

Welcome

Going Zero for Builders & Designers:
Building Science for Cost-Effective Approaches
for Zero Energy Homes

Portland, ME

October 13th, 2015

Steve Easley

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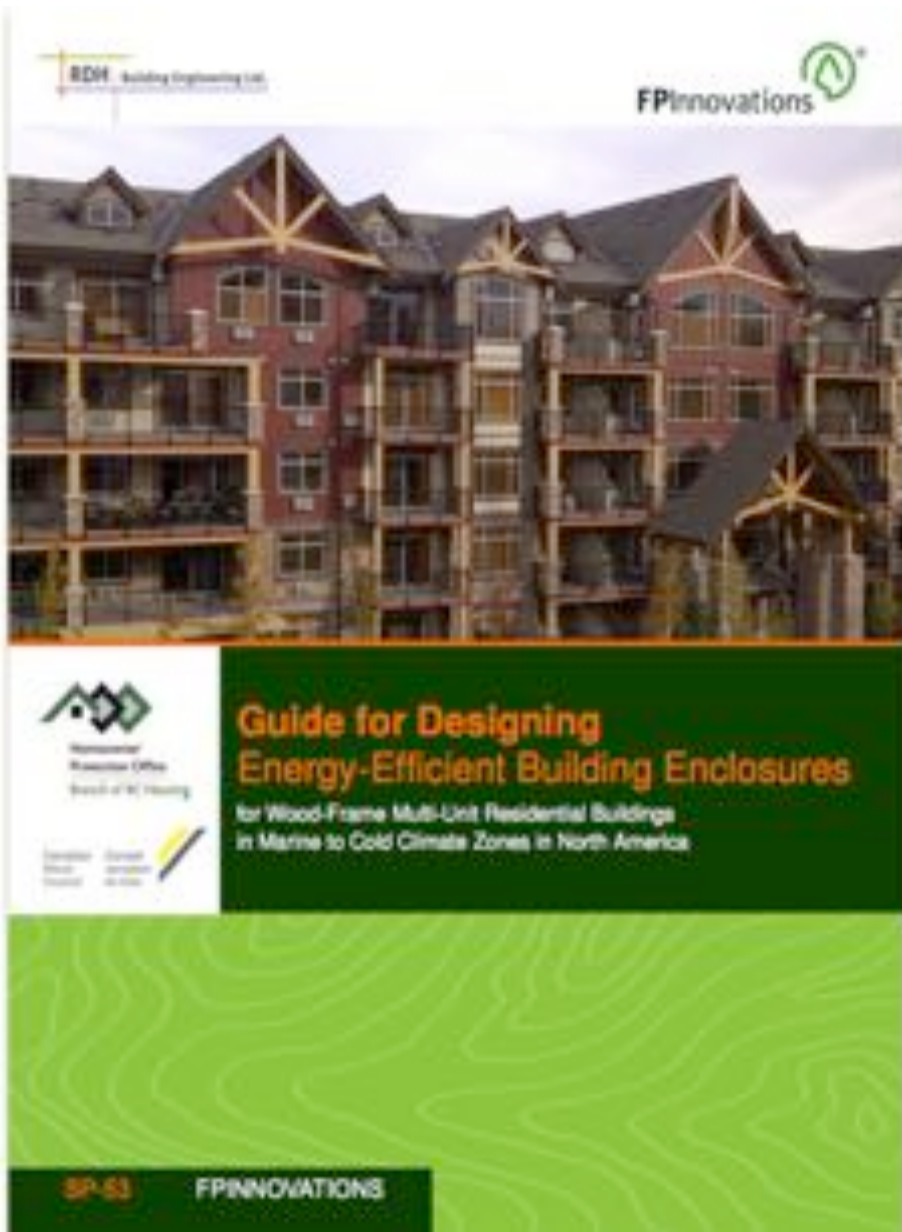
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FPInnovations is a not-for-profit world leader that specializes in the provision of scientific solutions in support of the Canadian forest sector's global competitiveness and responds to the priority needs of its industry members and government partners. It is ideally positioned to perform research, knowledge, and deliver state-of-the-art solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. FPInnovations staff numbers more than 525, its R&D laboratories are located in Québec City, Ottawa, Montréal, Thunder Bay, Edmonton, and Vancouver, and it has technology transfer offices across Canada. For more information about FPInnovations, visit www.fpinnovations.ca.



RDH Building Engineering Ltd. is an engineering consulting firm based in the province of British Columbia and in the states of Washington and Oregon. RDH focuses on the integration of building science, engineering, architecture, and construction management services for the building enclosure of new construction projects and existing buildings. In the wake of the Pacific Northwest's deadly building disaster in the 1980s and 1990s, RDH played a major role in restoring confidence in the building design and construction industry. RDH has published numerous research and guidance documents, thus contributing to profound improvements in the performance of building enclosures and in the understanding of building science across North America and around the world. For more information about RDH, visit www.rdh.ca.

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CLT Handbook

CROSS-LAMINATED TIMBER

US EDITION



Enclosure

Building enclosure design for
cross-laminated timber construction

CHAPTER 10

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www.masstimber.com

Solar Power for Your Home

A Consumer's Guide



<http://www.lsuagcenter.com/solarpub>



, 2014

Objectives

- **Understand principles of Integrated Design**
- **Understand the technologies systems for designing & building ZE/Ready homes.**
- **Understand water management principles**
- **Select the best enclosure-insulation and air barrier systems & products to offset PV demand.**
- **Understand new approaches to advanced framing techniques.**
- **Understand the latest window technologies.**
- **Understand LED Lighting metrics and options**



Over 146,000 Homes in the U.S. were HERS Rated and issued a HERS Index Score in 2014

Average HERS Index Score was 63

In 2014 there were 146,860 homes in the United States that were energy rated by certified RESNET HERS Raters and issued a HERS Index Score. According to the data from the U.S. Census Bureau this represents over 33.8% of all new homes sold in the nation. The average HERS Index Score of the homes rated in 2014 was 63.

The five leading states in terms of homes receiving a HERS Index were:

- Texas 28,784
- Florida - 14,994
- North Carolina - 10,271
- Colorado - 8,315
- Indiana 8,007

Integrated Design



ZE Homes Class Principles Overview

- **Design Fundamentals**
- **Integrated Project Delivery**
- **Enclosures & Assemblies**
- **Mechanical Systems**
- **People and Plug Loads**
- **Renewable Energy**

Top 8 reasons Homes Don't Perform as Expected

- High window to wall area ratio
- Wrong glazing choices
- High framing factor, thermal bridging
- Ineffective air barrier system
- Poorly installed insulation
- Focus is primarily on cavities
- Poorly designed/installed HVAC
- DHWH & Lighting is an afterthought

Or – the Future of HP Housing

- Integrated Design
 - HVAC & Fresh air ventilation
 - Fenestration & Design
 - DHW & Plumbing
- Ducts in conditioned space
- Pay for Performance, Better Q/C
- Reduced thermal bridging
 - Advanced framing, Cont. Insulation
- Lighting, Plug loads and green switches

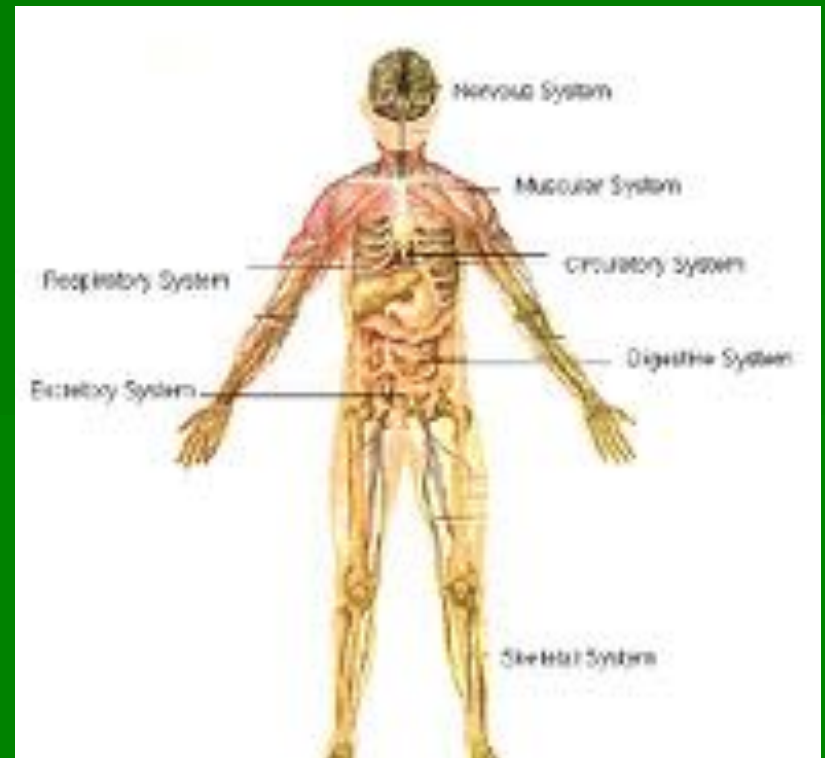
Building Science Fundamentals

Building Science, a definition:

“The understanding of the interworking relationships between climate and the various systems in a home and how those relationships impact energy use, comfort, indoor air quality and building longevity”

Steve Easley

- Systems in a Home:
- Building or structural systems
- Space conditioning system
- Water heating and plumbing system
- Electrical and lighting system



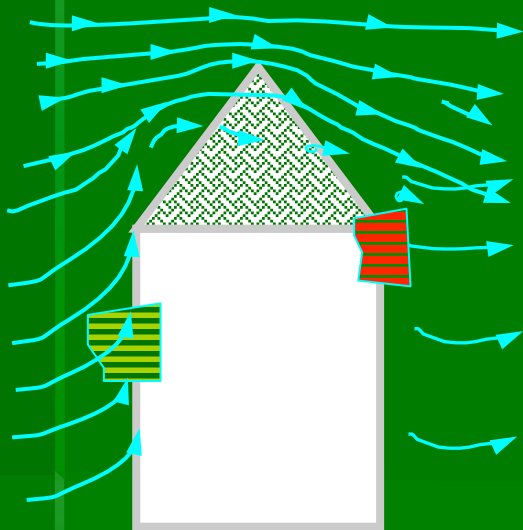
Having Building Science Knowledge Can:

- Help you select the most cost effective products. *Sort through product hype.*
- Reduce your mistakes, helps you make good choices
- Helps you match the right products to the application
- Helps you create a house that works
- Helps achieve better IAQ, & comfort
- you communicate with informed customers

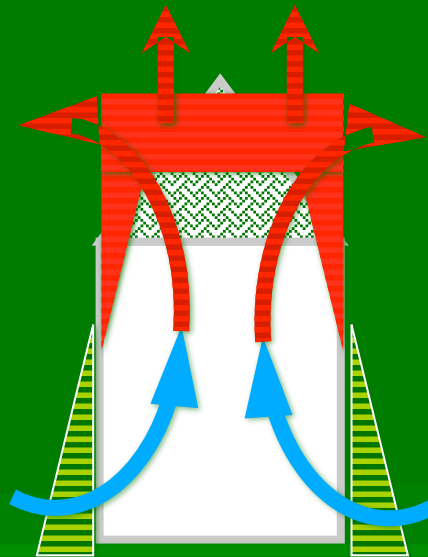
Heat Transfer

- **Conduction**
- **Convection**
- **Radiation**

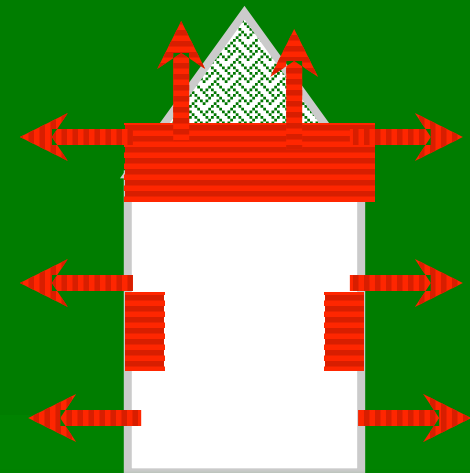
Cause of Air Infiltration in Buildings



**Wind
Pressure**



**Stack
Pressure**



**Mechanical
Pressure
(HVAC)**

Mandatory Requirements

Exhibit 1: DOE Challenge Home Mandatory Requirements for All Labeled Homes

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Version 3 ⁶
2. Envelope ⁷	☐ Fenestration shall meet or exceed latest ENERGY STAR requirements ^{7, 8} ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels ⁹
3. Duct System	☐ Ducts located within the home's thermal and air barrier boundary ¹⁰
4. Water Efficiency	☐ Hot water delivery systems shall meet efficient design requirements ¹¹
5. Lighting & Appliances ¹²	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ☐ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets ☐ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
6. Indoor Air Quality	☐ EPA Indoor airPLUS Verification Checklist and Construction Specifications ¹³
7. Renewable Ready ¹⁴	☐ EPA Renewable Energy Ready Home Solar Electric Checklist and Specifications ¹⁵ ☐ EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications ¹⁶

Encouraged:

- WaterSense Label (indoor and outdoor)
- Disaster Resistance (IBHS Fortified Home)
- Quality Management



For More Information:

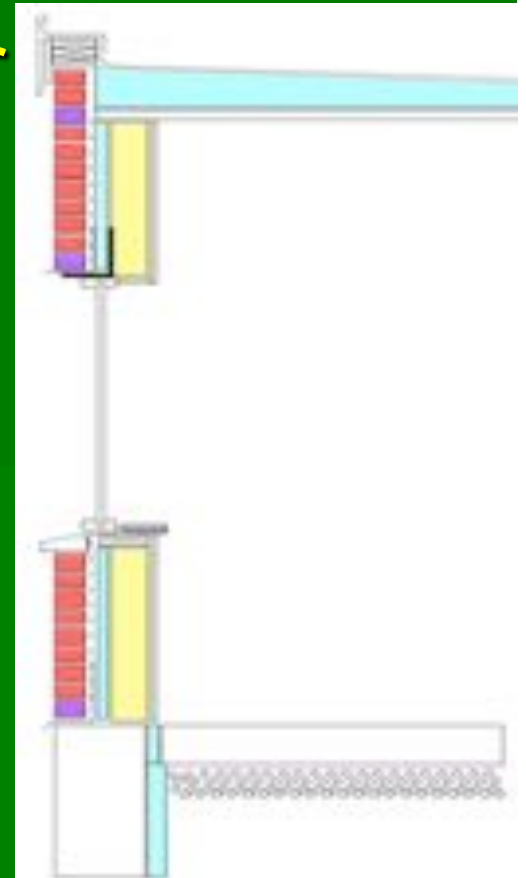
www.buildings.energy.gov/zero/

Why Focus on the Building Enclosure First

- Reduces the heating and cooling system energy use, size and costs
- Is likely to last for the life of the structure
- Energy savings do not diminish with age
- Reduces the loads thus reduces design risk factors for HVAC
- Can manage moisture and increase building durability
- Can enhance occupant comfort and building IAQ

4 - Enclosure Control Layers

- Water- WRB's & Rain Screens
- Air- Air barriers, building wraps, air sealing
- Thermal- insulation or exsulation
- Vapor- vapor retarders



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Green House Gas Emissions

- **1 kWh = 1-1.5 lbs**
- **1 Therm 100,000 BTU's = 11.7 lbs.**

- **Now, John Jones in the School of Engineering, at the University of Aberdeen, UK, suggests that the figures cited by Istvan Lakatos and Julianna Lakatos-Szabo for which they give no references grossly underestimates how much oil we have used already. Jones says that we have used at least 135 billion barrels of oil since 1870, the period during which J.D. Rockefeller established The Standard Oil Company and began drilling in earnest.**

- **135 billion barrels of oil since 1870**

Is this wall really R-20.5?



Impact of Windows

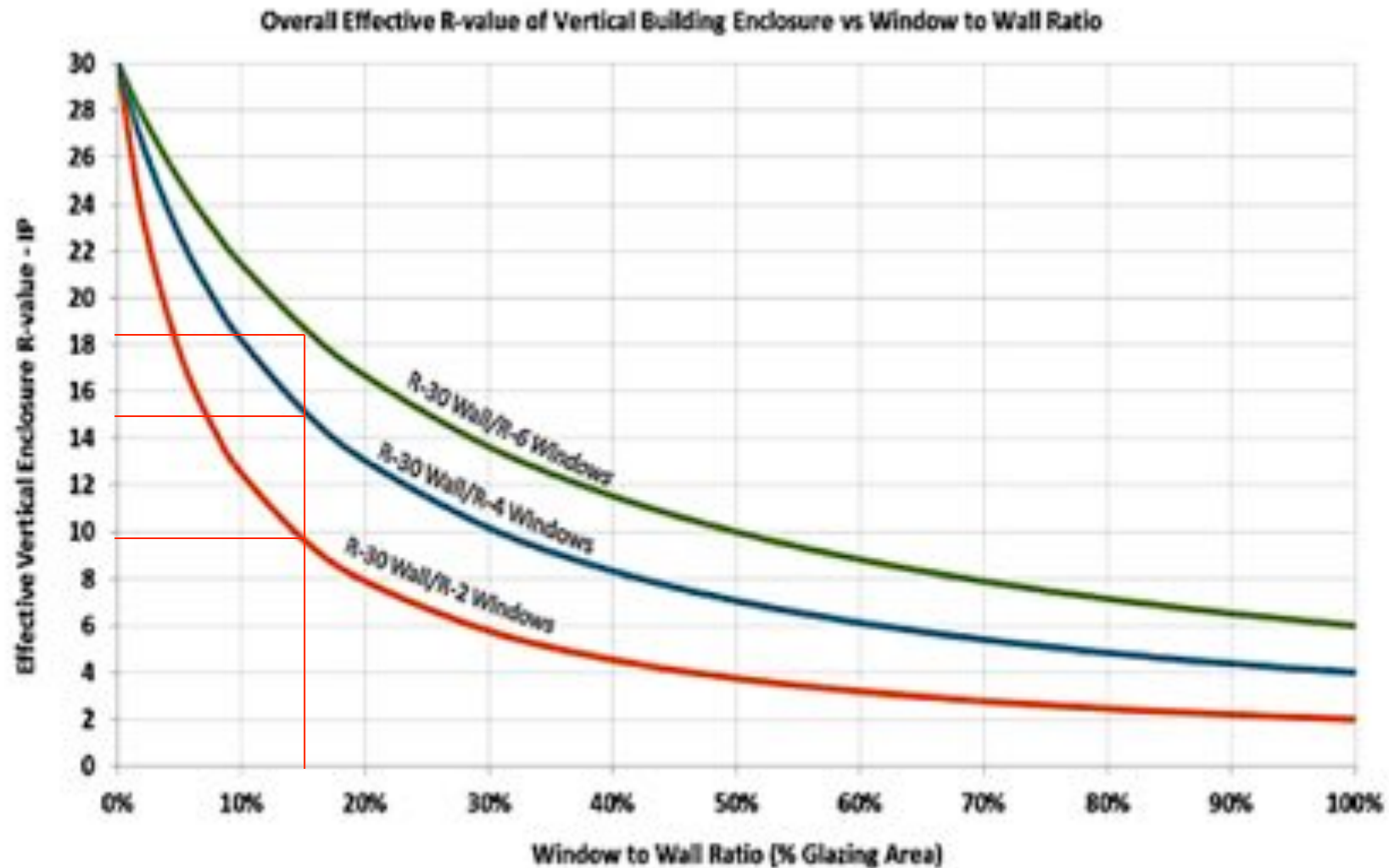
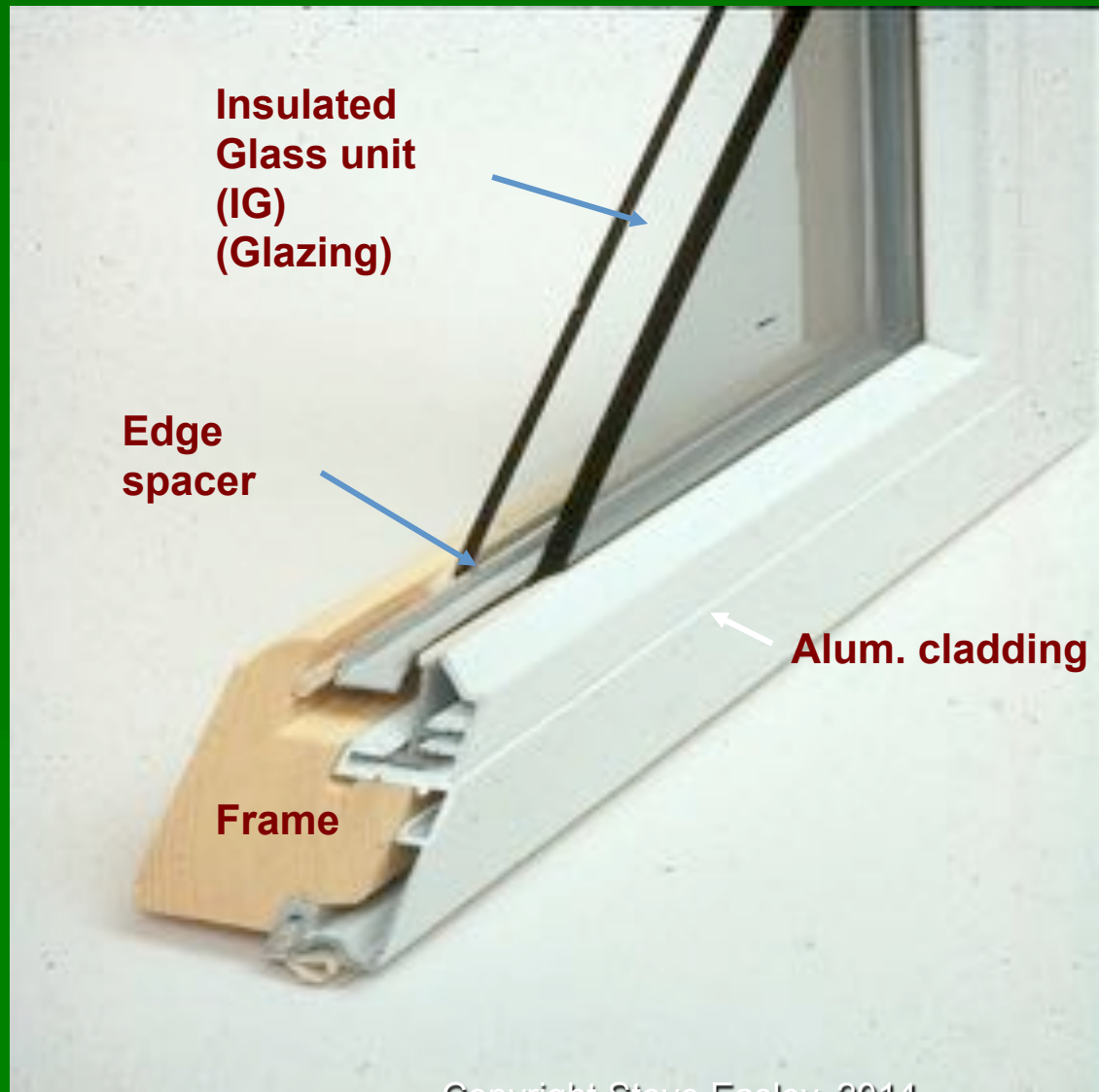


Fig. 3.2.9 Overall effective R-value of building enclosure versus window-to-wall ratio, for R-30 walls and R-2, R-4, and R-6 windows.

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[Courtesy fp innovations](#)

Anatomy of a Window



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Good, Better, Best Windows

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

	Hot Climates IECC CZ 1-2		Mixed Climates IECC CZ 3-4 except Marine		Cold Climates IECC CZ 5-8 and 4 Marine	
	SHGC	U-value	SHGC	U-value	SHGC	U-value
Mandatory: ENERGY STAR	0.27	0.60	[4] 0.40 [3] 0.30	[4] 0.32 [3] 0.35	Any ≥0.35 ≥0.40	0.30 0.31 0.32
Performance: Target Home	0.25	0.4	0.27	0.3	Any	0.27
Encouraged: R-5	0.22	0.21	0.25	0.21	Any	0.21



National Fenestration
Rating Council®

CERTIFIED

World's Best Window Co.

Millennium 2000+
Vinyl-Clad Wood Frame
Double Glazing • Argon Fill • Low E
Product Type: **Vertical Slider**

ENERGY PERFORMANCE RATINGS

U-Factor (U.S./I-P)

0.35

Solar Heat Gain Coefficient

0.32

**Heat
Loss**

**Heat
Gain**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance

0.51

Air Leakage (U.S./I-P)

0.2

Daylight

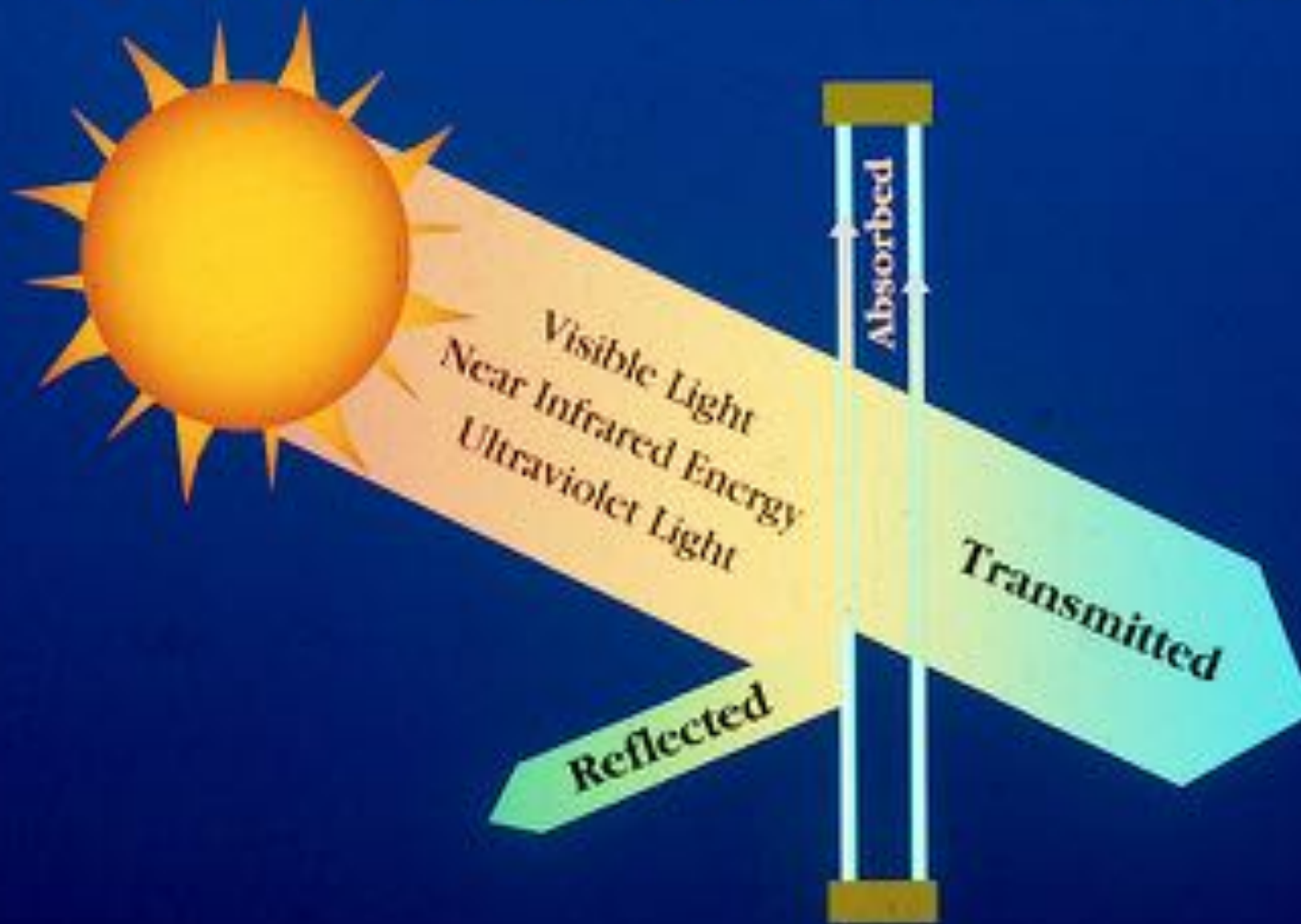
Infiltration

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for additional product performance information.

www.nfrc.org

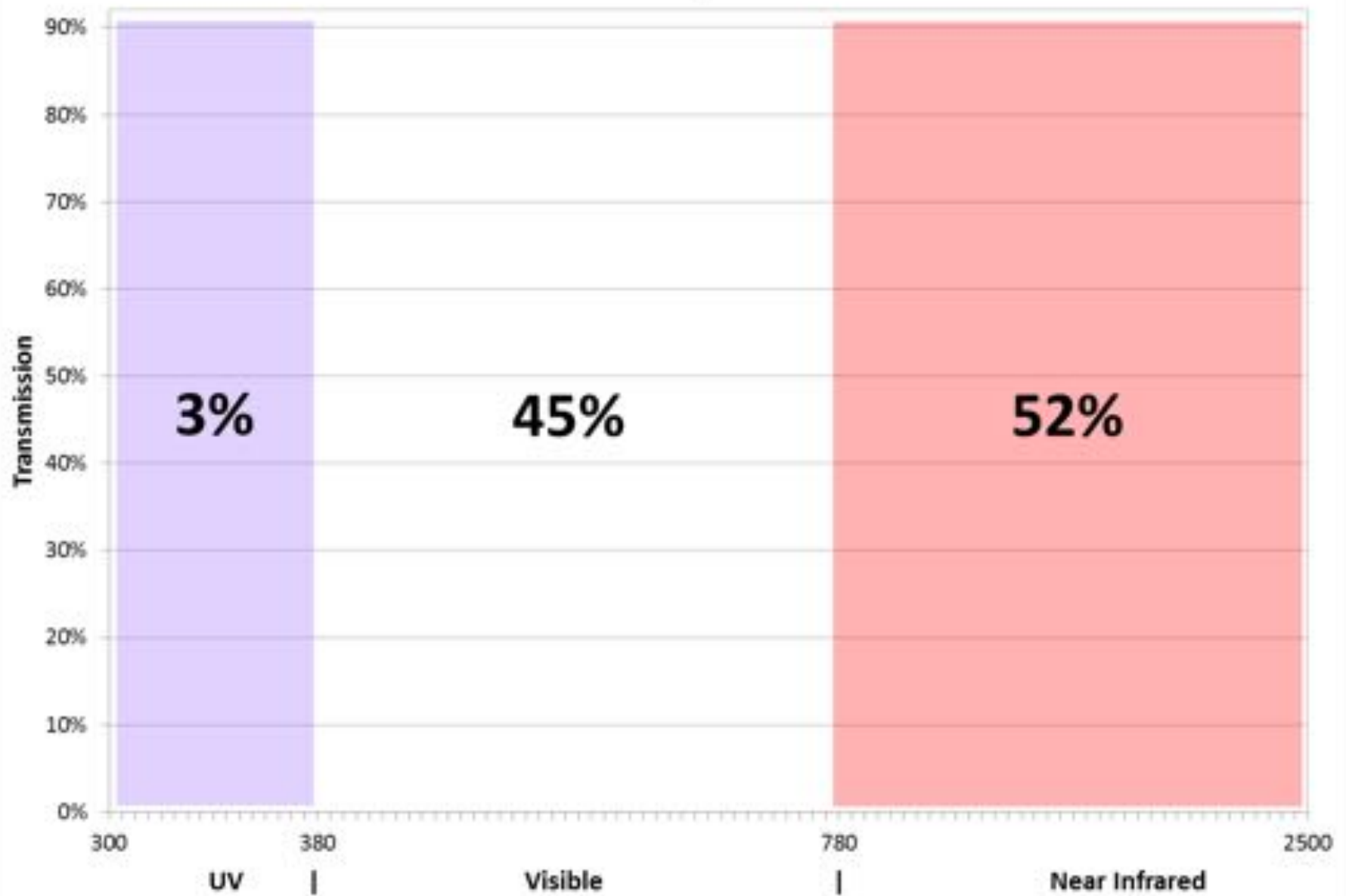
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Distribution of Sunlight Through a Window



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The Solar Spectrum



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Standard Glass Lets in 90% of the Sun's Heat



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Dark Tints Absorb Heat and Block Light



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Low E Coating in Winter



30° F



70° F

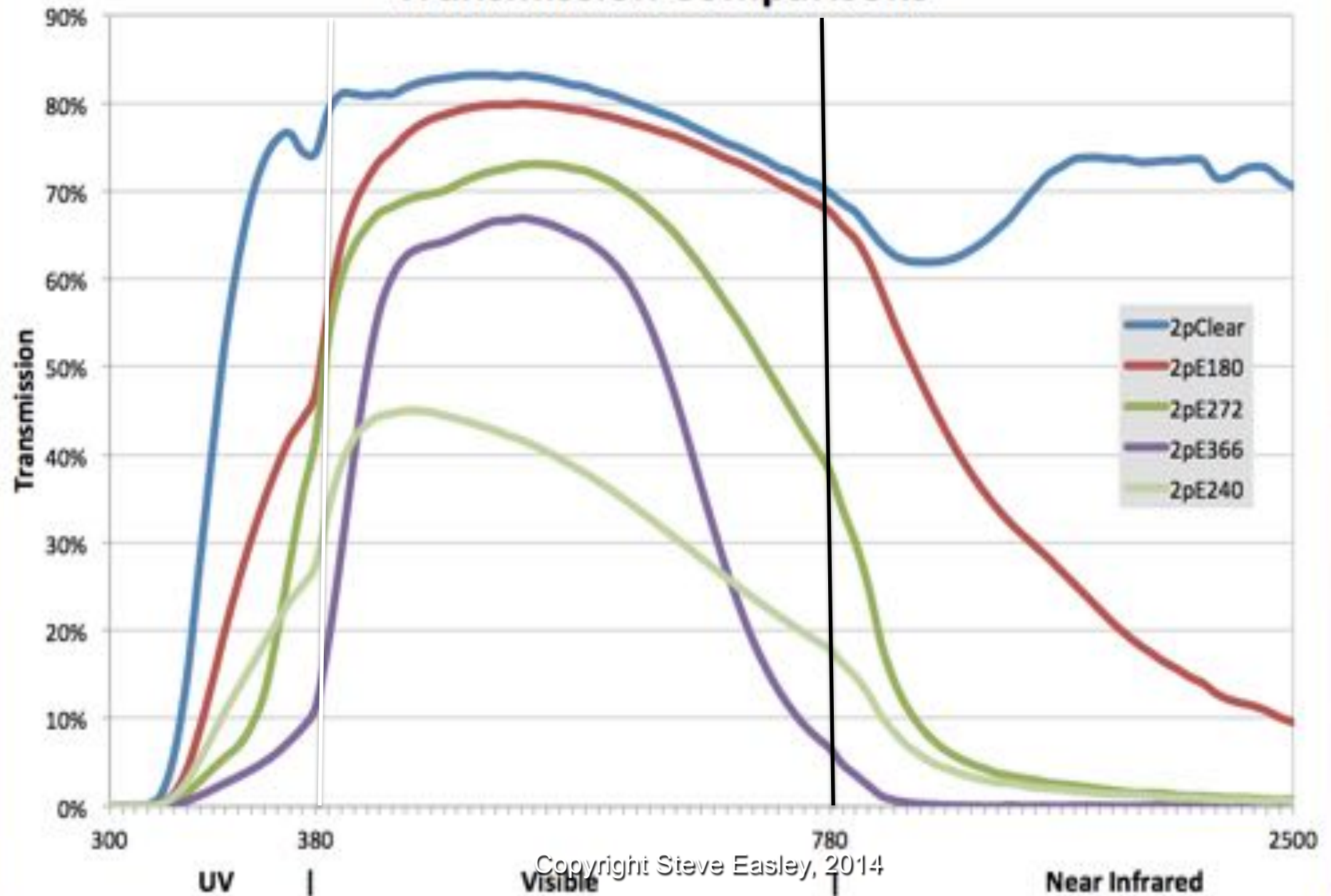
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Properties of Windows

How Spectrally Selective Low-E Works

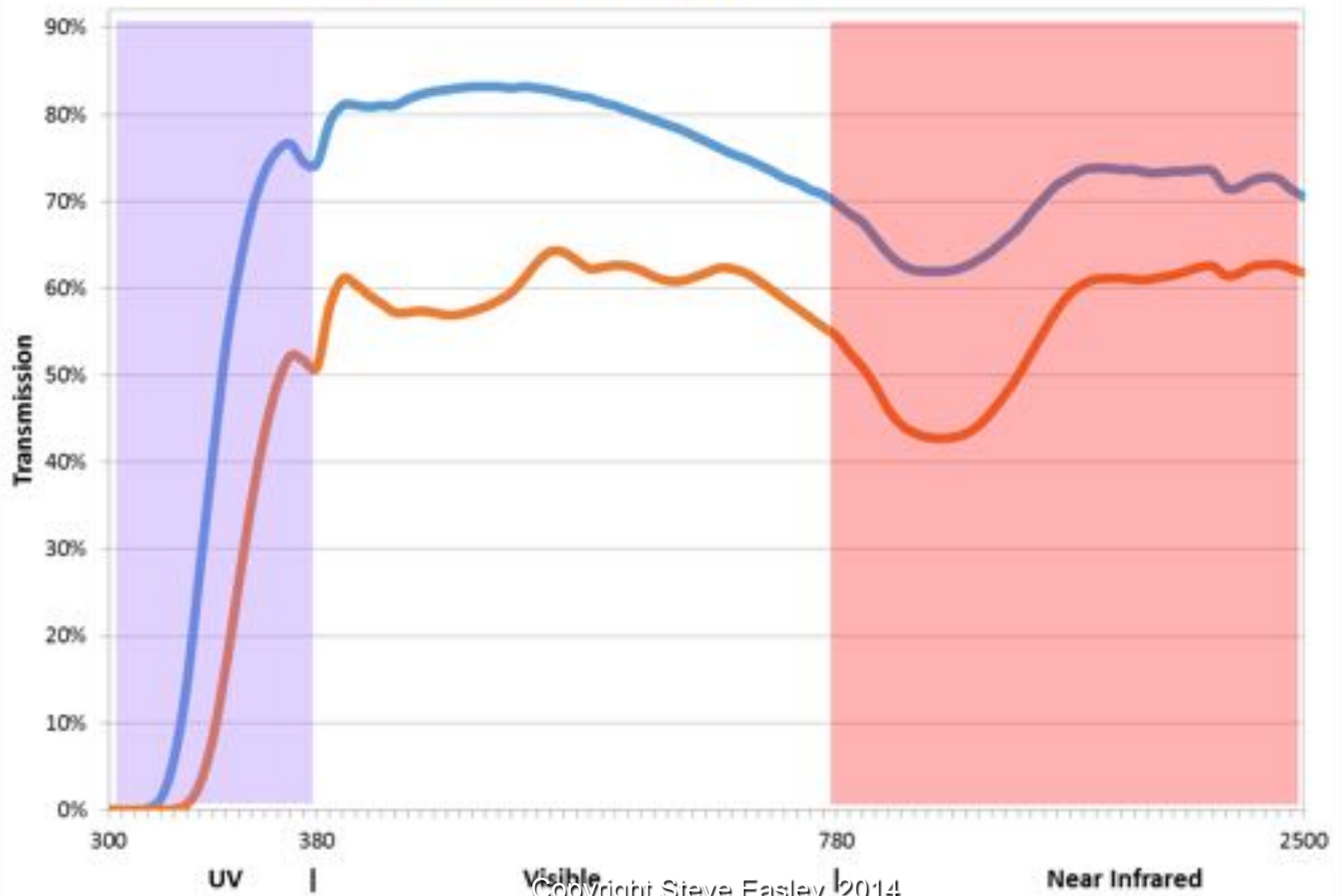
	Low-E Type	Glass VLT	"Typical" Window Properties		
			U-Factor	SHGC	VLT
Double Pane Insulating Glass	None (clear glass)	81%	0.55	0.60	0.60
	High Solar Gain	75%	0.33	0.52	0.56
	Medium Solar Gain	70%	0.32	0.32	0.53
	Low Solar Gain	66%	0.31	0.22	0.50

