Best Practices for the Design and Construction of the Building Envelope

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OSU – Green Housing Workshop
May 16, 2017

Agenda

Residential Envelope

1 - Energy Performance
2 - Air Infiltration
3 - Roof Systems
4 - Water Management
5 - Acoustics

1 - Energy Performance

Fundamental Driving Forces:

- Energy Codes
- Economics - Fuel Prices, Construction Costs
- Environmental Goals

Energy Codes

Climate Zones

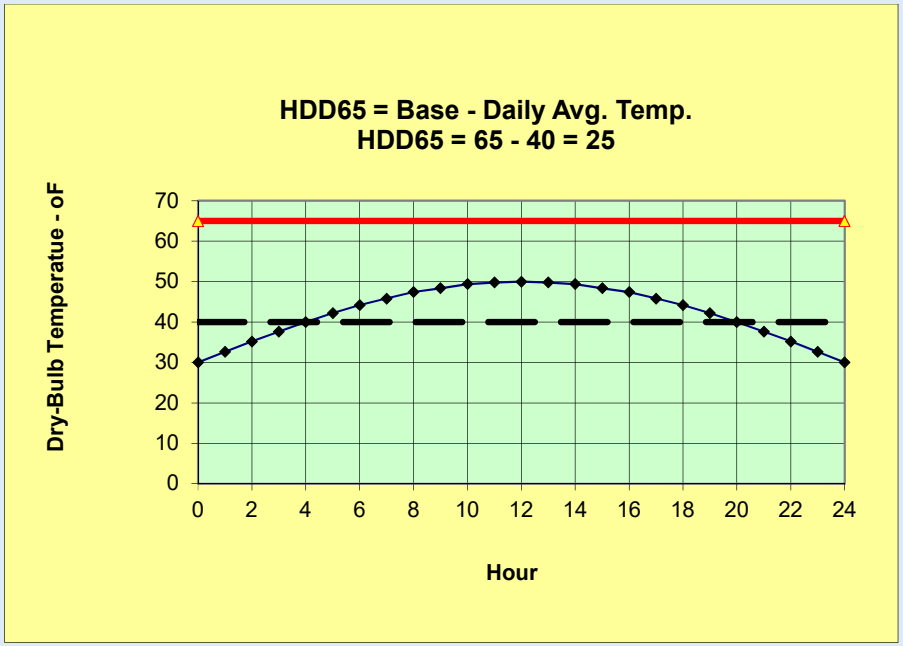
- **HDD65 – Heating Degree Days to Base 65oF**
- **CDD50 – Cooling Degree Days to Base 50oF**
- **Moisture Level – Moist, Dry, Marine**

Thermal Performance

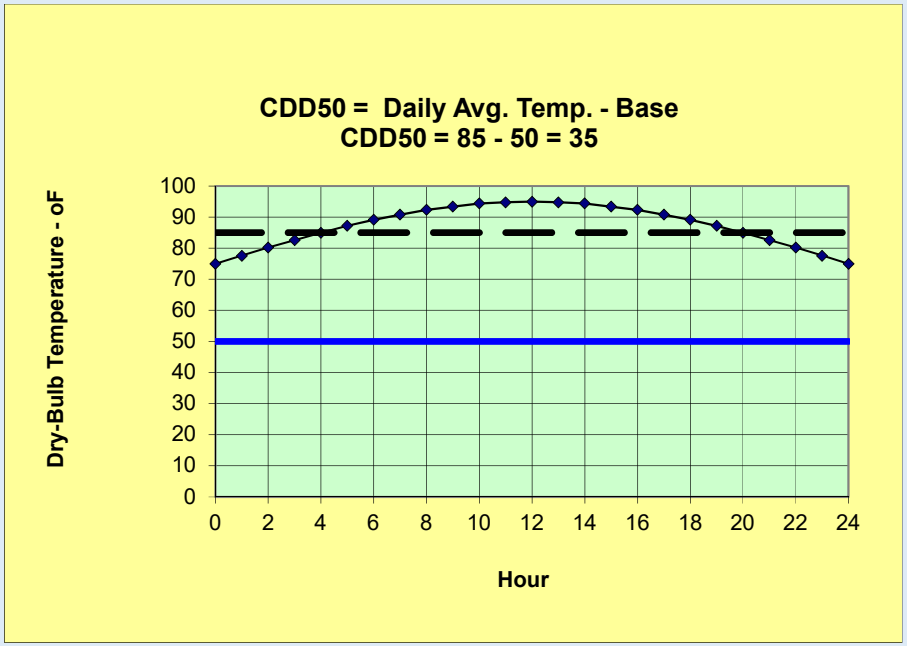
- **Thermal Resistance - R-value**
- **Thermal Transmittance - U-factor**
- **Solar Heat Gain Factor - SHGC**

