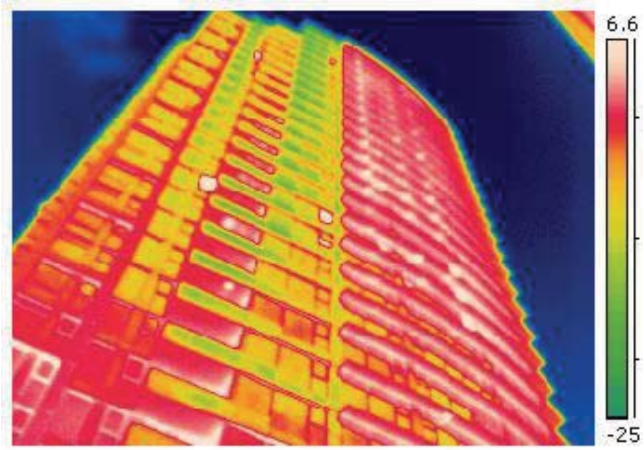
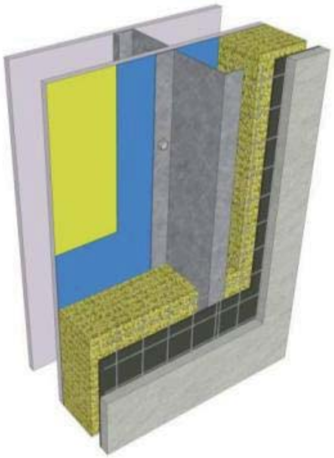
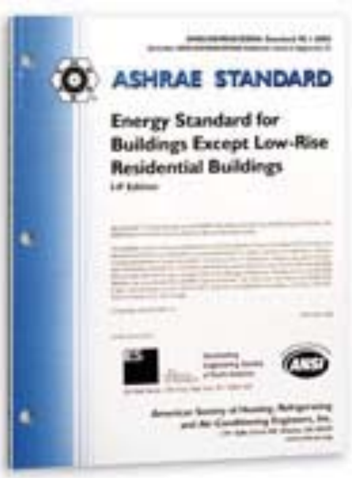
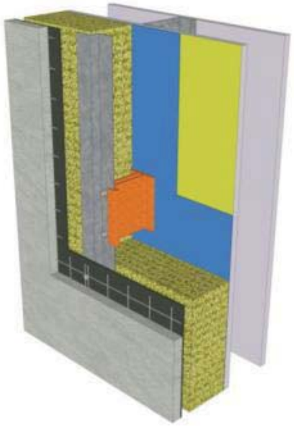
Understanding The Impact Of Insulation Distribution



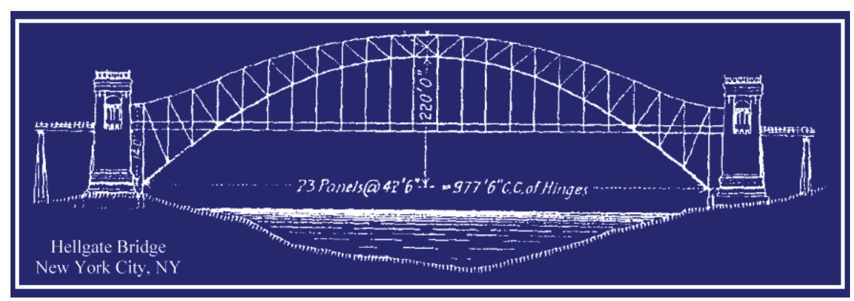
Big picture → Establishing targets → Details







Balsa Wood Bridge



Agenda

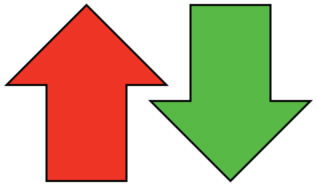
- Energy conservation – why?
- Codes and standards
  - ASHRAE 90.1
- Building enclosures
  - Details
- What to improve first?
  - Weak points
- Cost analysis
- Online tools

Effective Thermal Performance
Of The Building Enclosure

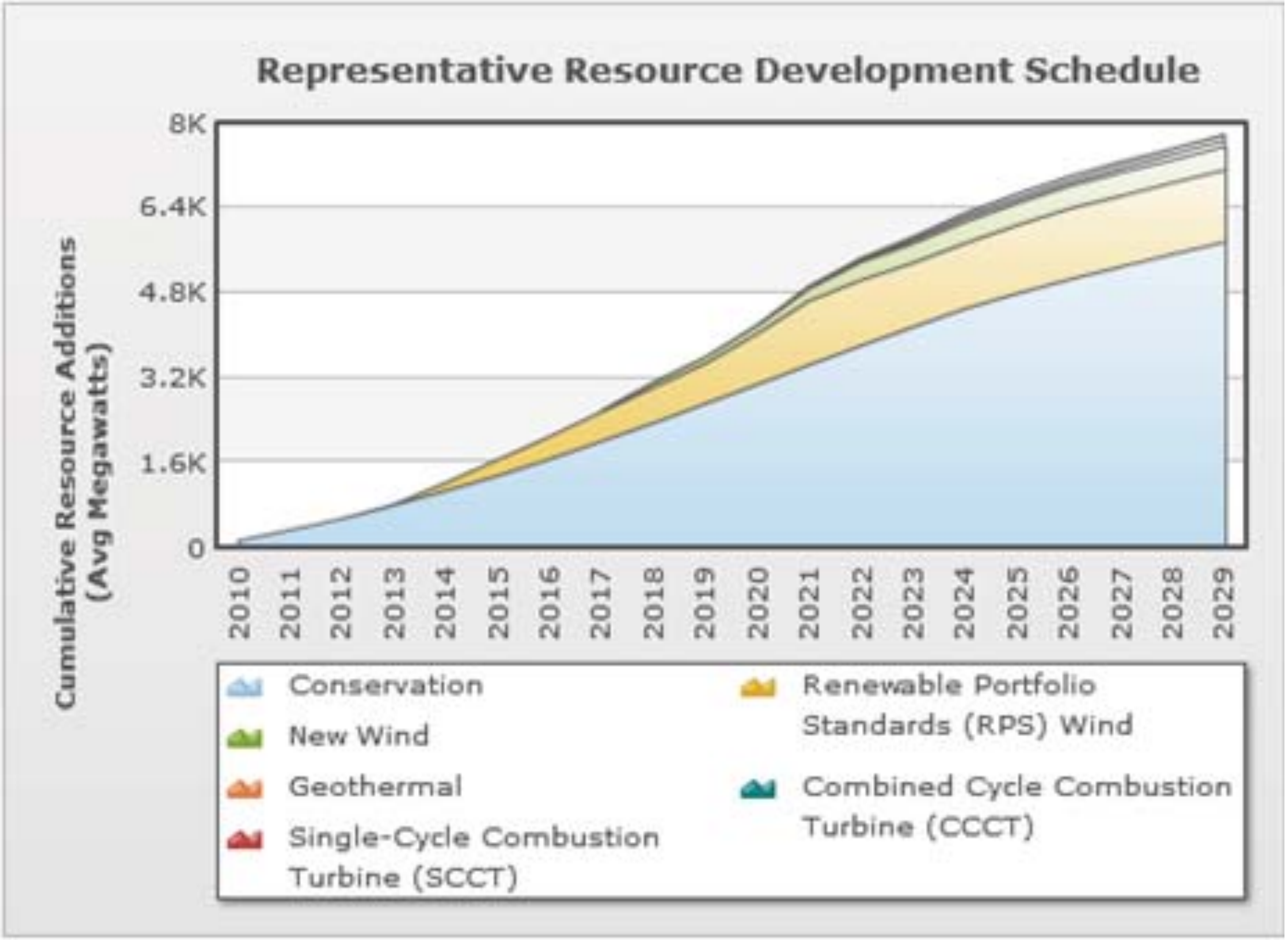
Let's resolve to use less energy!