Transmission Comparisons



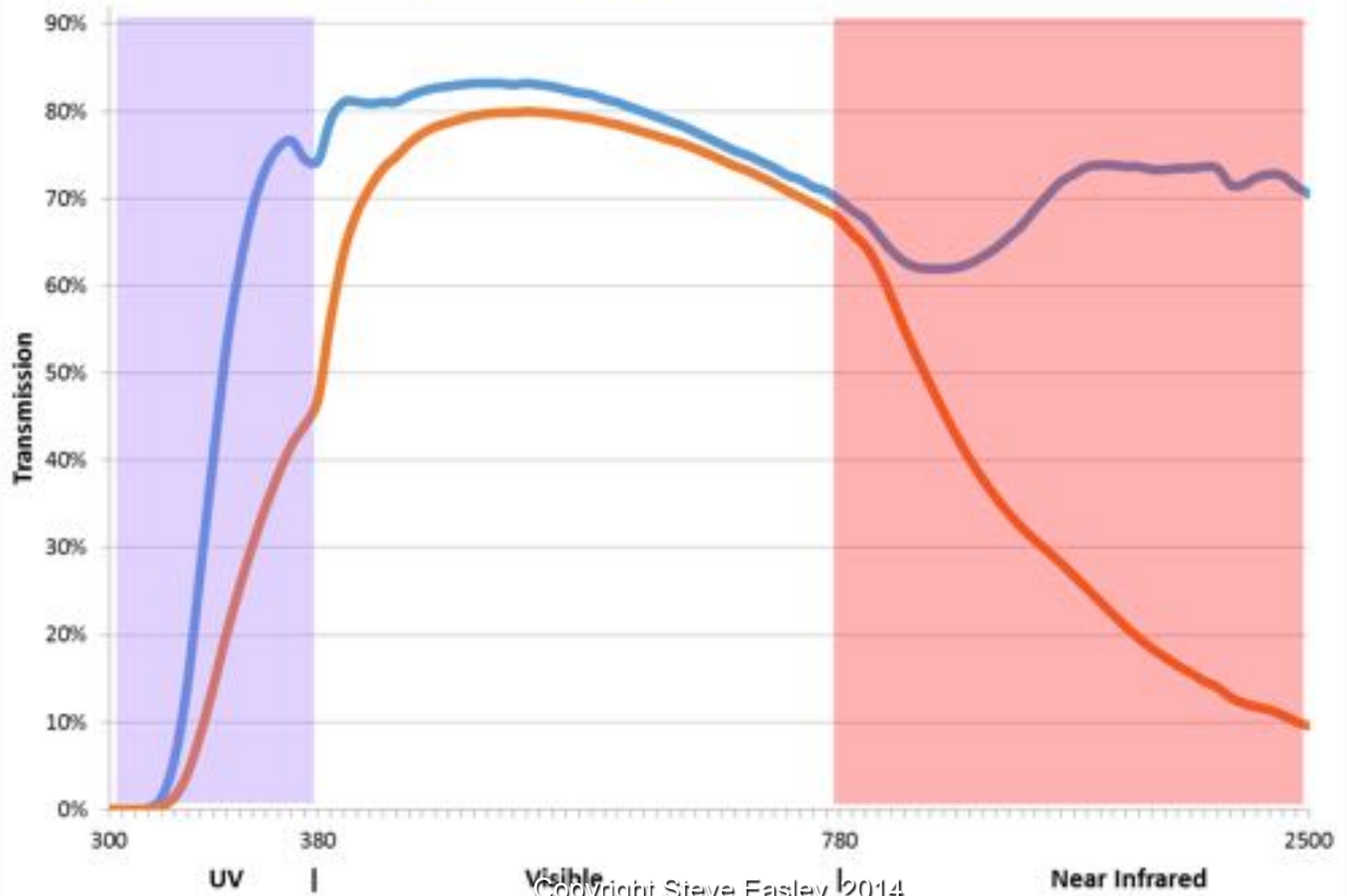
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Residential Tinted SHGC - 0.62



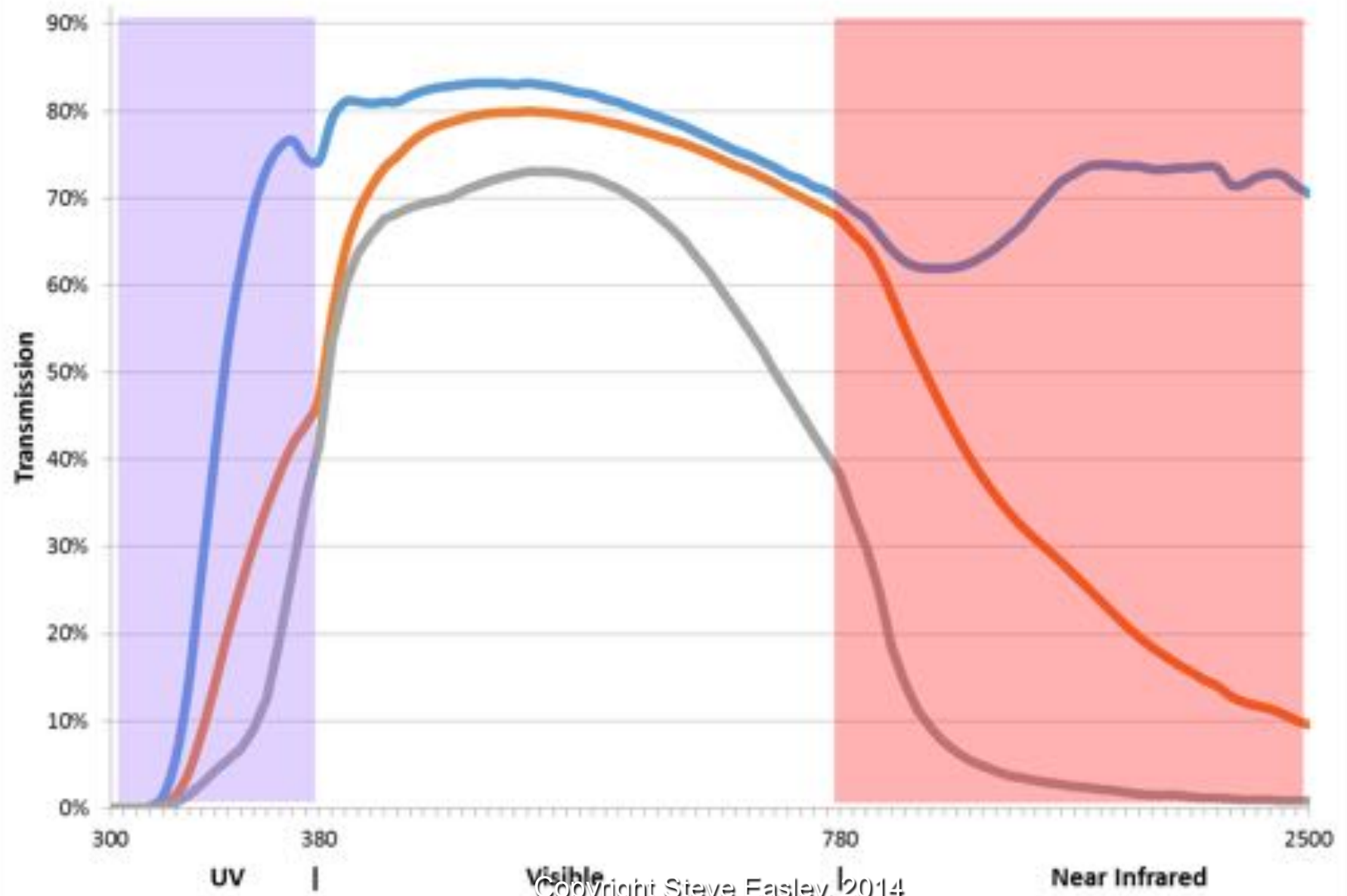
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High Solar Gain Low-E SHGC - 0.68



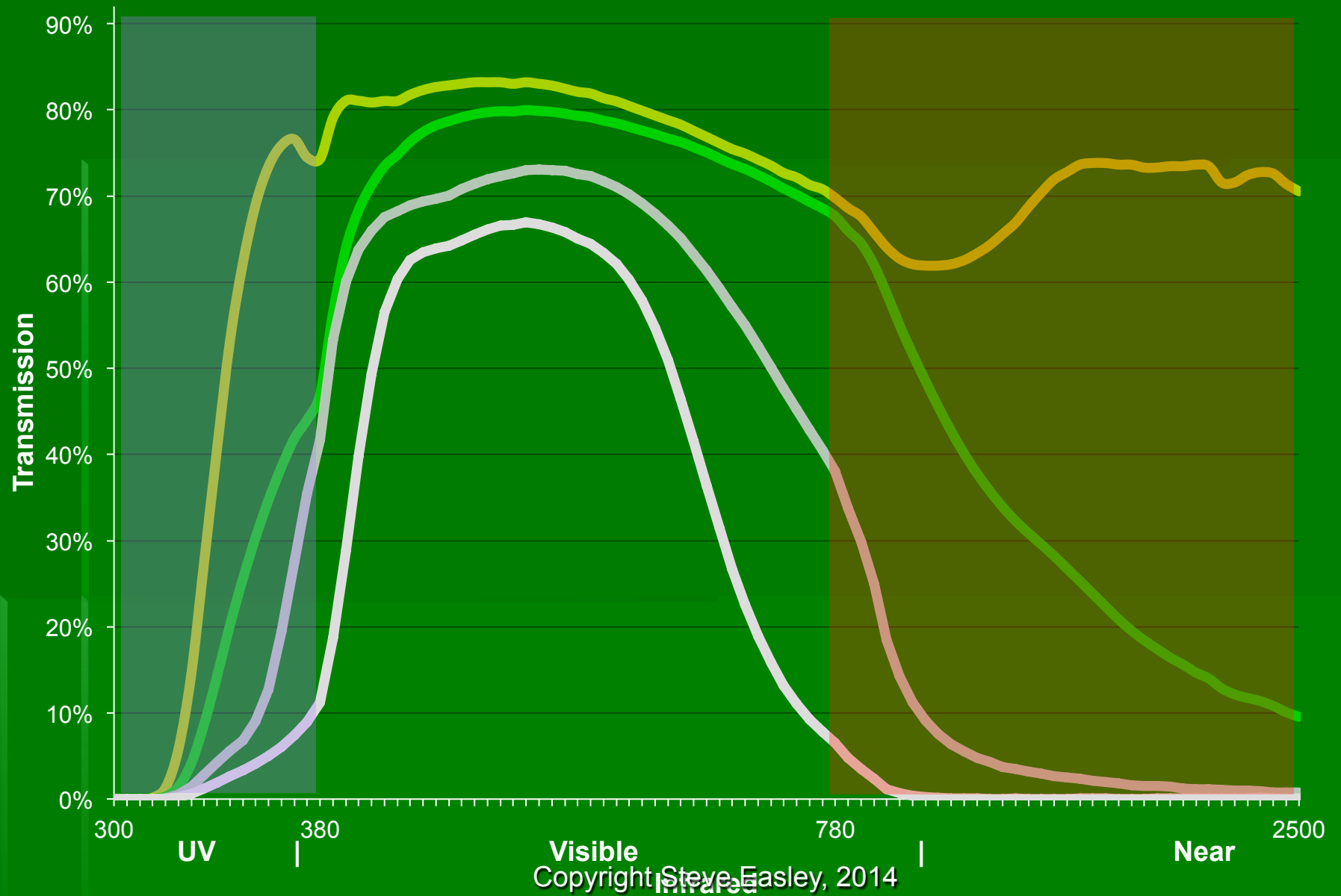
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Medium Solar Gain Low-E SHGC - 0.40



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Low Solar Gain Low-E SHGC - 0.27



IG UNIT

U-FACTOR

Double-Pane, Clear, Air

0.48

Double-Pane w/LoE³-366, Argon

0.24

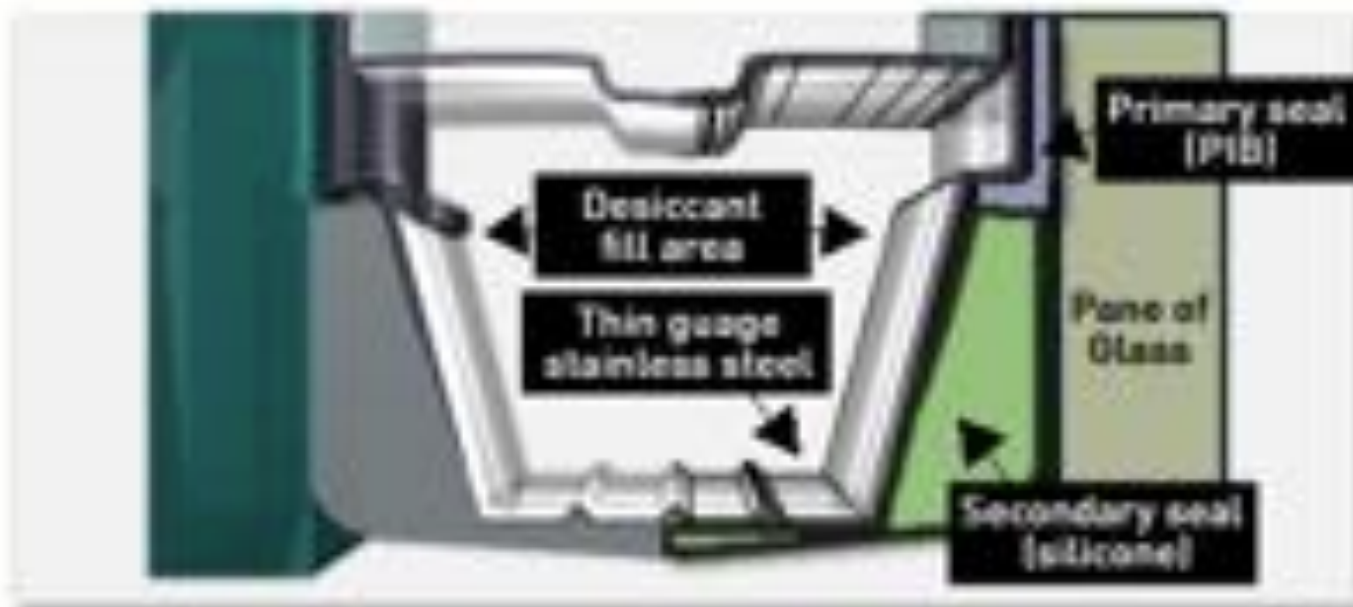
Double-Pane w/LoE³-366 and LoE-189, Air

0.23

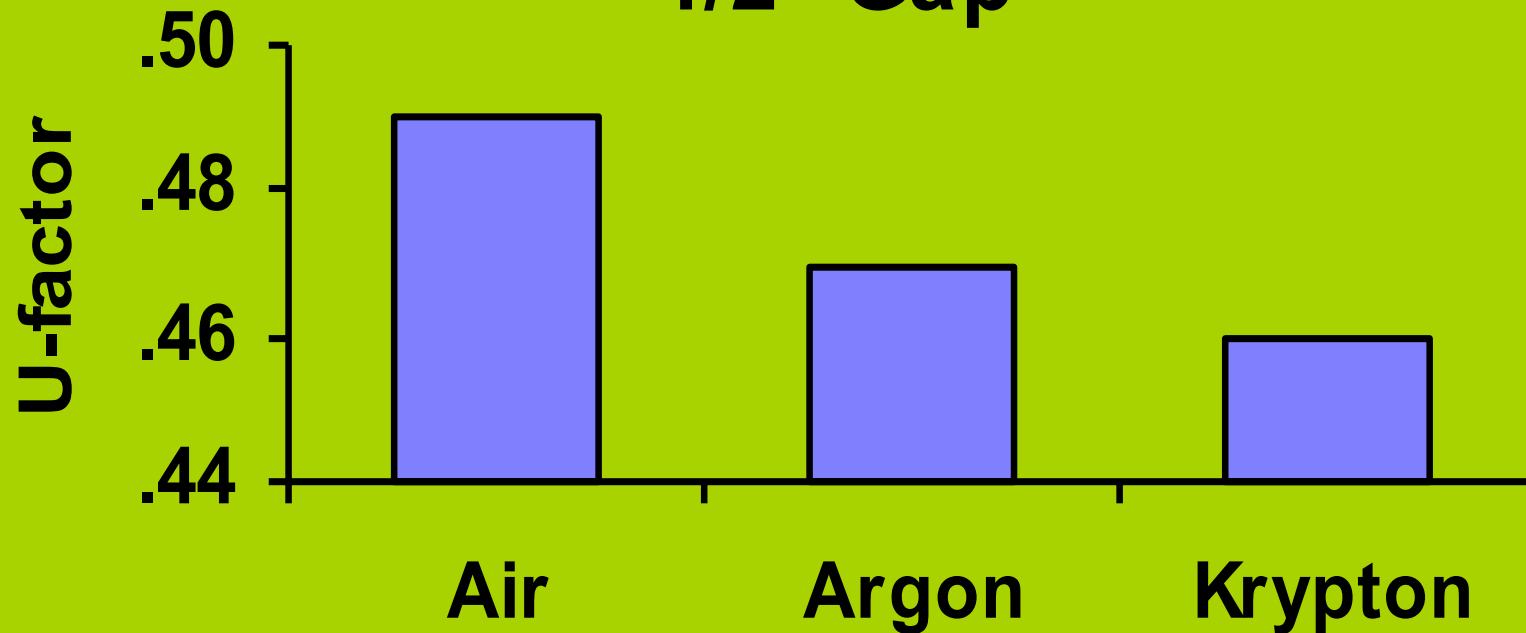
Double-Pane w/LoE³-366 and LoE-189, Argon

0.20

Cardinal Glass Spacer



Cavity Fills: Center of Glass U-factor 1/2" Gap



Building Enclosures Manage

- Water flow
- Air flow
- Heat flow & surfaces temps
- Moisture as a vapor
- Sound Control
- Fire separation

Thermal Performance Factors

- Framing factor 25%+ (“opaque whole” wall R-value frame & studs)
- Thermal bridging @ Frame and Studs
- Wind washing
- Gaps in insulation



Enclosure Thermal Performance

- Thermal performance is a 2 component process
- Conductive losses...Solution...Insulation
- Convective losses....Solution...Air sealing
- High performance enclosure = less loads
= lower costs...purchase, operation,
maintenance....forever

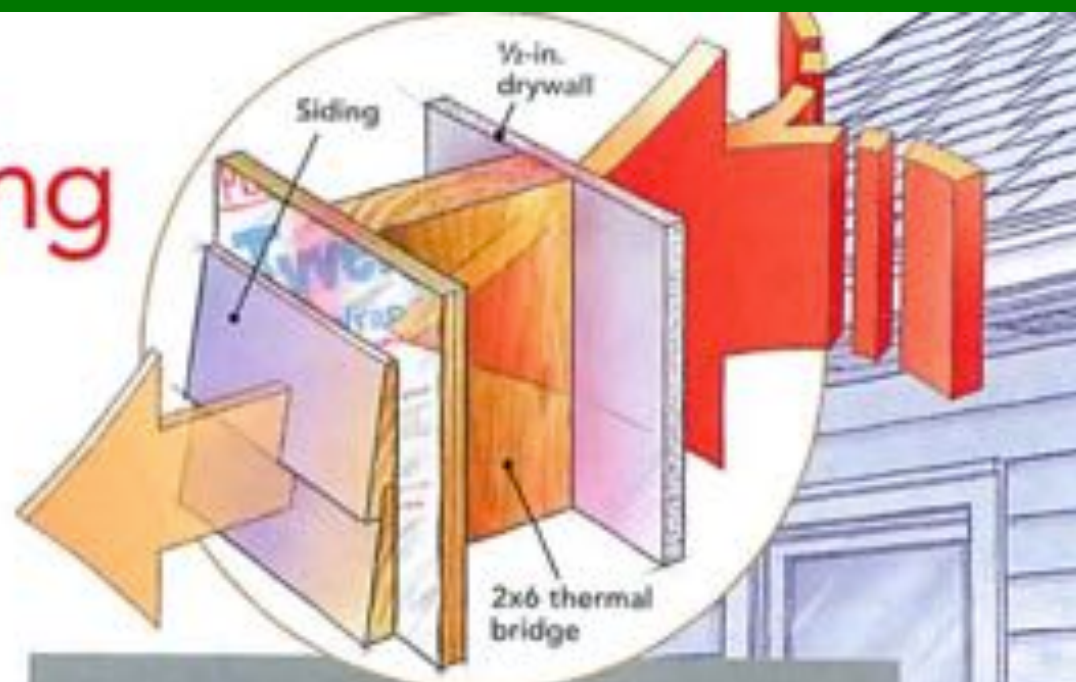
Thermal bridging

BY MARTIN HOLLADAY

On pp. 48-53, Jefferson Kolle takes an in-depth look at the Passive House standard. Houses certified by the Passive House Institute are so tight and so well insulated that they use 90% less energy than code-built homes. Many design practices must be included when building such a high-performance home. One requirement is significantly reducing thermal bridging, which is a major cause of heat loss. Before you reduce thermal bridging, though, you need to understand it. Here's how it works.

THERMAL BRIDGING REDUCES THE EFFECTIVENESS OF INSULATION

In a typical stick-frame house, lumber occupies 27% of the wall area, leaving little room for insula-



THE FLAW IN A CONVENTIONAL WALL

Studs are the weak thermal link in every framed wall. In the case of a wall cavity, heat travels through building components with a high thermal conductivity—framing members like studs, plates, and headers—at a greater rate than through building components with a low thermal conductivity, like insulation. Because conventional wall assemblies effectively link interior and exterior environments, they contribute to heat loss.

Typical Framing Factors @ Spacing -Wood

Table 4.2.2 Effective R-values for 2x4, 2x6, 2x8, and 2x10 stud walls, by framing factor.

Wood framing	Nominal fill insulation [R-value/inch (RSI/cm)]	Framing factor	
		25% (16 inches o.c.) [R-value (RSI)]	22% (24 inches o.c.) [R-value (RSI)]
2x4	R-3.4/inch [R-12] (0.24/cm [RSI 2.1])	10.7 (1.9)	11.0 (1.9)
	R-4.0/inch [R-14] (0.28/cm [RSI 2.5])	11.5 (2.0)	11.8 (2.1)
2x6	R-3.4/inch [R-12] (0.24/cm [RSI 2.1])	15.5 (2.7)	16.1 (2.8)
	R-4.0/inch [R-14] (0.28/cm [RSI 2.5])	16.6 (2.9)	17.4 (3.1)
2x8	R-3.4/inch [R-25] (0.24/cm [RSI 4.4])	19.6 (3.5)	21.1 (3.7)
	R-4.0/inch [R-29] (0.28/cm [RSI 5.1])	21.1 (3.7)	22.8 (4.0)
2x10	R-3.4/inch [R-25] (0.24/cm [RSI 4.4])	24.4 (4.3)	25.4 (4.5)
	R-4.0/inch [R-29] (0.28/cm [RSI 5.1])	26.3 (4.8)	27.5 (4.8)

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Typical Framing Factors @ Spacing- Steel

Impact of Thermal Bridging
on Effective Installed R-Value for Steel-Framed Walls

		Actual Cavity Depth, inch	Rated R-Value	Effective R-Value
16" O.C.	3.5 in. depth		R-11	R-5.5
			R-13	R-6.0
			R-15	R-6.4
	6.0 in. depth		R-19	R-7.1
			R-21	R-7.4
	24" O.C.	3.5 in. depth		R-11
			R-13	R-7.2
			R-15	R-7.8
6.0 in. depth			R-19	R-8.6
			R-21	R-9.0

Source: TABLE A3.3 Assembly U-Factors for Walls From ASHRAE 90.1-2007
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Framing Factors

Table 3 : R-values for analyzed wall systems

Case	Description	Whole Wall R-value	Rim Joist	Clear Wall R-value	Top Plate	Framing Fraction
1a	2x6 AF, 24"oc, R19FG + OSB	15.2	12.3	16.1	12.5	16%
1aii	2x6, 16"oc, R19FG + OSB (25%ff)	13.7	12.3	14.1	12.5	25%
1b	2x4 AF, 24"oc, R13FG + OSB	11.1	9.8	11.5	9.8	16%
1bii	2x4, 16"oc, R13FG + OSB (25%ff)	10.0	9.8	10.1	9.8	25%
2a	2x6 AF, 24"oc R19FG + 1" R5 XPS	20.2	18.5	20.6	20.3	16%
2b	2x6 AF, 24"oc R19FG + 4" R20 XPS	34.5	29.0	35.6	35.4	16%
3	2x6 AF, 24"oc, 2x3 R19+R8 FG	21.5	13.4	23.5	18.4	16%
4	Double stud wall 9.5" R34 cellulose	30.1	14.4	33.5	28.8	
5	Truss wall 12" R43 cellulose	36.5	18.6	40.5	34.4	
6a	SIPs (3.5" EPS)	14.1	12.3	14.5	10.6	
6b	SIPs (11.25" EPS)	36.2	14	41.6	28.2	
7a	ICF - 9" foam ICF (5" EPS)	20.2		20.2		
7b	ICF - 15" foam ICF (5" EPS)	20.6		20.6		
7c	ICF - 14" cement woodfiber ICF with Rockwool	17.4		17.4		
8a	2x6 AF, 24" o.c., 5" 2 pcf R29 SPF, OSB	19.1	13.6	20.3	19.5	16%
8b	2x6 AF, 24" o.c., 5.5" R21 0.5 pcf SPF, OSB	16.5	13.1	17.2	16.6	16%
9	2x6 AF, 24"oc, 2" SPF and 3.5" cellulose	17.5	13.2	18.4	17.7	16%
10	Double stud with 2" 2.0 pcf foam, 7.5" cell.	32.4	15.9	36.2	28.5	
11	Offset frame wall with ext. spray foam	37.1	18.8	40.6	41.9	16%
12	2x6 AF, 24"oc, EIFS - 4" EPS	30.1	23.8	31.4	31.1	16%

*AF - Advanced Framing

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Framing Factors

Table 303.4.1.3. Default Framing Fractions for Enclosure Elements

Enclosure Element	Frame Spacing (in o.c.)	Default Frame Fraction (% area)
Walls (standard):		
@16" o.c.	16	23%
@24" o.c.	24	20%
Walls (advanced):		
@16" o.c.	16	19%
@24" o.c.	24	16%
Structural Insulated Panels	48	10%
Floors (standard):		
@16" o.c.	16	13%
@24" o.c.	24	10%
Floors (advanced):		
@16" o.c.	16	11%
@24" o.c.	24	8%
Ceilings (standard trusses):		
@16" o.c.	16	14%
@24" o.c.	24	11%
Ceilings (advanced trusses – "raised heel"):		
@16" o.c.	16	10%
@24" o.c.	24	7%
Ceilings (conventional framing):		
@16" o.c.	16	13%
@24" o.c.	24	9%

Typical Framing Factors –Wood + CI

Table 4.1.2 Effective R-values for assembly of wood-frame walls with R-5/inch exterior split insulation (rigid XPS) and screw fasteners (#12 at 12x16 inches o.c.) through the insulation, by thickness of insulation. Stud wall consists of standard framing at 16 inches o.c. (25% framing factor) with insulation as shown.

Wood framing	Nominal stud-space insulation [R-value (RSI)]	Exterior insulation						
		None [R-value (RSI)]	R-5 (1 inch) [R-value (RSI)]	R-10 (2 inches) [R-value (RSI)]	R-15 (3 inches) [R-value (RSI)]	R-20 (4 inches) [R-value (RSI)]	R-25 (5 inches) [R-value (RSI)]	R-30 (6 inches) [R-value (RSI)]
2x4	R-12 (2.1)	10.7 (1.9)	15.9 (2.8)	20.6 (3.6)	25.1 (4.4)	29.6 (5.2)	33.9 (6.0)	38.1 (6.7)
	R-14 (2.5)	11.5 (2.0)	16.7 (2.9)	21.4 (3.8)	25.9 (4.6)	30.4 (5.4)	34.7 (6.1)	38.9 (6.9)
2x6	R-19 (3.3)	15.5 (2.7)	20.7 (3.6)	25.5 (4.5)	29.9 (5.3)	34.4 (6.1)	38.7 (6.8)	43.0 (7.6)
	R-22 (3.9)	16.6 (2.9)	21.9 (3.9)	26.6 (4.7)	31.1 (5.5)	35.6 (6.3)	39.9 (7.0)	44.1 (7.8)

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[Courtesy fp innovations](#)

Conventional Framing

16"o.c. Member Spacing

CONVENTIONAL FRAMING:

2x4 Studs at 16" o.c., Double top plate, 3-Stud corners,
2-Stud 'T' junctions, Double 2x12 header on jack studs,
Redundant cripples at ends of window sill plate



Advanced Framing

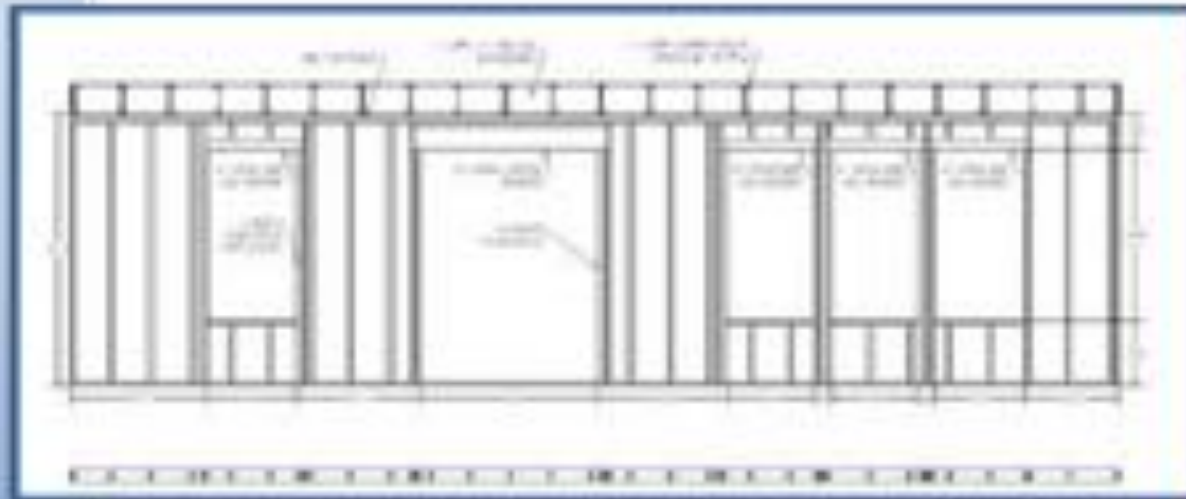
24" o.c. Member Spacing

ADVANCED FRAMING:

2x6 Studs at 24" o.c., Single top plate, 2-Stud corners,
Ladder junctions, Wood structural panel headers,
Single studs at sides of openings, Redundant cripples omitted

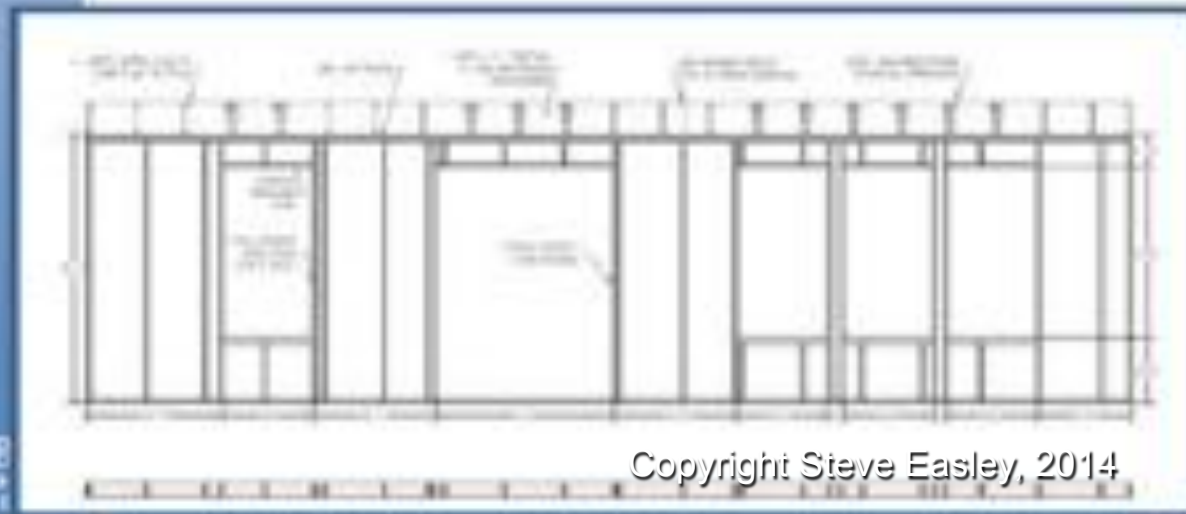


Framing: Advanced Design



Typical Wall

- Stud Count: 52
- Framing: 20%



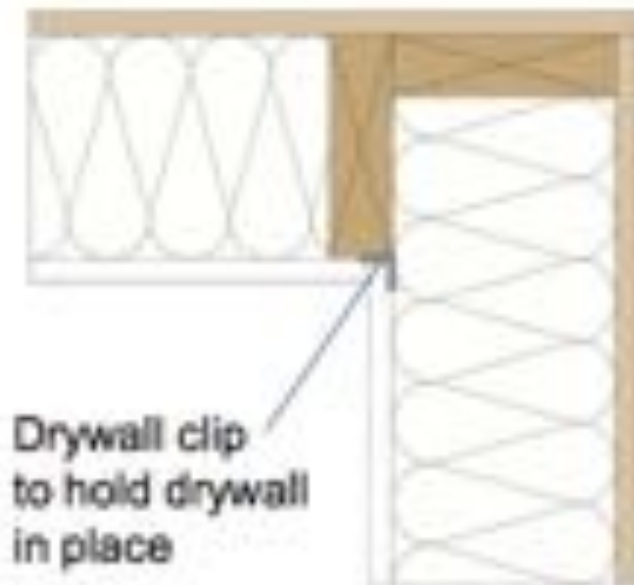
Energy Efficient Wall

- Stud Count: 37
- Framing: 13%

Two-stud Corners

Two-stud Corner (with Drywall Clips)

Outside corner

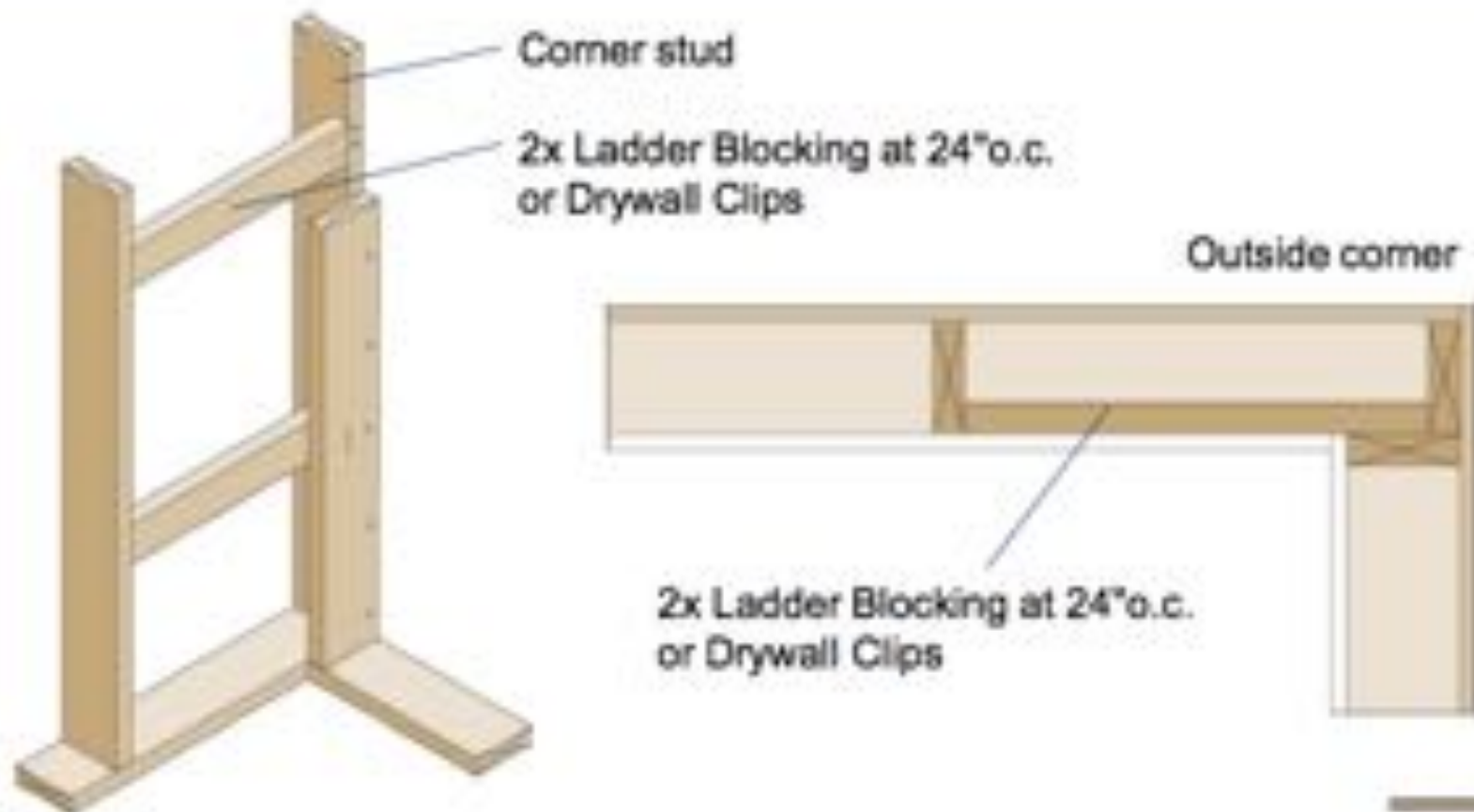


Alternatives 2012 IRC, Figure R602.3(2) FRAMING DETAILS

Note: A third stud and/or partition backing stud shall be permitted to be omitted through the use of wood back-up cleats, metal drywall clips, or other approved devices that will serve as adequate backing for facing materials.

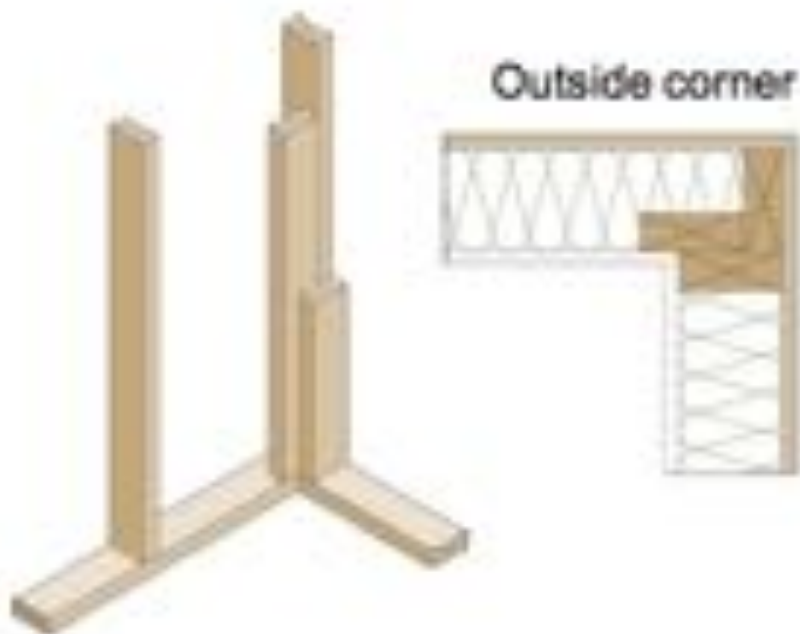


Two-stud Corners

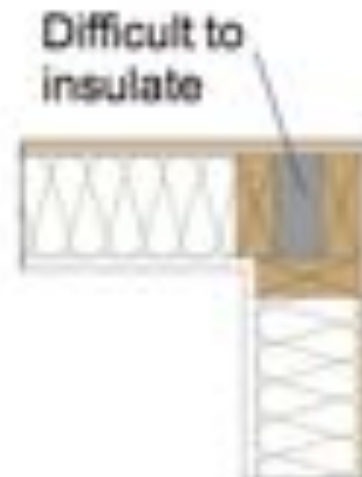


Three-stud Corners

Insulated Three-stud Corner (California Corner)

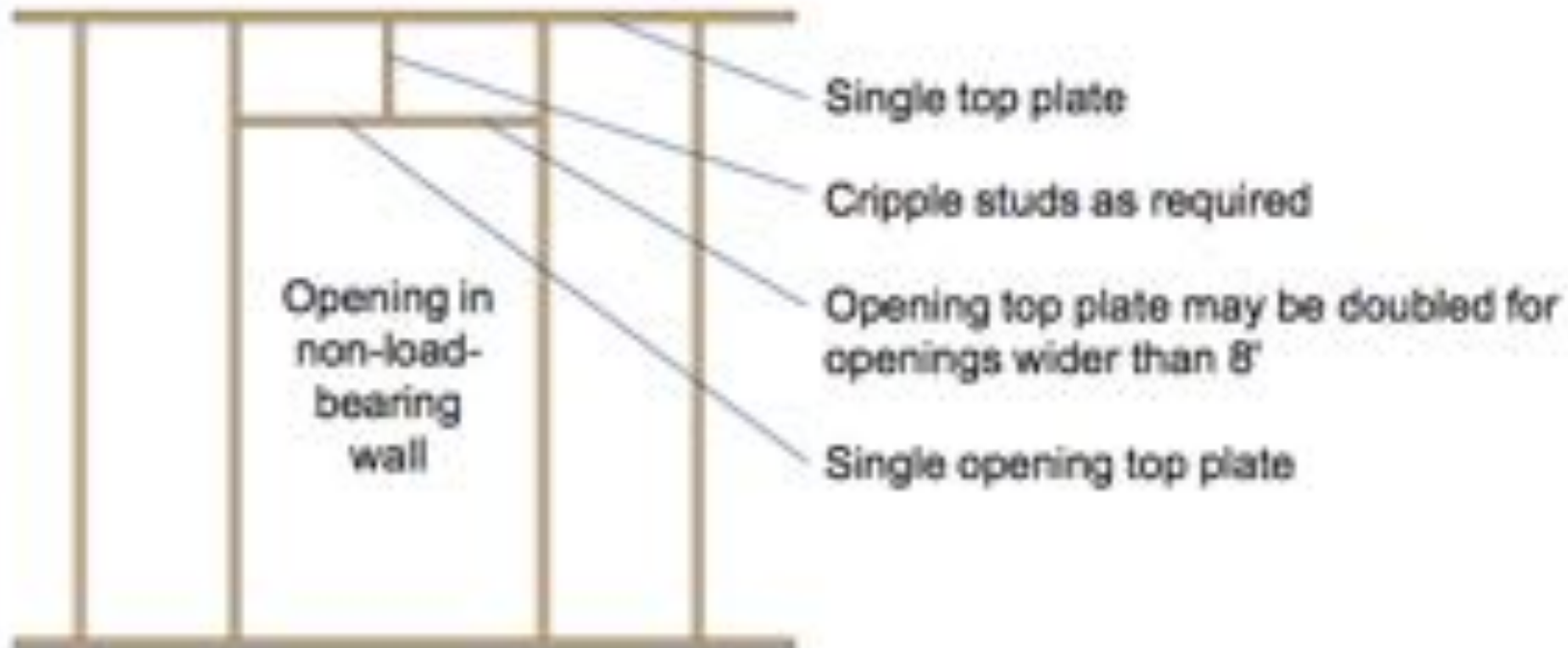


Traditional Corner

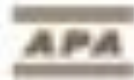


Openings Non-Load-Bearing Walls

Conventional Headers Not Required



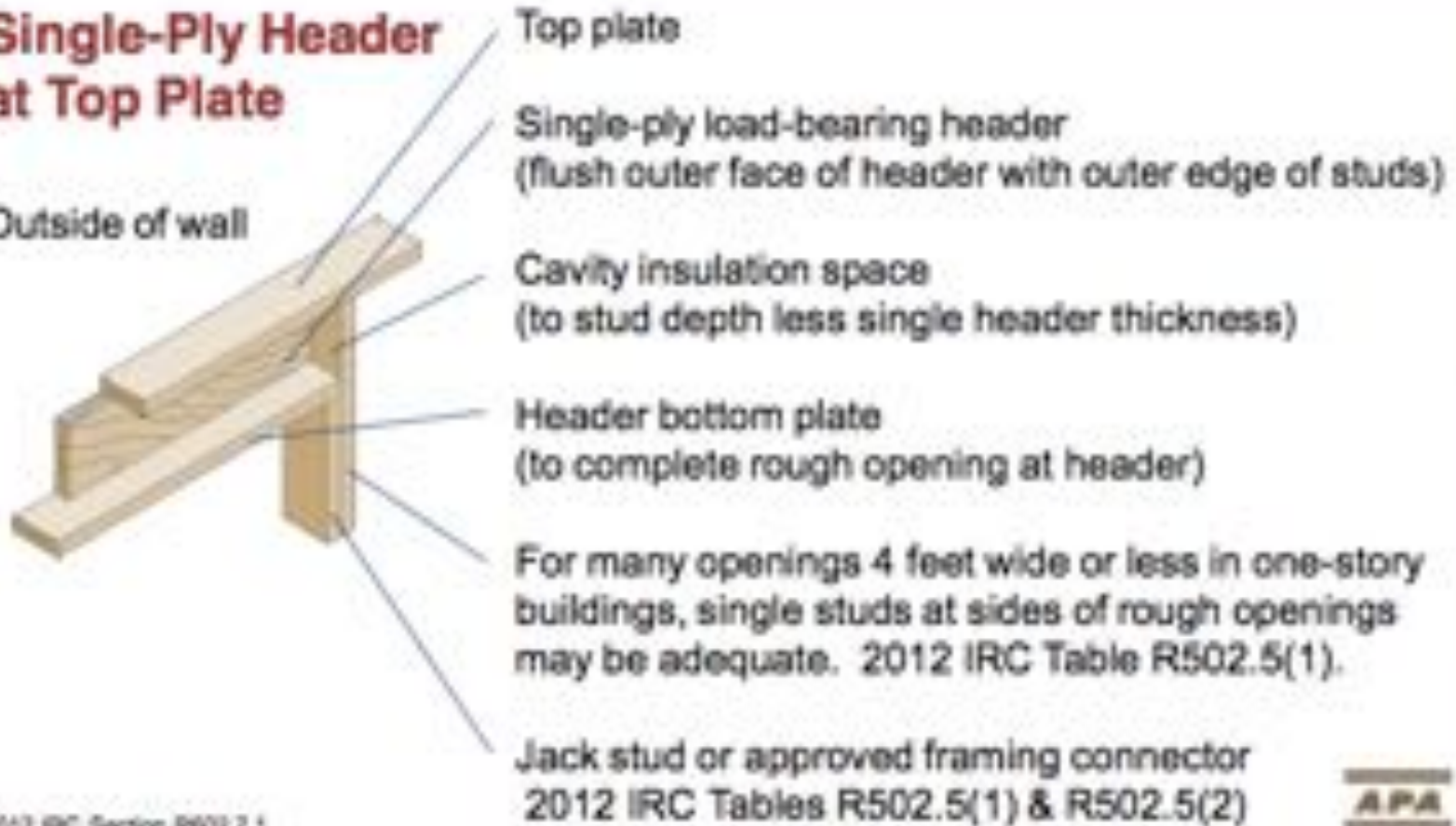
Note: Use jack studs as required.