Climate Zones Defined by Heating Degree Days & Cooling Degree Days

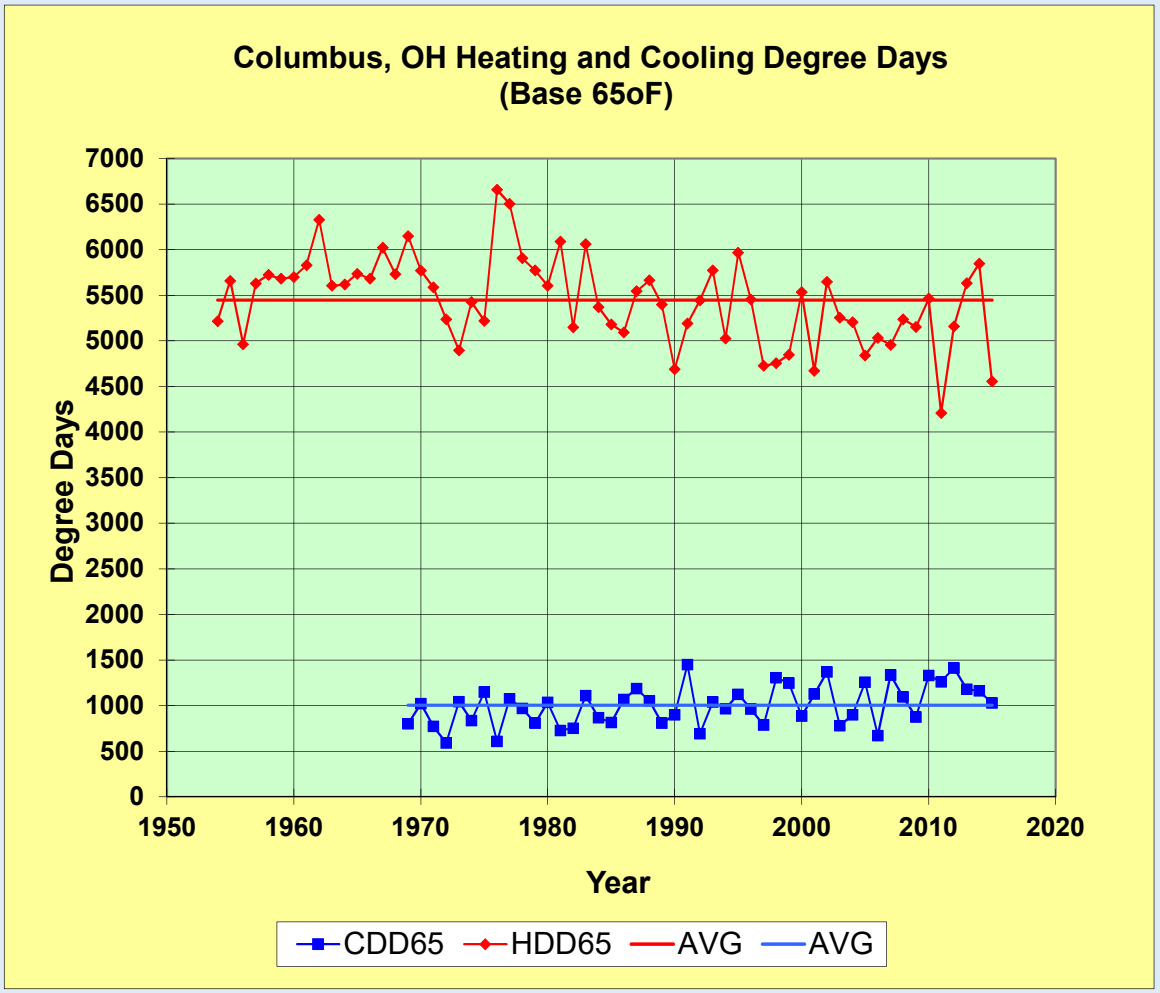
HDD65



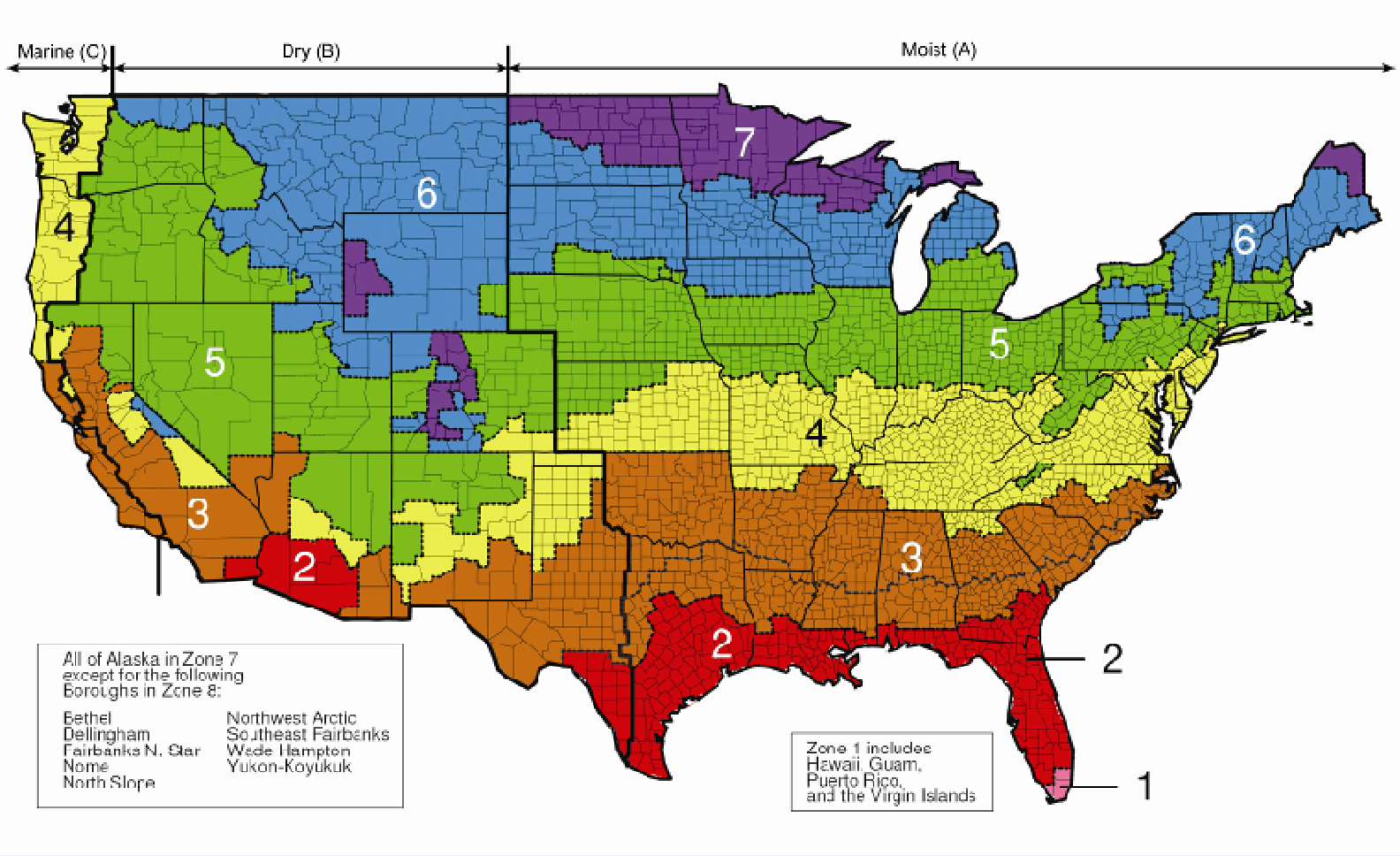
CDD50



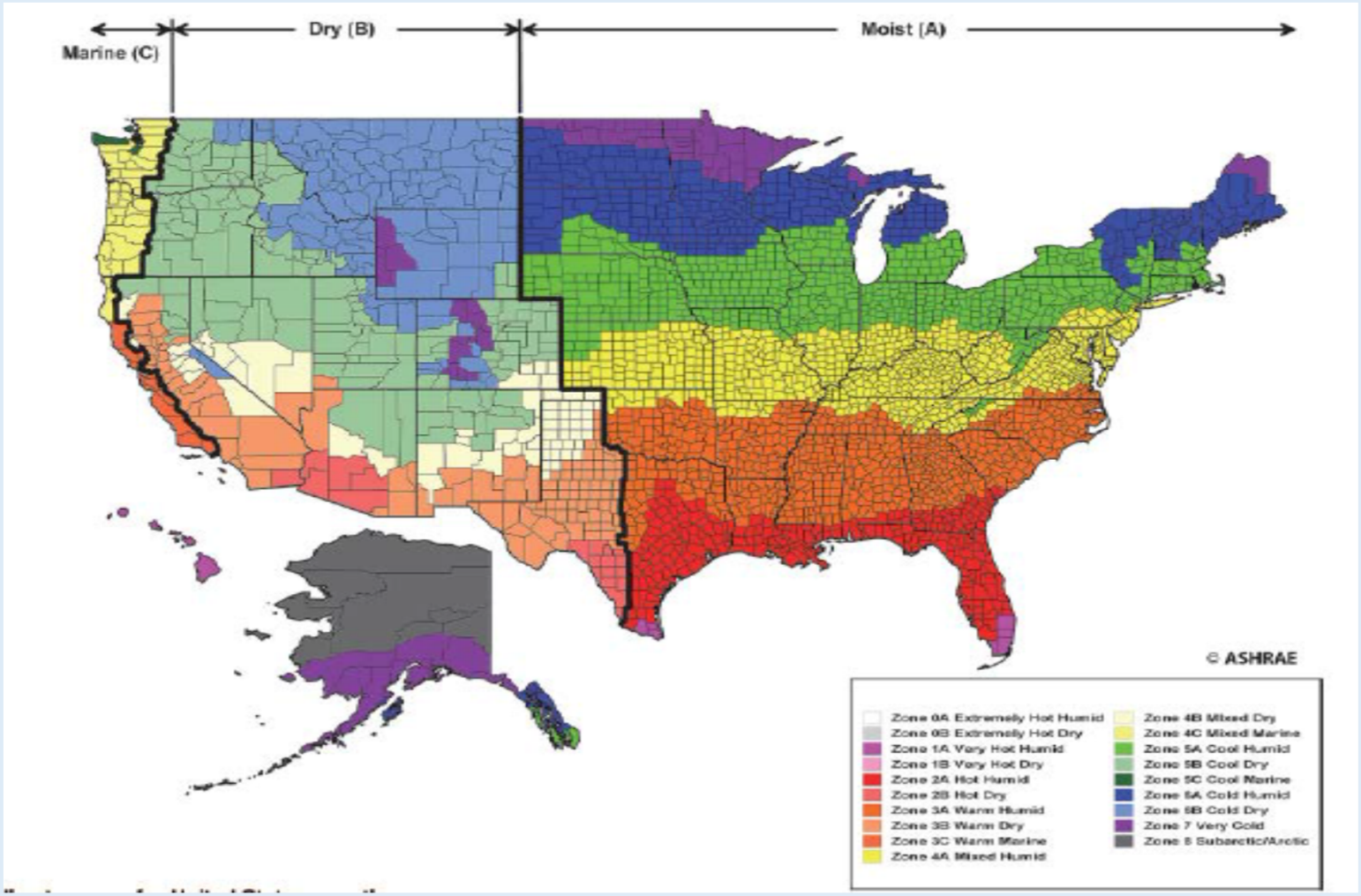
Columbus – Long Term Averages



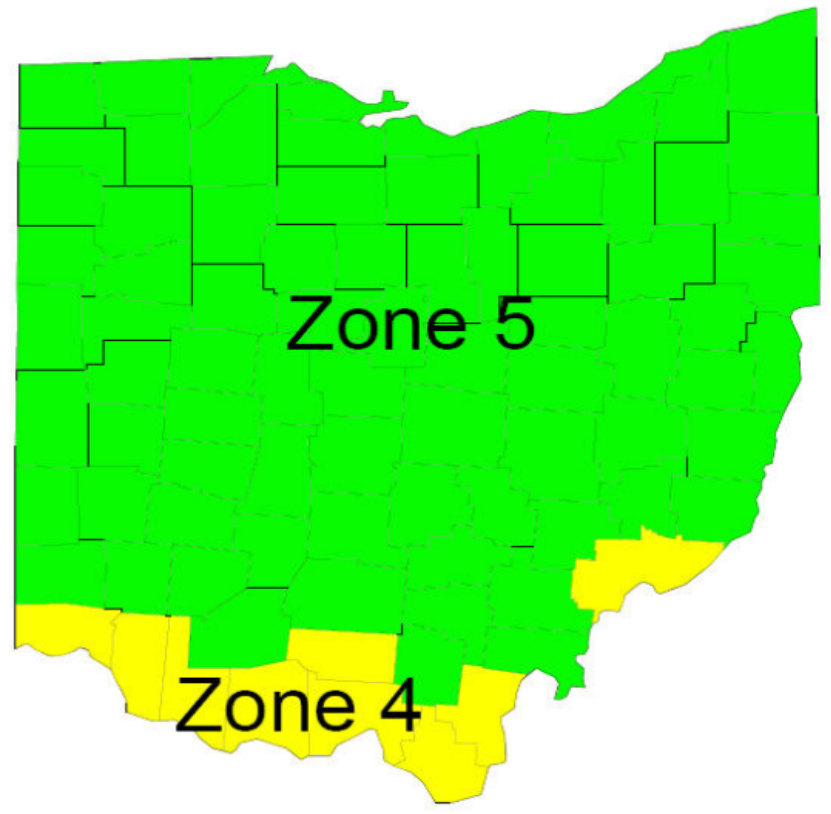
Current Climate Zone Map

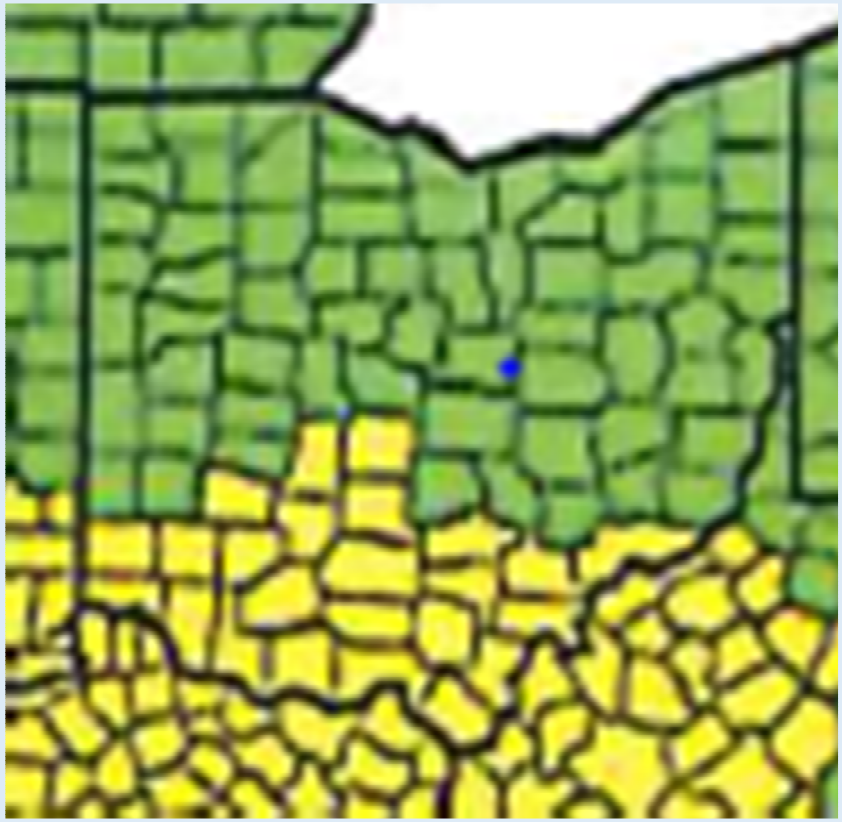


New Climate Zone Map

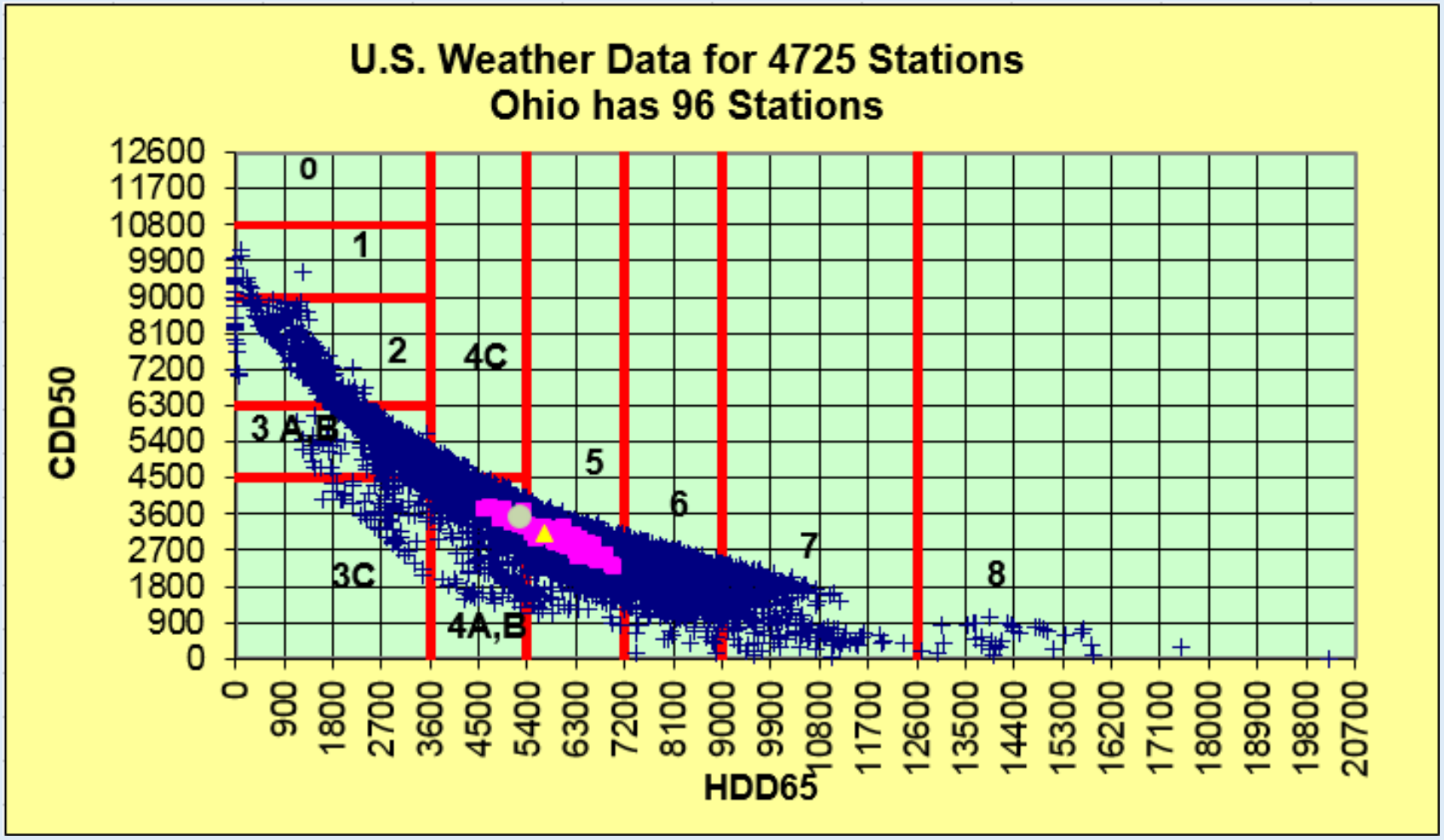


Current (9) vs New (24) Climate Zones

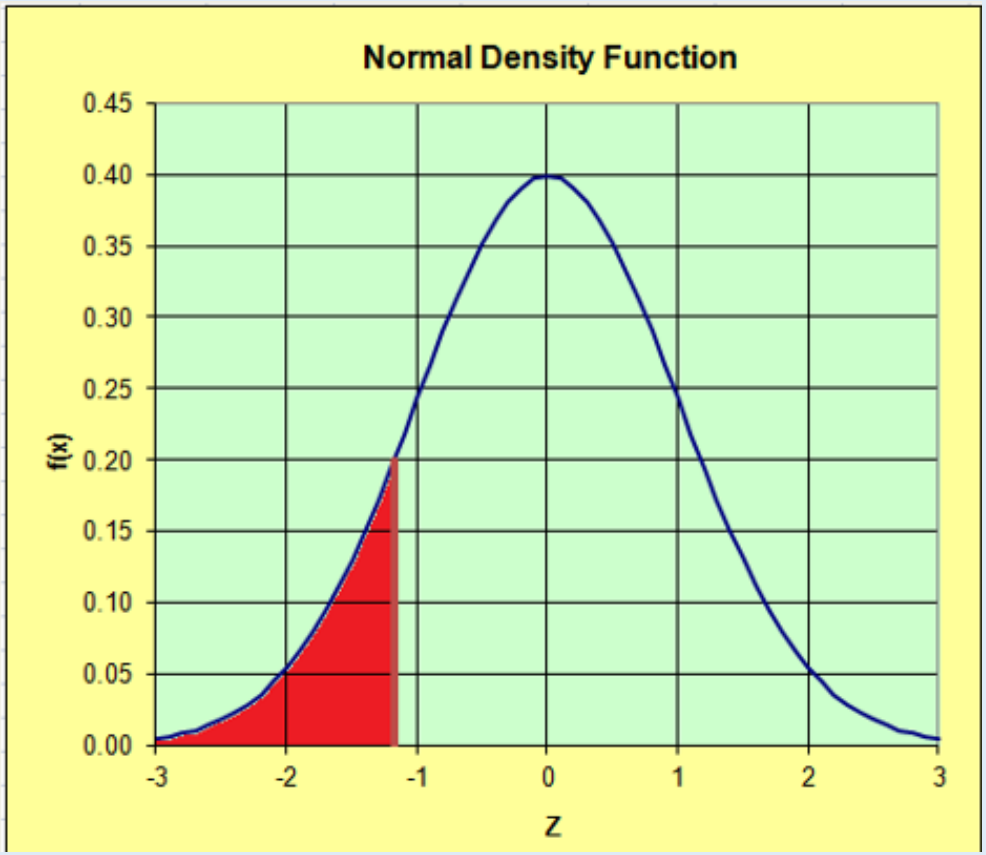




ASHRAE Std. 169-2013 Climate Zones

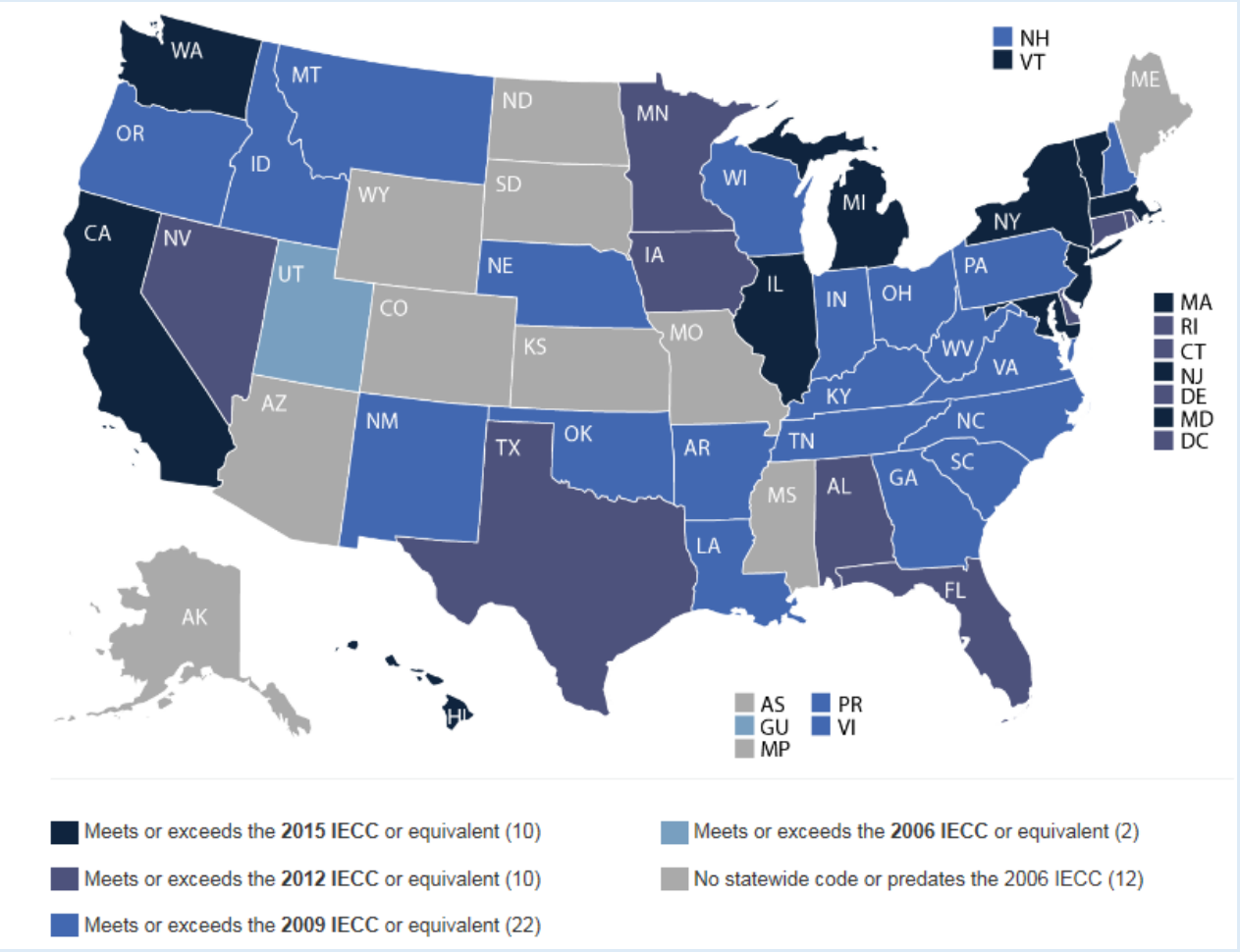


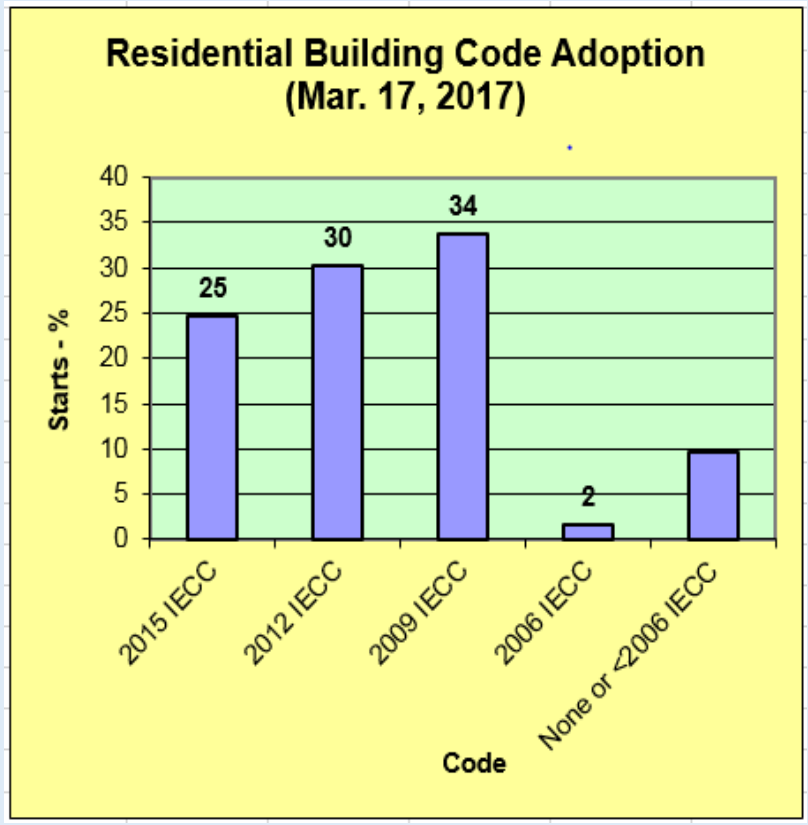
ASHRAE Std. 90-1975
(Eliminate lowest 20%)



BCAP – Residential

(Ohio Adopted IECC 2012 on 9/30/16, Effective 1/1/2017)





Thermal Resistance – R-value (hr-ft2-oF/Btu)

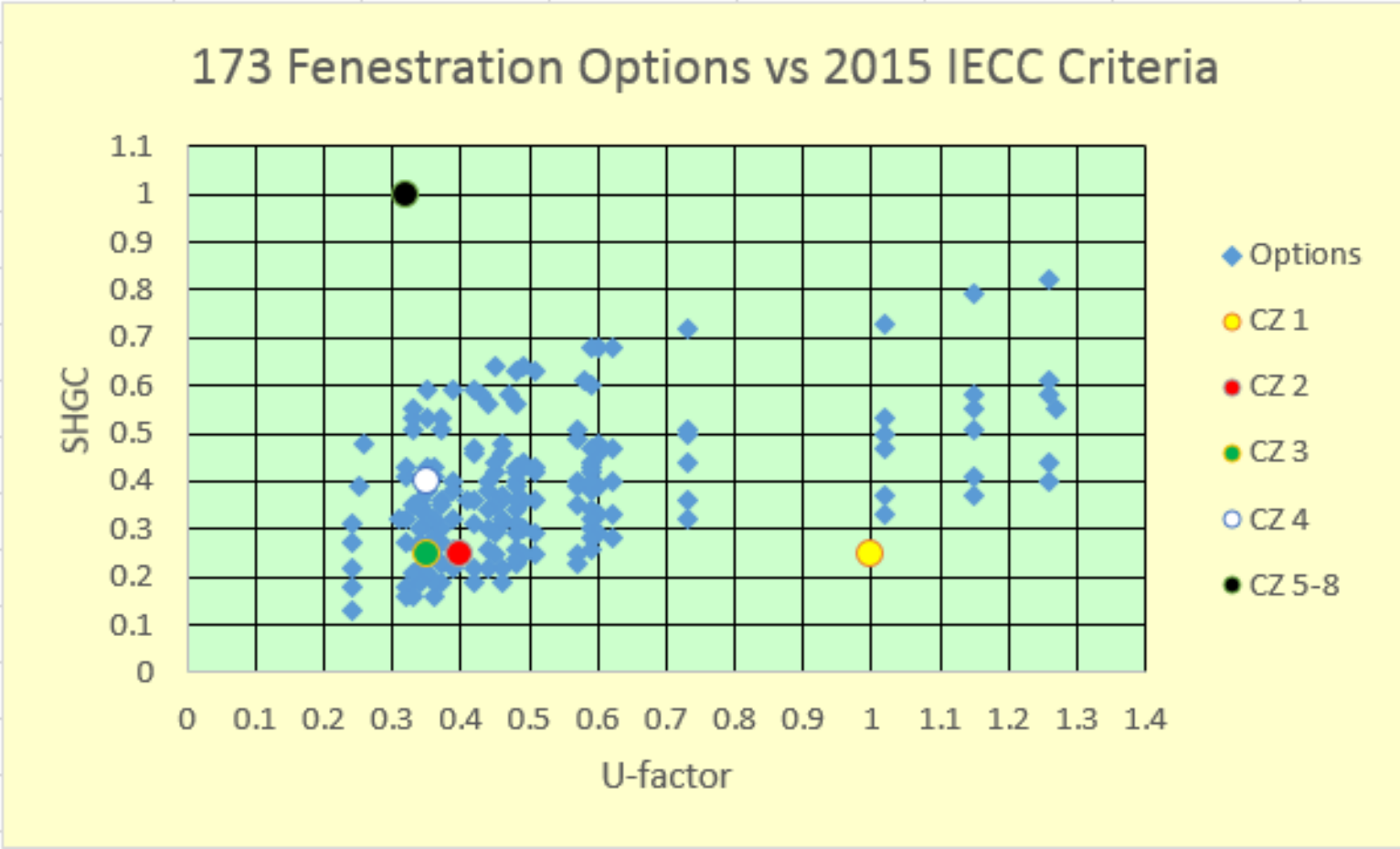
Material	R-value	Material	R-value
• Single Glass Pane	0.11	• Double Pane Window	3.0
• Asphalt Shingles	0.44	• 2x4 Wood Stud	4.35
• ½ inch Drywall	0.45	• 1 inch XPS Board	5.00
• ½ inch OSB	0.61	• 2x6 Wood Stud	6.88
• Aluminum Siding	0.61	• 3.5 inches F/G	11, 13,15
• 8 inch CMU	1.0	• 6.0 inches F/G	19, 21
• Carpet & Pad	2.08	• 12.0 inches F/G	38

IECC 2015 Residential Criteria

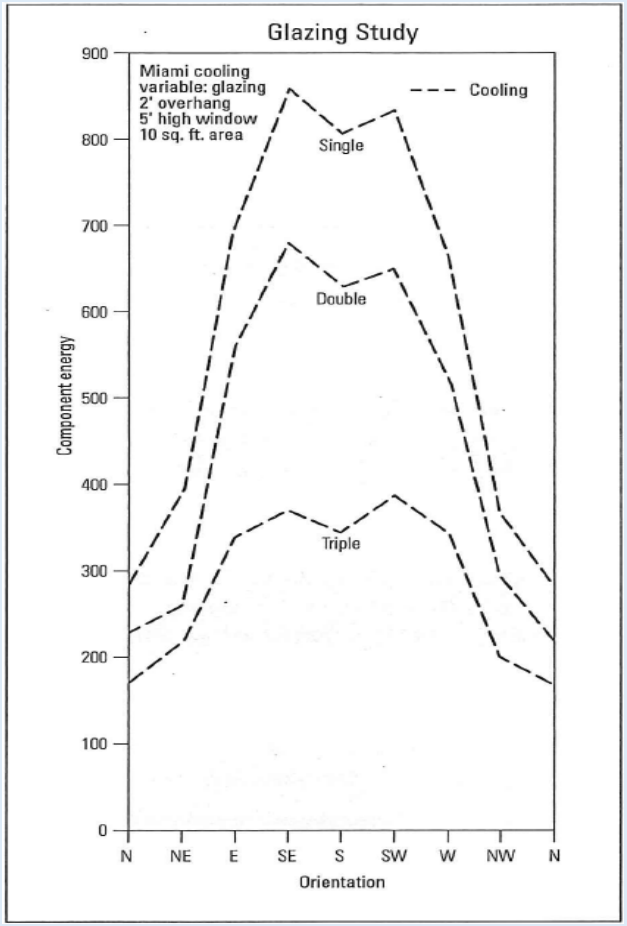
TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

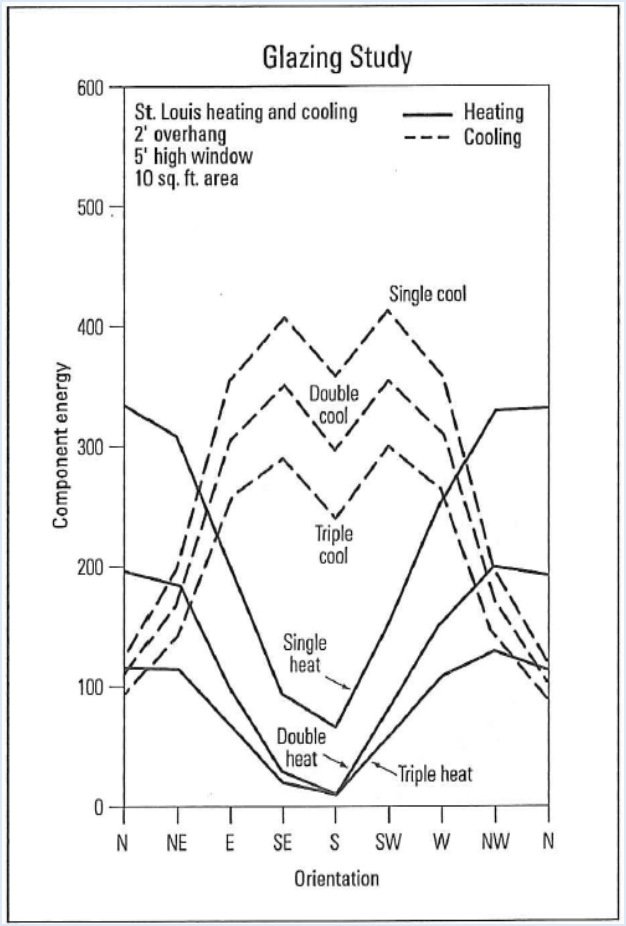
CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

