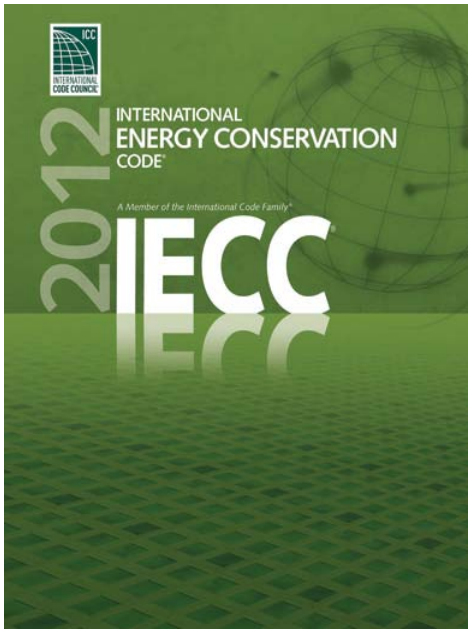
Energy Boot Camp for Builders

Building Science and Changes to the Montana Energy Code



NCAT

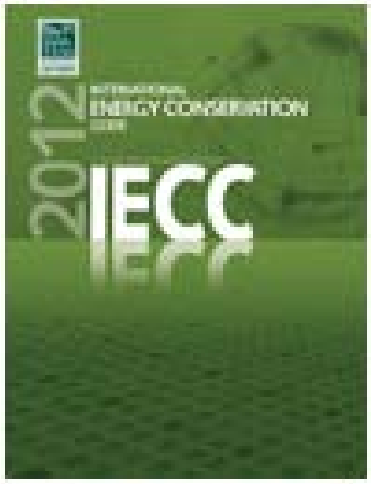
December 2013

Presented by Dale Horton, Architect
National Center for Appropriate Technology

Organization of 2012 IECC

Organization of 2012 IECC

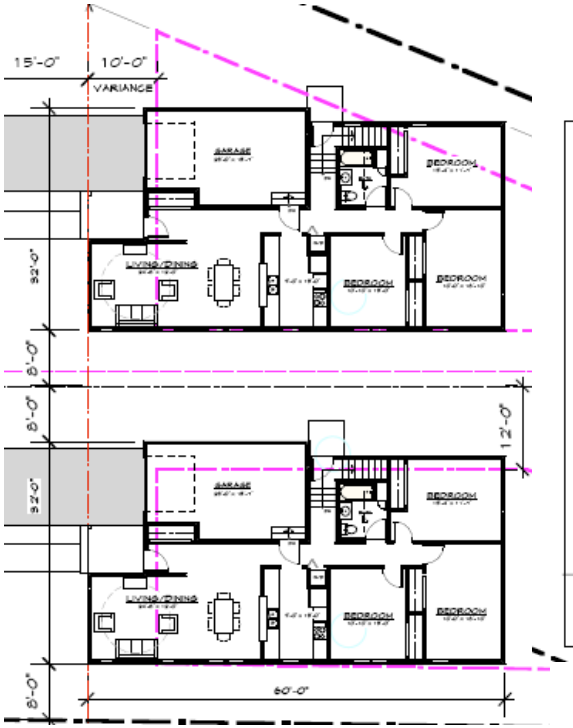
Chapter	Commerical Section	Chapter	Residential Section
1	Scope and Administration	1	Scope and Administration
2	Definitions	2	Definitions
3	General Requirements	3	General Requirements
4	**Commercial Energy Efficiency**	4	**Residential Energy Efficiency**
5	Referenced Standards	5	Referenced Standards

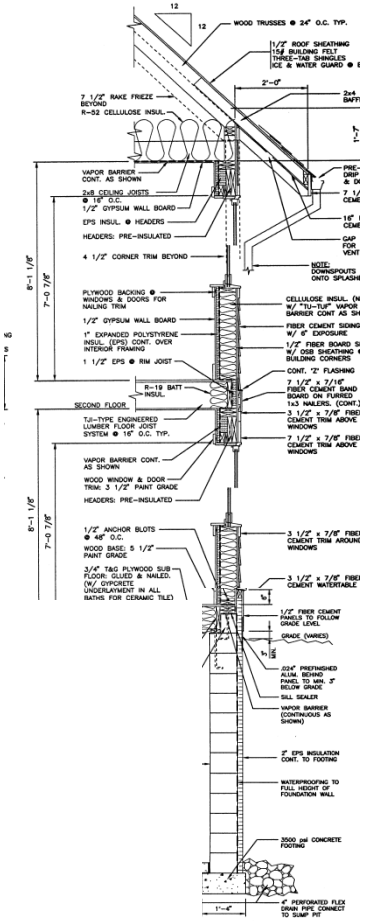


Construction Document Requirements

R103.1

…sufficient clarity to indicate the location, nature and extent of work proposed,…





Construction Documents - Details Shall Include… R103.1

- Insulation materials and R-value
- Fenestration U-factors and SHGCs
- Mechanical system design criteria
- Mechanical and service water heating system and equipment types, sizes and efficiencies
- Equipment and system controls
- Fan motor HP and controls
- Duct sealing, duct and pipe insulation
- Lighting fixture schedule with wattage and control narrative
- Air sealing details

GAS–FIRED FURNACE SCHEDULE (ALTERNATE)

TAG	MANUFACTURER	MODEL	ARRANGEMENT	FUEL	FURNACE RATINGS				BLOWER PERFORMANCE (HIGH SPEED)					VOLT/PH	UNIT AMPS	MOP AMPS
					INPUT MBH	OUTPUT MBH	AFUE	AIR TEMP. RISE–°F	NOM CFM	IN. W.C.	HP	AMPS	RPM			
F 1	TRANE	TUX040C924	UPFLOW (MTD ON FLOOR STAND)	NATURAL GAS	40	38	92.0	35	1000	0.10	1/5	6.2	1075	120/1 PH	4.7	15

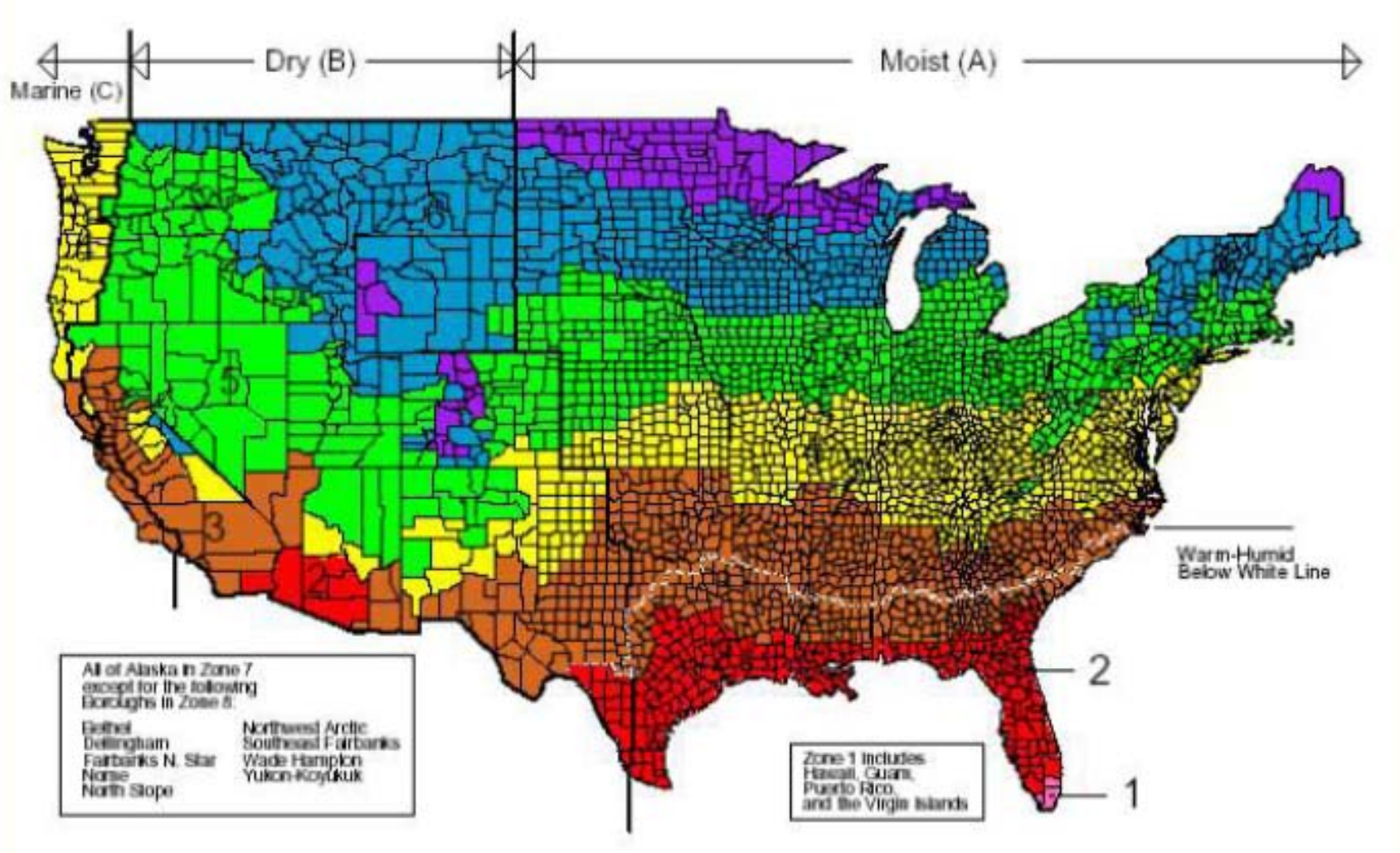
NOTES: TYPICAL FOR ALL UNIT TYPES A, B, BB, & C
FURNISH ALL FURNACES WITH FACTORY LOW VOLTAGE DIGITAL PROGRAMMABLE THERMOSTAT WITH HEAT–COOL–AUTO–OFF, "AUTO–ON" FAN CONTROL
FURNISH ALL FURNACES WITH LITTLE GIANT CONDENSATE PUMP COMLETE WITH FILTER RACK
FURNISH ALL FURNACES WITH LITTLE GIANT CONDENSATE PUMP COMLETE WITH CHECK VALVE AND BASIN, RUN DRAIN TO STAND PIPE

HEAT EXCHANGER TRANSFER UNIT

TAG	MANUFACTURER	MODEL	TYP. AIRFLOW RANGE (CFM)	DESIGNED (CFM)	AIRFLOW RATING POINTS (CFM) (FOR ARI)	NUMBER MOTORS	VOLTAGE (V)	HERTZ (HZ)	PHASE	INPUT WATTS	FLA	CONTROL VOLTAGE (VAC)
HE 1	RenewAire	EV130	50–140	60	95 AND 71	0.07 hp	115	60	SINGLE	124@0.4" esp.	1.1	24

Climate Specific Requirements

Table R301.1



Cut to the Chase **- Major Changes**

- More efficient windows (U-0.33 to U-0.32)
- More efficient skylights (U-0.60 to U-0.55)
- More efficient crawlspace walls (R-10/19 to R-15/19)
- Mandatory whole-house pressure test (1 yr transition)
- Mandatory thermal envelope tightness checklist
- More stringent duct leakage test
- Mandatory mechanical ventilation
- 75% high efficacy lamps mandatory
- RESCheck will now be ”better than code” (it had been “easier than code”)

Cut to the Chase – Major Non-changes

- Wall insulation requirement unchanged (IECC requires added R5 insulation sheathing)*
- Maximum House Air Tightness (4 ACH50)*
- Retains prohibition on envelope-equipment trade-offs
- May use building cavities as return ducts*
- DHW distribution pipe requirements – minimal changes*

* - Montana Amendments

Compliance Paths

R402 & R405

Compliance Paths

Mandatory +
Prescriptive R-Values

TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

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

Mandatory +
Prescriptive U-Factors

TABLE R402.1.3
EQUIVALENT *U*-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.082	0.165	0.064	0.360	0.477
3	0.35	0.55	0.030	0.057	0.098	0.047	0.091[c]	0.136

Mandatory +
Prescriptive Total UA

REScheck™
DOE's Building Energy Codes Program

Mandatory +
Performance

REM/Design™

EnergyGauge®

Mandatory +
Above-code Program

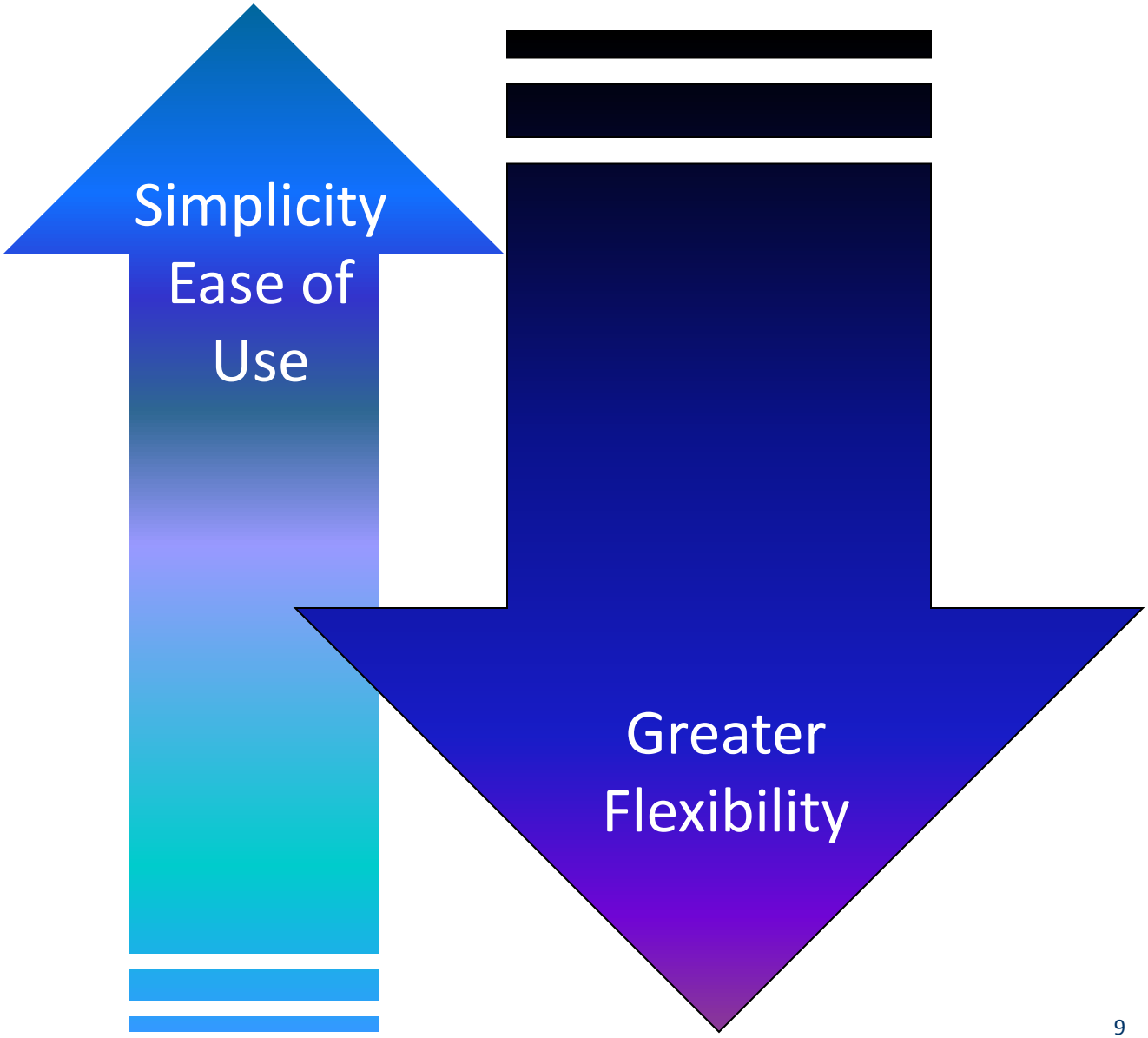
ENERGY STAR

RESNET HERS INDEX

Compliance Paths

R402 & R405

Compliance Paths
Mandatory + **Prescriptive R-Values**
Mandatory + **Prescriptive U-Factors**
Mandatory + **Prescriptive Total UA**
Mandatory + **Performance**
Mandatory + **Above-code Program**



Compliance Paths

R402.1.1

Compliance Paths

Mandatory +
Prescriptive R-Values

Mandatory +
Prescriptive U-Factors

Mandatory +
Prescriptive Total UA

Mandatory +
Performance

Mandatory +
Above-code Program

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2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

For SI: 1 foot = 304.8 mm.

a. *R*-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed *R*-value of the insulation shall not be less than the *R*-value specified in the table.

b. The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration. Exception: Skylights may be excluded from glazed fenestration SHGC requirements in Climate Zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.

c. "15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home. "10/13" means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.

d. R-5 shall be added to the required slab edge *R*-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.

e. There are no SHGC requirements in the Marine Zone.

f. Basement wall insulation is not required in warm-humid locations as defined by Figure R301.1 and Table R301.1.

g. Or insulation sufficient to fill the framing cavity, R-19 minimum.

h. First value is cavity insulation, second is continuous insulation or insulated siding, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation or insulated siding. If structural sheathing covers 40 percent or less of the exterior, continuous insulation *R*-value shall be permitted to be reduced by no more than R-3 in the locations where structural sheathing is used – to maintain a consistent total sheathing thickness.

i. The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

Compliance Paths

R402.1.3

Compliance Paths

Mandatory +
Prescriptive R-Values

Mandatory +
Prescriptive U-Factors

Mandatory +
Prescriptive Total UA

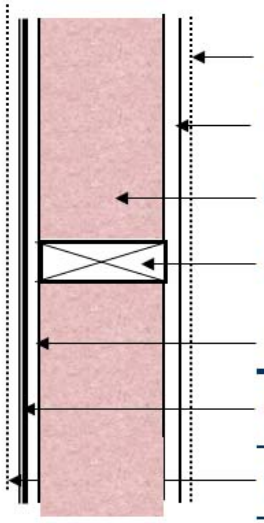
Mandatory +
Performance

Mandatory +
Above-code Program

TABLE R402.1.3
EQUIVALENT *U*-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.082	0.165	0.064	0.360	0.477
3	0.35	0.55	0.030	0.057	0.098	0.047	0.091[c]	0.136
4 except Marine	0.35	0.55	0.026	0.057	0.098	0.047	0.059	0.065
5 and Marine 4	0.32	0.55	0.026	0.057	0.082	0.033	0.050	0.055
6	0.32	0.55	0.026	0.048	0.060	0.033	0.050	0.055
7 and 8	0.32	0.55	0.026	0.048	0.057	0.028	0.050	0.055

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.
b. When more than half the insulation is on the interior, the mass wall *U*-factors shall be a maximum of 0.17 in Climate Zone 1, 0.14 in Climate Zone 2, 0.12 in Climate Zone 3, 0.087 in Climate Zone 4 except Marine, 0.065 in Climate Zone 5 and Marine 4, and 0.057 in Climate Zones 6 through 8.
c. Basement wall *U*-factor of 0.360 in warm-humid locations as defined by Figure R301.1 and Table R301.1.



	R-value Cavity	R-value Stud
Inside air film	0.68	0.68
Gypsum board	0.45	0.45
Cavity insulation	21	
5.5” Stud		6.8
Exterior sheathing	0.5	0.5
Exterior siding	1.0	1.0
Outside Air Film	.17	.17
Total R-value	23.8	9.68

Compliance Paths

R402.1.4

Compliance Paths

Mandatory +
Prescriptive R-Values

Mandatory +
Prescriptive U-Factors

Mandatory +
Prescriptive Total UA

Mandatory +
Performance

Mandatory +
Above-code Program

TABLE R402.1.3
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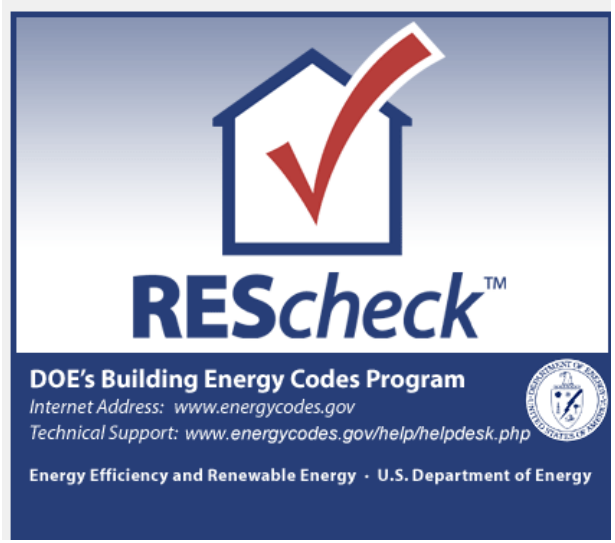


$$U=(A_{1fraction}xU_1)+(A_{2fraction}xU_2)+\ldots$$

Compliance Paths

R405

Compliance Paths
Mandatory + **Prescriptive R-Values**
Mandatory + **Prescriptive U-Factors**
Mandatory + **Prescriptive Total UA**
Mandatory + **Performance**
Mandatory + **Above-code Program**

REM/Design™

EnergyGauge®

Compliance Paths

R102.11

Compliance Paths
Mandatory + **Prescriptive R-Values**
Mandatory + **Prescriptive U-Factors**
Mandatory + **Prescriptive Total UA**
Mandatory + **Performance**
Mandatory + **Above-code Program**

Above Code Programs

R102.11

"The code official…shall be permitted to deem a national, state or local energy efficiency program to exceed the energy efficiency required by this code."
(Mandatory requirements must be met.)