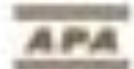
Engineered Wood & Lumber Headers

Single-Ply Header at Top Plate

Outside of wall

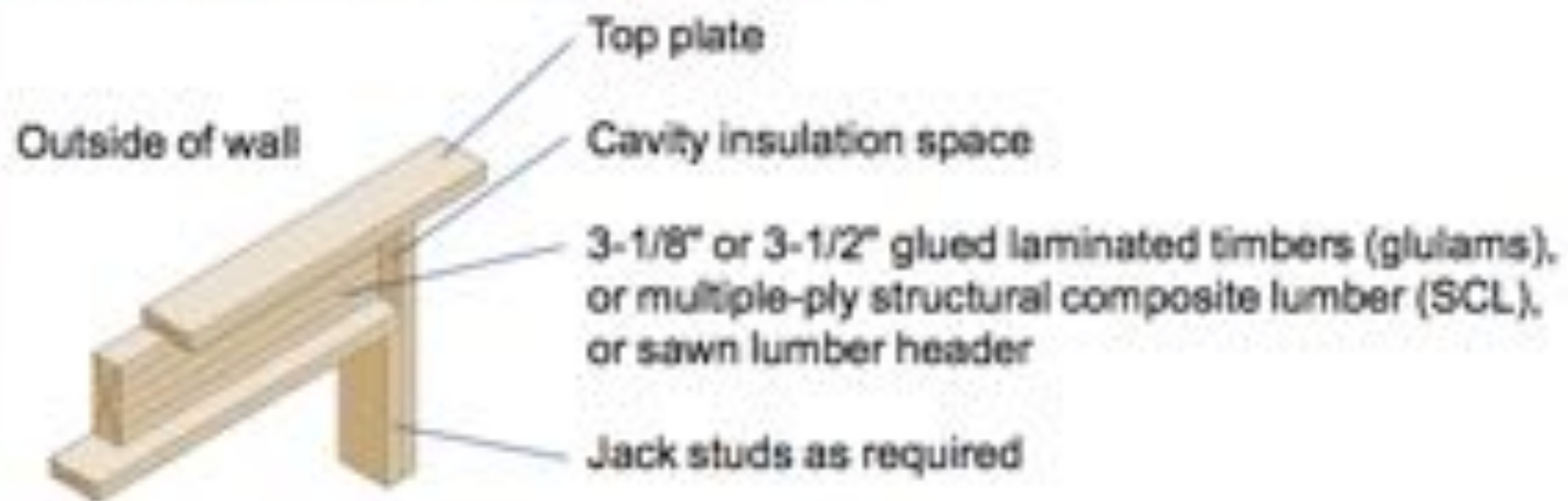


2012 IRC Section R602.7.1

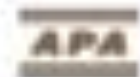


Engineered Wood & Lumber Headers

Large Opening Single Headers



2012 IRC Section R602.7.1

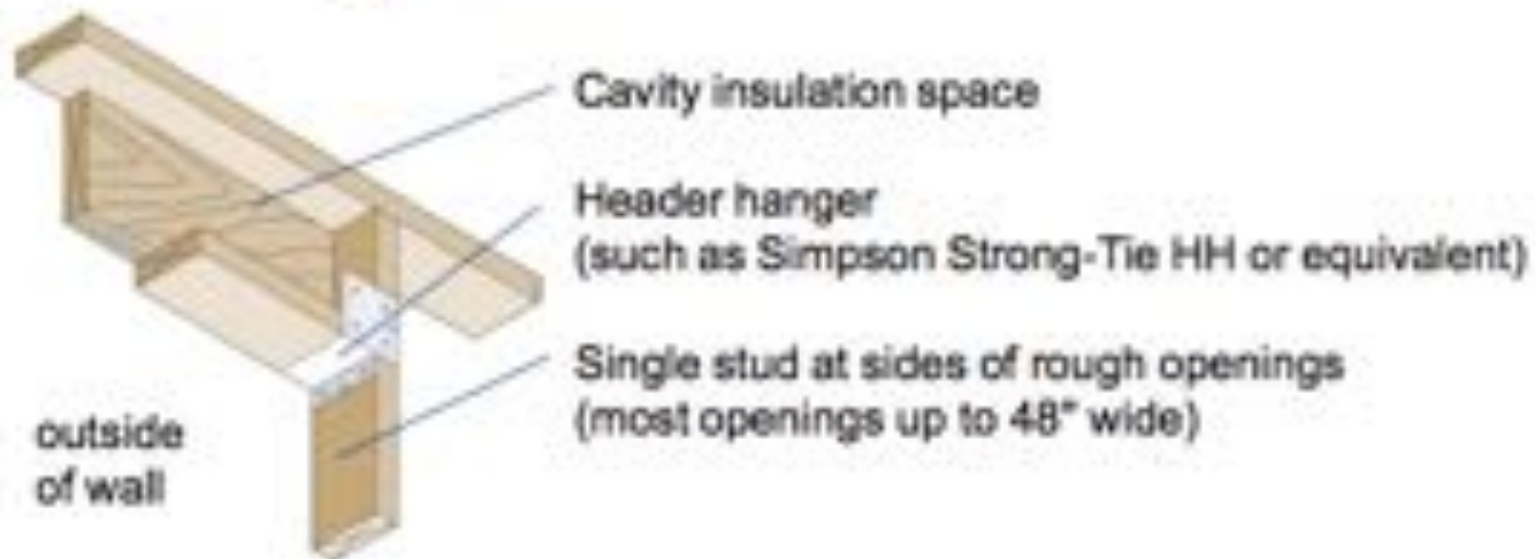


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Engineered Wood & Lumber Headers

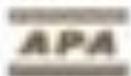
Approved Framing Connector Option

Single or Double-ply Headers



Alternate Header Connection: Where the number of required jack studs equal one, the header is permitted to be supported by an approved framing anchor attached to the full-height wall stud and to the header.

2012 IRC Section R602.7.1



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Single Top Plate Connections



Longitudinal Top Plate Splice

Prescriptive Connection

**3" x 12" x 0.036" Galvanized steel plate
12- 8d (2-1/2" x 0.113") Nails each side***

*Plate size and number of fasteners required is greater than 2009 International Residential Code.

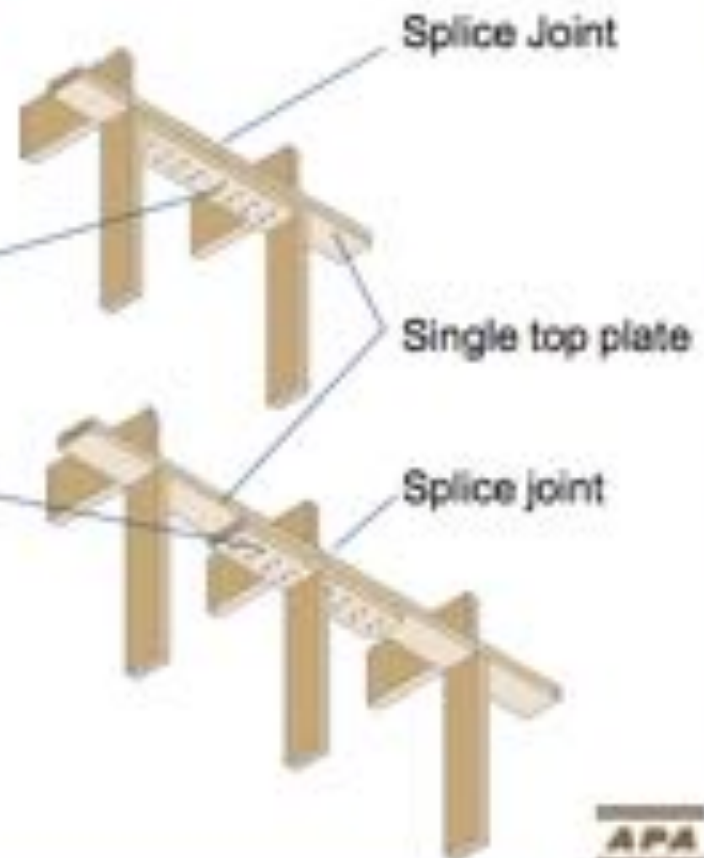
Exception: A single top plate may be installed in stud walls, provided the plate is adequately tied at joints, corners and intersecting walls by a minimum 3-inch-by-6-inch by a 0.036-inch-thick (76 mm by 152 mm by 0.914 mm) galvanized steel plate that is nailed to each wall or segment of wall by six 8d nails on each side, provided the rafters or joists are centered over the studs with a tolerance of no more than 1 inch (25 mm).

Single Top Plate Connections

Longitudinal Top Plate Splice

Alternate Connection:
Wood Splice

8-16d (3-1/2" x 0.135") nails
each side of splice.



Single Top Plate Connections

Corner Framing

Prescriptive Connection

3" x 6" x 0.036" galvanized steel plate
6-8d (2-1/2" x 0.113") nails each side
2012 IRC, Section R602.3.2

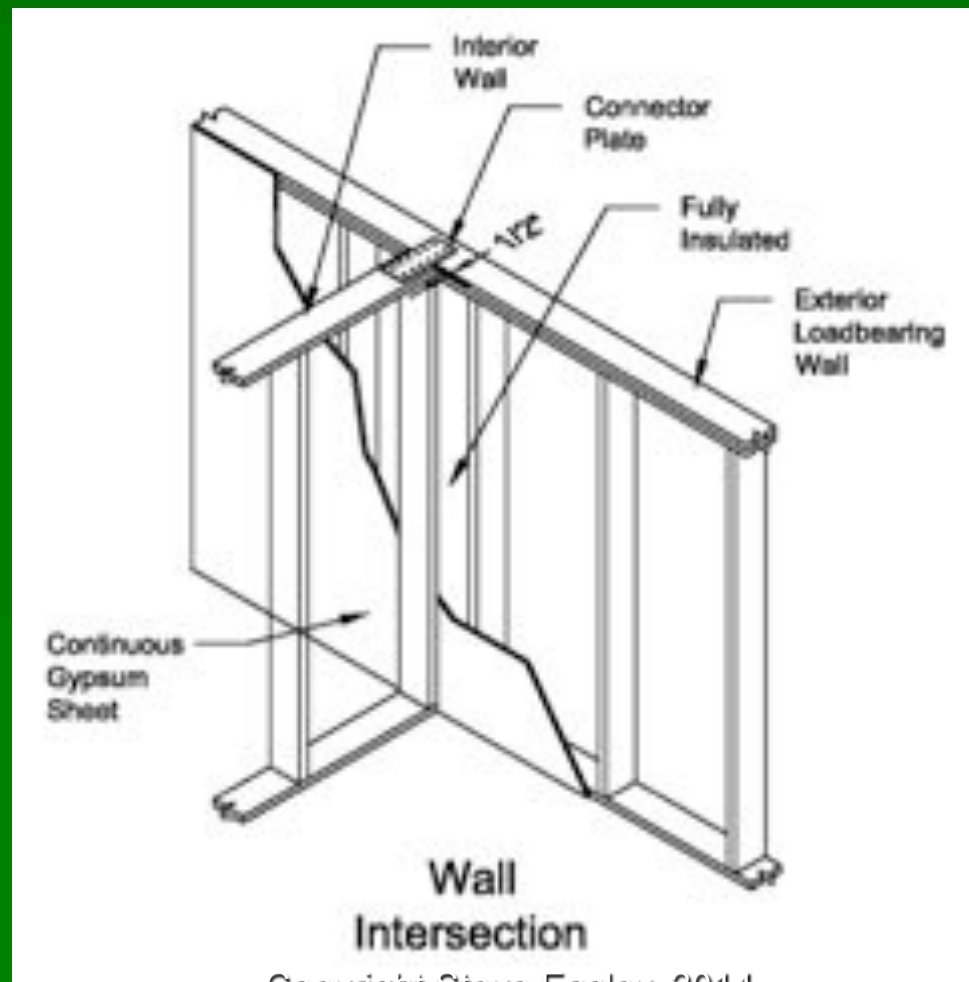


Alternate Connection

2x6 lumber splice
2-10d (3" x 0.128") nails each side
2012 IRC, Table R602.3(1), Item 19



Offset Interior Wall Intersection



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Single Top Plate Connections

Intersecting Wall Connection

Prescriptive Connection

3" x 6" x 0.036" galvanized steel plate
6-8d (2-1/2" x 0.113") nails each side
2012 IRC, Section R602.3.2

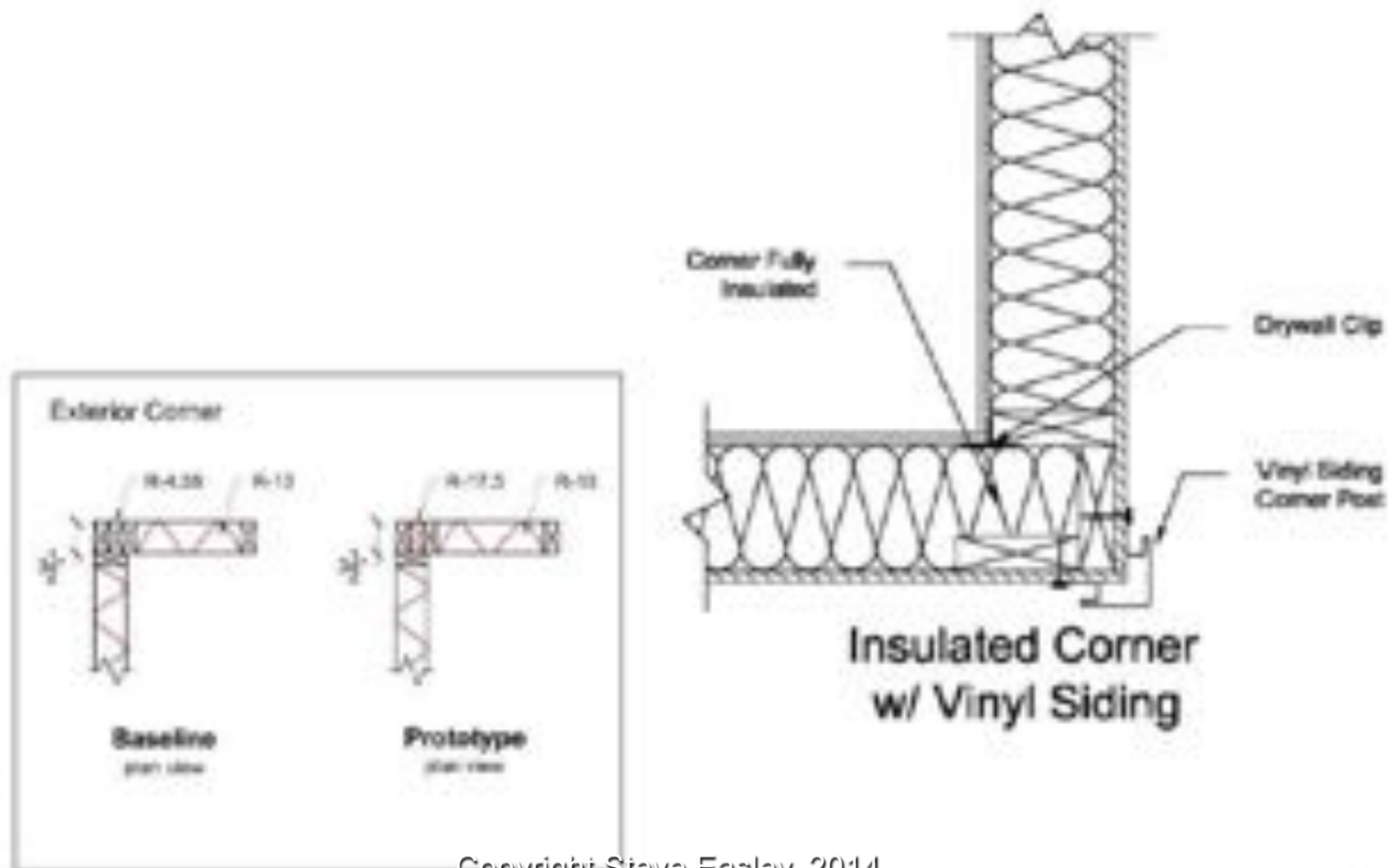


Alternate Connection

2x6 lumber splice
2-10d (3" x 0.128") nails each side
2012 IRC, Table R602.3(1), Item 19



Insulated 3-Stud Corner



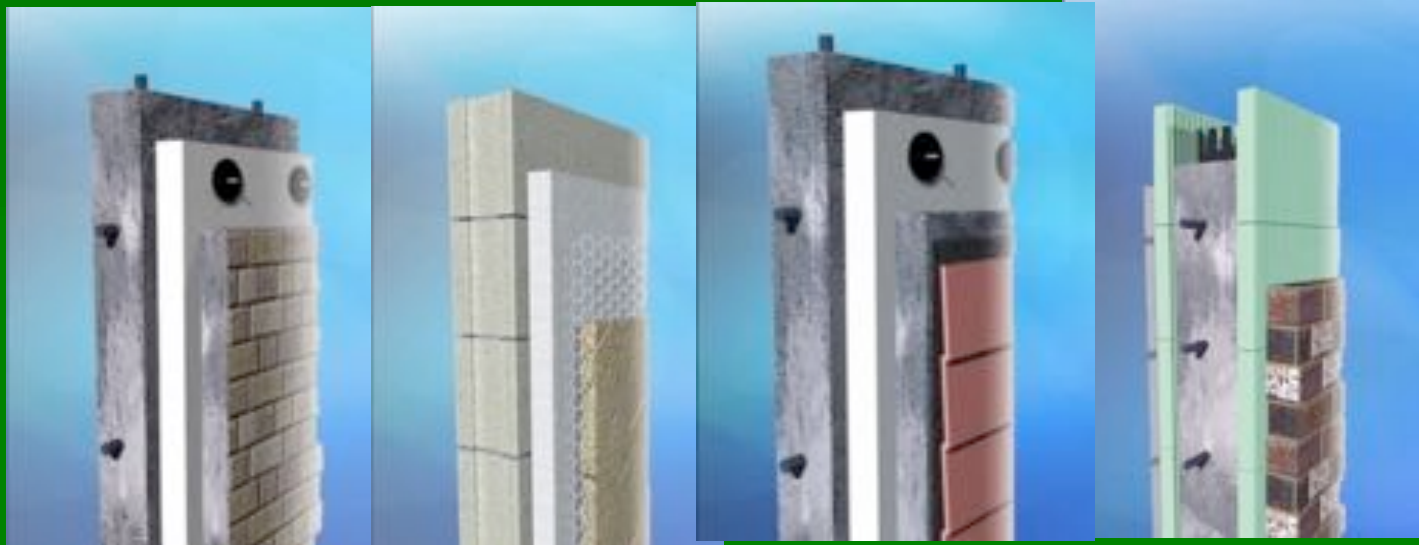
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A photograph of a modern, multi-story building at dusk. The building features a prominent concrete wall system with large glass windows and balconies. The interior lights are on, and the sky is a mix of orange, pink, and blue. In the foreground, there is a curved concrete wall and some landscaping. The text "Concrete Wall Systems" is overlaid in green on a white background.

Concrete Wall Systems

Above Grade Concrete Wall Systems

- Conventionally Formed
- Concrete Masonry
- Precast Concrete
- Insulating Concrete Forms

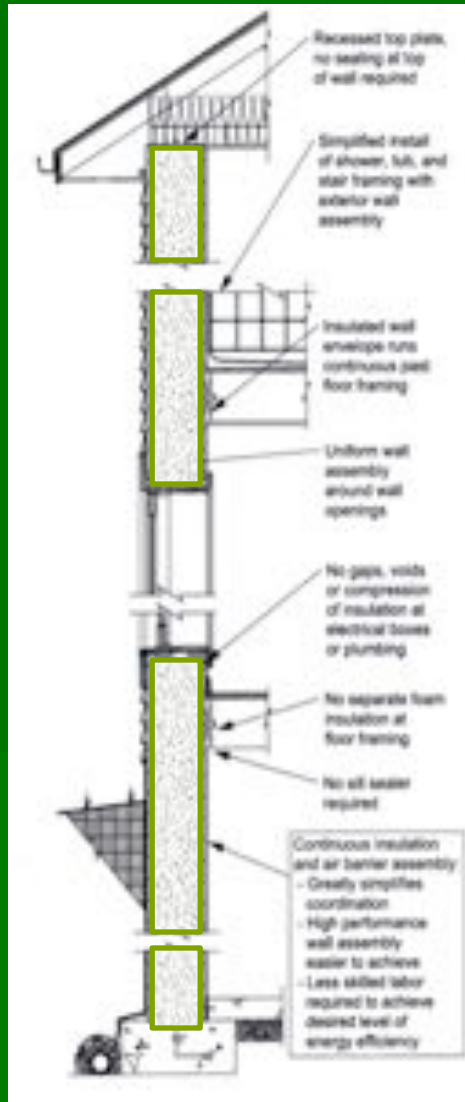


Foundations

- All four systems commonly used for below grade foundations



Above Grade Concrete Wall Assembly



- Monolithic Wall
- Air Barrier/Thermal Barrier
 - Contiguous
 - Continuous
- Fewer gaps
- Fewer seams
- Less demand on labor
 - Simpler high performance assembly

Above Grade Concrete Wall Systems

- **Conventionally Formed**
 - Site Assembled
 - Removed once concrete hardens
 - Clips/pins for insulation
 - Form liners for finish textures



Integral Insulation Systems



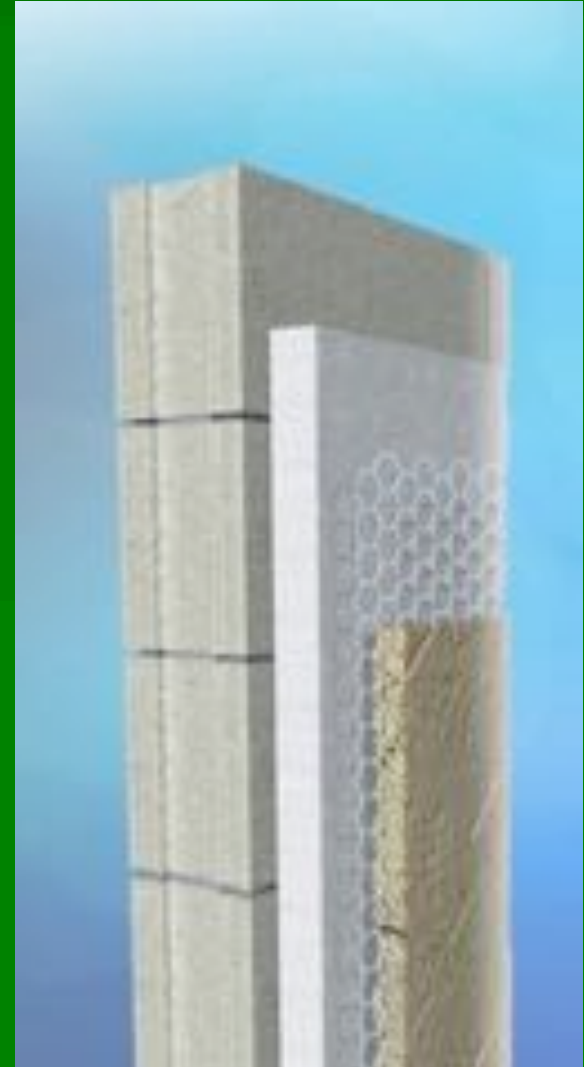
Sandwich Wall



Exterior

Above Grade Concrete Wall Systems

- **Concrete Masonry**
 - Long used for residential construction
 - Insulation within cores or outside surface
 - Prefinished textures, colors
 - Site applied finishes



Above Grade Concrete Masonry



Concrete Masonry Systems

- Individual units (block) assembled with mortar by masons
- Reinforcement and grout can be used in cavities to make system taller, thinner, stronger

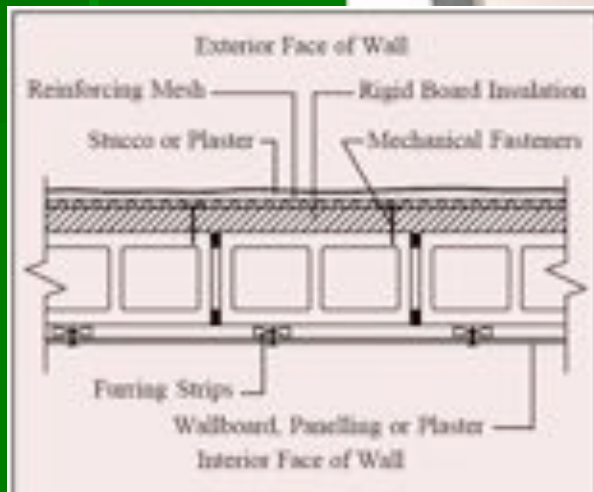
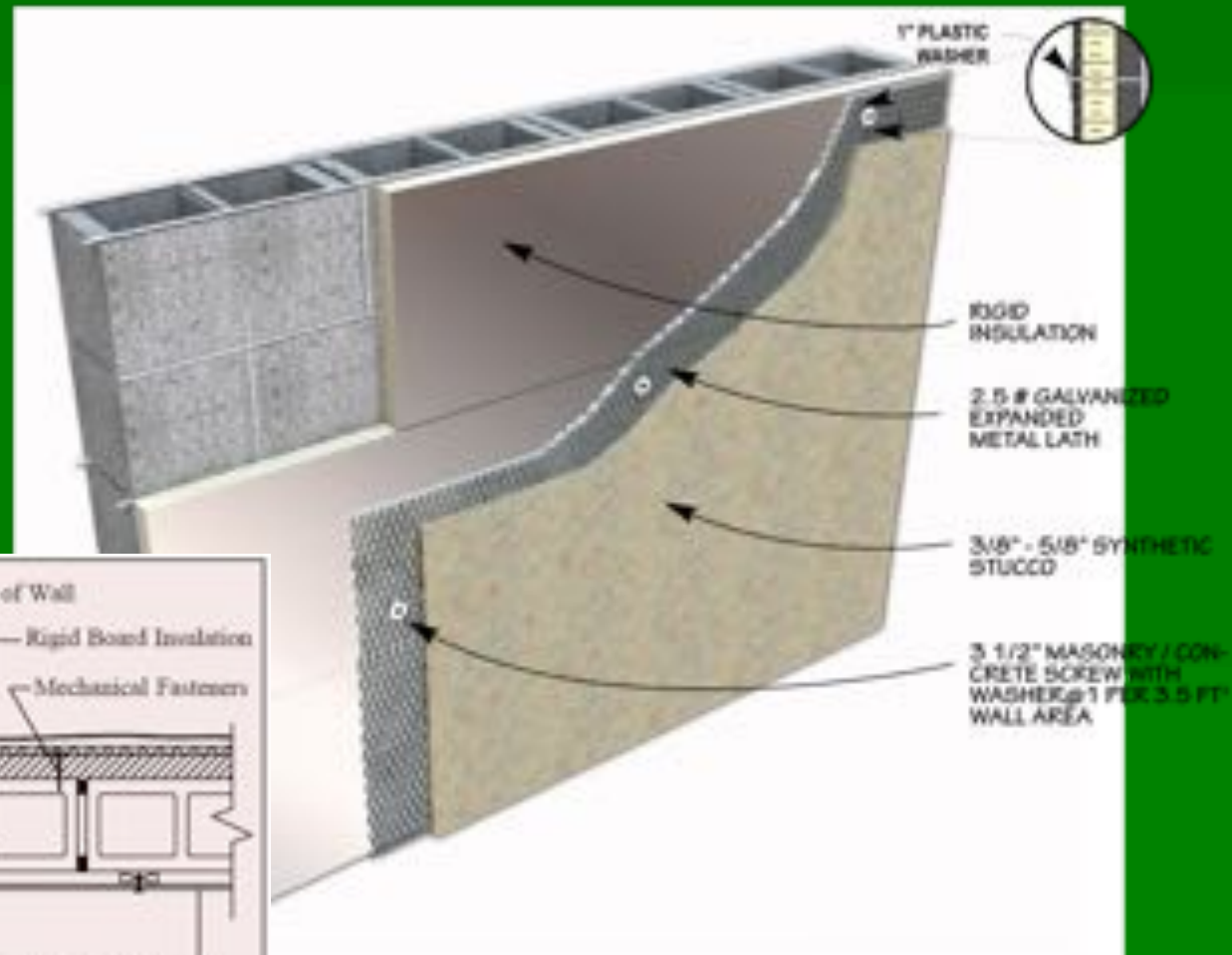


Masonry Systems (CMUs)

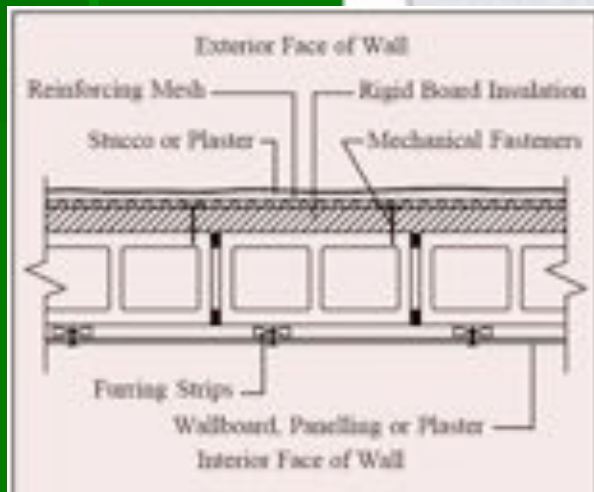
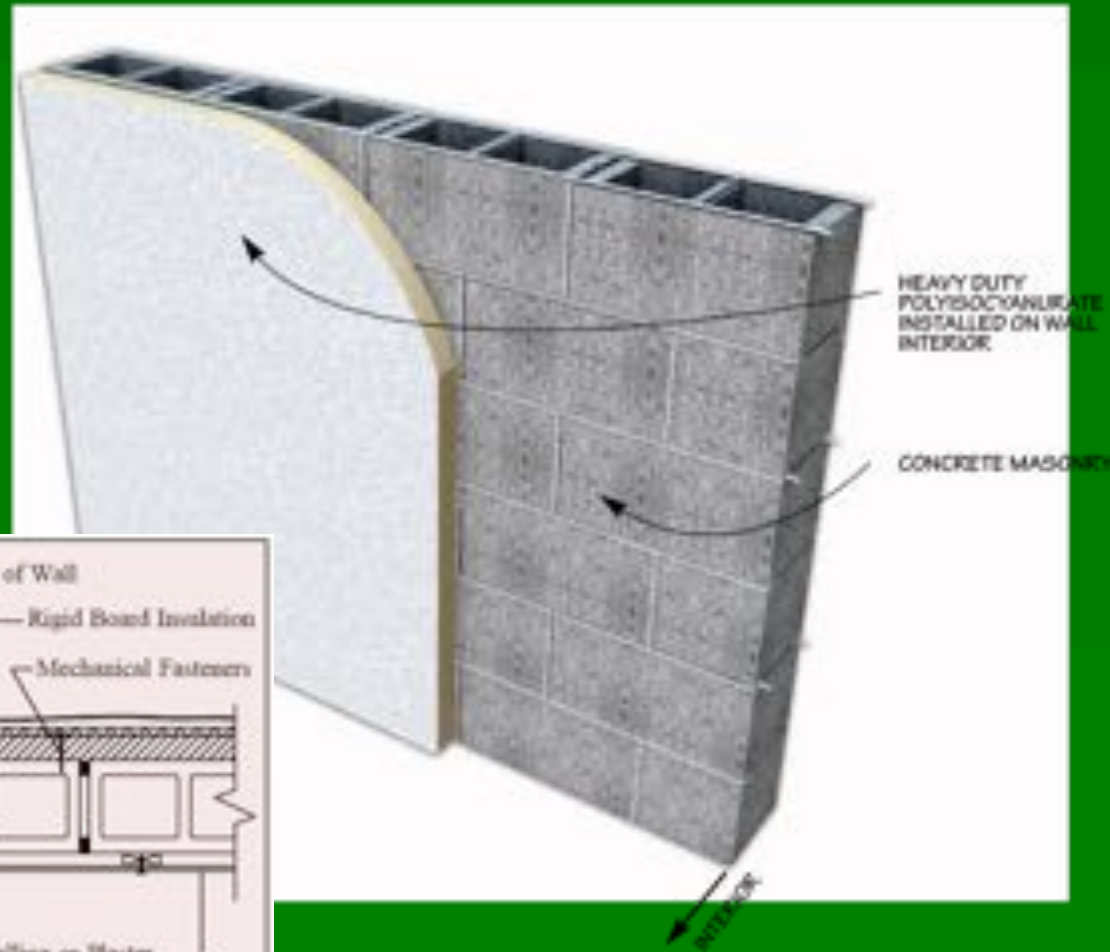
- Split Face
- Ground Face
- Ribbed
- Sandblasted
- Glazed
- Offset Face
- Color



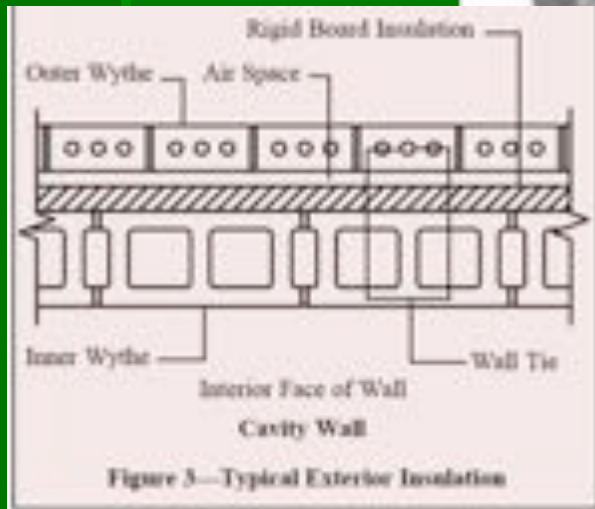
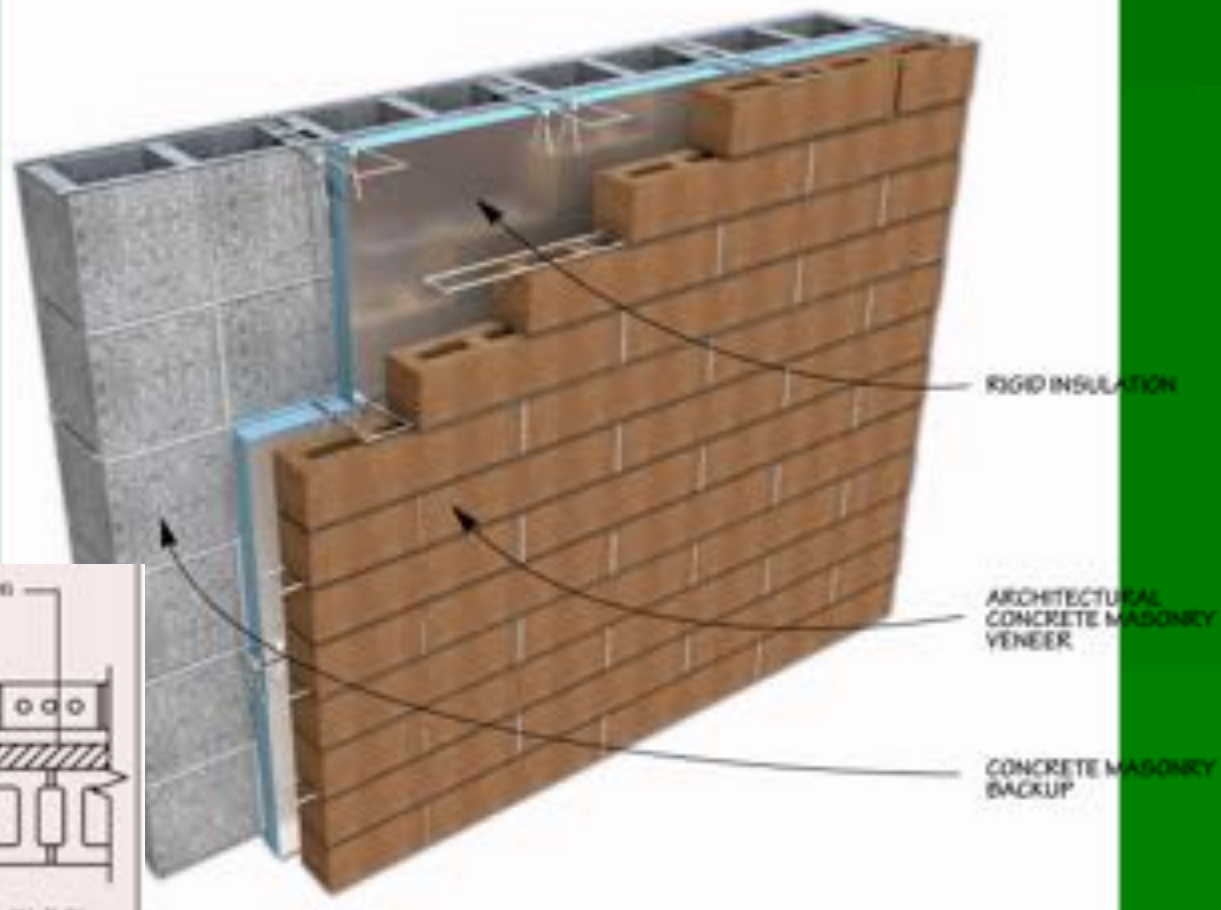
Continuous Insulation Strategies