The Energy Factor

- The energy supply side is limited, dirty, and increasingly expensive
- Across Canada and the US, national, regional, and local governments have shifted their focus to optimizing utilization
- Going forward, increased demand is going to be met by conserving how much we use
  - **Demand Side Management**



Sixth Northwest Power Plan (2010)



Limiting Heat Loss In Buildings

Importance of Limiting Heat Flow in Buildings

- Thermal Comfort
- Condensation control
- Energy
  - Over 40% of all energy in North America is used in Buildings
  - In residential buildings, 30-60% energy is used for space-heating
  - Building enclosure must manage all mechanisms of heat-flow
- Building codes require that heat flow be controlled

Heat Flow

- Fundamental Rule #1:

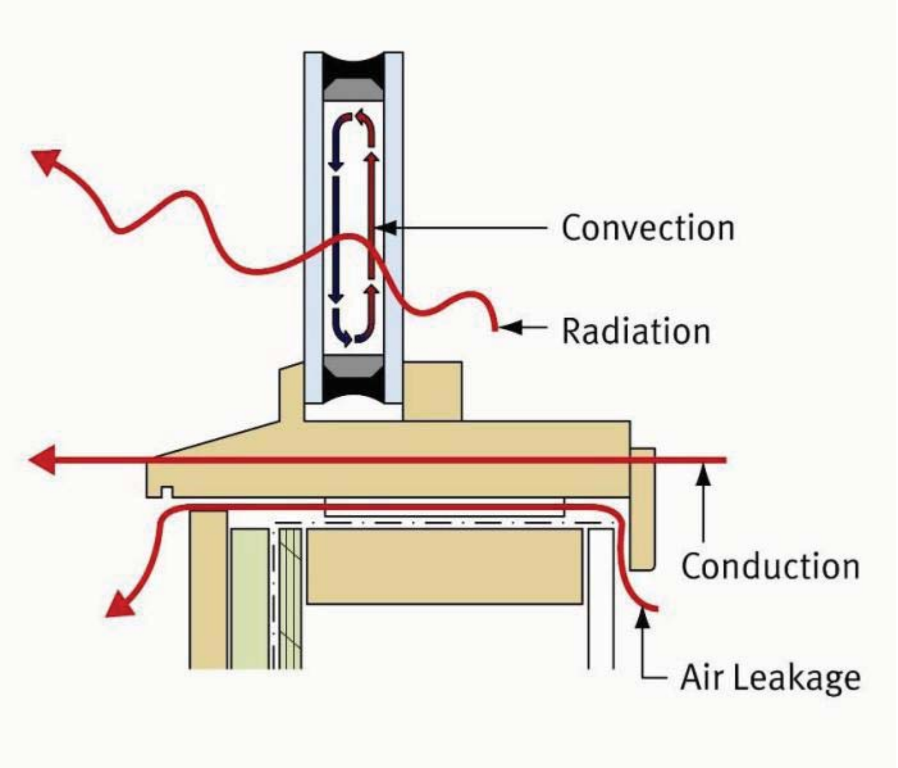
  Heat Flows from HOT to COLD

- There are no exceptions

- You **cannot prevent** heat flow with insulation, you can only **slow it down**

Mechanisms of Heat Flow

- **Conduction**
  (Heat flow by touch)
- **Convection**
  (Heat flow by air)
  - **Within** Closed Air-spaces
  - **Through** air, i.e. air-leakage
- **Radiation**
  (Heat flow by waves)



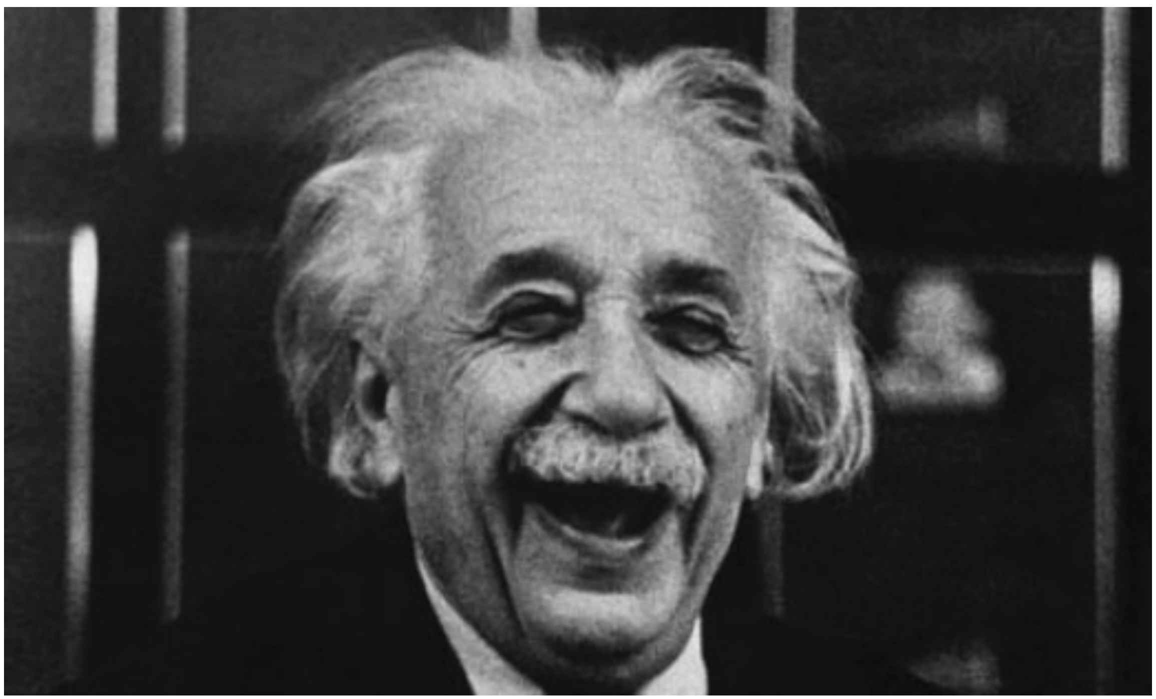
* The focus of this presentation is on <u>conduction</u> and related thermal bridging.

Real World Example – What Heat Flow Mechanisms Are Occurring?