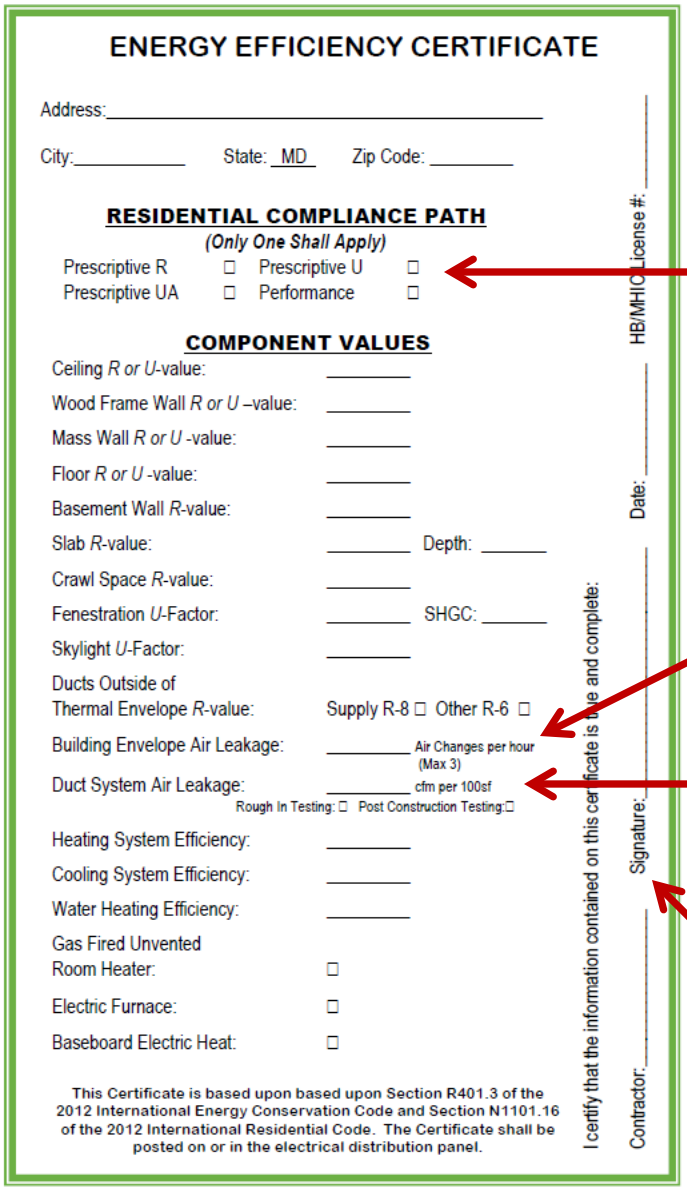
Example Mandatory Provisions

R401.2

IECC Mandatory Provisions	
Applies to all performance paths. Can not be traded off.	
Certificate	**R401.3**
Air Leakage (Testing & Visual Checklist)	**R402.4**
Controls for Heating and Cooling System	**R403.1**
Duct Sealing	**R403.2**
No Building Cavities as Ducts	**R403.2.3**
Mechanical System Pipe Insulation	**R403.3**
Mechanical Ventilation Required	**R403.5**
Equipment Sizing (ACCA Manuals S & J)	**R403.6**
Lighting Minimum Requirements	**R404.1**

Certificate (Mandatory)

R401.3



ENERGY EFFICIENCY CERTIFICATE

Address:_____

City:_____ State: MD Zip Code: _____

RESIDENTIAL COMPLIANCE PATH

(Only One Shall Apply)

Prescriptive R ☐ Prescriptive U ☐

Prescriptive UA ☐ Performance ☐

COMPONENT VALUES

Ceiling *R or U*-value: _____

Wood Frame Wall *R or U* –value: _____

Mass Wall *R or U* -value: _____

Floor *R or U* -value: _____

Basement Wall *R*-value: _____

Slab *R*-value: _____ Depth: _____

Crawl Space *R*-value: _____

Fenestration *U*-Factor: _____ SHGC: _____

Skylight *U*-Factor: _____

Ducts Outside of Thermal Envelope *R*-value: Supply R-8 ☐ Other R-6 ☐

Building Envelope Air Leakage: _____ Air Changes per hour (Max 3)

Duct System Air Leakage: _____ cfm per 100sf

Rough In Testing: ☐ Post Construction Testing: ☐

Heating System Efficiency: _____

Cooling System Efficiency: _____

Water Heating Efficiency: _____

Gas Fired Unvented Room Heater: ☐

Electric Furnace: ☐

Baseboard Electric Heat: ☐

This Certificate is based upon based upon Section R401.3 of the 2012 International Energy Conservation Code and Section N1101.16 of the 2012 International Residential Code. The Certificate shall be posted on or in the electrical distribution panel.

I certify that the information contained on this certificate is true and complete:

HB/MHIC License #: _____

Date: _____

Signature: _____

Contractor: _____

Place on electrical panel box.

Specify Compliance Path

Envelope Air Leakage

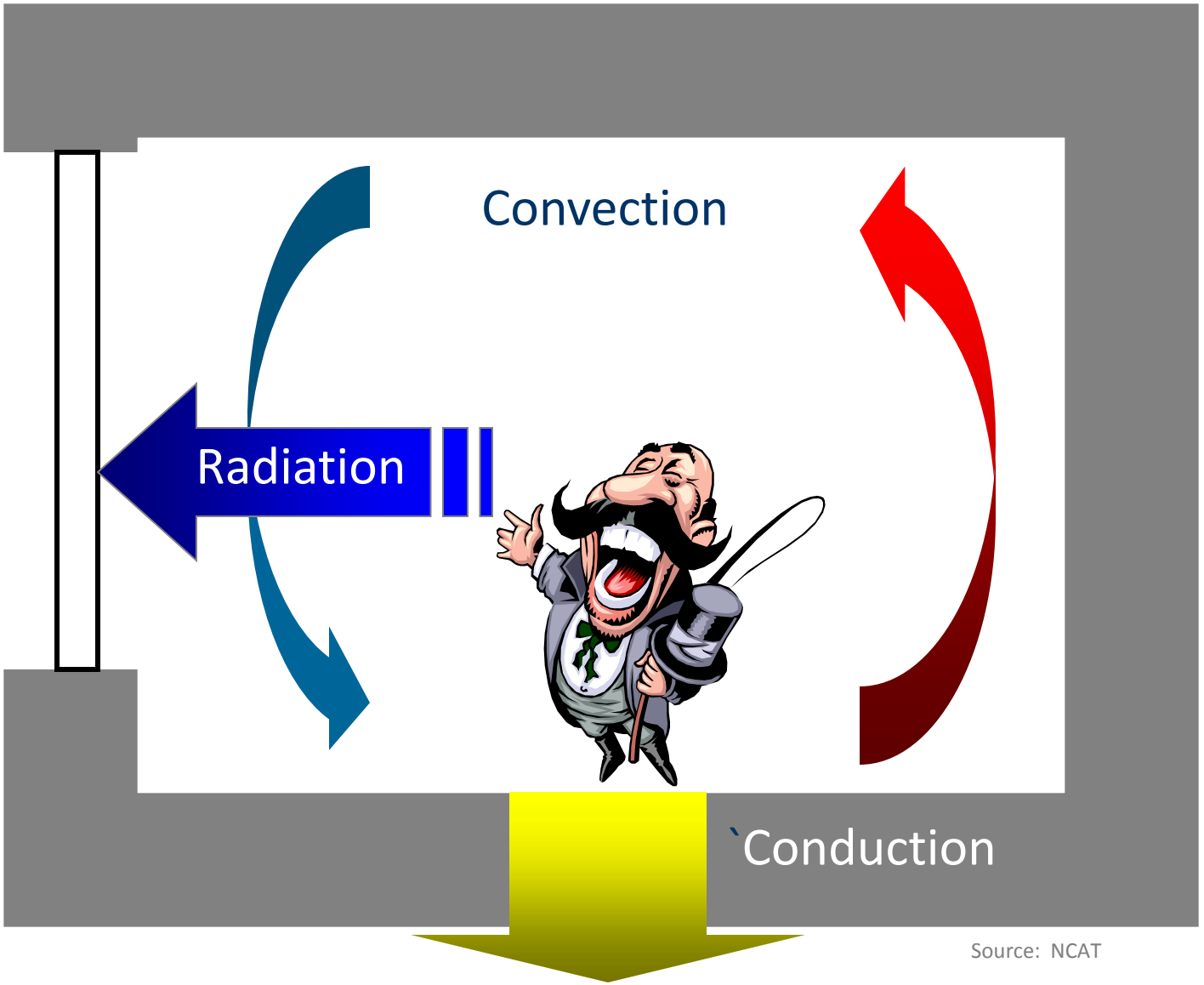
Duct System Air Leakage

Builder Signature

It's About the Movement of…..

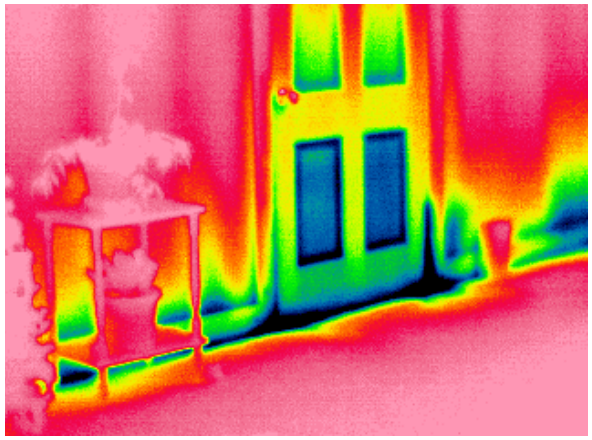
- Heat
- Air
- Moisture

The 3 Heat Transfer Mechanisms



Source: NCAT

Conduction



- Heat flow through solid objects and materials.
- Molecules vibrate more vigorously, passing heat through the material.
- Generally the slowest of the three heat transfer methods.

Convection

- Heat transfer by a moving fluid such as air or water.
- Caused by density difference between warmer and cooler parts of fluid.
- Heat transfer by convection is considered the fastest because the molecules physically move.

Radiation

- Hot surfaces are able to warm objects distant from them because they have a higher temperature.
- Radiation requires a temperature difference, a gap, and “line of sight”

R-Values and U-Values

R-Values Measure Thermal Resistance

R-Values are additive (R-1 + R-1 = R-2)

R-Value is the inverse of U-value (R=1/U and U=1/R)

U-Value: Heat flow through a material at specific

- Area (SF)
- Temperature difference (^{o}F)
- Period of time (Hr)

U-Value is in units of Btus/ft^2•hr•^{o}F

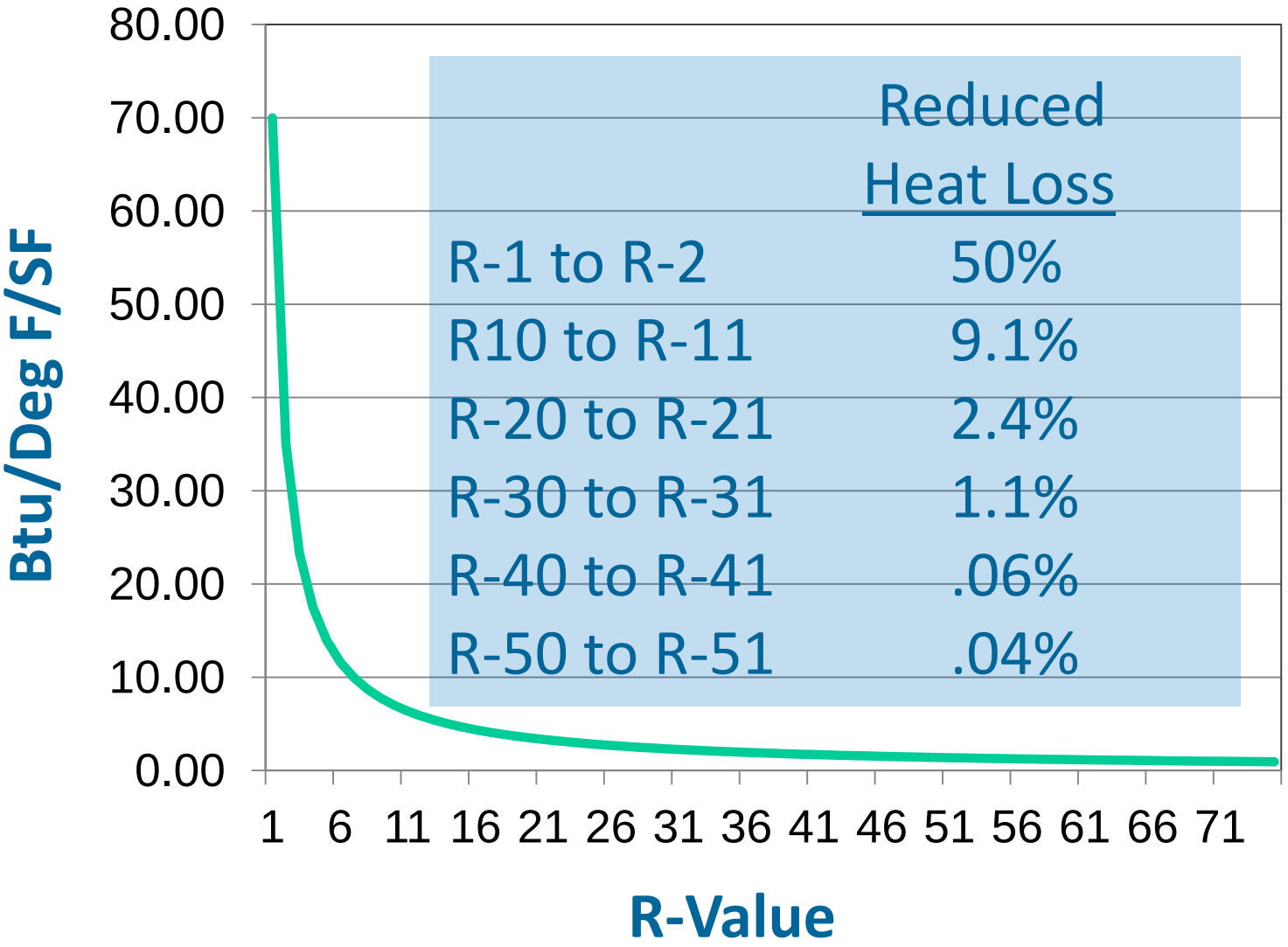
R-Values and U-Values

R-Values are additive and useful for comparing the insulating qualities of both materials and assemblies.

U-Factors can be used to calculate heat loss and gain.

Heat Load in BTUs = Area x U-Value x Temp. Diff.

British Thermal Unit (Btu) = Amount of heat required to raise one pound of water on degree.

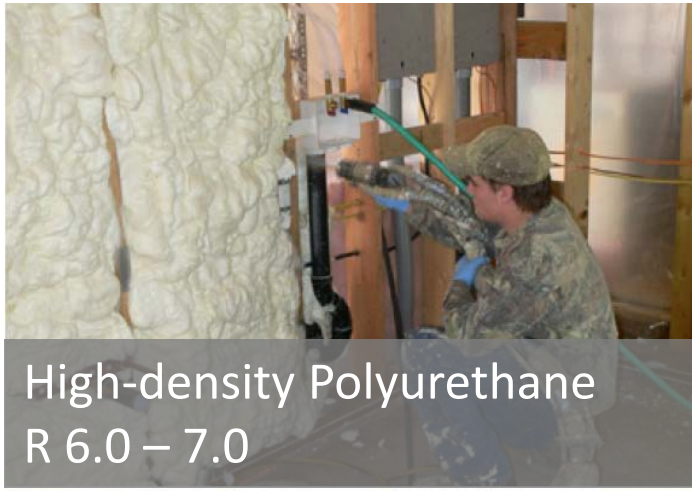

80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Btu/Deg F/SF
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71
R-Value
Reduced Heat Loss
R-1 to R-2 50%
R10 to R-11 9.1%
R-20 to R-21 2.4%
R-30 to R-31 1.1%
R-40 to R-41 .06%
R-50 to R-51 .04%

Common Insulation Materials

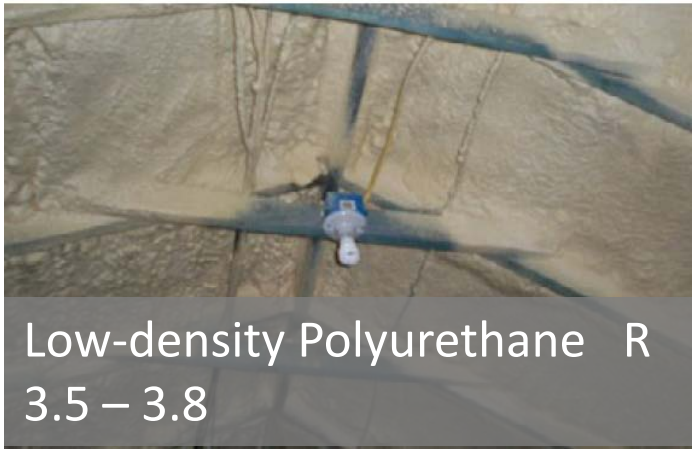
Batt Insulation In Ceiling

Blown-in Insulation

Spray Foam



High-density Polyurethane
R 6.0 – 7.0



Low-density Polyurethane R 3.5 – 3.8

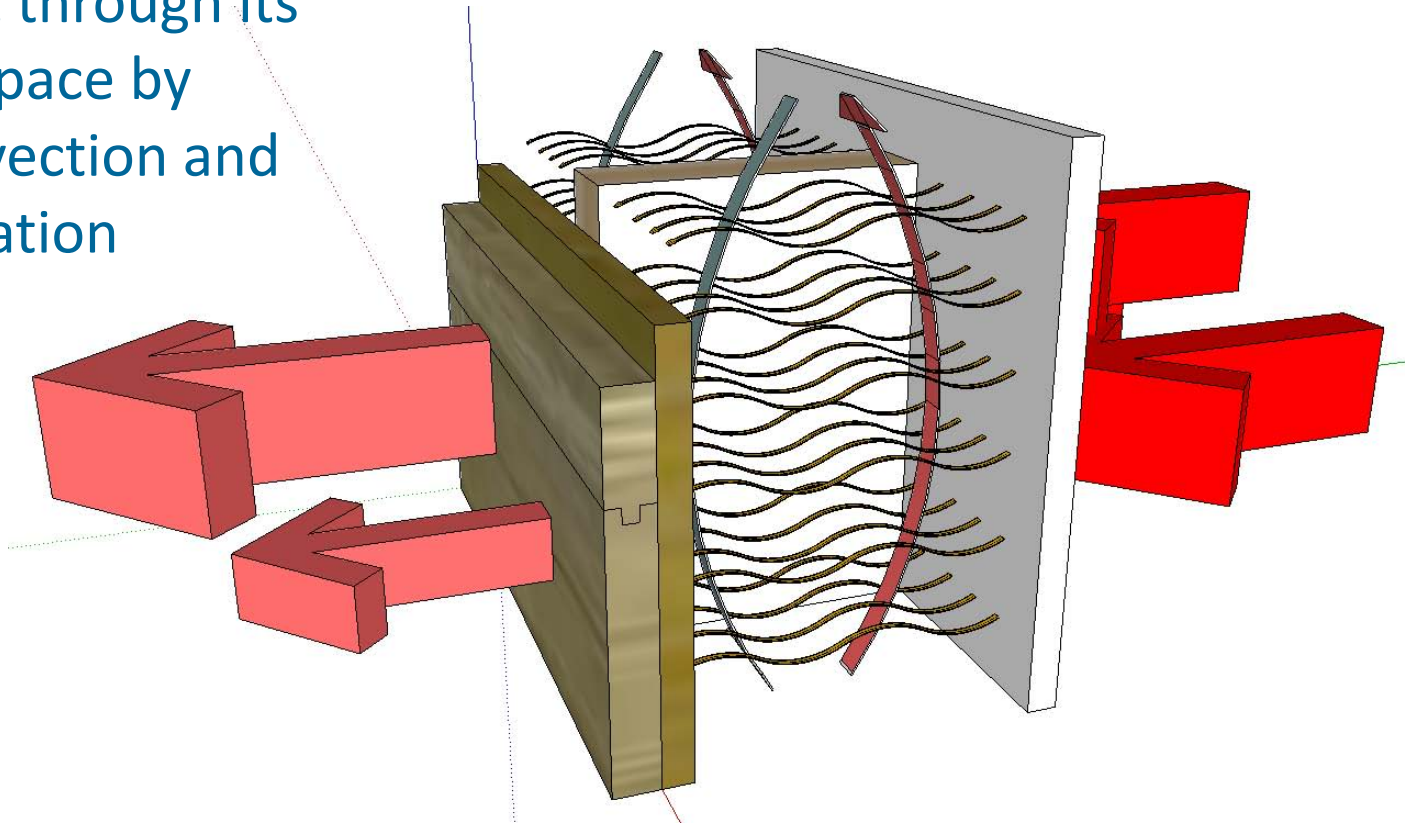
Spray foam applied along the underside of the roof deck

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

Heat Transfer Through Walls

Uninsulated walls transmit heat through its air space by convection and radiation

Convection & Radiation

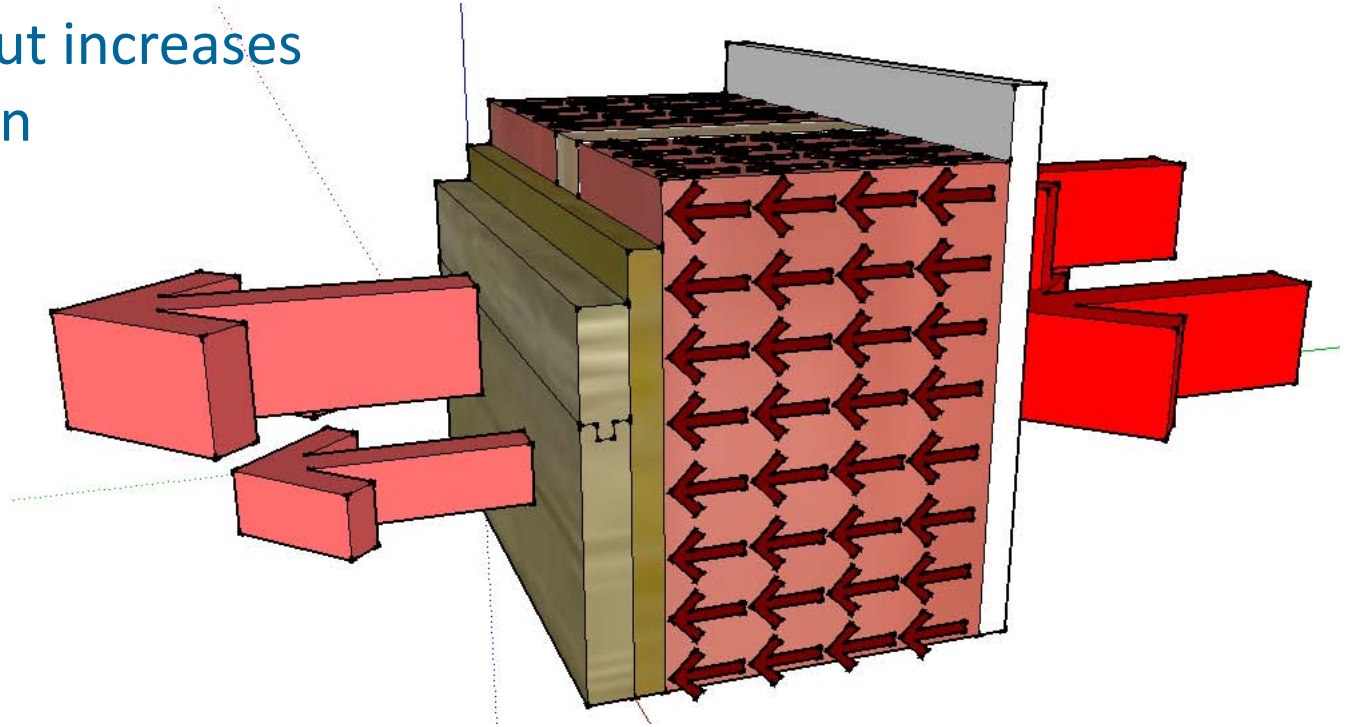


Source - **NCAT**

Heat Transfer Through Walls

Insulating walls reduces convection and radiation heat transfer but increases conduction

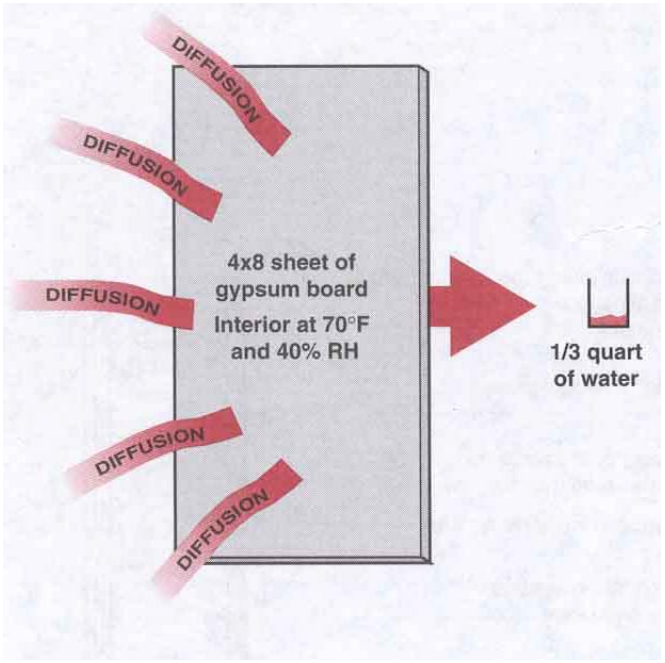
Conduction

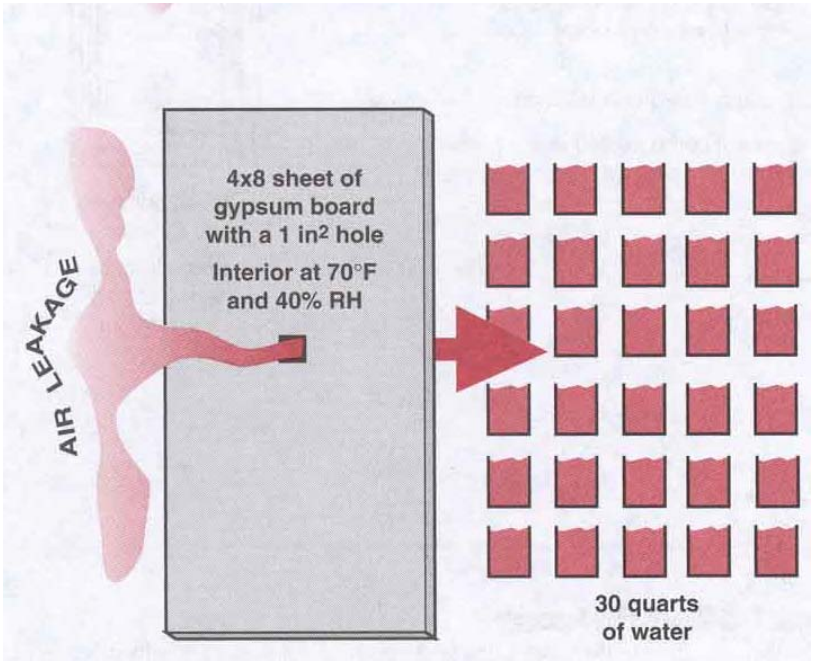


Source - **NCAT**

Vapor Diffusion vs. Air Transport

Air movement is typically far more important than vapor diffusion.



