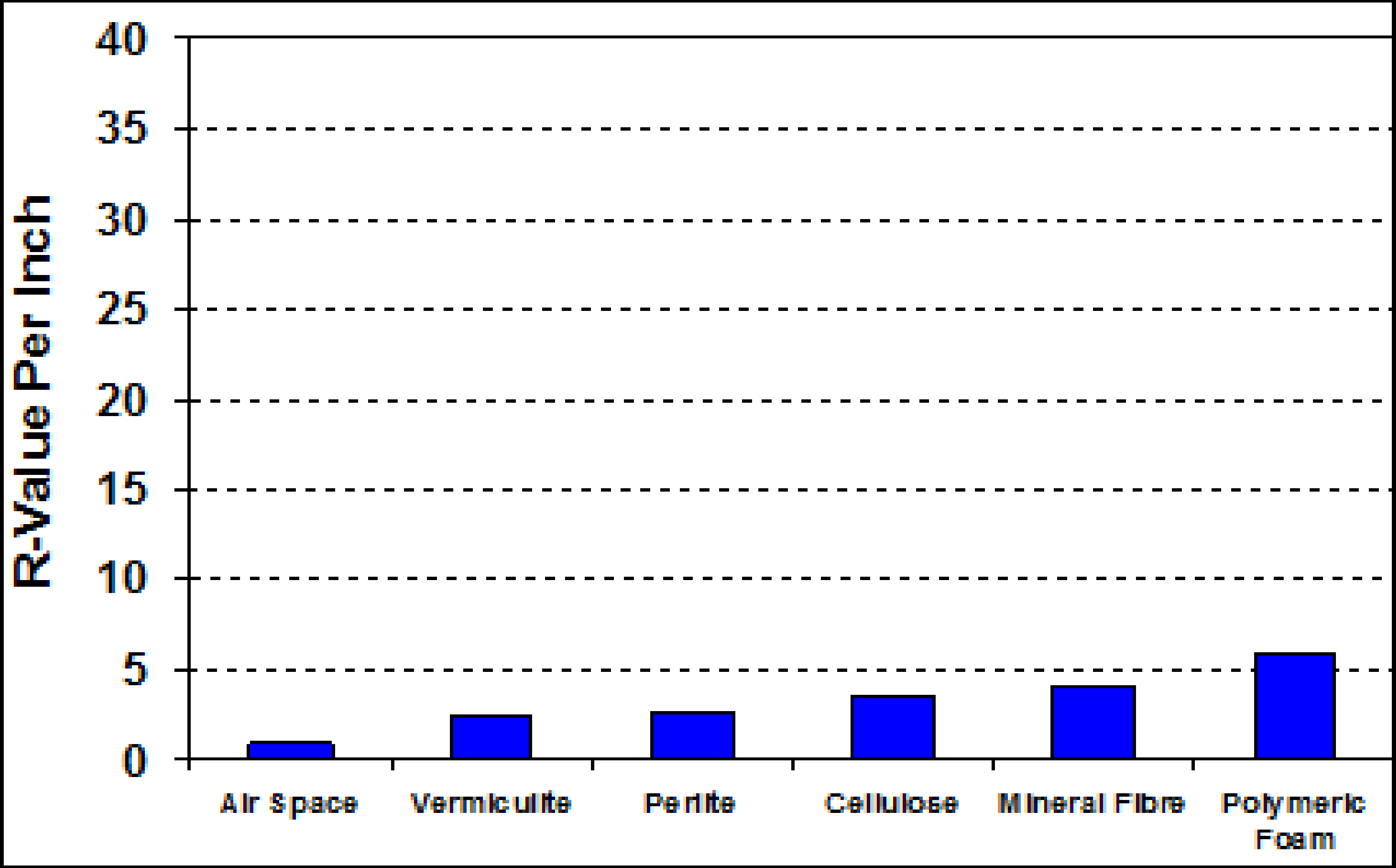
Some Insulation Materials



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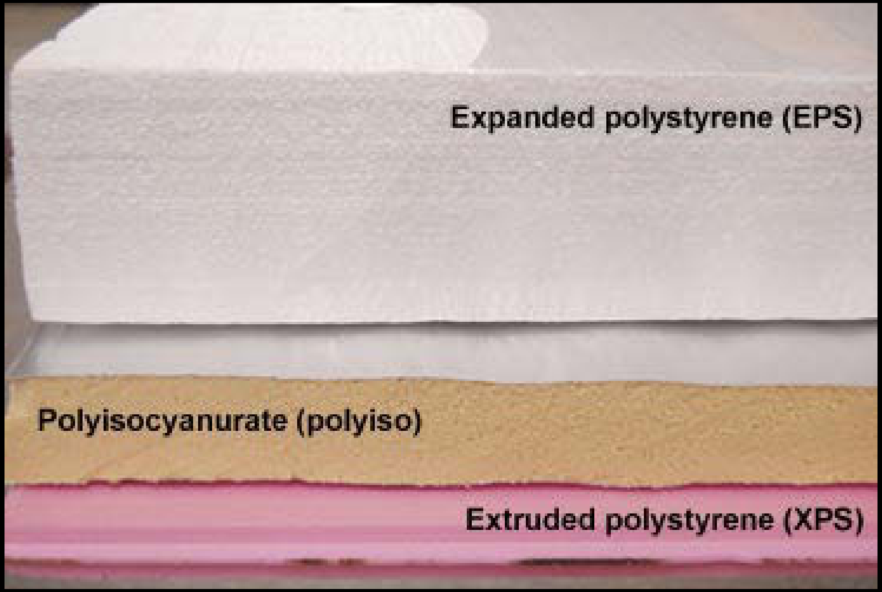
Expanded Polystyrene (EPS)



- Glass Fiber Board: ~5 R per inch
- Economical


OWENS CORNING
PINK
EcoTouch
INSULATION
Soft to the Touch
Absorbs Noise
Validated Formaldehyde Free
R-19
FACED
FIBERGLAS™
ROLL
6.25"
15"
39'2"
1
48.96
2x6 Walls

Glass Fiber

Photo courtesy of Best And Worst Ever Photo Blog. License: CC BY.

- ❑ Glass Fiber Batt: ~4 R per inch
- ❑ Economical

LAB

Mineral Fiber/Wool

- Mineral Fiber: ~4 R per inch
- More pleasant to work with than glass fiber.

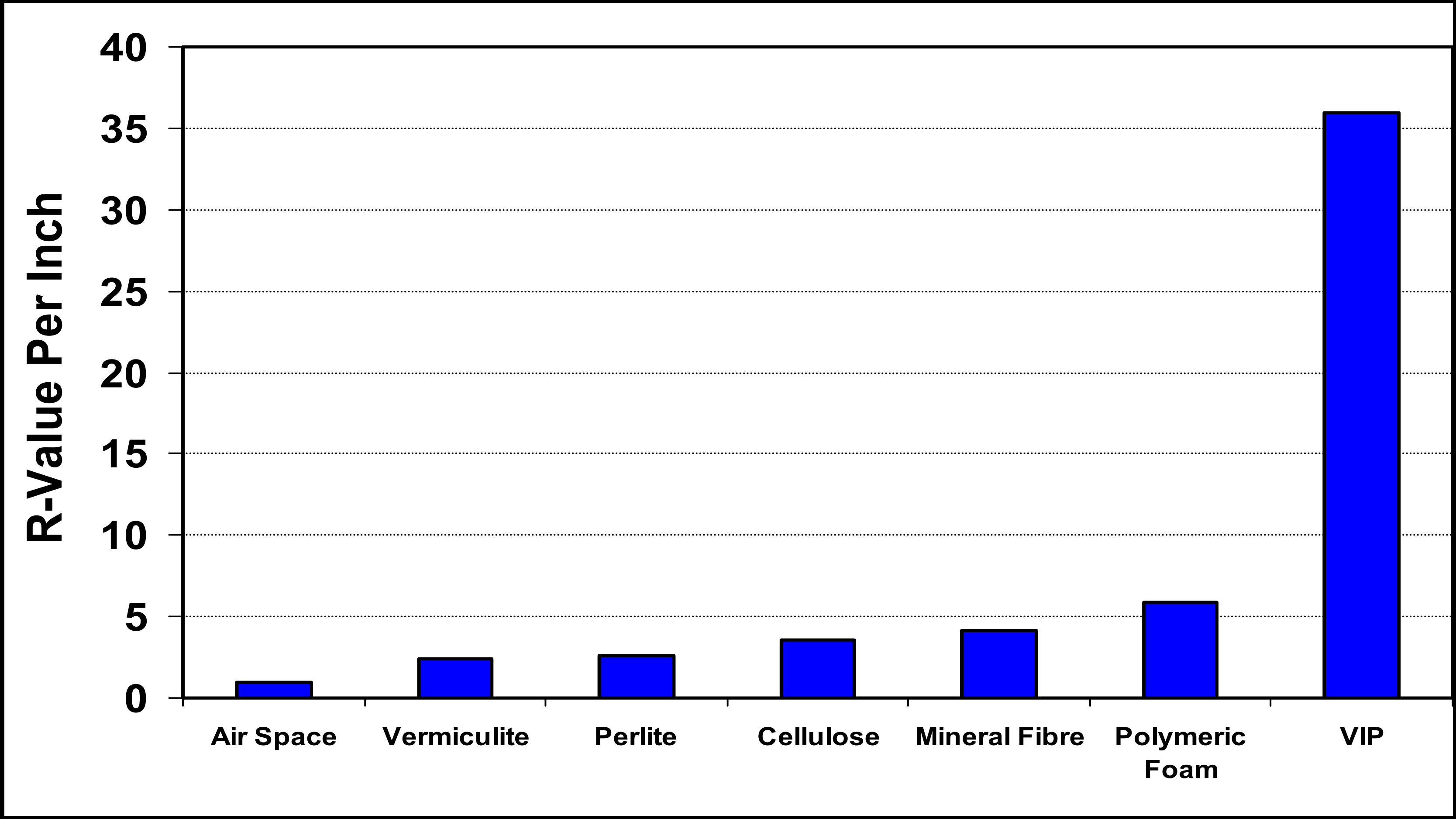
Cellulose

- Cellulose: ~3.5 R per inch
- Can be blown into existing wall cavities during energy retrofits.
- Can fill cavities of any shape.
- Make sure that cavity is dry all year round.
- Make sure that the whole cavity gets equally filled.

Straw Bale

- Straw bale: ~2.7 R per inch - Can be built very thick (18")

Vacuum Insulation Panels (VIP)



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Vacuum Insulation Panels (VIP)

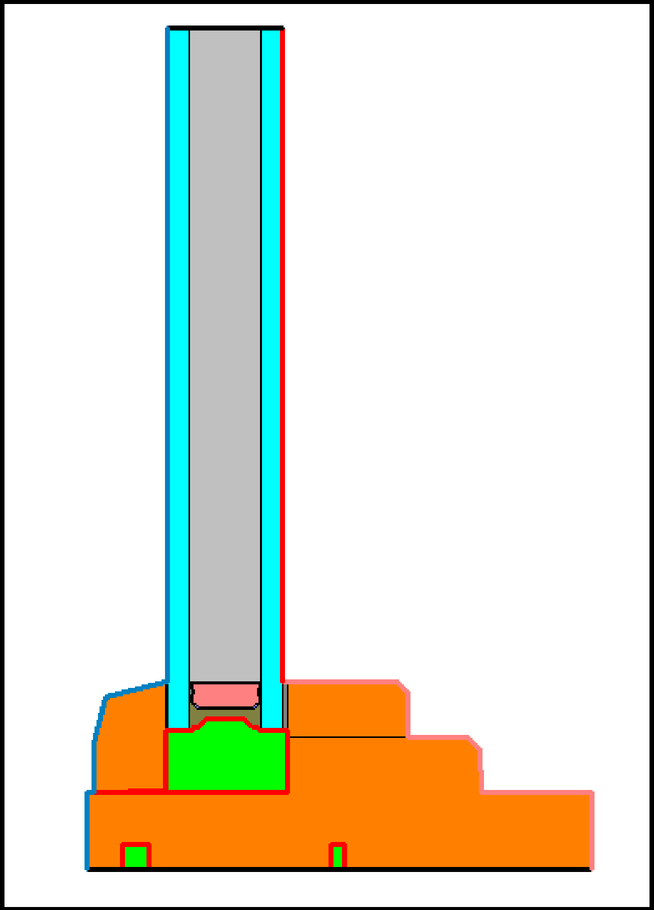
- VIP are typically installed where space is very limited, for example in a basement or for a retrofit in a room with limited floor-to-ceiling height.

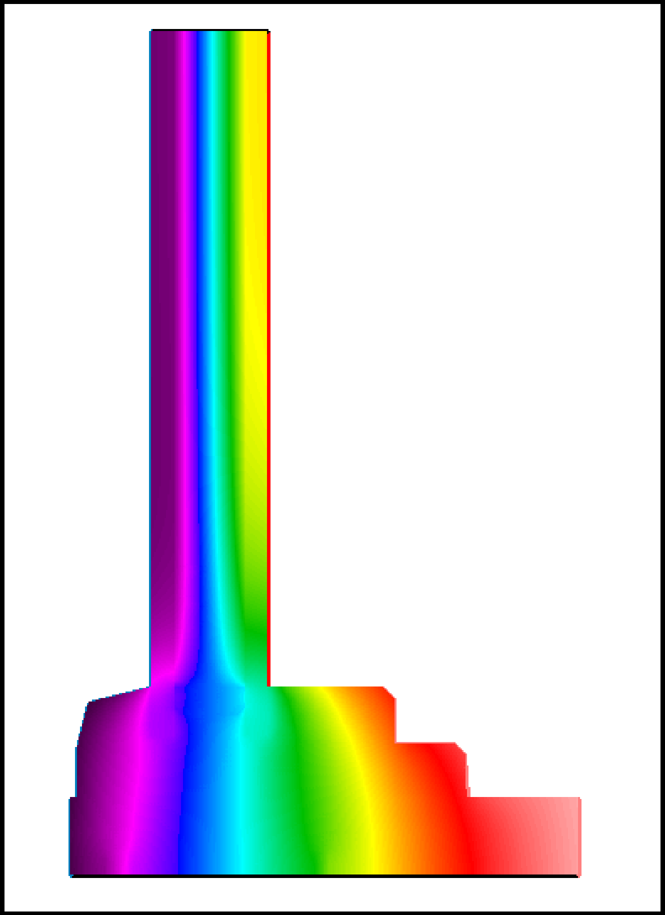
Vacuum Insulation Panel (VIP)

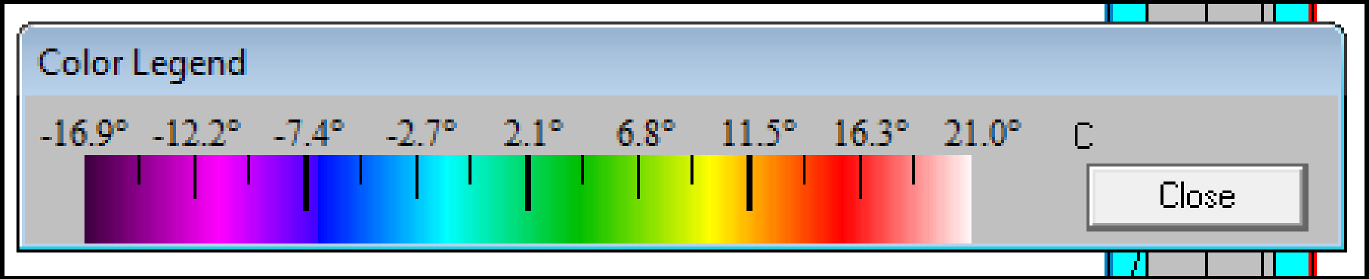
- VIP: ~35 R per inch
- VIP are typically installed where space is very limited, for example in a basement or for a retrofit in a room with limited floor-to-ceiling height.
- With precast concrete units plus VIP, building assemblies can achieve a U-value of 0.15 W/m^2K, which complies with the passive house standard, with a total thickness of only 27 cm as opposed to the more standard 60 cm.