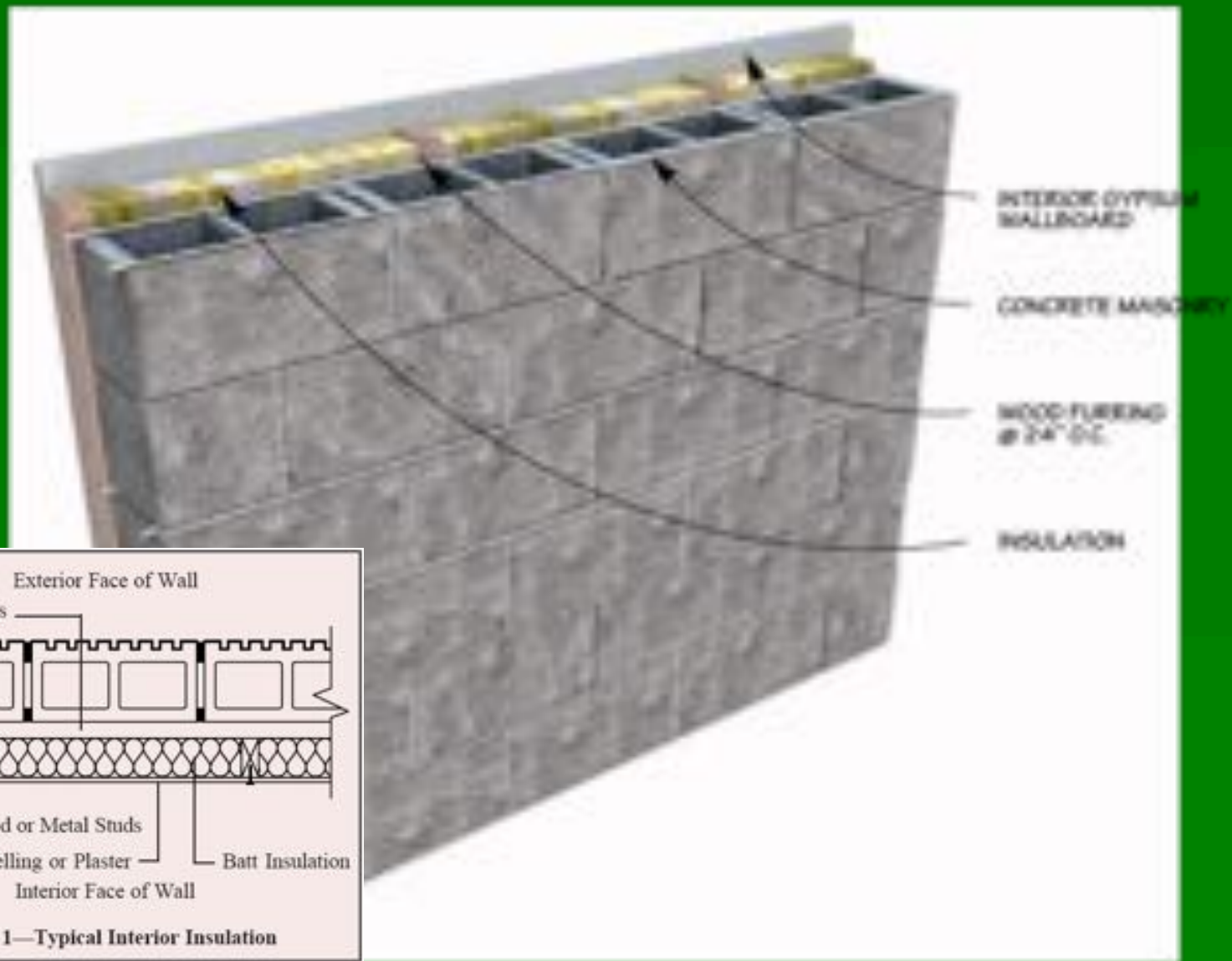
Continuous Insulation Strategies



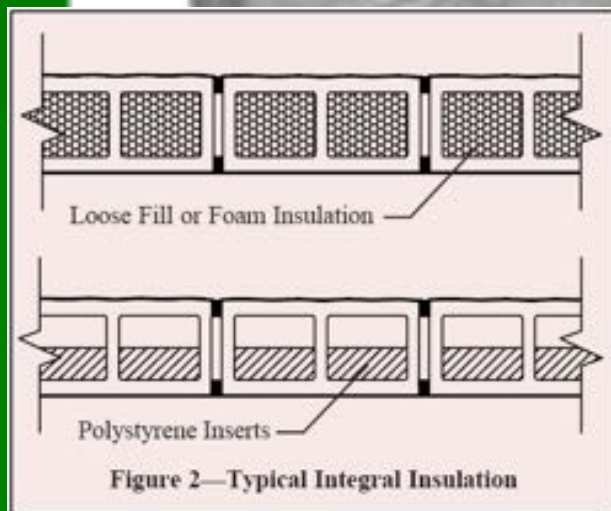
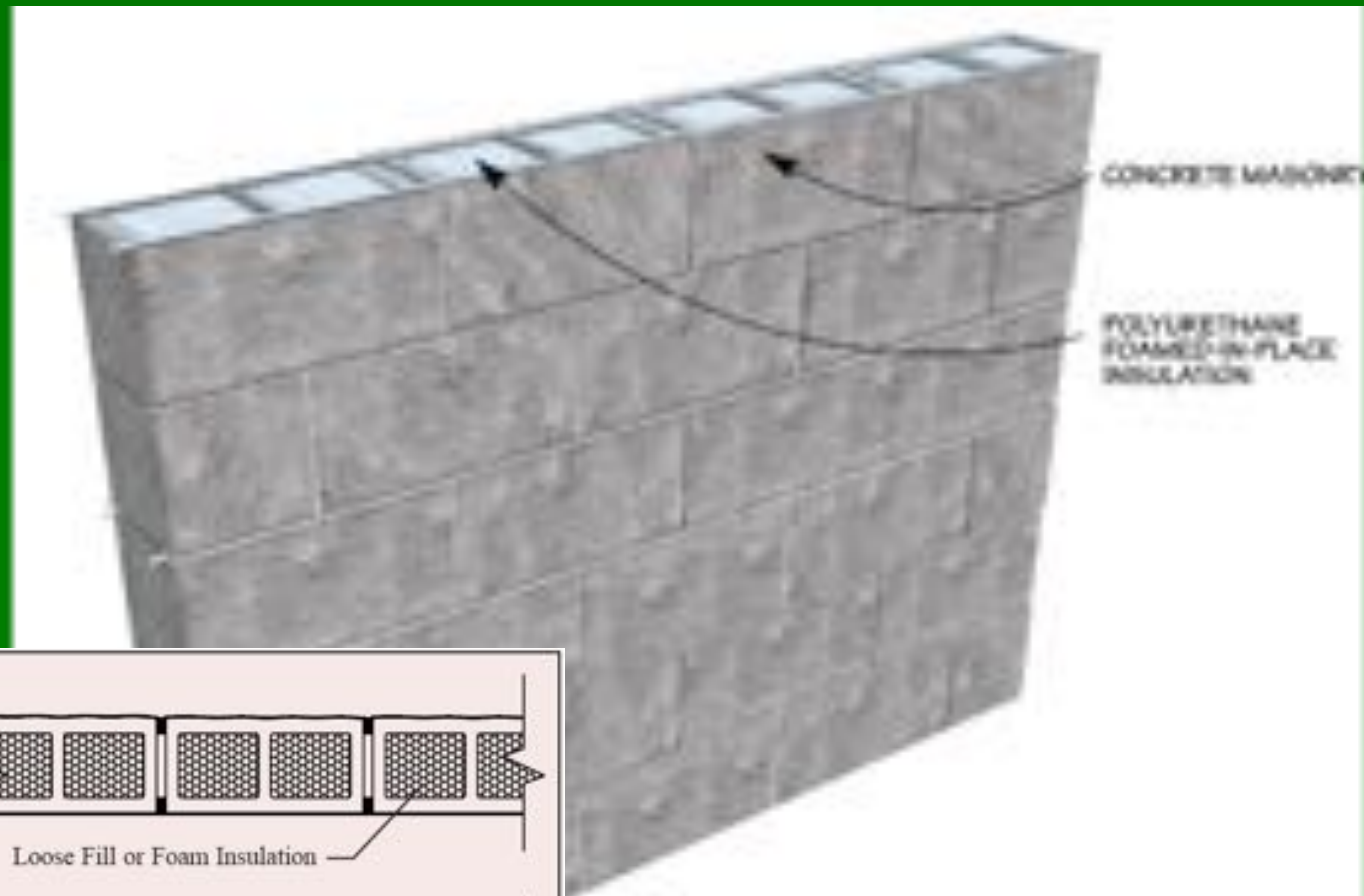
Continuous Insulation Strategies



Non-Continuous Insulation



Non-Continuous Insulation



Above Grade Concrete Wall Systems

- **Precast Concrete**
 - Larger panels
 - Fabricated off site or site cast and tilt up
 - Insulation incorporated within “sandwich” of concrete
 - Form liners for exterior finishes and textures



Precast Concrete



Precast Concrete

- Fast Assembly
- Minimal Site Waste
- Design Flexibility



Above Grade Concrete Wall Systems

- **Insulating Concrete Forms**
 - Stay-in-place formwork
 - Insulating formwork
 - Form ties have attachment surfaces



Components

Face Shell

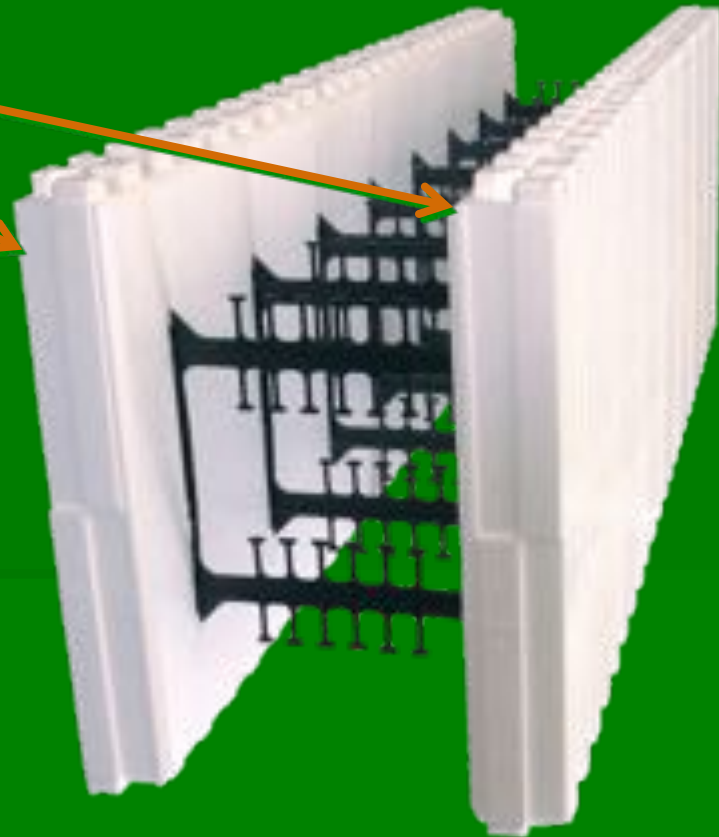
2" or greater

R- 18 to R-22

EPS or XPS

Interlocking edge

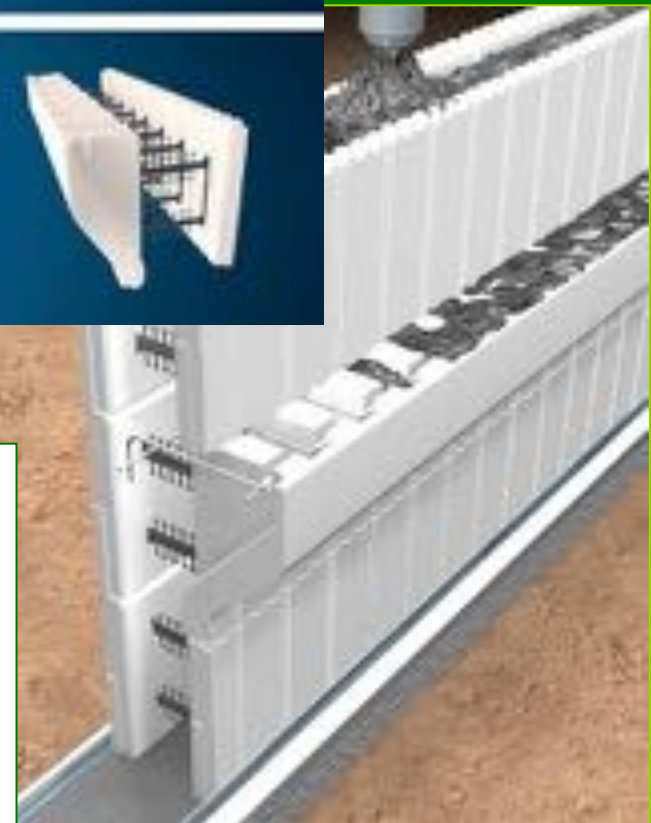
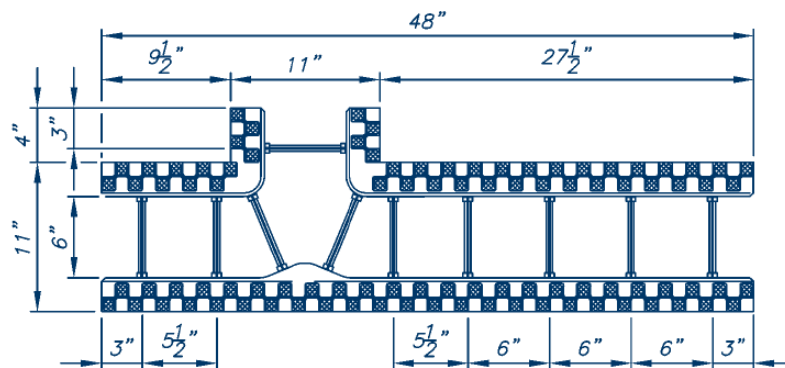
Withstands internal
pressure of concrete
(600 psf)



Components

Specialty Blocks

- 90/45 corners
- Brick ledge
- T - Block



Components

Reinforced Concrete Core

4", 6", 8", 10", 12" thick

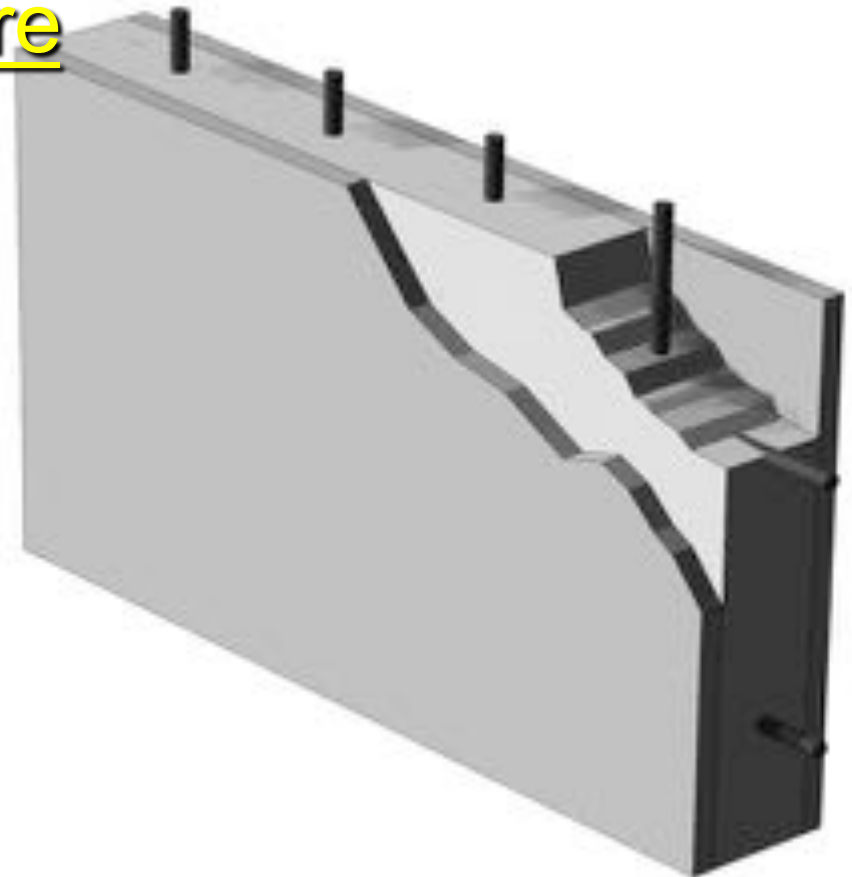
Monolithic,

2,500 to 4,000 psi

6" slump

3/8" aggregate

Rebar = 40 or 60 ksi



Handling/Fabrication

Lightweight



Common Hand-
tools

Versatile



Assembly



Concrete Placement



ICF Floor Systems



Insulating Concrete Forms



- Monolithic Structure
- Insulation
- Integral Furring
- Chase Cavity



Concrete Wall Systems Performance

Sustainable High Performance

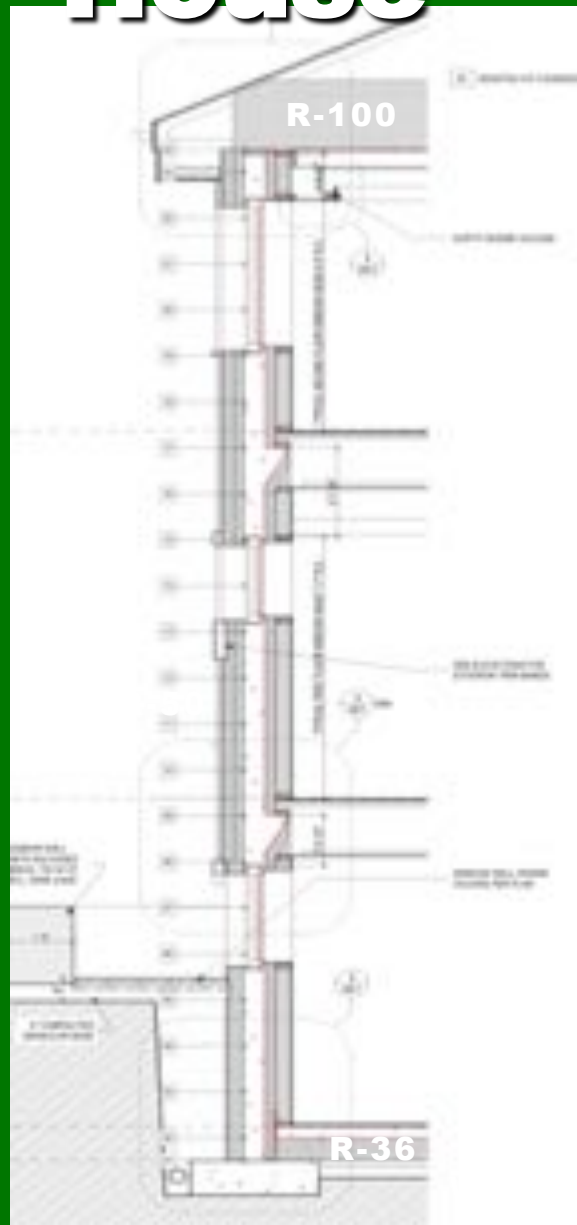
Three Major Influences

High R- values	R-18 to R-22
Thermal Mass benefits	Varies by climate.
Low Infiltration	Virtually none through the wall.



Concrete Wall System Innovations

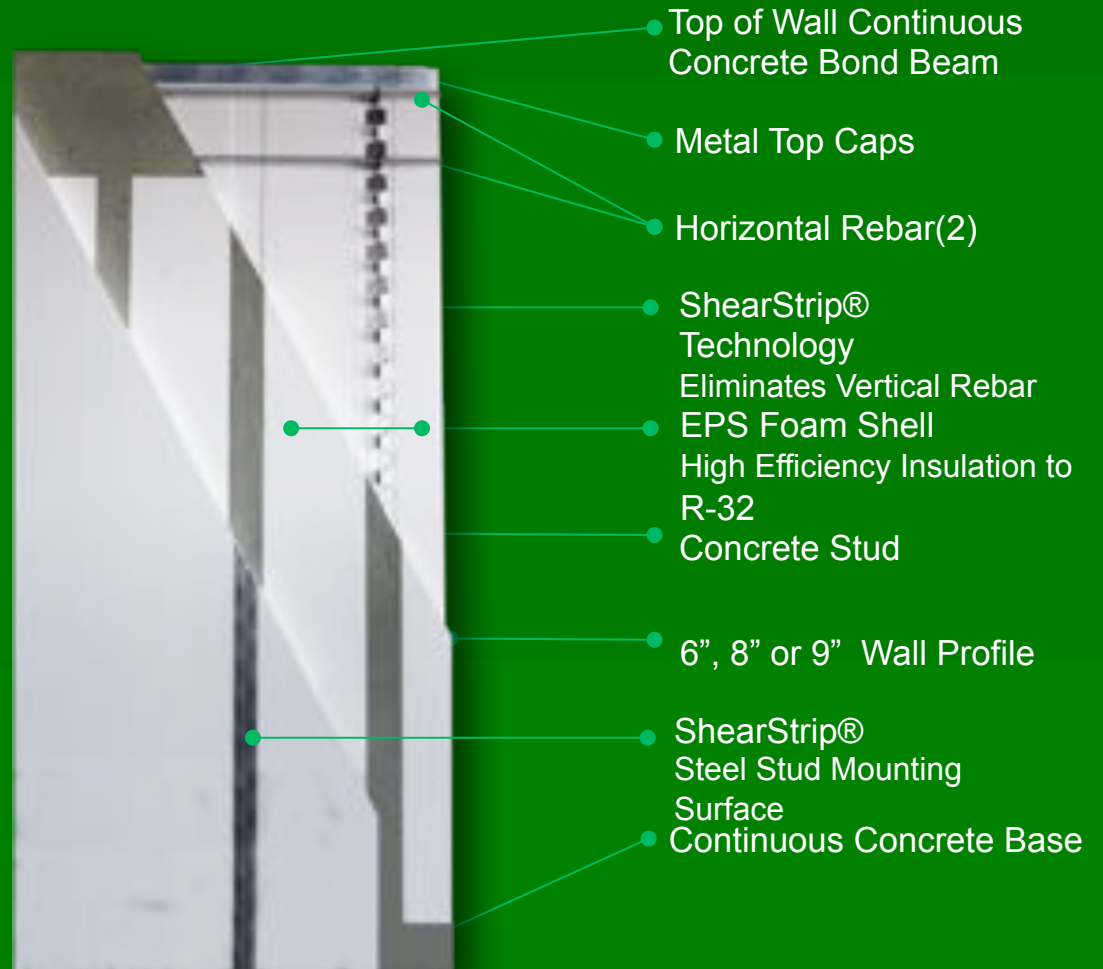
ICF Innovation - Passive House



Section

Innovation – Insulated Concrete Panel

- Precision Engineered
- Automated Fabrication
- Faster Construction
- Air Barrier/Insulation
- Stronger Structure
- Rot/Mold Resistant
- More Durable
- Tighter



Prefabricated Light Weight Panels



Formed Concrete Stud Wall



Erection Time: 36 SF Per Minute



Ready for Trusses – One Day



Conventional Interior Partitions



Fast Window and Door Installation



Factors Affecting Insulation Performance

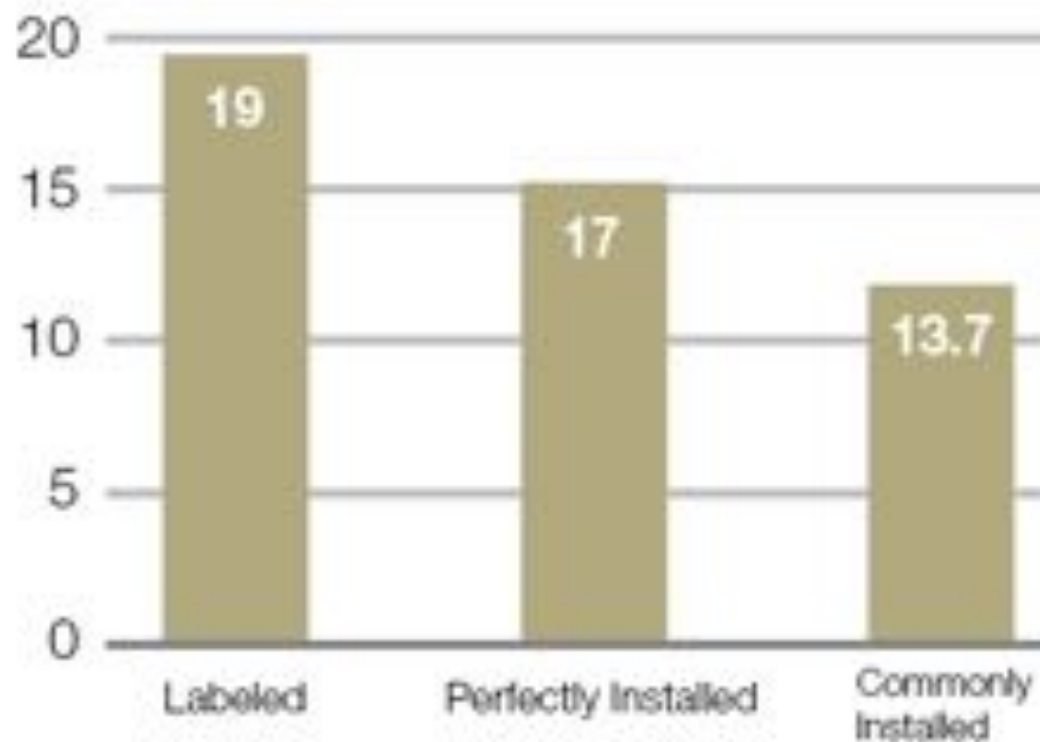
Keys to a high performance system

- Stops air flow
- Not affected by moisture
- Stable R value
- Protects structure

R-value Comparison

Insulation Type	R-Value Per Inch
Fiberglass loose-fill	2.5 – 3.7
Cellulose	2.8 – 3.5
Rockwool or mineral wool	3.2 - 3.7
Fiberglass batt	3.1 – 4.3
Expanded polystyrene (EPS)	3.6 – 4.7
Extruded polystyrene (XEPS)	4.2 – 5.4
Polisocyanurate (PIR)	4.3 – 8.3
Polyurethane (PUR)	5.0 – 8.0

Installed R-Values of Fiberglass



28% loss of R-Value found in
"Commonly installed" insulation

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Specification Tips

- **Insulation**
- No voids/spaces, complete alignment with air barriers
- No compression
- Cavities filled
- **Air sealing**
- All Penetrations sealed
- Air testing

RESNET Specifications

Insulation

Table. Summary of Insulation Standards

Criteria	Grade I	Grade II	Grade III
Gaps in insulation coverage:	Minimal, occasional	Up to 2%	More than 2%, up to 5%
Compression or incomplete fill (up to 30% of intended thickness missing):	Up to 2%	More than 2%, up to 10%	More than 10%
Walls, rim or band joist between floors:	Enclosed on all 6 sides	Enclosed on all 6 sides	Open on one side
	In contact with interior or exterior sheathing	In contact with interior or exterior sheathing	"Floating" in the middle of the cavity
Ceilings:	In contact with interior sheathing (drywall)		
	Requires eave baffles		
Floors:	In contact with interior sheathing (subfloor)		
Floors over outdoor air or vented:	Enclosed on all 6 sides		

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The Goal

- **Conductive losses** (solved by proper insulation)
- RESNET Grade 1



Copyright S

Insulation Grades

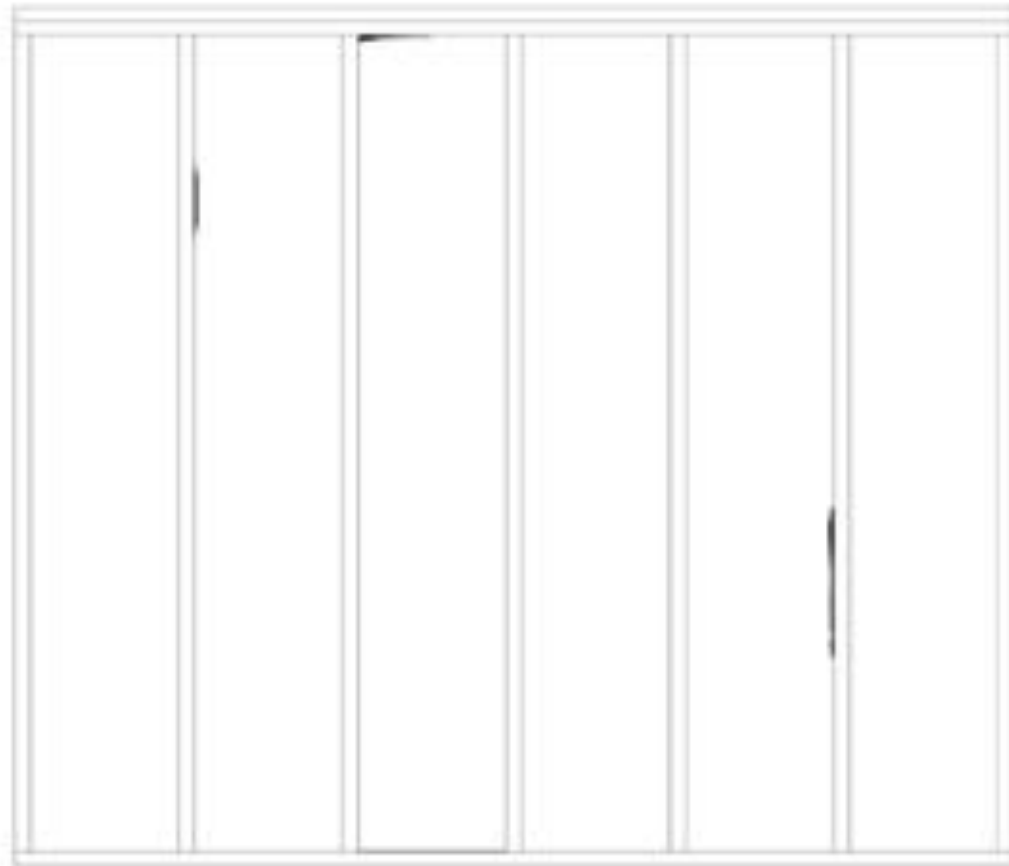


Figure 1 *Grade I boundary condition: minimal gaps.*

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Insulation Grades

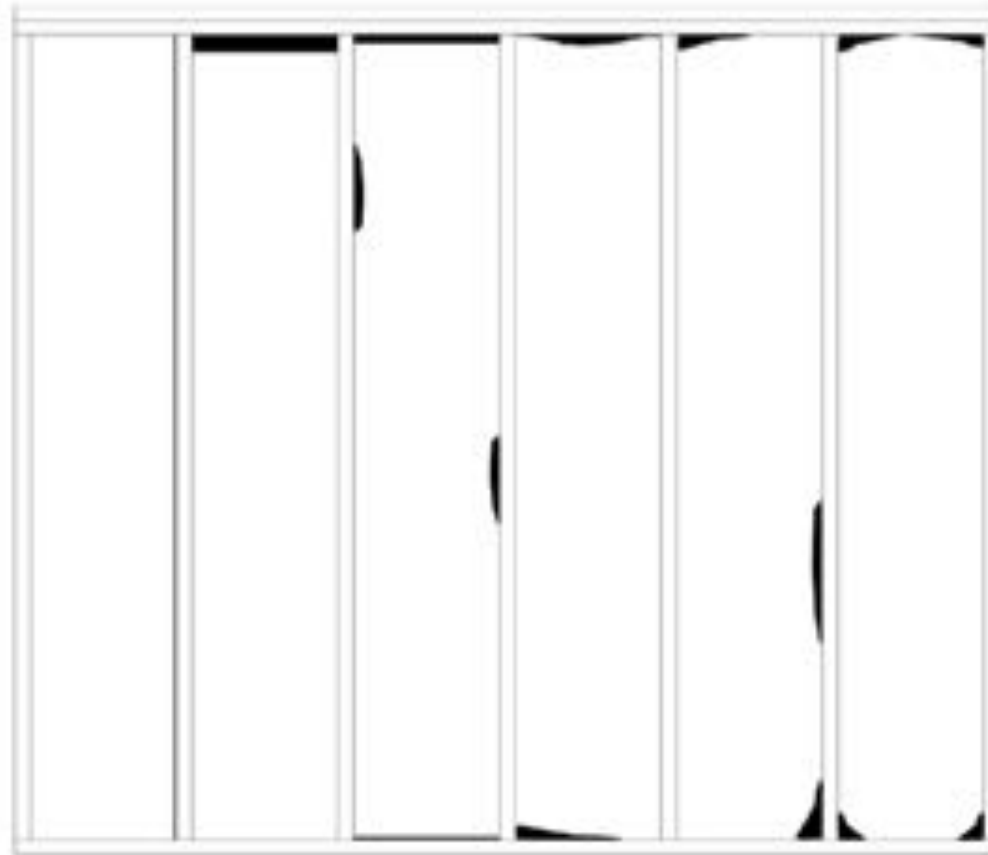


Figure 3 Grade II boundary condition: 2% gap area.

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Resources

ACHIEVING GRADE I INSULATION WITH FIBERGLASS BATTS

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Presented by
Advanced

ACHIEVING GRADE I INSULATION WITH FIBERGLASS BATTS INSULATION CHECKLIST

INSULATION: CRITICAL DETAILS			
		X	✓
PRE-CHECK	1	Bottom plates of all exterior walls and party/common walls (ALL floors), and vertical members at foundation step-downs are caulked, grouted, or glued	
	2	There is both a top and bottom plate installed at every knee wall (TERC 3.3, 3.1.3, 3.2.2)	
	3	All knee walls are backed with a rigid material or other supporting material (e.g. wall to attic, skylight shaft, wall to porch roof, staircase to attic) (TERC 2.3, 3.1.3)	
	4	All shafts/chases are capped (TERC 3.3.1)	
	5	All floor system cavities between conditioned areas and unconditioned areas (e.g. floor/garages, bonus rooms/attic, cantilevers, porch/floor) are separated by blocking and air sealed (TERC 3.2.1, 3.2.2, 3.2.3)	
	6	Work site is clean prior to beginning work	
	* Proceed without detail being corrected Stop work until detail is corrected		
Builder's Signature _____		Date _____	
SELF-CHECK	1	Insulation is installed without gaps/voids or misalignments/compressions. Insulation material is in full contact with all sides of the cavity. Insulation is cut/spilt around blocking, plumbing, HVAC, and electrical components (TERC 2.3, 3.1, 4.3)	
	2	Floor framing shall be completely filled with insulation or insulation is installed to maintain permanent contact with the sub-floor decking (e.g. bonus room floor, crawl space, cantilever) (TERC 3.2)	
	3	Insulate any overhanging floor cavities before closing them in with rigid sheathing (TERC 3.2.2)	
	4	Insulation is installed behind showers, tubs, staircases, and fireplaces on exterior, attic, and party walls and rigid sheathing or other supporting material is installed to hold insulation in place (TERC 2.3, 3.1)	
	5	Access panels to attic/kneewall, drop down stairs, and whole-house fans are weather stripped and insulated to the same R-value as the surrounding area when possible (see R-10) (TERC 3.2.2, 3.3.3)	
	6	Work site is clean after work is complete.	
Installer Signature _____		Date _____	
Company Name _____		Builder's Job # _____	
The sub-contractor who signs and completes this form is doing so to the best of his/her knowledge and should not be held legally responsible for work completed by other organizations. The intent of this form is to ensure job sites are ready prior to beginning work.			

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Insulation Installation (RESNET Grade 1)

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Scope

High Performance Insulation

All ceiling, wall, floor, and slab insulation shall achieve RESNET-defined Grade I installation or, alternatively, Grade II for surfaces that contain a layer of continuous, air impermeable insulation $\geq$ R-3 in [Climate Zones 1 to 4](#), $\geq$ R-5 in [Climate Zones 5 to 8](#).

A. Install insulation without misalignments, compressions, gaps, or voids in all wall cavities along the thermal barrier of the house.

Notes:

What is grade I installation?

Grade I installation requires that the insulation material uniformly fill each cavity side-to-side and top-to-bottom, without substantial gaps, or voids around obstructions (such as blocking or bridging), and be split, installed, and/or fitted tightly around wiring and other services in the cavity.

To attain a rating of Grade I, wall insulation shall be enclosed on all six sides and shall be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity.

The forced air insulation Grade I can be documented for side attached tubes provided the tubes are installed

IDEAL INSTALLATION OF INSULATION
Properly installed insulation consists of insulation between all of the studs, including top and bottom plates, near blocking, foot blocking, and header board above the blocking is correctly installed before the start of insulation.



Properly installed insulation consists of insulation between all of the studs, including top and bottom plates, near blocking, foot blocking, and header board above the blocking is correctly installed before the start of insulation.

All ceiling, wall, floor, and slab insulation shall achieve RESNET-defined Grade I installation



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ENERGY STAR® Qualified Homes

THERMAL ENCLOSURE SYSTEM RATER CHECKLIST



Revised 2012

THERMAL ENCLOSURE SYSTEM RATER CHECKLIST

3 FULLY-ALIGNED AIR BARRIERS

3 CEILINGS



A. No air barrier is present between the dropped ceiling/soffit and the attic.



Air barrier is present between the dropped ceiling/soffit and the attic.



A. No air barrier is present between the dropped ceiling/soffit and the attic.



Air barrier is present between the dropped ceiling/soffit and the attic.



B. Seams of air barrier not sealed.



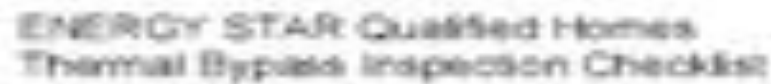
Seams and penetrations of air barrier properly sealed



B. Seams of air barrier not sealed.



GOOD PIC OF PROPERLY SEALED DROPPED CEILING



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A. Compression and misalignment because insulation is not split around plumbing.



RESNET Grade I installation of blown insulation.



A. Compression and misalignment because insulation is not split around wires.



Batt was properly split around wires to achieve RESNET Grade I.

Safety 1st!!!