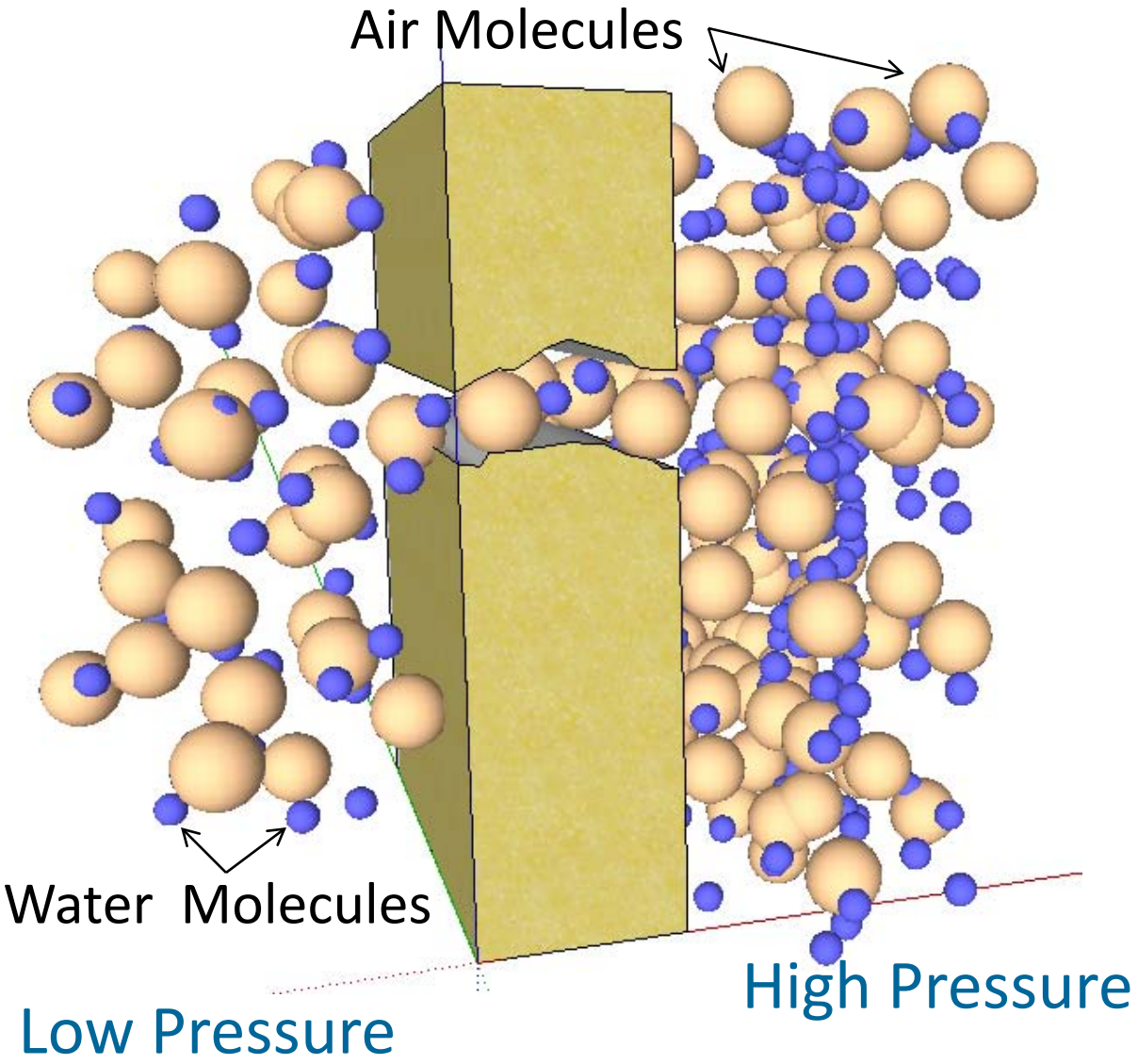


Water vapor moves in two ways

- Vapor Diffusion (movement through solid material)
- Air Transport (the more important)

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

Air and Vapor Migration

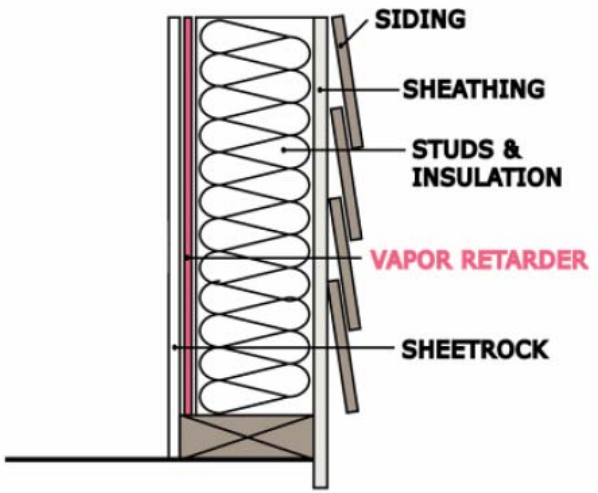


Source - **NCAT**

Vapor Retarders

IRC R702.7

Class I or II vapor retarder at warm side of wall required.
Exception: Basement Walls and any portion or below grade walls.



Class III vapor retarder permitted if:

- Vented cladding over fiberboard
- Vented cladding over gypsum’
- Insulated sheathing with R >=7.5 over 2x4 wall
- Insulated sheathing R >=11.25 over 2x6 wall

Vapor Retarder Class

IRC R702

check

Class I: 0.1 Perm or Less

Class II: 0.1 < Perm <= 1.0 Perm

Class III: 1.0 < Perm <= 10 Perm

IRC R702.7.2

Class I: Sheet Polyethylene, Aluminum Foil

Class II: Kraft-faced Fiberglass Batts

Class III: Latex or Enamel Paint

Vapor Retarders

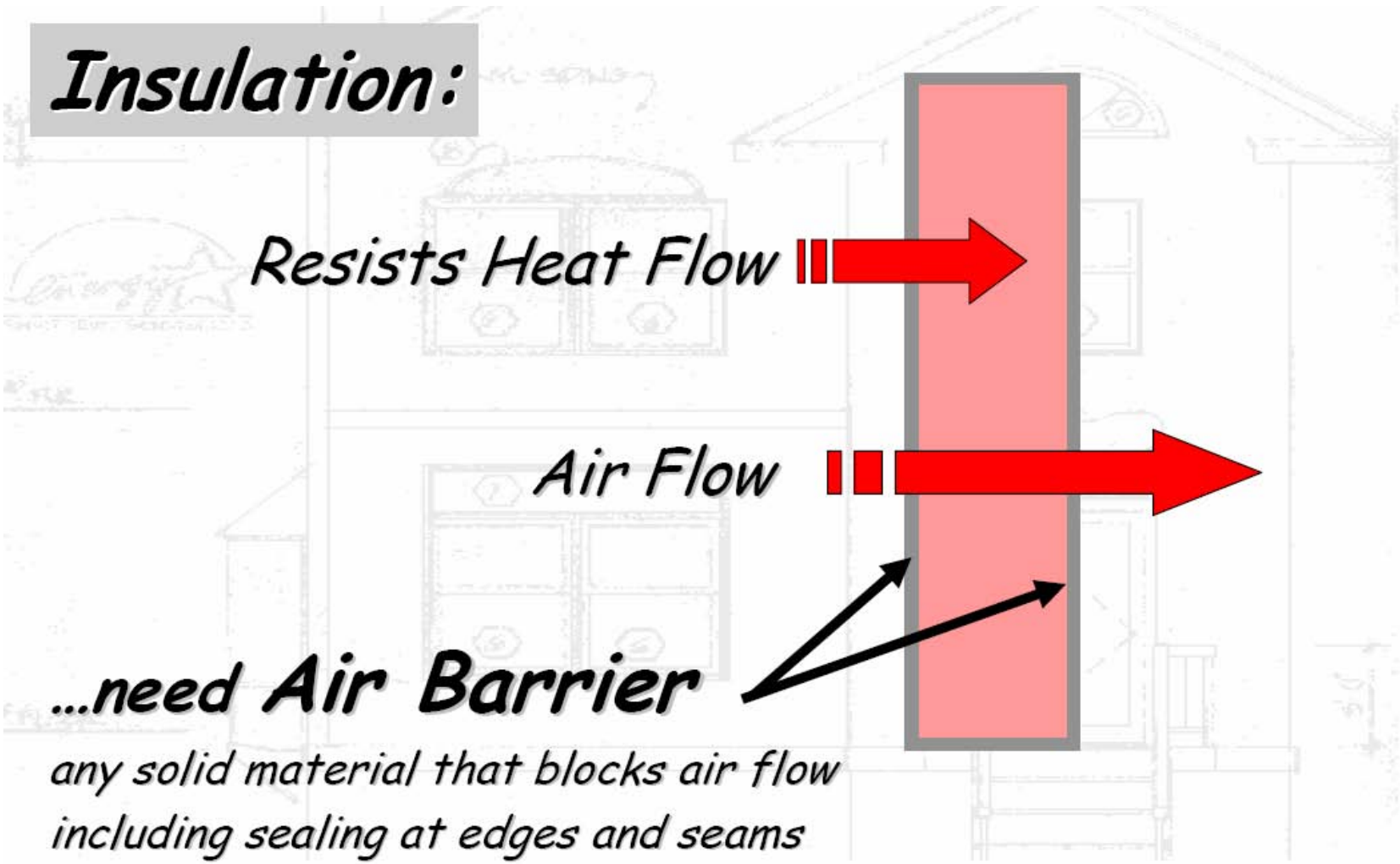
Poly Vapor Retarder

Kraft-faced Vapor Retarder

USDOE Building Energy Codes Program

1. Air Barrier and Thermal Barrier

Table R402.4.1.1



Air Barrier

Air Barrier - A **system of materials** designed and constructed to control airflow between a conditioned and an unconditioned space.

- An air barrier is intended to resist the air pressure differences that act on them. Rigid materials such as gypsum board, plywood, OSB, and supported flexible barriers are typically effective air barriers if joints are sealed.
- **Exterior air barriers** keep outside air out of the building enclosure.
- **Interior air barriers** keep inside air out of the building enclosure.

Common Air Barrier Systems in Residential Construction

- **Interior** air barrier system using gypsum board and framing
- **Interior** air barrier system using polyethylene
- **Exterior** air barrier system using exterior sheathing
- **Exterior** air barrier system using house wraps
- Damp spray cellulose is not an air barrier, it is an air retarder

Source: Paul Tschida, MT DEQ

Source: Paul Tschida, MT DEQ

Vapor Retarders

Vapor Retarder Definitions

The 2009 IRC R601.3 gives the following definitions and examples for vapor retarder classes:

Class	Definition	Examples
I	0.1 perm or less	Sheet polyethylene, sheet metal, non-perforated aluminum foil
II	Greater than 0.1 perm to less than 1.0 perm	Kraft-faced fiberglass batts or low-perm paint
III	Greater than 1.0 perm to less than 10 perm	Latex or enamel paint

Impermeable = vapor barrier

Semi-impermeable

Semi-permeable

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

Perm Ratings of Common Sheathing Materials

Plywood sheathing	More than 1.0 perm
OSB	More than 1.0 perm
Exterior gypsum	More than 1.0 perm
Fiberboard sheathing	More than 1.0 perm
Extruded polystyrene foam sheathing 1 inch	1.0 perm or less
Film-faced extruded polystyrene 0.5 inch thick with perforated facing	More than 1.0 perm
Nonperforeated foil-faced rigid insulation	Less than 0.1 perm
Polypropylene-faced rigid insulation	Less than 0.1 perm
Three-coat, hard-coat stucco over 2 layers of Type D asphalt-saturated Kraft paper and OSB	Less than 1.0 perm

Source: Lstiburek 2006. See Building Science Corporation 2006 for an extensive list of building material perm ratings.

Hygroscopic Materials: Materials that absorb water, their vapor permeability goes up as the relative humidity goes up.

Hydrophobic Materials: Materials with permeance that does not change with relative humidity.

Refer to Residential Energy for a Vapor Permeability Table

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

Vapor Retarders (Climate Zone 6)

IRC R702.7

Class I or II vapor retarders required on interior side of frame walls except at:

- Basement or any below grade walls
- If moisture and freezing will not damage materials

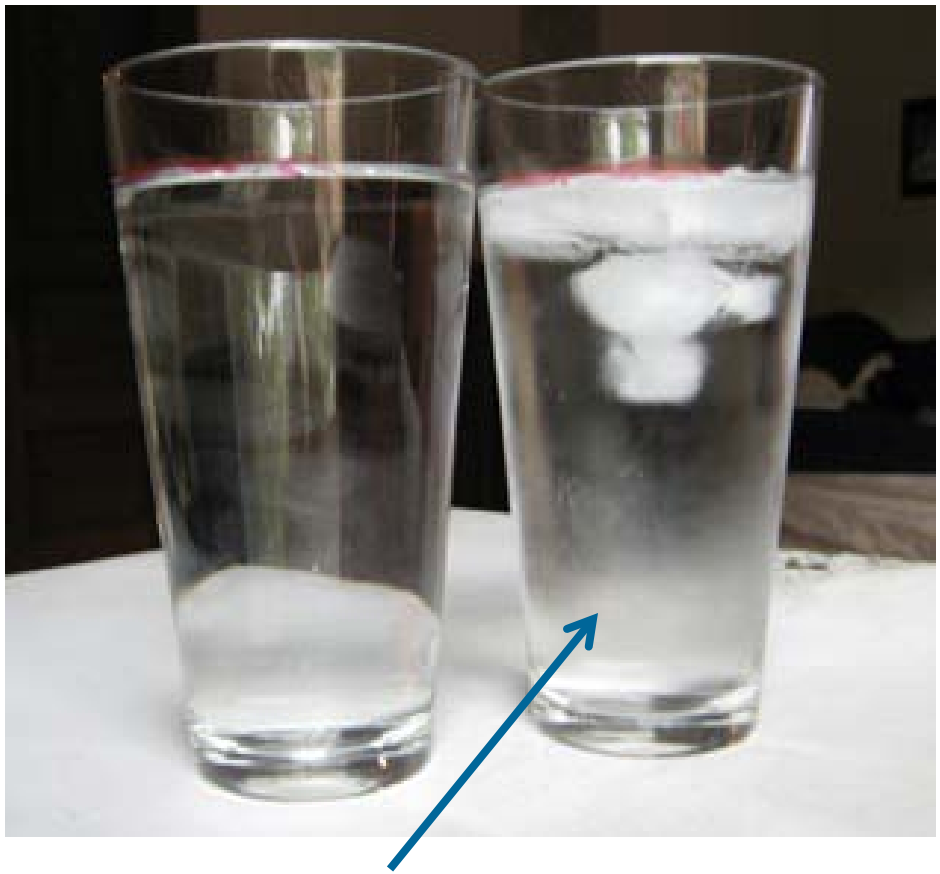
Class III vapor retarders may be used if:

- Vented Cladding over SIPS, fiberboard, or gypsum
- Insulated sheathing R-Value >= 5 over 2x4 wall
- Insulated sheathing R-Value >= 11.25 over 2x6 wall

Moisture in Construction Cavities is a Major Problem

- Water is related to 90% of building and material failures (ASHRAE)
- Estimated $9 Billion/year in repairs for water related failures

Relative Humidity and Dew Point



When condensation appears on the glass of ice water the glass has reached the dew point temperature.

Important Relative Humidity Considerations

- The tighter the house the higher the RH
- The higher the RH the greater likelihood of condensation
- To reduce likelihood of condensation:
  - Reduce of eliminate moisture sources
  - Provide mechanical ventilation

Fenestration and Skylight U-Factors

R402.1.1

TABLE R402.1.1

INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

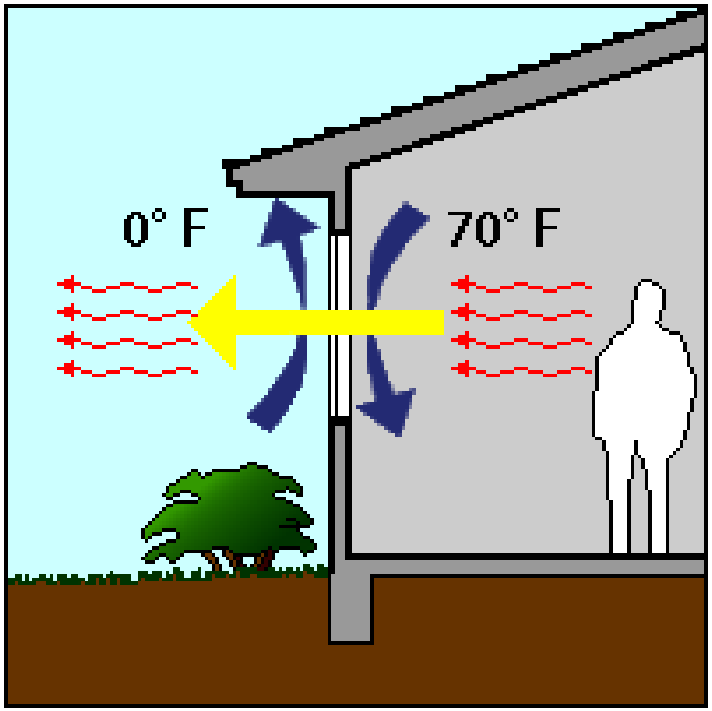
CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.4	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	######
4 except Marine	0.35	0.55	0.4	49	20 or 13+5[h]	8/13	19	13-Oct	10, 2 ft	13-Oct
5 and Marine 4	~~0.32~~	~~0.55~~	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.33 0.32	0.60 0.55	NR	49	21 or 13+5[h]	15/20	30[g]	15/19	10, 4 ft	10/19 15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Window U-Factor

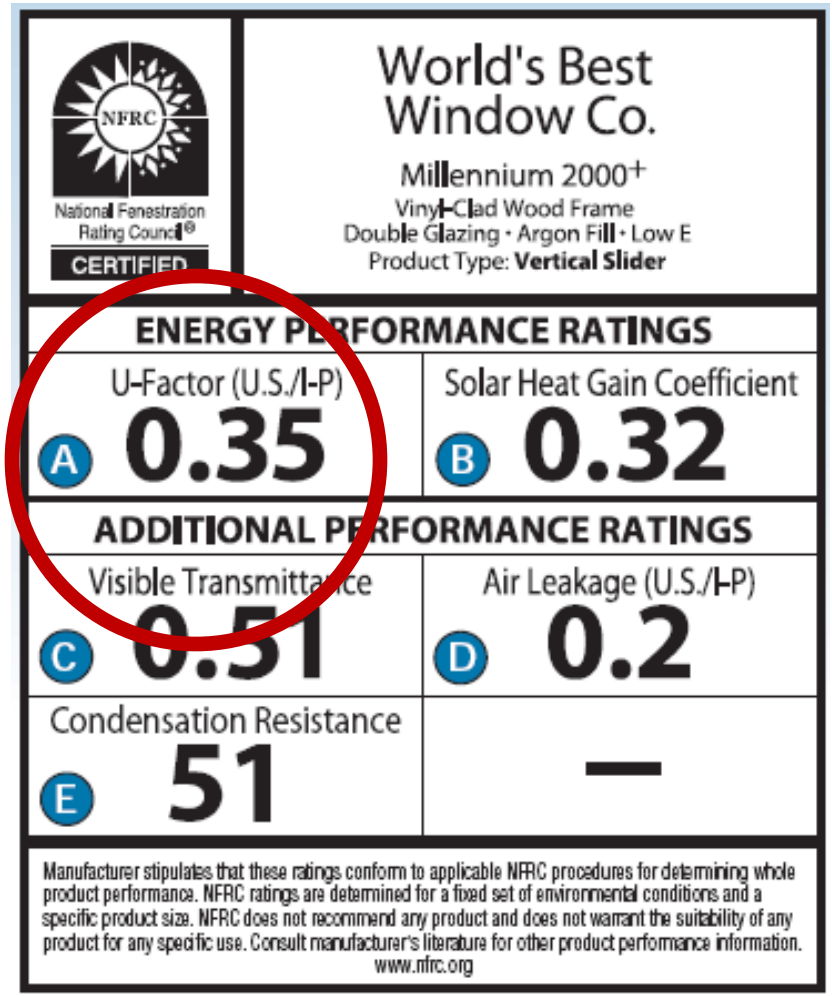
R402.1.1

from 0.32 **U-Factor** to 0.33

Lower means less heat loss.