Source ENOB (www.enob.info/en/new-technologies/projects/details/precast-concrete-units-with-vacuum-insulation/)

THERM Analysis

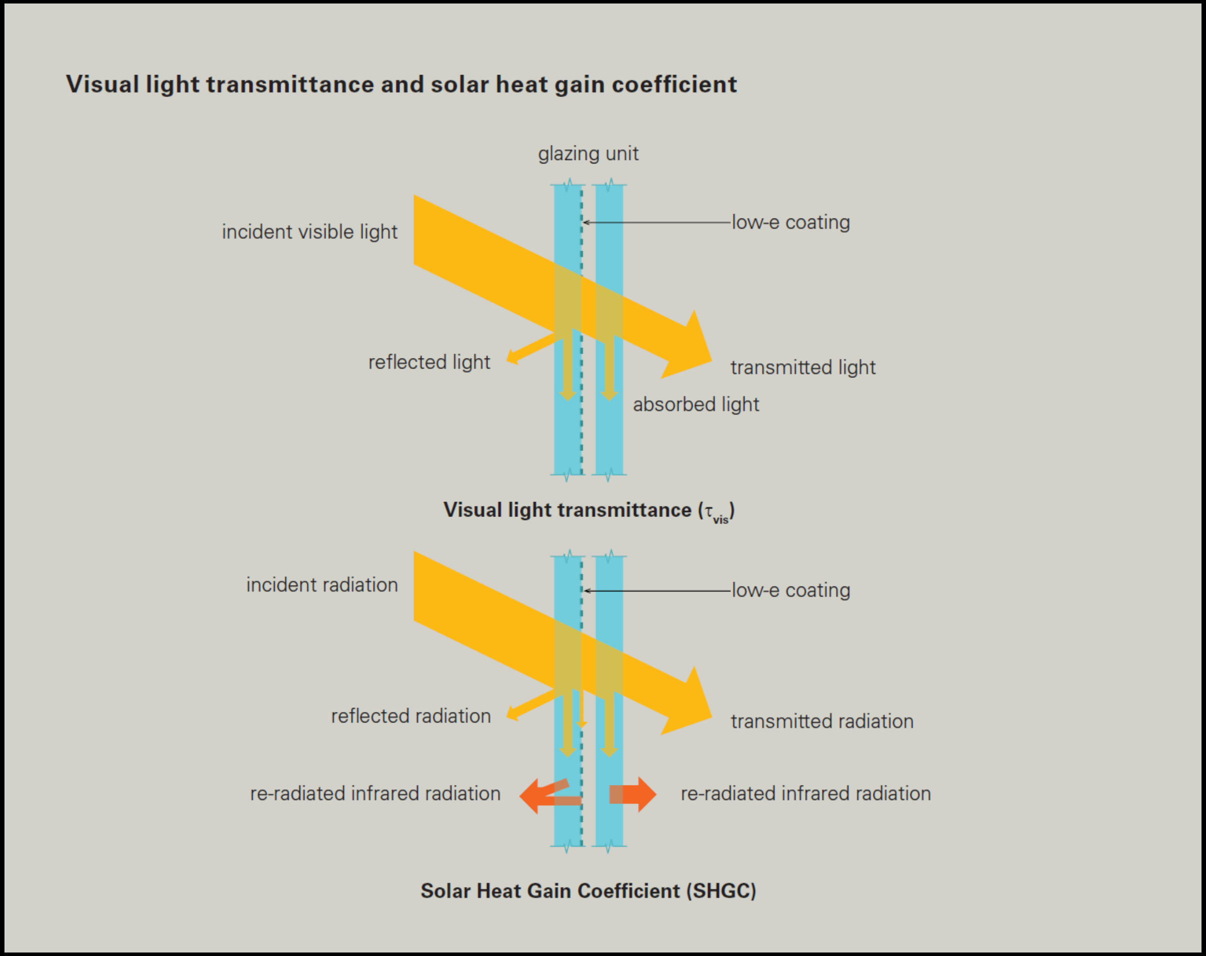






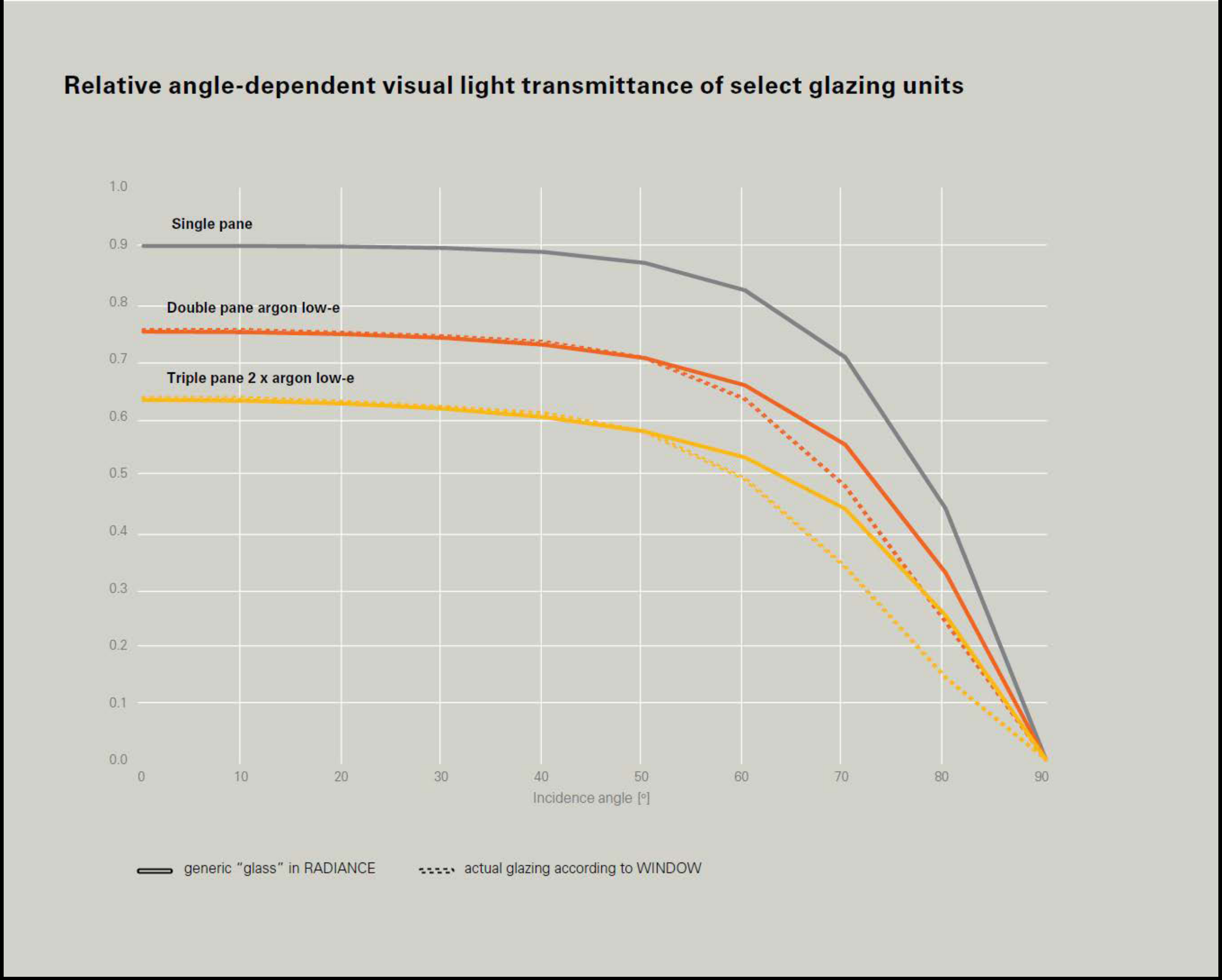
Windows

Interaction of Radiation with Windows



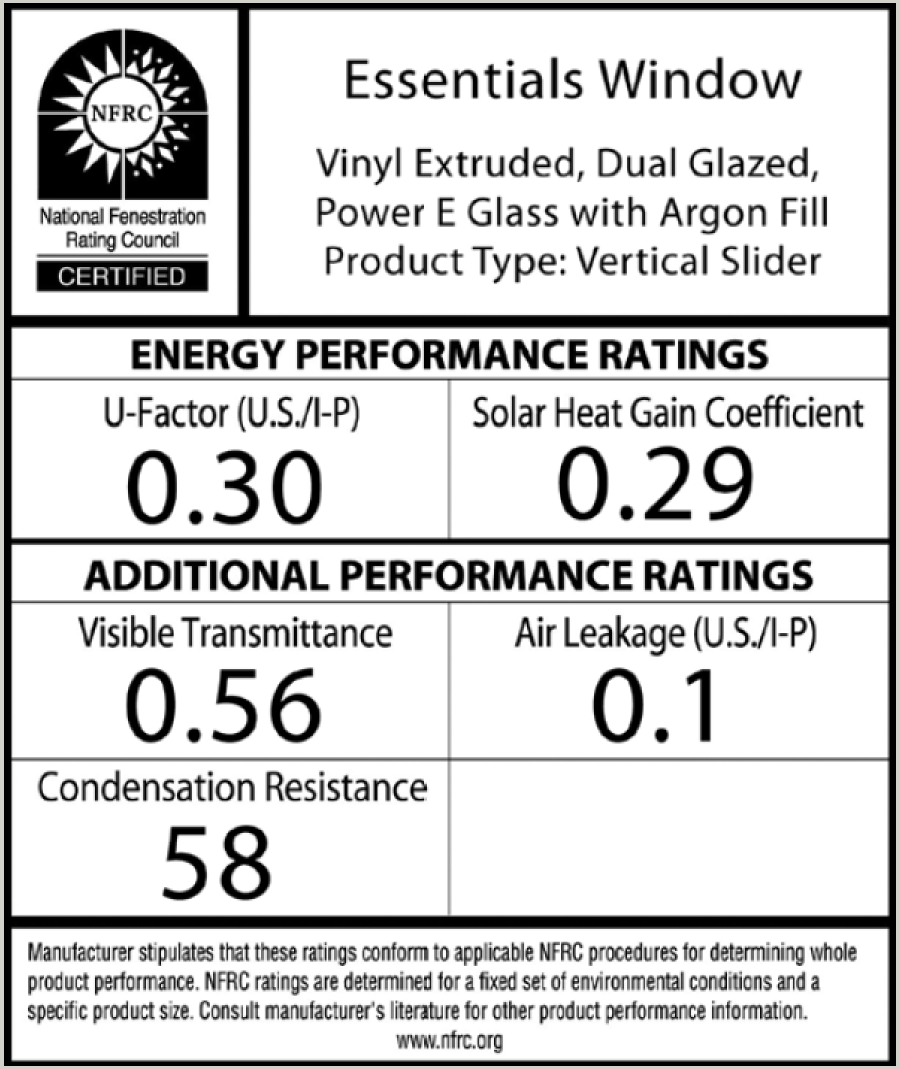
Solar heat gain coefficient (SGHC): Fraction of incident total solar radiation that reaches the interior.
Visual Transmittance (τ): Fraction of incident visible radiation that reaches the interior.

Angle-Dependent Transmittance

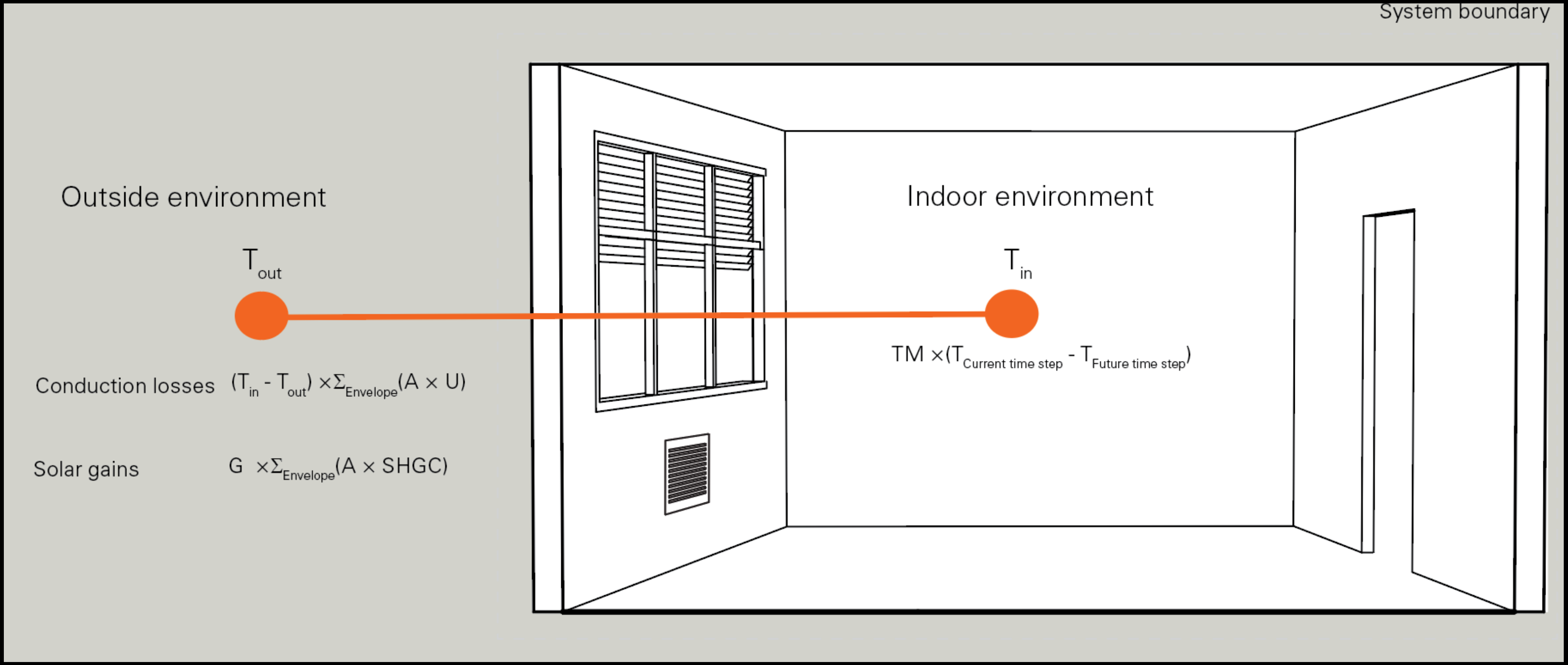


Coated glazings have a faster transmittance falloff with rising incidence angles than single pane windows.