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Climate Based Recommendations

CertaTeed Hybrid Insulation Winter Season Closed-Cavity Surface Condensation Analysis

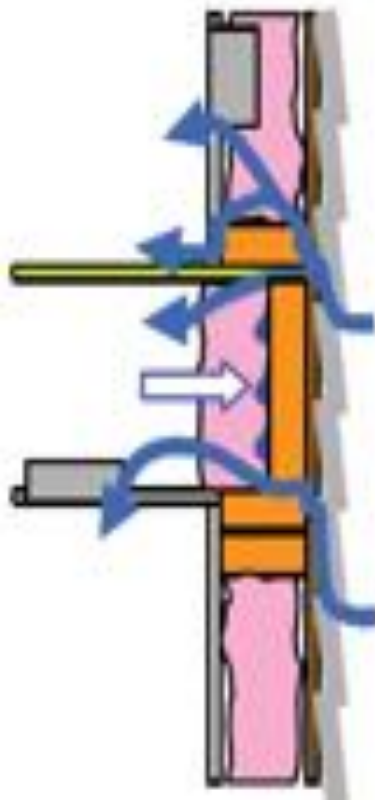
Climate Zone	2x4 Wood Stud Wall (No additional vapor retarder)			2x4 Wood Stud Wall (Additional vapor retarder)			Vapor Retarder Requirement
	Insulation Layer Thickness			Insulation Layer Thickness			
	CertaSpray CC SPF (inch)	High Density Fiber Glass (inch)	Hybrid Insulation Cavity R-value	CertaSpray CC SPF (inch)	High Density Fiber Glass (inch)	Hybrid Insulation Cavity R-value	
1a	1/2	3	15.5	1/2	3	15.5	Unfaced
2a	1/2	3	15.5	1/2	3	15.5	Unfaced
2b	1/2	3	15.5	1/2	3	15.5	Unfaced
3a	1/2	3	15.5	1/2	3	15.5	Unfaced
3b	1/2	3	15.5	1/2	3	15.5	Unfaced
3c	1/2	3	15.5	1/2	3	15.5	Unfaced
4a	1	2 1/2	16.3	1/2	3	15.5	Class II or MemBrain
4b	1	2 1/2	16.3	1/2	3	15.5	Class II or MemBrain
4c	1	2 1/2	16.3	1/2	3	15.5	Class II or MemBrain
5a	1 1/2	2	17.1	1/2	3	15.5	Class II or MemBrain
5b	1 1/2	2	17.1	1/2	3	15.5	Class II or MemBrain
6a	2	1 1/2	17.9	1/2	3	15.5	MemBrain
6b	1 1/2	2	17.1	1/2	3	15.5	MemBrain
7a	2	1 1/2	17.9	1/2	3	15.5	MemBrain
7b	1 1/2	2	17.1	1/2	3	15.5	MemBrain
8	Requires custom hygrothermal analysis.			Requires custom hygrothermal analysis.			NA

Climate Based Recommendations

CertainTeed Hybrid Insulation Winter Season Closed-Cavity Surface Condensation Analysis

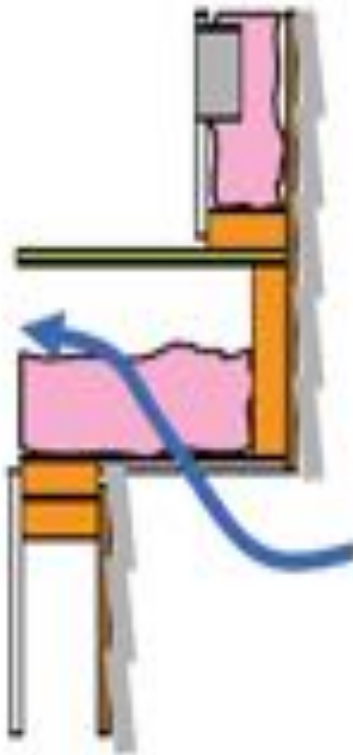
Climate Zone	2x6 Wood Stud Wall (No additional vapor retarder)			2x6 Wood Stud Wall (Additional vapor retarder)			Vapor Retarder Requirement
	Insulation Layer Thickness			Insulation Layer Thickness			
	CertaSpray CC SPF (inch)	High Density Fiber Glass (inch)	Hybrid Insulation Cavity R-value	CertaSpray CC SPF (inch)	High Density Fiber Glass (inch)	Hybrid Insulation Cavity R-value	
1a	1/2	5	23.9	1/2	5	23.9	Unfaced
2a	1/2	5	23.9	1/2	5	23.9	Unfaced
2b	1/2	5	23.9	1/2	5	23.9	Unfaced
3a	1/2	5	23.9	1/2	5	23.9	Unfaced
3b	1/2	5	23.9	1/2	5	23.9	Unfaced
3c	1/2	5	23.9	1/2	5	23.9	Unfaced
4a	1 1/2	4	25.5	1/2	5	23.9	Class II or MemBrain
4b	1 1/2	4	25.5	1/2	5	23.9	Class II or MemBrain
4c	1 1/2	4	25.5	1/2	5	23.9	Class II or MemBrain
5a	2	3 1/2	26.3	1/2	5	23.9	Class II or MemBrain
5b	2	3 1/2	26.3	1/2	5	23.9	Class II or MemBrain
6a	2 1/2	3	27.1	1/2	5	23.9	MemBrain
6b	2	3 1/2	26.3	1/2	5	23.9	MemBrain
7a	3	2 1/2	29.7	1/2	5	23.9	MemBrain
7b	2 1/2	3	27.1	1/2	5	23.9	MemBrain
8	Requires custom hygrothermal analysis.			Requires custom hygrothermal analysis.			NA

COMMON PROBLEMS:



- **Un-insulated / under-insulated**
Missing, compressed or poorly-fitted fiber glass batts
- **No air sealing**
Air leaks through common joint for framing and sheathing
- **Improper moisture control**
Missing or reversed vapor retarder can result in condensation, especially in moist interiors

COMMON PROBLEMS:



- **Uncomfortable rooms**

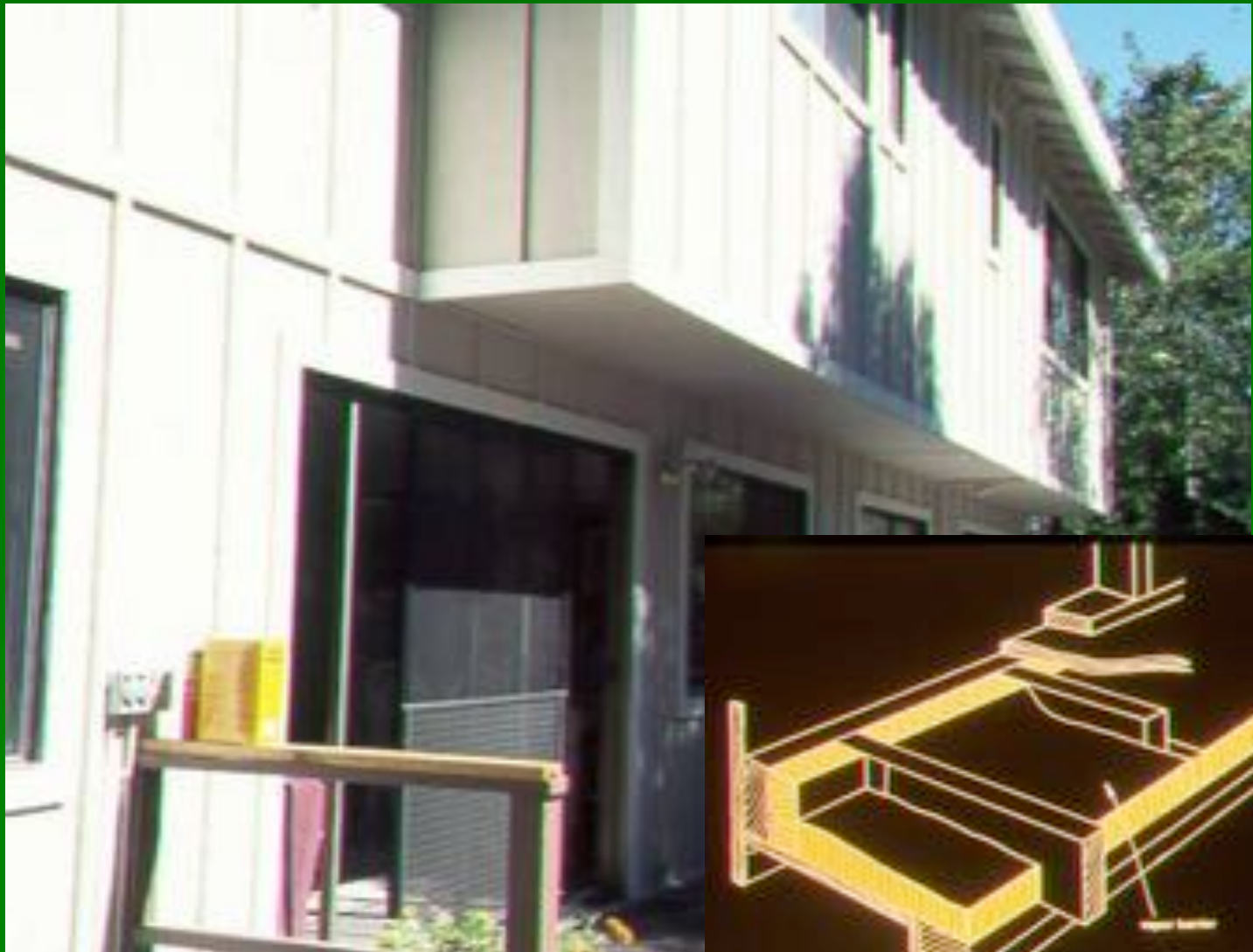
Floor cantilevered is too hot in summer, too cold in winter

Caused by air movement between settled/undersized insulation and subfloor

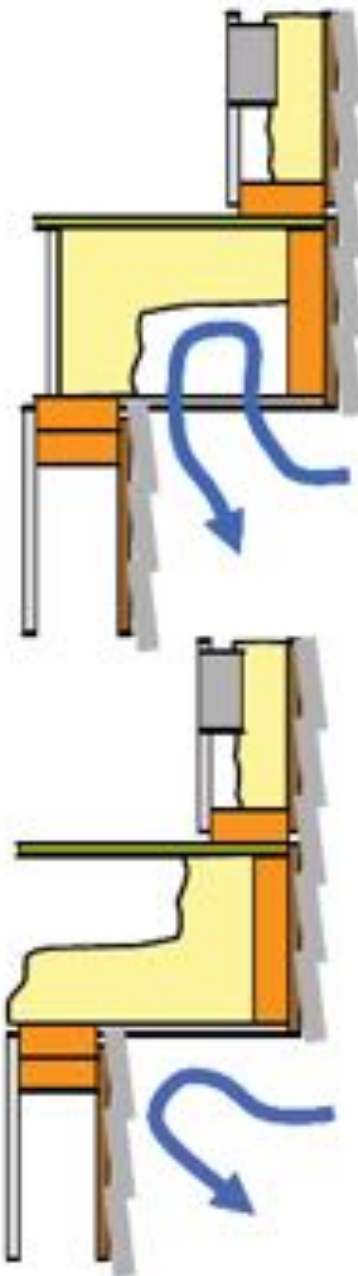
- **Plumbing and duct problems**

In extreme cases, supply and drain lines freeze

Ducts effectiveness reduced



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- **Permanent contact**

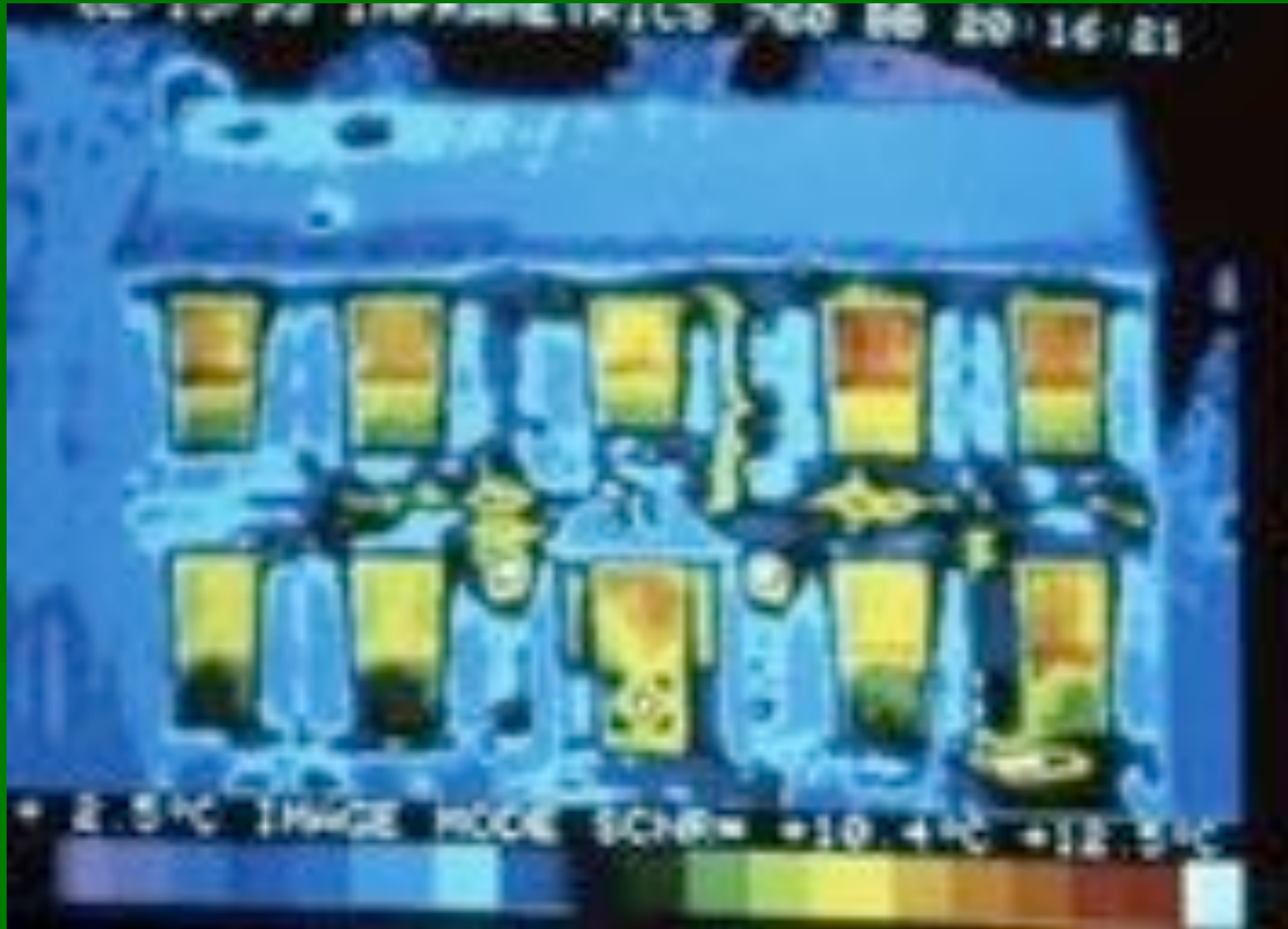
Insulation remains in place and provides superior effective performance through all conditions

Air barrier and insulation always in contact

- **Completely encloses plumbing and ducts**

Offers continuous thermal protection and air sealing to prevent cold, moist area from impacting utilities

Air Leakage



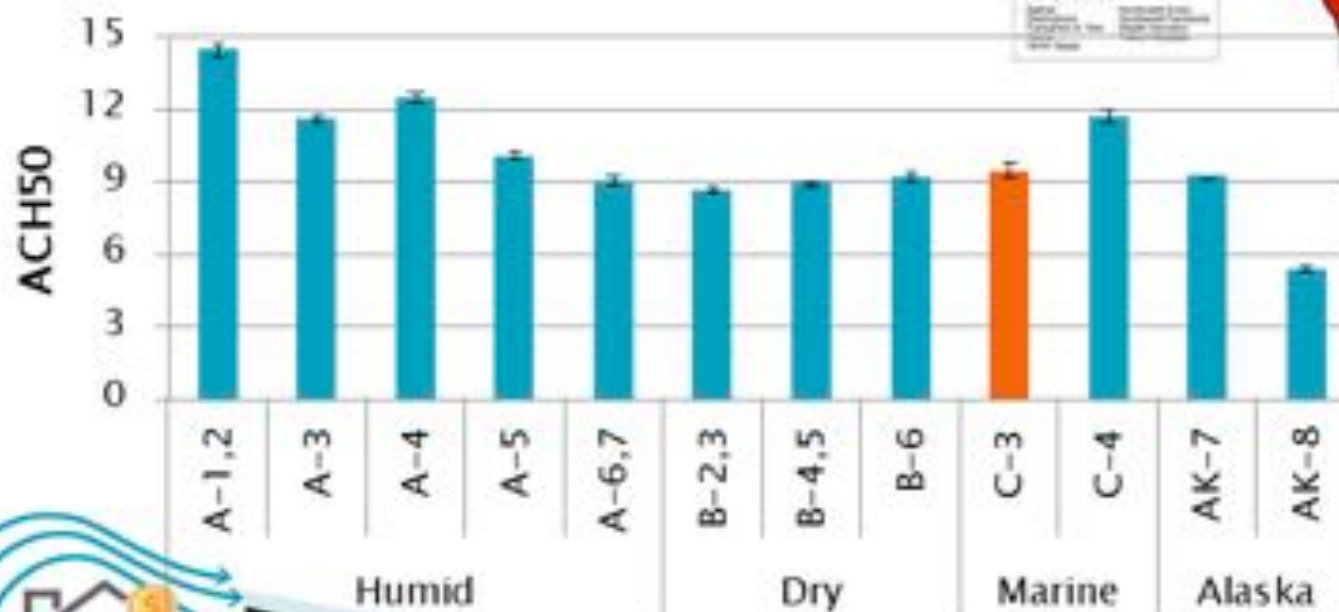
Air Leakage along the corner joint

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Regression results of air leakage by IECC climate zones

- ▶ ACH50 predictions for a 200 m², 1-story house built in 1980s

Air Leakage Predictions



In CA, estimates range from 4 to 11.3 ACH50



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Error bars show the 95% confidence interval of the parameter being compared

Target Home Air-Tightness

	ACH50 Requirements/Targets			
Climate Zones	Zero Energy Ready Home	ENERGY STAR V3	2012 IECC	Passive House
1-2	3.0	6.0	5.0	0.6
3-4	2.5	5.0	3.0	0.6
5-7	2.0	4.0	3.0	0.6
8	1.5	3.0	3.0	0.6

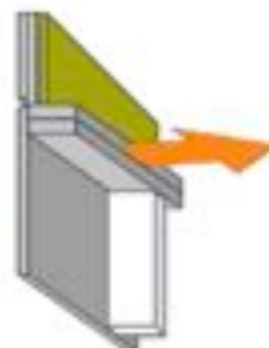
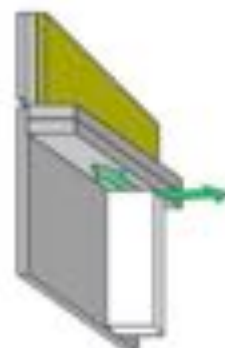
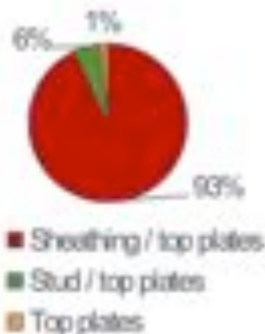
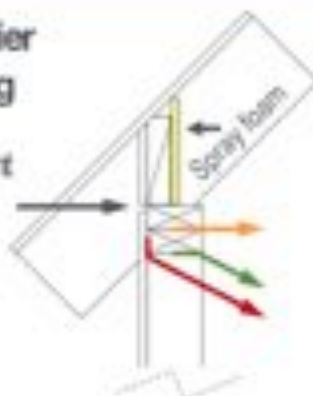
Air Leakage Distribution

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Exterior air barrier
Cathedral ceiling

Sheathing / roof joint
1.1 cfm/ft @ 50 Pa



2-Story house (Floor area = 2,000 ft²)

Sheathing / roof joint unsealed $\approx 0.5 \text{ ACH}_{50}$

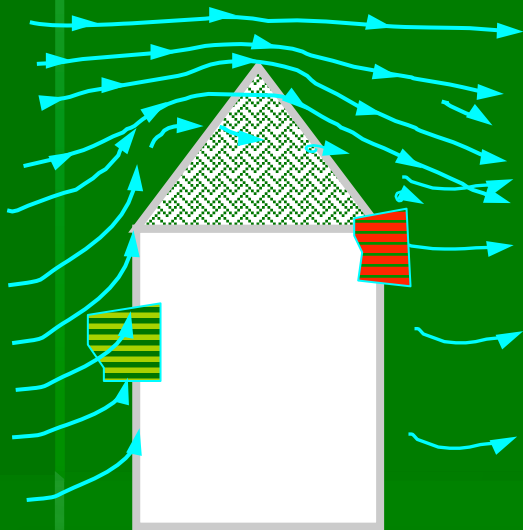
Zones	DOE Challenge Home		IECC 2012	
	Requirement	Contribution to requirement (%)	Requirement	Contribution to requirement (%)
1 – 2	3	17	5	10
3 – 4	2.5	20	3	17
5 – 7	2	25	3	17
8	1.5	33	3	17

Getting the Envelope Right

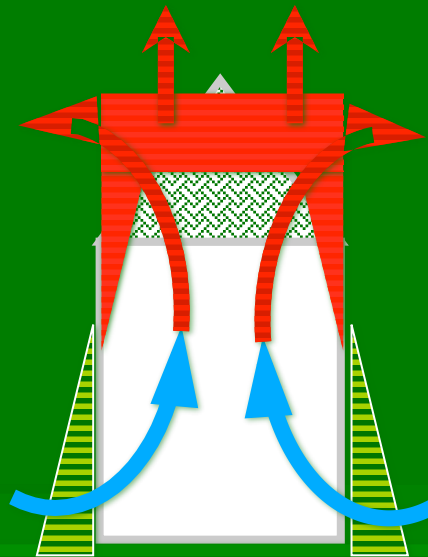


S

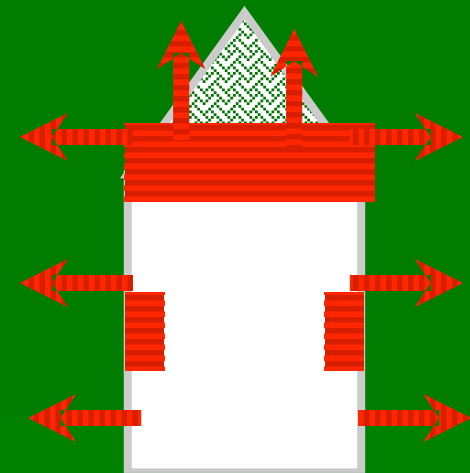
Cause of Air Infiltration in Buildings



**Wind
Pressure**



**Stack
Pressure**



**Mechanical
Pressure
(HVAC)**



outside.hobo

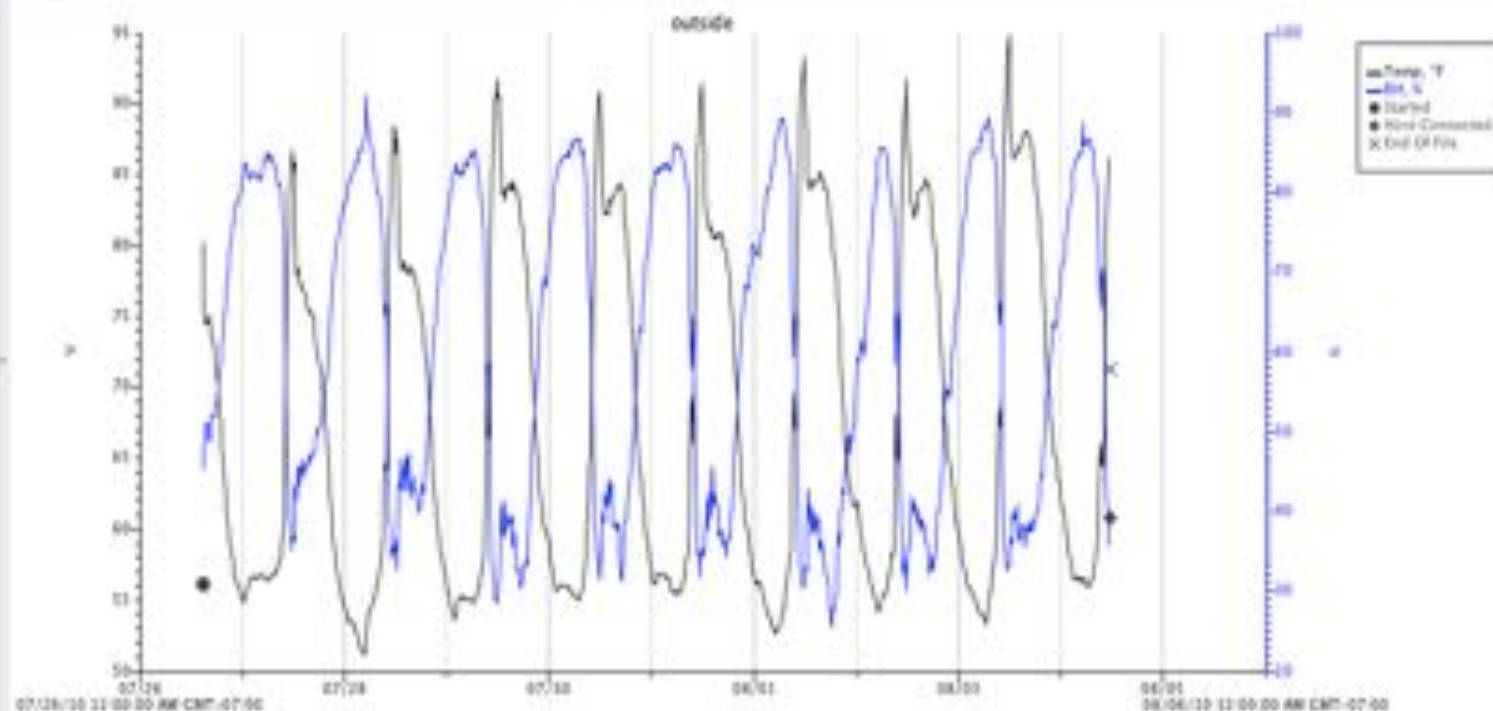
#	Time, GMT-07:00	Temp, °F	RH, %	Started	Host Connected	End Of File
1	07/26/10 02:51:20 PM	80.227	45.220	Logged		
2	07/26/10 03:06:20 PM	75.810	47.360			
3	07/26/10 03:21:20 PM	74.554	49.825			
4	07/26/10 03:36:20 PM	74.597	51.106			
5	07/26/10 03:51:20 PM	74.467	50.969			
6	07/26/10 04:06:20 PM	74.597	49.443			
7	07/26/10 04:21:20 PM	75.029	48.668			

Show All

Hide All

Details

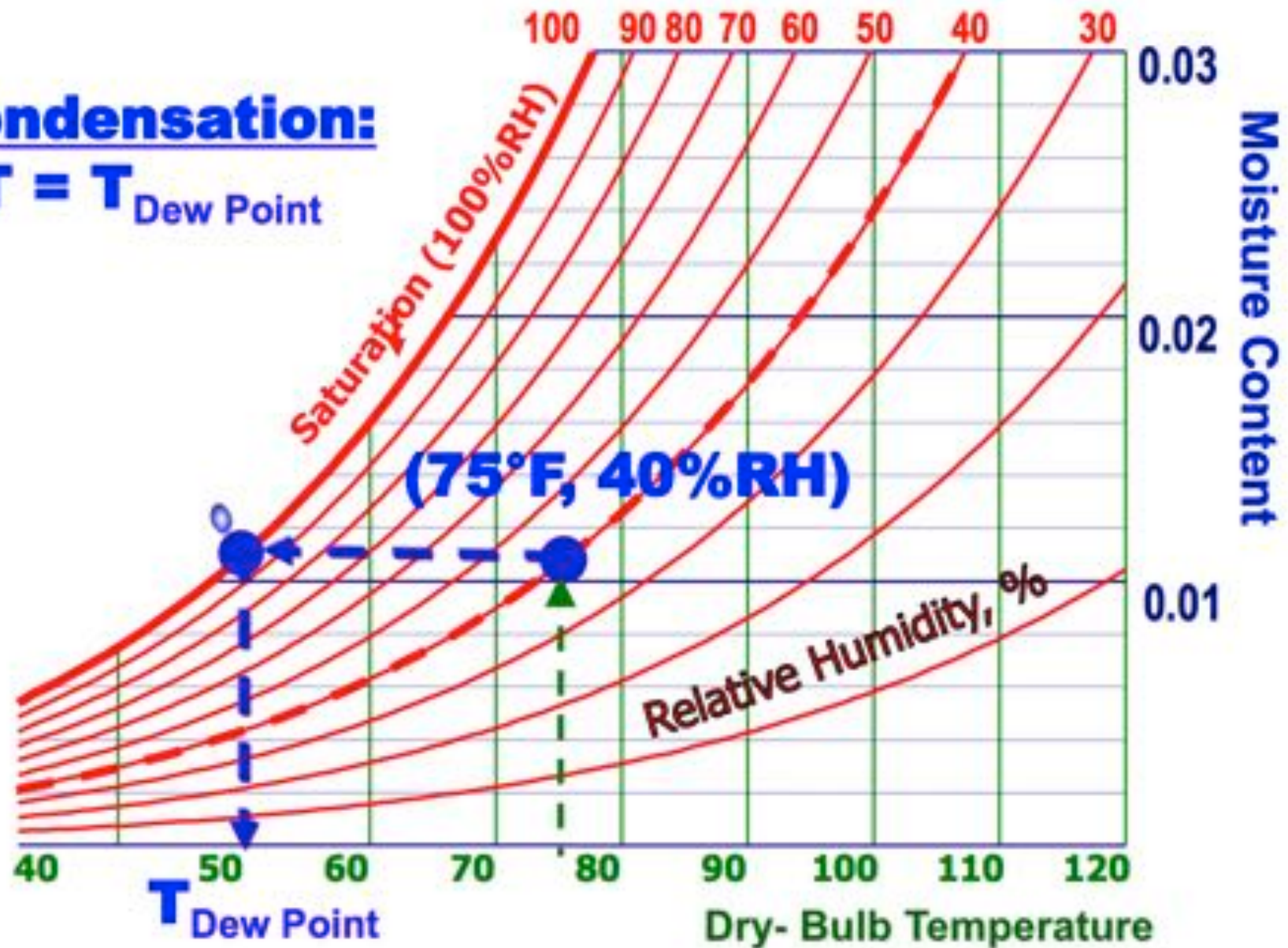
- ✓ Series: Temp, °F
- ✓ Series: RH, %
- △ Event Type: Started
- △ Event Type: Host Connected
- △ Event Type: End Of File



Air carries moisture vapor which can condense on cooler surfaces

Condensation:

$$T = T_{\text{Dew Point}}$$



Dew Point Location

70 Degrees F
30% Relative
Humidity

INSIDE

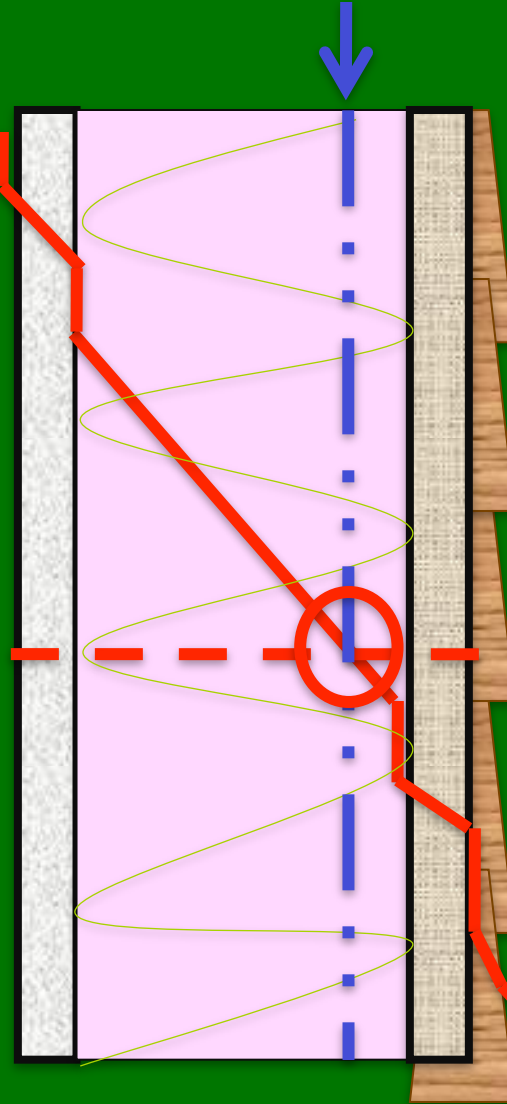
OUTSIDE

Dew Point

0 Degrees F

NOTE:
Perm is a
unit of water
vapor
transmission

www.woodworks.org



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

BUILDING TECHNOLOGIES PROGRAM



VOLUME 18

BUILDING AMERICA BEST PRACTICES SERIES



Retrofit Techniques & Technologies:

Air Sealing

A Guide for Contractors
to Share with Homeowners

Developed by:
Florida Performance Training Laboratory
& Oak Ridge National Laboratory

April 12, 2010



www.eere.energy.gov

Can-Less Down Lights



SLD Series
The LED Surface
Downlight Luminaire

LASTS **22**
YEARS



SLD6
6" LED Surface Downlight Luminaire



SLD4
4" LED Surface Downlight Luminaire



SLD6 ENERGY DATA

	SLD6	SLD6
Lumens	810	810
Input Voltage	120V	120V
Frequency	50/60 Hz	50/60 Hz
Input Current	0.17 A	0.17 A
Input Power	14.4 W	14.4 W
Efficiency	18 lm/W	18 lm/W
Watt	14.4 W	
Power Factor	1.00	
Temperature	40 °C	40 °C
Beam Angle	120°	

UP TO \$400 SAVINGS

*Based on savings vs. incandescent light.

**Note:
Savings are based on the life of the LED light fixture.
Energy savings: \$400
Replacement cost savings: \$100
Savings based on \$0.12/kWh and 10,000 hours of use. Actual savings may vary based on local utility rates and usage.



SLD4 ENERGY DATA

	SLD4	SLD4
Lumens	405	405
Input Voltage	120V	120V
Frequency	50/60 Hz	50/60 Hz
Input Current	0.17 A	0.17 A
Input Power	14.4 W	14.4 W
Efficiency	18 lm/W	18 lm/W
Watt	14.4 W	
Power Factor	1.00	
Temperature	40 °C	40 °C
Beam Angle	120°	

UP TO \$325 SAVINGS

*Based on savings vs. incandescent light.

**Note:
Savings are based on the life of the LED light fixture.
Energy savings: \$325
Replacement cost savings: \$100
Savings based on \$0.12/kWh and 10,000 hours of use. Actual savings may vary based on local utility rates and usage.

THE ALL-IN-ONE P8022 AC LED SURFACE MOUNT

The P8022 Series unites performance, cost and safety benefits for an innovative LED solution unlike any other on the market.

State of the Art Design

Superior Performance

Versatility

Unparalleled Value



NEW CONSTRUCTION AND REMODEL

Maximum Versatility

Complete with adapters and mounts for use in recessed and flushmount applications, the P8022 embraces an installation system that is versatile, simple and seamless.

Recessed



Flushmount



Round aperture

SimSurface LED 5" and 7" round aperture
sim LED instant mount downlighting



SimSurface LED 5" downlight



SimSurface LED 7" downlight



Ordering guide

Round 5-inch aperture

Catalog No.	CRI	CCT	Listing	Finish (optional)
SPR8022N7	90	2700K	Yes	White
SPR8022NAL	90	2700K	Yes	Aluminum
SPR8022N7	90	3000K	Yes	White
SPR8022NAL	90	3000K	Yes	Aluminum
SPR8022N7	90	3500K	Yes	White
SPR8022NAL	90	3500K	Yes	Aluminum
SPR8022N7-D	90	3000K	Dimm	White

Round 7-inch aperture

Catalog No.	CRI	CCT	Listing	Finish (optional)
SPR8022N9	90	2700K	Yes	White
SPR8022NAL	90	2700K	Yes	Aluminum
SPR8022N9	90	3000K	Yes	White
SPR8022NAL	90	3000K	Yes	Aluminum
SPR8022N9	90	3500K	Yes	White
SPR8022NAL	90	3500K	Yes	Aluminum
SPR8022N9-D	90	3000K	Dimm	White



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Basements are Usually Wet



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Basement Moisture Loads

- Bulk Water
- Capillary, Wicking
- Vapor Diffusion (exterior or interior)
- Plumbing Leaks
- Occupant Generated Moisture

Basement Moisture Loads



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Basement Moisture Loads

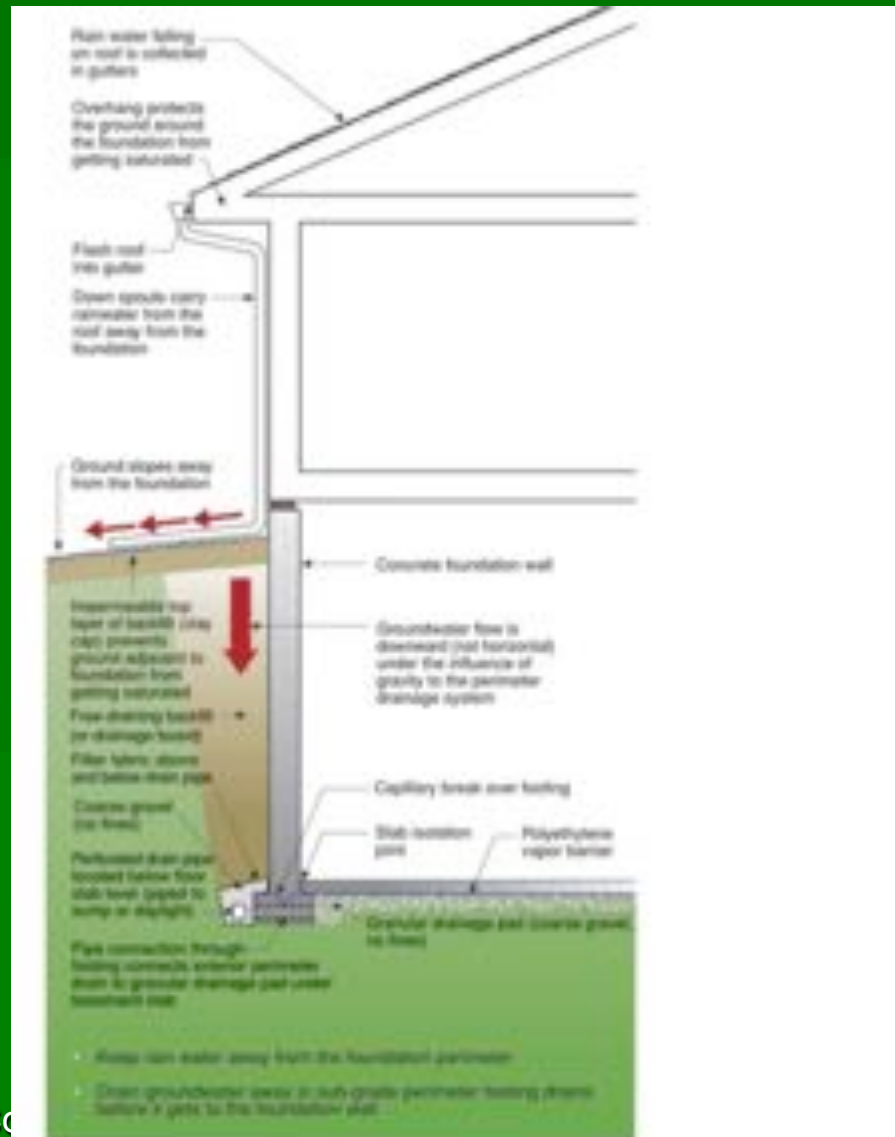


Figure 2: Traditional Approach to Basement Water Control

Courtesy Building Science Corp.

Co

Basement Moisture Loads



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Basement Moisture Loads

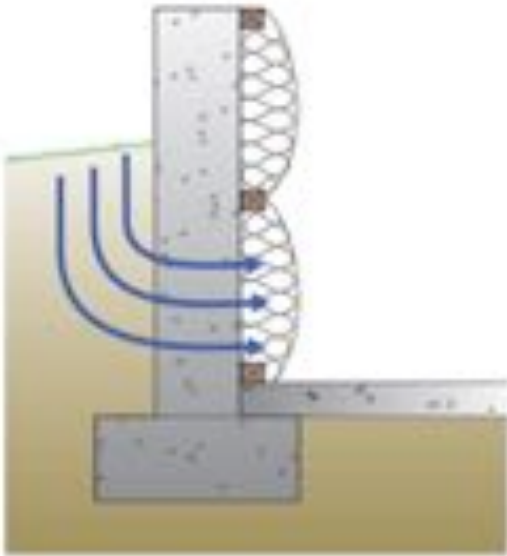


Figure 6: Groundwater Entry

- Interior insulation layer is typically water sensitive and prevents inward drying

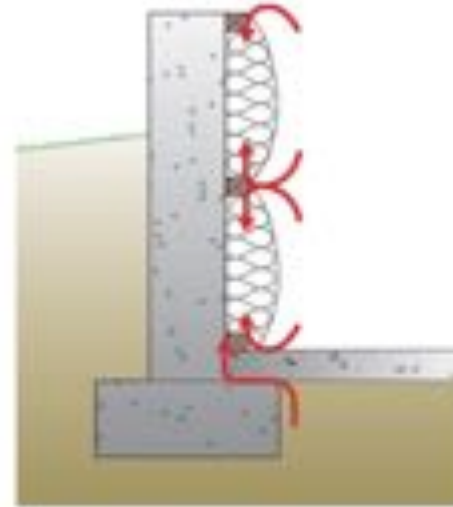


Figure 8: Condensation From Interior Air Leakage

- Interior insulation layer is typically not airtight and does not prevent interior air from condensing on concrete foundation wall
- Soil gas often enters assembly at concrete slab-perimeter wall interface leading to condensation

Moisture from interior

Capillary from soil

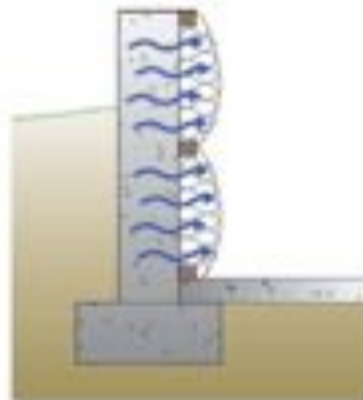


Figure 7: Moisture of Conduction

- Interior insulation layer is typically water sensitive and prevents inward drying
- Several thousand pounds of water in freshly placed concrete attempts to dry inward

Moisture from concrete

Courtesy Building Science Corp.

Basement Moisture Loads

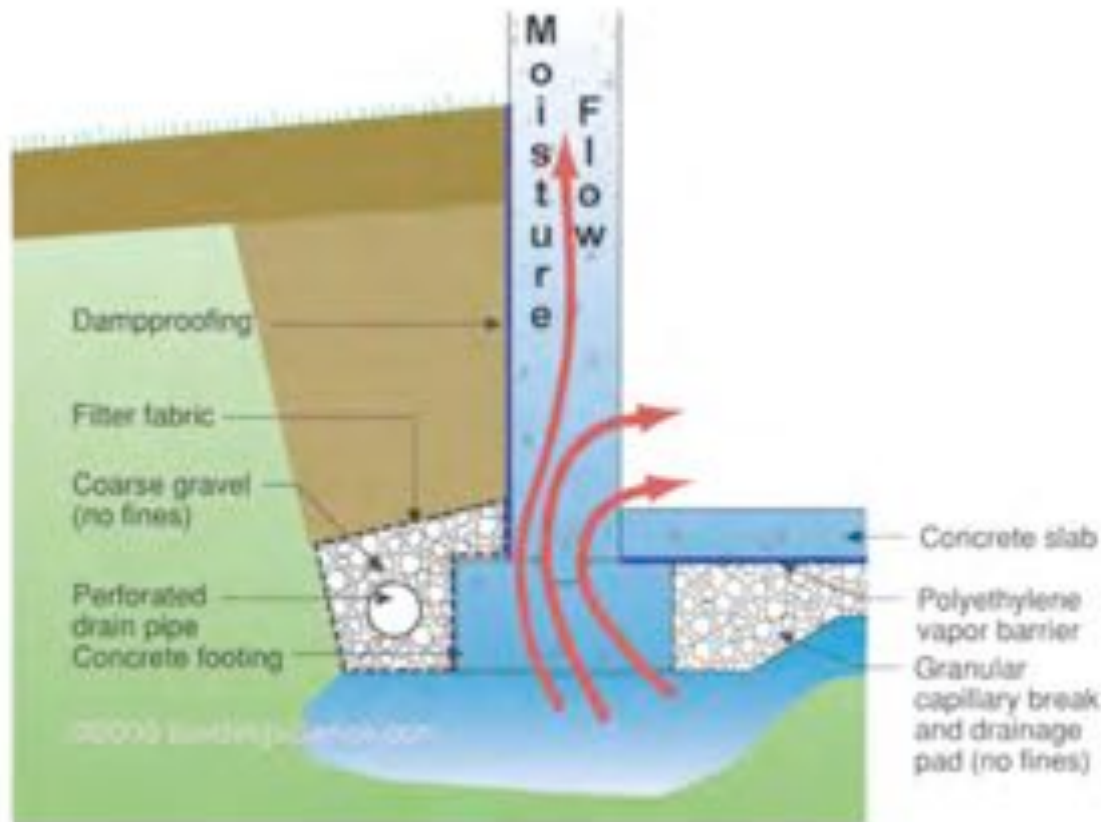


Figure 9 : Capillary rise through basement footing

Courtesy Building Science Corp.