Photo credit to movie: *Dumb and Dumber*

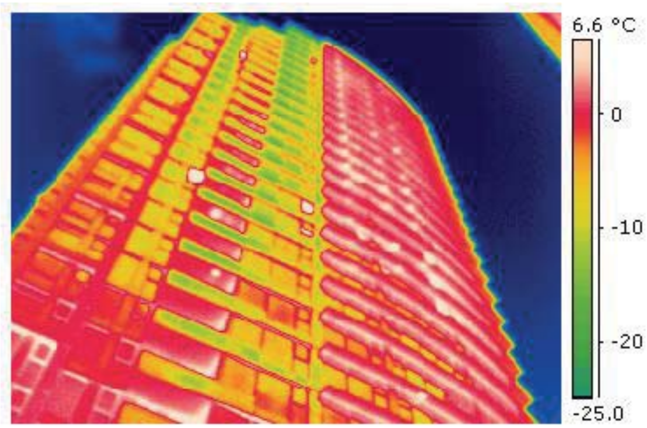
Physics Refresher

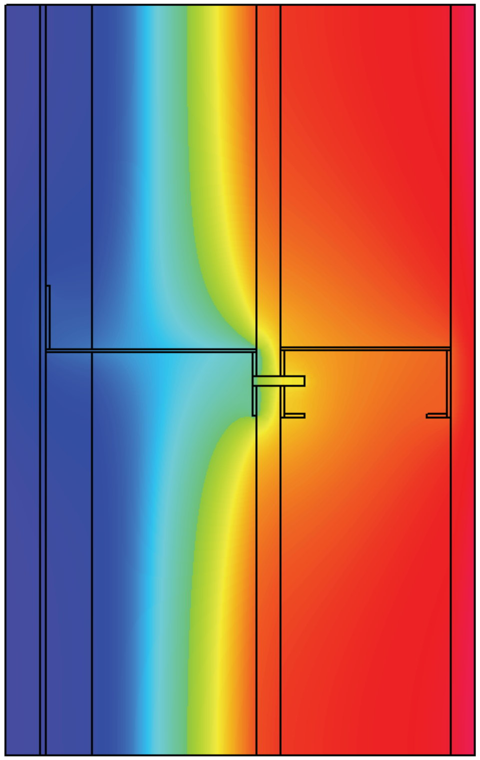
- Fast physics refresher on heat flow.



Conduction

- **Conduction** is the transfer of energy through a solid material, and between materials that are in contact.
- Practical Examples:
  - Heating of a pot on an electric stove
  - Heat flow through a metal window frame
  - Heat flow through a steel Z-girt in a conventional exterior insulated wall assembly
  - Heat flow through a concrete balcony slab





Conduction

- The rate of heat flow through a material is dependent on its conductivity (k).
  - Metric units are W/m·K
  - Imperial units are Btu/hr·ft·F°
- For example:
  - Aluminum ~160 W/mK
  - Steel ~60 W/mK
  - Stainless Steel ~14 W/mK
  - Fiberglass – 0.15 to 0.30 W/mK
  - Wood ~0.10 to 0.15 W/mK
  - Insulation Materials 0.022 to 0.080 W/mK
- For building enclosure components to be thermally efficient – must **minimize highly conductive materials** extending through the insulation.

Conductivity Calculations

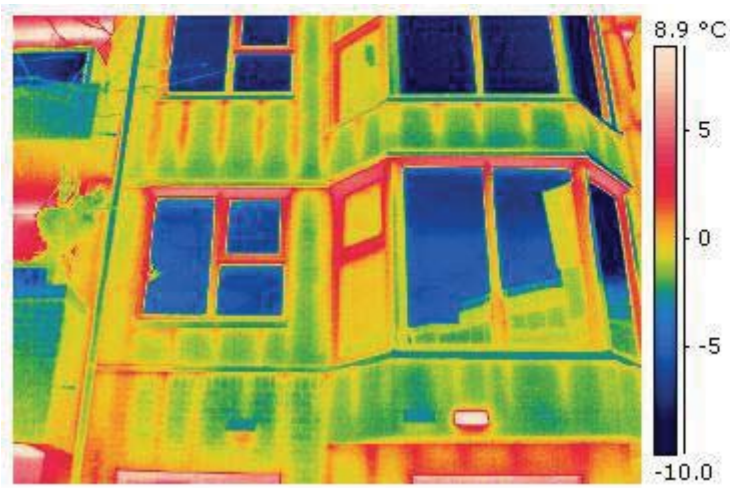
- The term, **Conductance** (C) is simply the conductivity (k) divided by the thickness of the material (t)
  - this is the "U-value" for a specific material

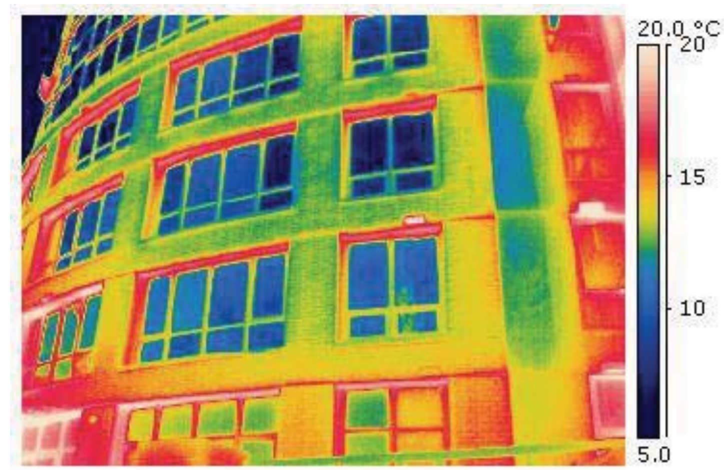
- The inverse of a material's conductance is its thermal resistance also called "R-value"