Window Label NFRC



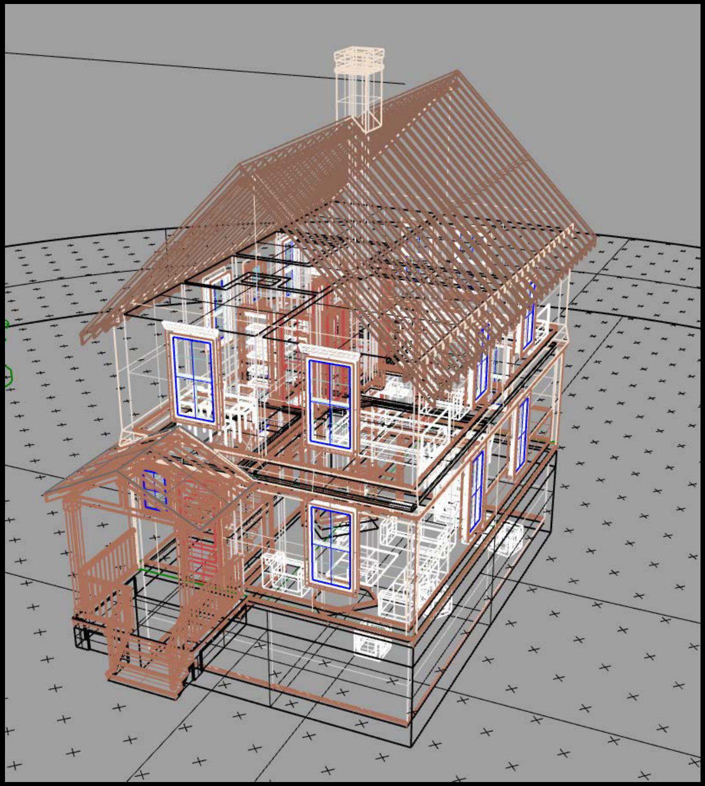
Heat Balance Equation with Solar Gains



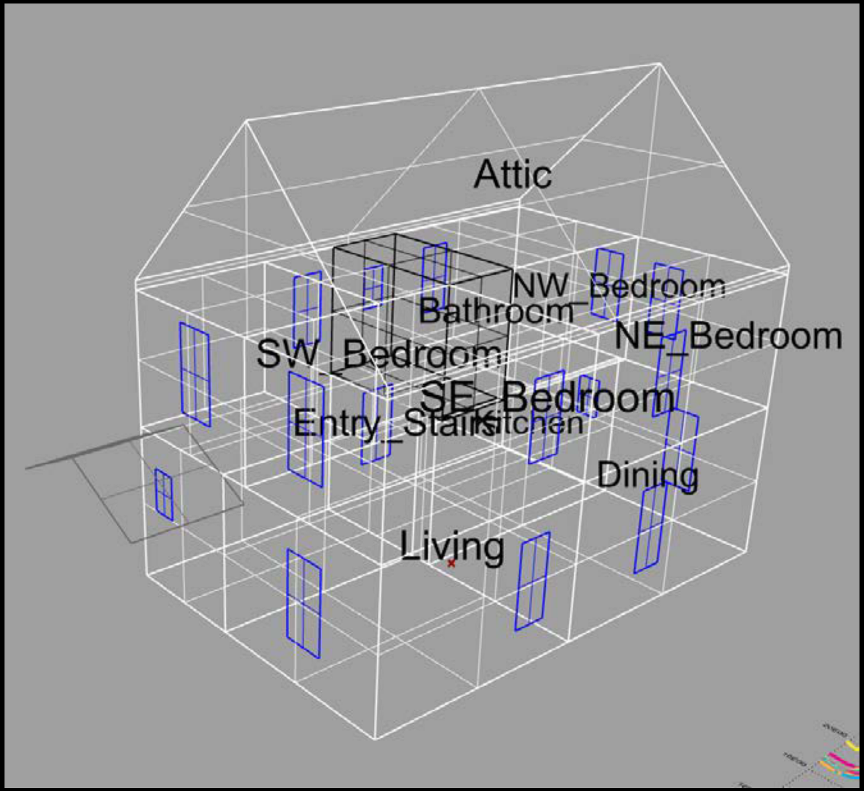
New England Home

From Architectural to Thermal Model

Thermal model courtesy of Nathaniel Jones. Used with permission.



Architectural model



Multi zone thermal model

- In a multi-zone thermal model we are treating each room as a well-mixed thermal entity.
- All windows are modeled coincident with the walls that they belong to.
- External shading objects (entrance roof) are modeled separately.
- The basement is being ignored and it is assumed that there is no heat flow between basement and the 1st floor.
- Friday's tutorial will discuss building a simple thermal model in Archsim.

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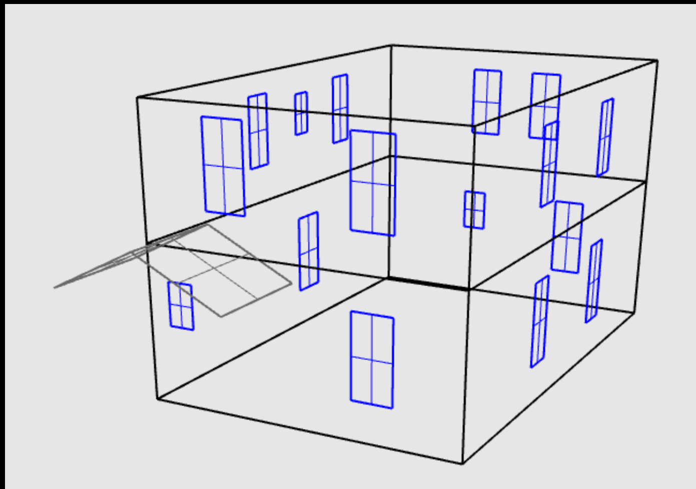
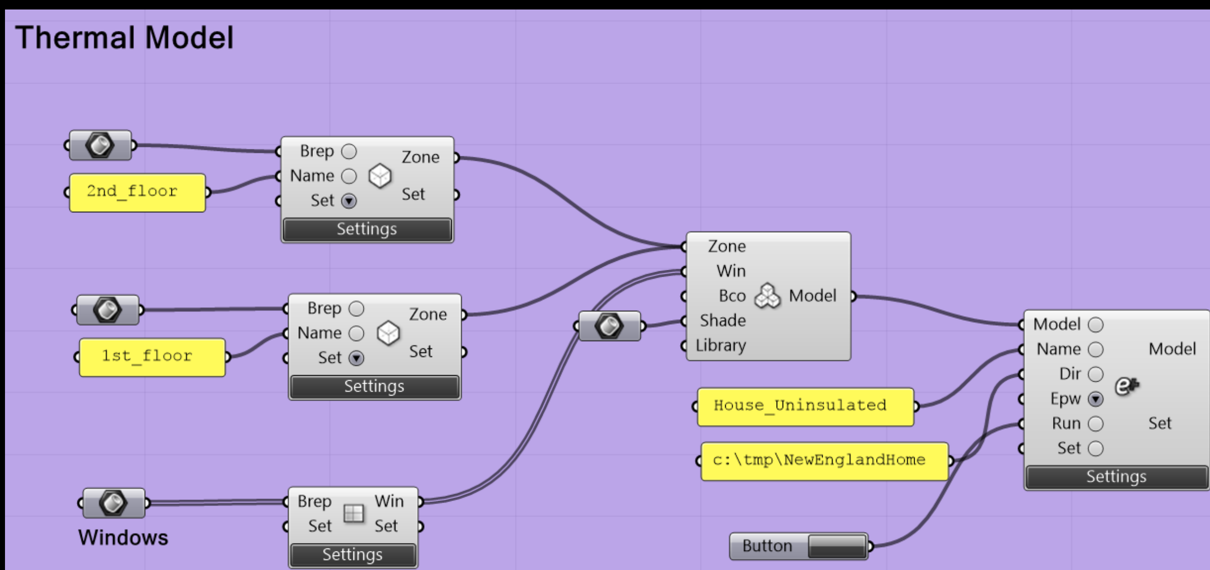
Glazing Study using DIVA/Archsim



Rhino viewport

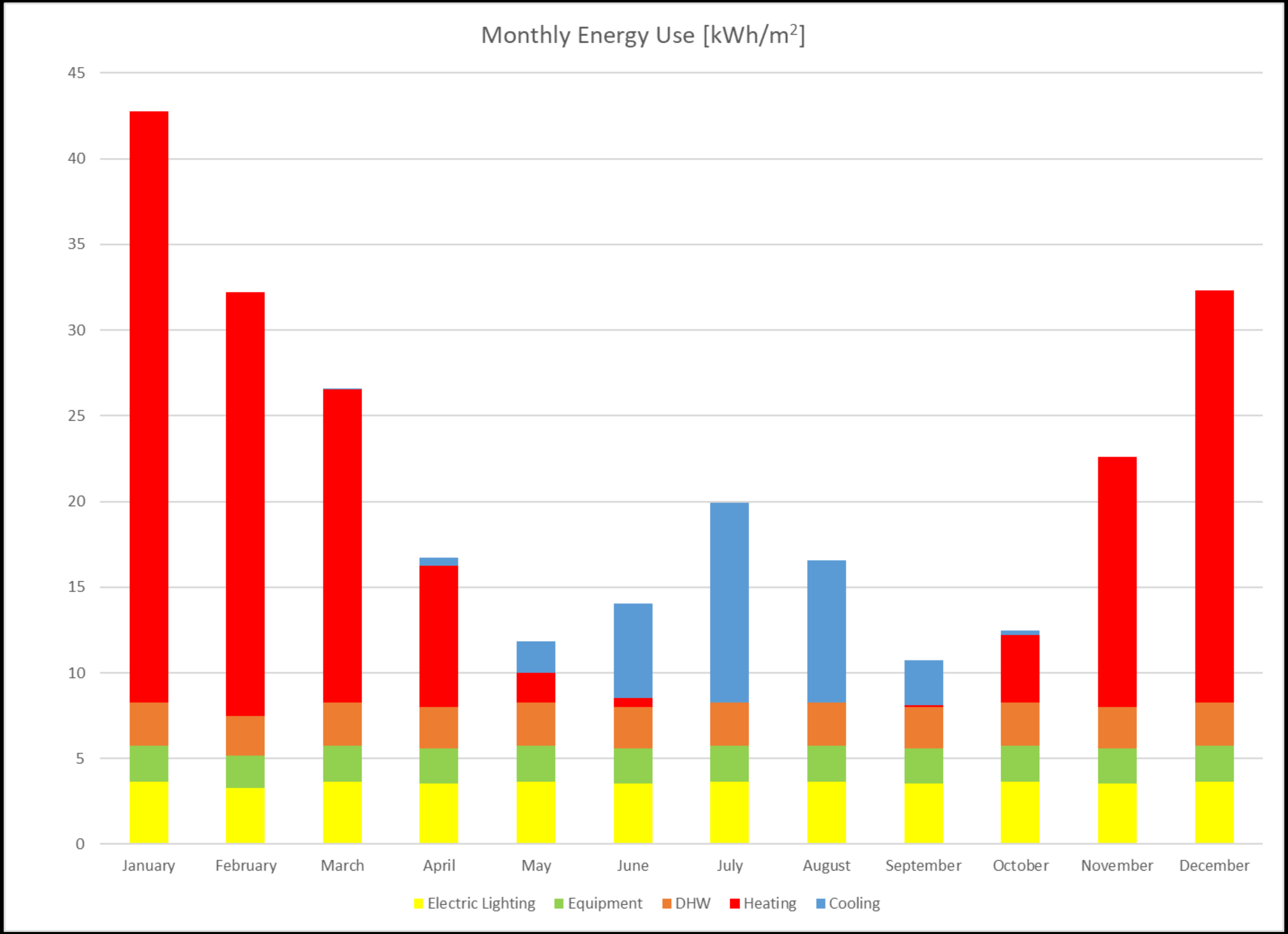


Thermal model in Grasshopper

Two zone energy model.