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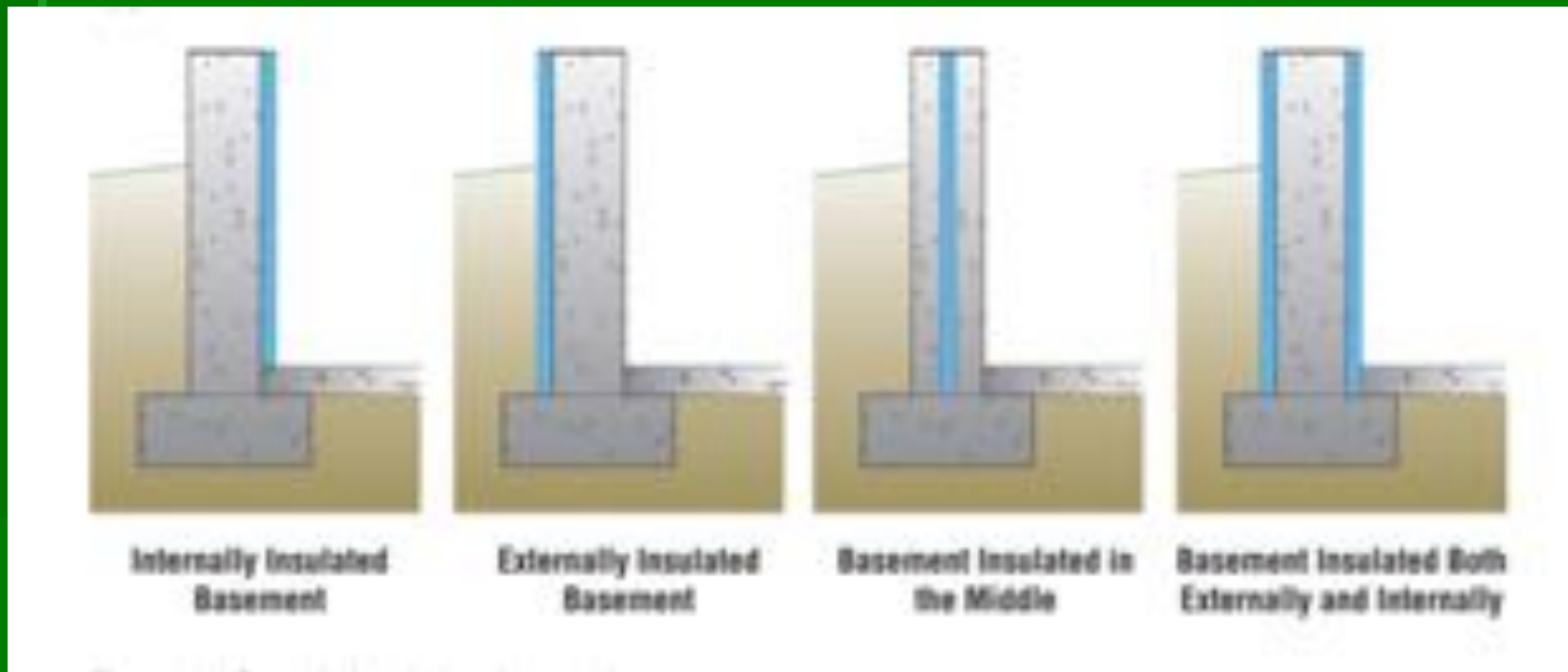
Concrete Wall R-value

- 8" wall R= .44 - .82
- Codes require basement insulation

Basement Insulation Strategies Assessment:

- Structural integrity
- Water and moisture management
- Insect and pest management
- Combustion safety

Basement Insulation Strategies



Courtesy Building Science Corp.

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Basement Insulation Strategies

Exterior Insuation

- Usually only practical for new construction
- Protecting the insulation at and above grade
- Insect and pest management
- Transitions between foundation insulation and above-grade walls
- Achieving higher R-values can be more difficult than with interior insulation (though a combination of both interior and exterior insulation is possible).

Basement Insulation Strategies

Exterior Insulation

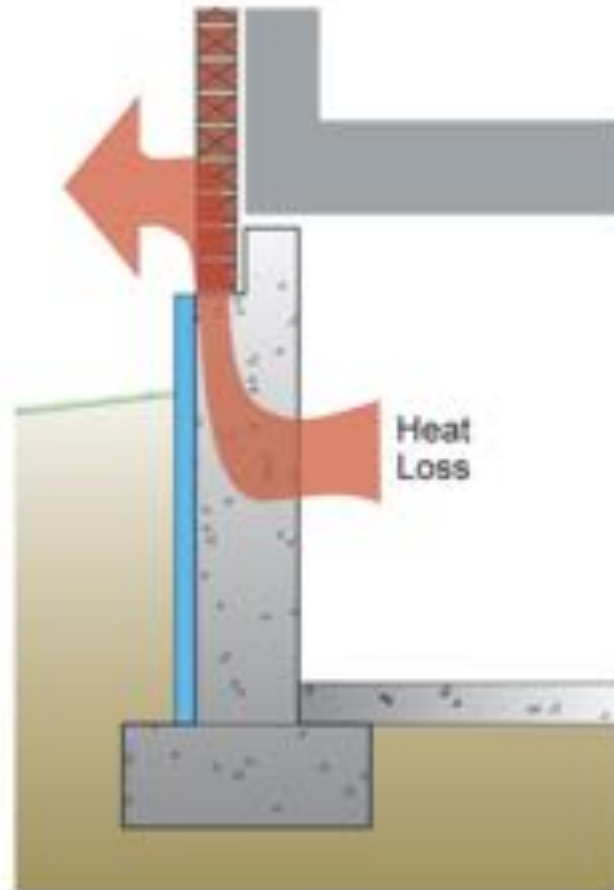


Figure 5: Brick Veneer Thermal Bridge

- Thermal bridge associated with brick veneer reduces effectiveness of the insulation at top of wall

Courtesy Building Science Corp.

Building America Special Research Project: High-R Foundations Case Study Analysis

Building America Report - 1003

20 August 2010

Jonathan Smegal and John Straube

Basement Insulation Strategies

Exterior Insulation

D. Conclusions

Heating energy loss calculations for all of the assemblies were calculated using Basecalc and the summary is shown in Table 5 below. The heating energy losses were conducted for a basement in Minneapolis (DOE climate zone 6), with an area of 1614 ft².

Table 5 : Summary of Basecalc Results

Case	Description	location	Installed Insulation R-value	Parallel Path Method	underlab and thermal break R10	MM8bus Annual Energy Loss
1	no insulation	NA	0	na	N	56.7
2	R10 continuous, code min. (roll batt)	interior	10	na	N	25.5
3	2x4 wood framed, R13 fiberglass batt (code min.)	interior	13	12.6	N	23.9
4	1" XPS, 2x4 wood framed, R13 fiberglass batt	interior	18	18	N slab / Y t.break	21.7
5	2" Polyisocyanurate, 2" XPS	interior	23	23.4	Y	15.8
6	3.5" 2.0 pcf closed cell spray foam	interior	21	na	Y	16.4
7	6" 0.5 pcf open cell spray foam	interior	21	22.3	Y	16.0
8	2" XPS, 2x4 wood framed, R13 fiberglass batt	interior	23	23.2	Y	15.8
9	2" Polyisocyanurate, 2x4 wood framed, R	interior	25	25.4	Y	15.4
10	6" 0.5 pcf spf, 2x4 wood framed offset 2" from concrete	interior	21	21.3	Y	16.3
11	4" XPS on the exterior of foundation wall	exterior	20	na	Y	19.4
12	4" XPS in the middle of foundation wall	interstitial	20	na	Y	19.2
13	Insulated Concrete Form - 2" EPS int. and ext.	int/ext (ICF)	15	na	Y	18.6
14	2" XPS, 2x6 wood framed, R19 fiberglass batt	interior	29	28.7	Y	14.8
15	4" PIC, 2x6 wood framed, R19 fiberglass batt	interior	45	45	Y (R20)	11.1

Table 6 : Comparison Criteria Matrix with Scoring Results

	Thermal Control	Durability (wetting/drying)	Buildability	Cost	Material Use	Total
Criteria Weighting	1	1	1	1	1	
Case 1: uninsulated	-	-	-	-	-	
Case 2: R10 continuous with poly (roll batt)	1	1	5	5	5	17
Case 3: R13 batt, 2x4 wall with poly	1	1	4	4	5	15
Case 4: 1" XPS, 2x4 framed wall with fgb	2	3	3	3	4	15
Case 5: 2" XPS, 2" PIC	4	4	3	3	3	17
Case 6: 3.5" 2.0pcf cc spuf	4	5	5	3	3	20
Case 7: 6" 0.5pcf oc spuf	4	4	5	4	4	21
Case 8: 2" XPS, 2x4 framing with fgb	3	3	3	3	4	16
Case 9: 2" PIC, 2x4 framing with cellulose	3	3	3	3	4	16
Case10: 2.5" 0.5 oc spuf, 2x4 framing with same foam	4	4	4	3	3	18
Case 11: 4" XPS on the exterior	4	4	2	2	3	15
Case 12: 4" XPS in the centre of foundation wall	4	4	3	1	3	15
Case 13: ICF - 2" XPS interior and exterior	4	5	4	1	3	17
Case 14: 2" XPS, 2x6 framing with fgb	5	4	3	2	3	17
Case 15: 4" PIC, 2x6 framing with fgb	5	5	3	2	2	17

Water Management and High R Walls



ste

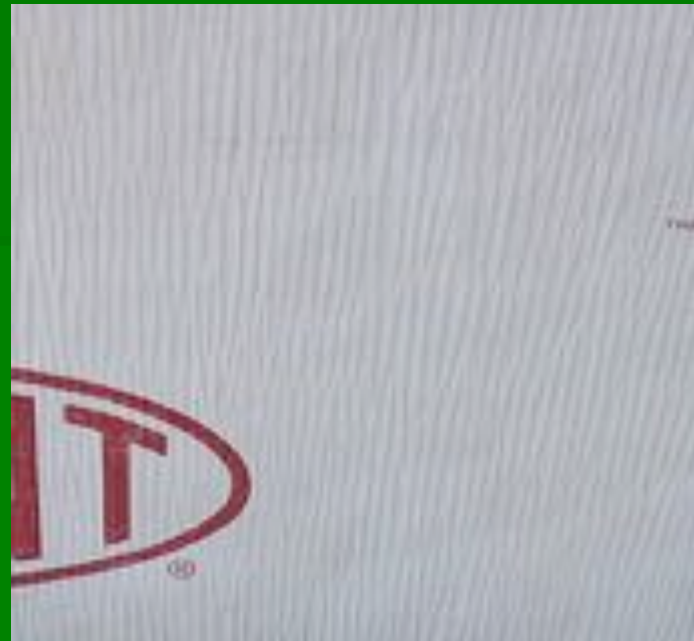
Barrier Wall

- Surfaces are face sealed
- Have no path for drainage



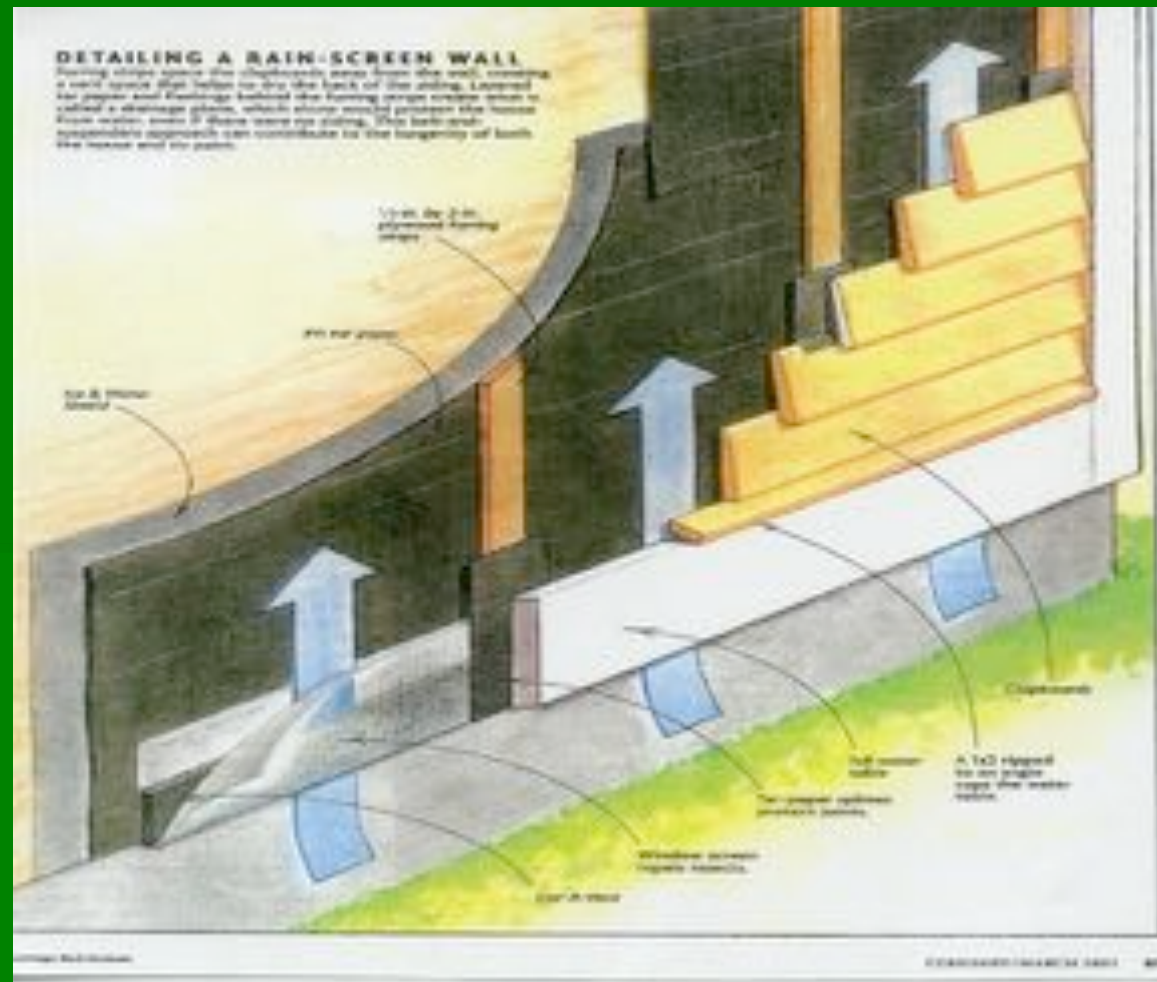
Drainable Walls

- Walls are not face sealed
- Have secondary barriers to reduce water penetration
- Ideal to have drainage gap



Rain Screen Walls

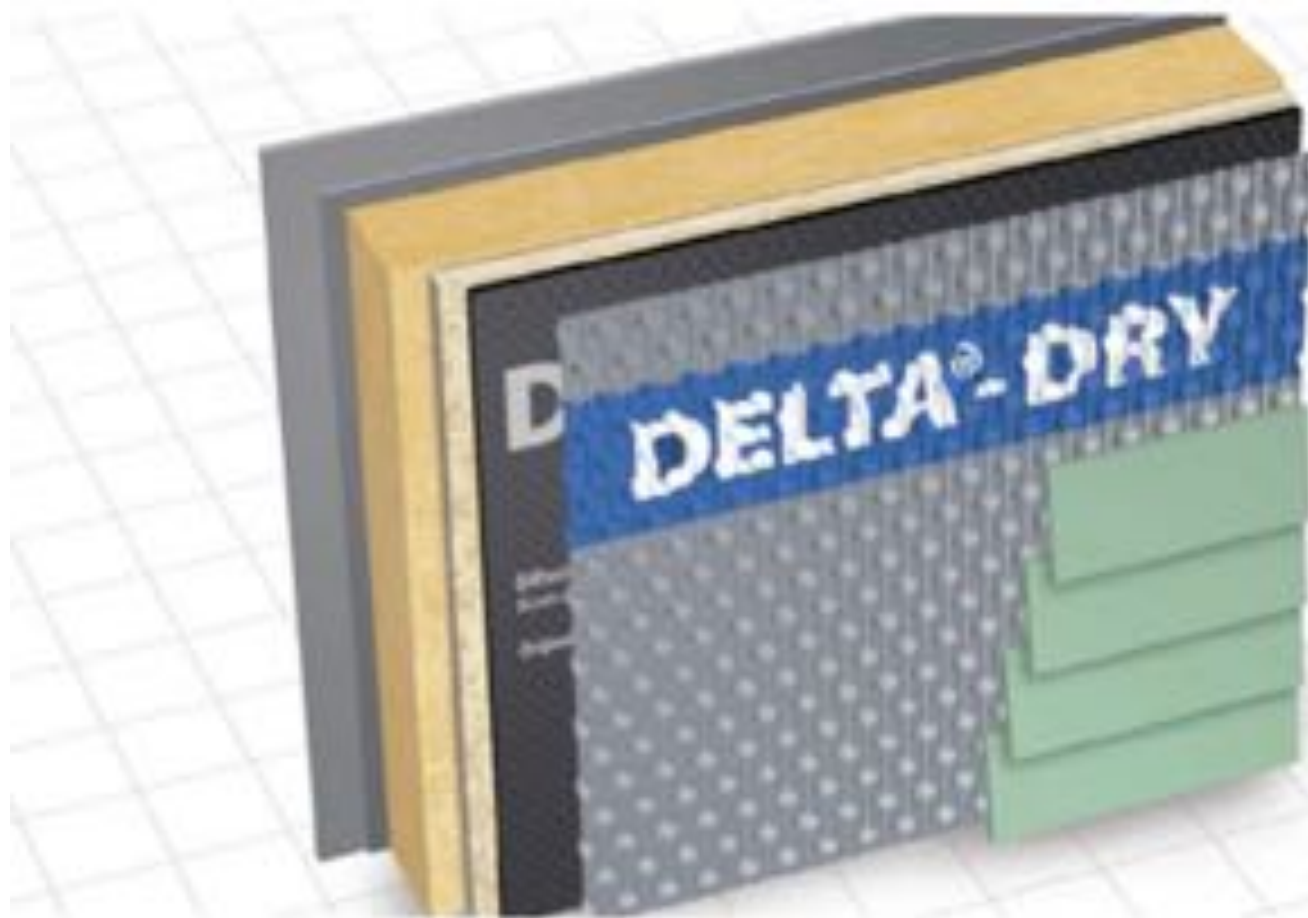
- Rain screens provides air space for drainage and a capillary break. Min ¼ "
- Idea 1"



Wood Frame Wall Designed as a Rain Screen



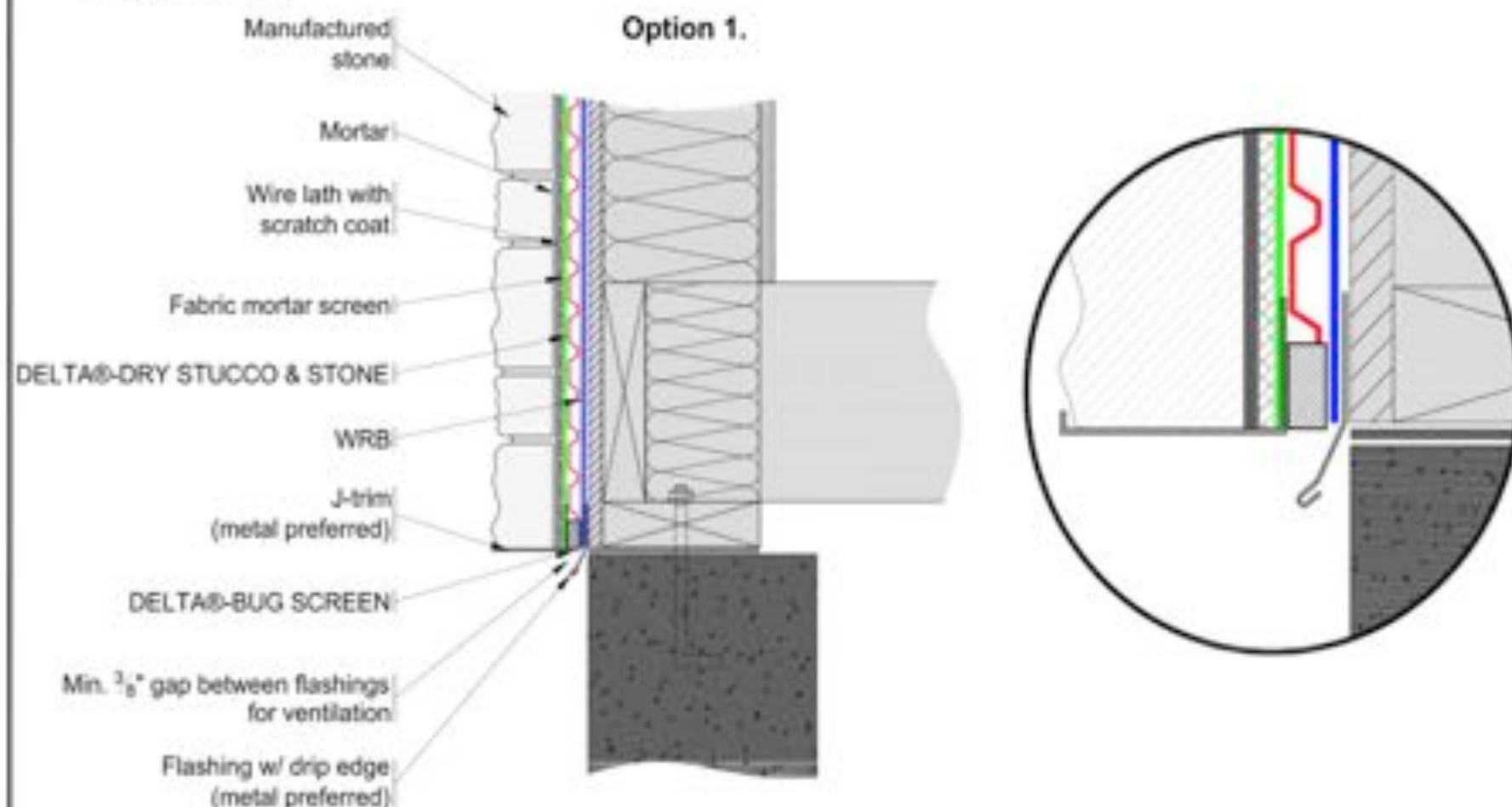
Cement Board





NOTE:
WRB (WATER-RESISTIVE BARRIER) TO BE
INSTALLED AS PER MANUFACTURER'S
SPECIFICATIONS

Option 1.



For proper performance of DELTA®-DRY ensure top and bottom remain open to allow ventilation and drainage

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TITLE: DELTA®-DRY STUCCO & STONE RAINSCREEN APPLICATION WITH
MANUFACTURED STONE BOTTOM OF WALL DETAIL OPTION 1

APP'D BY: DATE:

DRAWN BY: KADYSZTOR APRAZL

CH'D BY:

DATE: February 8, 2011

SCALE: NTS

FILE NAME: DRY1_54581.dwg

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Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Moisture Research— Optimizing Wall Assemblies

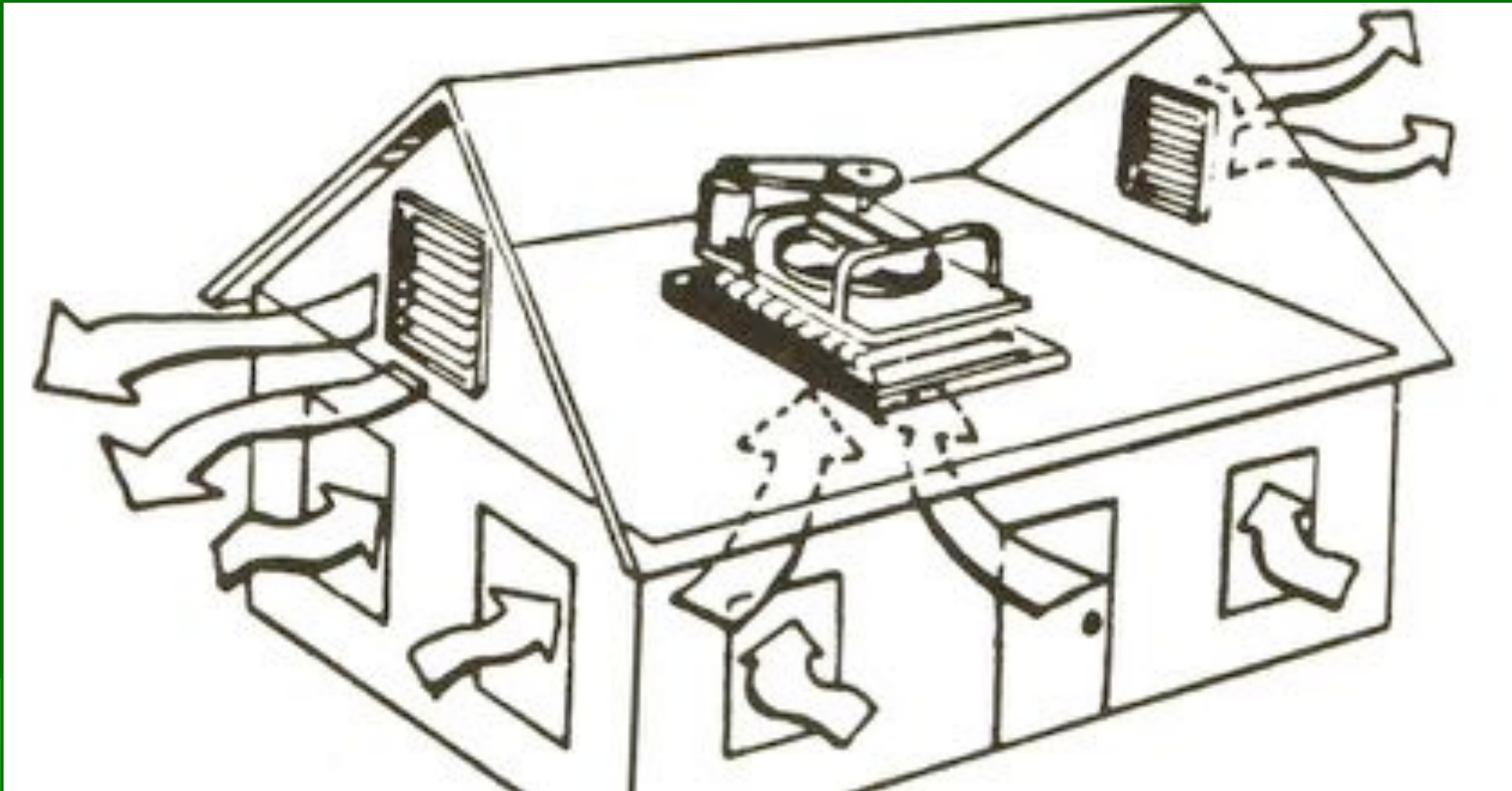
Lois Arena and Pallavi Mantha

Consortium for Advanced Residential Buildings

May 2013

Building
AMERICA
U.S. Department of Energy

Whole House Fans



12- 20 CFM/Watt

Copyright Steve Easley, 2014

Basic Whole House Fan Operation

SLASH YOUR A/C COOLING COSTS BY 50-90%
COOL YOUR HOME, ATTIC, AND GARAGE 24 HOURS A DAY

ATTIC FAN - CABLE
GARAGE/ATTIC FAN
CLASSIC, TIRENT
CLASSIC LINE
ENERGY SAVER, CONTRACTOR, STEALTH

HOW IT WORKS | TRADITIONAL OPERATION

ATTIC/GARAGE FAN SAVINGS COMPARISON

	CFM/ WATT	1 Year Cost*	5 Year Cost*	10 Year Cost*
QuietCool Attic Fan	52	\$21	\$108	\$216
Other Attic Fans Avg.	3.5	\$287	\$1,483	\$2,866

*Cost of Running Fan for cooling season (7.5, 3000 h, 600 hrs)

1 Your open window brings in fresh, natural air.

2 QuietCool fans draw cool air in through your home into the attic through ceiling mounted grilles.

3 Patented, whisper quiet, ducted design allows system to suspend in attic - keeping noise & vibration out of your living space.

4 Hot attic air is forced outside through vents.

OPTIONAL FULLY-AUTOMATED ECONOCOOL PACKAGE

Set your QuietCool smart thermostat to your desired interior temperature and humidity level.

QuietCool's integrated wall unit allows the system to operate without managing doors/windows.

Advanced Search - Results

QUICK LINKS

- Energy Saver
- Feedback Form
- Report an Appliance Efficiency Violation

Display all fields

Compare Checked Results

Previous Page 1 of 85 Next

Sort by Date Sort by Cost

Display 10 per page

Records 1 - 10 of 843

Manufacturer Name	Brand Name	Model Number	Fan Type	Air Flow CFM	Fan Motor Watts	Air Flow Efficiency (CFM/Watt) *
QC Manufacturing, Inc.	Quiet Cool	APC ES-1500	Direct-Drive Single Whole House Fan	1500	30.0	52.000
QC Manufacturing, Inc.	Quiet Cool	QC ES-1250	Direct-Drive Single Whole House Fan	1265	36.0	35.139
QC Manufacturing, Inc.	Quiet Cool	QC STL-1.5	Direct-Drive Single Whole House Fan	1545	48.7	33.084
QC Manufacturing, Inc.	Quiet Cool	QA ES-1100	Direct-Drive Single Whole House Fan	1452	48.8	31.626
QC Manufacturing, Inc.	Quiet Cool	QC ES-1100	Direct-Drive Single Whole House Fan	1765	78.8	22.582
QC Manufacturing, Inc.	Quiet Cool	QC ES-2000	Direct-Drive Single Whole House Fan	2034	88.8	22.905
QC Manufacturing, Inc.	Quiet Cool	QC STL-2.5	Direct-Drive Single Whole House Fan	2560	137.0	18.686
QC Manufacturing, Inc.	Quiet Cool	RM ES-1100	Direct-Drive Single Whole House Fan	1130	66.0	17.121
Triangle Engineering	Dayton	35A42	Direct-Drive Single Whole House Fan	3140	184.0	16.186
Triangle Engineering	Triangle Engineering	CA3021	Direct-Drive Single Whole House Fan	3140	184.0	16.186

Your Search Criteria

Fans and Dehumidifiers
Type: Whole House Fans &
Residential Exhaust Fans

Added Filters: 1 edit filters

Reset Search

Previous Searches

1. Fans and Dehumidifiers
Whole House Fans &
Residential Exhaust Fans

HVAC Problems & Green Solutions



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High Efficiency Equipment is part of the Solution



at Steve



Exhibit 2: DOE Zero Energy Ready Home Target Home ^{7, 20}

HVAC Equipment ²¹			
	Hot Climates (2012 IECC Zones 1,2) ²²	Mixed Climates (2012 IECC Zones 3, 4 except Marine)	Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10 ²³
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 60% SRE
Insulation and Infiltration			
- Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards. - Infiltration²⁴ (ACH50): 3 in CZ's 1-2 2.5 in CZ's 3-4 2 in CZ's 5-7 1.5 in CZ 8			

Effective for Homes
Permitted Starting 6/21/2014

Revised April 21, 2014

Page 2 of 9

Existing Technicians Fail to Follow Standard Recommendations

National Training Directors' Estimates

- Courtesy of Philip Wernhoff

- Failure to use Recommended Evacuation Method (Refrigerant Lines and Coil)

72%

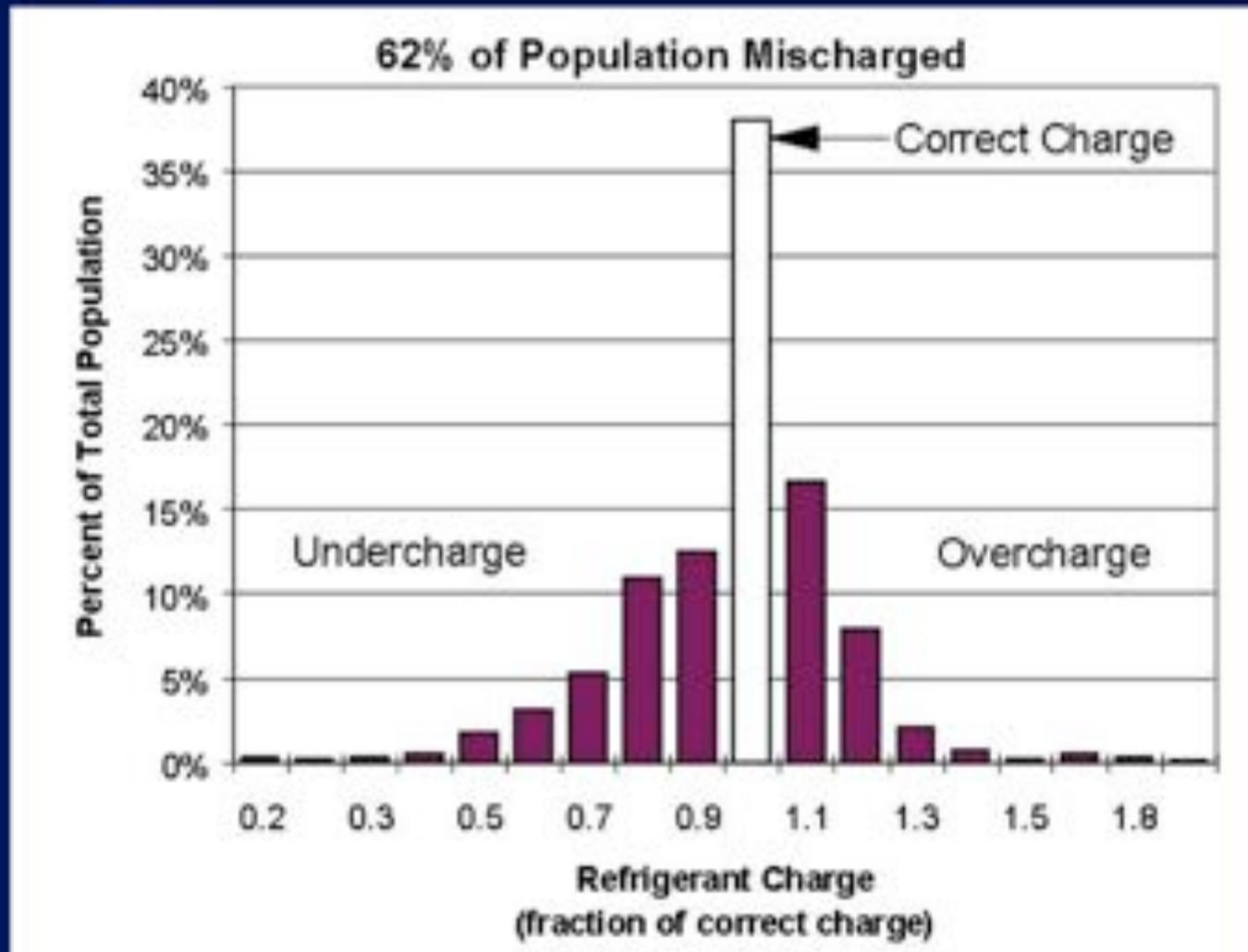
- Failure to Confirm 350 to 450 CFM/Ton

72%

- Failure to Use Recommended Charging Method

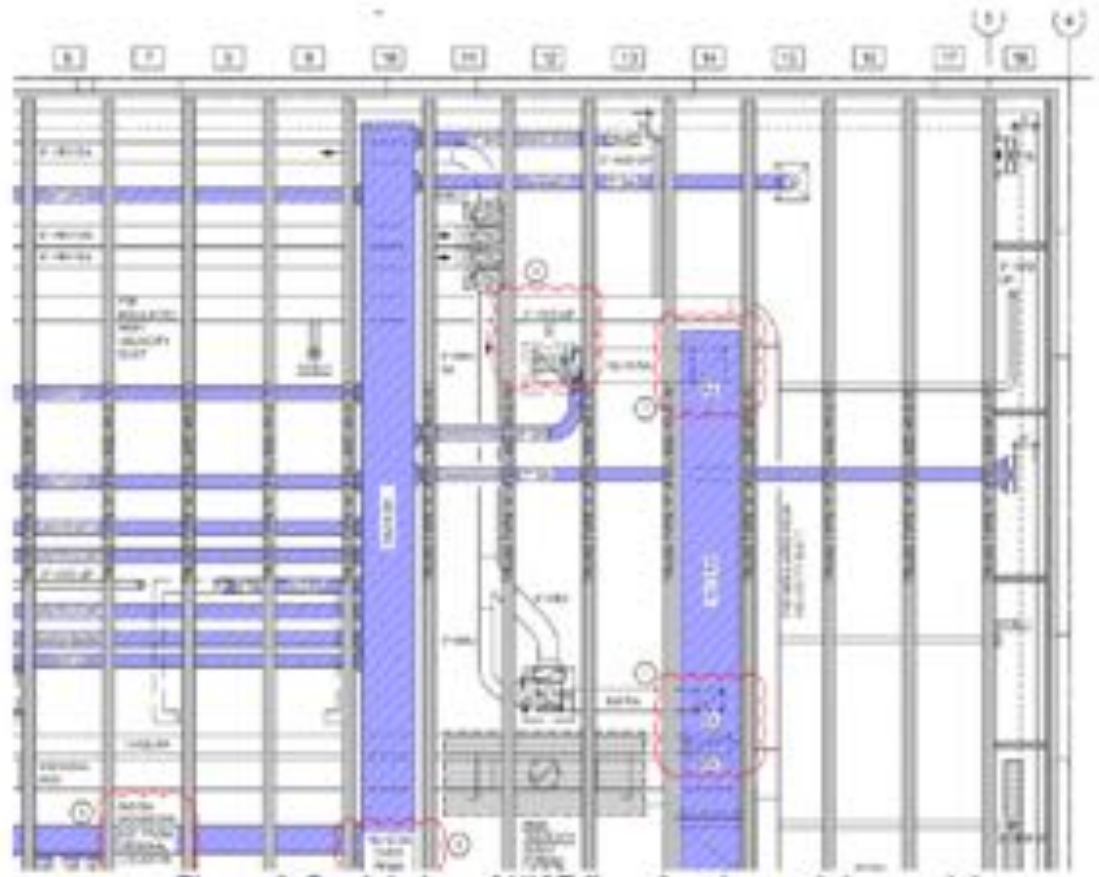
74%

Charge Incorrect 62% of Time



QMS Strategies for ZERH

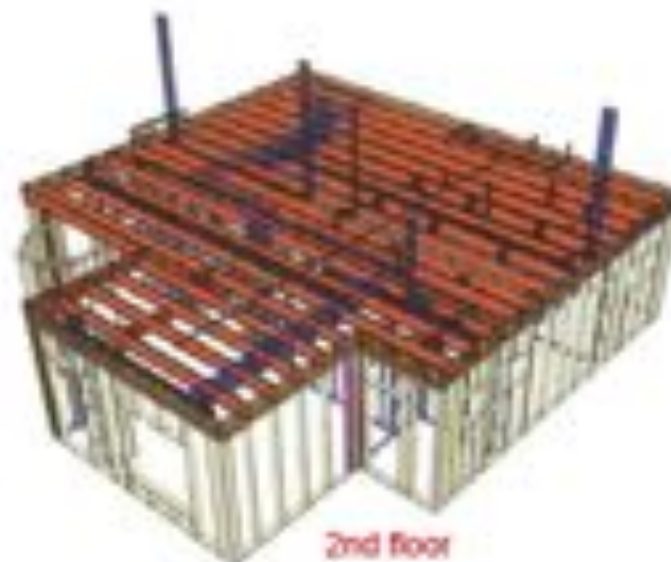
Example coordination drawing for framing and ducts



Duct layout in 3-D plan to assure accurate and consistent installation



3rd floor



2nd floor



1st floor

2. Duct Conduction (H/C)

- Duct conduction can be calculated with the formula

$$Q = (A * \Delta T) / R$$

- Duct surface area typically equals 40% of the floor area



2. Duct Conduction (H/C)

- If a 2,000 square foot house has an attic temperature of 140°F what is the duct conduction when the system is running and the duct insulation is R-2.1?