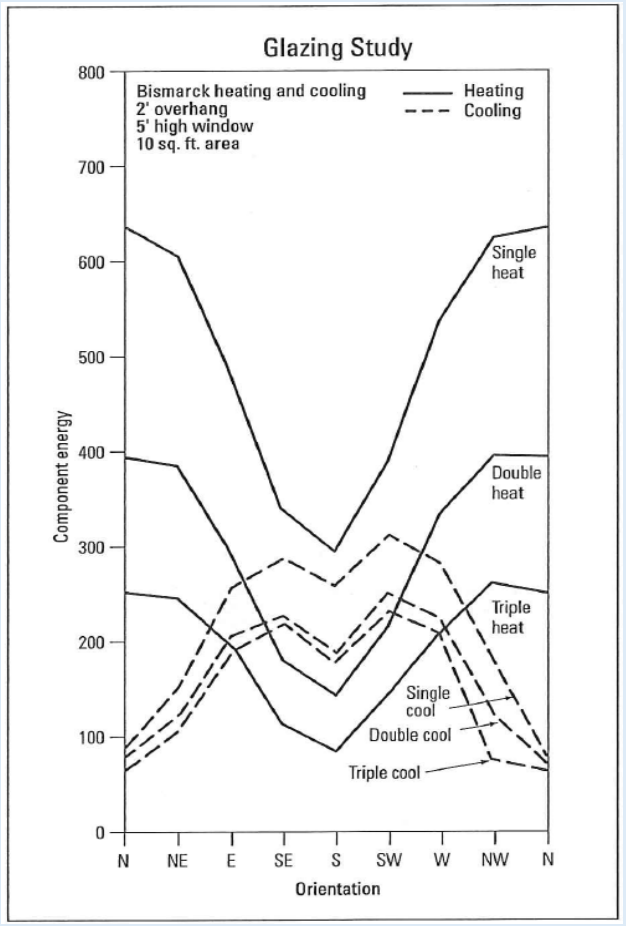
Fenestration



Fenestration Study

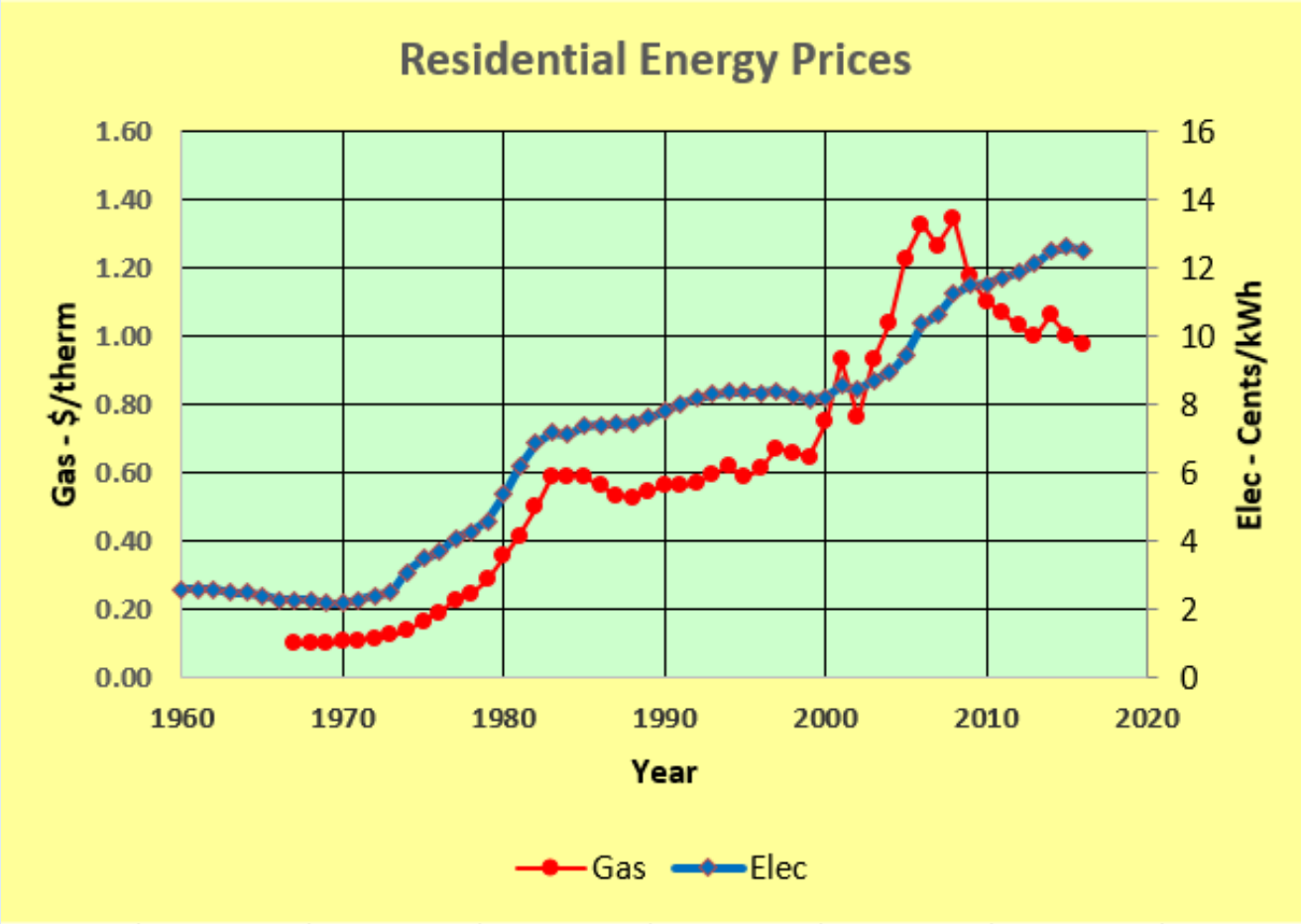






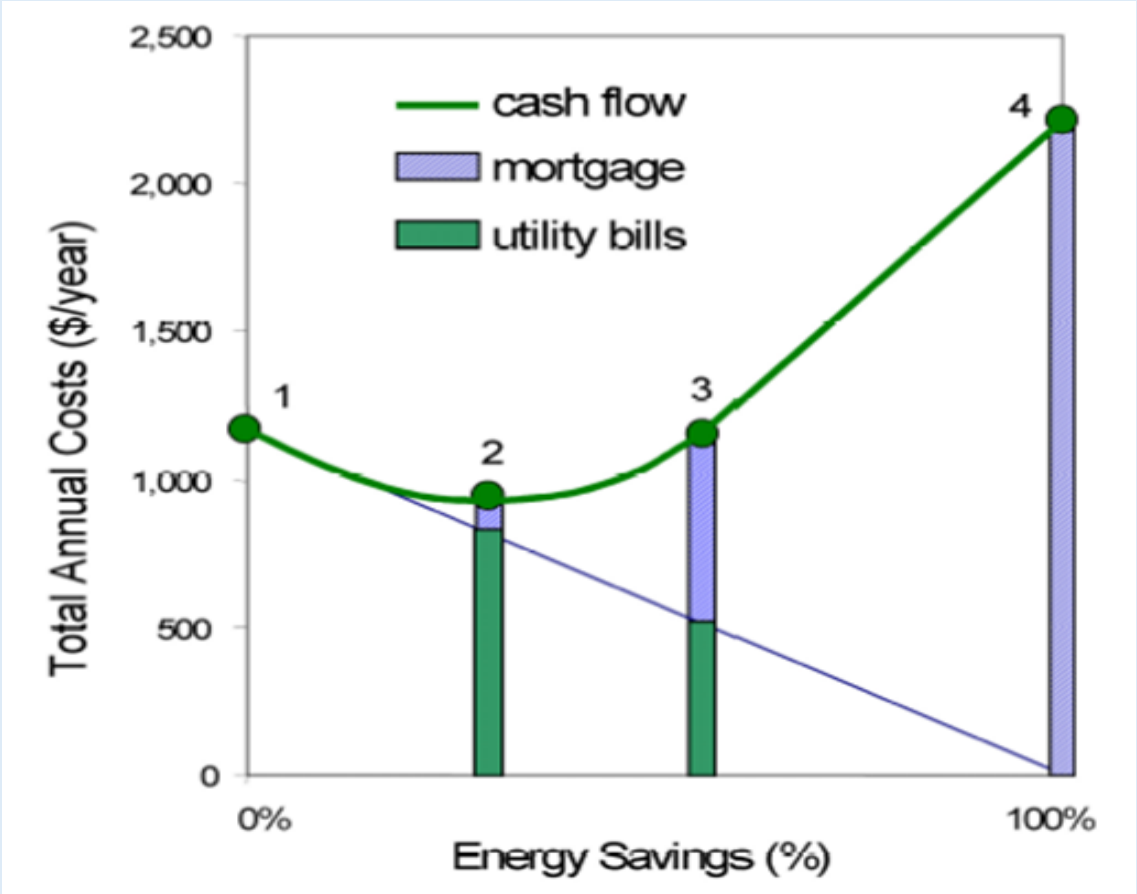
Economics

Fuel Prices

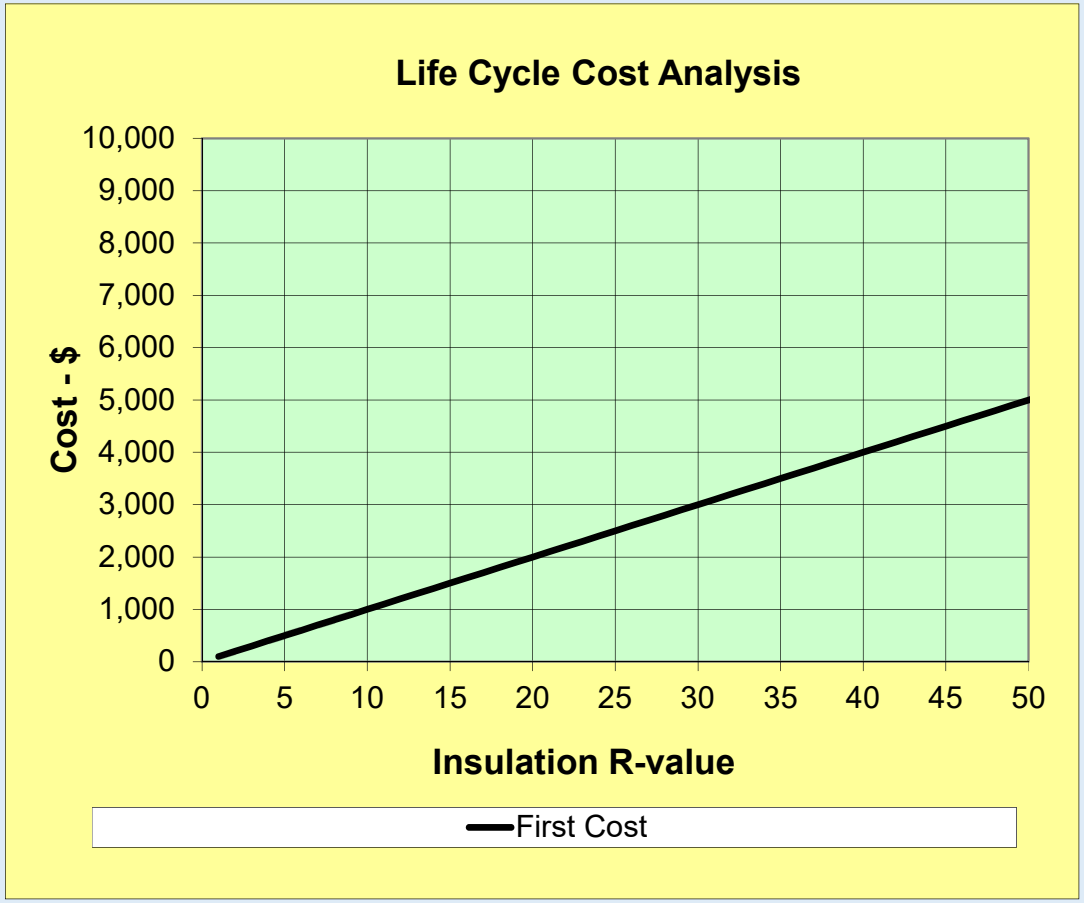


Economics

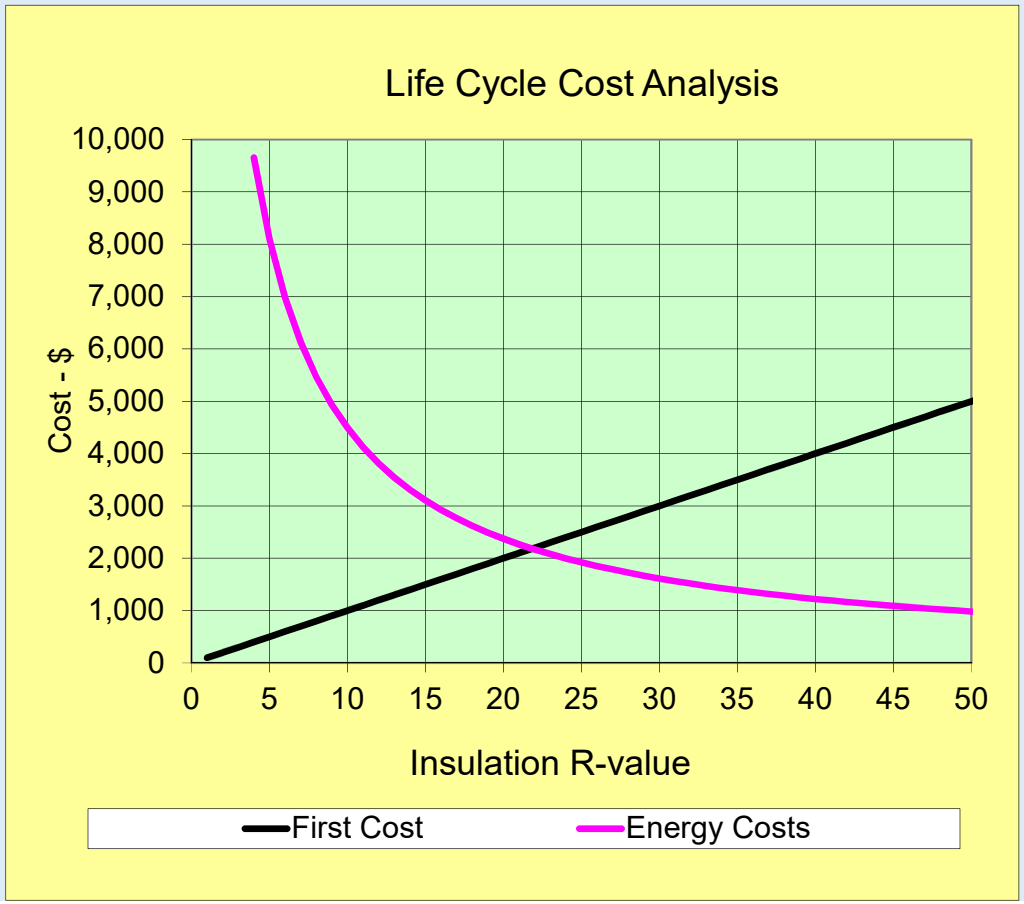
Characteristic Cost Curve



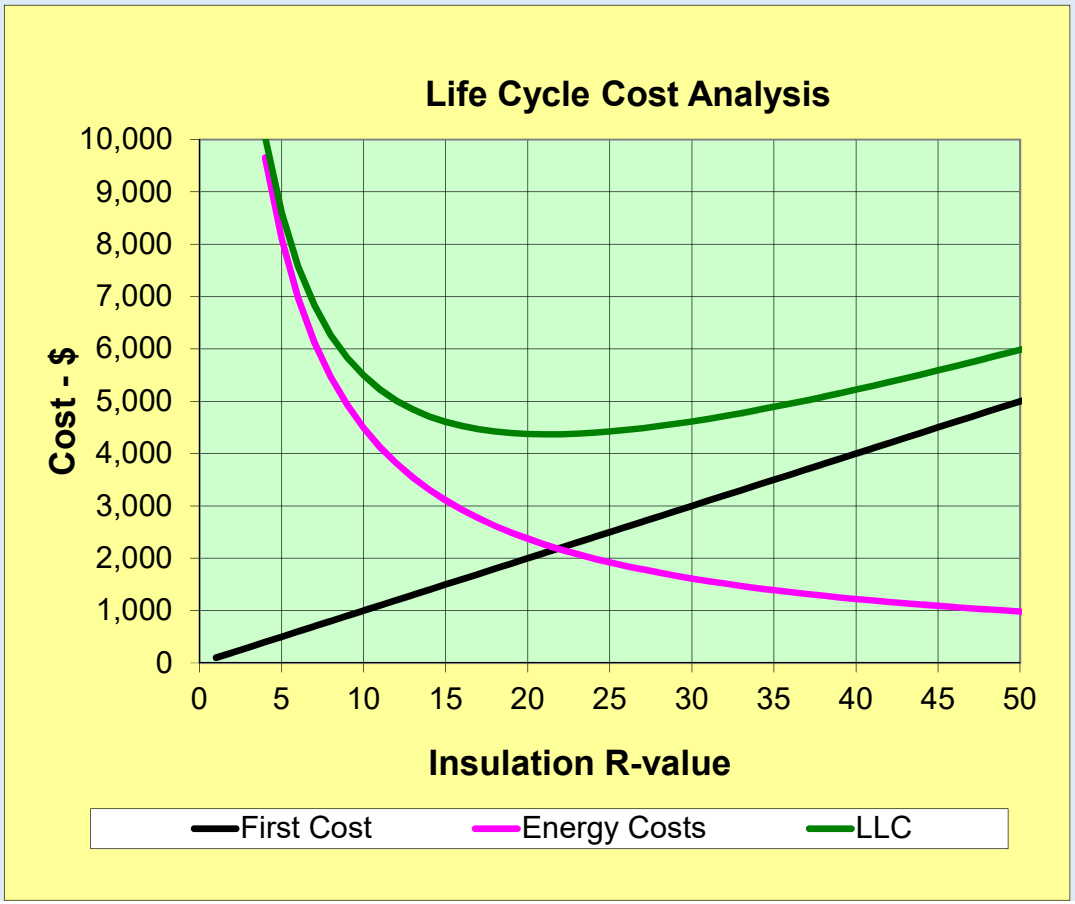
Life-Cycle Cost Analysis – First Costs



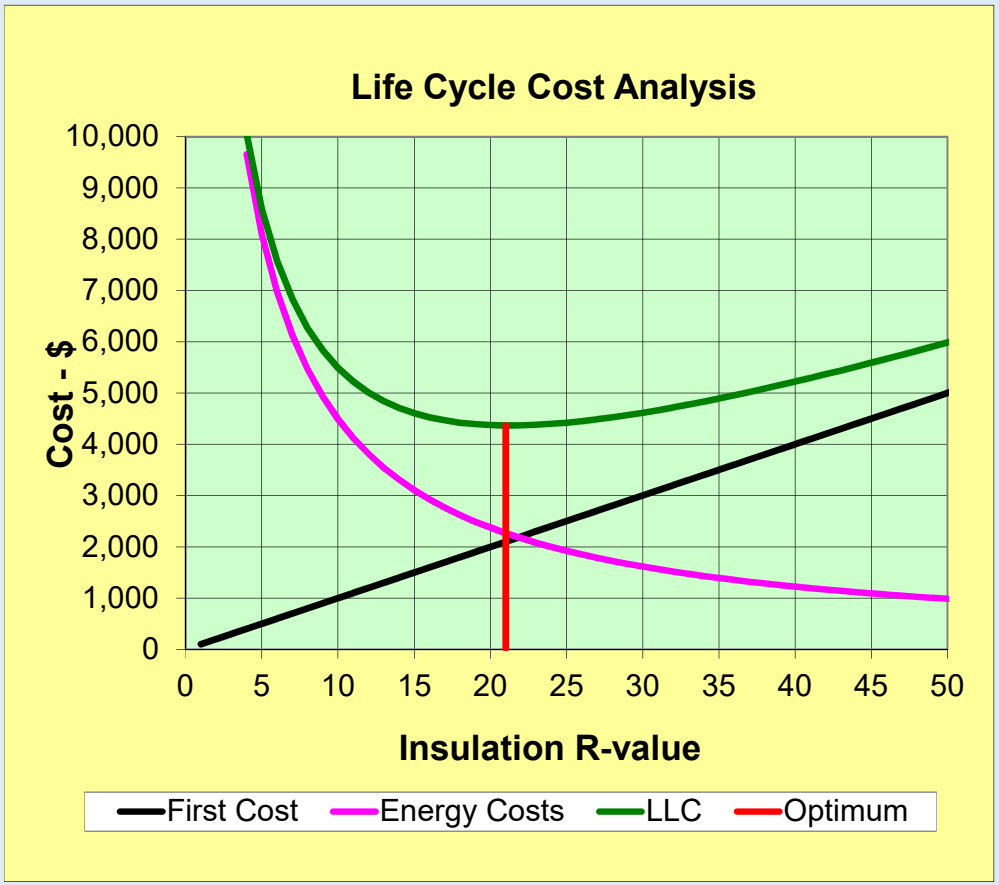
Life-Cycle Cost Analysis – Energy Costs



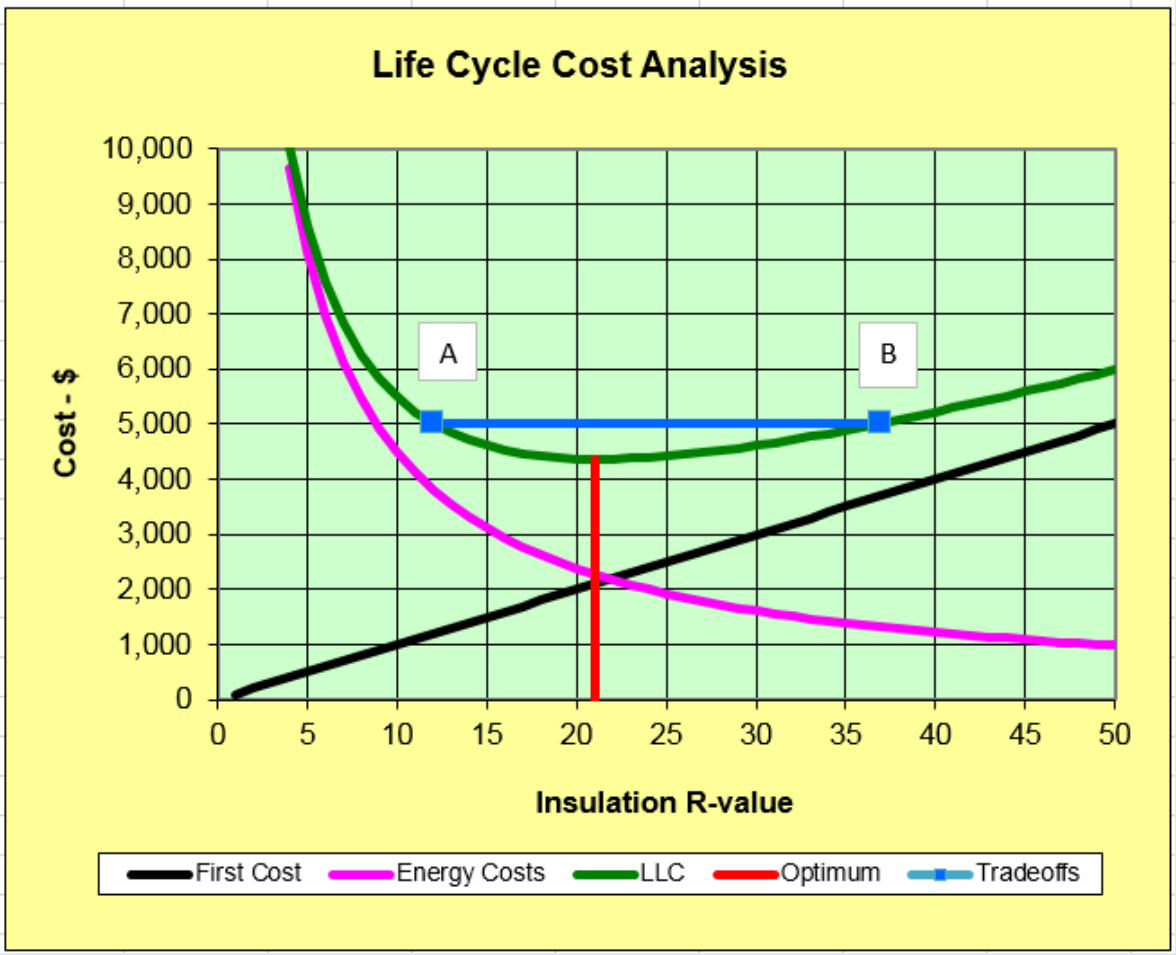
Life-Cycle Cost Analysis – Total Costs



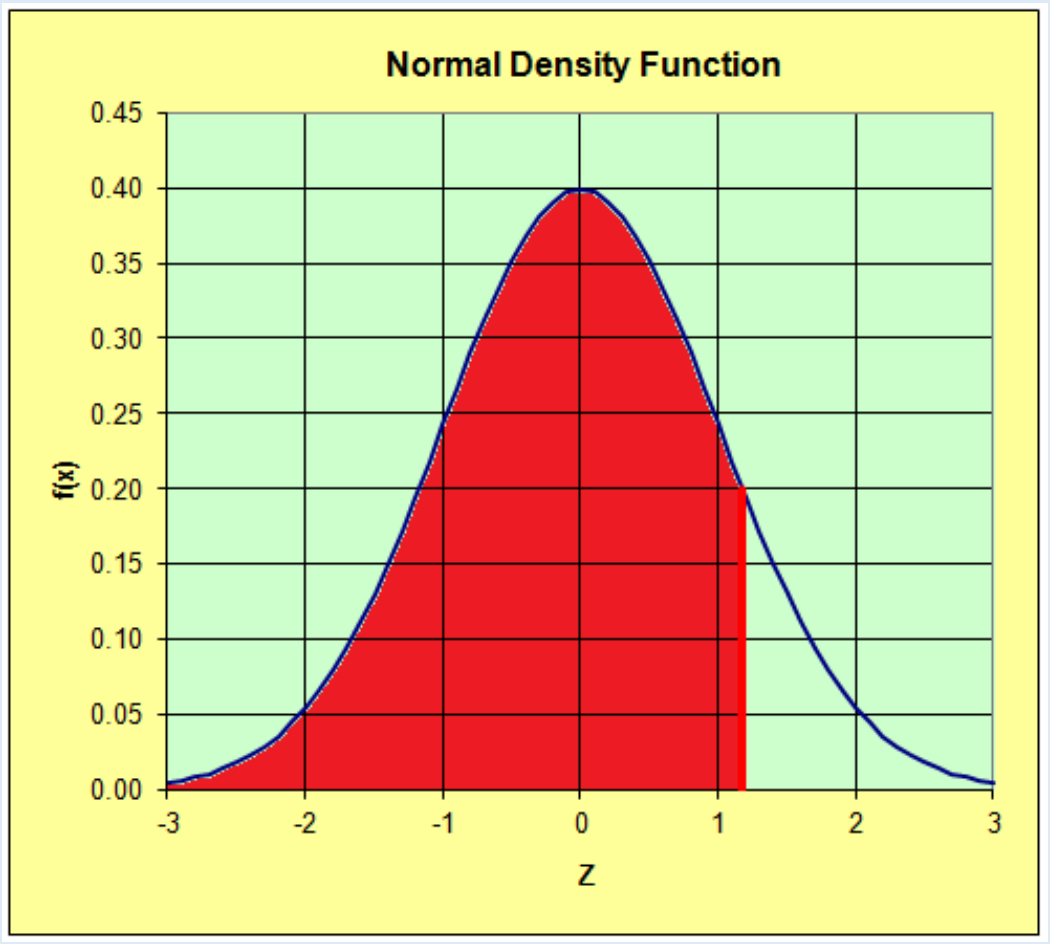
Life-Cycle Cost Analysis - Optimum



Life-Cycle Cost Analysis - Options



Eliminate Lowest 80%



Environmental Goals