Source: **www.nfrc.org**

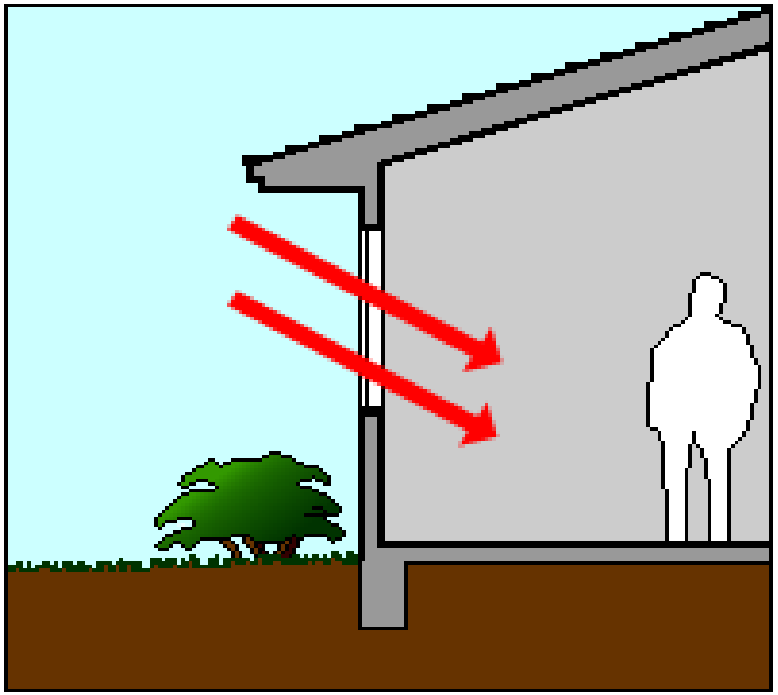


Window Solar Heat Gain Coefficient

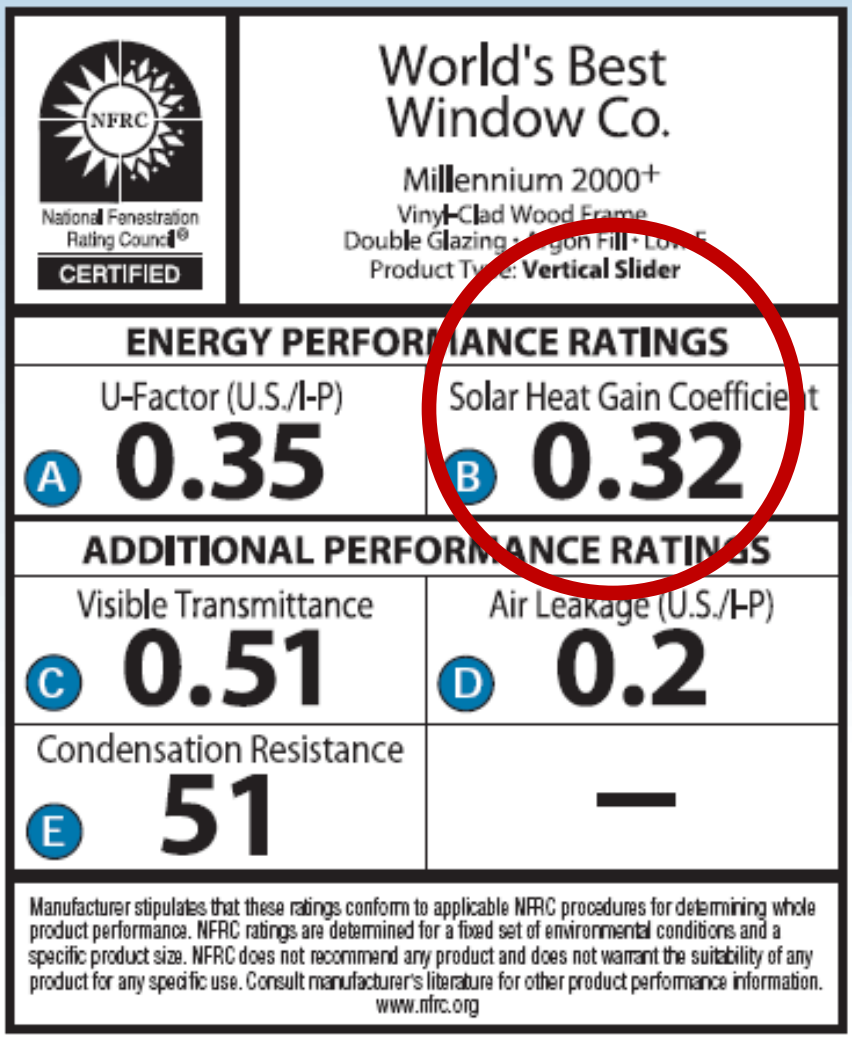
R402.1.1

No requirement for Zone 6 (Montana)

Lower means less solar gain.
Single pane glass is 0.87



Source: **www.nfrc.org**

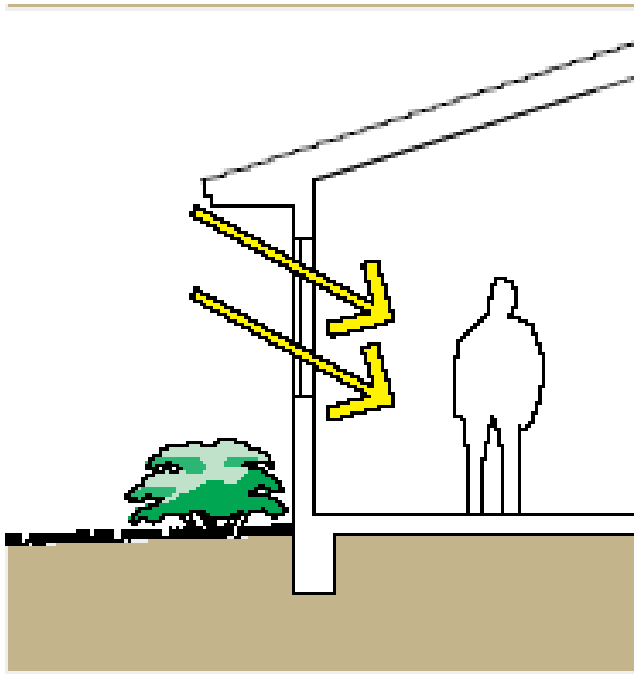


Window Visible Transmittance

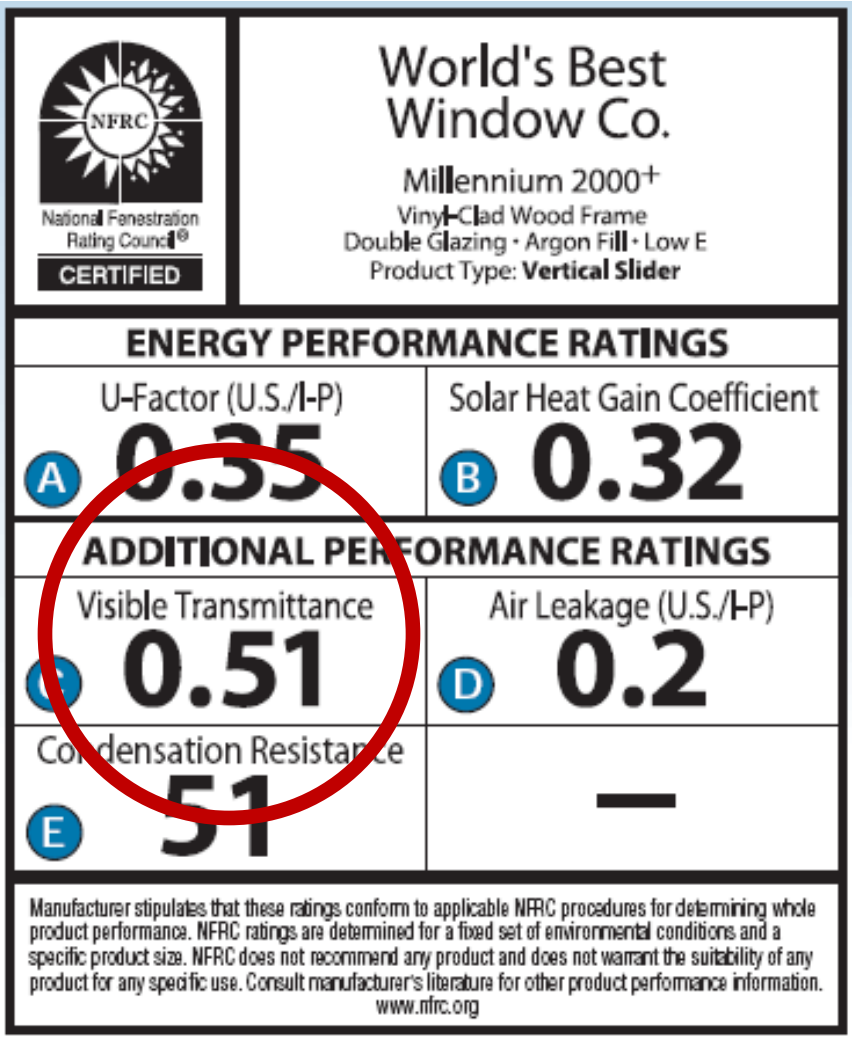
R402.1.1

No code requirement.

Higher means greater potential for daylighting.



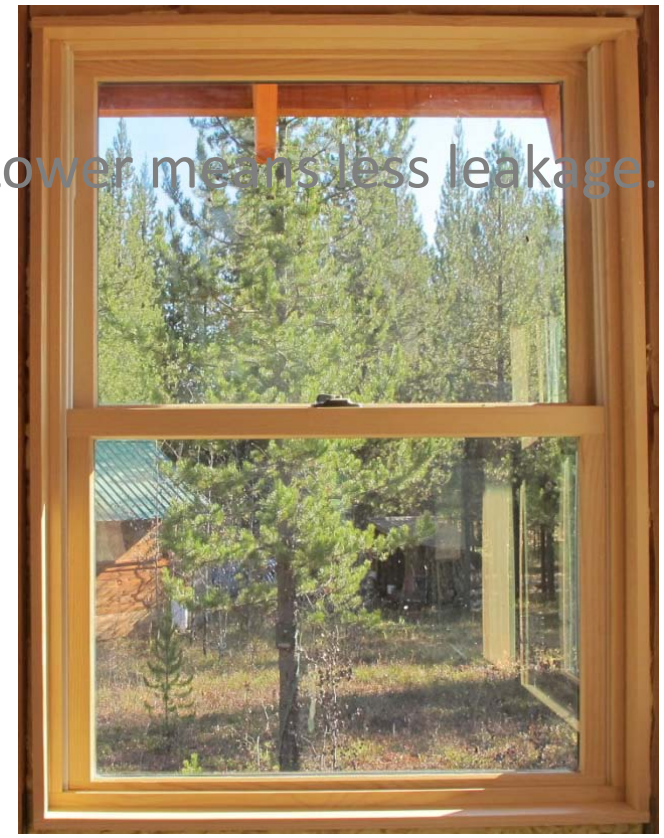
Source: **www.nfrc.org**



Windows – Maximum Air Leakage

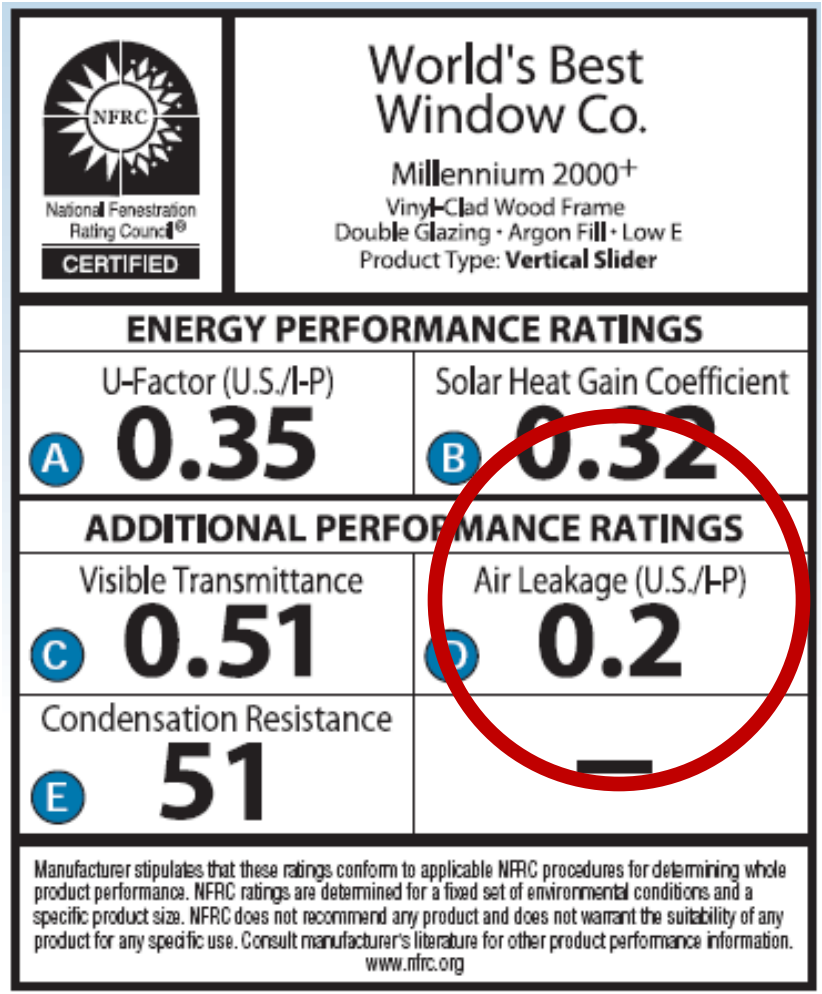
R402.4.3

0.3 cfm/SF No change.



Lower means less leakage.

Source: **www.nfrc.org**



NFRC
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)	Solar Heat Gain Coefficient
A **0.35**	B **0.32**

ADDITIONAL PERFORMANCE RATINGS

Visible Transmittance	Air Leakage (U.S./I-P)
C **0.51**	D **0.2**
Condensation Resistance	
E **51**	—

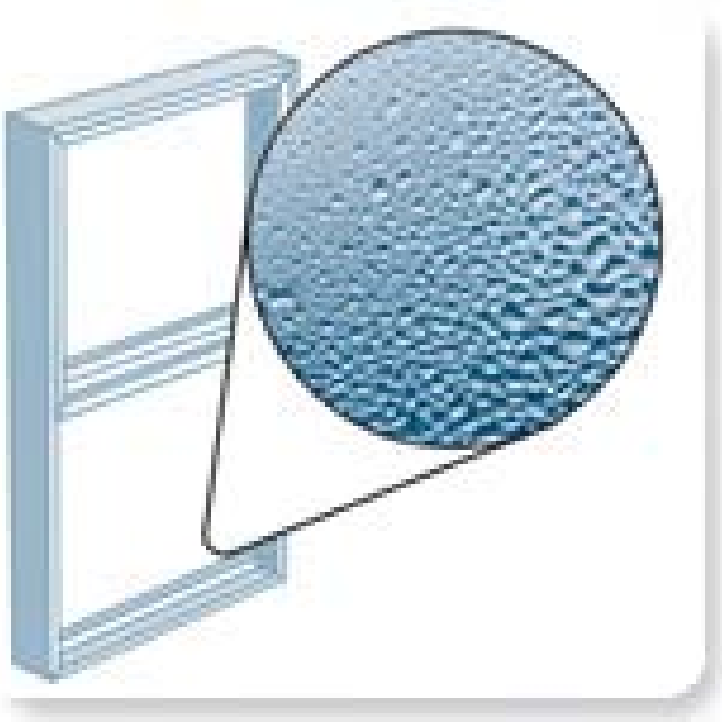
Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of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

Window Condensation Resistance

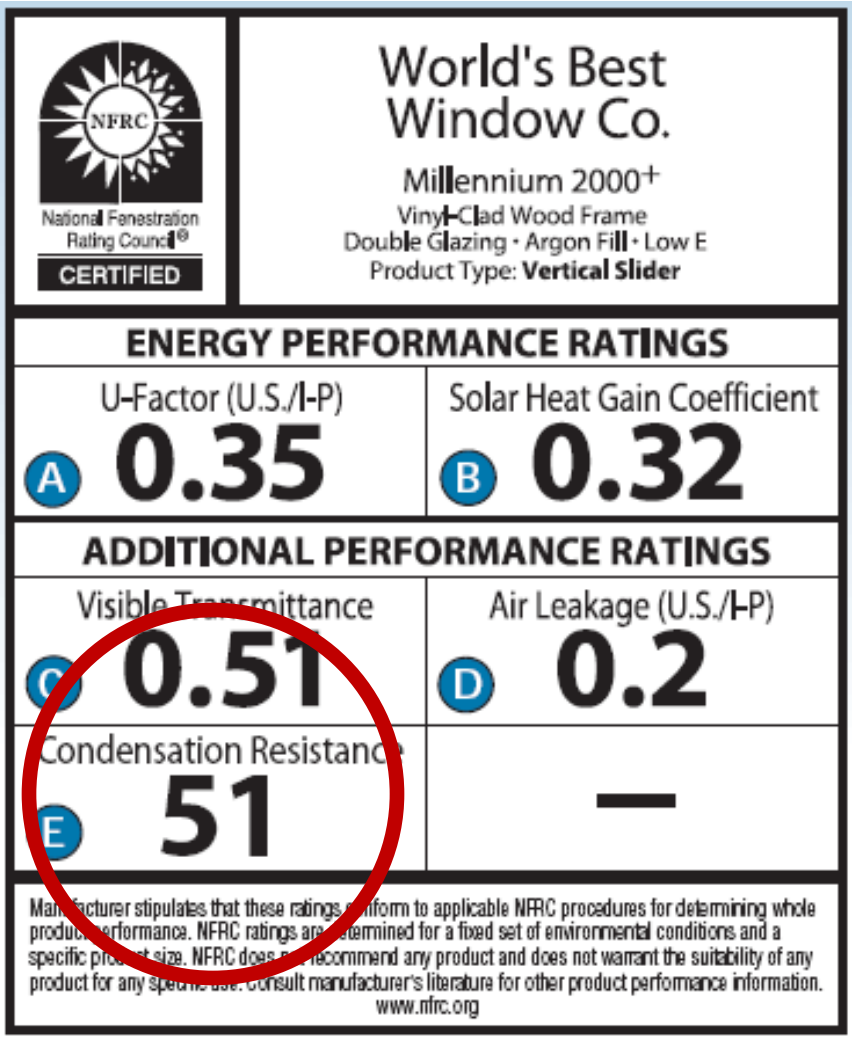
R402.1.1

No code requirement.

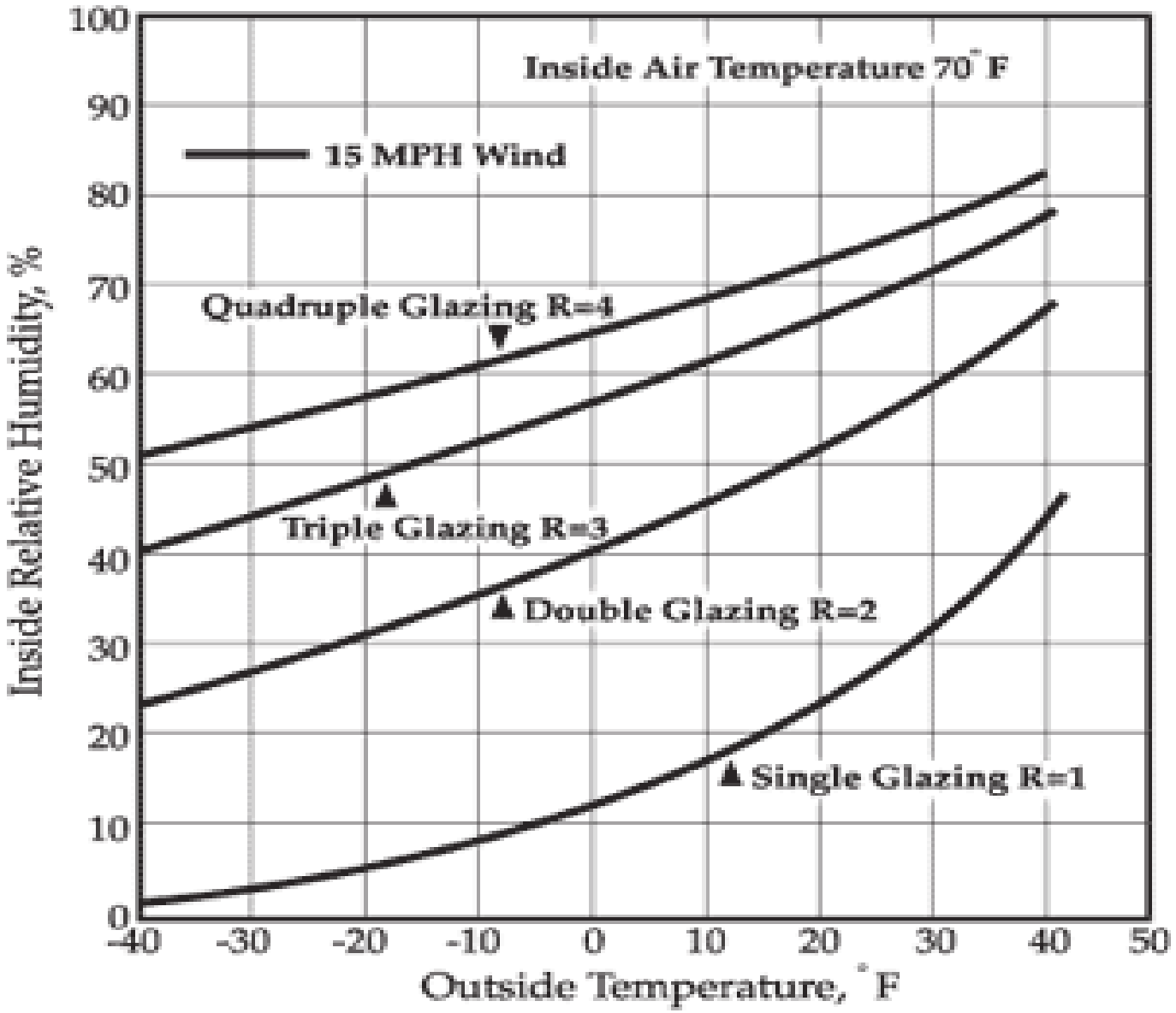
Higher means better as resisting condensation.



Source: **www.nfrc.org**



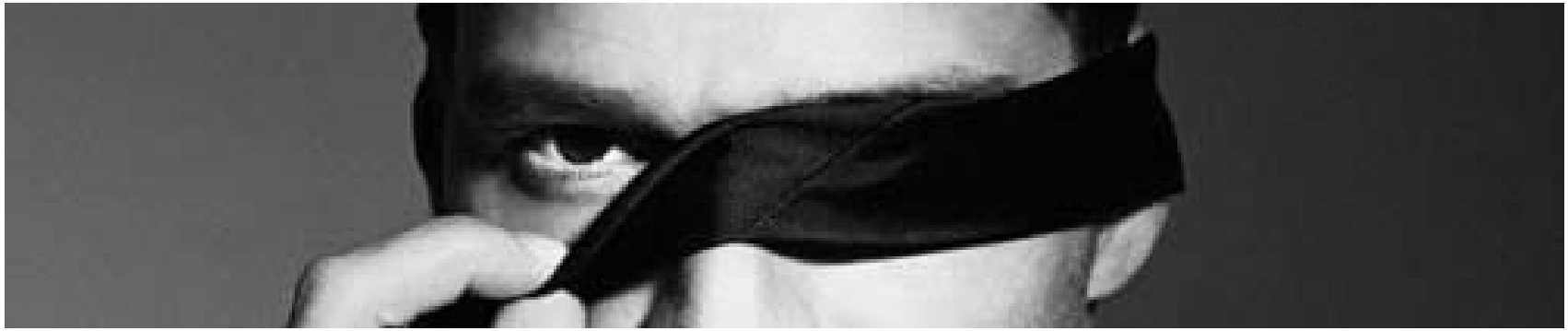
Window Condensation Chart



If Fenestration Not Labeled by NFRC

R301.1.3

If not NFRC labeled, must use tables 303.1.3(1&2) to assign a default SHGC and U-Factor



Other Window Provisions – All Compliance Options

No code change.