SDLAB

Glazing Study of the New England House



Base case (uninsulated) with single pane glazing

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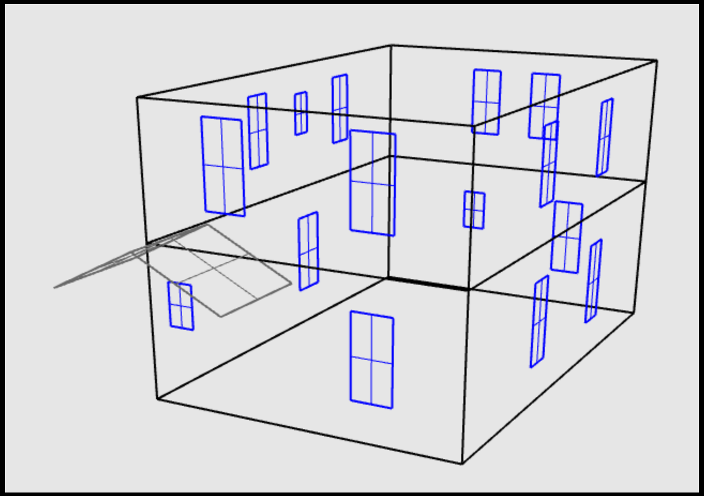
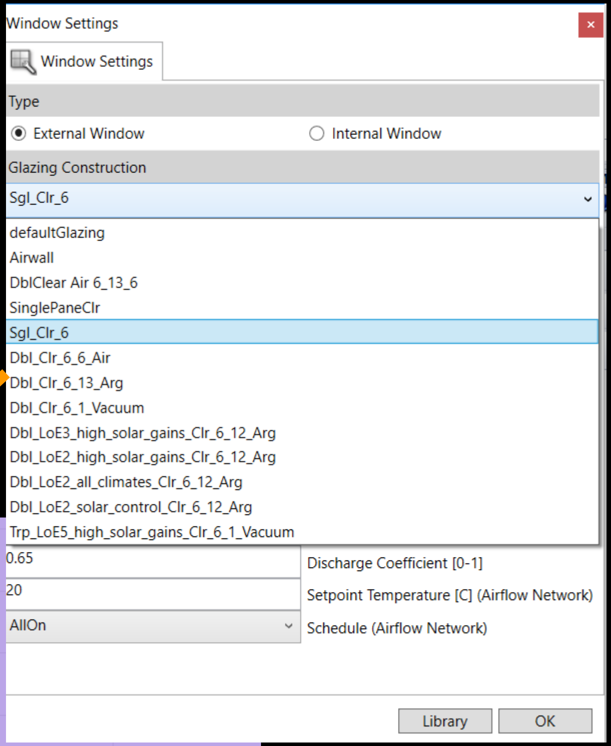
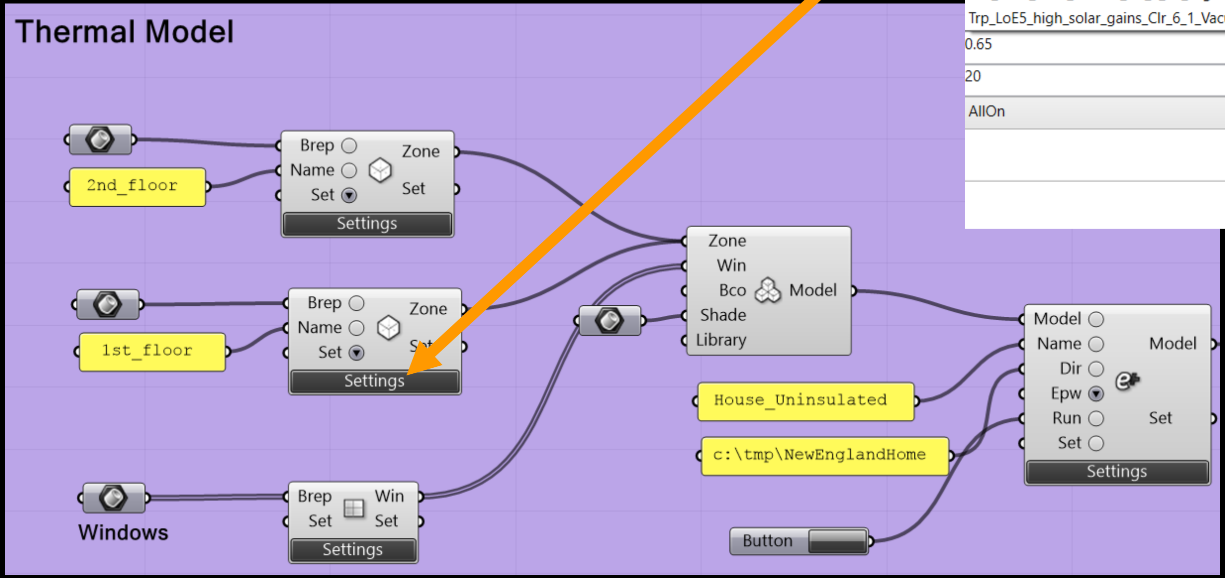
Glazing Study using DIVA/Archsim



Rhino viewport





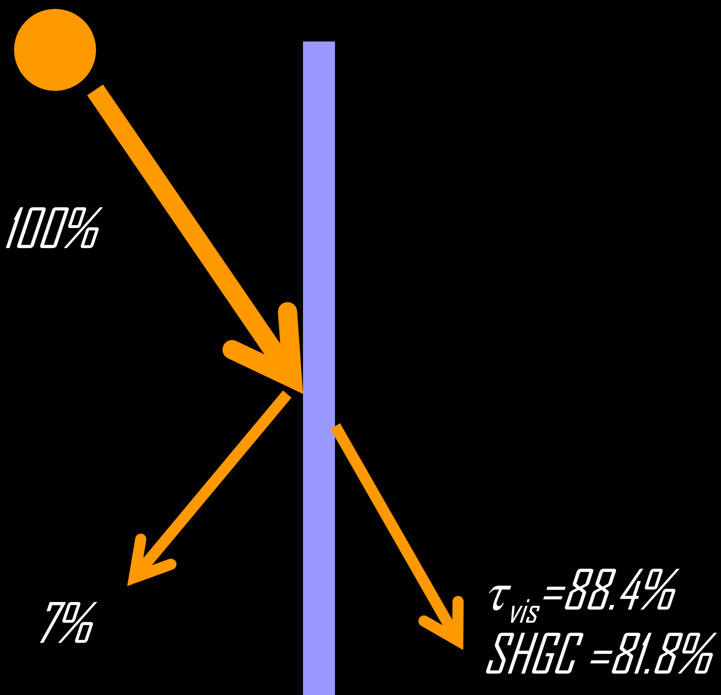
Thermal model in Grasshopper

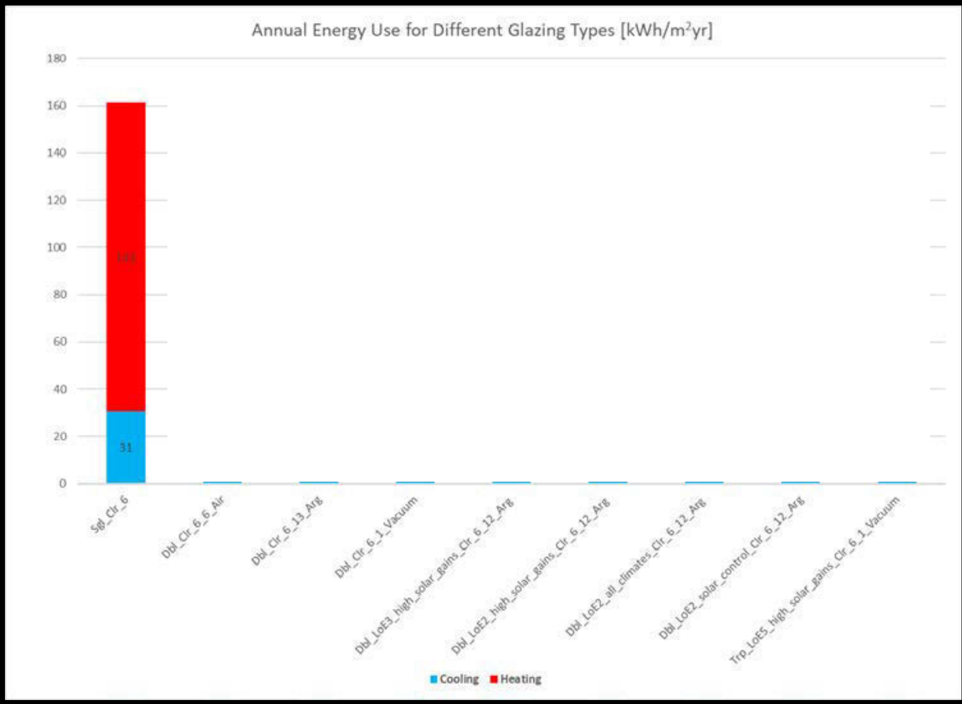
Two zone energy model.

Varying glazing types. What is 'Sgl_Clr_6'?

Sgl_Clr_6

Single pane glazing, 6 mm clear glass





$R\sim 1$ ($U = 5.818\ W/m^2K$)

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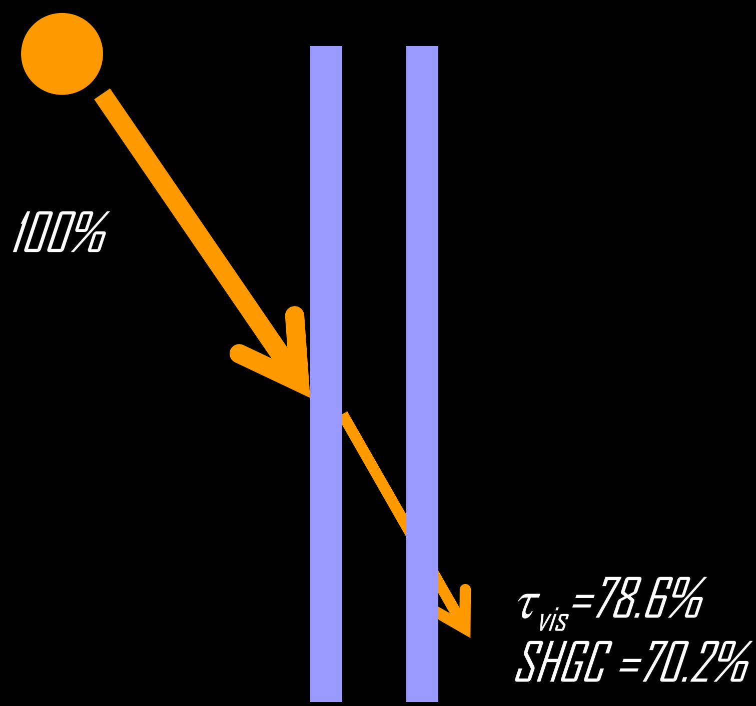
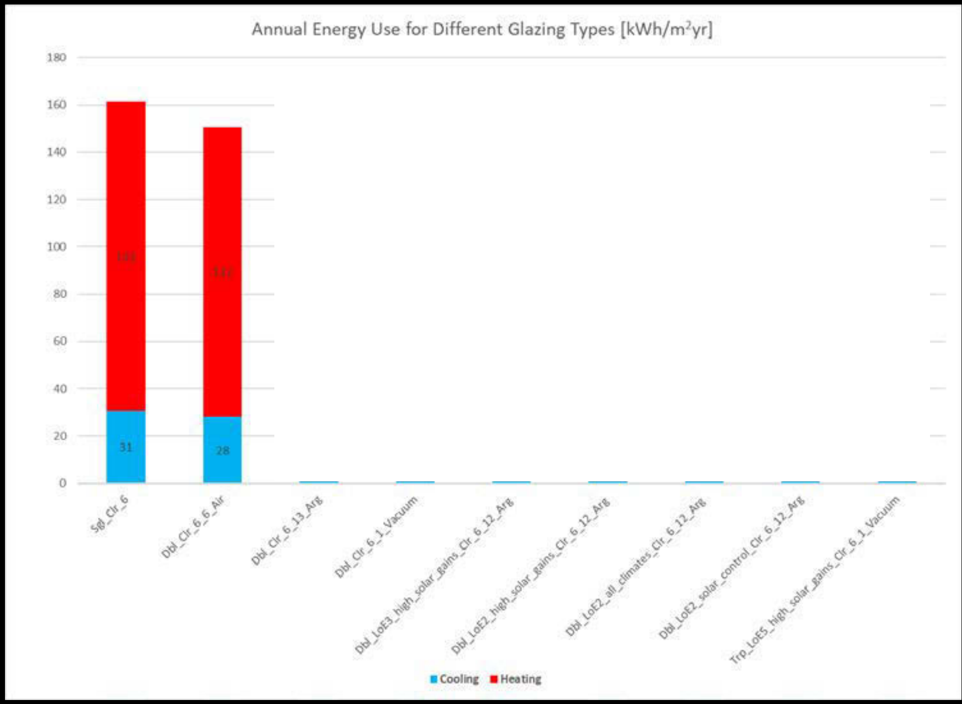
Dbl_Clr_6_6_Air

Double glazing: 6 mm clear glass, 6 mm air gap, 6 mm clear glass





R~2 (U= 3.114 W/m²K)

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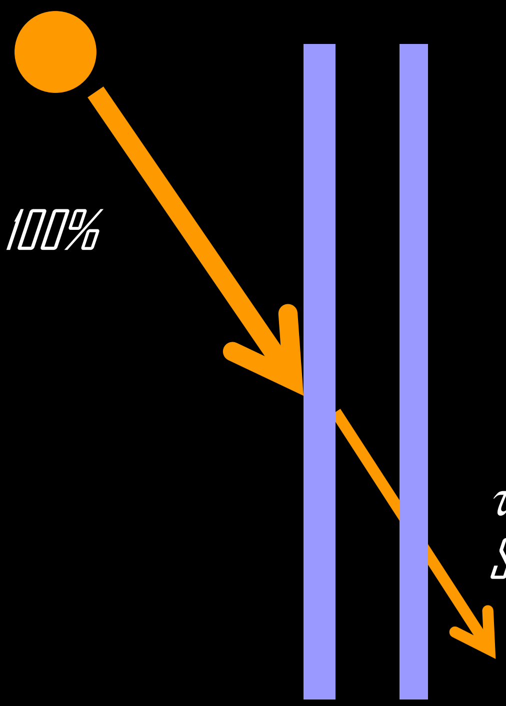
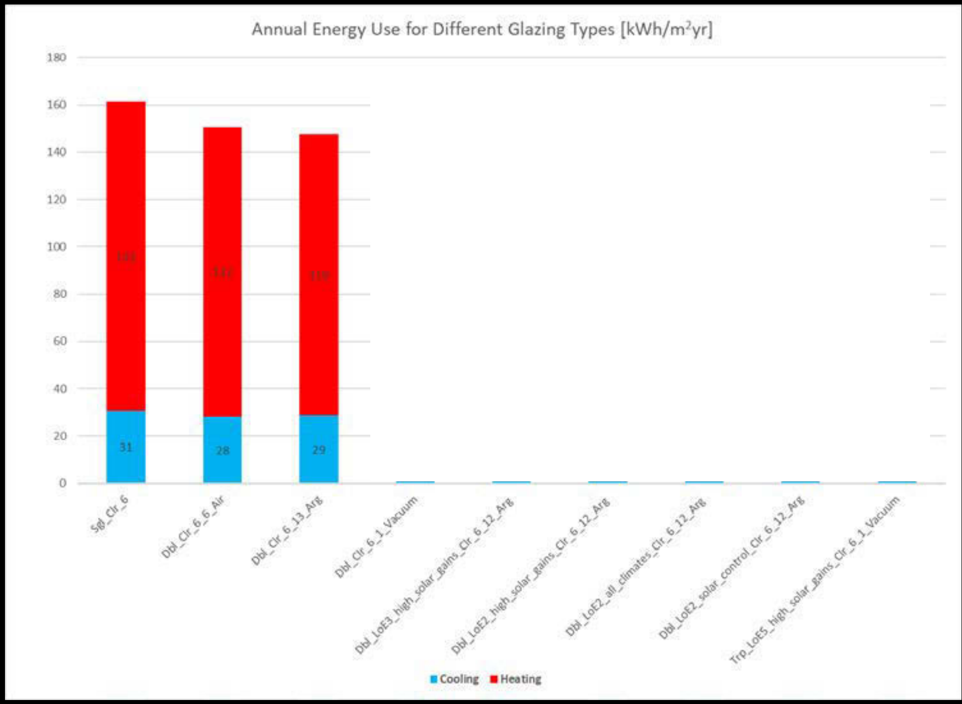
Dbl_Clr_6_13_Arg