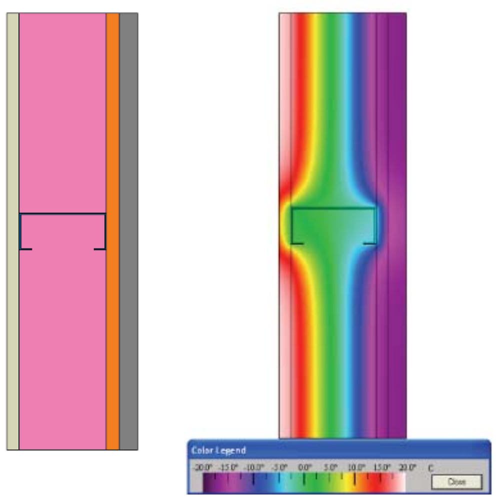
Understanding Thermal Bridging

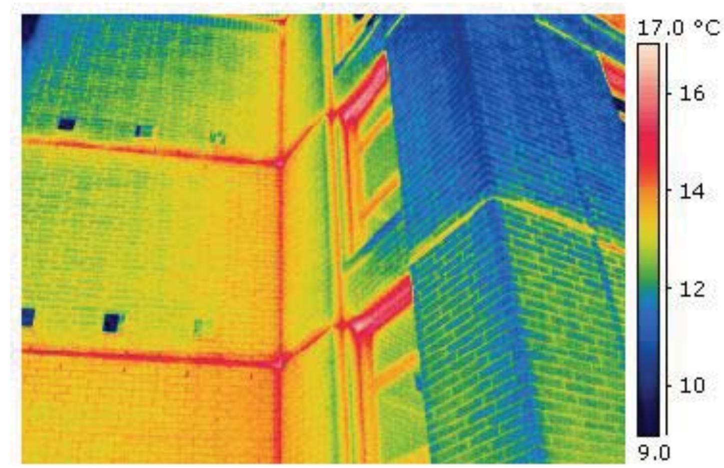
Thermal Bridging

Steel Studs & Brick Shelf Angles



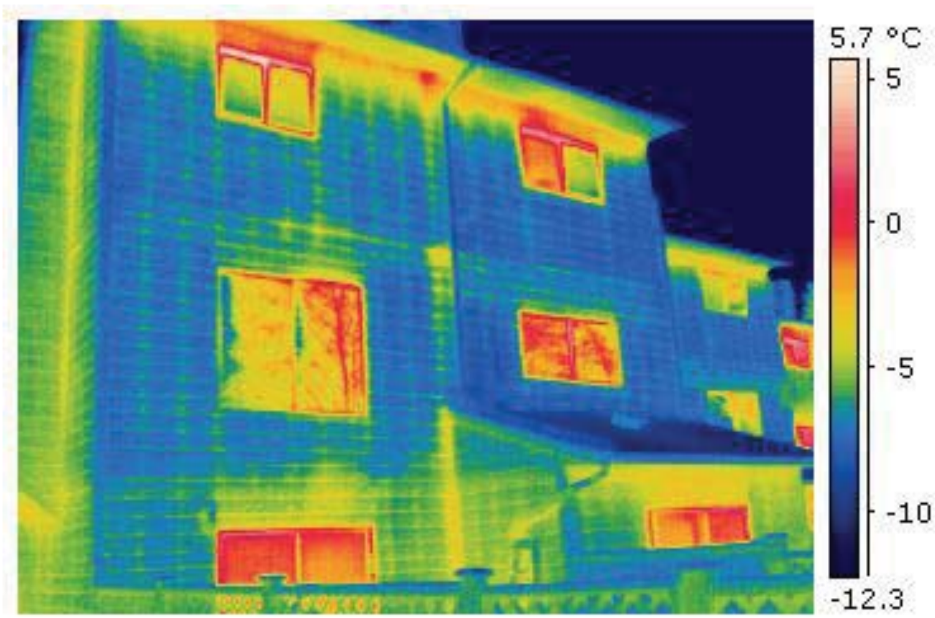


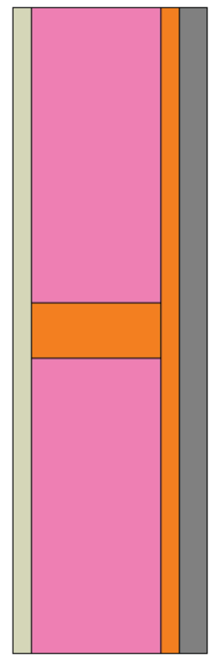


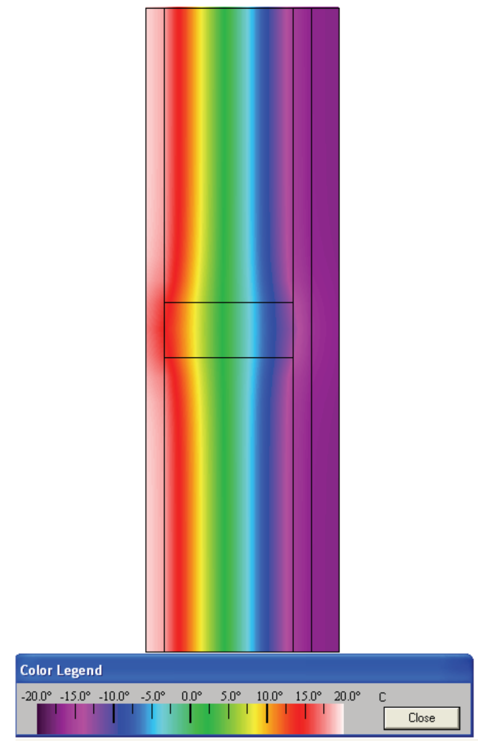


Thermal Bridging

Wood Frame



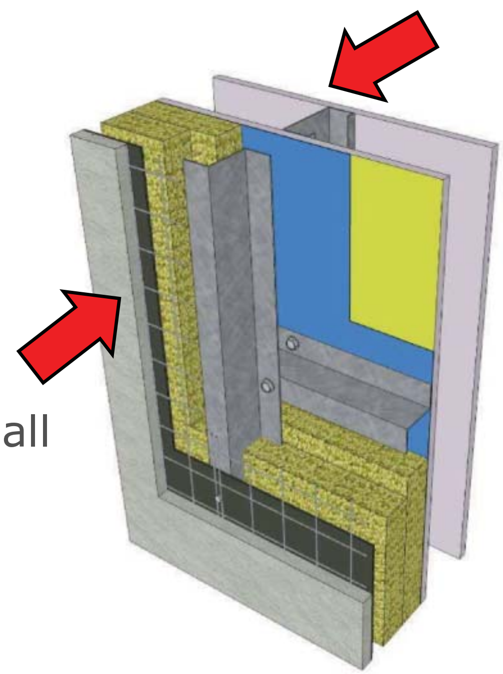




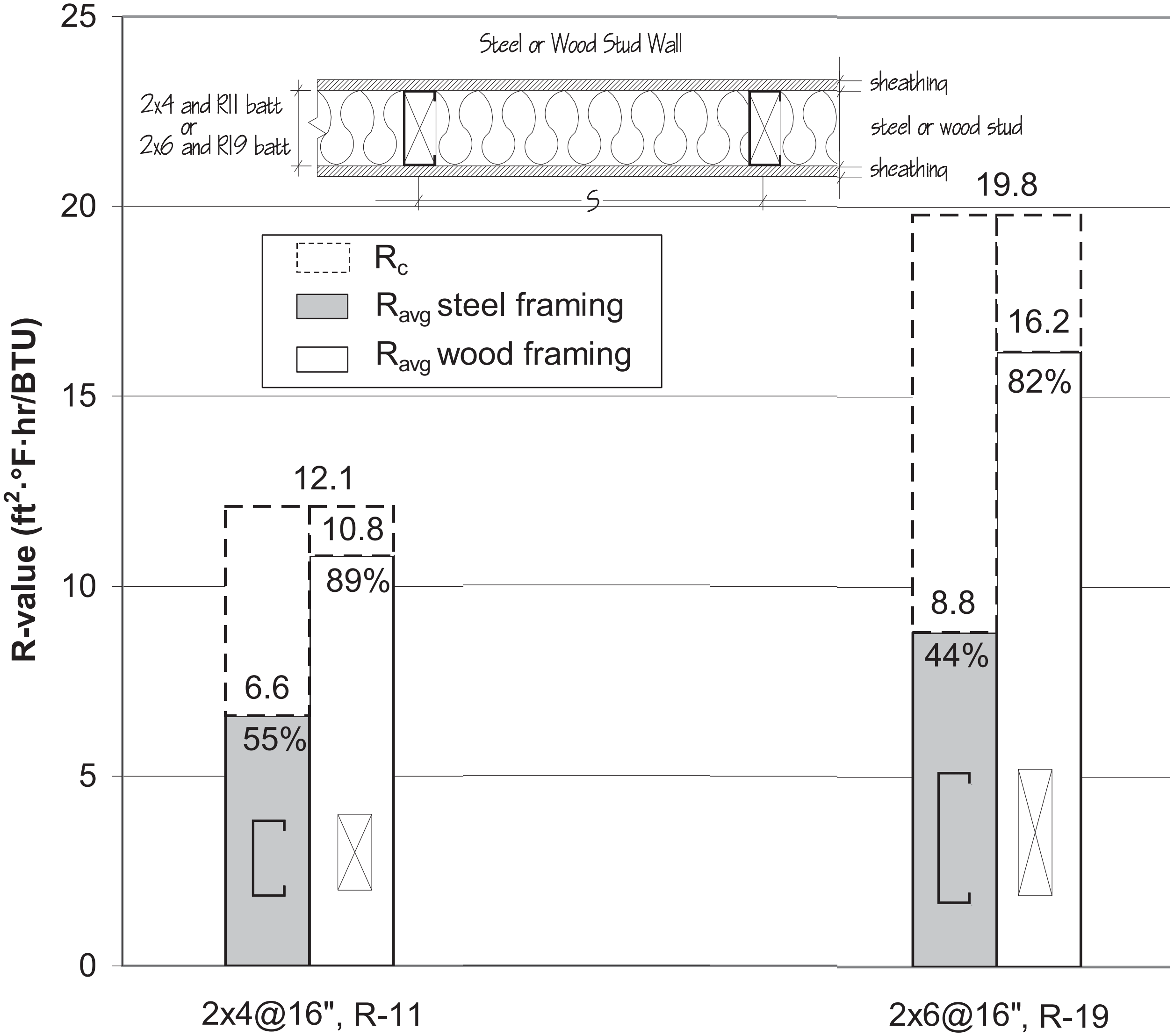
Two More Key Terms

- Nominal R-value
  - The R-value of just the insulation itself

- Effective R-value
  - The overall value of the assembly (wall), including all components, air films, and the effect of all thermal bridging.



Steel versus Wood Studs

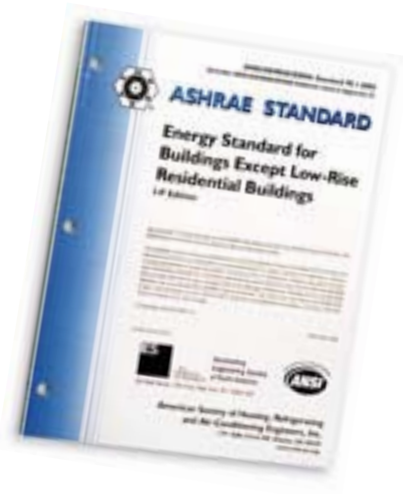


Codes and Standards

ASHRAE 90.1

ASHRAE 90.1

- ASHRAE 90.1 - three methods to comply with wall thermal performance requirements:
  - Prescriptive Path
  - Building Enclosure Trade-off Path
  - Energy Cost Budget Path



- ASHRAE 90.1 stipulates that wall R-values must consider the effect of thermal bridging, to be representative of actual thermal performance