AIA 2030 Challenge

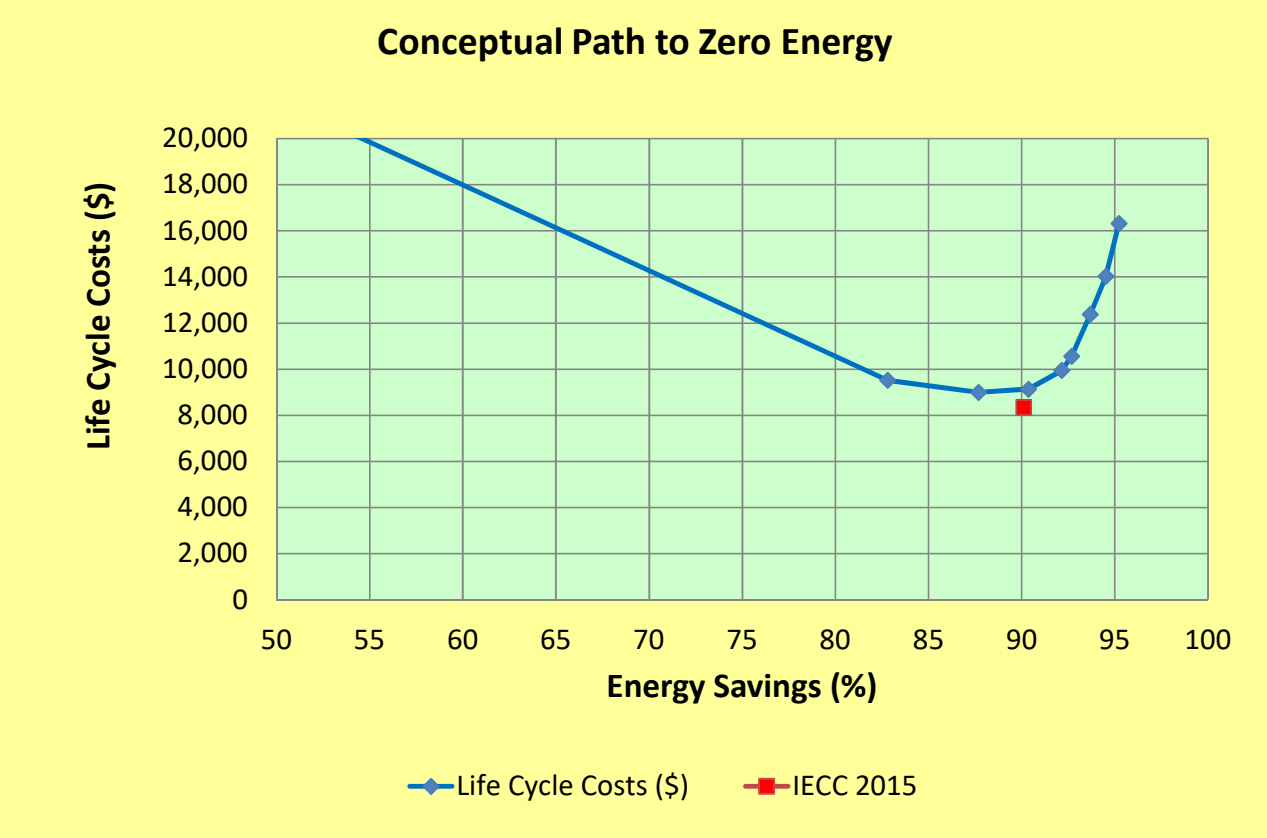
- Edward Mazria, FAIA, Hon. FRAIC
  Founder and CEO

- “Net Zero Energy Buildings by 2030”

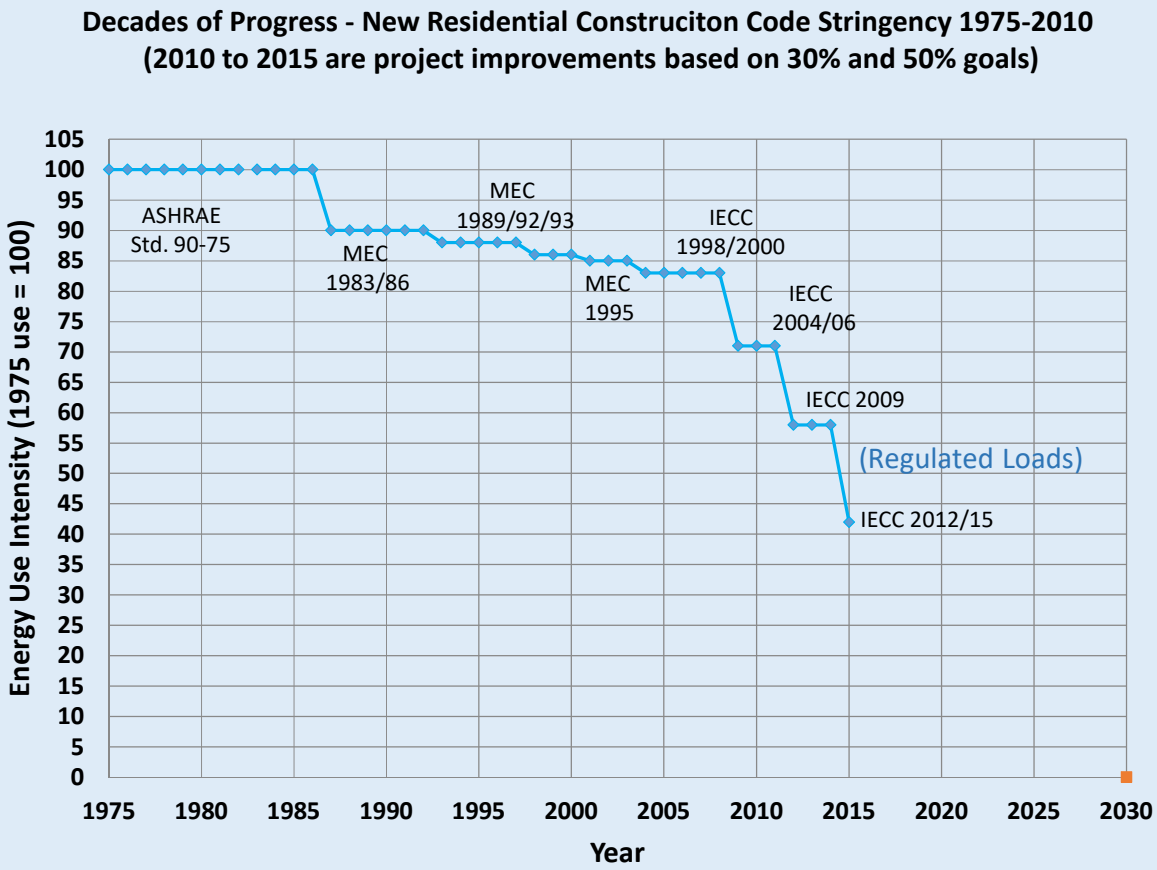
Alignment on 2030 Goal

- ASHRAE
- AIA
- USGBC
- U.S. Conference of Mayors
- State of Florida

Net Zero Energy

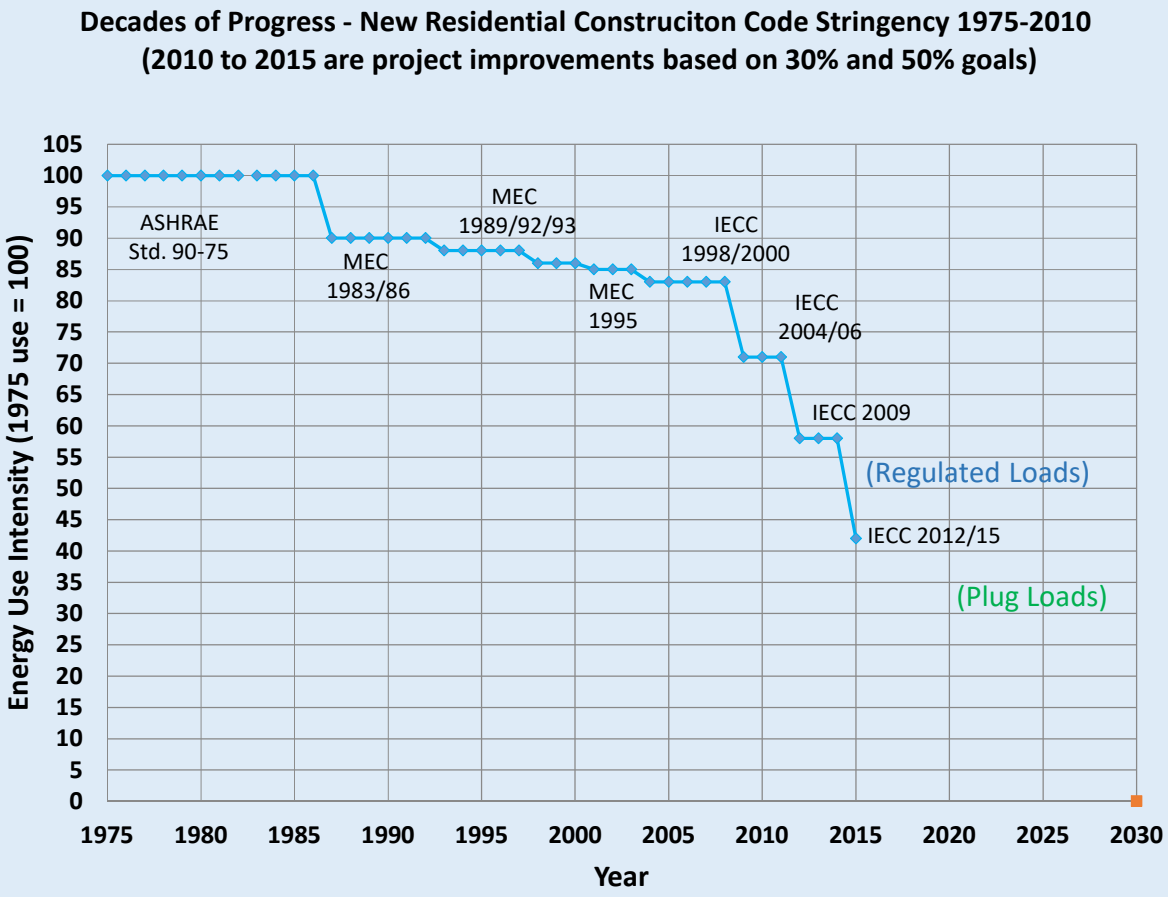


Energy Savings



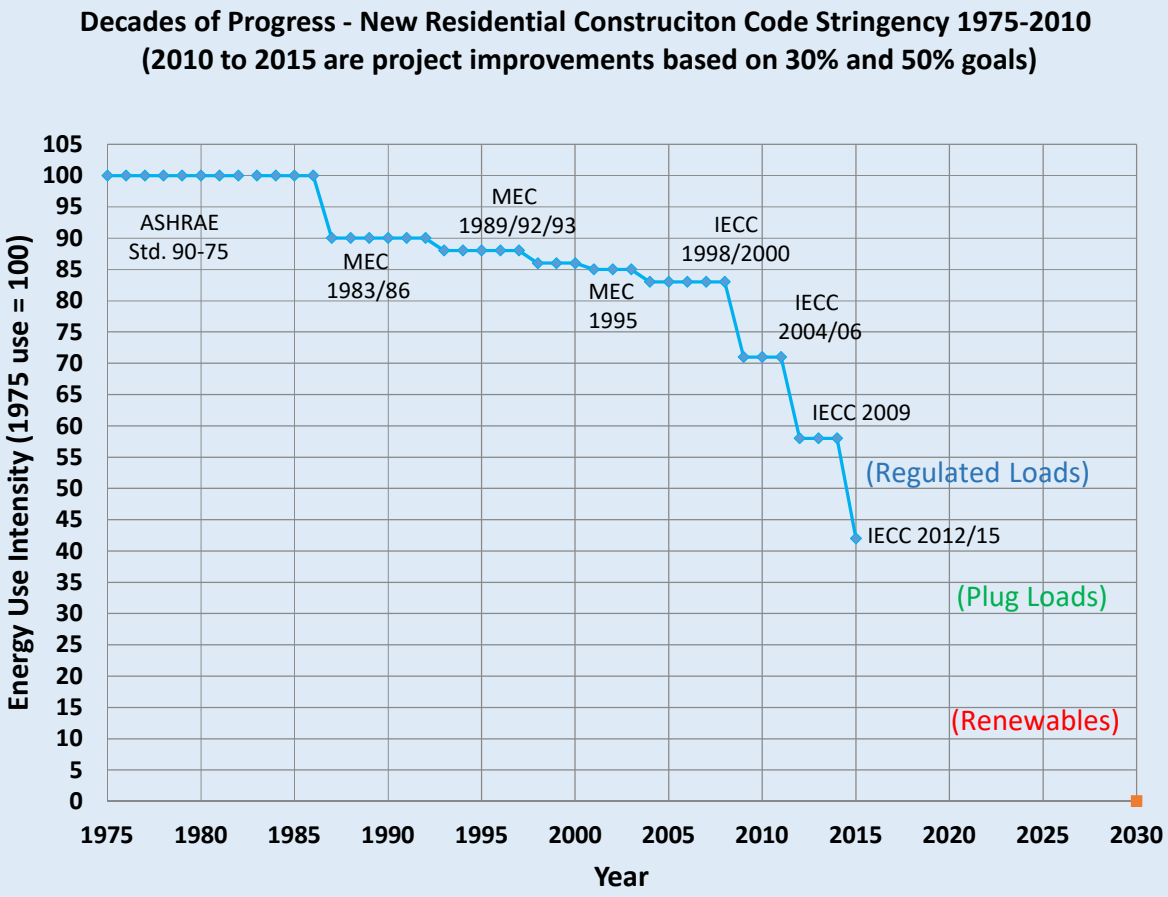
- Regulated Loads: Envelope, Air Infiltration, Lighting, HVAC, SWH

Energy Savings



- Regulated Loads: Envelope, Air Infiltration, Lighting, HVAC, SWH
- Plug Loads: Refrigerator, Oven, Microwave, Toaster, Coffee Maker, Washer, Dryer, Iron, Sweeper, Stereo, Radio, TV, Computer, Printer, Clocks