Double glazing: 6 mm clear glass, 13 mm argon gap, 6 mm clear glass



τ_{vis}=78.6%

SHGC =70.5%



R=2.2 (U= 2.531 W/m^{2}K)

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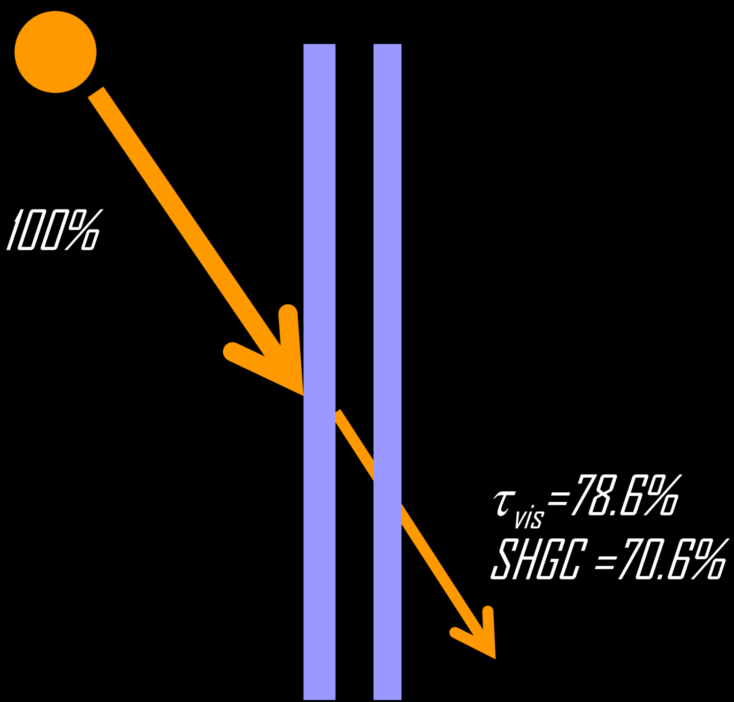
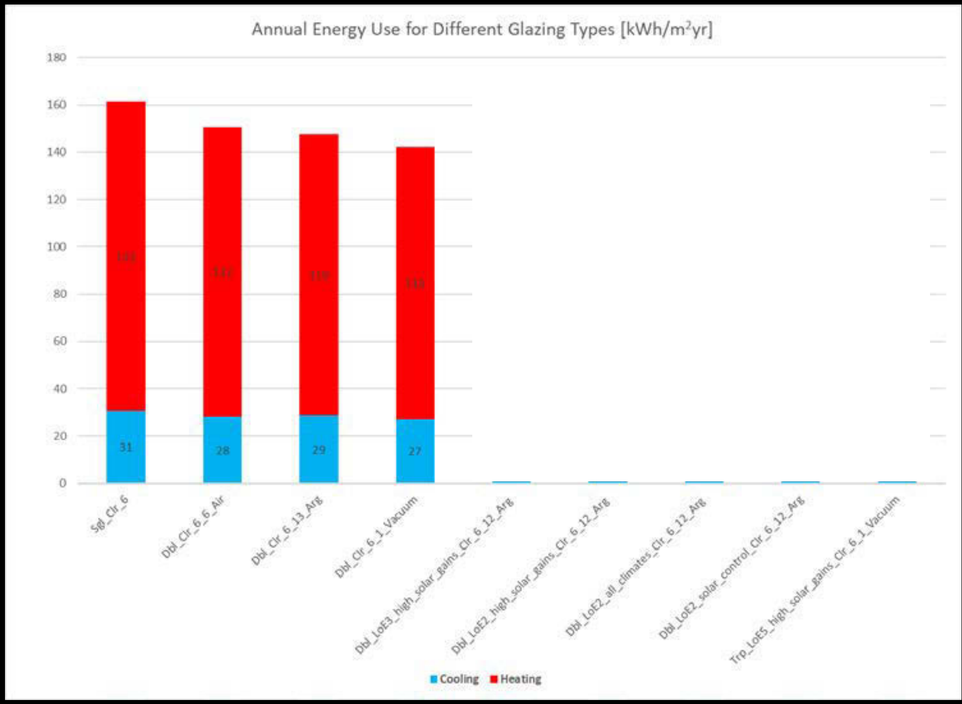
Dbl_Clr_6_1_Vacuum

Double glazing: 6 mm clear glass, 1 mm vacuum, 6 mm clear glass





R=2.5 (U= 2.238 W/m²K)

- ❑ Vacuum effective to keep a glazing unit thin

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Vacuum Glazing in Building 2

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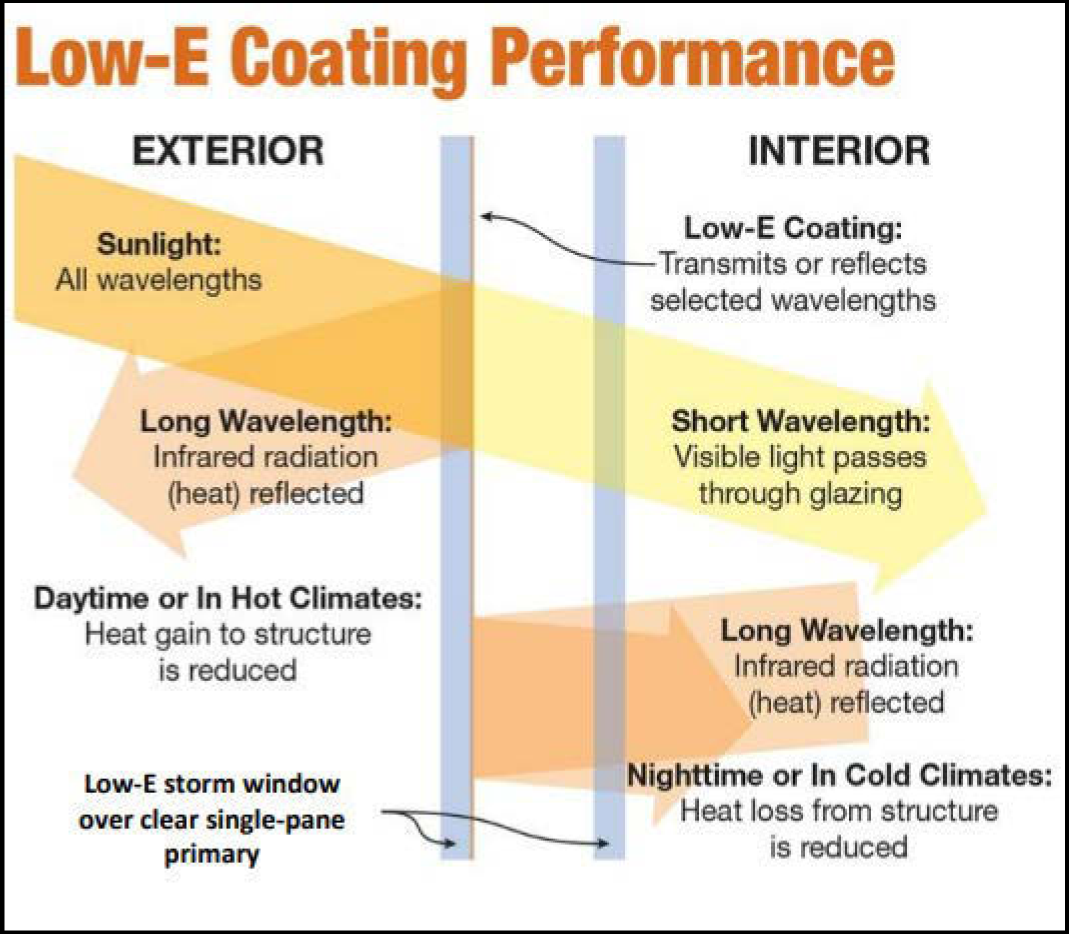
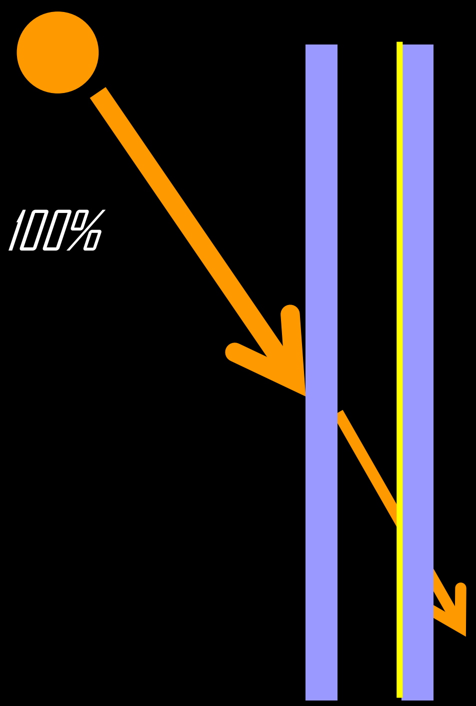
Selective Coatings



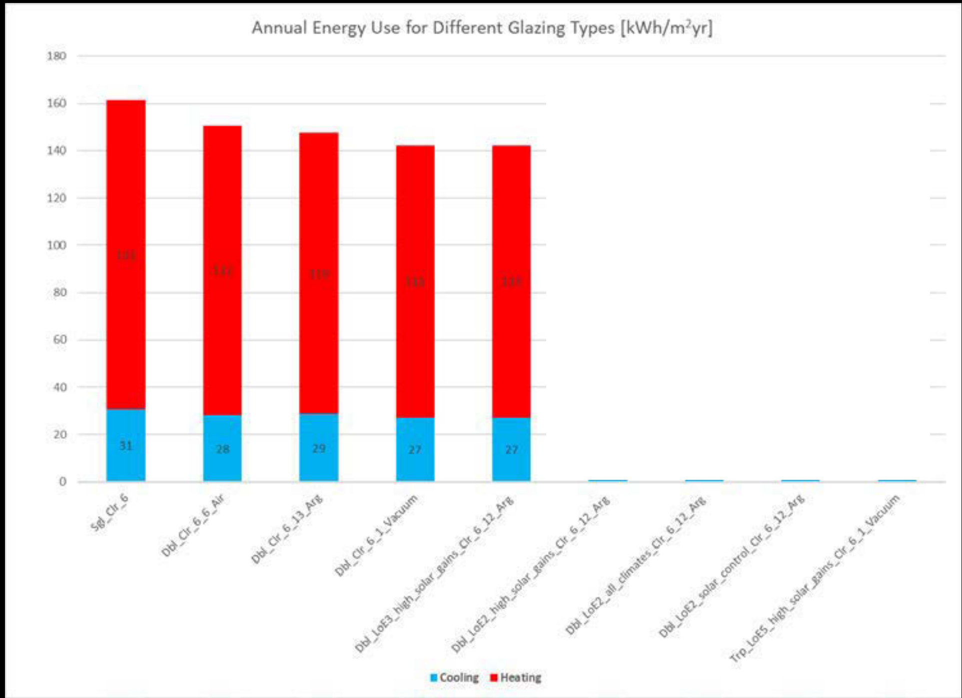
Public domain image courtesy of US EPA.

❑ Dbl_LoE3_high_solar_gains_Clr_6_12_Arg

Double glazing: 6 mm clear glass Low –ε coating high solar gains on 3rd surface, 13 mm argon gap, 6 mm clear glass



τ_{vis}=76.2%
SHGC =62.9%



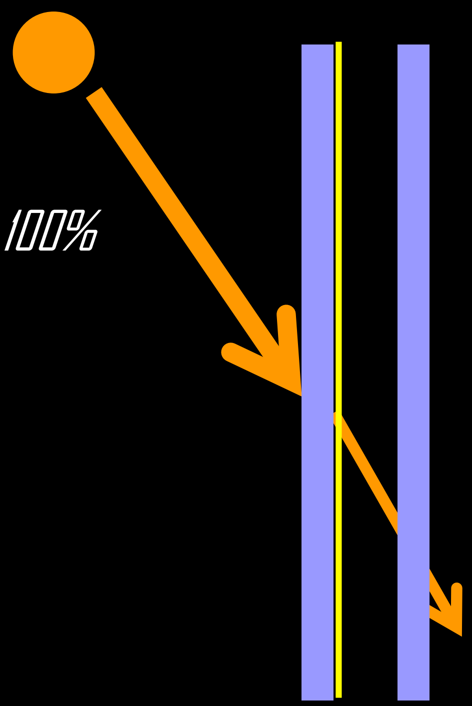
R=4 (U= 1.434 W/m²K)

❑ Surfaces are counted from the outside. The coating is on surface 3.