Hard Limits – Can't be exceeded, even in trade-offs.

Glazed Fenestration: Maximum area weighted U-Factor .40

R402.5

Skylights: Maximum area weighted U-Factor .75

R402.5

Skylights

R402.1.1

from 0.60 U-Factor to 0.55

Source: USDOE Building Energy Codes University

National Fenestration Rating Council

A

NFRC

National Fenestration Rating Council®

CERTIFIED

B

World's Best Door Co.

Entrance Door

CPD#000-x-000

Insulated Steel Wood Edge Door

ENERGY PERFORMANCE RATINGS

Product Description F Default Frame** Wood	U-Factor/Solar Heat Gain Coefficient (SHGC) 1/4 Lite ≤410† G	1/2 Lite ≤900† H	3/4 Lite ≤1100† I	Full Lite >1100† J
2/A1/na/AIR/0.250 D	0.23 / —	0.30 / —	— / —	0.40 / 0.40 E
2/A1 /.020(3)/ARG/0.750	0.21 / —	0.24 / —	— / —	0.28 / 0.36
2/A1/na/AIR/0.675	— / —	0.28 / —	0.33 / —	0.34 / 0.40
3/S5/na/AIR/0.250	0.21 / —	0.25 / —	— / —	0.29 / 0.40
Flush/Embossed	U-Factor 0.19 SHGC 0.04			

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.

* #glazing layers / spacer type / low-e emissivity (surface) / gap fill / gap width (na=not applicable)

**per NFRC 100 Section B3.24 † square inches C

www.nfrc.org

www.nfrc.org

Ceiling R-Value

R402.1.1

TABLE R402.1.1

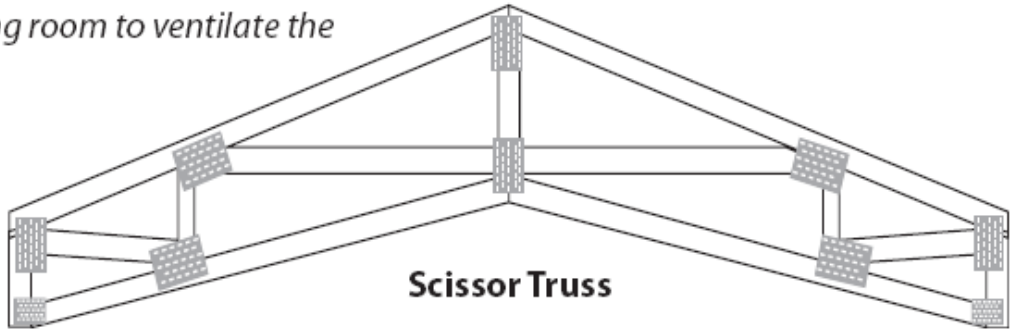
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

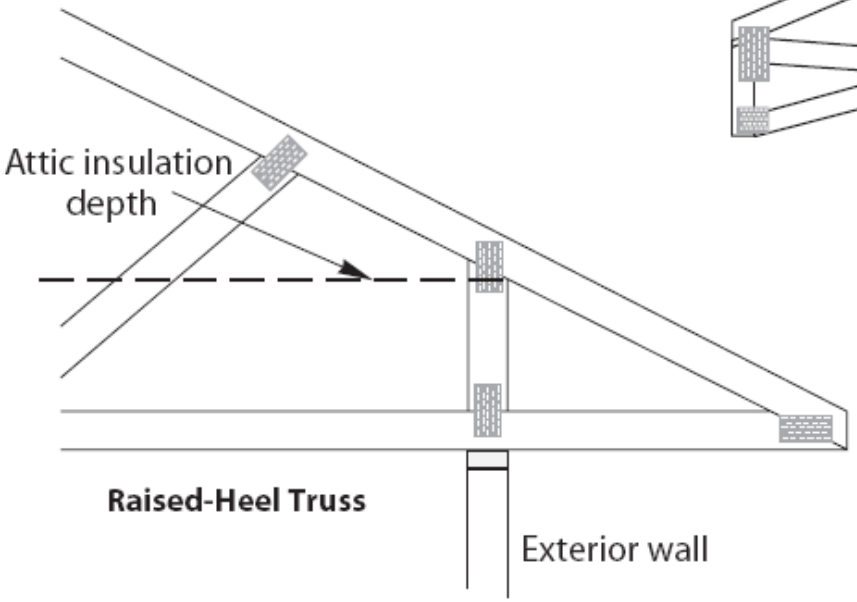
CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.4	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	######
4 except Marine	0.35	0.55	0.4	49	20 or 13+5[h]	8/13	19	13-Oct	10, 2 ft	13-Oct
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.33 0.32	0.60 0.55	NR	49	21 or 13+5[h]	15/20	30[g]	15/19	10, 4 ft	10/19 15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Energy Trusses Allow R-38

R402.1.1

Scissor trusses solve the problem of how to insulate a cathedral ceiling while allowing room to ventilate the insulated space.



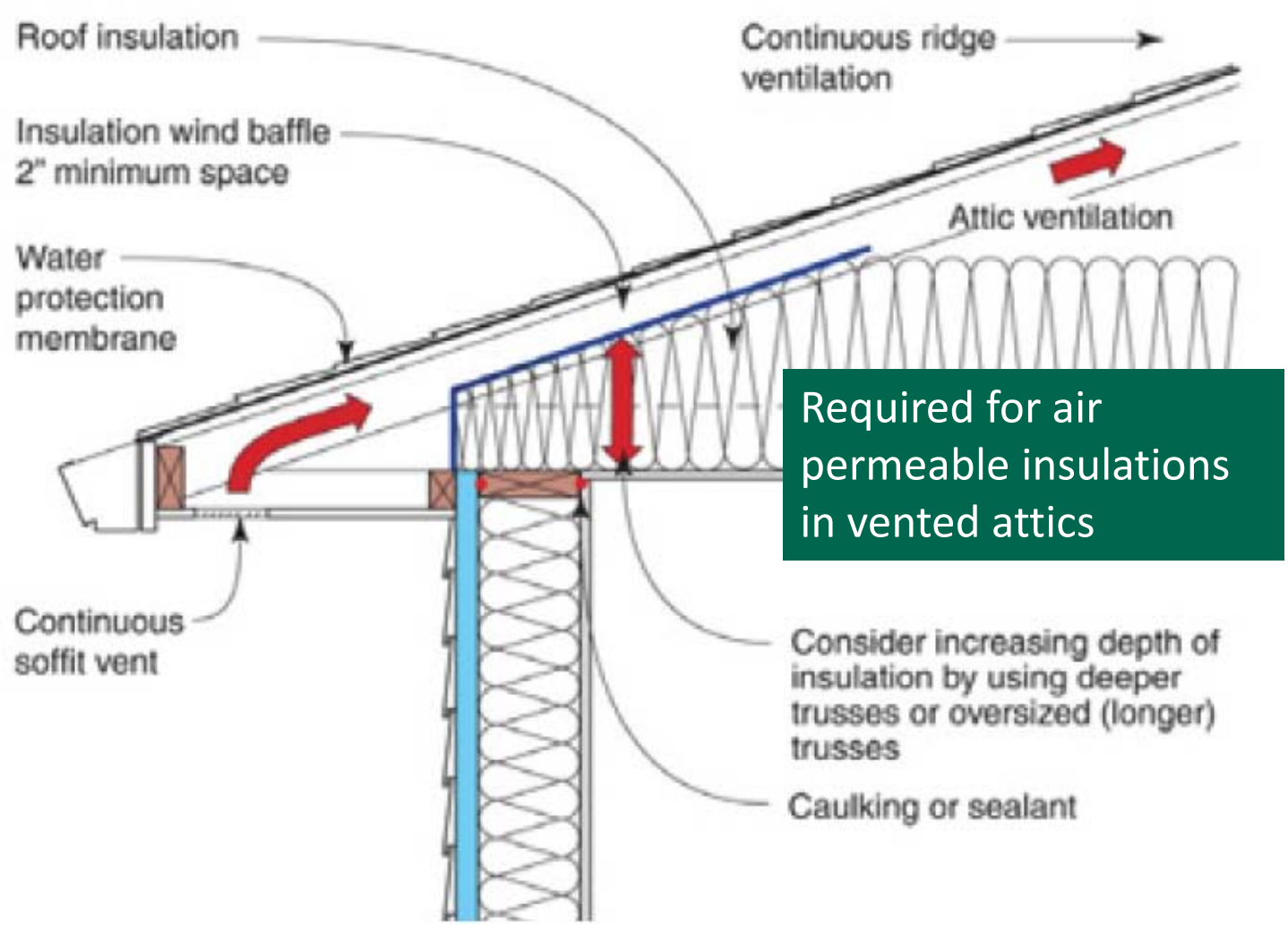


Raised-heel trusses allow the full depth of attic insulation to extend over the top of the exterior wall.

Source - **Residential Energy**

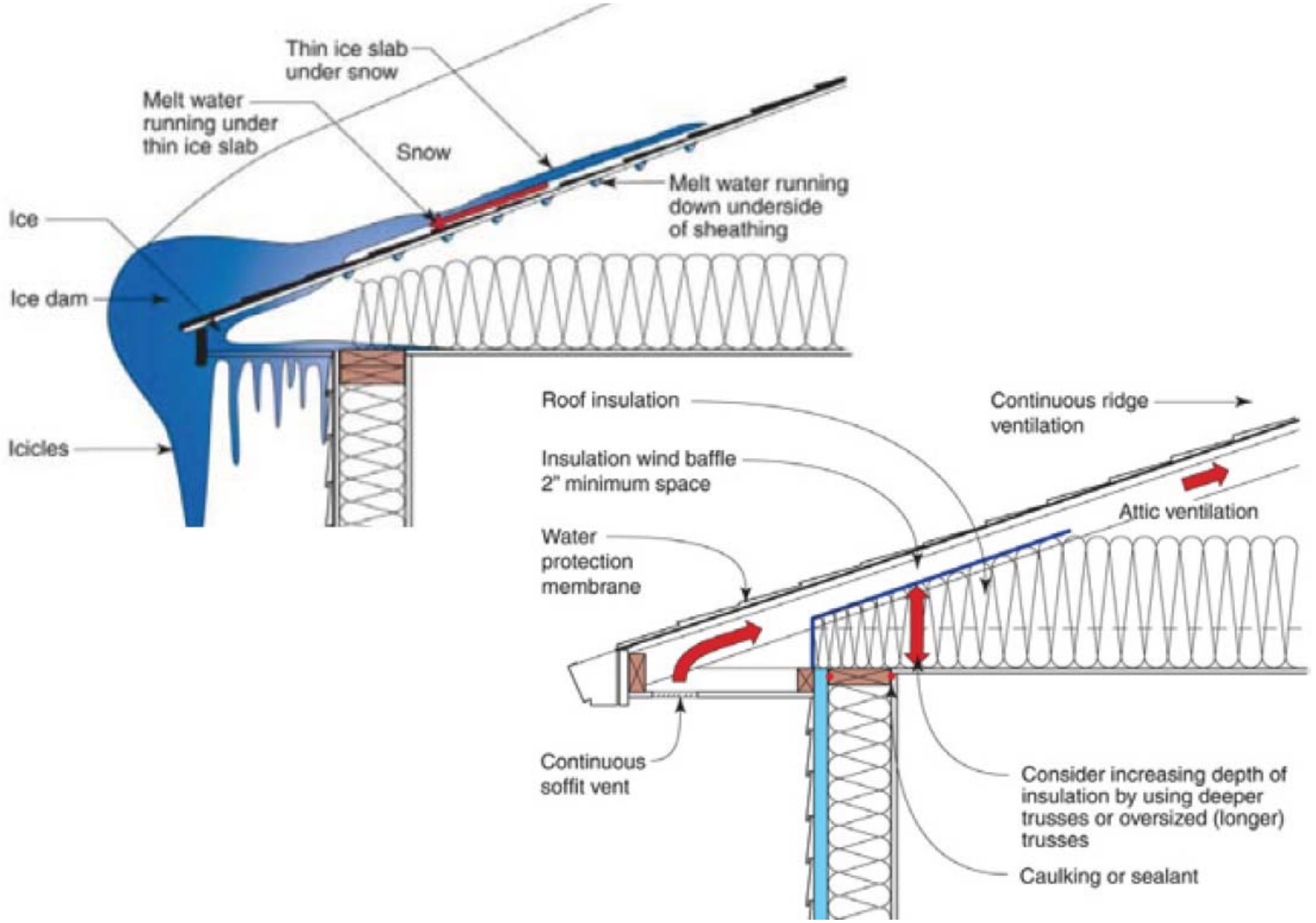
Eave Baffles Required

R402.2.3



Source: USDOE Building Technologies Program, Introduction to Building Systems Performance: Houses That Work II

Ice Dams



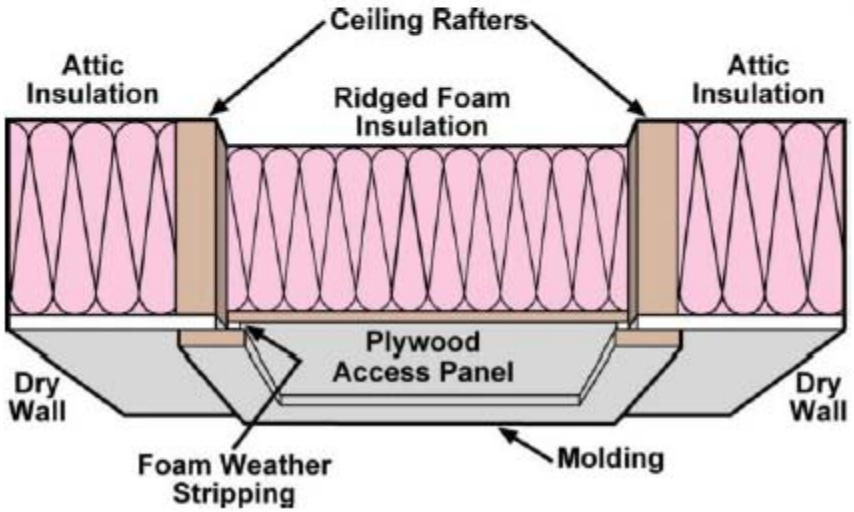
Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

Weatherstrip and insulate doors from conditioned spaces to unconditione spaces *(e.g., attics and crawl spaces)*

- ✓ Insulate to level equivalent to surrounding surfaces
  - e.g., required ceiling insulation = R-38, then attic hatch must be insulated to R-38

Provide access to all equipment that prevents damaging or compressing the insulation

Install a wood framed or equivalent baffle or retainer when loose fill insulation is installed



Source: USDOE Building Energy Codes University

Wood Frame Wall R-Value

R402.1.1

TABLE R402.1.1

INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.4	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	######
4 except Marine	0.35	0.55	0.4	49	20 or 13+5[h]	8/13	19	13-Oct	10, 2 ft	13-Oct
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.33 0.32	0.60 0.55	NR	49	21 or 13+5[h]	15/20	30[g]	15/19	10, 4 ft	10/19 15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

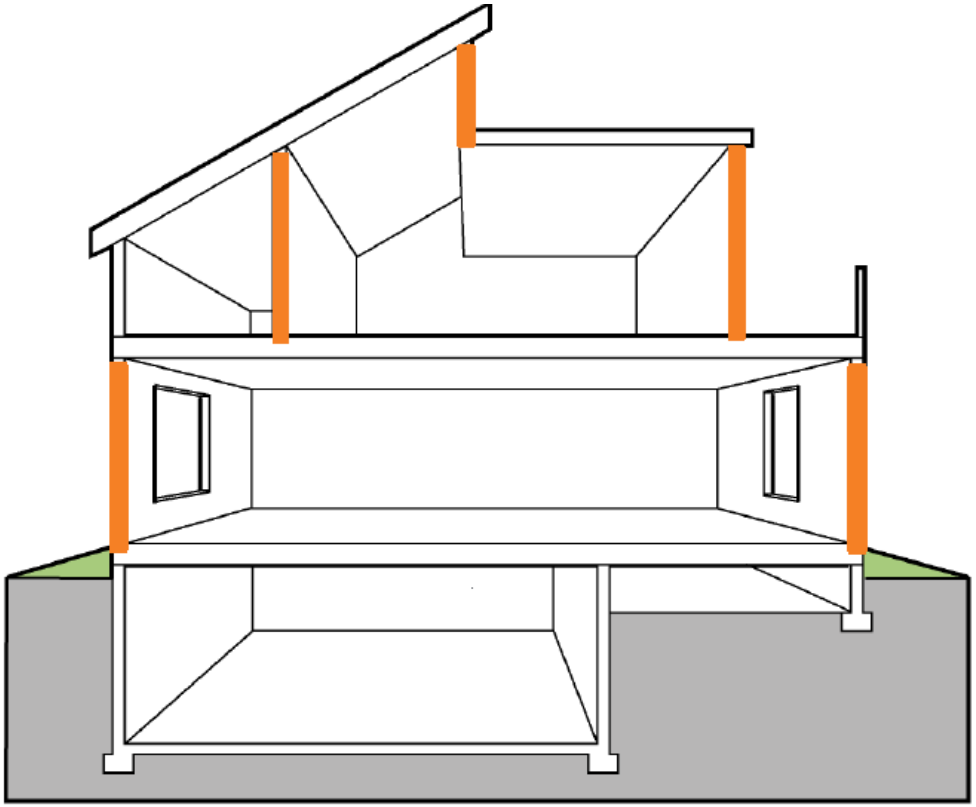
Wood Frame Wall R-Value

R402.1.1

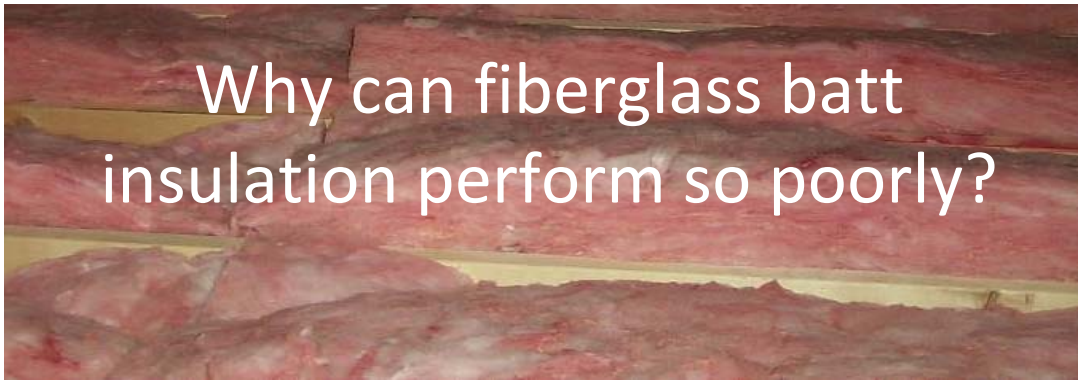
From R21 or R13+R5 R-Value to No Change

2012 IECC ~~R20+R5 or R13+R10~~

- Exterior above-grade walls
- Attic kneewalls
- Skylight shaft walls
- Perimeter joists
- Basement walls
- Garage walls *(shared with conditioned space)*

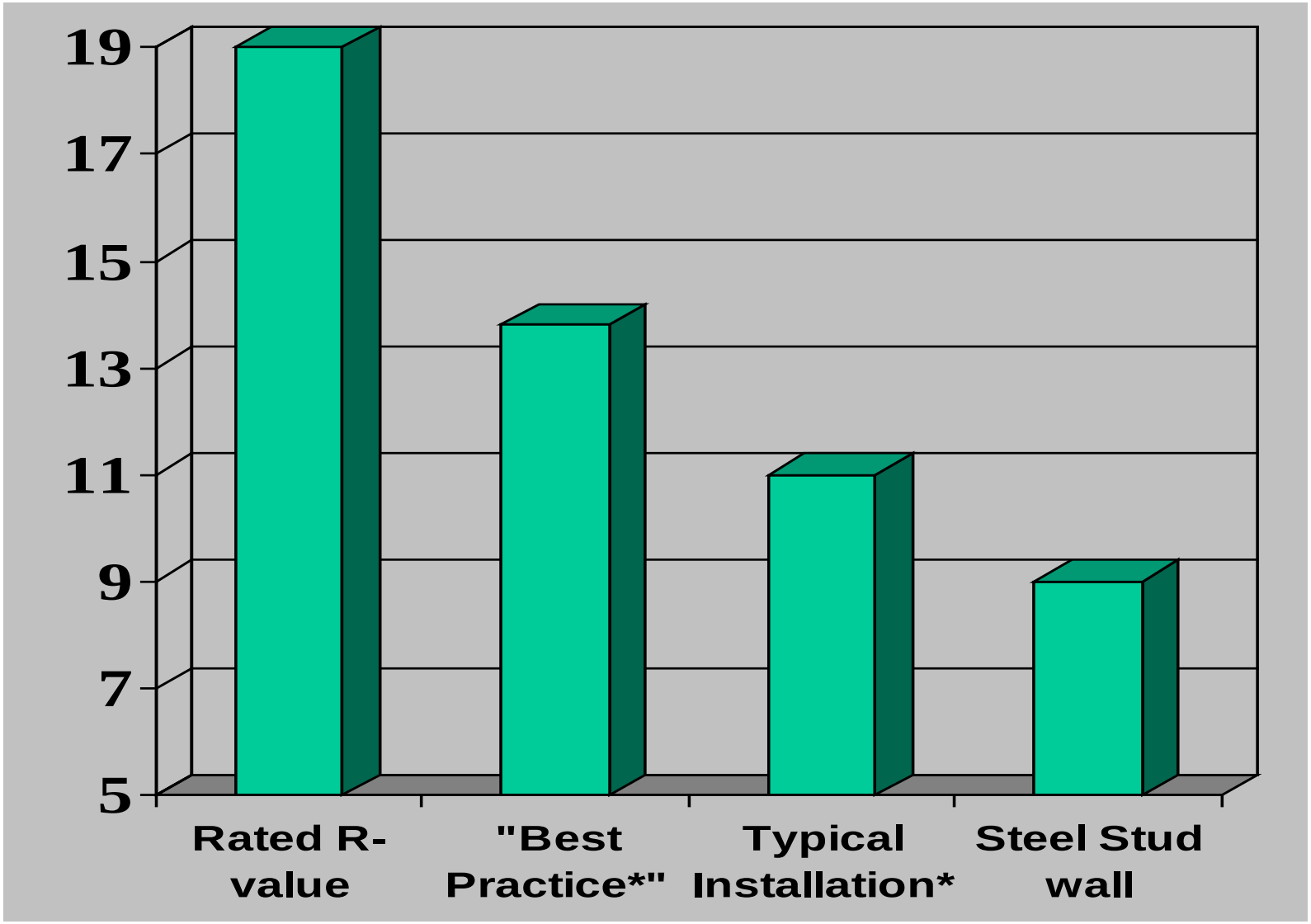


It is not just about the R-Value



Common Batt Insulation Installation Defects

Fiberglass Batts (Real World)