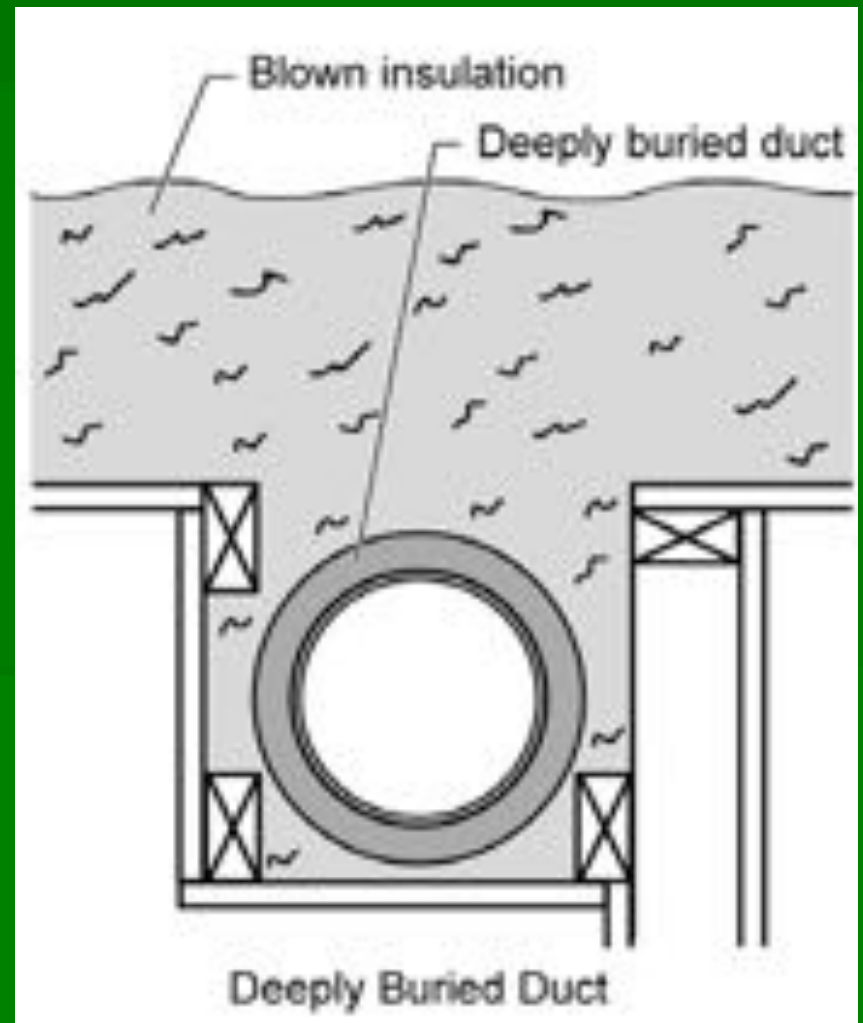
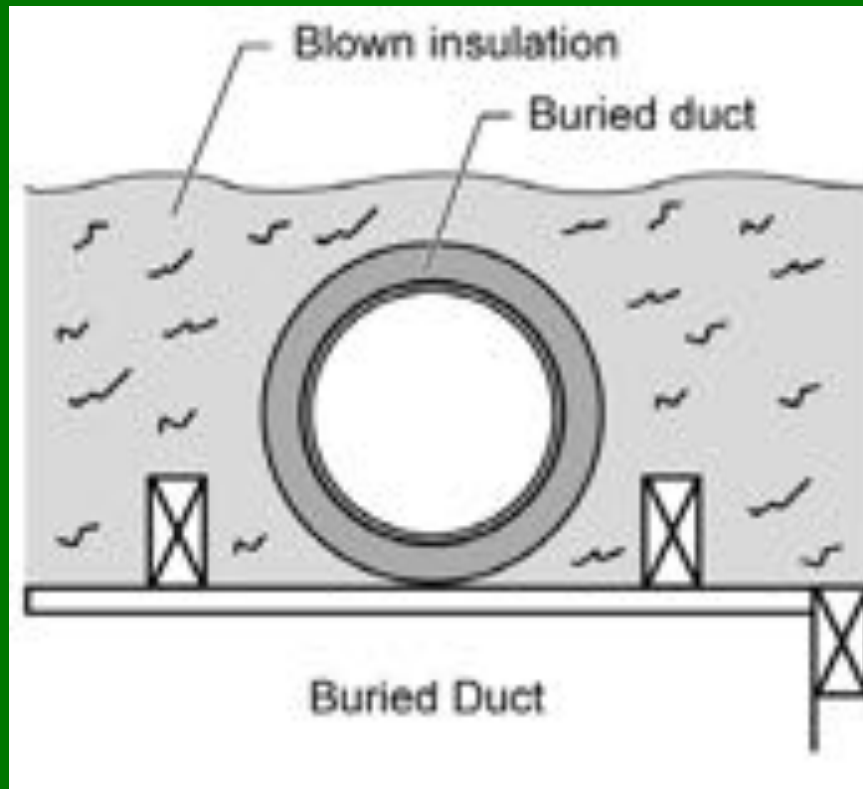
1. $Q = (A * \Delta T) / R$

2. $Q = ((2,000 \text{ sq.ft.} * 0.4) * (140^\circ\text{F} - 60^\circ\text{F})) / R2.1$

3. $Q = 800 * 80^\circ\text{F} / R2.1$

4. $Q = 30,500 \text{ BtuH (2.5 Tons)}$

R-8.0 + Buried Ducts = R-20.0 (or more)



Courtesy Rick Chitwood.

Copyright Steve Easley, 2014

2. Duct Conduction (H/C)

- Same example. ...but with reduced surface area and buried R-8 ducts

1. $Q = (A * \Delta T) / R$

2. $Q = ((2,000 \text{ sq.ft.} * 0.2) * (140^{\circ}\text{F} - 60^{\circ}\text{F})) / R_{20}$

3. $Q = 400 * 80^{\circ}\text{F} / R_{20}$

4. $Q = 1,600 \text{ BtuH} (0.13 \text{ Tons})$

Effective R-values



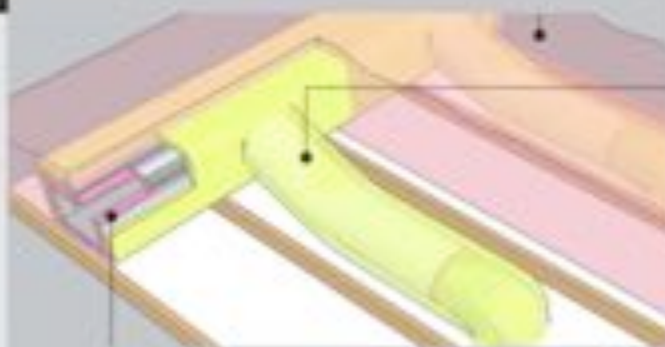
Duct Configuration	R-4.2 Ducts	R-6 Ducts	R-8 Ducts
Traditional hung ducts	4.6	5.9	7.2
Hung ducts encapsulated in 1.5" of ccSPF	11.3	12.0	12.7
Partially-buried	8.1	10.2	12.3
Fully-buried	12.0	14.1	16.2
Deeply-buried	20.7	22.1	23.5
Encapsulated in 1.5" of ccSPF and partially-buried	18.4	19.7	21.0
Encapsulated in 1.5" of ccSPF and fully-buried	22.6	23.8	25.0
Encapsulated in 1.5" of ccSPF and deeply-buried	29.6	30.3	31.1



Measure Guideline: Buried and/or Encapsulated Ducts

C. Shapiro, W. Zoeller, and P. Mantha
Consortium for Advanced Residential Buildings

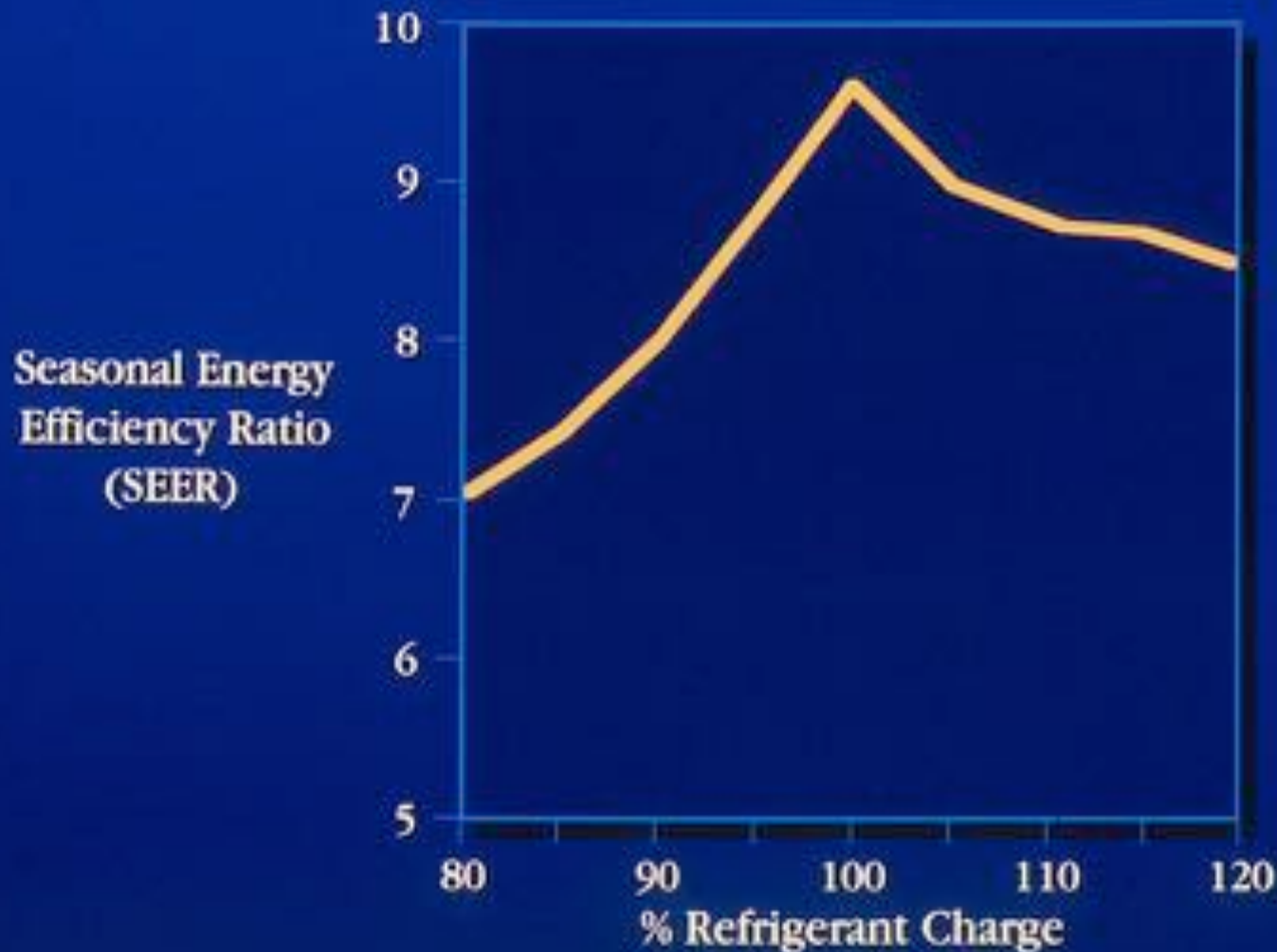
August 2013



Duct Installation

- Duct runs straight with no kinks or crushed areas.
- Ducts to have no more than 90° angle turns.
- Ducts sealed with mastic sealant.
- Flex duct connections to boots fastened with duct ties
- Duct leakage to be no more than 6% of fan flow @ 25pa

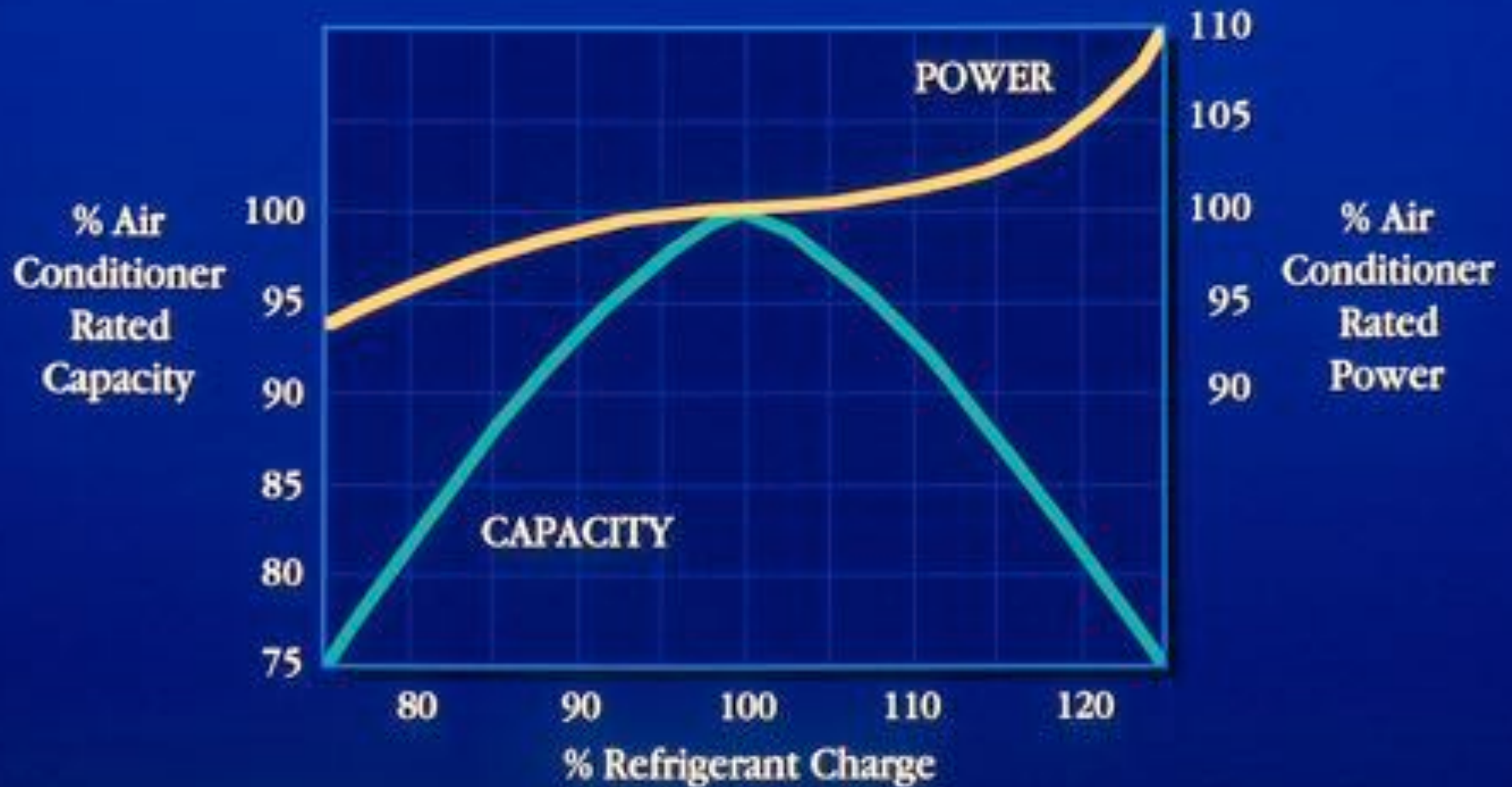
Effects of Charge on SEER



Source: Home Energy Magazine, May/June 1993

Copyright Steve Easley, 2014

Effects of Refrigerant Charge on Capacity and Power Input (simulated)



Source: Home Energy Magazine, May/June 1992

Copyright Steve Easley, 2014

System 2: HVAC System Basic Concepts

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Thermal
Enclosure

Heating, Cooling
& Ventilation

Water
Management

Design:

1. Calculate Heating/Cooling Loads
2. Select Equipment that Meets Loads
3. Design Duct System that Gets Air from Equipment to Rooms and Back

Commission:

- A. Check Airflow at Air Handler
- B. Check Refrigerant Charge
- C. Measure Airflow at Registers/Exhaust

HVAC QI
Contractor
Checklist

HVAC QI
Rater
Checklist

Total Connect Comfort = Total Control

- Visit the portal or app:
 - View and change their HVAC system settings
 - View and change the temperature, fan, humidity
 - View and change the schedule
 - View outdoor conditions and forecast
 - Access multiple thermostats if their system is zoned
 - Access all locations if multiple systems are registered



Lyric key features

- Geofencing
- Fine Tune
- Shortcuts
- Smart Cues



Lyric makes it simple.

- Your customers are in. They're out. They're all over the place, even when they're home.
- Lyric can use their smartphone to know when they're away, and save energy. It senses their return and helps make them comfortable when they are home.
- There's no learning curve. No elaborate programming.

LyricTM
Life in tune.

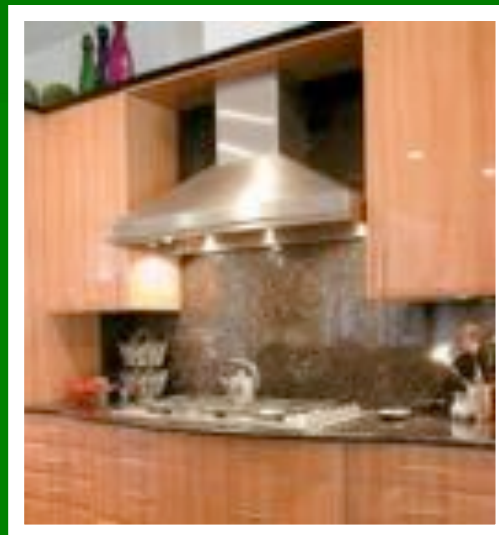
Controlling Interior Moisture



**Bath fans >50 cfm, vented
thru roof**



Automatic controls



**Kitchen exhaust fans
vented to outdoors**

Clearing the Air:

Fresh Ideas in Bathroom Ventilation



The Need for Bathroom Ventilation

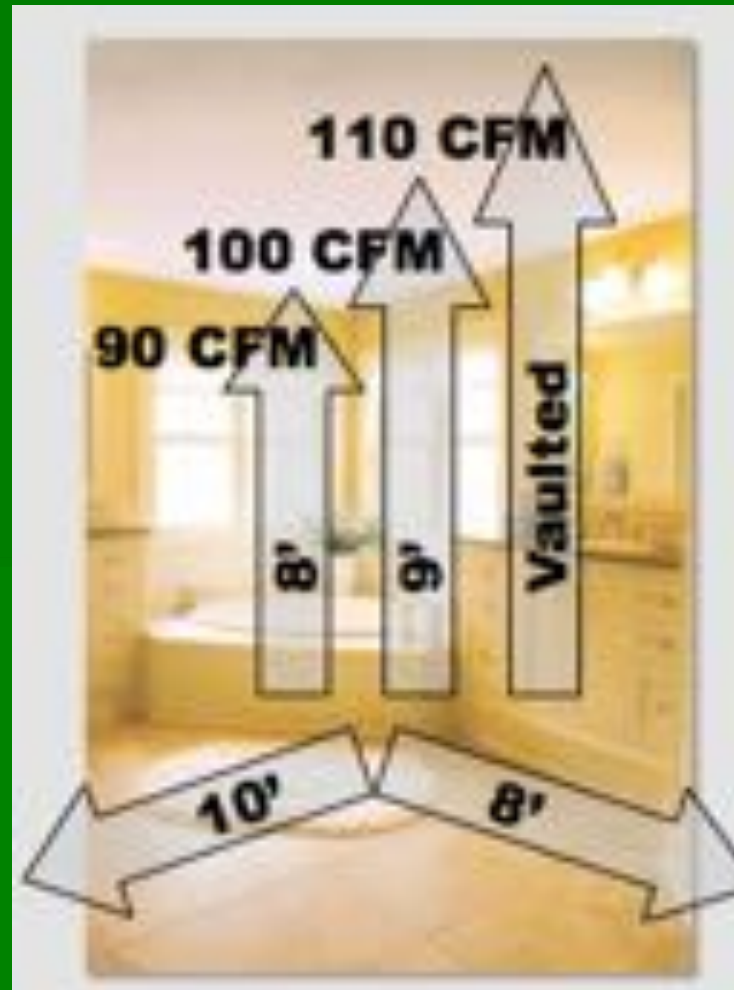
Problems

- Excess moisture – supports mold growth, leads to aggravating steamed mirrors and destroys paint and wallpaper



Calculating CFM for Proper Ventilation (cont.)

Ceiling Height:



Calculating CFM for Proper Ventilation (cont.)

How Critical is the Ductwork - Example:



Calculating CFM for Proper Ventilation (cont.)

How Critical is the Ductwork - Example:



It is all about Measured Performance

Compliance with ASHRAR 62.2 the national ventilation standard, is now required for ENERGY STAR® for Homes 3.0

Effective date July 1st 2013

- Measured ventilation rate is within 100-120% of HVAC contractor design value
- Rater shall measure ventilation and exhaust air flow using a flow hood, flow grid, anemometer or substantially equivalent method in accordance with AABC, NEBB or ASHRAE procedures
- **Intermittent bath fan measured air flow requirement $\geq$ 50 CFM**
- Continuous supply and exhaust fans rated at 1.0 sones or less
- Exhaust-only whole-house mechanical ventilation system must be verified that the fan turns on automatically, without homeowner intervention



Don't Trust Verify

Here is a story of two Ventilation fans on the surface they are equal

- Both fans are Energy Star qualified
- Both fans are 70 CFM certified from HVI
- Both fans are in the same cost category

But these fans are not equal....

- Fan A is being widely used by National Estar Home Builders
- Installed Performance under (static) pressure is a deciding factor

Let us see how Fan A and Fan P both perform

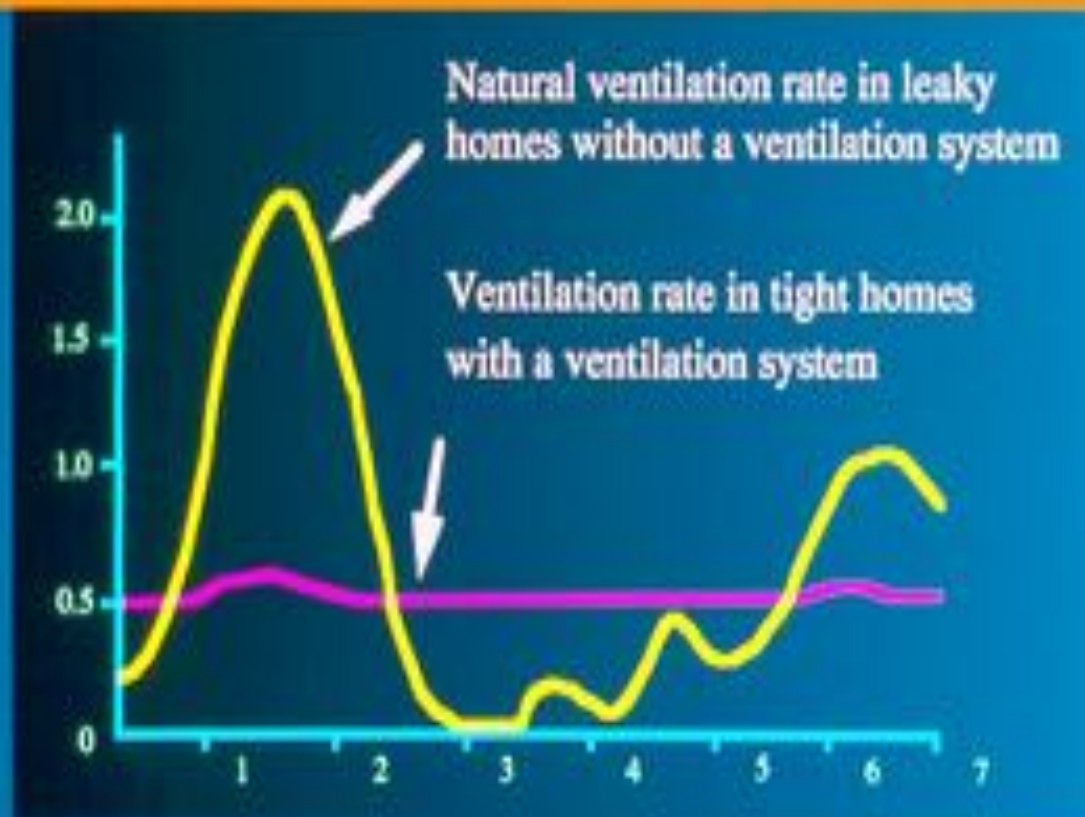
Whole-House Ventilation

- Whole-House Ventilation or continuous refers to providing a consistent level of ventilation throughout the day in order to remove indoor air pollutants of all types.



N

Natural vs. Mechanical Ventilation Rates



ASHRAE 62.2

What is ASHRAE 62.2?

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- It is the only nationally recognized indoor air quality standard developed solely for residences.
- 62.2 2010 for 2012-15 codes



ASHRAE 62.2

Where is ASHRAE 62.2?

- Top Green building Programs
 - U.S.G.B.C. LEED® Program for Homes
 - NAHB Green Home Building Guidelines
 - EPA Indoor Air Plus
- Proposed for International Residential Code (IRC)

ASHRAE 62.2

- Building codes written to meet 62.2 require two types of ventilation in every home
 - Intermittent ventilation for every kitchen and bathroom.
 - Bathroom = minimum 50 CFM, 3 Sones or less.
 - Kitchen = minimum 100 CFM, 3 Sones or less.
 - Continuously operating mechanical ventilation system
 - High-rise residential – More than 3 stories (slightly higher ventilation rate)
 - Low-rise residential – 3 stories or less
 - Ventilation air requirements are based upon size of the home (ft²) and the number of bedrooms.
 - Sound level to be equal to or less than 1 Sone.

ASHRAE 62.2 Continuous Low-rise Ventilation Rate (CFM)

Floor Area (ft ²)	Bedrooms				
	0 - 1	2 - 3	4 - 5	6 - 7	> 7
< 1500	30	45	60	75	90
1501 - 3000	45	60	75	90	105
3001 - 4500	60	75	90	105	120
4501 - 6000	75	90	105	120	135
6001 - 7500	90	105	120	135	150
> 7500	105	120	135	150	165

A 4500 square foot home with 5 bedrooms requires an average of 90 CFM of continuous ventilation

Example:

2,500 sq. ft. house with 3 bedrooms,
4 occupants = $[2500 \times 0.03] + [(3+1) \times 7.5] = 105 \text{ CFM}$

The ASHRAE 62.2 2010 standard would have required 55 cfm of fresh air for the same exact house. This is due to the assumption that a leaky house had some natural ventilation that helped dilute pollutants.

Improve the Air Quality Throughout the Home

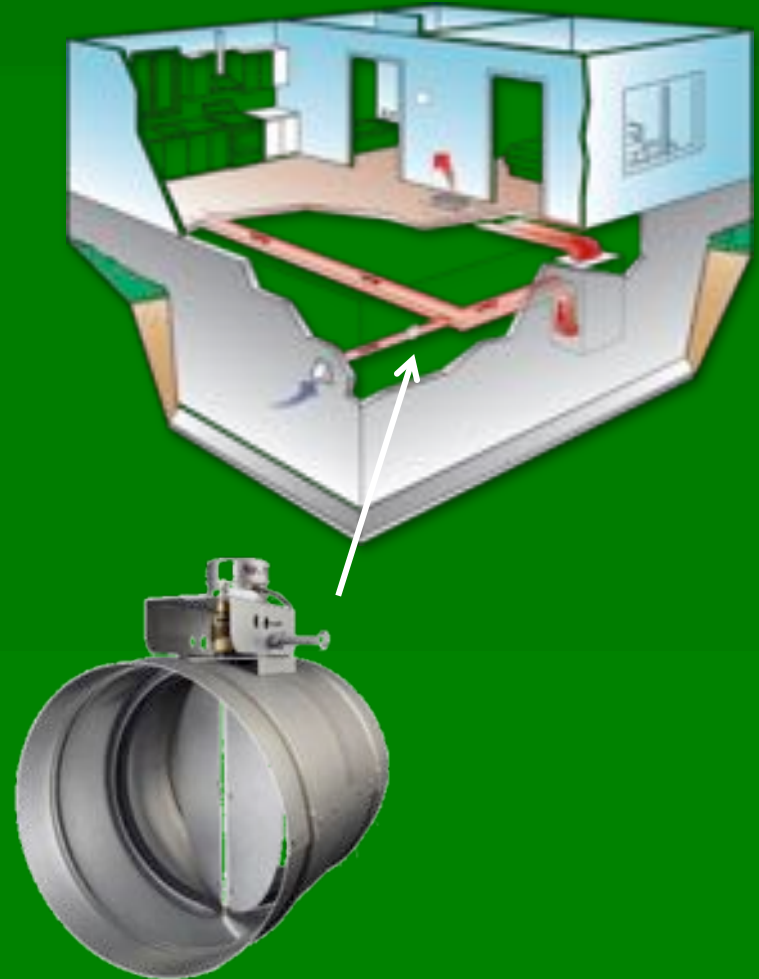
Automatically and Efficiently

A new system of ventilation fans that once worked independently now work together as an integrated ventilation system. Because these fans can ventilate from different locations, you're assured of ongoing fresh air distribution throughout the home.

A Special Consideration

Make-Up Air

- The whole-house automatic ventilation system also works with make-up air dampers to allow outside fresh air into the return air system, whenever a fan is running.
- This may be desirable in extremely tight homes and for those with naturally vented combustion appliances.



Fresh Air Ventilation



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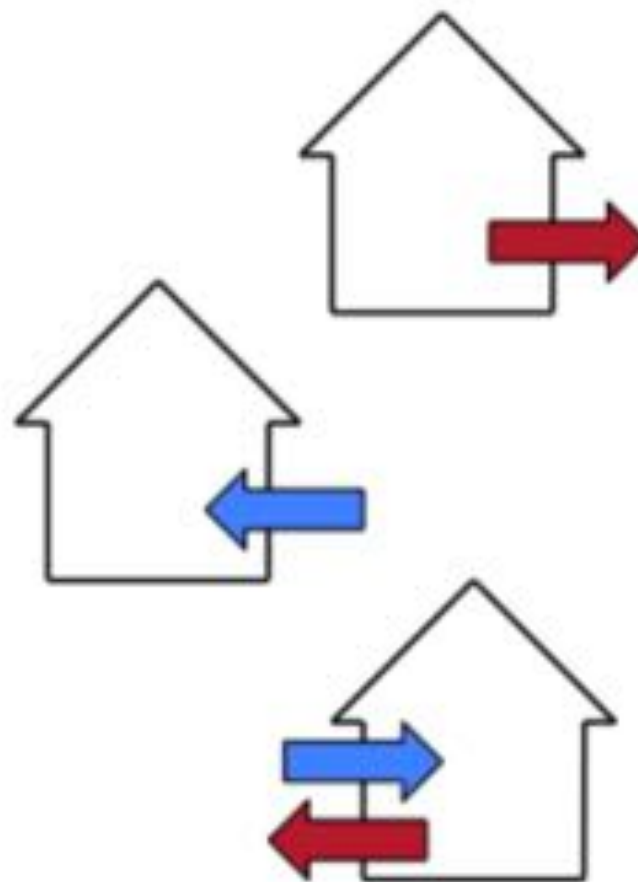




Whole-House Ventilation

Three main types

- Exhaust only
- Supply only
- Balanced



Source: ASHRAE 62.2-2010, Figure 6.2.1

Types of Ventilation – Pro's & Con's

	Exhaust Only	Supply Only	HRV	ERV
Pro's	•Inexpensive Install •Easy to Retrofit •Low Maintenance •Low Energy Fan	•Inexpensive Install •Easy to Retrofit •Low Maintenance •Air is filtered	•High Energy Savings •Low Maintenance •Air is filtered •Balanced pressures	•High Energy Savings •Air is filtered •Humidity Control •Balanced pressures
Con's	•No heat recovery •Can pull humid air into building cavities	•Use furnace fan – high energy use •No heat recovery •Could push humid air into building cavities	•Expensive Install •Hard to Retrofit •Higher Energy Use Fan •Condensate Drain Needed	•Expensive Install •Hard to Retrofit •High Maintenance •Condensate Drain Needed
Best Use	•No outdoor pollutants •Outdoor humidity is not a problem	•High outdoor pollutants – incoming air should be filtered	•Areas where indoor humidity is too high •Areas where humidity is not a concern	•Areas of high outdoor humidity •Areas with low indoor humidity

Clearing the Air:

Fresh Ideas in Kitchen Ventilation



Key to Good Kitchen Ventilation:

The Range Hood

- Because the kitchen is a major source of pollutants, remove them at the source.

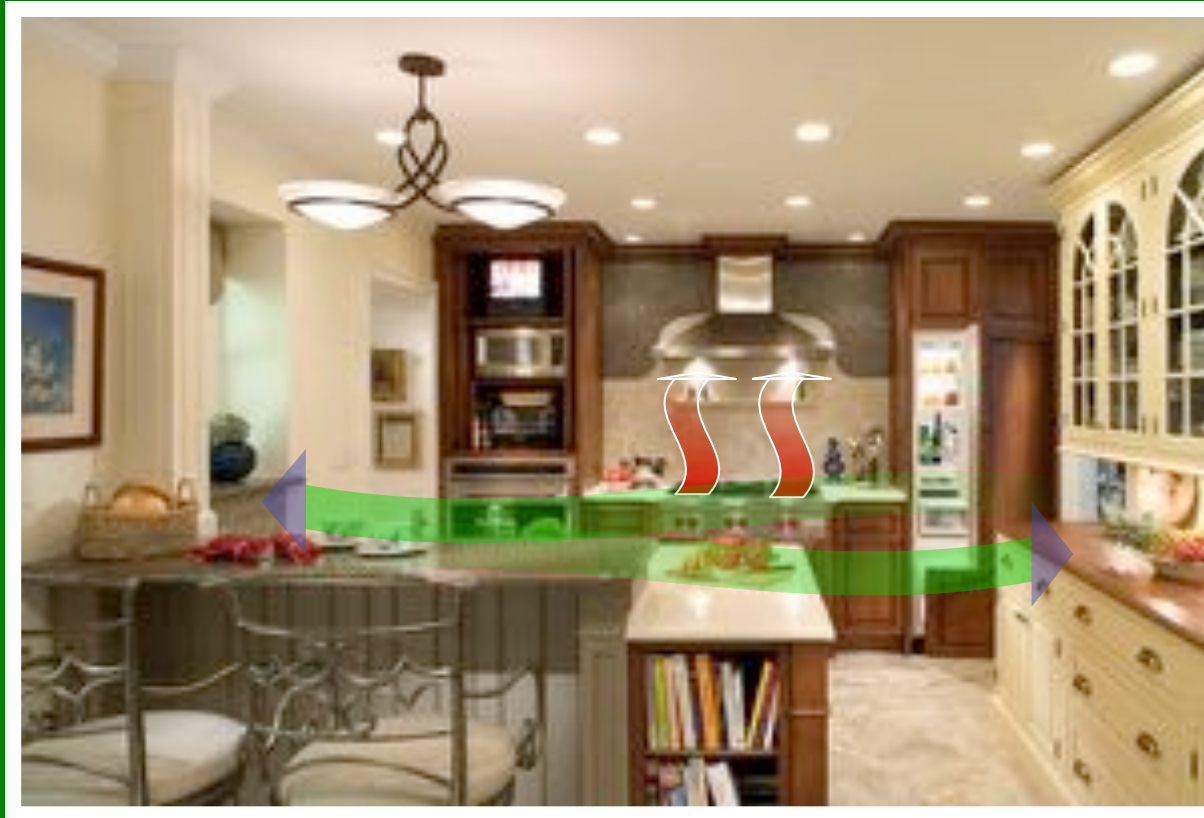


Photo Credit: Ellen Cheever, CMKBD, ASID, Ellen Cheever and Associates

The Concept of a Canopy “Capture Area”

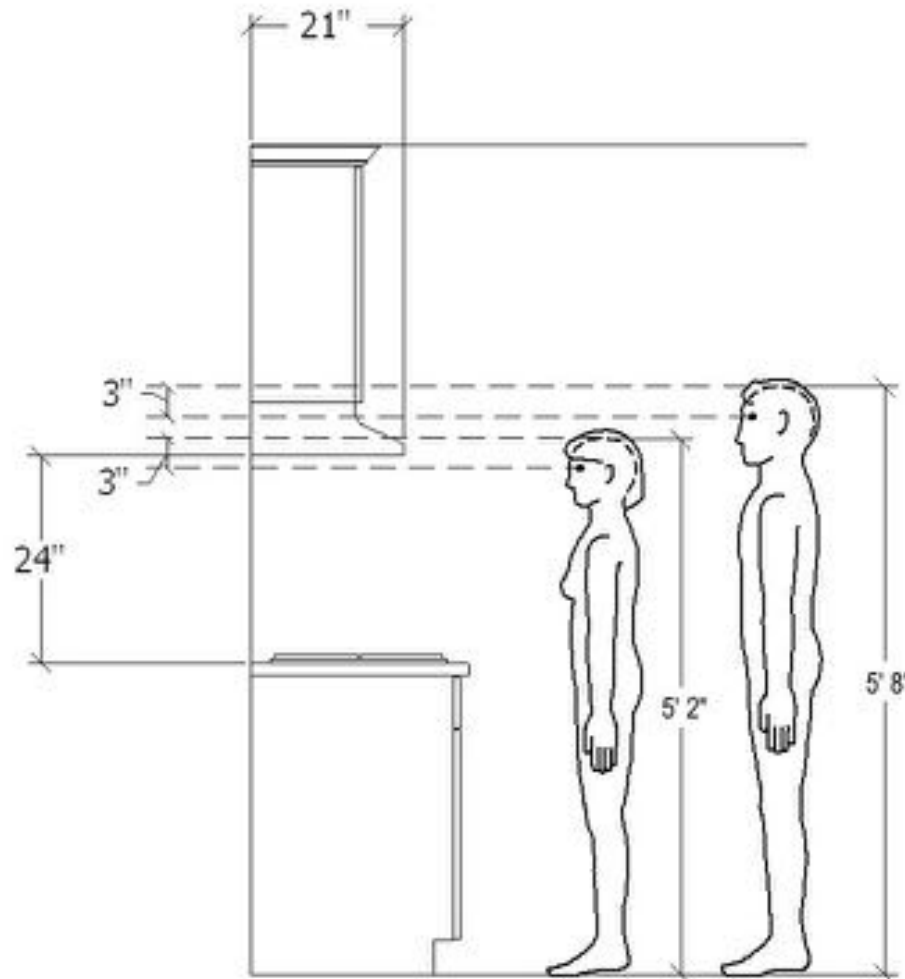


Photo Credit: Mark Thomas White, CKD, Kitchen Encounters

Range Hood Option #1

Conventional Overhead System 24" Off the Cooking Surface

- Minimum 21" deep canopy
- Assume average users eye level 3" below individual height
- Plan a minimum 100 CFM per linear foot of hood width



Note: Minimum recommendation
for gas appliances

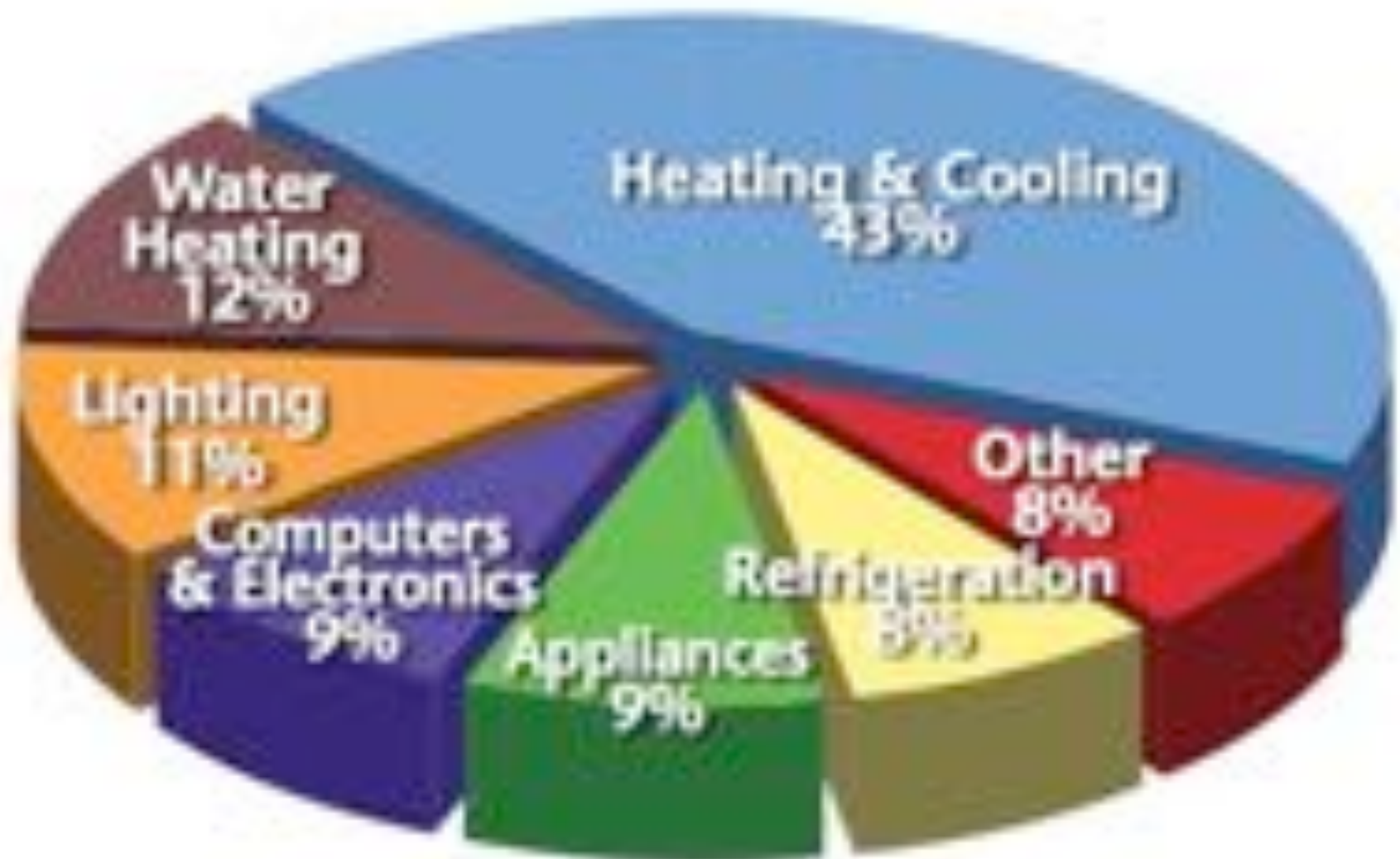
Range Hood Options:

Downdraft Ventilation System





Domestic Hot Water



Water Heating Facts

- Water heating accounts for 14-25% of home energy use
- 2nd or 3rd largest energy user in the home
- As enclosures become more efficient water heating costs become more important

Water Heating Use & HERS

HERS Index

$$\frac{PE_{frac} \times 100 \times (E_{heating} + E_{cooling} + E_{wh} + E_{la})_{rated\ home}}{(E_{heating} + E_{cooling} + E_{wh} + E_{la})_{reference\ home}}$$

Legend: E=energy consumption, wh=water heating, la=lights and some appliances, PE=purchased energy (fraction).

Basically, the way it works is the energy use of the rated home is compared to the energy use of the reference home. If the energy use for both works out to the same amount, then the fraction part of the equation (PE_{frac}) equals 1. Multiply 1 by 100 and in this case, you get a HERS Index Score of 100.

Now, if the rated home's energy use works out to half of that for the reference home, its HERS Index Score would be 50. However, if the rated home uses twice as much energy as the reference home, then its HERS Index Score would be 200.