Based on Cardinal Glass low-e 180 on 6 mm

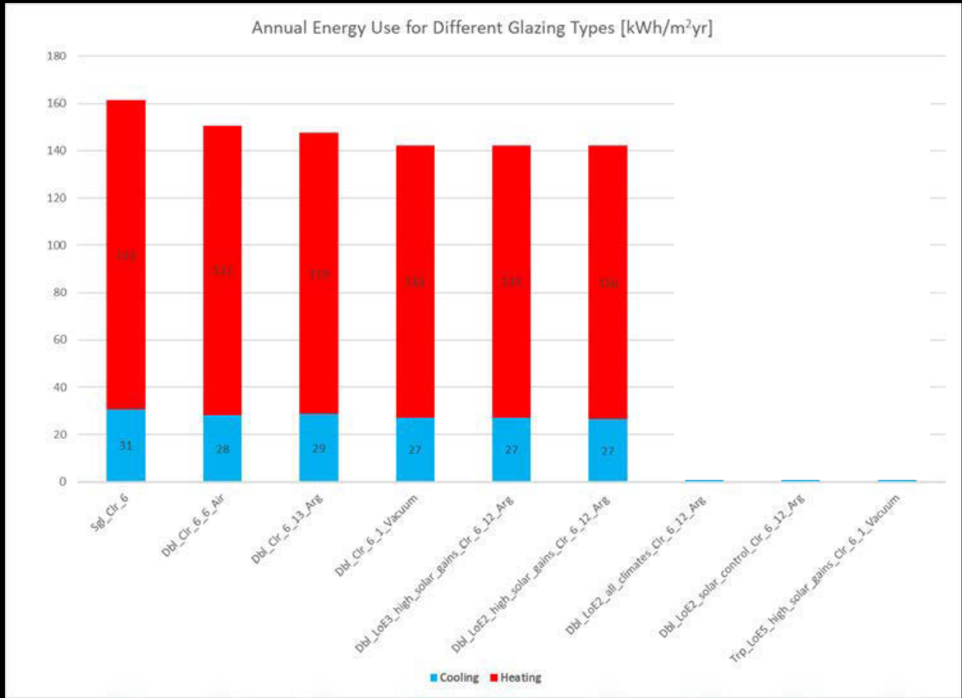
Dbl_LoE2_high_solar_gains_Clr_6_12_Arg

Double glazing: 6 mm clear glass Low –ε coating high solar gains on 2nd surface, 13 mm argon gap, 6 mm clear glass



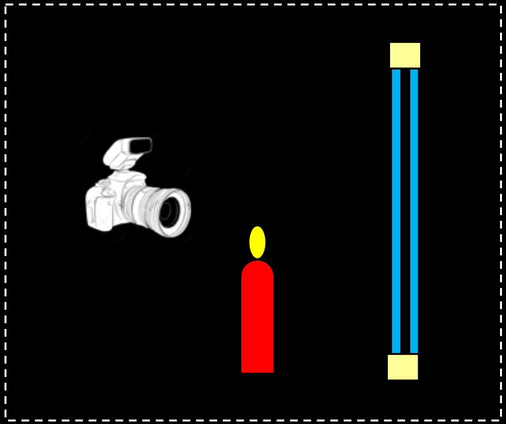
τ_{vis}=76.2%
SHGC =60.1%

R=4 (U= 1.434 W/m^{2}K)



Based on Cardinal Glass low-e 180 on 6 mm

Low–ε Locator Test



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Selective Coatings

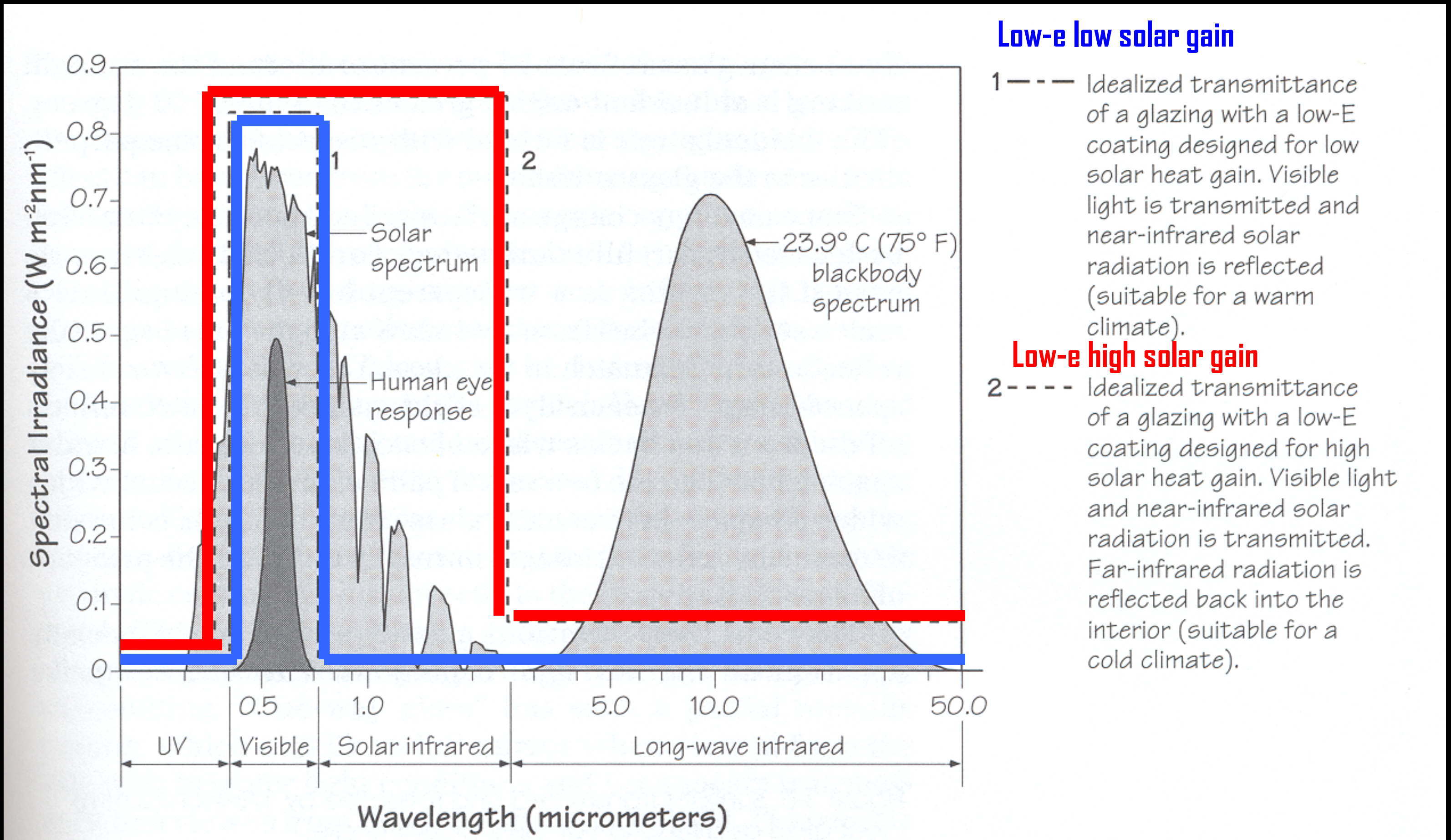

Figure 3-4. Ideal spectral transmittance for glazings in different climates. (Source: McCluney, 1996.)

Residential Windows by Carmody, Heschong, Selkowitz; 2nd edition (2000)

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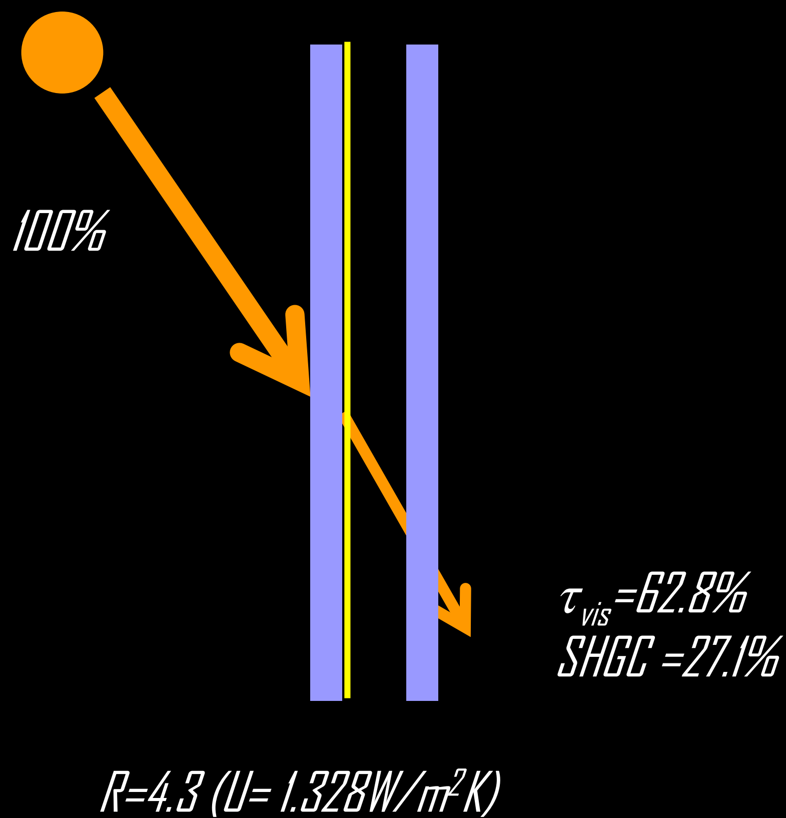
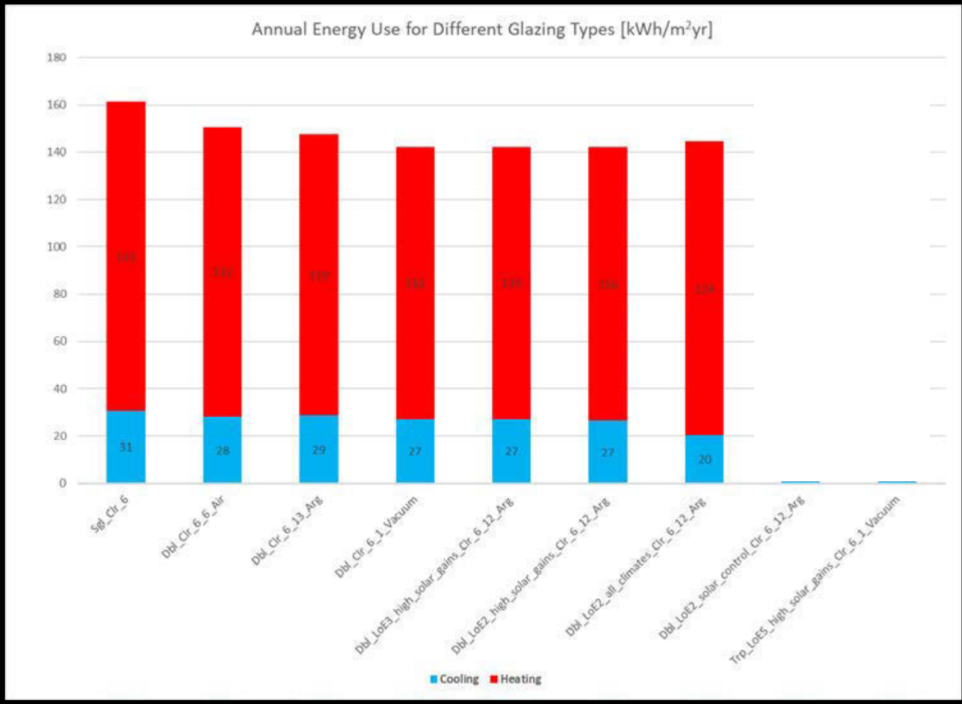
Dbl_LoE2_all_climates_Clr_6_12_Arg

Double glazing: 6 mm clear glass Low –ε coating all climates, 13 mm argon gap, 6 mm clear glass

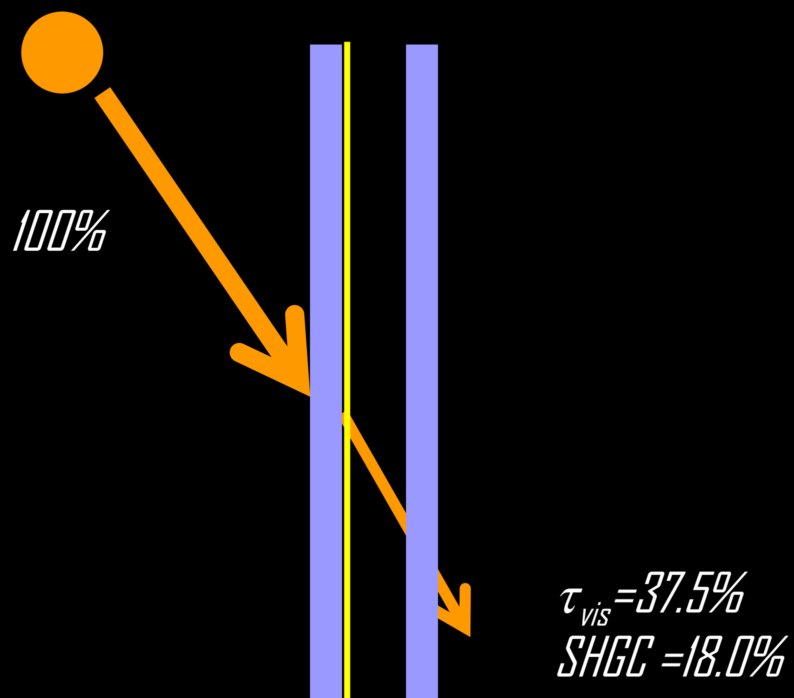




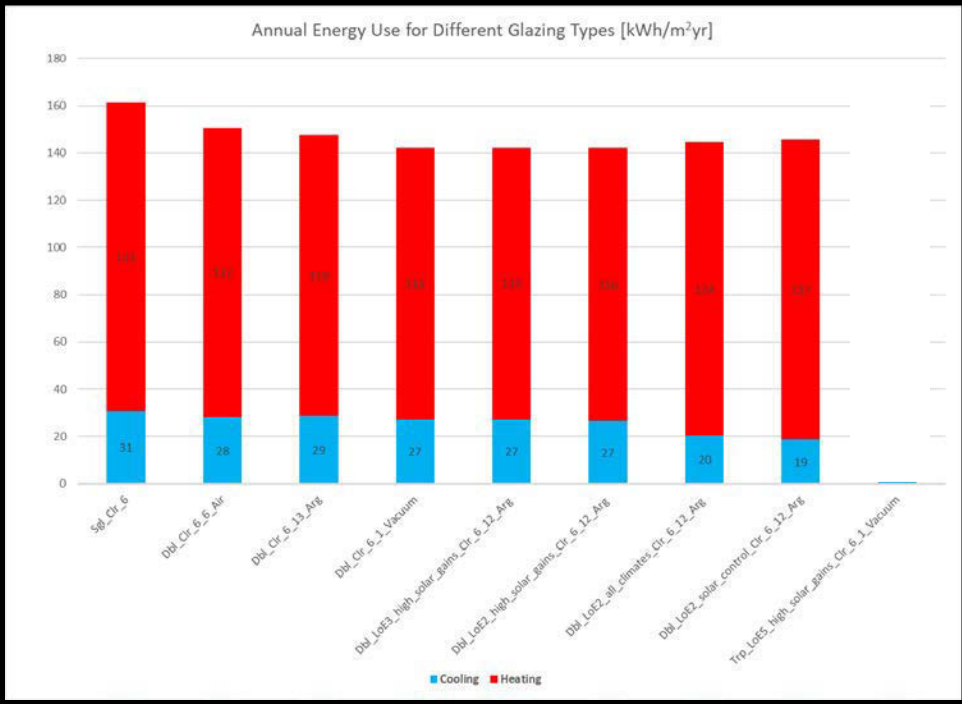
Based on Cardinal Glass low-e 366 on 6 mm