Correct Installation

Loose Fill Fiberglass Methods

Blown in—open attics

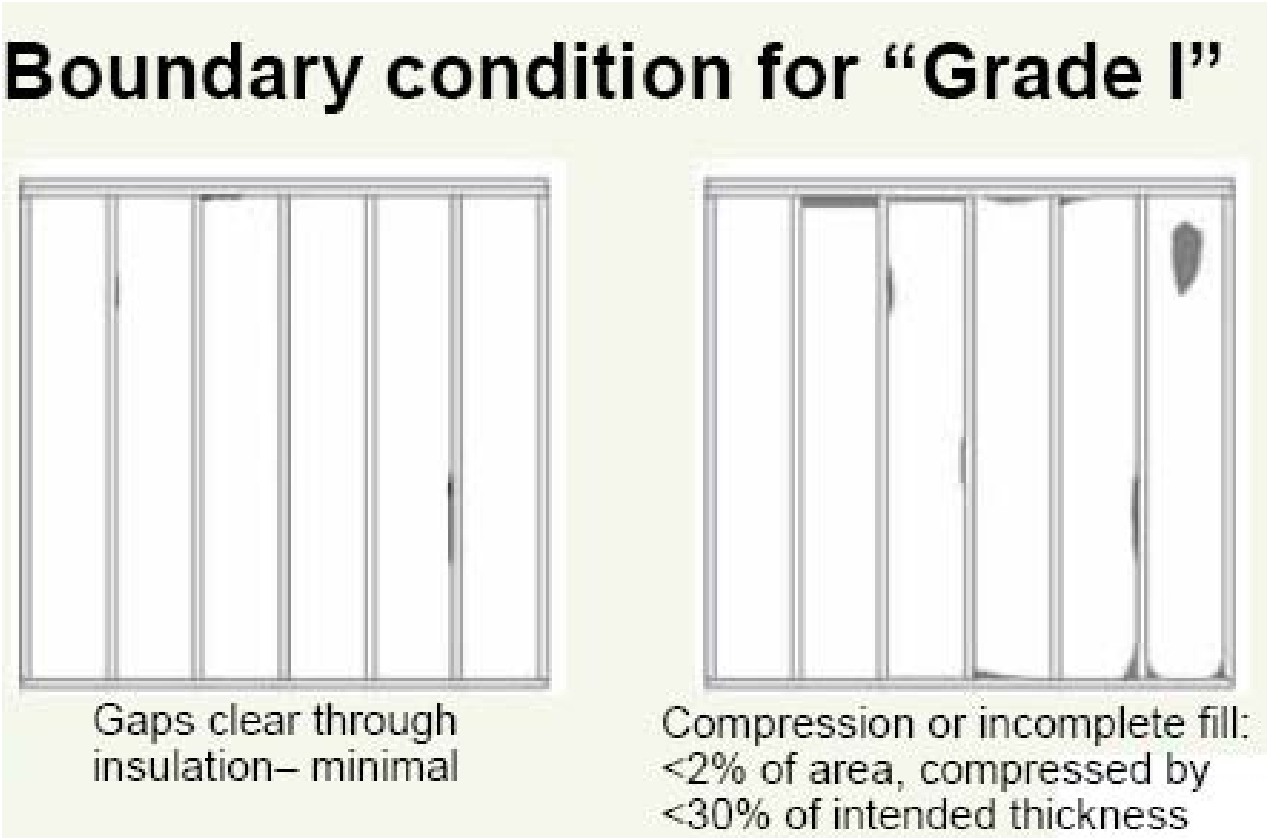
- Desired R-value achieved by installing the number of bags specified by the manufacturer (by square feet)

Blown in Blanket (BIB) system

- Loose fill fiberglass installed behind netting stapled over framing members
- Installed R-value dependent on density
- Typical for a 2x6 wall is R-21 to R-23

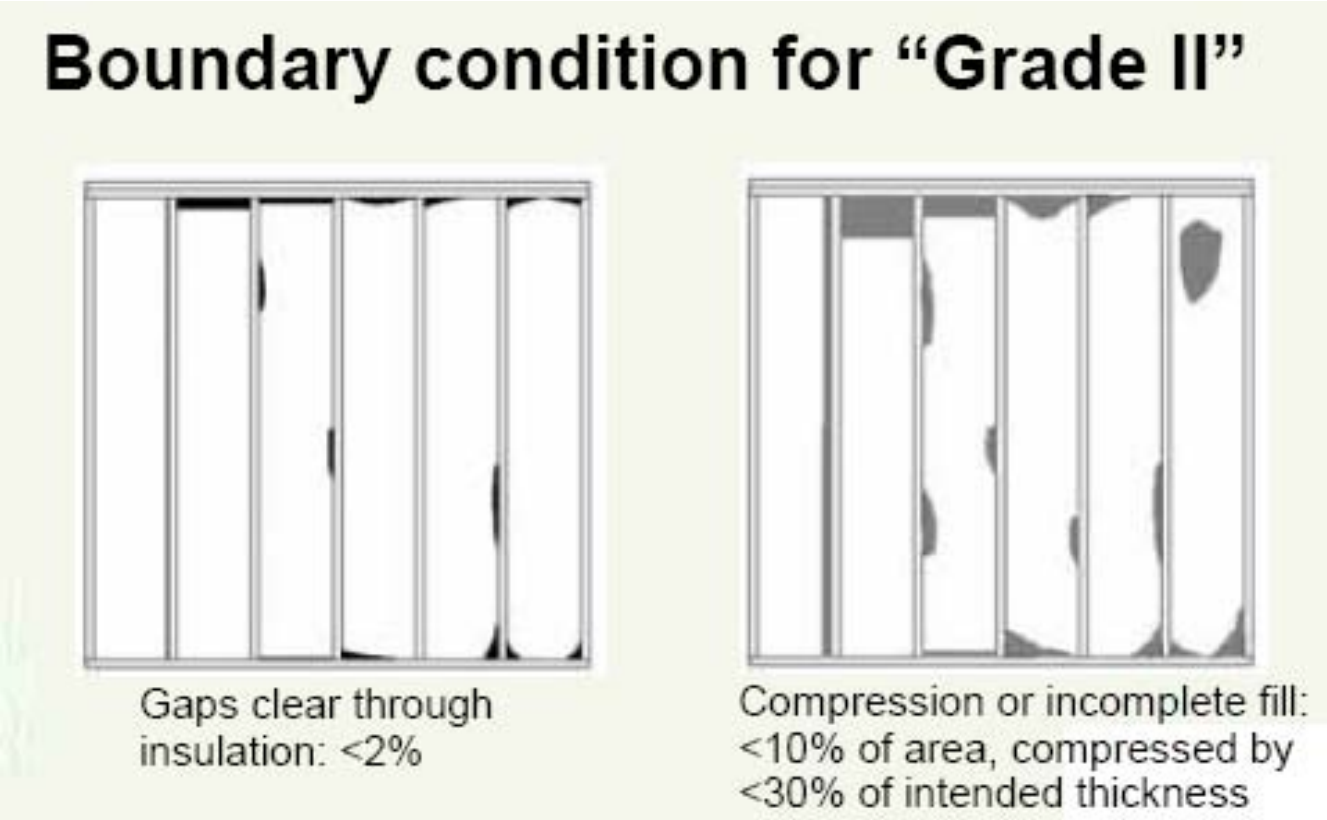
Grade I Assessment

Installed according to manufacturer's instructions, fills each cavity completely, no substantial gaps or voids, split and fit tightly around wiring and other services.



Grade II Assessment

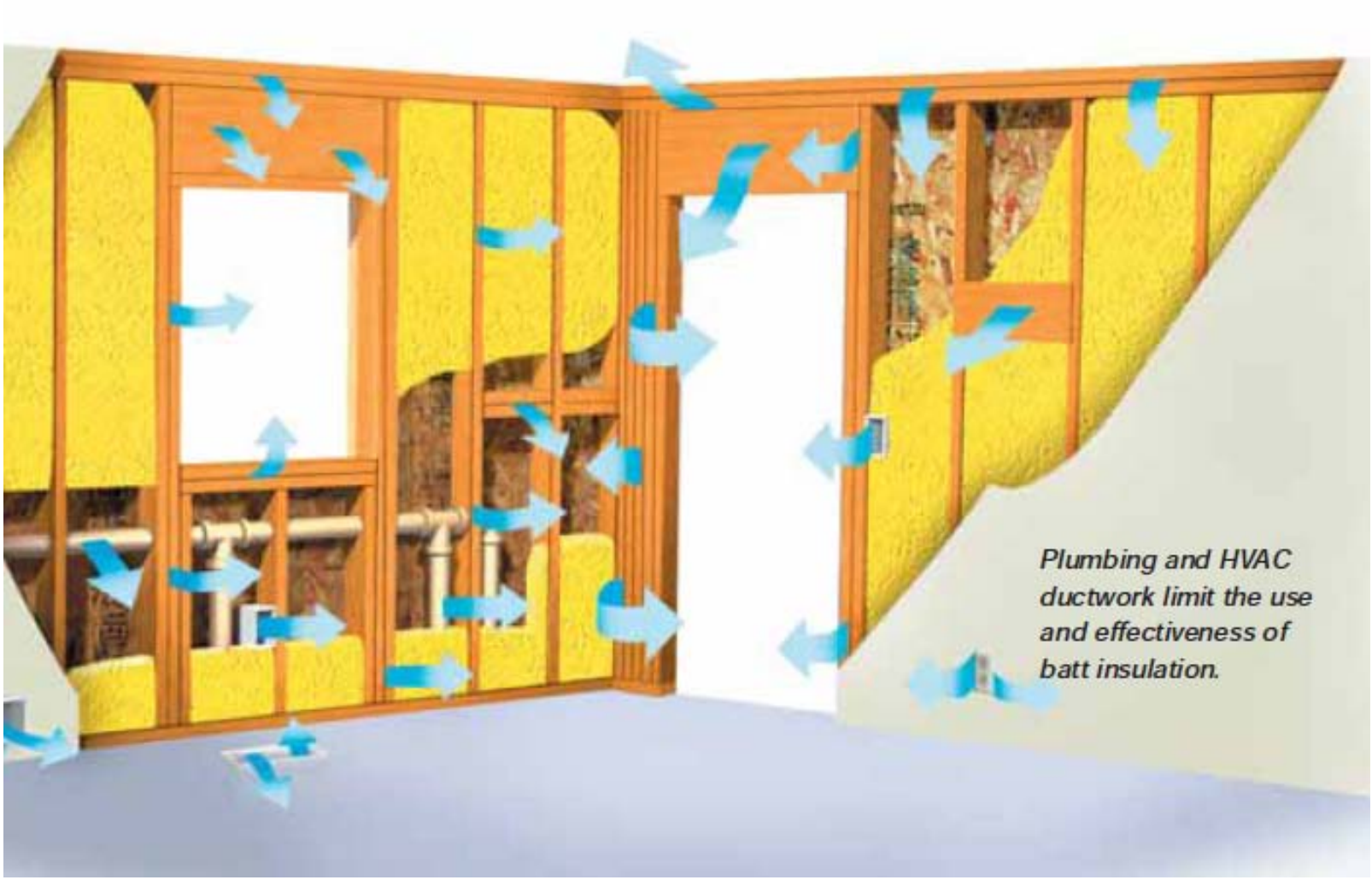
Moderate to frequent defects such as gaps around wiring, electrical outlets, plumbing, and other services; rounded edges or shoulders.



Insulation Grading

To be **Grade I floor insulation** must be in complete contact with the surface it is intended to insulate.

Why Continuous Insulated Sheathing in 2012 IECC?



Source: DOW Chemical Company publication titled “Improve Energy Efficiency and Air Sealing in Above-Grade Walls.”

Why Insulated Sheathing?

Rigid Insulation = **Air Barrier + Insulation + Thermal Break**

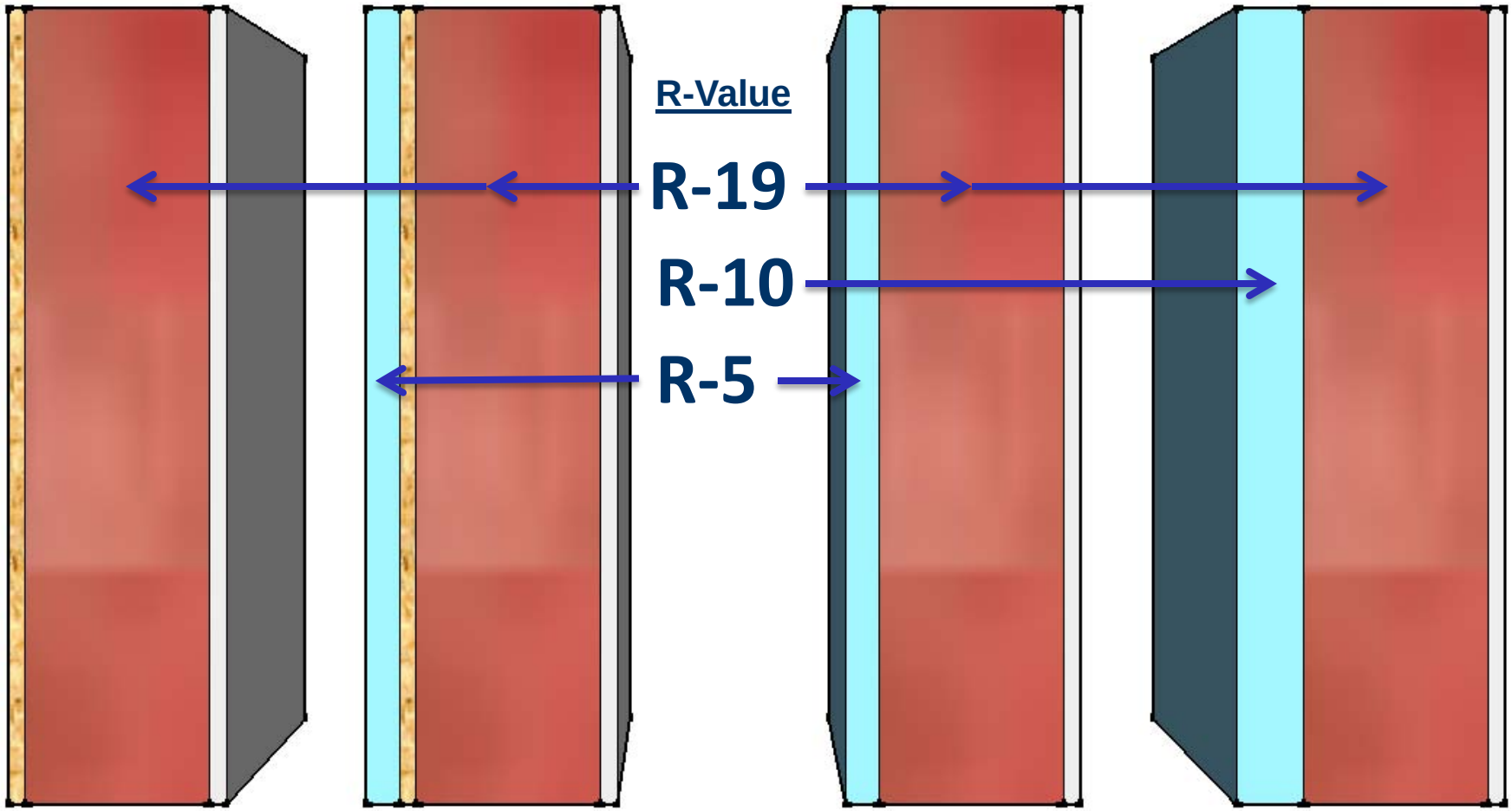
Where code acceptable, consider using at:

- *Exterior Sheathing*
- *Attic Knee Walls*
- *Skylight Shafts*
- *Porch/House Interface*

Continuous Insulated Sheathing – **Not in the MT Code**

Source: DOW Chemical Company publication titled “Improve Energy Efficiency and Air Sealing in Above-Grade Walls.”

Effective R-Value of Typical Wall Assemblies



Wall Drying Potential - Cold Climate

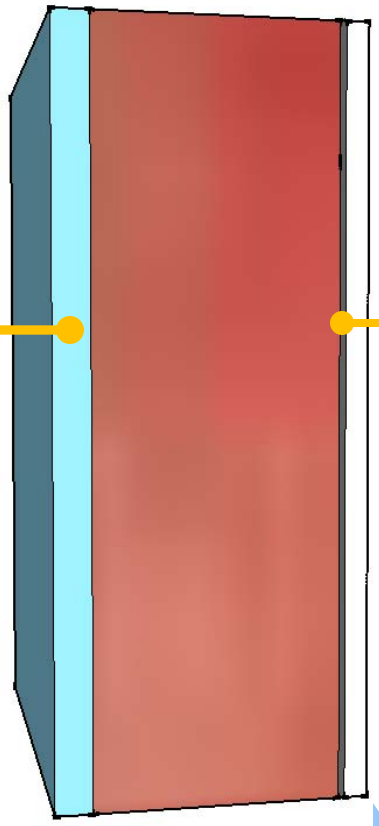
Cooler
Lower
Humidity

Exterior

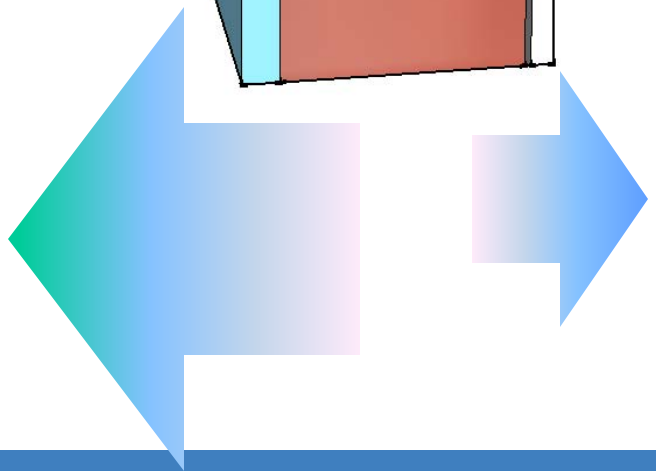
Interior

Warmer
Higher
Humidity

Semi-Permeable



Vapor Retarder Layer
Semi-Impermeable



Drying
Primarily to
the Exterior

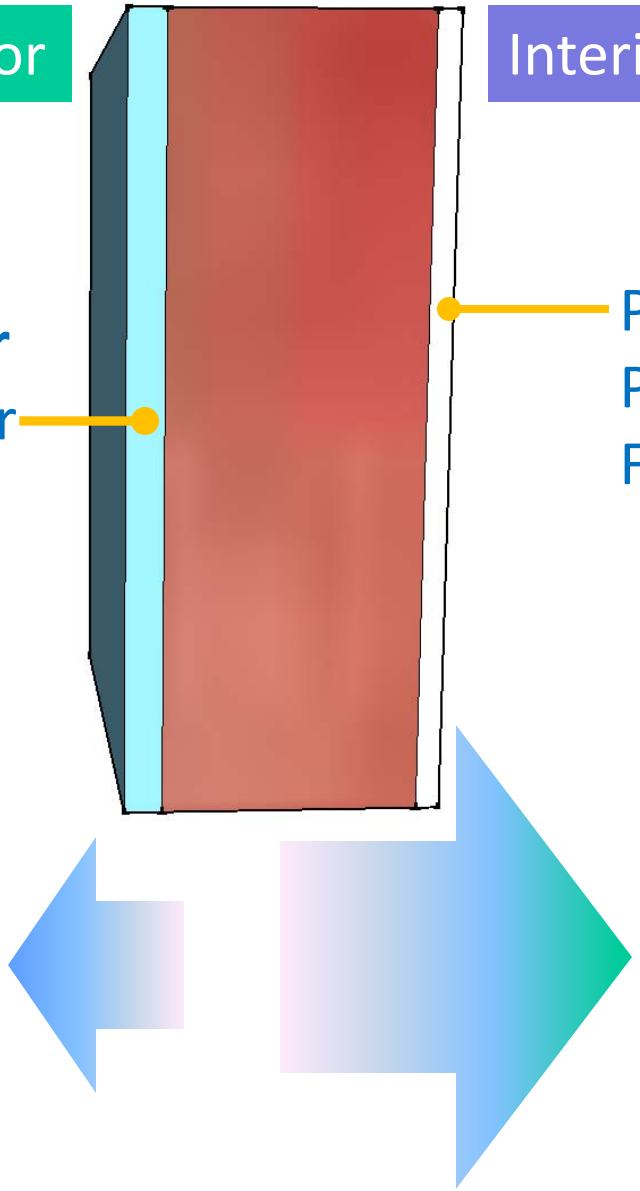
Wall Drying Potential – Hot Humid Climate