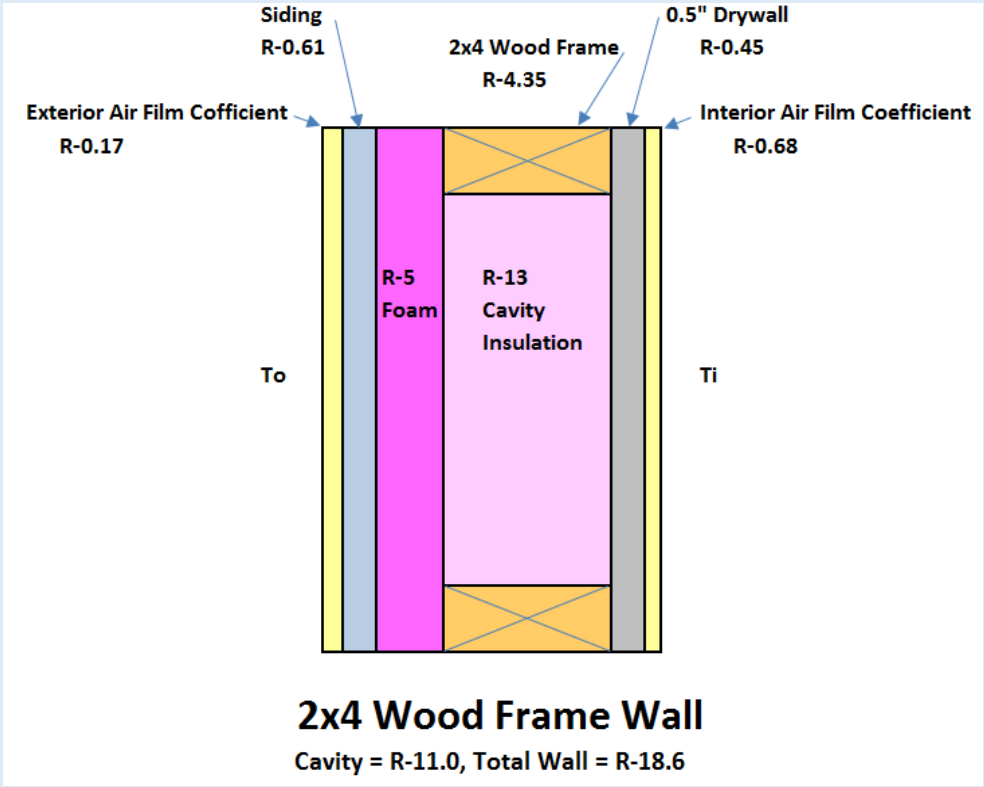
Energy Savings



- Regulated Loads: Envelope, Air Infiltration, Lighting, HVAC, SWH
- Plug Loads: Refrigerator, Oven, Microwave, Toaster, Coffee Maker, Washer, Dryer, Iron, Sweeper, Stereo, Radio, TV, Computer, Printer, Clocks
- Renewables: Photovoltaics, Wind, Passive Solar

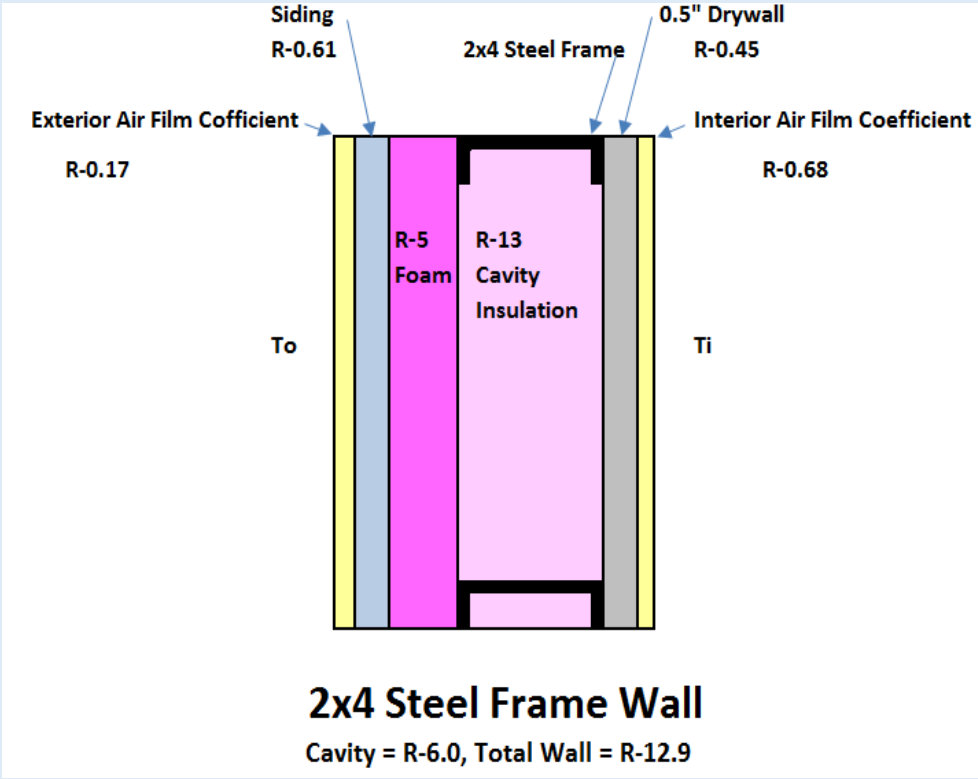
Thermal Bridges

“a low thermal resistance path connecting two surfaces”



2x4 Wood Frame Wall

Cavity = R-11.0, Total Wall = R-18.6

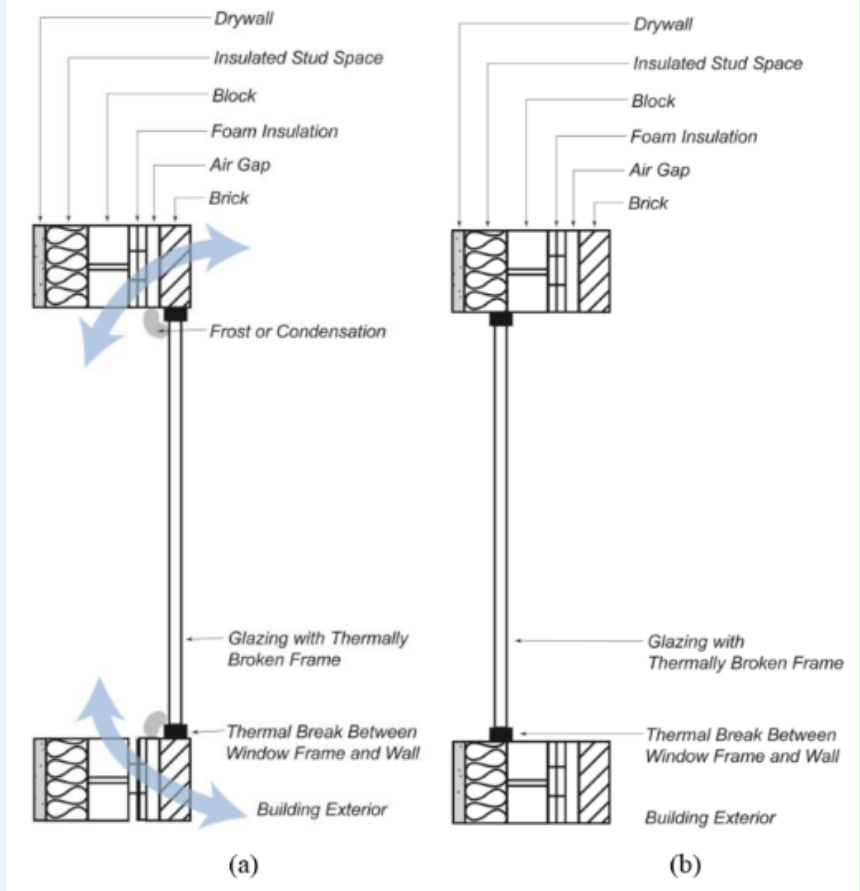


2x4 Steel Frame Wall

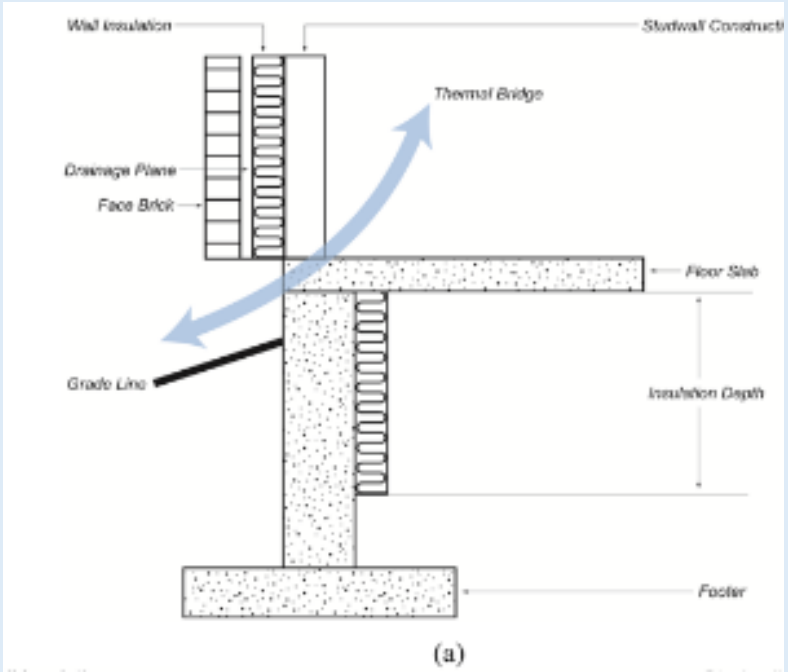
Cavity = R-6.0, Total Wall = R-12.9

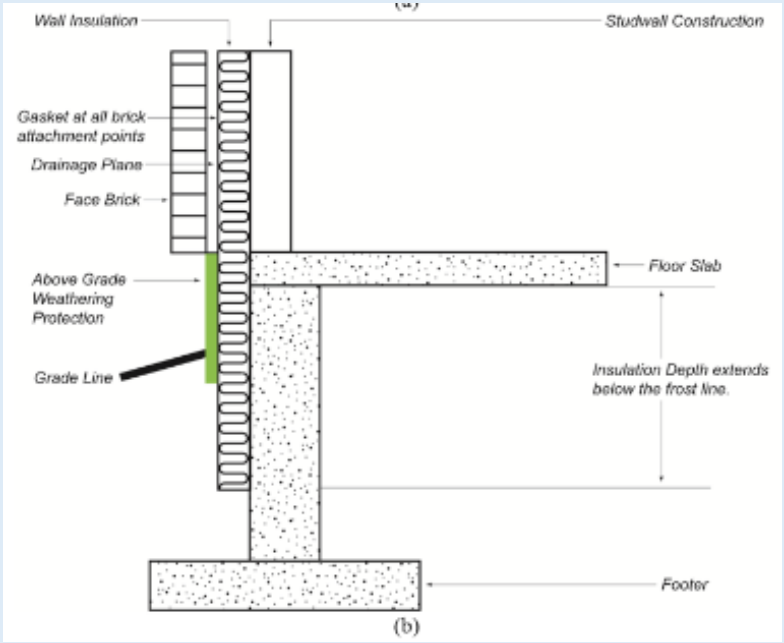
Thermal Bridges

Fenestration Thermal Bridge

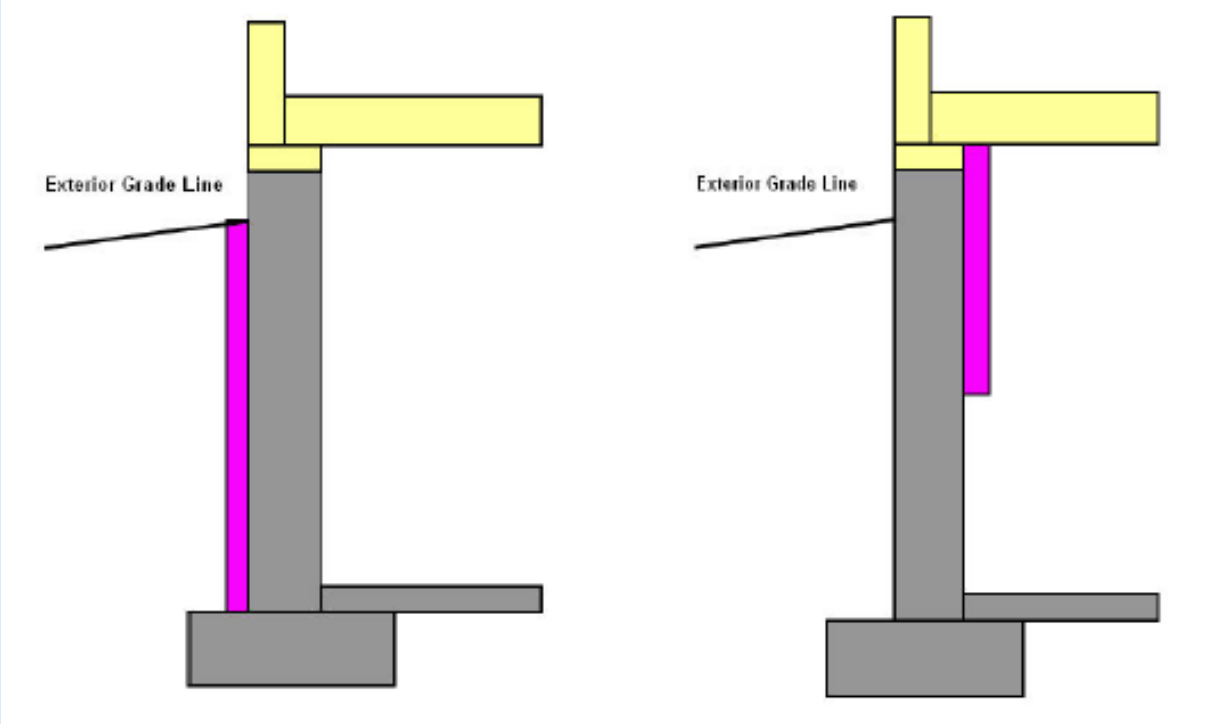


Slab Thermal Bridge





Basement Walls

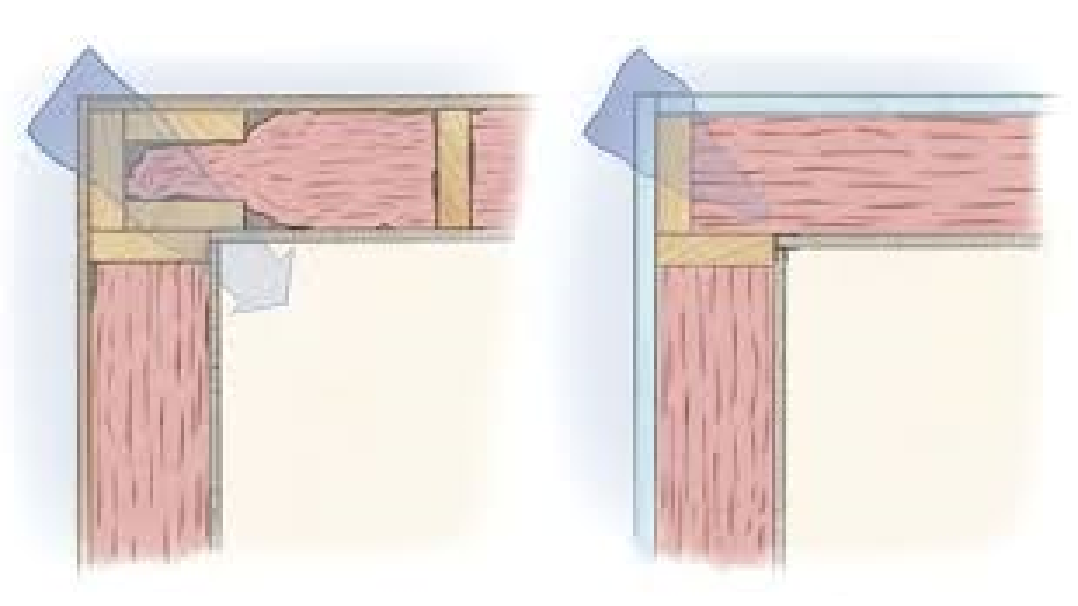


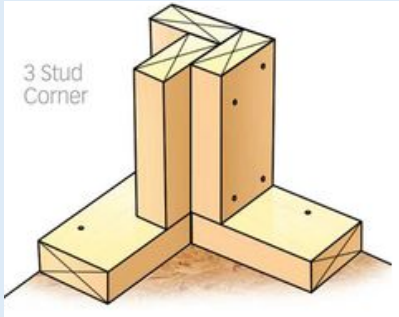
Window Framing Details

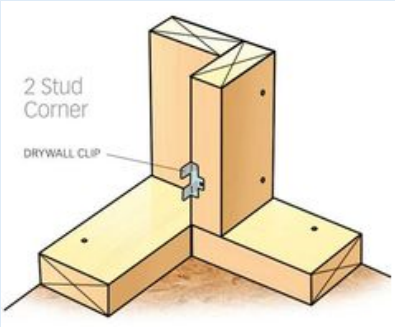
Window and Door Framing

Wood Framing Details

Wood Framing Corner Details







Wood Framing Corner Details





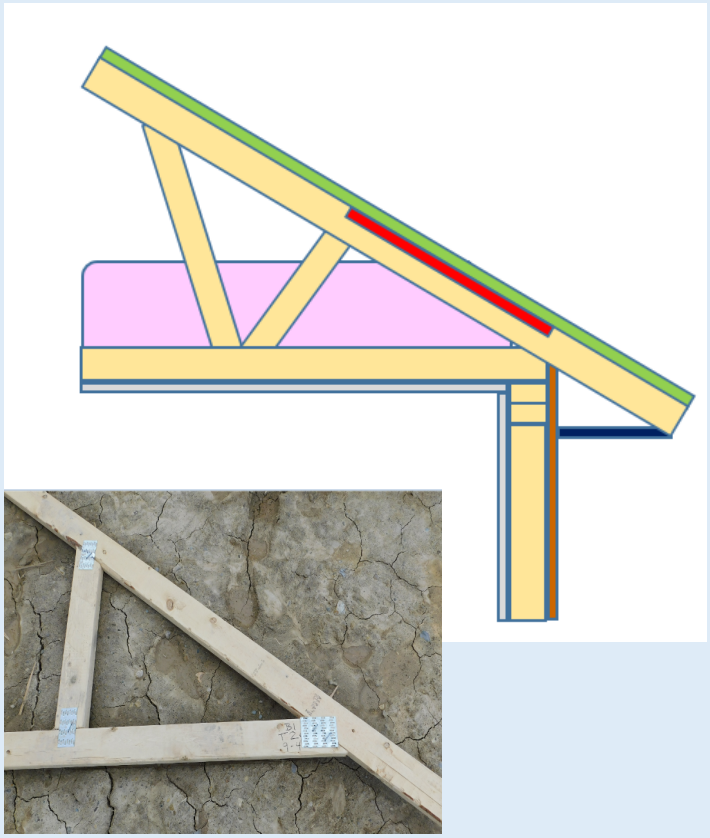


Wood Framing Details

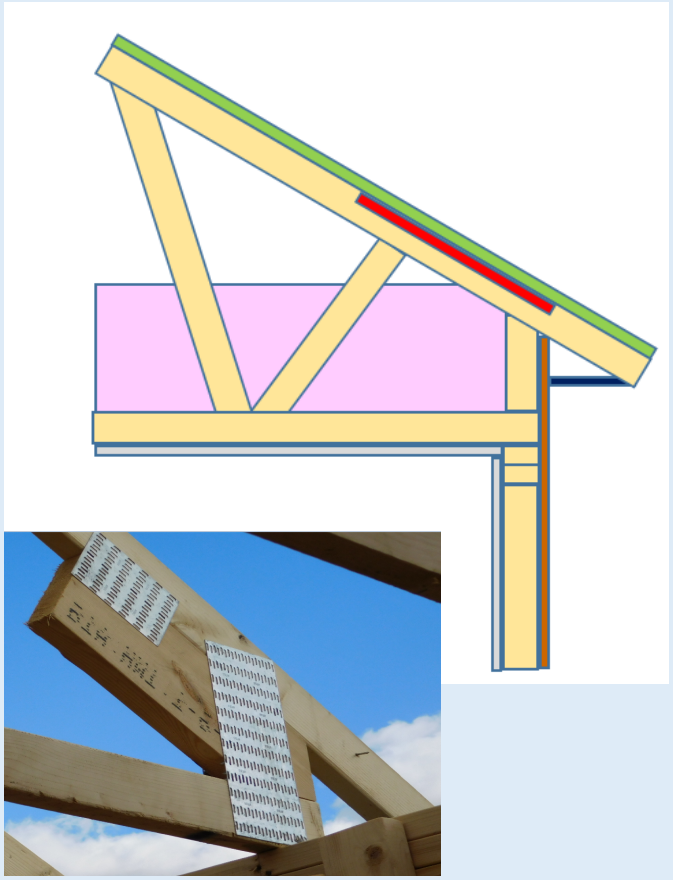
Steel Framing

Eave Details

- Standard Truss



- Raised Heel



Foam Board Sheathing

One Inch Foam Board

R-5 XPS

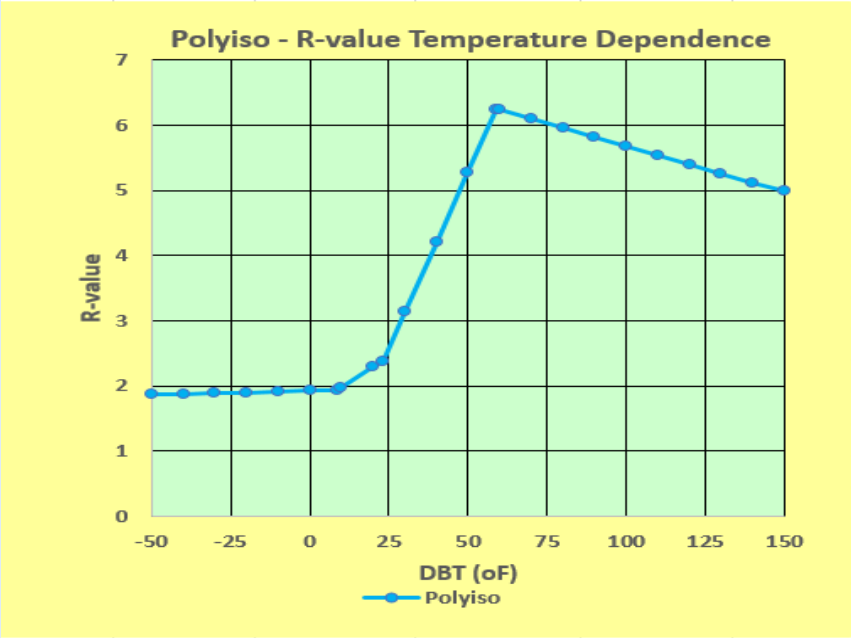
R-6 Polyiso

Foam Board Temperature Dependence

(FTC Rule 460 requires ratings at 75oF)