Dbl_LoE2_solar_control_Clr_6_12_Arg

Double glazing: 6 mm clear glass Low –ε low solar gains, 13 mm argon gap, 6 mm clear glass



R=4.2 (U= 1.343 W/m^{2}K)



Based on Cardinal low-e 340 on 6 mm

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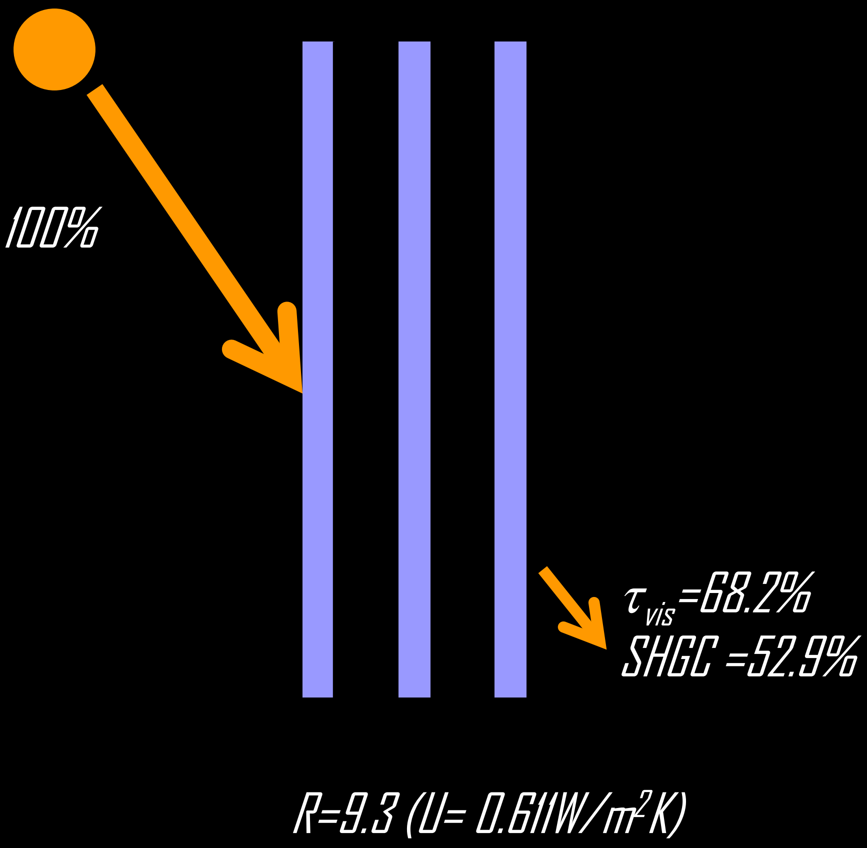
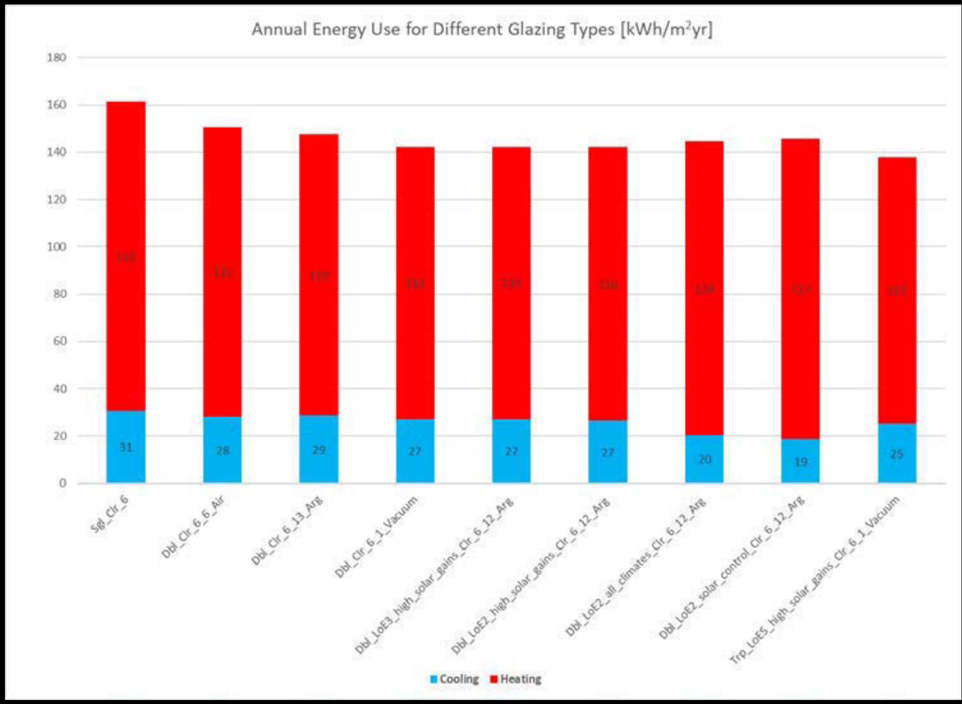
Triple Trp_LoE5_high_solar_gains_Clr_6_1_Vacuum

Triple glazing: 6mm clear glass, 1mm vacuum gap, 6mm clear glass, 1mm vacuum gap, 6mm Low-e high solar gains on 6mm clear glass





Based on Cardinal Glass low-e 180 on 6mm

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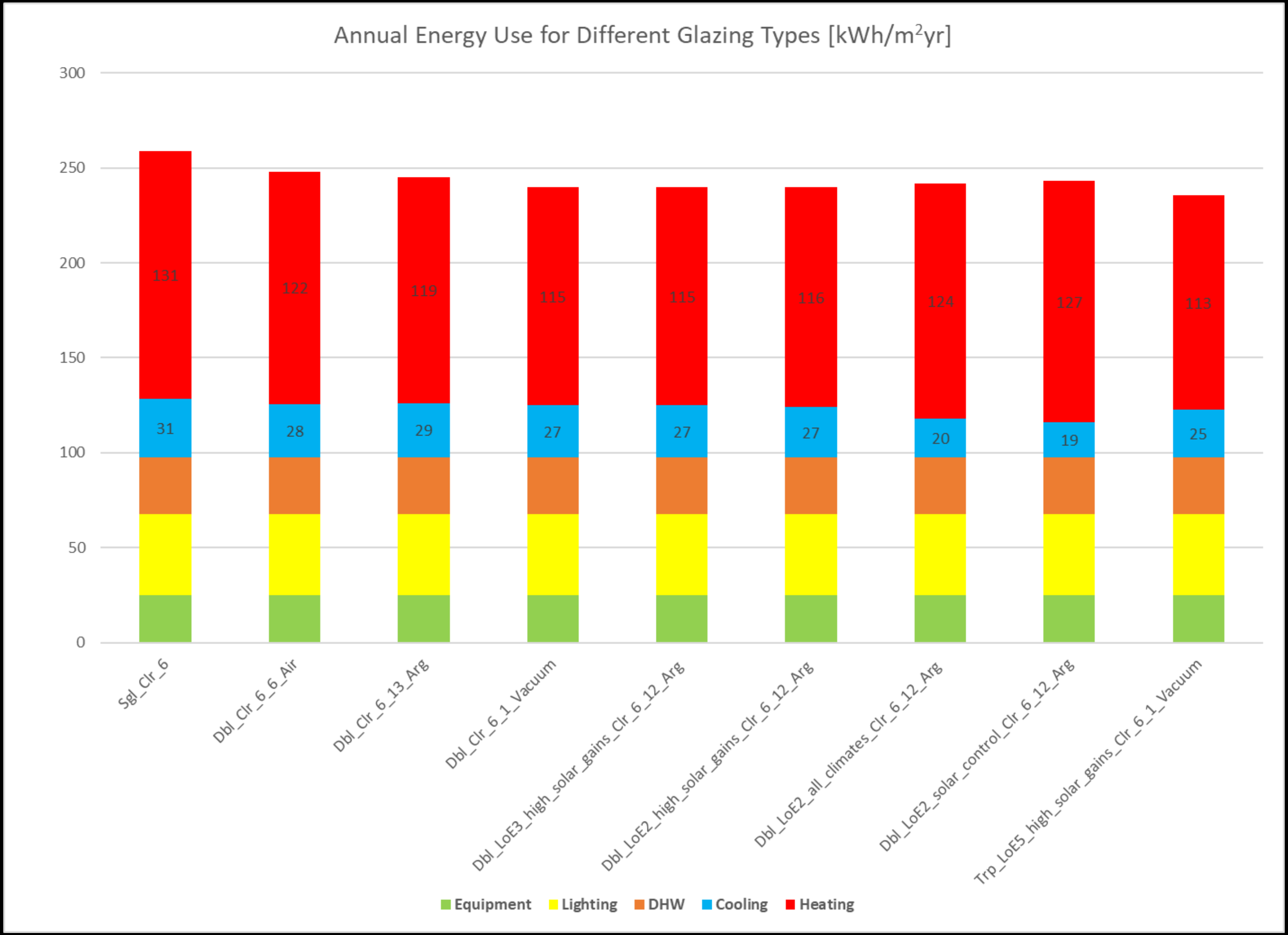
Summary Glazing Study



- ❑ Why is the overall effect of replacing glazings moderate in this case?

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Properties for Common Glazing Types

Glazing Unit	U Factor [W/m²K]	SGHC	t_{vis}
Single pane	5.818	0.816	0.881
Double pane	2.730	0.762	0.811
Double pane with argon filling	2.568	0.762	0.811
Double pane with argon filing & low-e coating on surface 3	1.730	0.716	0.749
Double pane with argon filing & low-e coating on surface 2	1.730	0.653	0.749
Double pane with argon filing & low-e coating on surface 2 and 3	1.135	0.571	0.629