Warmer Higher Humidity

Exterior

Interior

Cooler Lower Humidity

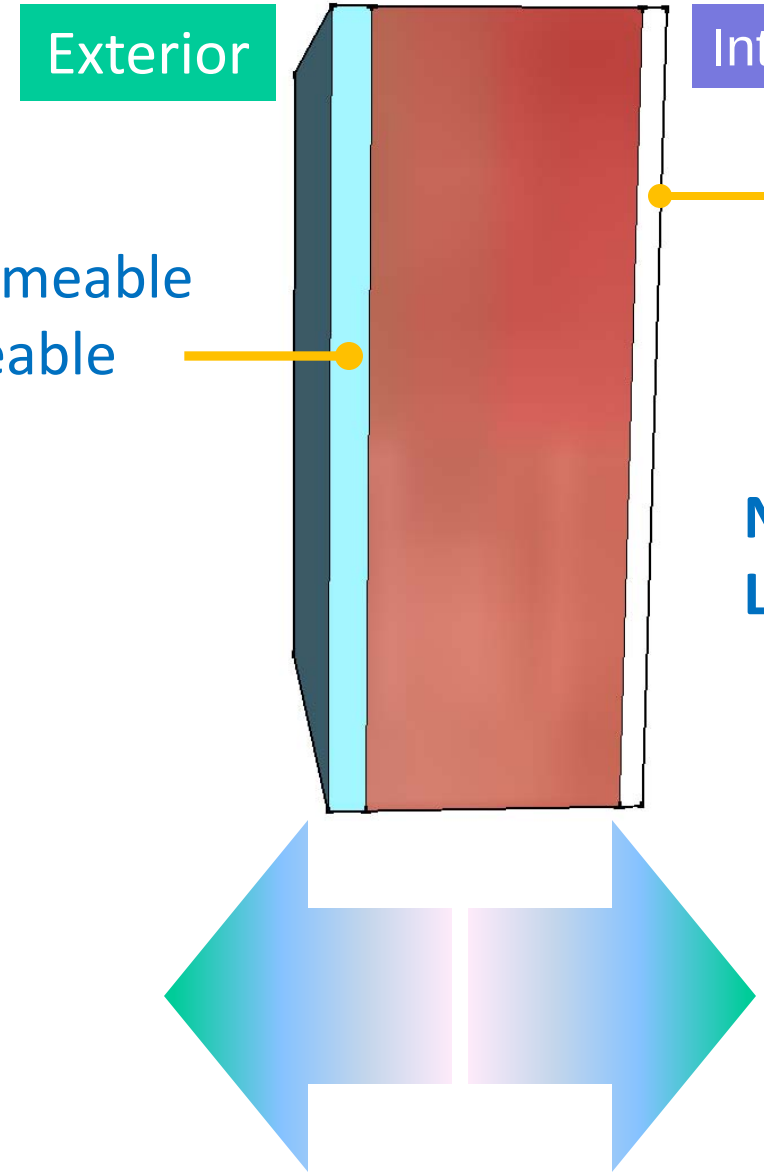


Vapor Retarder Layer
Semi-Impermeable or Impermeable

Permeable or Semi-Permeable Interior Finish

Drying Primarily to the Interior

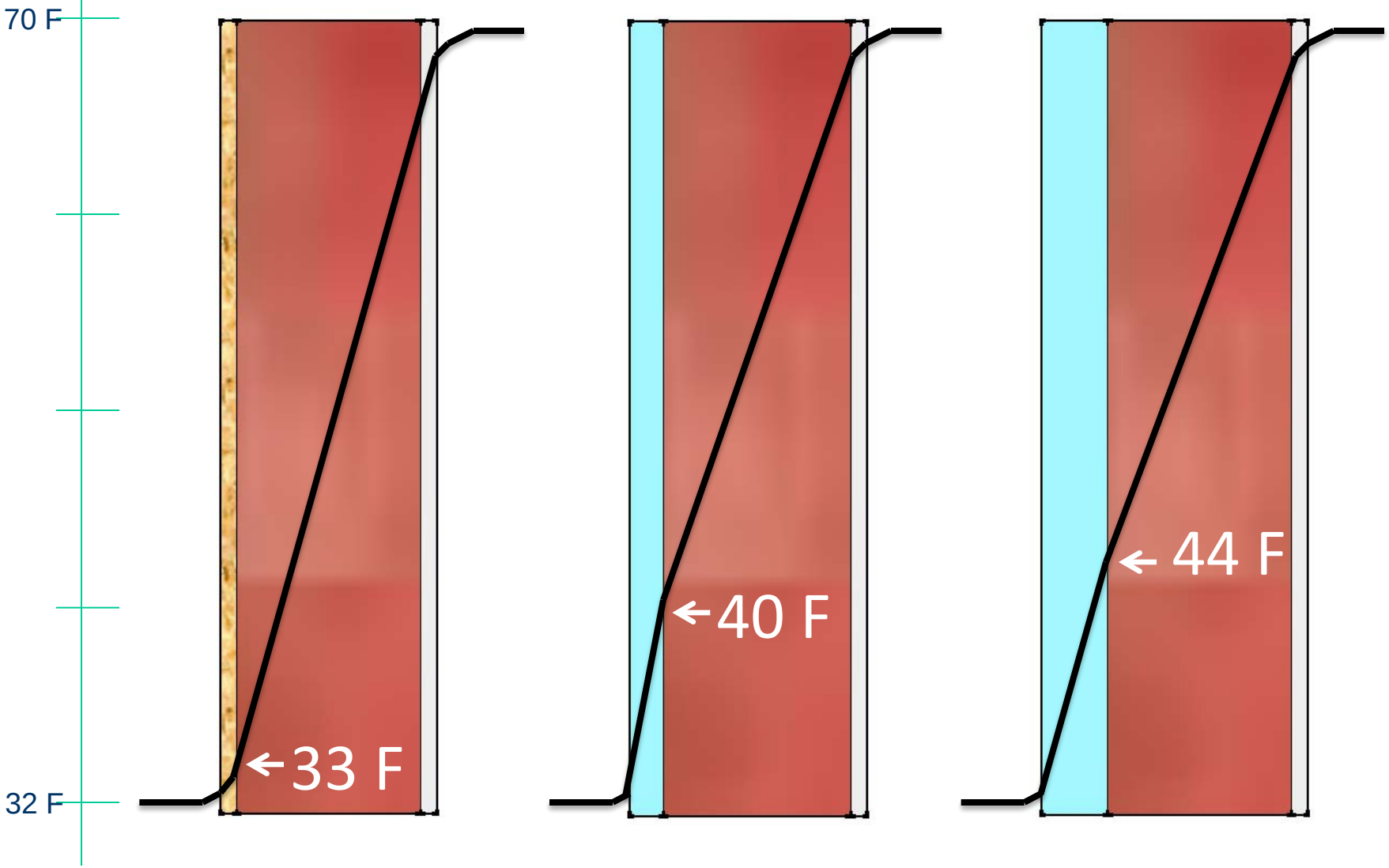
Wall Drying Potential – Mixed-Humid Climate



No Vapor Retarder Layer in Wall

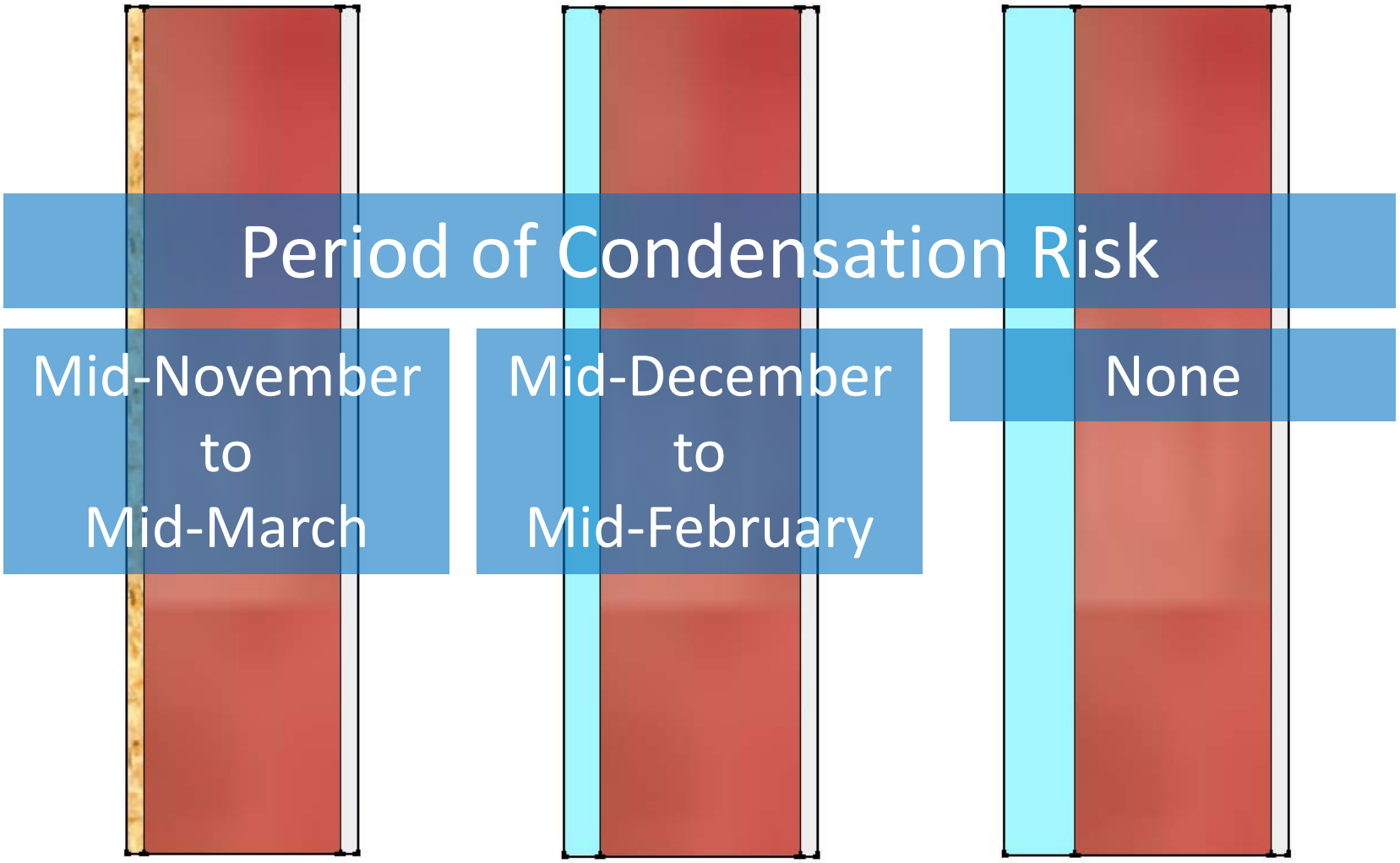
Drying to both the Exterior and Interior

Exterior Insulated Sheathing & Condensation Resistance



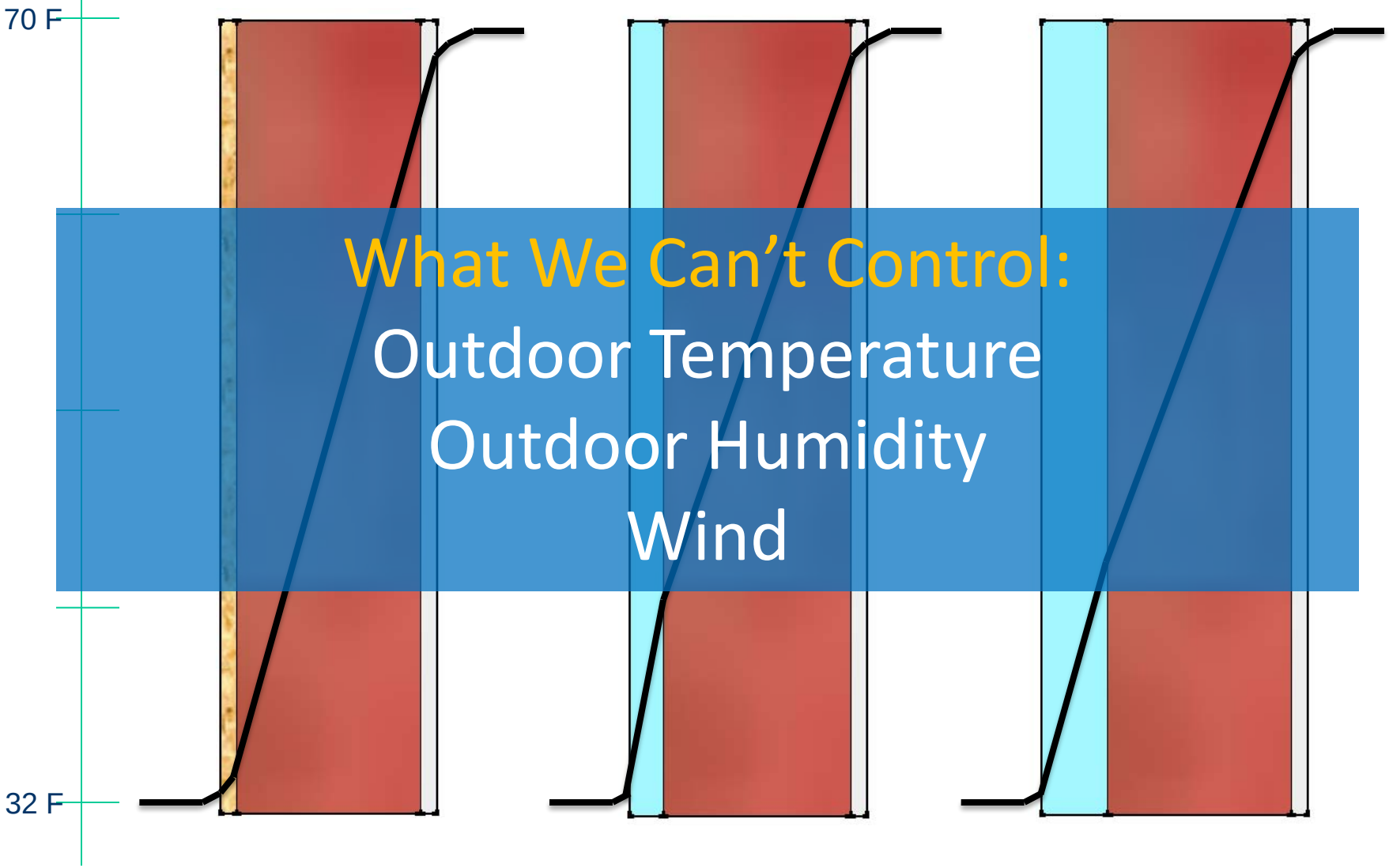
Condensation Risk on Back of Exterior Sheathing

Interior: 70 F and 35% Humidity



Chicago example by Building Science Corporation (buildingscience.com)

House as a System – Other Factors



House as a System – Other Factors

What we can control:

Indoor Temperature (sort of)

Indoor Humidity (sort of)

Thermal Resistance of Components

Permeability of Components

Exterior Sheathing Material Properties

	R-Value/Inch	Density (pcf)	Permeability (Perms)	Compressive Strength (PSI)
Expanded Polystyrene (EPS)	**3.9**	**1.0**	**5.0**	**10**
Extruded Polystyrene (XPS)	**5.0**	**1.3**	**1.1**	**15**
Polyisocyanurate (ISO)				
Foil Faced	**6.5**	**2.0**	**0.03**	**25**
Glass Fiber Faced	**6.5**	**2.0**	**<1.0**	**25**
ISO Structural Insulated Sheathing (SIS)				
DOW Styrofoam SIS	**5.5**	**2.0**	**0.03***	**20**
Zip R-Sheathing	**3.6**	**2.0**	**1.5****	**20**

Notes:
1. R-Values are given at 75 F.
2. Typical values shown. Specific products may vary.
* - Rating shown is for facer material, the product also includes ISO and fiber board.
** - Product includes facer (12-16 perms), ISO, and OSB (2-3 perms).

Common Brand Names		
EPS	**XPS**	**ISO**
Insulfoam	**Blue Board**	**Thermax**
R-Tech	**Formular**	**Tuff-R**
Benchmark	**Green Guard**	**Rmax**

Cathedral Ceiling Exception

R402.2.2

Ceilings without Attic Spaces Section

R-30 allowed, if insufficient space, for up to 500 ft^2 (or 20% of total insulated ceiling area, whichever is less) where Insulation levels are required greater than R-30

Note: This reduction ONLY applies to the R-value prescriptive path, not the U-factor or Total UA alternatives

Basement Wall R-Value

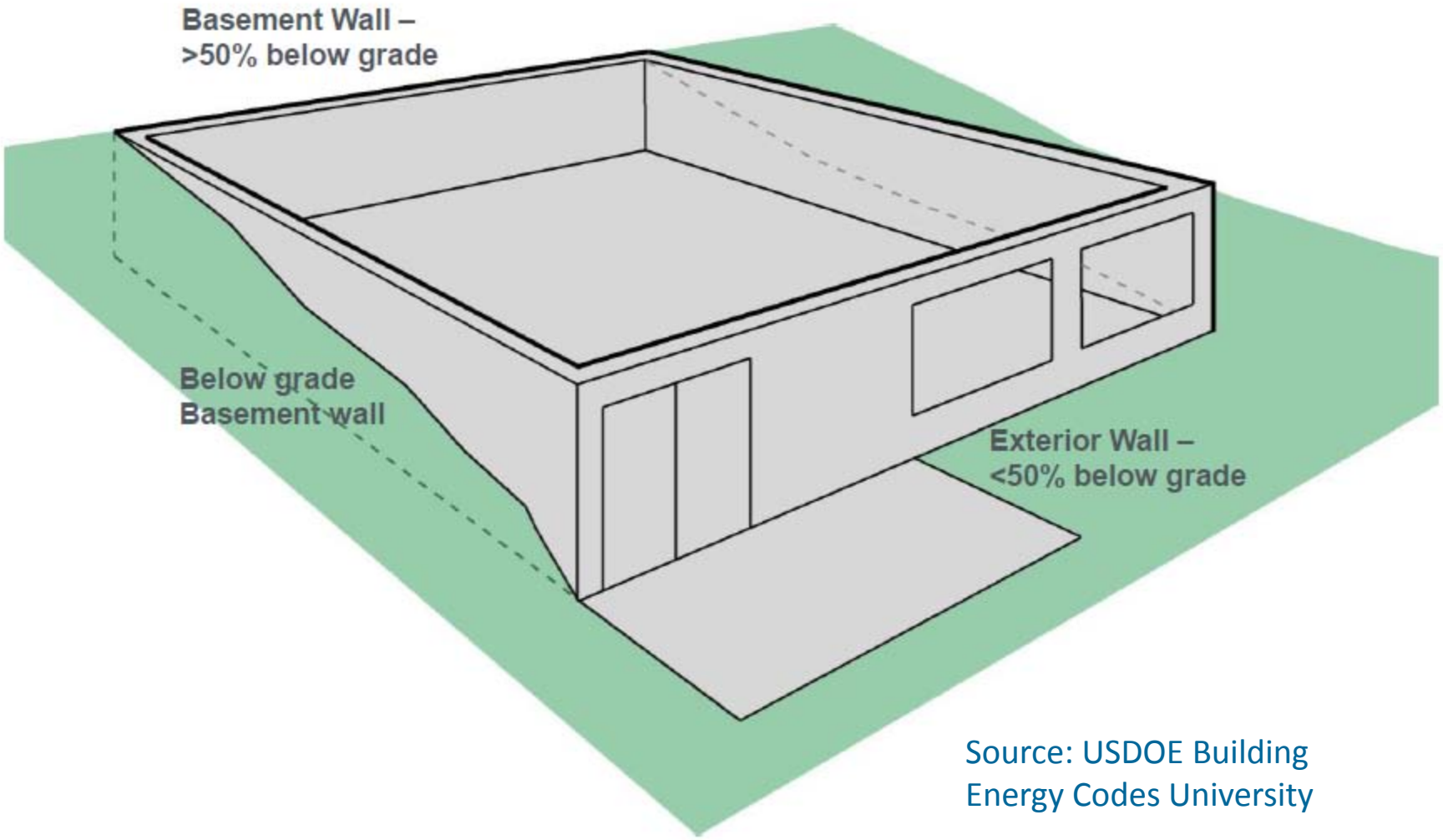
R402.1.1

TABLE R402.1.1

INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.4	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	######
4 except Marine	0.35	0.55	0.4	49	20 or 13+5[h]	8/13	19	13-Oct	10, 2 ft	13-Oct
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.33 0.32	0.60 0.55	NR	49	21 or 13+5[h]	15/20	30[g]	15/19	10, 4 ft	10/19 15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

What Is a Basement Wall?



Source: USDOE Building Energy Codes University

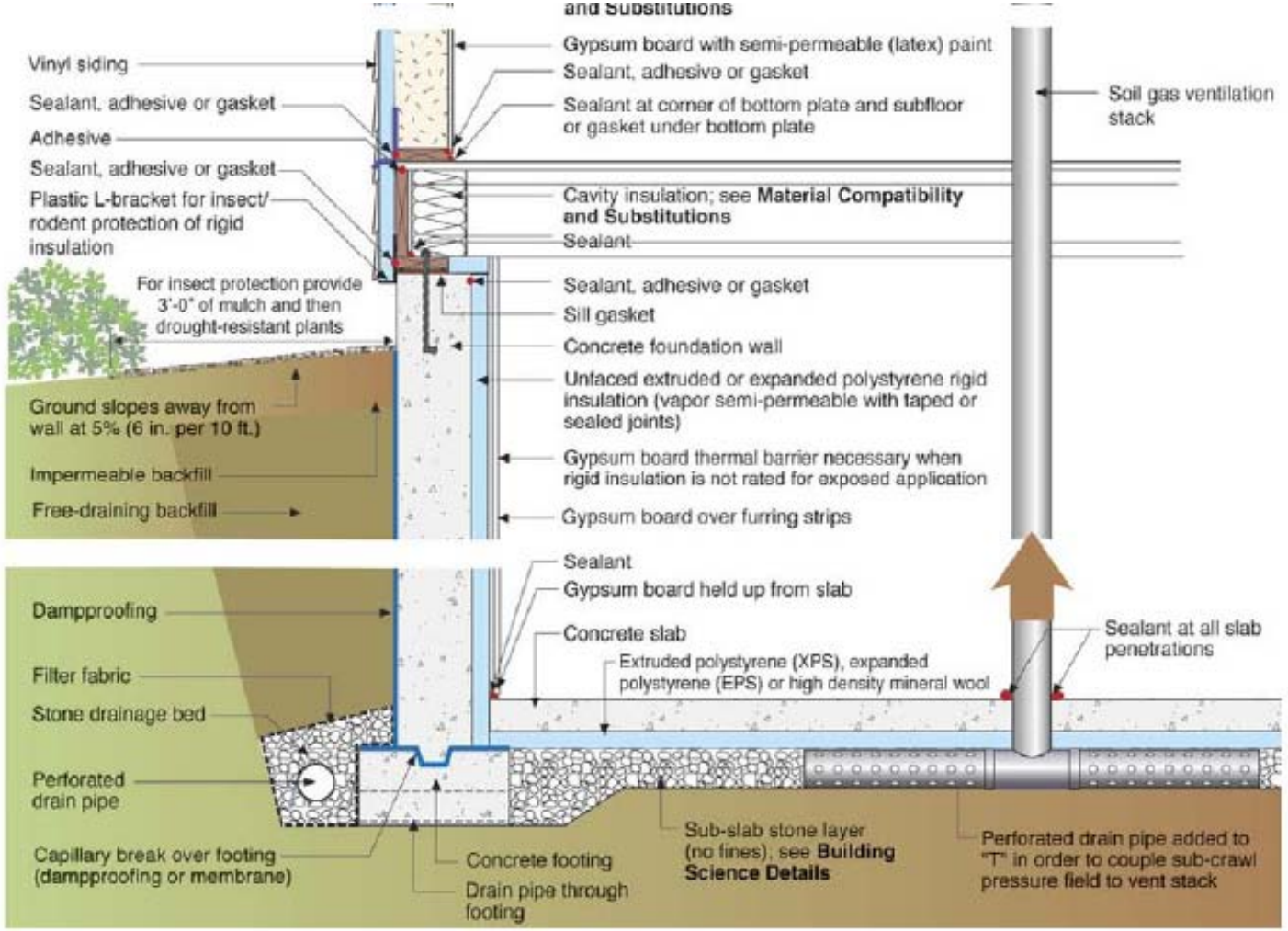
Unfinished Basement Insulation Options

Source: Ecocell by Cellulose Material Solutions, LLC

Source: Paul Tschida, MTDEQ

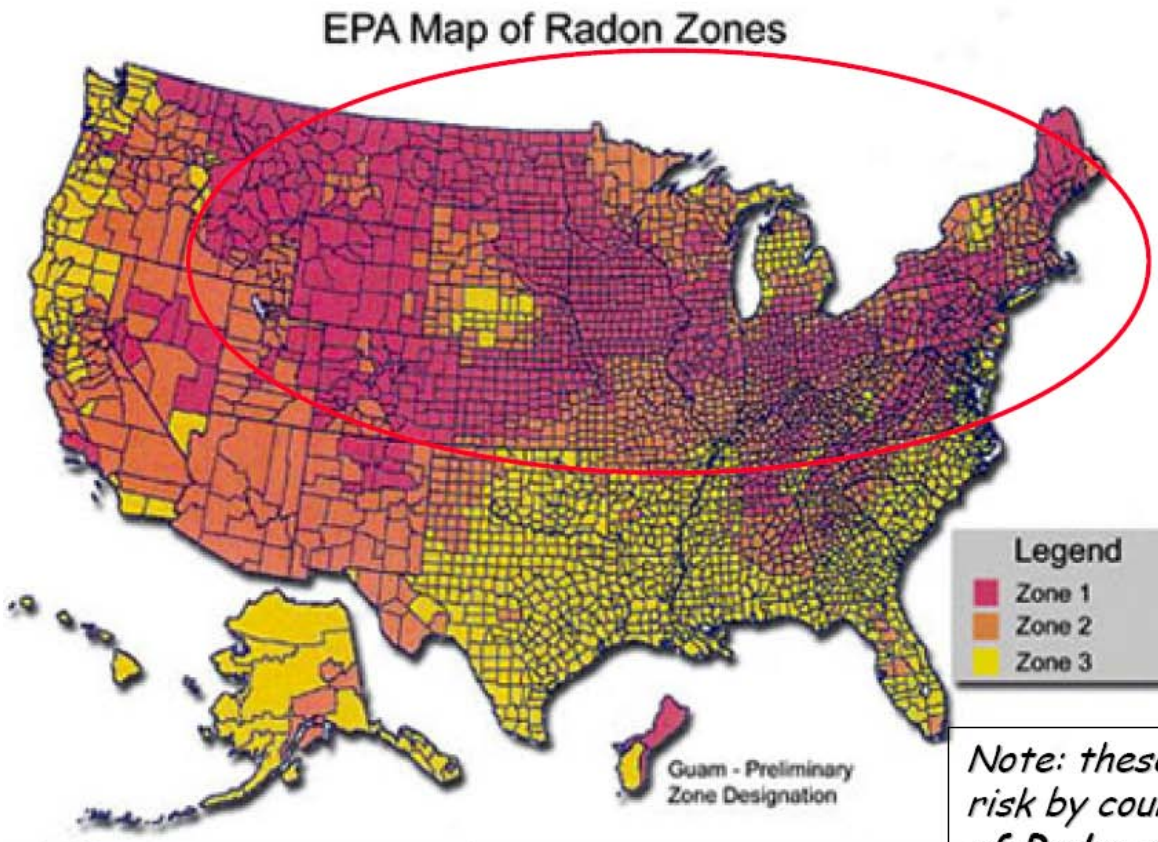
Source: U.S. Department of Energy
Building Energy Codes Program

Basement Foundations



Source: USDOE Building Technologies Program, Introduction to Building Systems Performance: Houses That Work II

Radon Mitigation



Radon Risk is High in much of the U.S. Check State & local authorities for more detailed information on Radon risk in your area.