ASHRAE 90.1 – Prescriptive Table
Zone 5 example

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A,B,C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maxi-mum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.173	R-5.0 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.123	R-7.6 ci	U-0.090	R-11.4 ci	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
Steel-Framed	U-0.084	R-13.0 + R-3.8 ci	U-0.064	R-13.0 + R-7.5 ci	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Wall, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.087	R-8.3 ci	U-0.074	R-10.4 ci	U-0.322	NR
Steel-Joist	U-0.052	R-19.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.840	R-10 for 36 in.	F-0.840	R-10 for 36 in.	F-1.020	R-7.5 for 12 in.

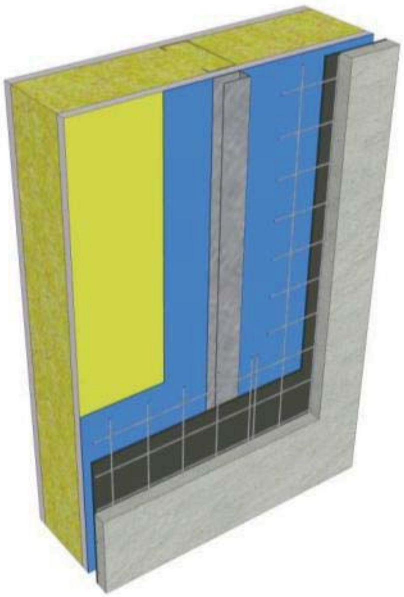
Overall U-value (inverse of *Effective* R-value)

Nominal R-values

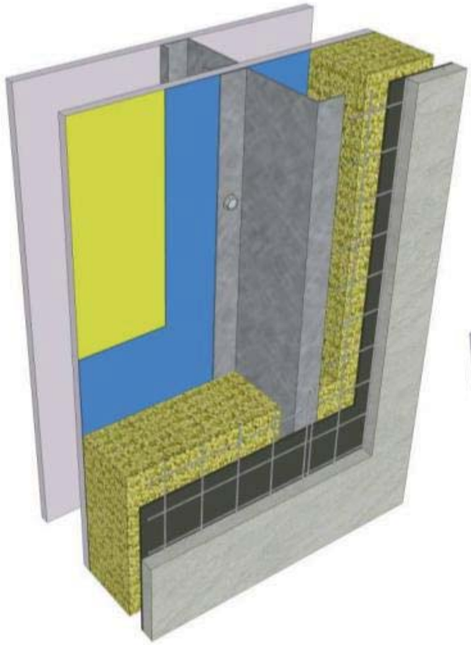
What are we doing?

Does it work?

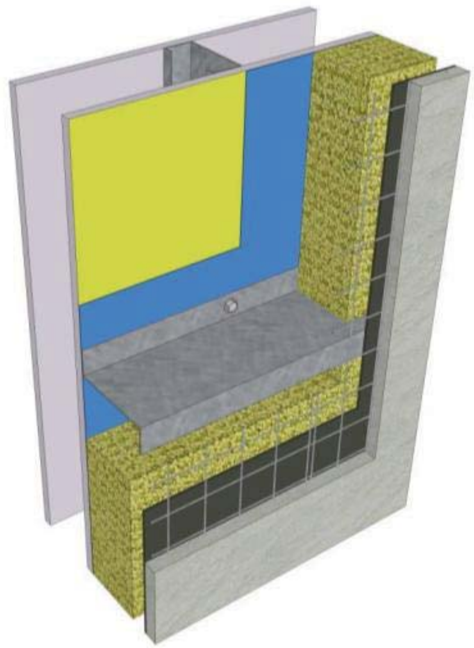
Conventional Exterior Insulated Wall Assemblies