Fig 12.15 Optical and thermal properties for generic common glazing units

Skylights

Conventional Skylight

R-2
U=2.8 W/m^{2}K

Insulating Glass Skylight

R-10
U=0.5 W/m^{2}K
τ_{vis} = 62%
SHGC= 0.25

Nanogel filled

R-20
U=0.28 W/m^{2}K

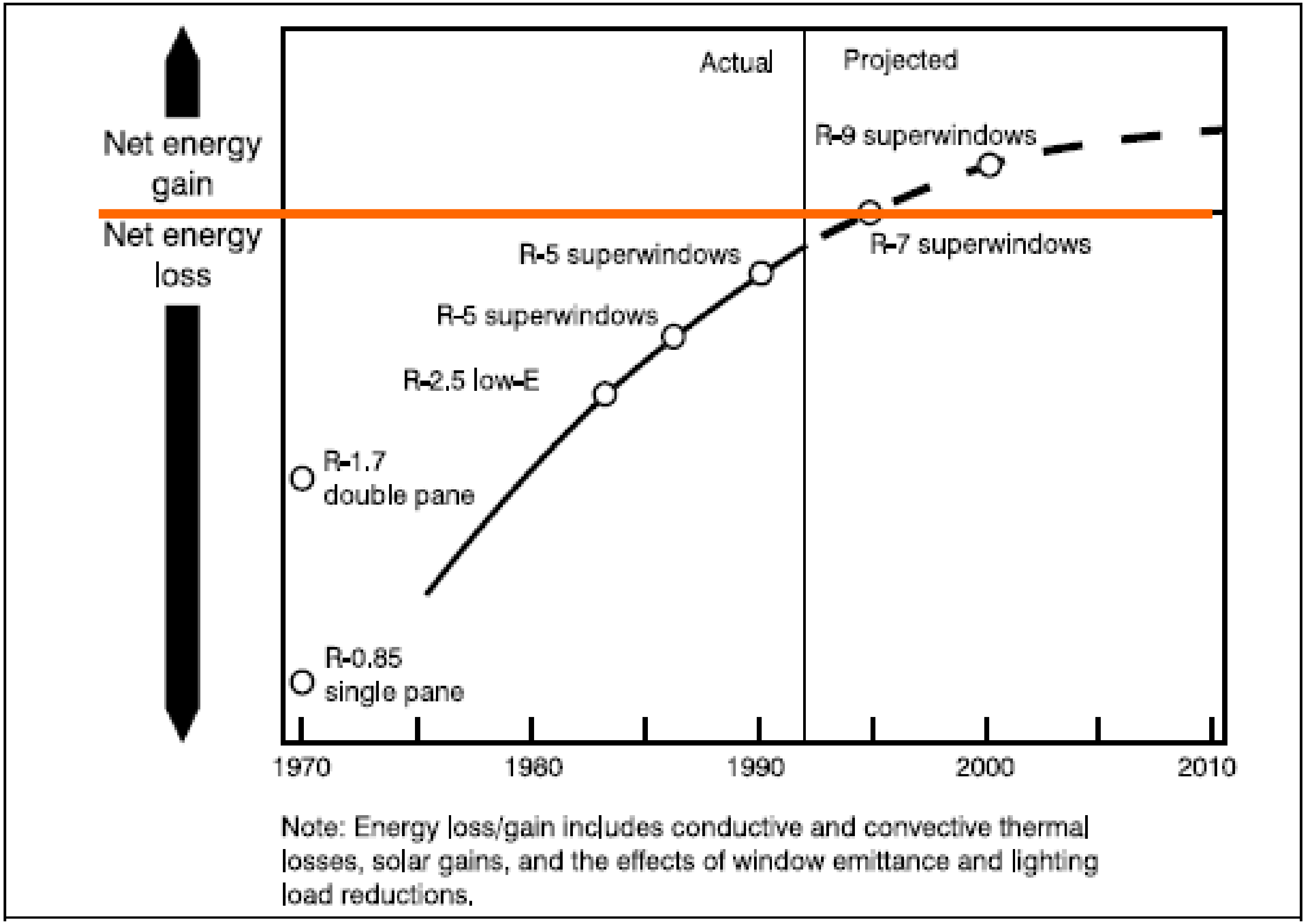
Nanogel


nanogel
TLD302
Translucent Aerogel
nanogel
TLD302
Translucent Aerogel

Other Aspects

- *20% of window is frame.*
- *Center of glazing vs. frame effects.*

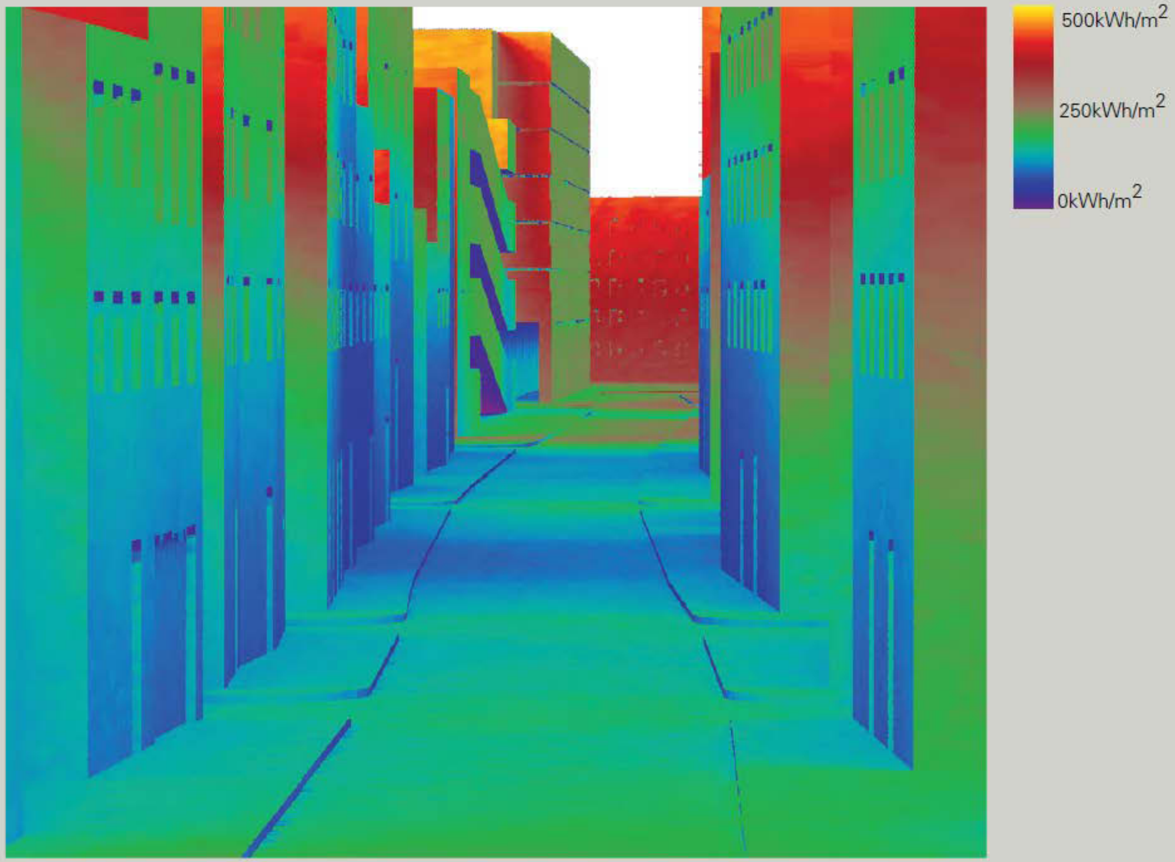
Historic R-Values for Windows



Advanced glazings have increased windows' resistance to heat flow, or R-value.

vc-cd16-a1515-06

Passive Solar Heating Potential

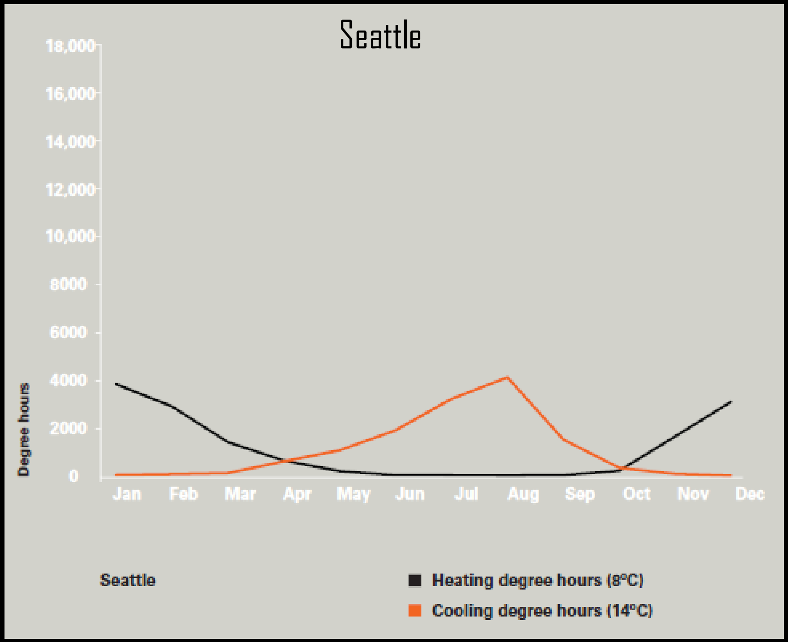


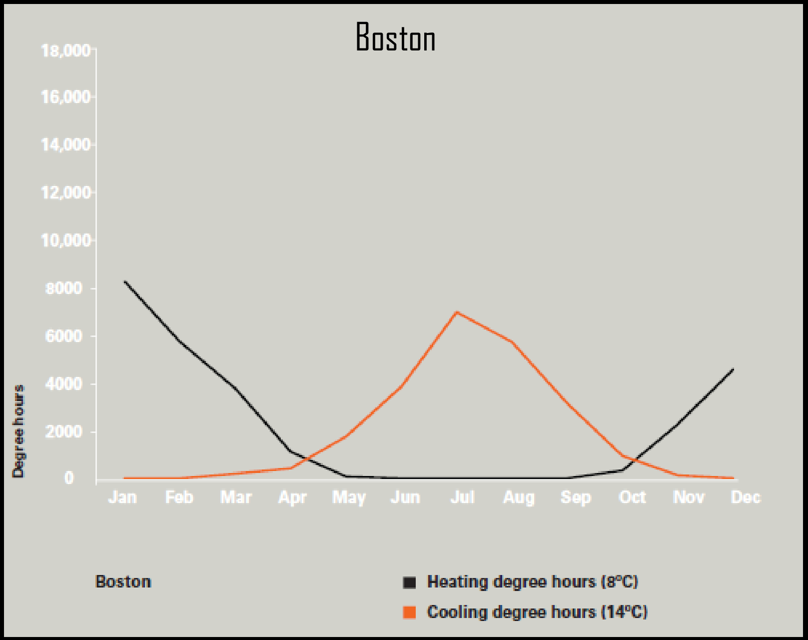
$G_{threshold} \times SHGC \times \eta >$ heating degree hours x U **Equ 9-4**

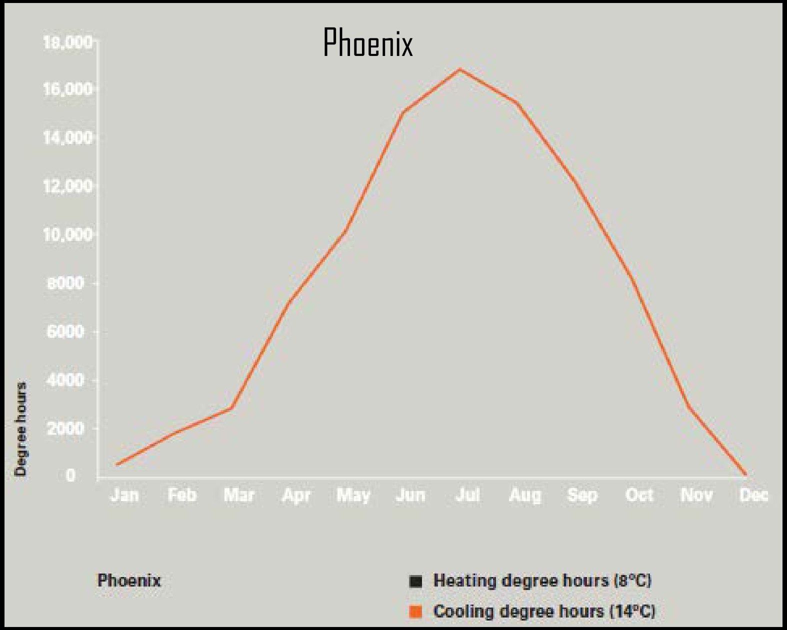
$$-G_{threshold} = \frac{24500Kh \times 1.6W/Km^2}{0.28 \times 0.7} = 200kWh/m^2$$ **Equ 9-5**

MIT SDLAB

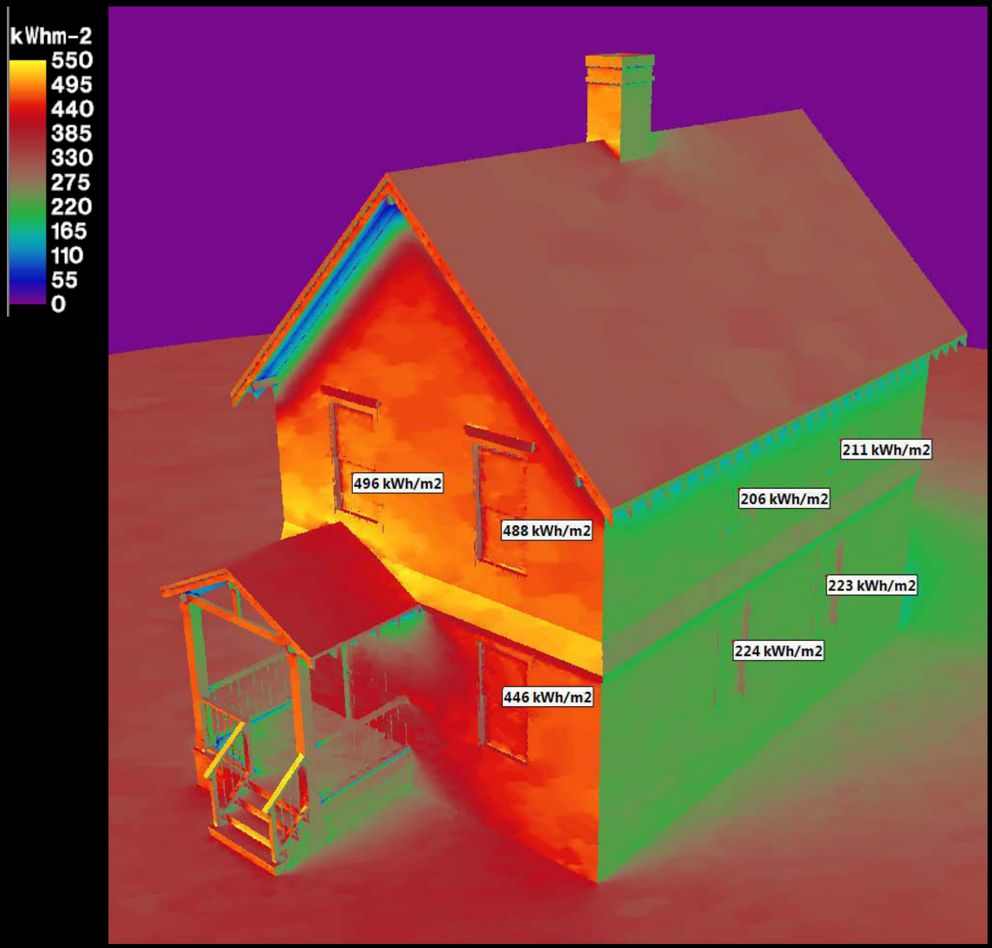
Heating and Cooling Degree Hours



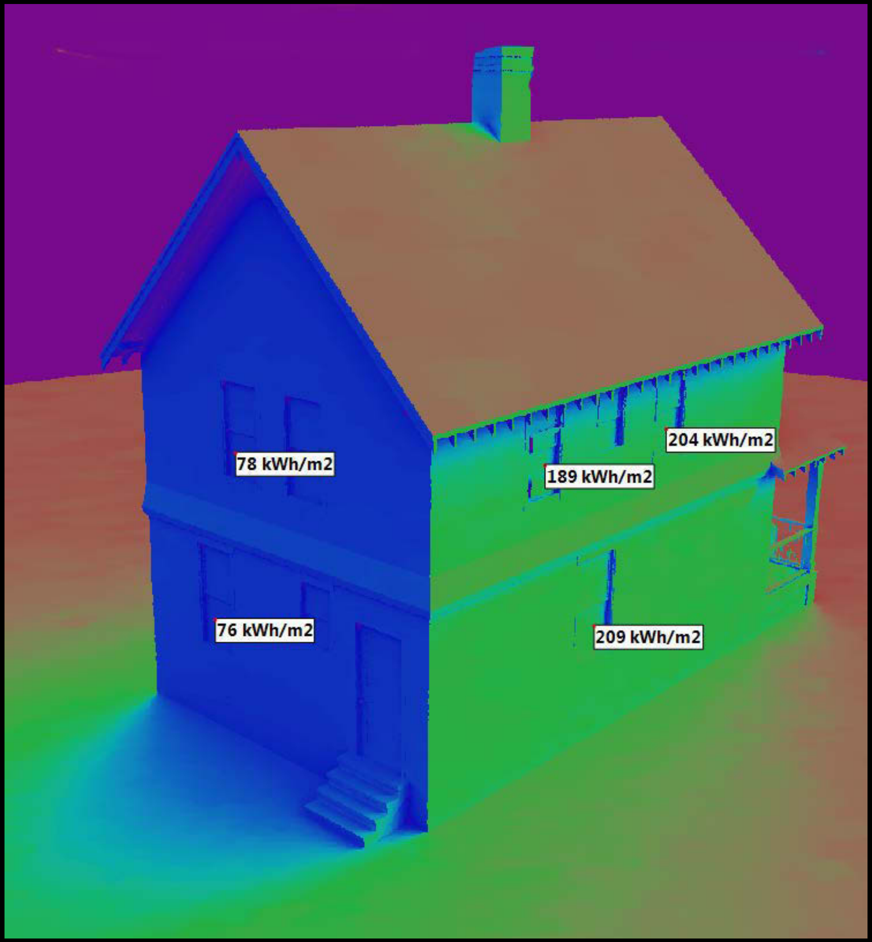




Radiation Map During Heating Season (Nov 1 to Mar 31)



Perspective view facing northwest



Perspective view facing southeast

- Windows lead to a net gain on the south; east and west are borderline; north windows lead to a net heat flow loss.

Questions?