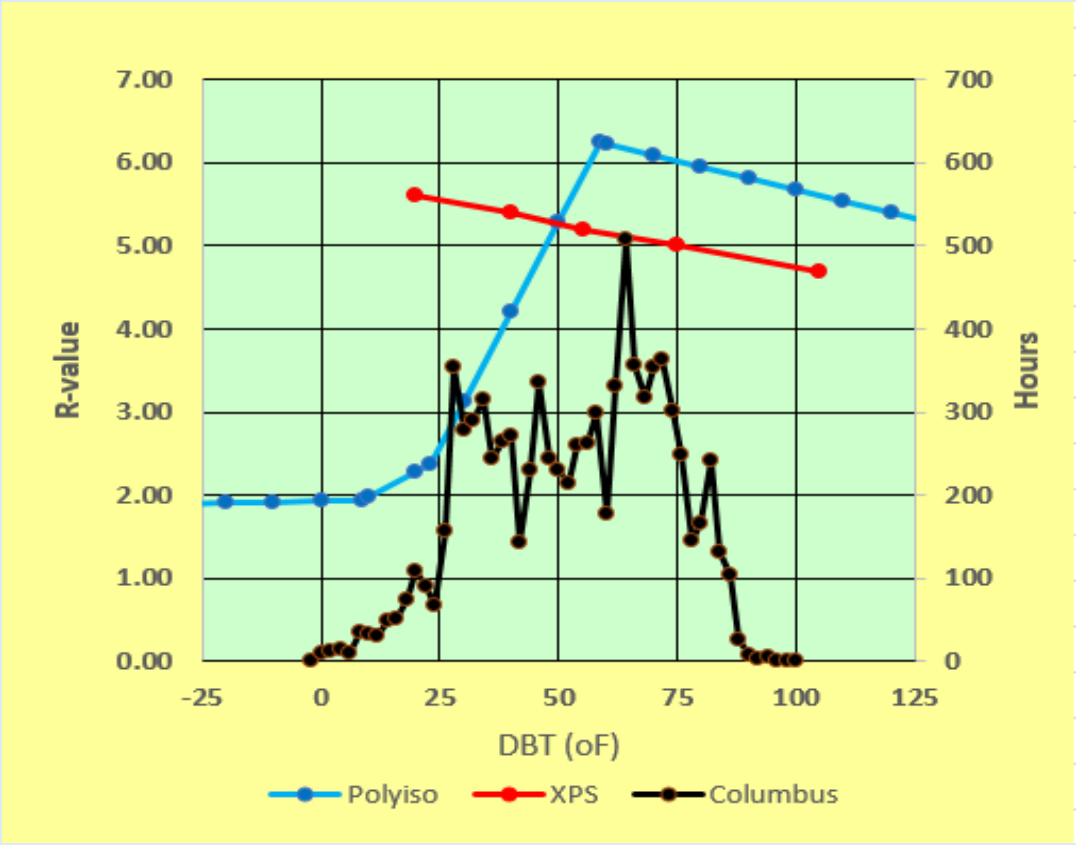
XPS

Polyiso



Foam Board Temperature Dependence

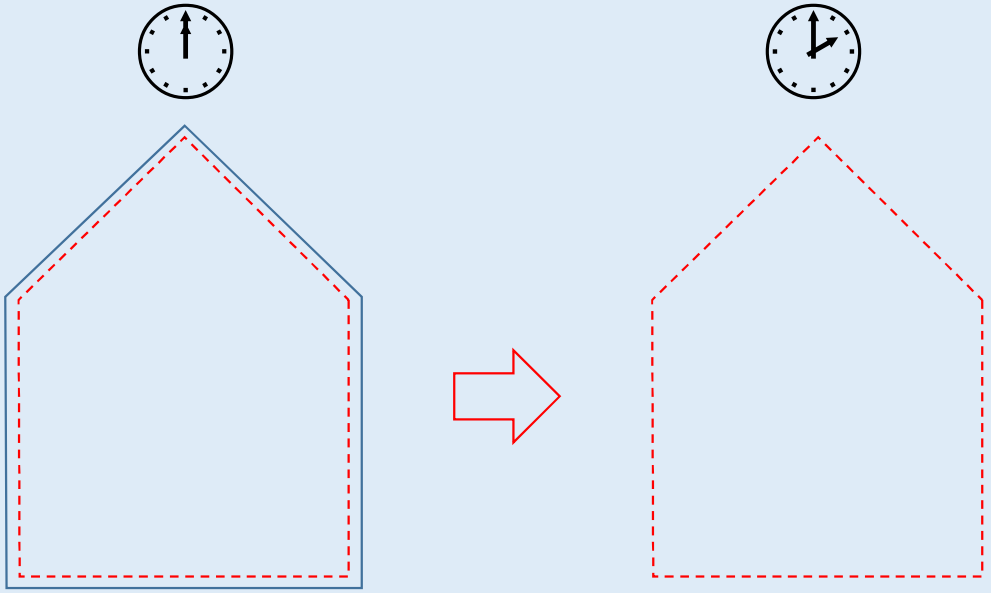
(FTC Rule 460 requires ratings at 75oF)



2 - Air Infiltration

The flow of air from one side of the envelope to the other due to pressure and openings.

How leaky is a typical house?



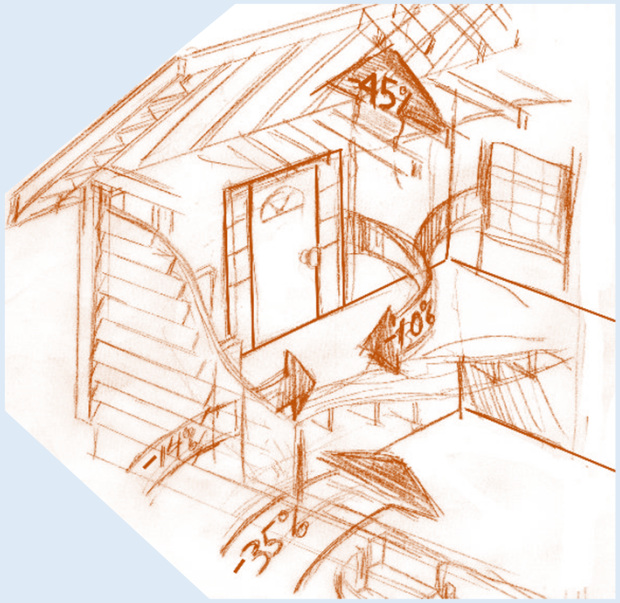
Leaky enough to exchange all of its volume with the outside <u>every two hours</u>.

Median air leakage of existing homes is 0.5 NACH.*Residential Energy*, Krigger & Dorsi.

What's the energy penalty?

- It depends on many factors …
  - Climate
  - Size of house
  - Baseline leakiness
  - And more

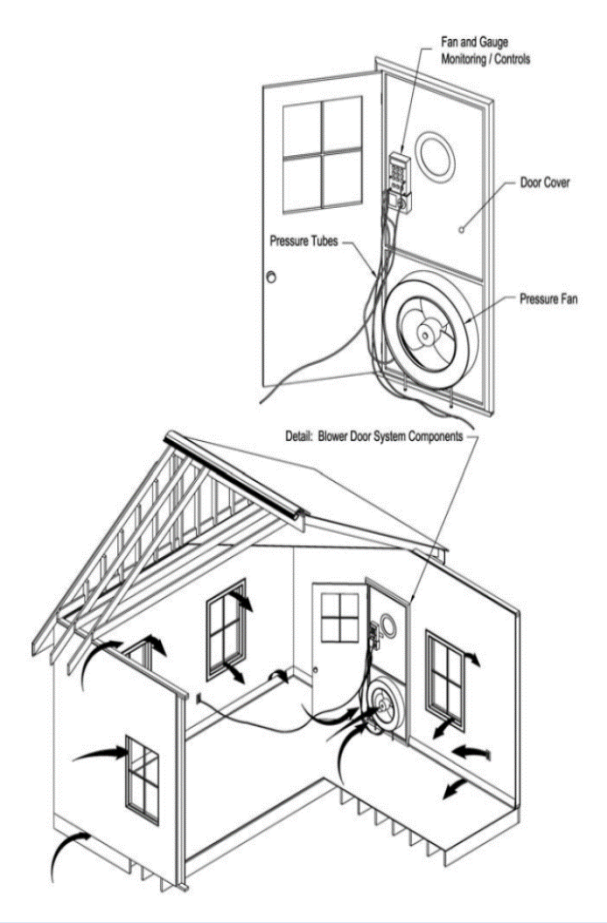
- In general, air leakage accounts for between 25% and 40% percent of the energy used for heating and cooling in a typical residence.[1]



[1]Building Envelope Improvement: Air Sealing, U.S. Environmental Protection Agency

Testing Requirements

- A blower door test can quantify the air leakage of a building.
- The newest model energy code (2015 IECC) requires blower door testing to demonstrate performance.
- CZ 3-8 requires 3ACH50

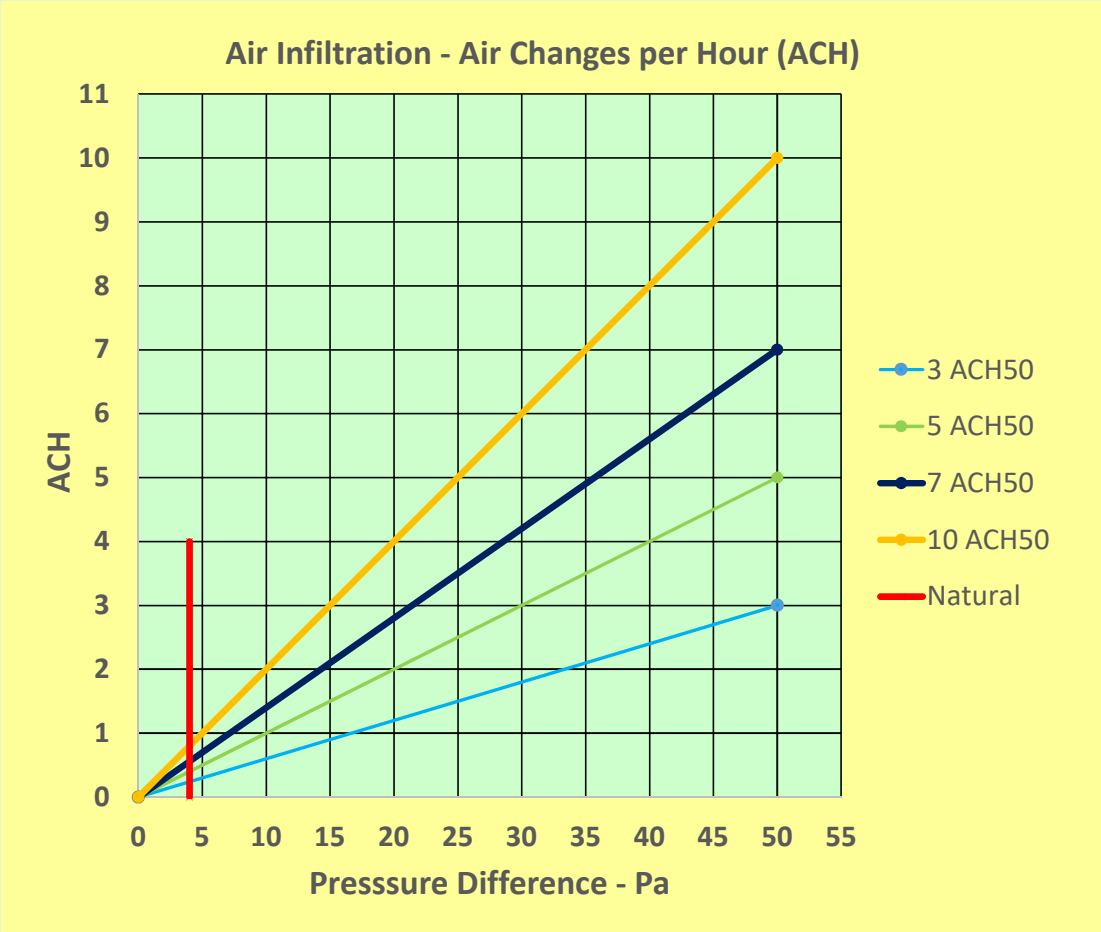


The Builder's Challenge

With nearly a mile of joints on a typical house that connect the inside to the outside …

… which ones are the most important to air seal?

Air Infiltration



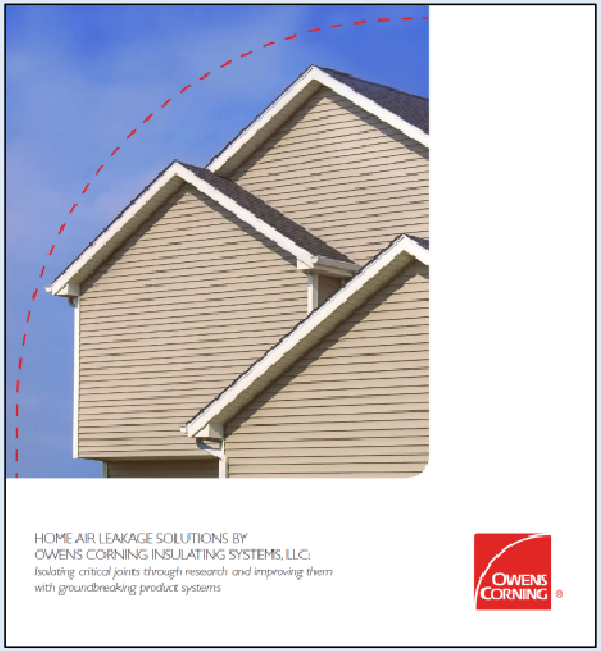
- 50 Pa ~ 20 mph
- 4 Pa ~ 4 mph

- 10ACH50 ~ 0.80 ACH Natural
- 7ACH50 ~ 0.56 ACH Natural
- 5ACH50 ~ 0.40 ACH Natural
- 3ACH50 ~ 0.24 ACH Natural

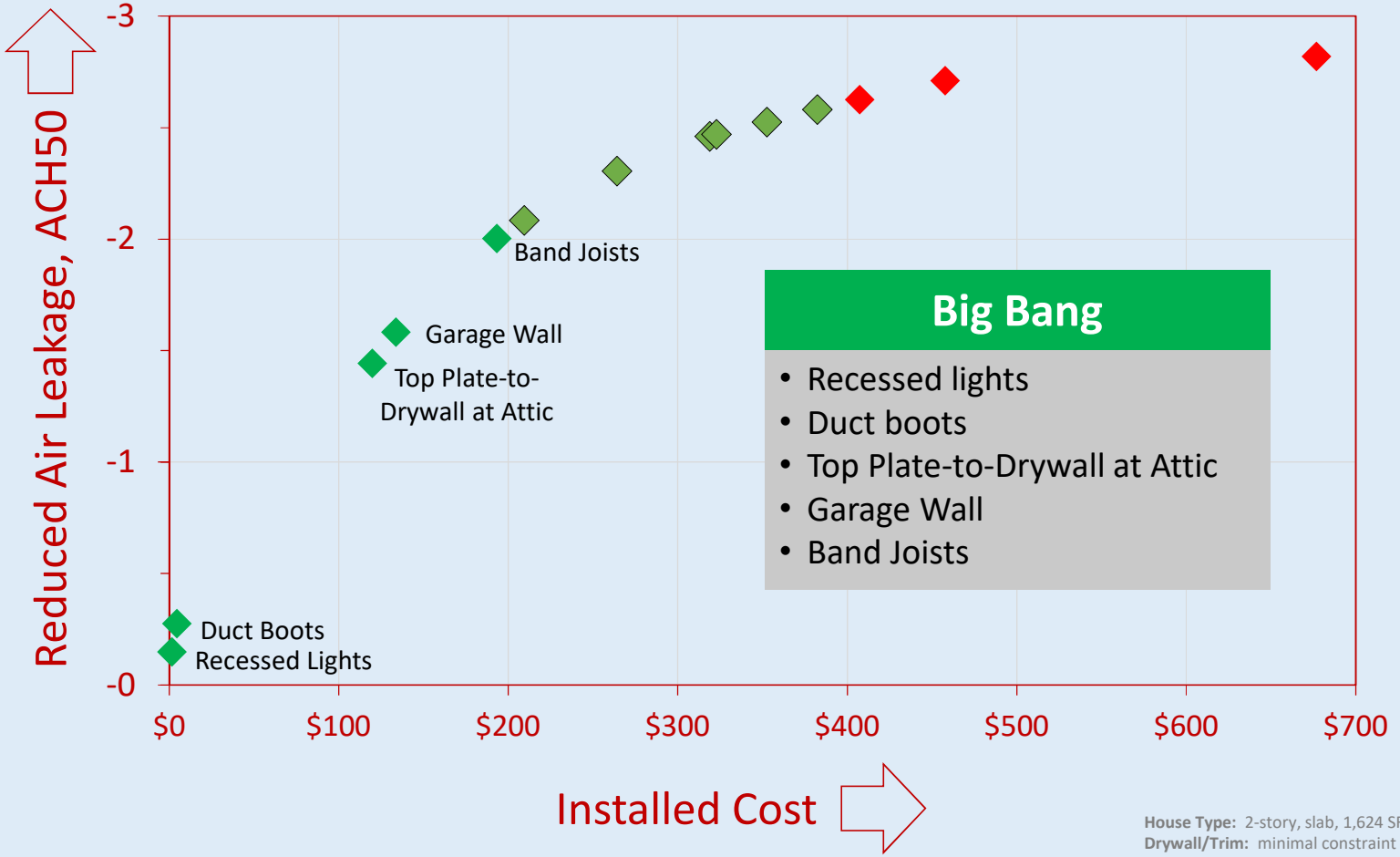
Owens Corning's Response

Air Sealing Study

- From Owens Corning Building Science
  - Best-in-industry knowledge and experience
- Peer-reviewed research
- Tells you where to seal to get the most "bang for your buck"