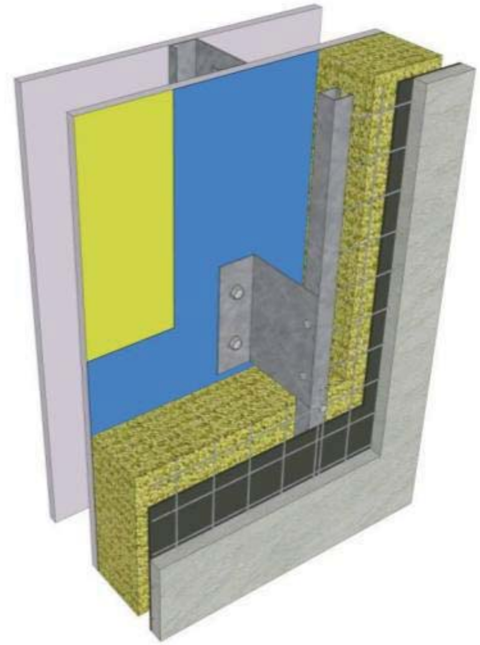
Stud Insulated
R-5.5 $ft^2 \cdot °F \cdot hr/Btu$



Vertical Z-Girts
R-7.0 $ft^2 \cdot °F \cdot hr/Btu$

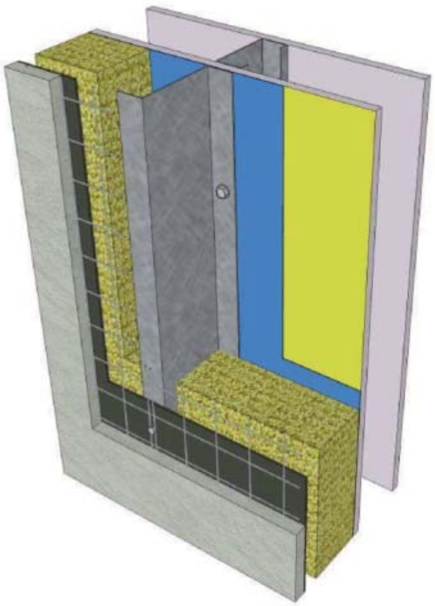


Horizontal Z-Girts
R-7.8 $ft^2 \cdot °F \cdot hr/Btu$



Galvanized Clips
R-11.0 $ft^2 \cdot °F \cdot hr/Btu$

Single Continuous Z-girt

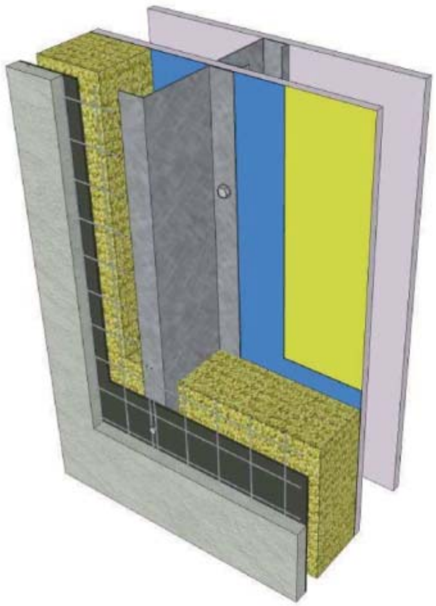


Effective R-values

Exterior Insulation	Galvanized Z-Girt
3 ½" Mineral Fiber (R-14.7)	7.4
4" Mineral Fiber (R-16.9)	7.8
8" Mineral Fiber (R-33.6)	9.8

- Not feasible to meet ASHRAE 90.1 minimum prescriptive requirement of R-15.6 effective with continuous girts.

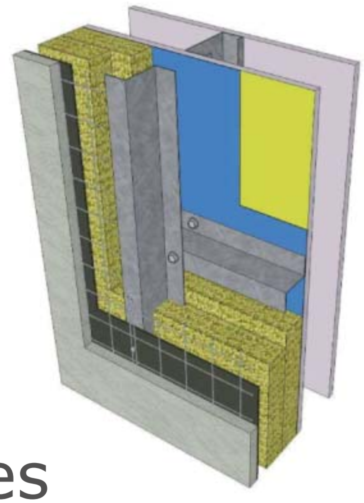
Thermal Weight of Girts



Exterior Insulation	Galvanized Z-Girt
8" Mineral Fiber (R-33.6)	9.8

- How much heat is flowing through steel vs field of wall?
- Use U-values for calculation – isolate effect of steel:
  - Nominal U-value: 1/33.6 = 0.030
  - Effective U-value: 1/9.8 = 0.102
  - Effect of presence of girt: 0.102 – 0.030 = 0.0723
  - Thermal weight of girt: 0.0723 / 0.102 = 71%
- 71% of the total heat loss flows through the steel girt.
- Diminishing returns.

Crossing Z-girts

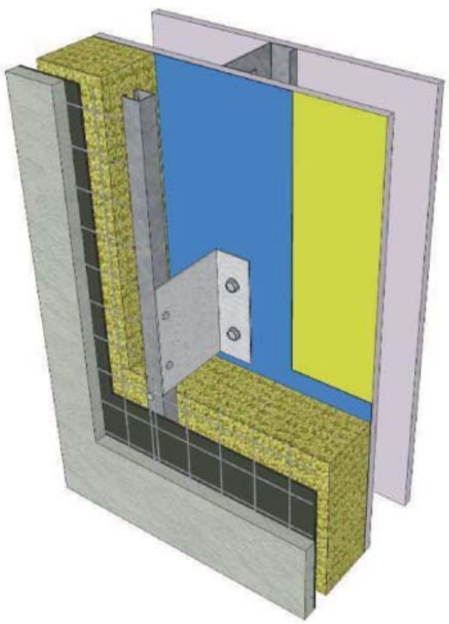


Effective R-values

Clip Assembly, Exterior Insulation	Purchased Insulation R-value	Effective Insulation R-value	% Effectiveness of Insulation	Effective Wall R-value
4" Mineral Fiber (R-16.9), Crossing Z-Girt	16.9	8.2	49%	11.4
4" Mineral Fiber (R-16.9), Crossing Z-Girt (w/ ¼ thermal shim between girts)	16.9	10.0	59%	13.1
6" Sprayfoam* (~R-36), Crossing Z-Girt	36.0	12.5	35%	**15.6**