The Purchased Energy or PE_{frac} is a multiplier that can reduce the HERS Index Score for those homes that produce some or all of the energy they use over the period of one year. There's a separate equation to achieve this number, which breaks down to something along these lines:

Terminology... Tankless Condensing, Non Condensing



Terminology... Storage, Condensing, Direct Vent



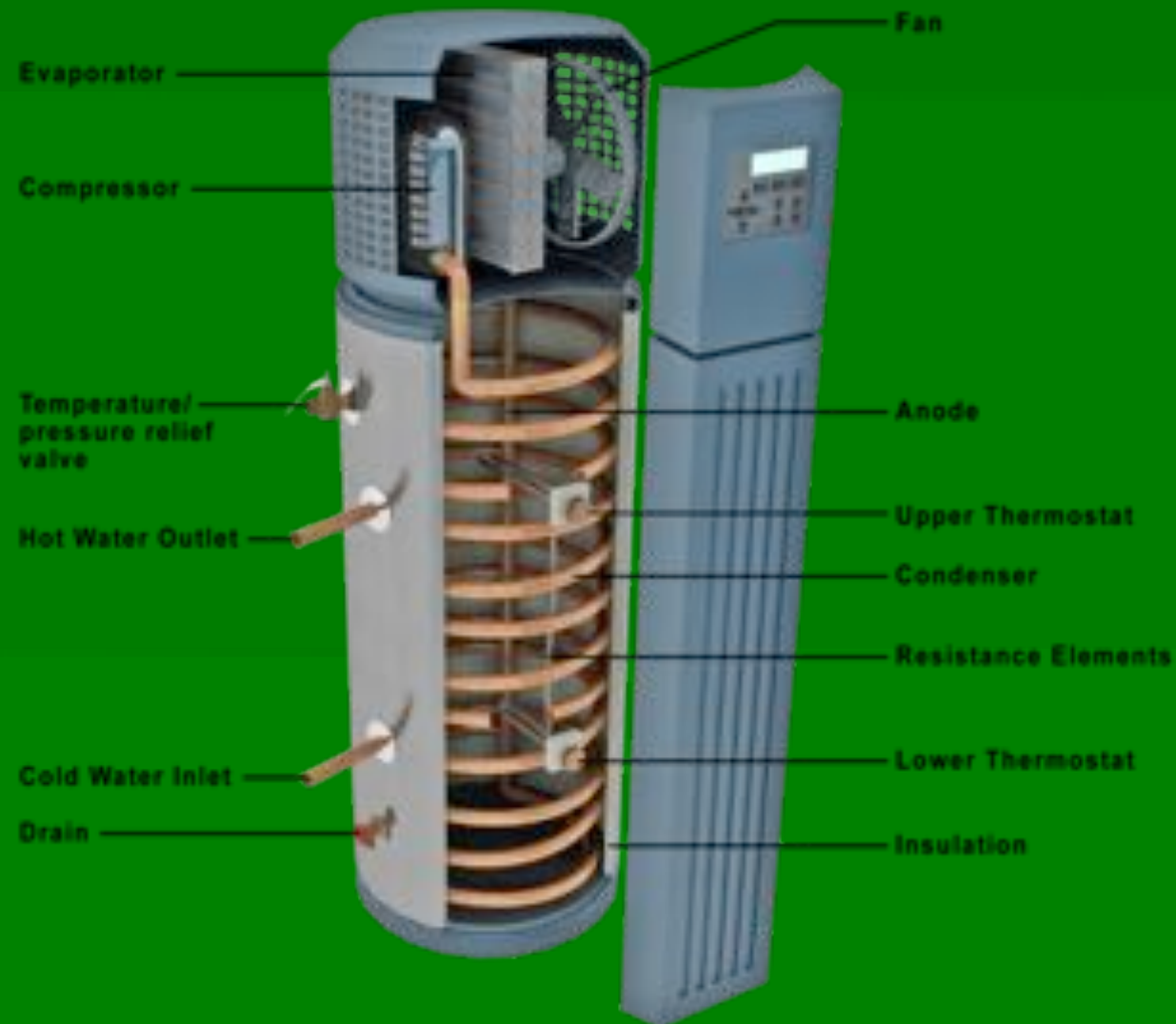
Terminology... Direct Vent Non-Condensing



Terminology... Power Vent



Terminology... Heat Pump



New DOE EF Requirements

Gas Storage Water Heaters

Volume	Current Federal Minimum	Federal Minimum from 2015
114L (30gal)	.61	.63
151L (40gal)	.59	.62
190L (50gal)	.58	.60
246L (65gal)	.55	.75
284L (75gal)	.53	.74

Gas Tankless Water Heaters

Current Federal Minimum	0.62
Federal Minimum from 2015	0.82

New DOE EF Requirements

Electric Storage Water Heaters		
Volume	Current Federal Minimum	Federal Minimum from 2015
114L (30gal)	0.93	0.95
151L (40gal)	0.92	0.95
190L (50gal)	0.90	0.95
246L (65gal)	0.88	1.98
303L (80gal)	0.86	1.97
378L (100gal)	0.84	1.94
454L (100gal)	0.81	1.92

Energy Star Water Heating Requirements

C. Product Performance Requirements for Gas Water Heaters:

a. Gas Storage Units:

Table 2: Criteria for Qualified Gas Storage Water Heaters

Criteria		ENERGY STAR Requirements
Energy Factor	≤ 55 gallons	EF ≥ 0.67
	> 55 gallons	EF ≥ 0.77
First Hour Rating		FHR ≥ 67 gallons per hour
Warranty		Warranty ≥ 6 years on system (including parts)
Safety		ANSI Z21.10.1/CSA 4.1

Energy Star Water Heating Requirements

B. Product Performance Requirements for Electric Water Heaters:

Table 1: Criteria for Qualified Electric Water Heaters

Criteria		ENERGY STAR Requirements
Energy Factor	≤ 55 gallons	EF ≥ 2.00
	> 55 gallons	EF ≥ 2.20
First Hour Rating		FHR ≥ 50 gallons per hour
Warranty		Warranty ≥ 6 years on sealed system
Safety		UL 174 and UL1995
Lower Compressor Cut-Off Temperature (Reporting Requirement Only)		Report ambient temperature below which the compressor cuts off and electric resistance only operation begins

Energy Star Water Heating Requirements for Resistance Heaters

b. Gas Instantaneous Units:

Table 3: Criteria for Qualified Gas Instantaneous Water Heaters

Criteria	ENERGY STAR Requirements
Energy Factor	$EF \geq 0.90$
Gallons-Per-Minute	$GPM \geq 2.5$ over a 77° rise
Warranty	Warranty ≥ 6 years on heat exchanger and ≥ 5 years on parts
Safety	ANSI Z21.10.3/CSA 4.3

EPA Water Sense, DOE NZE Ready Spec's

¹⁷ Hot water delivery systems shall meet efficiency requirements found in Section 3.3 of the EPA WaterSense Single-Family New Home Specification. Under the DOE Zero Energy Ready Home program, the approved verifier may also confirm compliance with these requirements. These requirements are stated below:

Hot Water Delivery System – To minimize water wasted while waiting for hot water, the hot water distribution system shall store no more than 0.5 gallons (1.9 liters) of water in any piping/manifold between the hot water source and any hot water fixture. In the case of occupant-controlled or occupancy sensor-based recirculation systems, the 0.5 gallon (1.9 liter) storage limit shall be measured from the point where the branch feeding the fixture branches off the recirculation loop, to the fixture itself. To verify that the system stores no more than 0.5 gallons (1.9 liters), verifiers shall calculate the stored volume using the piping or tubing inside diameter and the length of the piping/tubing.

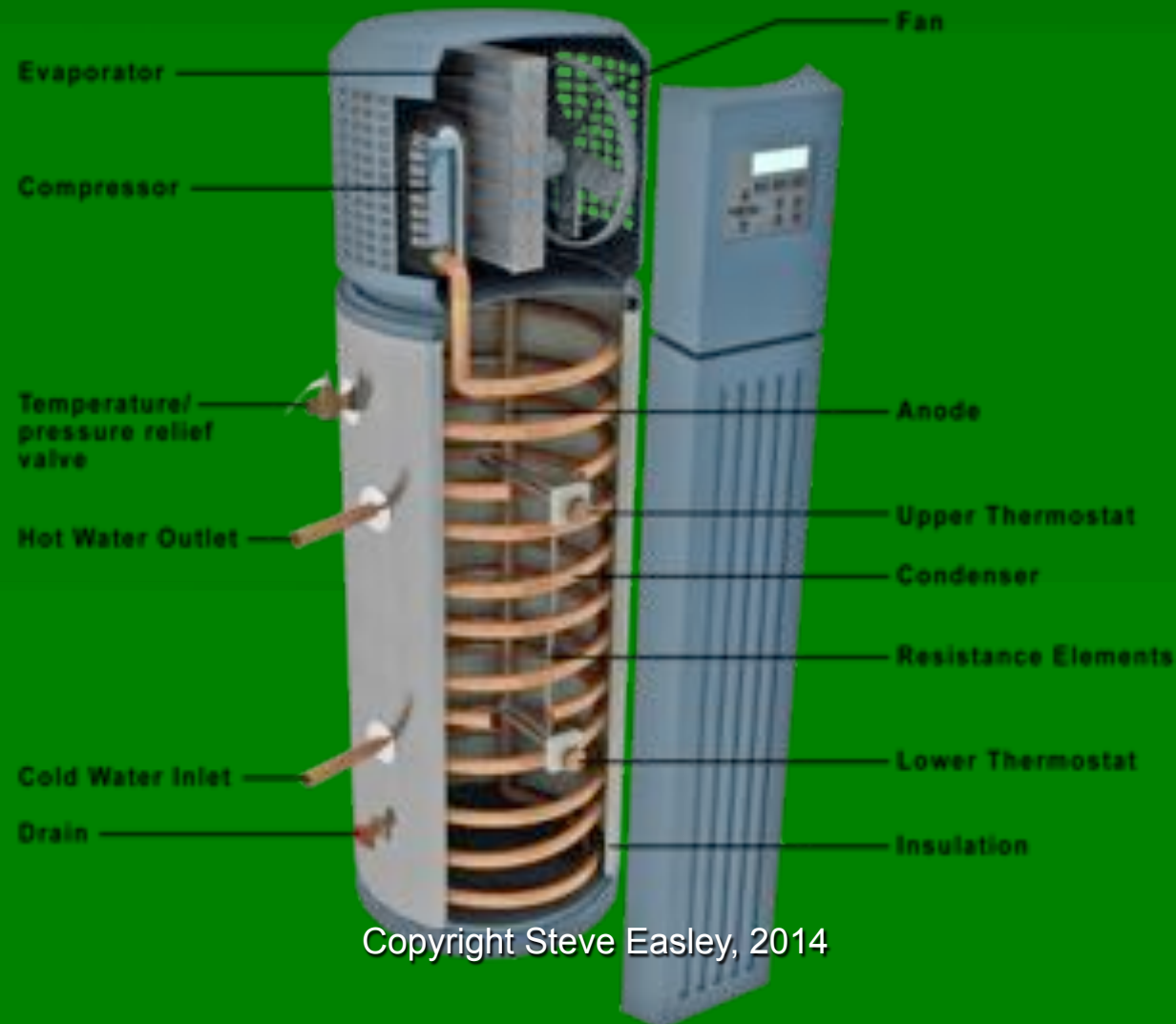
Energy Factor & COP are Not the Same

- EF is a DOE rating under specific federal specified testing criteria
- EF is not representative of typical actual HW water usage
- COP is a efficiency rating that can vary by environment

COP

- A COP of 3 means 1 KWH of electricity yields 3 KHW of heat
- Out door air already contains heat

How does a Heat Pump Water Heater Work?



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**Building America Case Study
Technology Solutions for
New & Existing Homes****Measure: Heat Pump
Water Heater Retrofit**

West Palm Beach, Florida

PROJECT INFORMATIONProject Name: Habitat for Humanity
of Palm Beach County, Inc.

Location: West Palm Beach, FL

Partners: Palm Beach County Habitat
for Humanity, Florida Solar Energy CenterBuilding America Partner:
Pacific Northwest National Laboratory

Building Component: Water Heating

Application: Single-Family Retrofit

Year Tested: 2011

Climate Zone(s): Hot Humid

PERFORMANCE DATACost of Energy-Efficiency Measure
(including labor):

Whole House Retrofit: \$5,875

Heat Pump Water Heater: \$1,350

Projected Energy Savings:

Whole House Retrofit: 40%

Heat Pump Water Heater: 70%

Projected Energy Cost Savings:

\$56 per month or \$676 per year

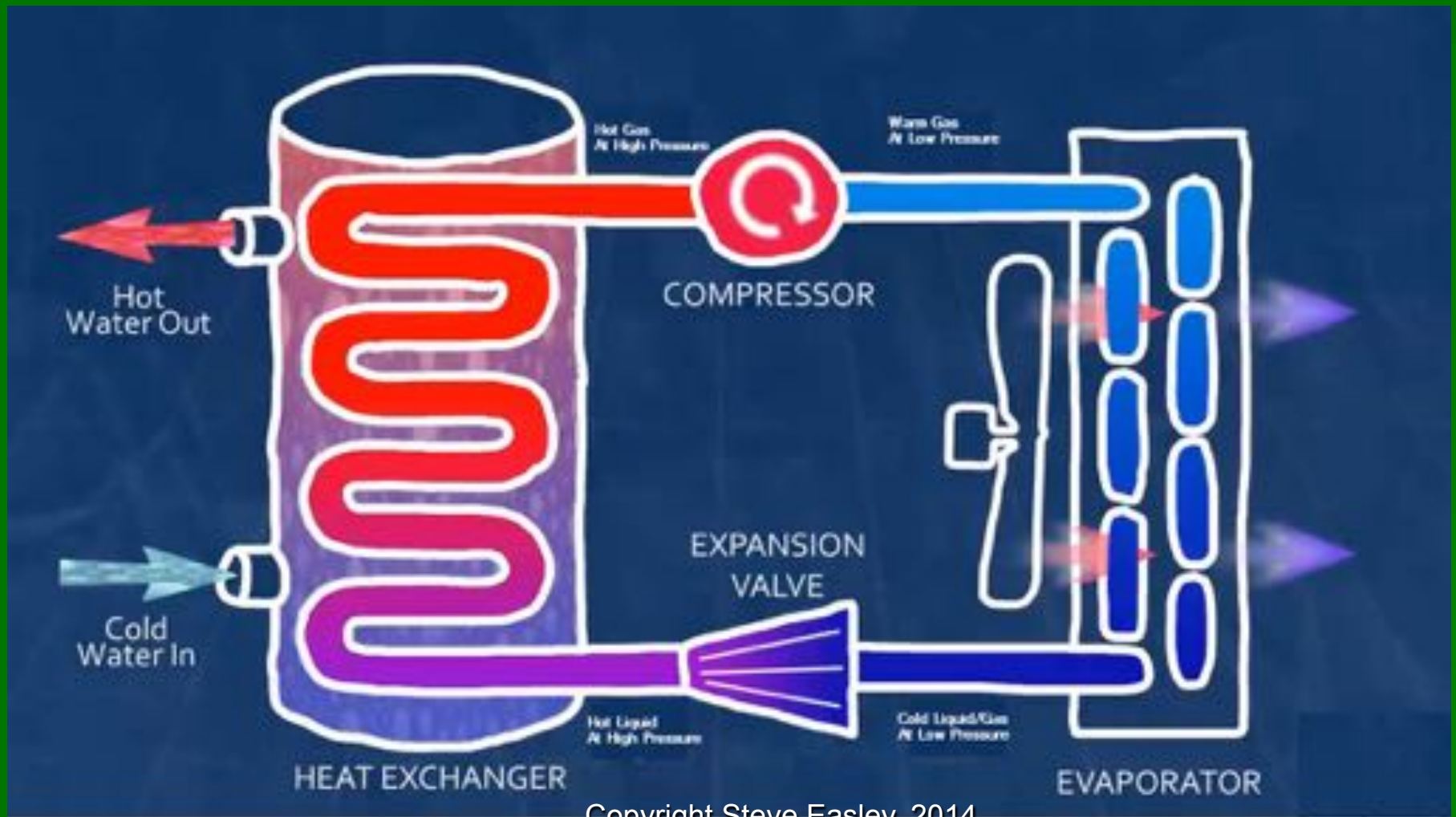


The U.S. Department of Energy reports that water heaters consume 14 to 25% of the energy used in homes across the U.S. on average (www.energy.gov). Heat pump water heaters are an efficient, cost-effective alternative to traditional electric resistance water heaters, improving energy efficiency by up to 62%. Heat pump water heaters work on a reverse refrigeration cycle, absorbing and using heat from the surrounding air to heat the water in the tank, and exhausting cool, dry air. In warmer climates, this cycle can offer additional energy benefits by cooling and dehumidifying the interior space and reducing the load on the cooling equipment.

In an unoccupied, foreclosed home being retrofit by Habitat for Humanity of Palm Beach County, a heat pump water heater was included as one of the primary retrofit measures to achieve a combined 40% whole house energy savings. Habitat worked with the Florida Solar Energy Center, as part of the Pacific Northwest National Laboratory Building America team, to identify cost-effective measures to achieve significant energy savings, including the recommended heat pump water heater. The heat pump water heater had a coefficient of performance (COP) of 2.35 compared to 0.9 for a typical electric water heater, and reduced the home's overall energy usage by more than 11%.

Ideally, heat pump water heaters should be located in conditioned space to fully realize the associated space cooling benefits in Florida's hot humid climate. However, the heat pump water heater could not be located in the conditioned space in this small (1,176 square foot) home. Instead, it was installed in an attached shed that shared airspace with the home's attic. Locating the water heater in this shed allowed it to simultaneously heat water and cool the attic, reducing the cooling load on the rest of the home while lowering the humidity in the attic. Also, the high outdoor temperatures in this climate will increase the efficiency of the heat pump water heater.

How does a Heat Pump Work? Cont'd



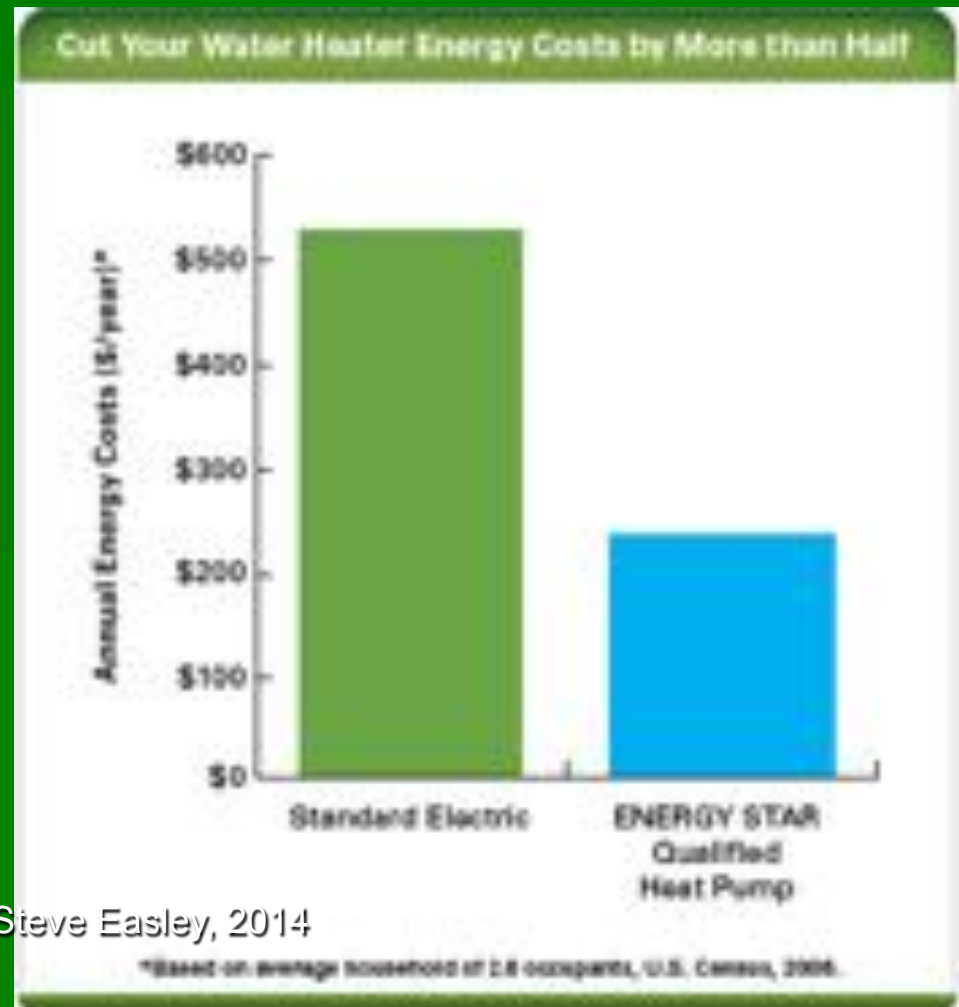
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How Much Energy & Money Will a Heat Pump Water Heater Save?

- Substantial savings by replacing electric-resistance water heaters with heat pump varieties
 - Up to 2.5 times more efficient
- Savings are dependent on:
 - Fuel prices
 - Life style, hot water demands, continuous or intermittent demand
 - Climate

Costs

- **Basic Unit**
 - Retail Range -\$1100 to \$2500
- **Installation Costs Depends on**
 - Plumbing requirements
 - Electrical Req's 240 volt
 - Condensation drains
 - Condensation Pump
 - Ventilation requirements
- **Operating Costs are variable:**
 - Climate
 - Water inlet temps
 - Life style & demand



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Location Requirements

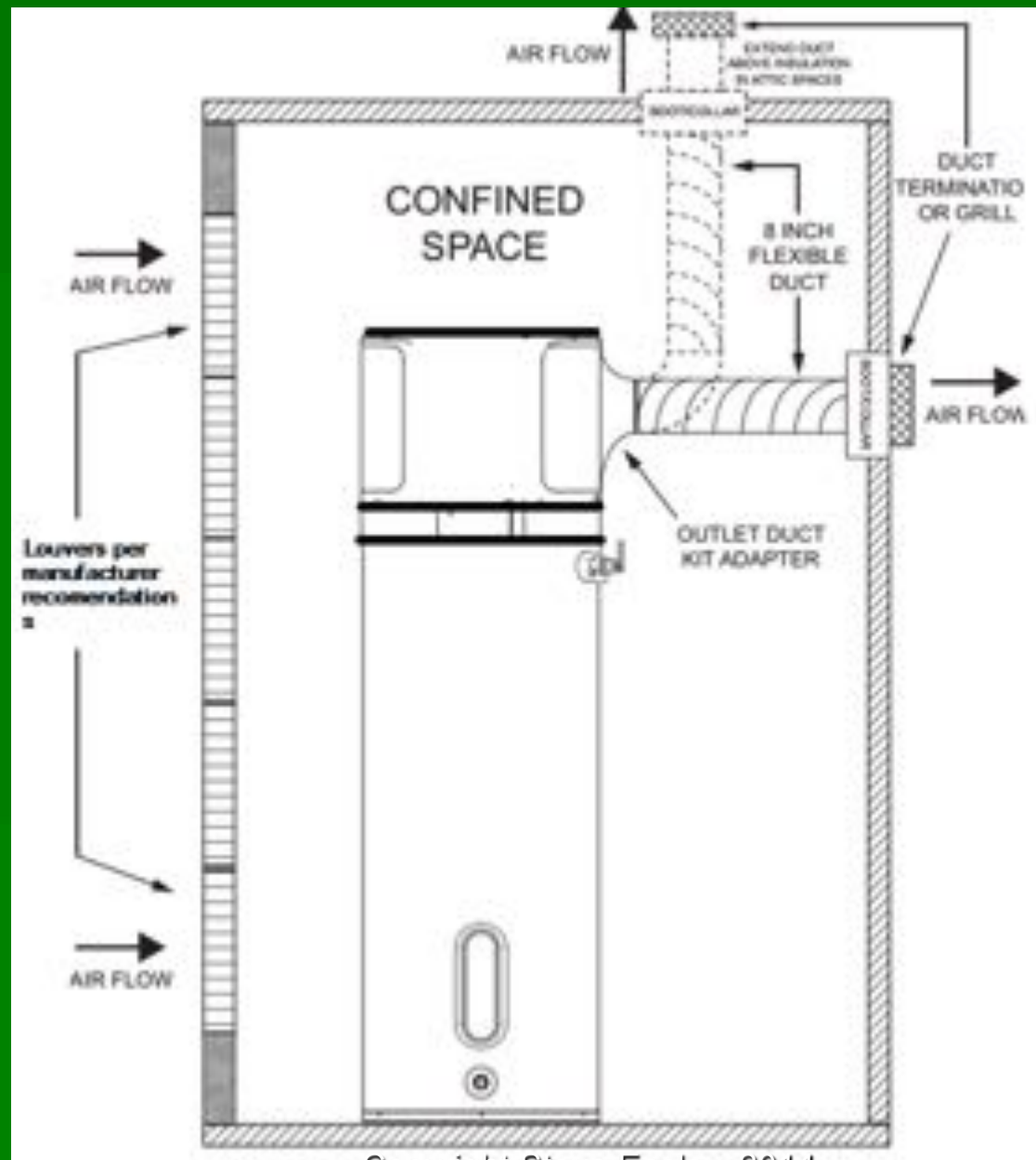
- HPWHs need adequate space to operate properly
- Depending on make and model, HPWH's typically needs between 750 ft³ and 1000 ft³
 - Equivalent to a 10'x10' room with 8' ceilings
 - Some models can be installed in smaller, confined spaces following manufacturer's ventilation requirements
- Appropriate spaces include Basements, Garages & Storerooms

Location Requirements

Cont'd

- Installation is permitted in smaller spaces:
 - Venting for smaller spaces – Maintain 750 CuFt equivalence
 - Spaces as small as 4ft x 4ft x 8ft – 128 CuFt
 - With appropriate ventilating (louver) doors
 - Meeting manufacturer's intake volume air requirements
 - Meeting manufacturer's exhausts volume air requirements
 - Exhaust kits available for certain makes & models
 - Some Codes might require water heater to be on an 18-inch platform
 - Check for height clearance

Intake air
from a
minimum
750 Cu Ft
Space



Exhaust air to
a minimum
750 Cu Ft
Space

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Location Requirements, Cont'd

- HPWHs operate more efficiently in humid and warm places:
 - Ambient air temperature operating ranges - 45°F and 120°F
- HPWHs exhaust cooler dehumidified air as a by-product
 - In warmer climates this will increase overall building efficiency by reducing space cooling load in summer months

Energy Efficient Appliances & Plug loads



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www.toptenusa.org

The screenshot shows the homepage of the website **toptenusa.org**. The header features the **topten** logo, a search bar, and a **Business Products** button. Below the header, there are three main sections:

- #2 topten**: Find top efficient products. Search, filter & compare the most energy efficient models.
- Find energy efficiency rebates**: Lower your energy bill and save even more with rebates.
- Know what's popular**: We analyze sales and user reviews from leading retailers.

Below these sections, there is a row of logos for partner organizations: ENERGY STAR, EPEAT, NRG, NRECA, ACEEE, and neea.

The main content area is titled "Choose a product category and start saving now." and displays a grid of 12 product categories, each with an image and a label:

- Refrigerators
- Gas Water Heaters Electric Water Heaters
- Clothes Washers
- Televisions
- Laptop Computers
- Furnaces
- Freezers
- Boilers
- Non-Expendable Downspouts
- LED Lighting
- Dishwashers
- Monitors

LED Lighting

- 2-4 years ago 30 LPW
- Today 90 LPW
- Soon 200 LPW

HIGH-EFFICACY RESIDENTIAL LIGHTING

LED lighting for single-family and multi-family homes



DEVELOPED BY THE CALIFORNIA LIGHTING TECHNOLOGY CENTER, UC DAVIS

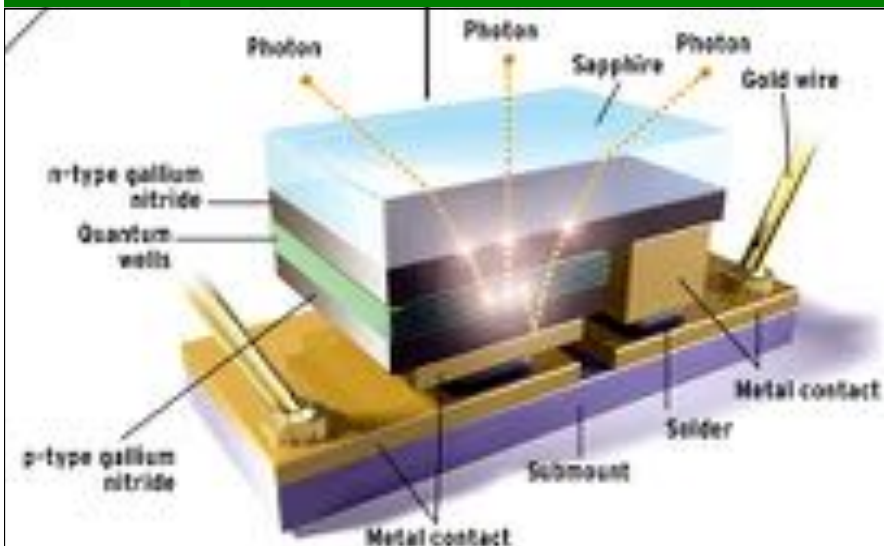
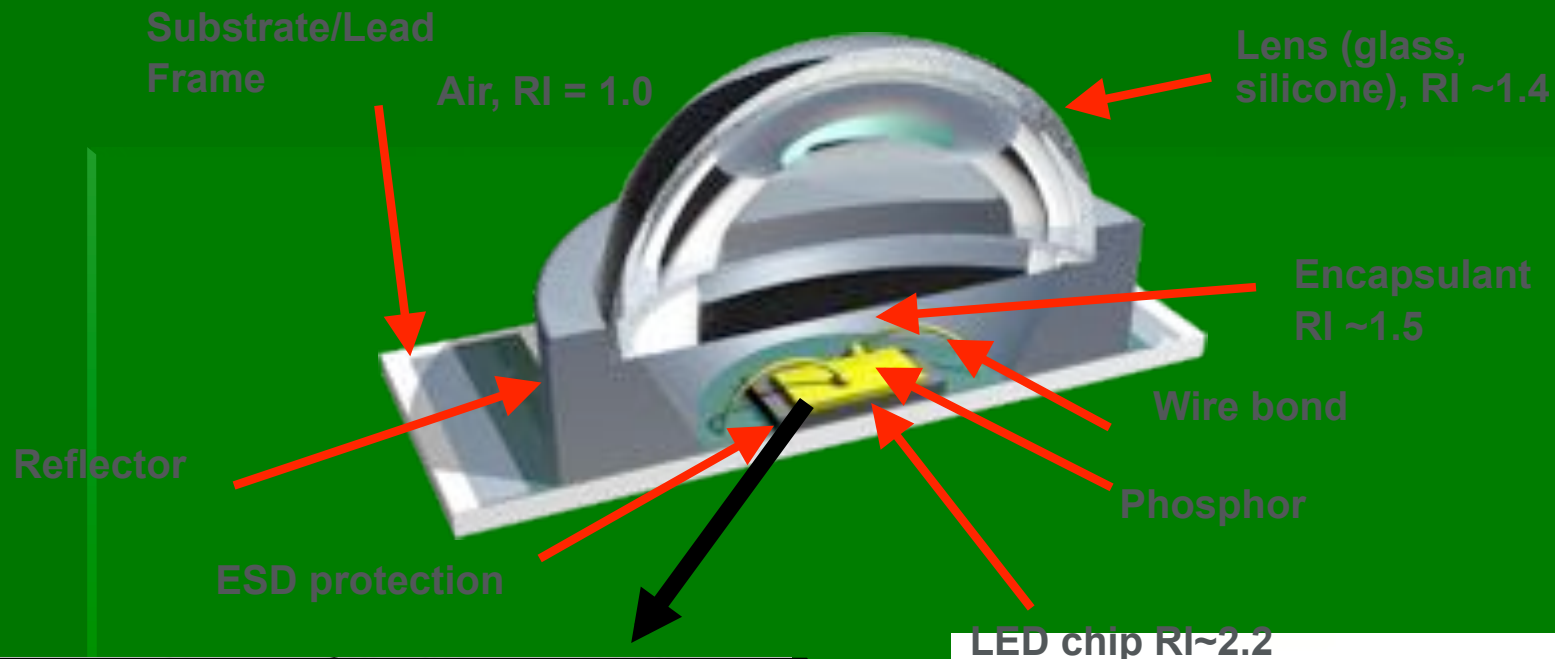
Current LED Lighting Fixtures

- Technology in LEDs for lighting is changing so fast, most fixtures designed into a commercial building today will be outdated when they are installed.
- LED fixtures, depending on the application, reduce input watts 50-80% when compared to the “old world” fixtures they replace.
- This input watt reduction is helping to drive the entire Solar energy production industry.
- A typical LED fixture is currently twice as efficient as the most energy efficient lighting fixtures used just 6 years ago.

LED Lighting – A few Quality Measures

- Fixtures shall meet local code, IECC, ES, T24
- Fixtures shall have at least 5 year warranty on system – not just LED array.
- Fixture performance shall be determined measuring lumens exiting the fixture, not just lumens exiting the Led array.
- Fixture shall offer color options including 80+ and 90+ CRI in at least four Kelvin temperatures.
- Fixtures shall be tested and data published using the IES LM79, LM80, TM-21 measuring standards.

Typical Lighting-class LED Package



LED chip RI~2.2



An LED package used in lighting products
Courtesy of Philips Lumileds

THE ALL-IN-ONE P8022 AC LED SURFACE MOUNT

The P8022 Series unites performance, cost and safety benefits for an innovative LED solution unlike any other on the market.

State of the Art Design

Superior Performance

Versatility

Unparalleled Value

NEW CONSTRUCTION AND REMODEL

Maximum Versatility

Complete with adapters and mounts for use in recessed and flushmount applications, the P8022 embraces an installation system that is versatile, simple and seamless.

Recessed



Flushmount



Round aperture

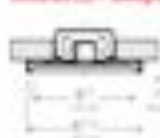
SimSurface LED 5" and 7" round aperture
sim LED instant mount downlighting



SimSurface LED 5" downlight



SimSurface LED 7" downlight



Ordering guide

Round 5-inch aperture

Catalog No.	CRI	CCT	Listing	Finish (optional)
SPR8022N7	90	2700K	Yes	White
SPR8022NAL	90	2700K	Yes	Aluminum
SPR8022N7	90	3000K	Yes	White
SPR8022NAL	90	3000K	Yes	Aluminum
SPR8022N7	90	3500K	Yes	White
SPR8022NAL	90	3500K	Yes	Aluminum
SPR8022N7-D	90	3000K	Dim	White

Round 7-inch aperture

Catalog No.	CRI	CCT	Listing	Finish (optional)
SPR8022N9	90	2700K	Yes	White
SPR8022NAL	90	2700K	Yes	Aluminum
SPR8022N9	90	3000K	Yes	White
SPR8022NAL	90	3000K	Yes	Aluminum
SPR8022N9	90	3500K	Yes	White
SPR8022NAL	90	3500K	Yes	Aluminum
SPR8022N9-D	90	3000K	Dim	White

Applications



Residential



Multi-Family and Commercial



Wet Location



Slot Profile
1.25"

PROGRESS 4014 R

Performance and Economy

The P8022 Series is leading the industry in LED technology. The state-of-the-art design eliminates the need for a traditional LED driver. The fixture not only demonstrates superior efficiency and performance, but the P8022 offers a low price point that makes it a cost-effective solution for customers and partners.



Current: 4000

Watts: 27 input power

Current output comparable to
a 400W incandescent lamp

Life: 40,000 hours*

2.2% THN

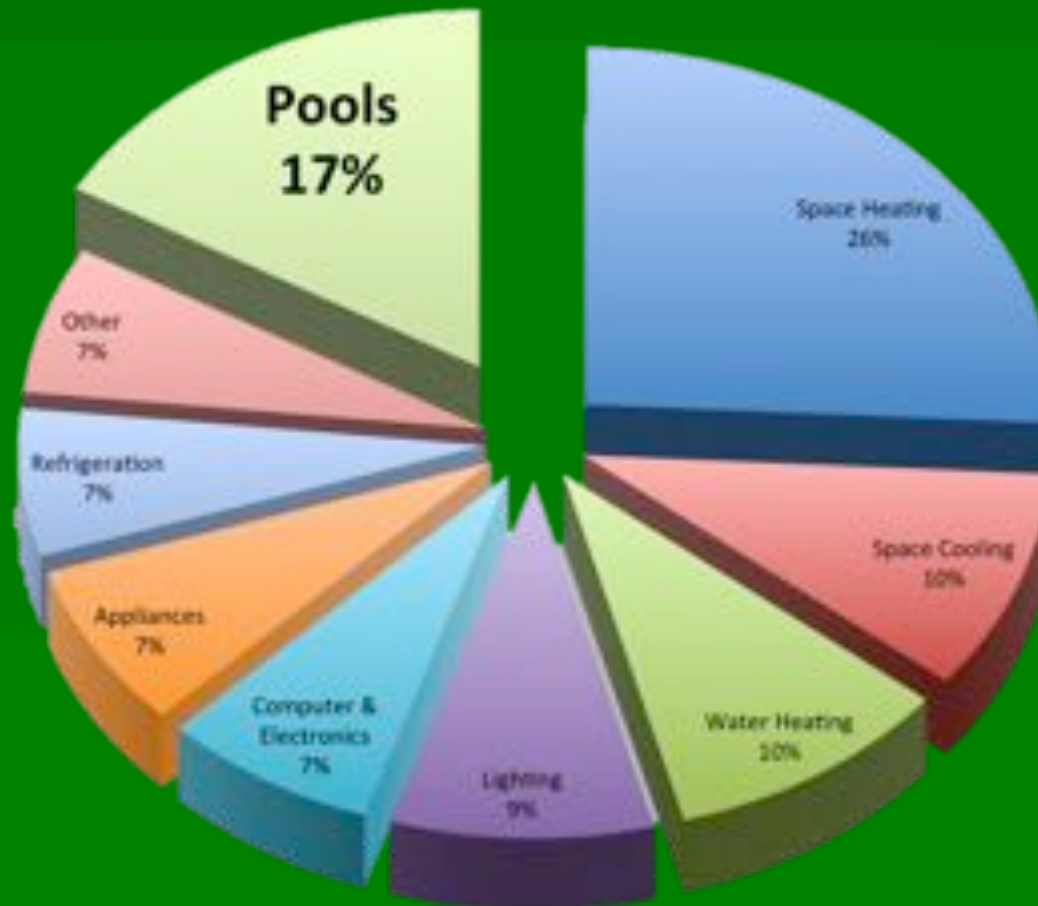
Reduces power by 50%
with more standard incandescent
downlights

POOLS



An Overlooked Energy Saving Opportunity

Typical Home Energy Use Homes with Pools



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A National View of Pool Energy Use

- \$1.1-1.6 billion spent per year in energy
- 9 to 14 billion kWh per year for pumps
- 36 to 63 million therms per year, heating
- CO2 emissions = 10 million tons per year
- Use the equivalent of 24 medium sized (500 MW) power plants
- Emissions of 1.3 million cars

Residential Inground Swimming Pool Installed base by State



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Estimated Residential Inground Pools

Table 1: 2007 estimated residential inground pools by state.

State	Inground Pools	State	Inground Pools
California	1,122,236	Arkansas	43,659
Florida	757,016	South Carolina	41,811
Texas	458,196	Washington	39,479
Arizona	299,251	Wisconsin	39,447
New York	250,494	West Virginia	37,076
New Jersey	203,774	Oregon	35,761
Pennsylvania	138,661	New Hampshire	32,283
Georgia	126,861	New Mexico	27,808
Ohio	118,241	Colorado	24,738
Louisiana	95,263	Kansas	24,677
North Carolina	86,363	Minnesota	23,066
Illinois	84,771	Iowa	21,973
Nevada	77,978	Rhode Island	20,113
Virginia	76,253	Maine	18,638
Michigan	69,901	Delaware	17,767
Connecticut	68,820	Utah	13,070
Maryland	68,038	Idaho	12,722
Alabama	67,922	Nebraska	11,907
Indiana	65,921	Vermont	9,720
Massachusetts	61,790	Wyoming	9,682
Tennessee	58,941	Montana	9,398
Oklahoma	57,181	South Dakota	5,634
Kentucky	47,564	North Dakota	5,303
Mississippi	42,372	District of Columbia	1,532
Missouri	40,578		

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U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings

A. Hunt and S. Easley
Building America Retrofit Alliance (BARA)

May 2012



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Retrofit Case Study

- Northern California
- 20,000 gallon pool, built 2002
- Tiered Utility Rates \$.12 - \$.40/kWh



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Retrofit Case Study, Before

- 1 ½-horsepower single speed pool pump (for filtration and solar heating)
- Sweep-style pool cleaner with a ¾-hp booster pump
- 2-hp single speed waterfall pump
- 500 watt incandescent light

Retrofit Case Study, After

- Variable-speed pump (for filtration, solar heating and pool cleaner)
- Over-sized Cartridge filter
- External Heater Bypass
- 2nd variable-speed pump for waterfall
- LED Color lighting
- NO booster pump for Cleaner

Retrofit Case Study, Summer, No Solar

- Original pump 6 hrs/day total run time
- Pump, $2,092 \text{ W} \times 6 \text{ hrs/day} = 12.5 \text{ kWh/day}$
- Cleaner, $1,372 \text{ W} \times 2.5 \text{ hrs/day} = 3.4 \text{ kWh/day}$

Total energy 15.9 kWh/day

- New pump, 10 hrs/day total run time
- Pump = $221 \text{ w} \times 7 \text{ hrs/day} = 1.6 \text{ kWh/day}$
- Pump & cleaner, $650 \text{ w} @ 3 \text{ hrs/day} = 2 \text{ kWh/day}$

Retrofit total energy = 3.6 kWh/day

- **Savings = $15.9 - 3.6 = 12.3 \text{ kWh/day}$**

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Thank you for your time!

QUESTIONS??

**This concludes The American Institute of Architects
Continuing Education Systems Program**

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