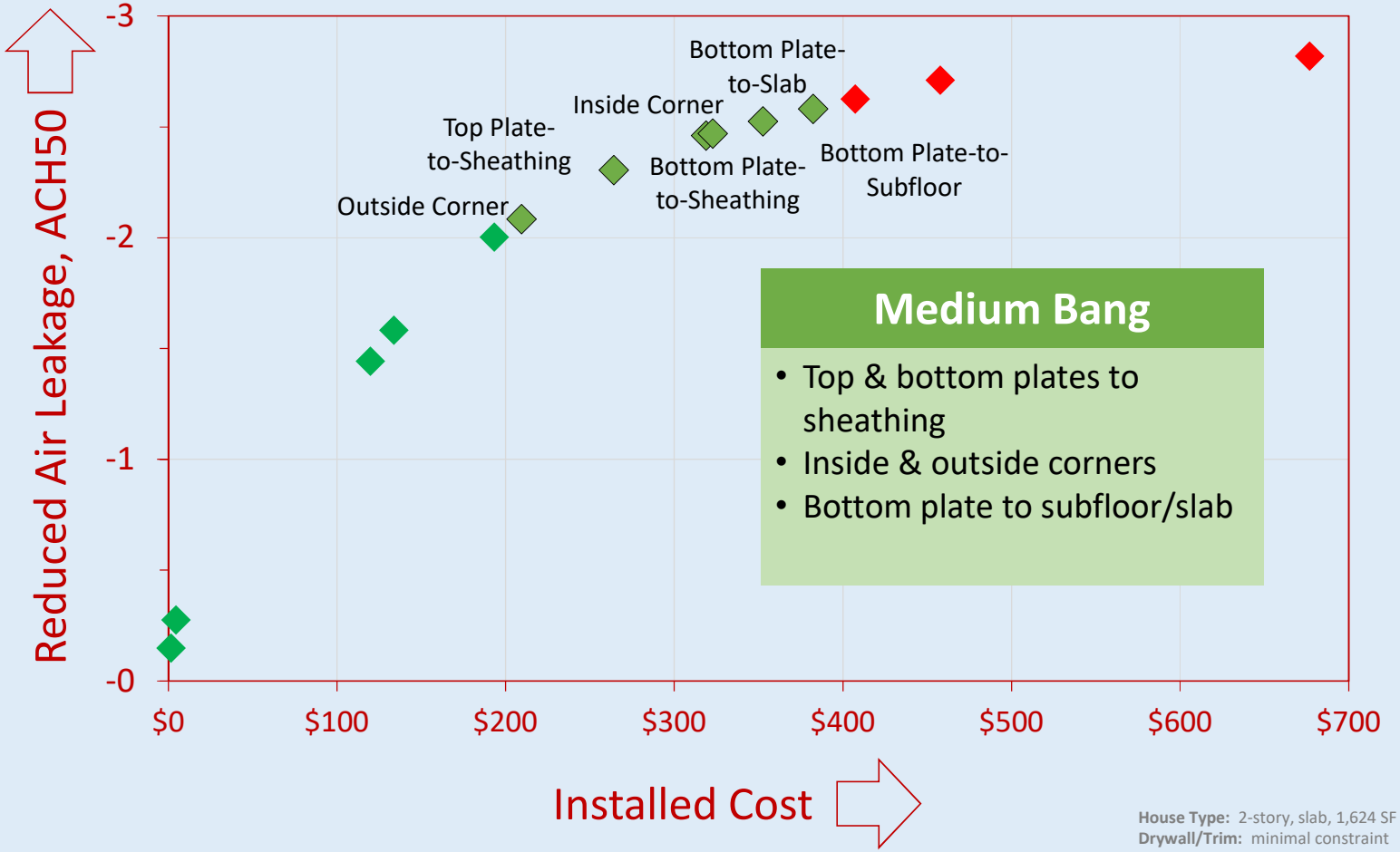


Bang for the Air Sealing Buck



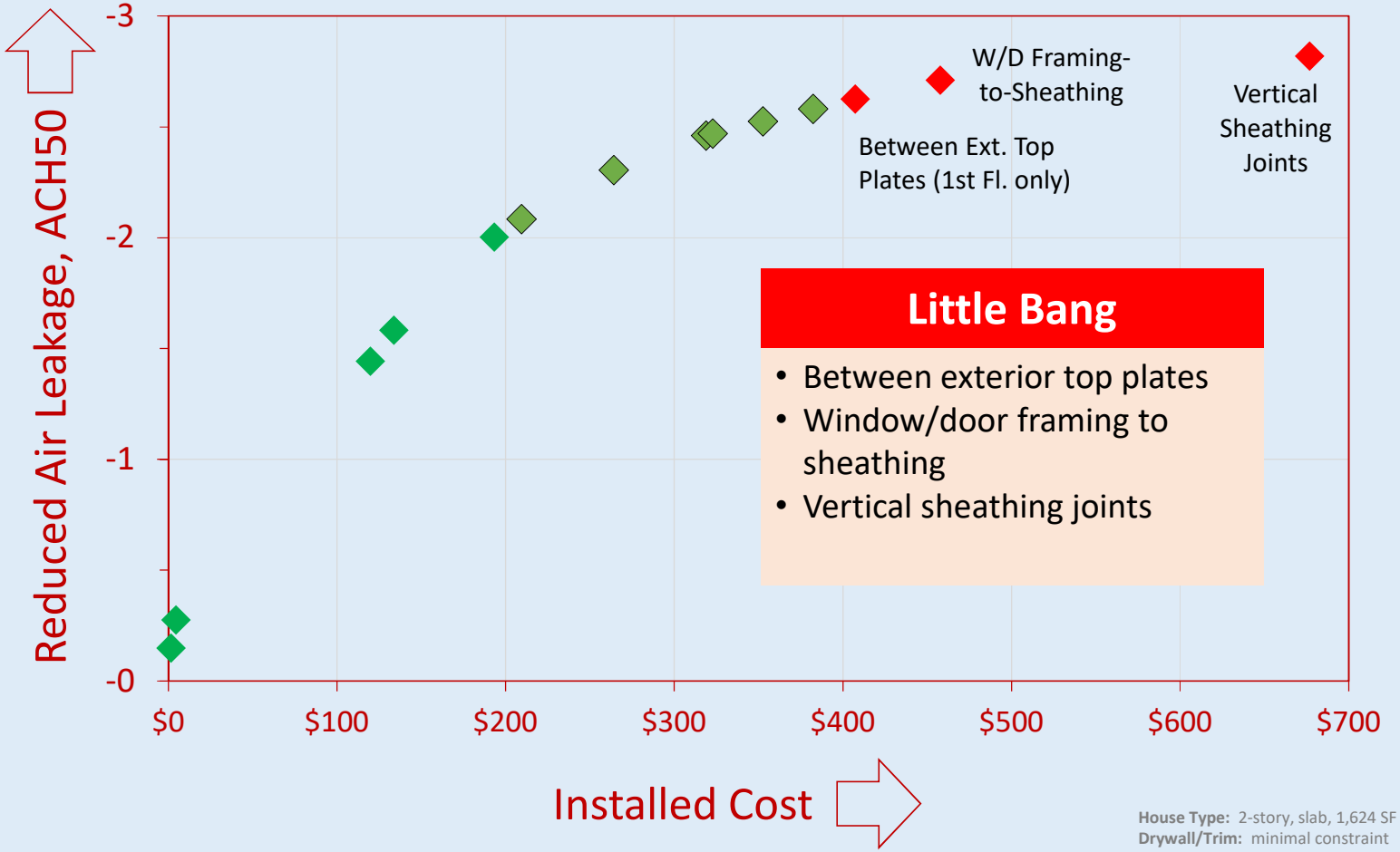
House Type: 2-story, slab, 1,624 SF
Drywall/Trim: minimal constraint

Bang for the Air Sealing Buck



House Type: 2-story, slab, 1,624 SF
Drywall/Trim: minimal constraint

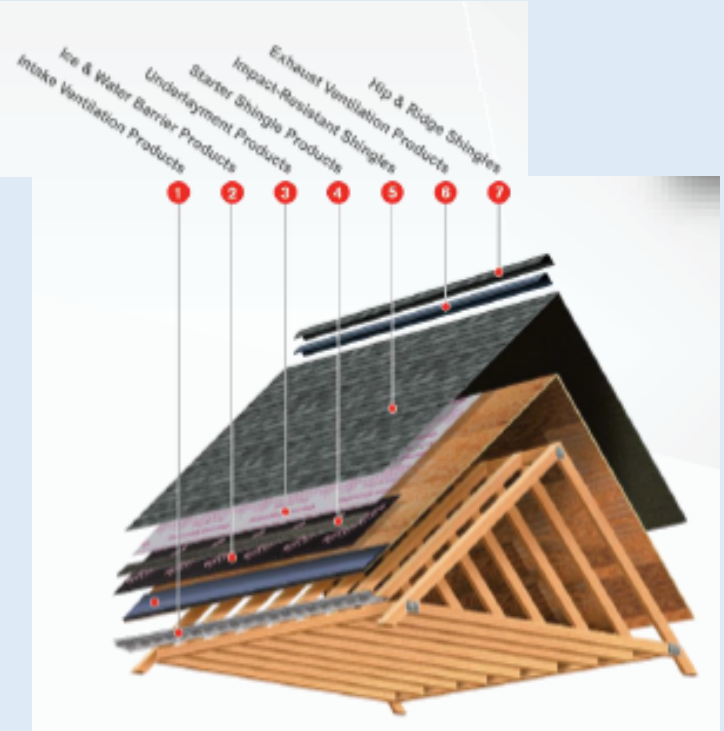
Bang for the Air Sealing Buck



House Type: 2-story, slab, 1,624 SF
Drywall/Trim: minimal constraint

3 - Roof Systems

An integrated roofing system, layer by protective layer.



Roof – Asphalt Shingles

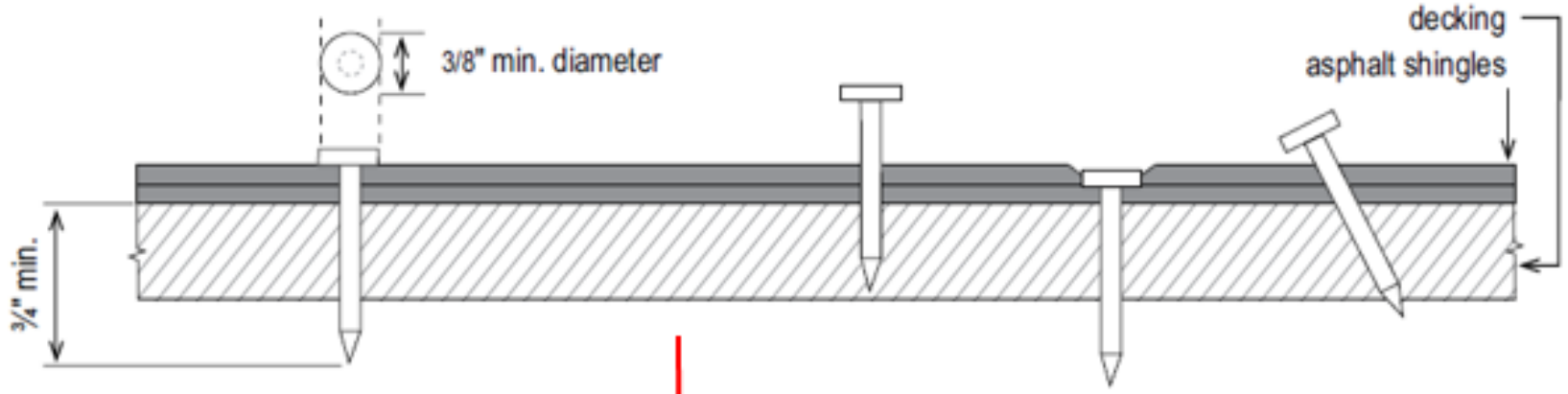
- Strip (3-tab) shingles
- Laminate Shingles
  - Standard weight
  - Heavyweight
  - Thick butt
- Hip & Ridge Shingles

Roof - Sheathing Requirements

Asphalt shingles shall be fastened to solidly sheathed decks.

Roof - Fastening

Proper fastening is crucial to shingle performance.



① straight, good penetration and flush with shingle surface

Properly Driven

② **Underdriven:** inadequate deck penetration

③ **Overdriven:** too deep cuts into shingle

④ **Crooked:** inadequate anchorage

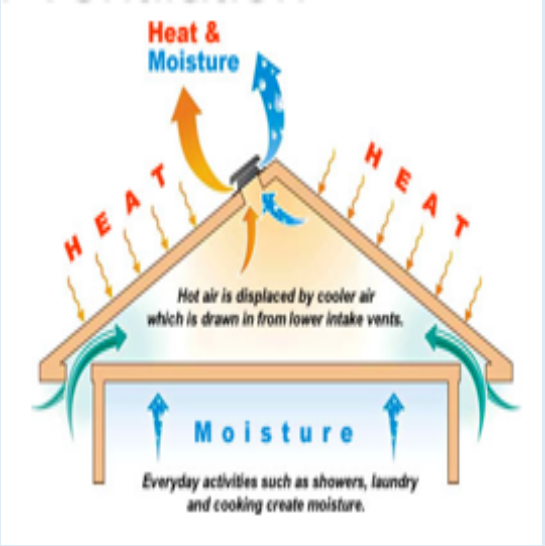
Improperly Driven

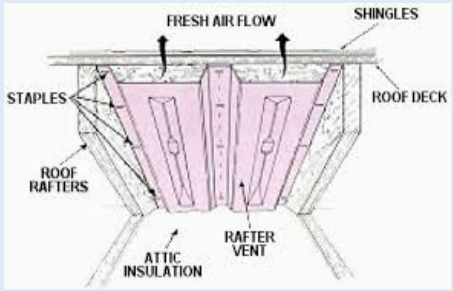
Roof - Ventilation

Ventilation required

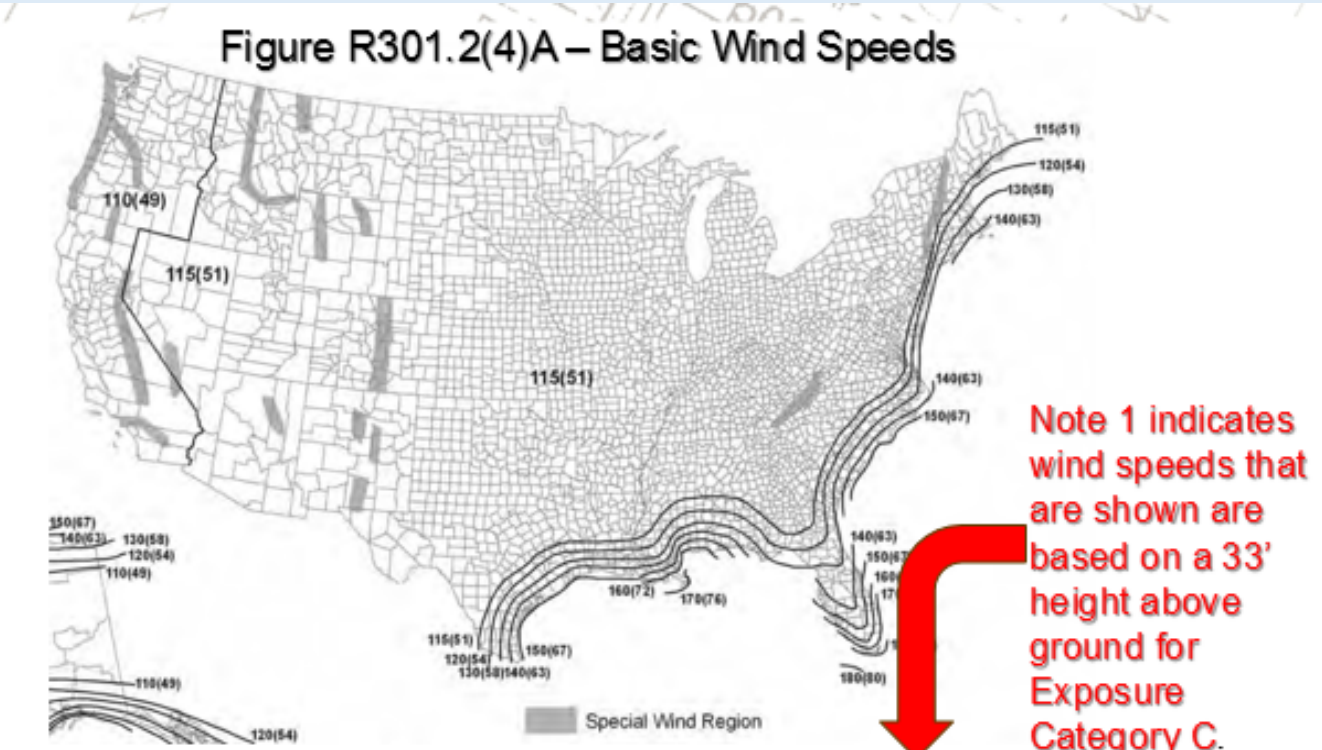
- Applies to enclosed attics and enclosed rafter spaces
- Requires cross ventilation for each separate space by ventilating openings protected against the entrance of rain or snow

- Ventilation opening dimensions
  - 1/16 inch (1.6 mm) minimum
  - 1/4 inch (6.4 mm) maximum.
  - If openings larger than 1/4 inch (6.4 mm), provide corrosion-resistant wire cloth screening, hardware cloth, or similar material with openings meeting the above.





Roof - Wind Resistance



3 Wind resistance ratings per D7158:

- Class D – Pass at wind speeds of 90 mph
- Class G – Pass at wind speeds of 120 mph
- Class H – Pass at wind speeds of 150 mph

Roof - Impact Resistance

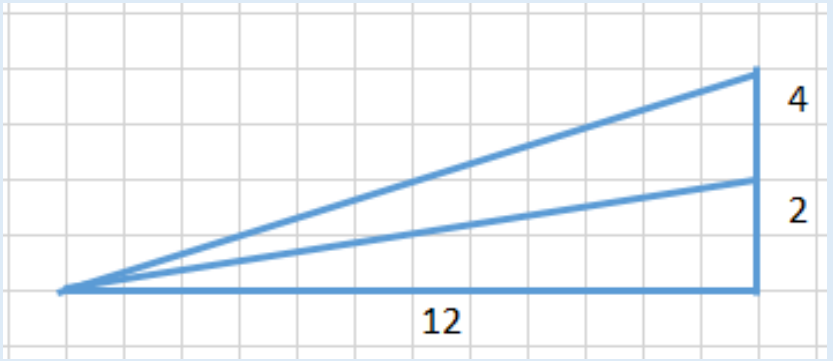
- **4 Impact Resistance Ratings**

Table 5.1
Drop height and kinetic energy

Class	Steel ball diameter		Distance		Kinetic energy	
	Inches	(mm)	Feet	(m)	ft-lbf	(J)
1	1-1/4	(31.8)	12.0	(3.7)	3.53	(4.78)
2	1-1/2	(38.1)	15.0	(4.6)	7.35	(9.95)
3	1-3/4	(44.5)	17.0	(5.2)	13.56	(18.37)
4	2	(50.8)	20.0	(6.1)	23.71	(32.12)

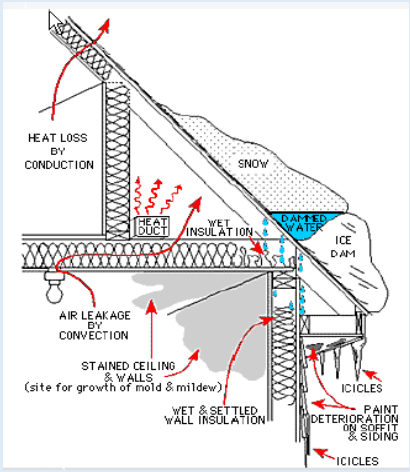
Roof - Slope

Asphalt shingles shall be used only on roof slopes of two units vertical in 12 units horizontal (2:12) or greater. For roof slopes from two units vertical in 12 units horizontal (2:12) up to four units vertical in 12 units horizontal (4:12), double underlayment application is required.