- R-36 insulation was required to achieve R-15.6 effective

Steel Clips



Effective R-values

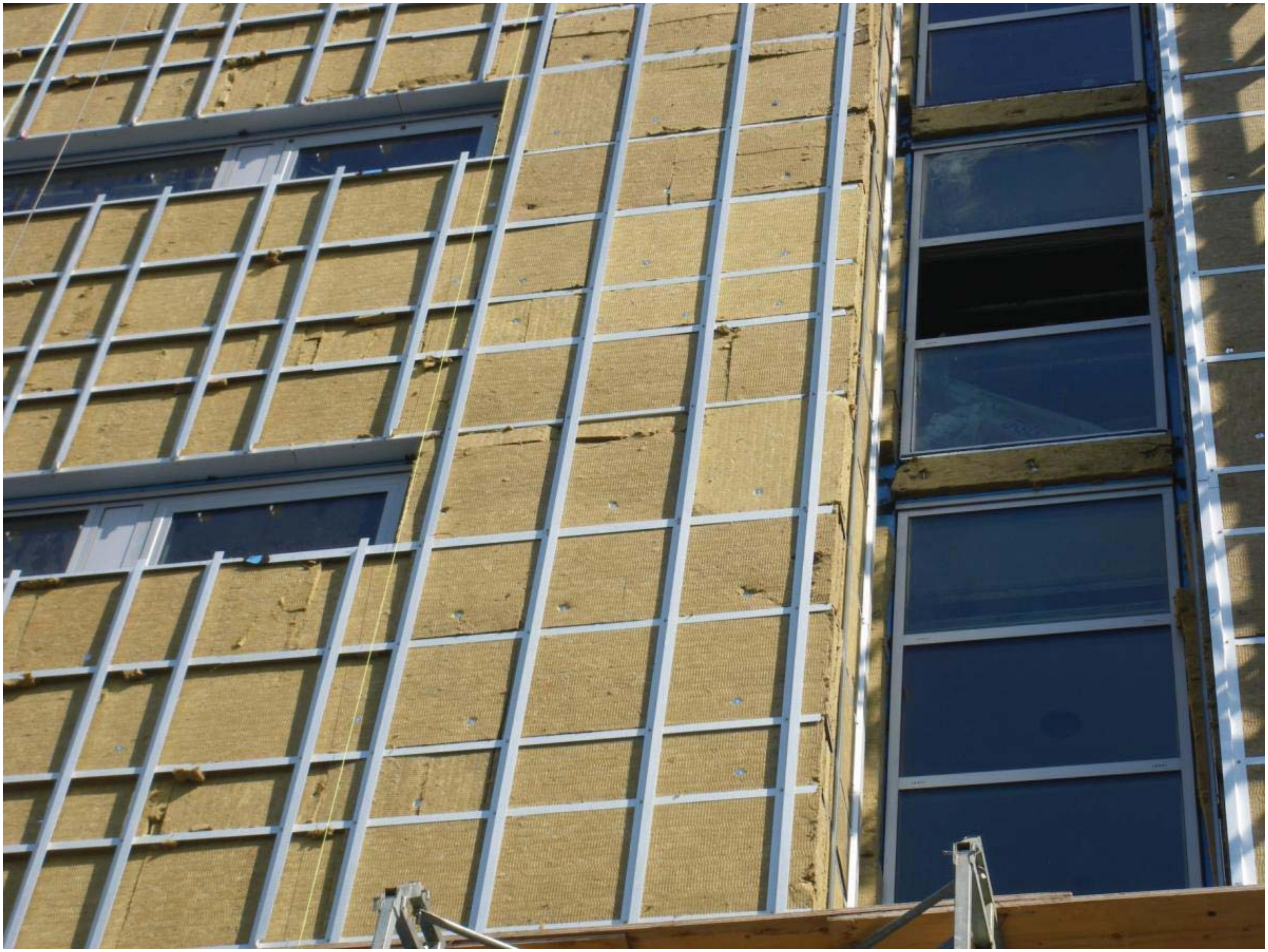
Exterior Insulation	Galvanized Steel Clip
3 ½" Mineral Fiber (R-14.7)	11.3
4" Mineral Fiber (R-16.9)	12.4
6" Mineral Fiber (R-25.1)	**15.6 ***

- R-25 insulation was required to achieve R-15.6 effective

So what's the answer?
How do we actually meet R-15.6 ?

Well, if steel reduces the insulation value by *half*,
then obviously, we just need *twice as much of everything*, right?

This is not the most practical answer...

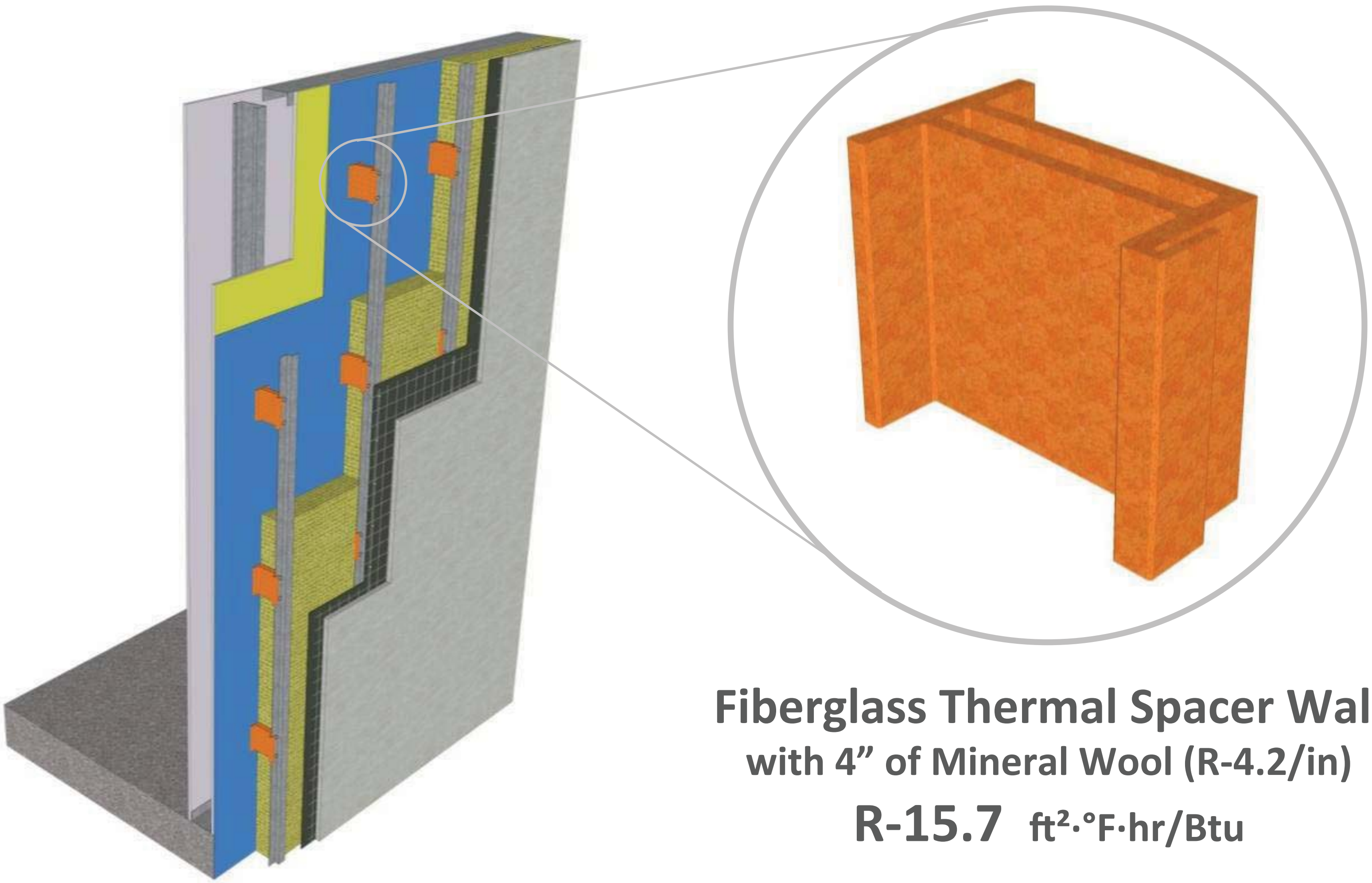


OK, let’s solve this…

Must-haves…

- Need to reduce thermal bridging of cladding supports, while keeping the following characteristics:
  - Acceptable in non-combustible
  - Appropriate substrate for cladding fasteners
  - Rigid enough for cladding attachment, and other loading
  - Inorganic (won’t rot)
  - Low thermal expansion/contraction
  - Won’t creep or deform over time (this might eliminate thermoplastics)
  - Easy to construct
  - Cost effective

Cascadia Clip
Fiberglass Thermal Spacer

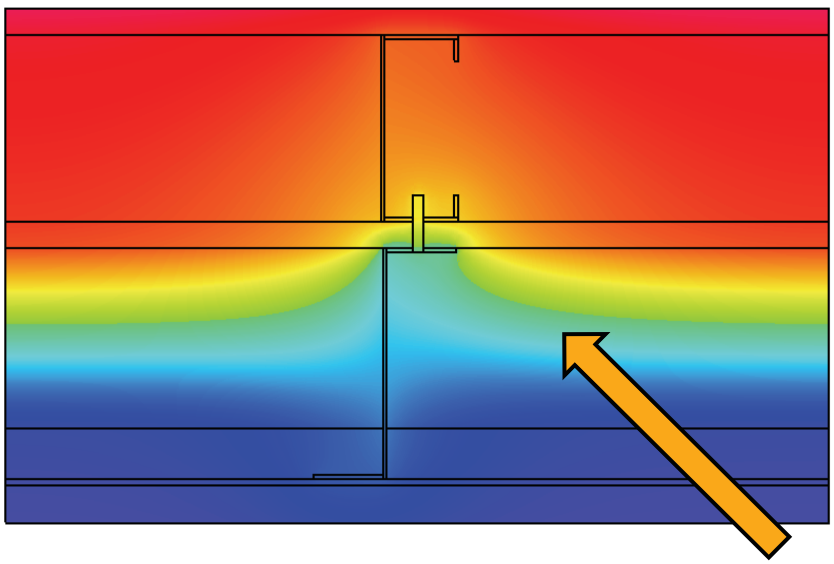


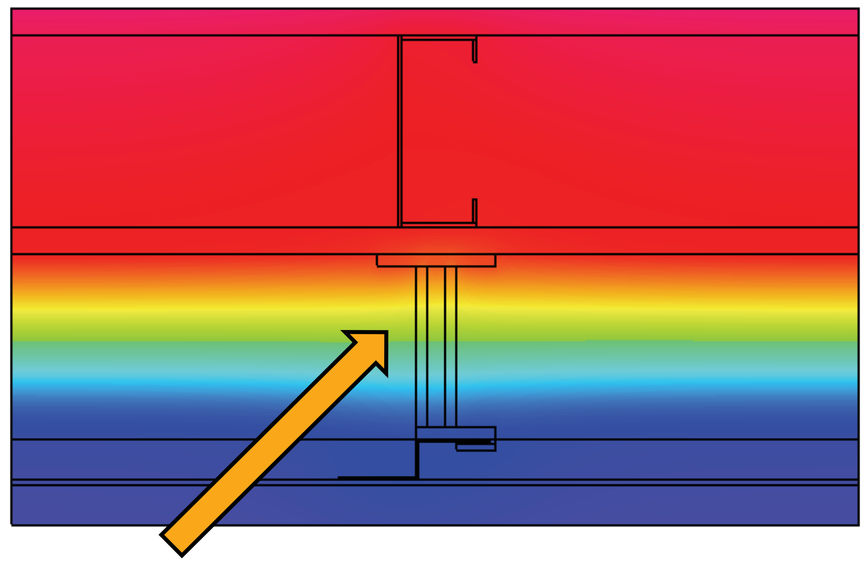
Fiberglass Thermal Spacer Wall
with 4” of Mineral Wool (R-4.2/in)
R-15.7 ft²·°F·hr/Btu

Low-conductivity fiberglass material reduces thermal bridging.
This greatly improves the effective thermal performance of the wall.

Need A Solution Without A Sacrifice

- Exterior insulated walls with typical girts:
  - Durable; good moisture management
  - Easy to sequence and to QC
  - Thermally poor





- For a THERM model, there’s no such thing as “nice curves”

So…

12" of Insulation

4" of Insulation

What to improve?

- Where does the improvement of insulation make the most economical sense?
- Target weak points…

Case study – my house

- 2200 SF
- 2 levels above grade
- 25 years old

- $2,400 per year on energy

- Roof R-25 nominal (approx)
- Walls R-10 effective (approx)
- Windows R-1 effective (approx)

If I had only enough money to improve one assembly, which one should it be?

• Roof R-25 effective (approx)	35% area
• Walls R-10 effective (approx)	50% area
• Windows R-1 effective (approx)	15% area

- Goal: Calculate the improvement that affects the overall R-value the most.

- Tool: Online area-weighted multi-assembly R-Value calculator:
- http://www.cascadiawindows.com/

Case study – my house

- Let's assume that each upgrade cost about the same
- Starting overall R-value: R-4.6
- Roof R-25 eff (approx)
  - Improve to R-50 eff
  - New overall R-value: R-4.8
  - Overall % improvement: 4%

Case study – my house

- Let's assume that each upgrade cost about the same
- Starting overall R-value: R-4.6
- Walls R-10 eff (approx)
  - Improve to R-20 eff
  - New overall R-value: R-5.3
  - Overall % improvement: 15%

Case study – my house

- Let's assume that each upgrade cost about the same

- Starting overall R-value: R-4.6

- Windows R-1 eff (approx)
  - Improve to R-2 eff
  - New overall R-value: R-7.2
  - Overall % improvement: 57%

- Further improve windows to R-4
  - New overall R-value: R-9.8
  - Overall % improvement: 113%

Case study – my house
$$$ conclusions

- Roof overall improvement: 4%
- Walls overall improvement: 15%
- Windows overall improvement: 113%

- Costs:
  - Energy per year: $2,400
  - Energy used for heating: $1,200 (at least)
  - Portion of heating energy lost to conduction: $800 (about 70%)

- Annual savings from improvements:
  - Roof: $34
  - Walls: $92
  - Windows: $424

- Other factors: small house, cheap energy

Conclusions

Remember this?

•How much heat is flowing through steel vs field of wall?

How about:

•How much heat is flowing through the weakest point vs rest of the building?

•To reduce conductive heat losses, target the thermally weakest link in the entire enclosure, to gain the highest percentage return on investment.

Bonus:

•If you do address weak points, do further improvements (roof and walls) then have a greater benefit?

•Let's try more scenarios:

•http://www.cascadiawindows.com/