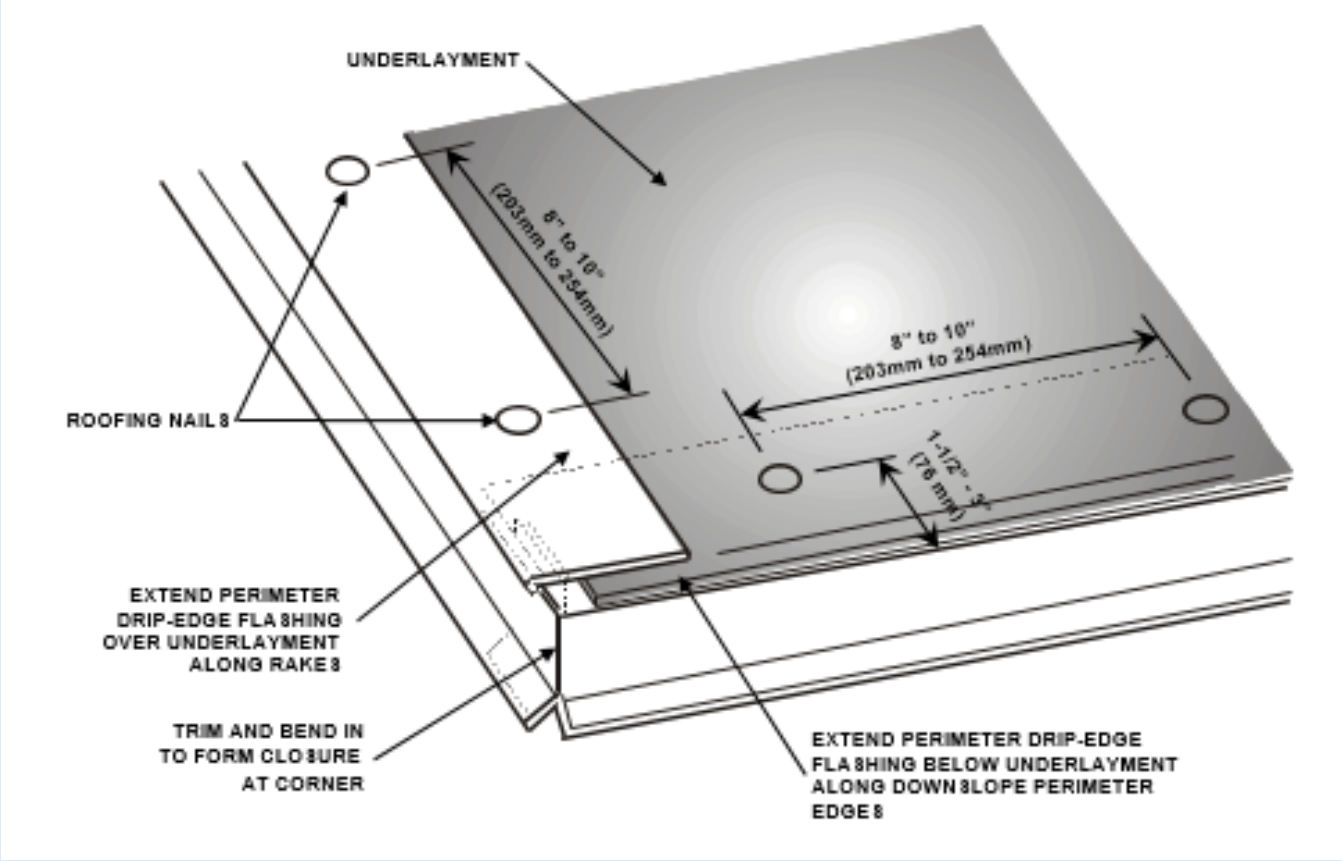


Roof - Ice Protection

An ice barrier that consists of a least two layers of underlayment cemented together or of a self-adhering polymer modified bitumen sheet, shall be used in lieu of normal underlayment and extend from the lowest edges of all roof surfaces to a point at least 24 inches (610 mm) inside the exterior wall line of the building.



Roof - Drip Edge and Underlayment

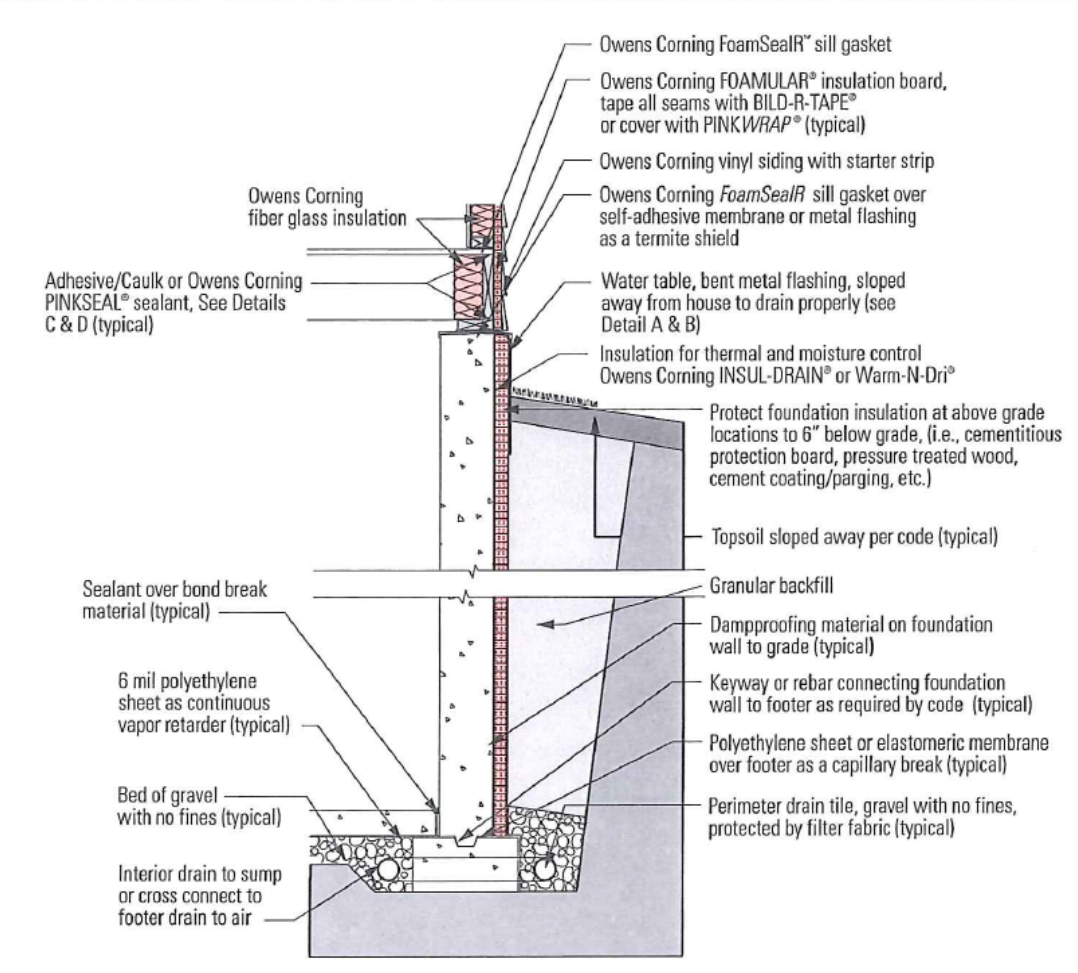


Roof - Fire

Consists of 3 primary fire tests:

- Burning Brand
  - 4 consecutive decks must pass
- Spread of Flame
  - 2 consecutive decks must pass
- Intermittent Flame
  - 2 consecutive decks must pass

4 - Water Management



Water Management

Water Management

Water Management




Foundation Drainage

5 - Acoustics

Problem – Noise is unwanted sound.

Solution – Quiet is achieved when the noise is significantly reduced and/or blocked from transmitting and is no longer bothersome.

Acoustics

- **Attenuation Locations:**
  - **Home Office**
  - **Bedrooms**
  - **Dedicated Entertainment Room**
  - **Home Theater**

- **Noise Sources:**
  - **Exterior**
    - **Traffic**
    - **Airplanes**
    - **Trains**
    - **Lawn Mowers**
  - **Interior**
    - **Entertainment Systems – Sound, TV**
    - **Exhaust Fans – Kitchen, Bathrooms**
    - **Dishwasher**
    - **Laundry Appliances**
    - **Vacuum Sweeper**
    - **Active Children**

Acoustics

- **Target Areas:**
  - **Ceiling**
  - **Interior Walls**
  - **Exterior Walls**
  - **Floors**
  - **Doors**
  - **Ducting**
  - **Plumbing**
  - **Electrical Service Boxes**
- **Solutions:**
  - **Cavity insulation – ceiling, wall, floor**
  - **Caulking – seal all air paths**
  - **Double layers of gypsum wallboard**
  - **Doors – solid and sealed**
  - **Electrical Boxes – sealed**
  - **Ducts – insulated and isolated to a single room**
  - **Windows – sealed**
  - **Walls – double studs or split with resilient connections**
  - **Floors – blocking between rooms**
  - **Plumbing – isolated with resilient mounts or hangers**

Residential Noise Control Best Practices

Some Do's and Don'ts

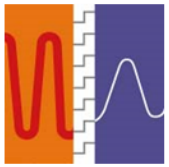
Basic Principles for Controlling Noise

Absorb

- *Sound Insulation*

Block

- Partition Membranes, Sheathings (drywall)
- Acoustic Sealant (caulk)



Vibration Breaks

- Decouple Energy Pathways (Double Walls)

Isolators

- Spring Isolators (RC channel, floating floor membranes)

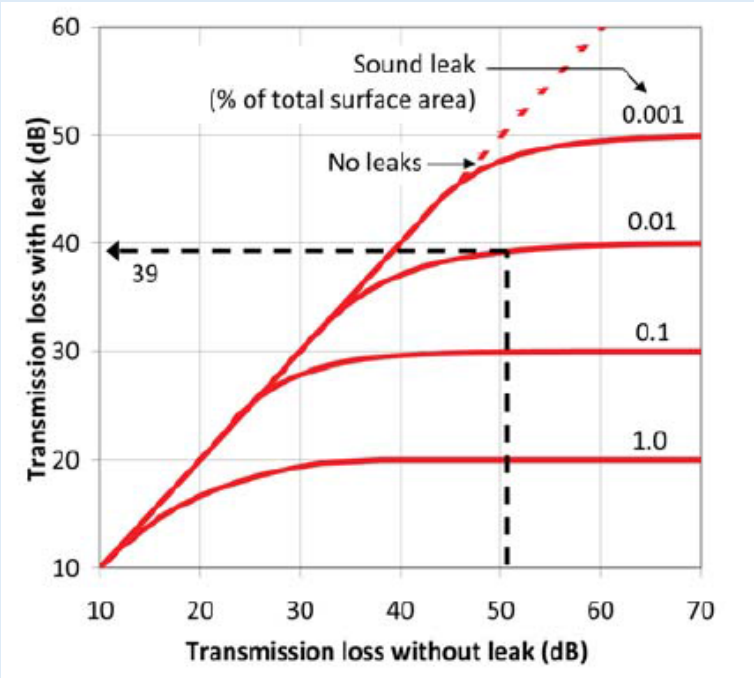
Best Noise Control Practices - Independent of Partition Type

- Do Seal All Open Penetrations!

Air infiltration and sound penetration through partitions occur as one in the same. If air penetrates through the assembly then sound (or noise) can too. In fact, it takes very little air leakage to cause significant sound leakage.

For example, a wall designed to achieve a sound transmission loss of 50 dB can reduce to 39 dB (an 11 dB drop) when only 0.01 percent of the partition surface area is unsealed.

- Don’t use sealants that can shrink or become brittle & crack over time.



Best Noise Control Practices - Independent of Partition Type

- Do “Decouple” The Vibration Path

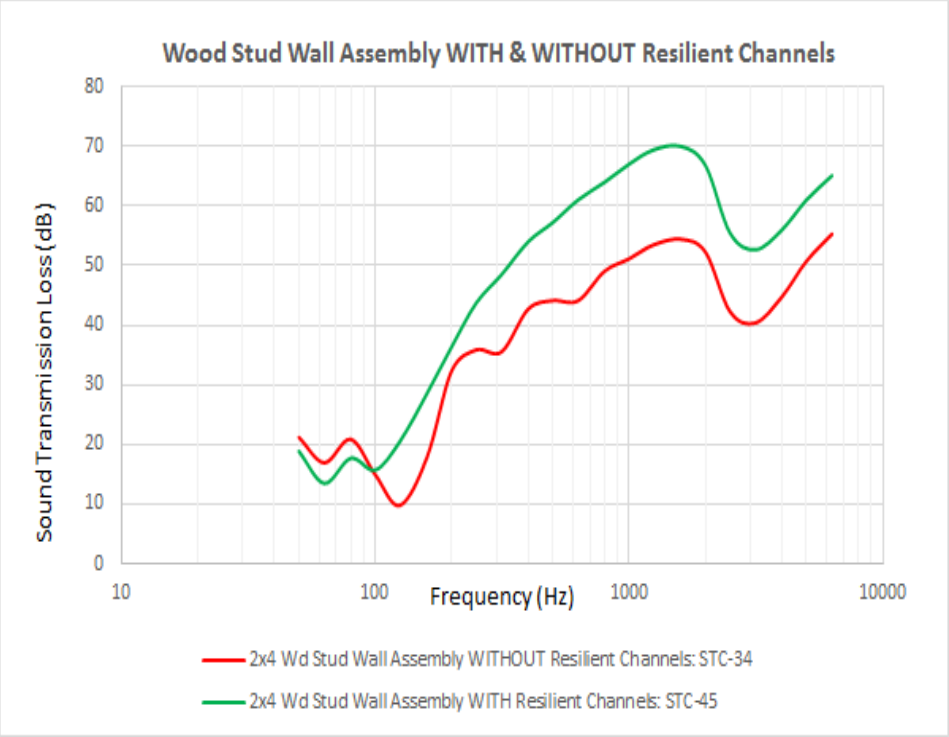
Acoustic energy flow through a partition follows the path of least resistance.

For a standard wood stud wall or joist floor assembly the greatest acoustic energy is transmitted through the partition via the sheathing or drywall into the wood framing to the adjacent sheathing or drywall.

Decoupling the sheathing, or drywall from the wood framing via resilient channels and/or a floating floor topping can isolate energy paths and increase noise attenuation. (STC and IIC)

- Don’t Install Resilient Channels On Top Of Existing Drywall.

The entrapped air stiffens the spring action of the channel and can actually result in an increase in sound transmission.



Best Noise Control Practices - Independent of Partition Type

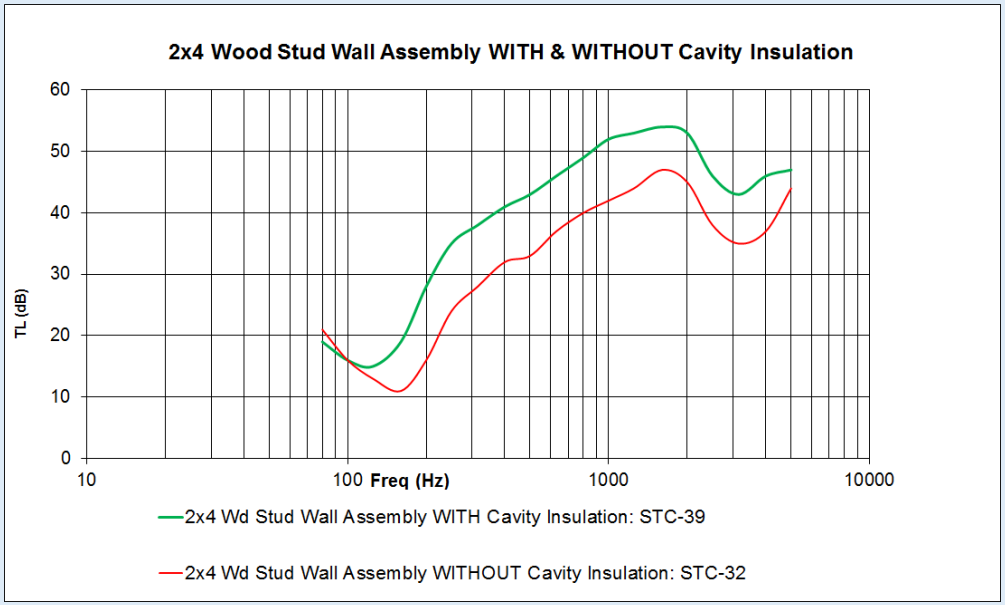
- Do Utilize Cavity Insulation To Absorb Sound Vibrations

One of the most efficient and cost effective means to control sound in walls, floors, and ceilings is through the use of cavity insulation.

Airborne sound vibrations cause air particles to vibrate back and forth much like a piston. When a sound (vibrating air particles) enters a porous material such as fiberglass or mineral wool the vibrating particles create resistance or drag over and around the many fibers to cause friction to occur. As a result, sound vibrations are converted to heat and sound energy is quickly dissipated.

- If You Are Seeking Higher Levels Of Noise Control Don't Rely On Cavity Insulation Alone.

Combine cavity insulation with resilient channels and layers of drywall.



Best Noise Control Practices Independent of Partition Type

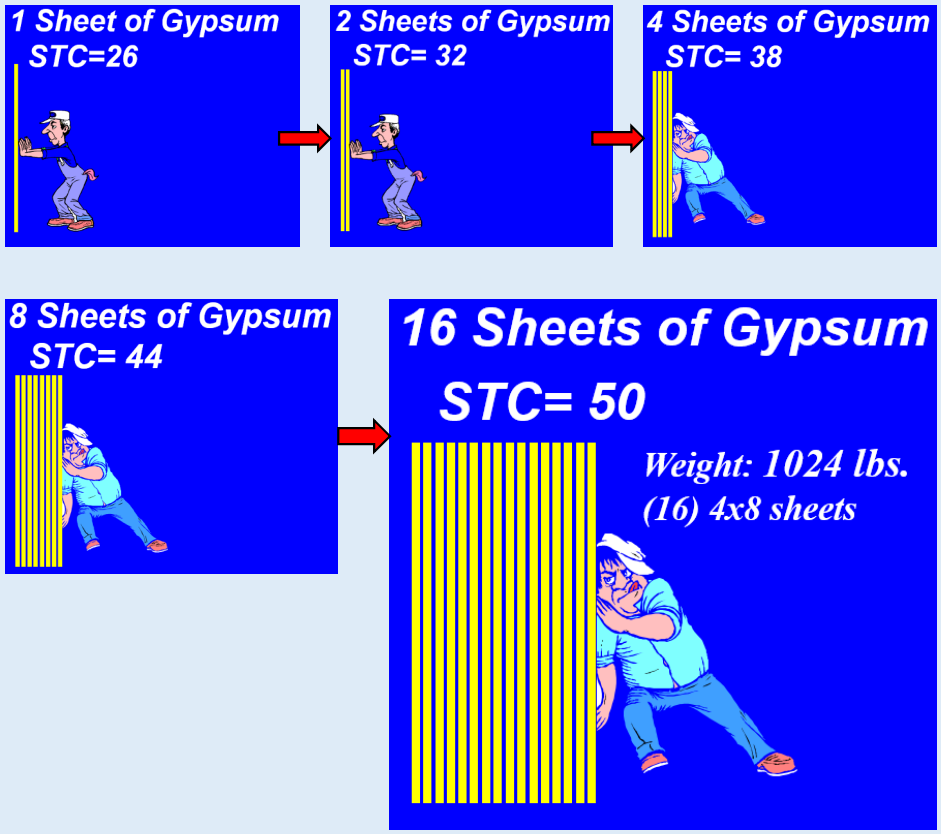
- Do Use Mass Wisely To Increase Noise Attenuation

For each doubling of the weight or frequency of a partition, mass law predicts a 6 dB increase in transmission loss.

Doubling the mass of a partition can quickly and noticeably increase the partition's noise attenuation.

- Don't rely only on mass alone to increase noise control. It can quickly become unreasonable and combining basic acoustic principles can be more efficient & effective.

Question: How many sheets of Type X drywall would be needed to achieve STC-50?



Best Noise Control Practices - Independent of Partition Type

- Do Try To Minimize The Effects of Flanking Noise

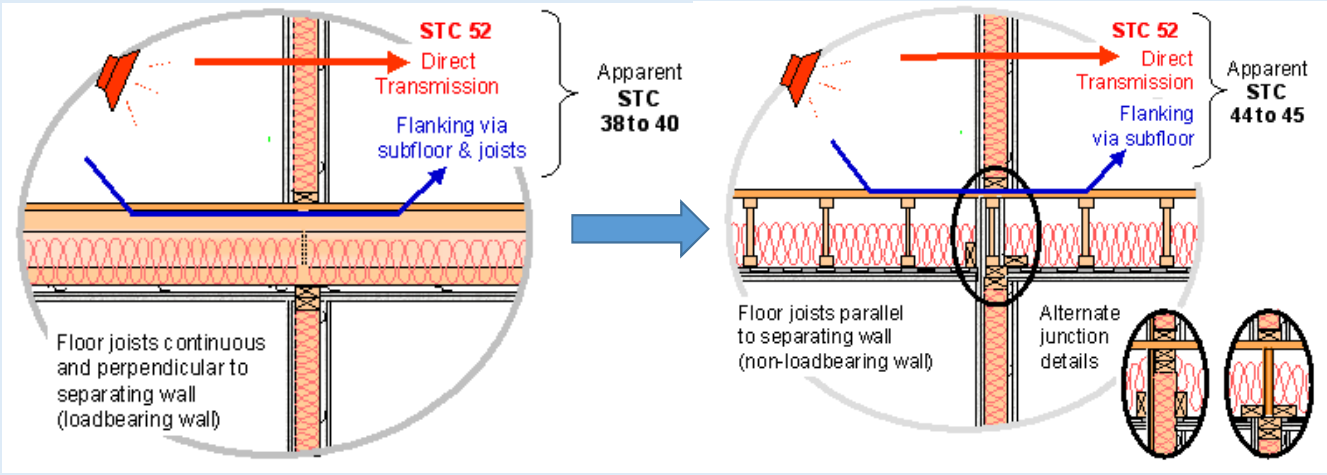
Example: With a *single stud wall construction, horizontal flanking transmission is strongest with joists perpendicular* to (and continuous under) the party wall.

Flanking noise transmission is the transmission of sound between rooms by paths other than directly through the wall or floor partition of concern.

Flanking noise exists in all buildings and must be considered whenever designing effective room environments for noise control.

- Don't Mismatch Wall, Floor, and Ceiling Acoustic Performance Levels.

Pay close attention to juncture details between walls, floors, and ceilings.



Perpendicular Joints

Parallel Joints

Best Practices for the Design and Construction of the Building Envelope

Merle McBride, Ph.D., P.E. – Research Fellow

Q & A

OSU – Green Housing Workshop

May 16, 2017