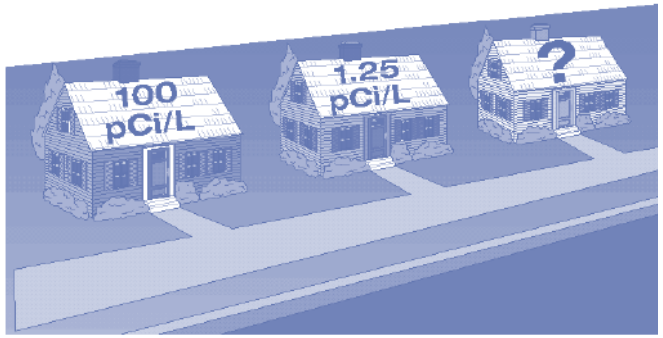
*Note: these maps indicate average risk by county. However, **High levels of Radon can be found anywhere, and soil gases may be toxic!***

EPA recommends that all homes built in Zone 1 have radon reduction systems.

Radon Mitigation

How Does Radon Enter A House?

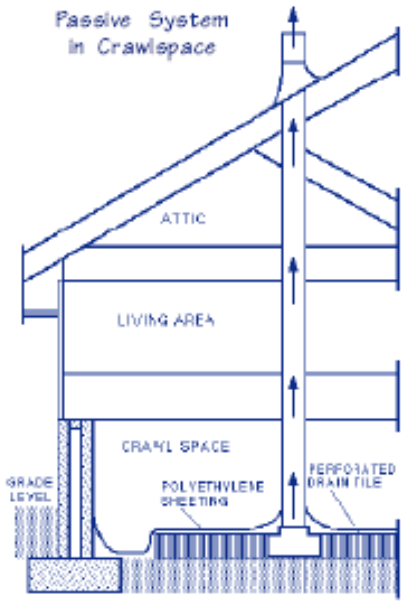
Common Radon Entry Points

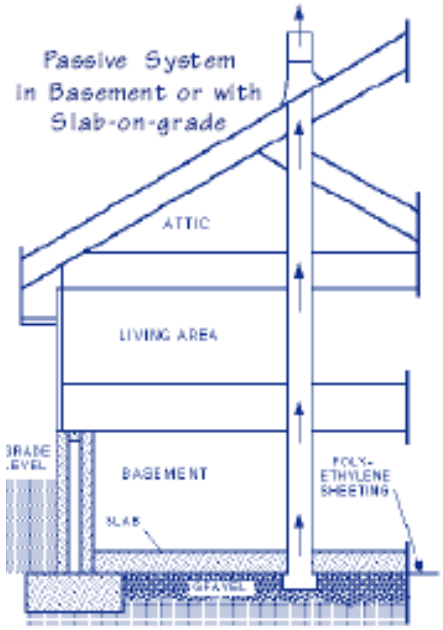


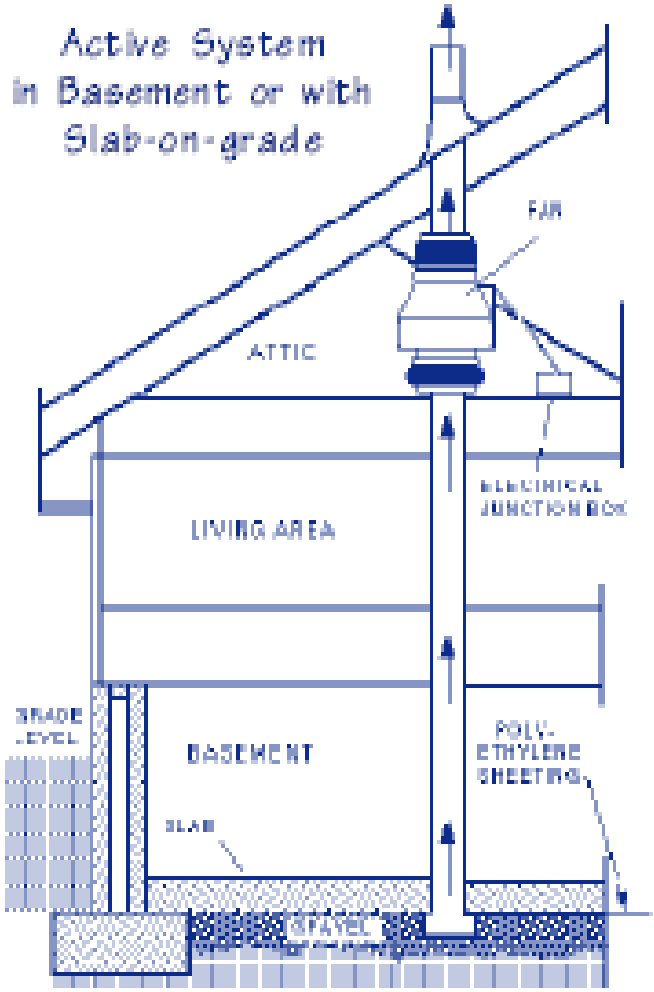
Radon enters a home through cracks in concrete, joints in construction below grade, and through poorly sealed crawl space construction.

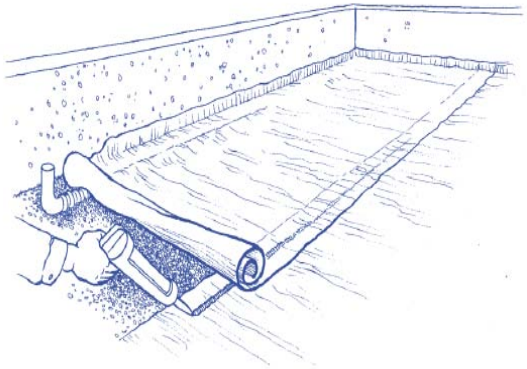
Source: USEPA Building Radon Out

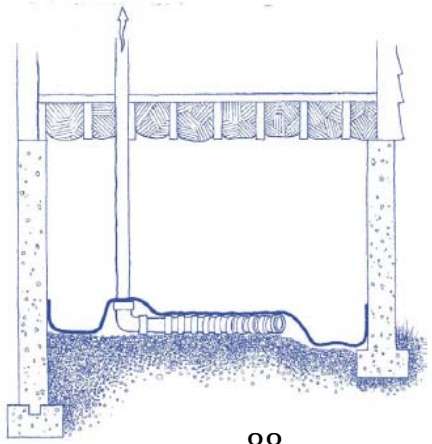
Radon Mitigation











Source: Paul Tschida, MTDEQ

Slab R-Value

R402.1.1

TABLE R402.1.1

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Slab Insulation

R402.2.9

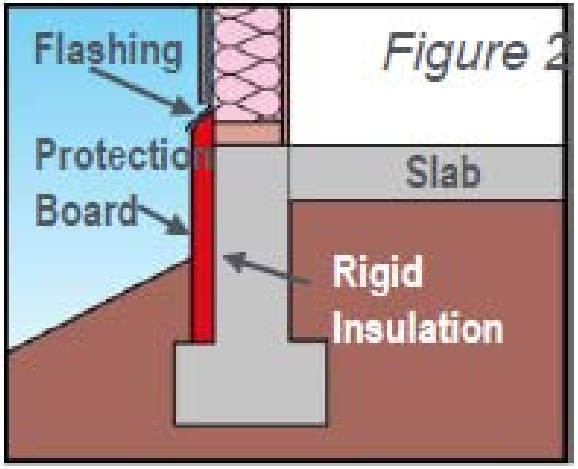


Figure 2

R-10 for 4’ Vertical or Horizontal
Add R-5 if the slab has radiant heat

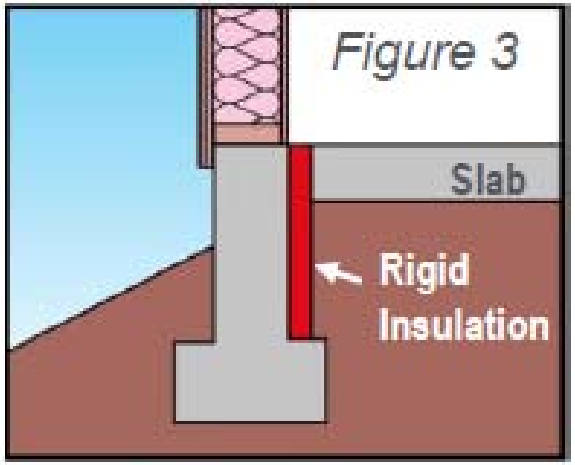


Figure 3

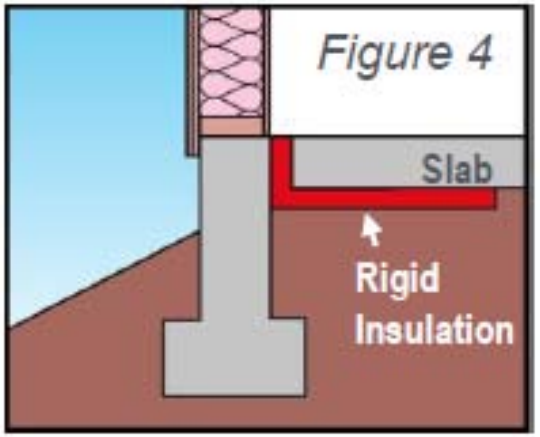
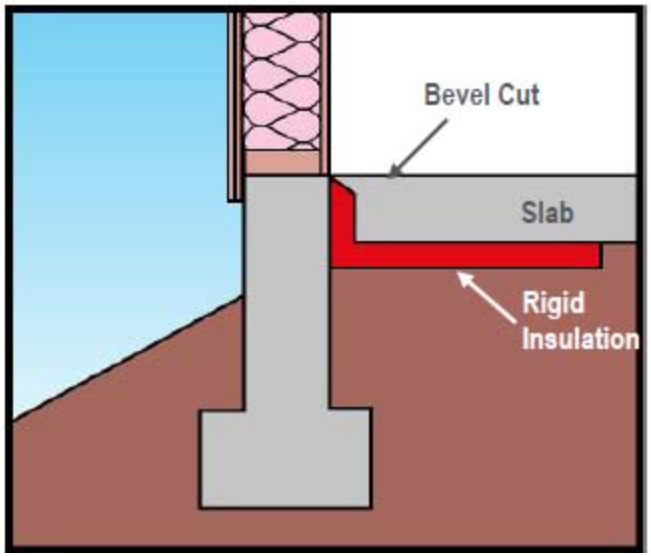


Figure 4

Source: USDOE Building Energy Codes University

Slab Insulation

R402.2.9



Source: USDOE Building Energy Codes University

Crawl Space Wall

R402.1.1

TABLE R402.1.1

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3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	######
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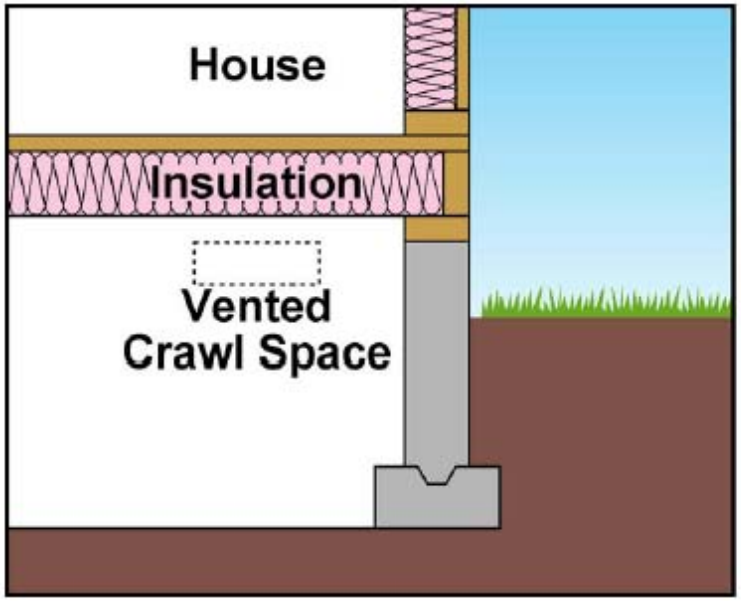
Crawlspace Wall

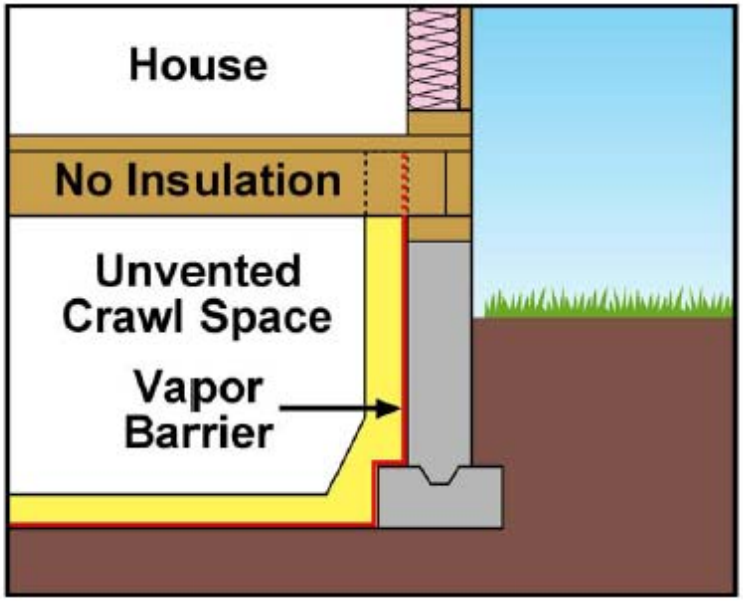
R402.1.1

From R10 / R19 R-Value to R15 / R19

(Continuous / Cavity)

- Must choose to insulate either floor or walls
- Either mechanically vented or minimally conditioned (*IRC)*
- Continuous Class I vapor retarder at exposed earth





Unvented Crawlspaces

IRC R408.3

Class I Vapor Retarder at Exposed Earth

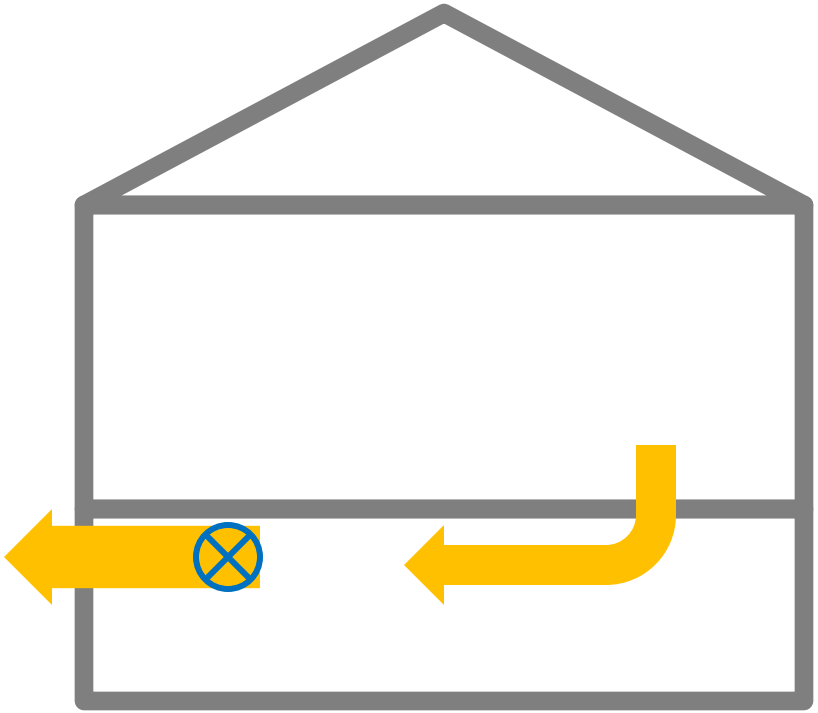
- 6” overlap sealed or taped
- Extend 6” up stem wall attached and sealed

Unvented Crawlspaces – Two Design Options

IRC R408.3

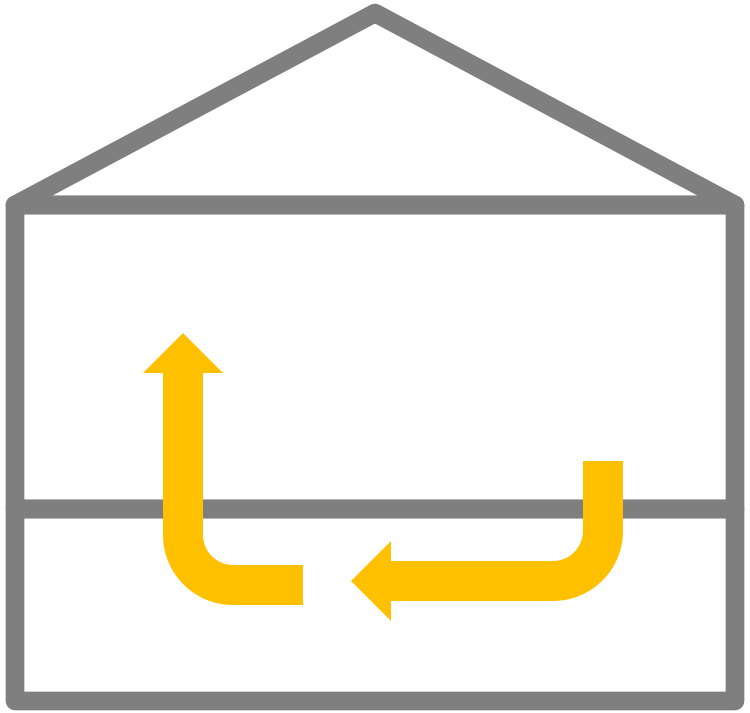
Continuous **Exhaust** to Exterior

- 1 CFM/50 SF Crawlspace Area
- Air Pathway to Common Area



Conditioned Air Supply

- 1 CFM/50 SF Crawlspace Area
- Air Pathway to Common Area



Foam Plastics

Surface Burning Characteristics

Flame Spread Index <= 75

Smoke Developed Index <= 450

Thermal Barrier

Shall be separated from interior of building by 1/2“ gypsum board or equivalent thermal barrier

Crawlspace and attic thermal barriers are not required under certain conditions. (IRC R316.5.3 and R316.5.4)

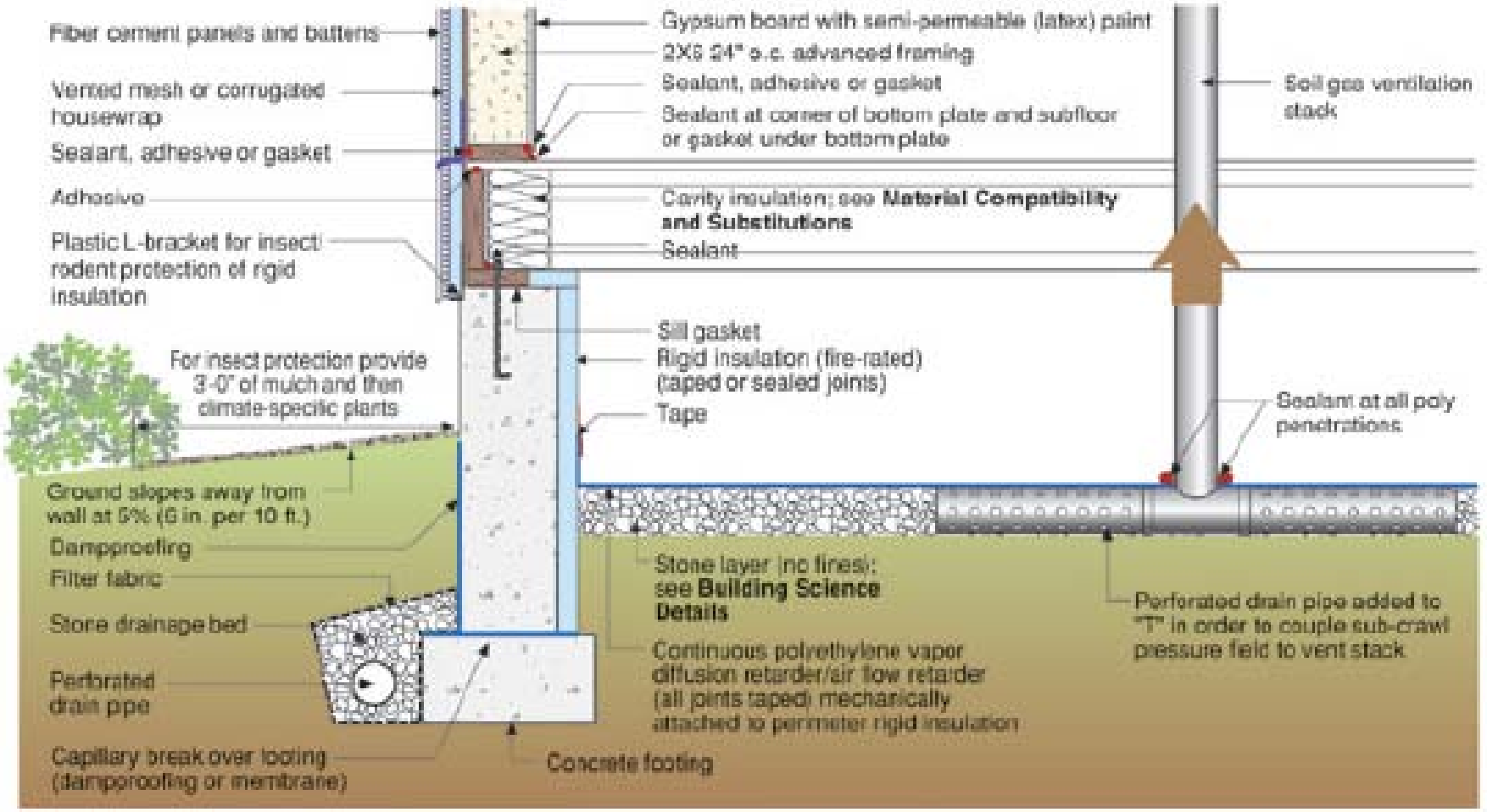
Foam Plastics at Sill Plates & Headers

IRC R316.5.11

Thermal Barrier may be omitted at sill plates and headers if:

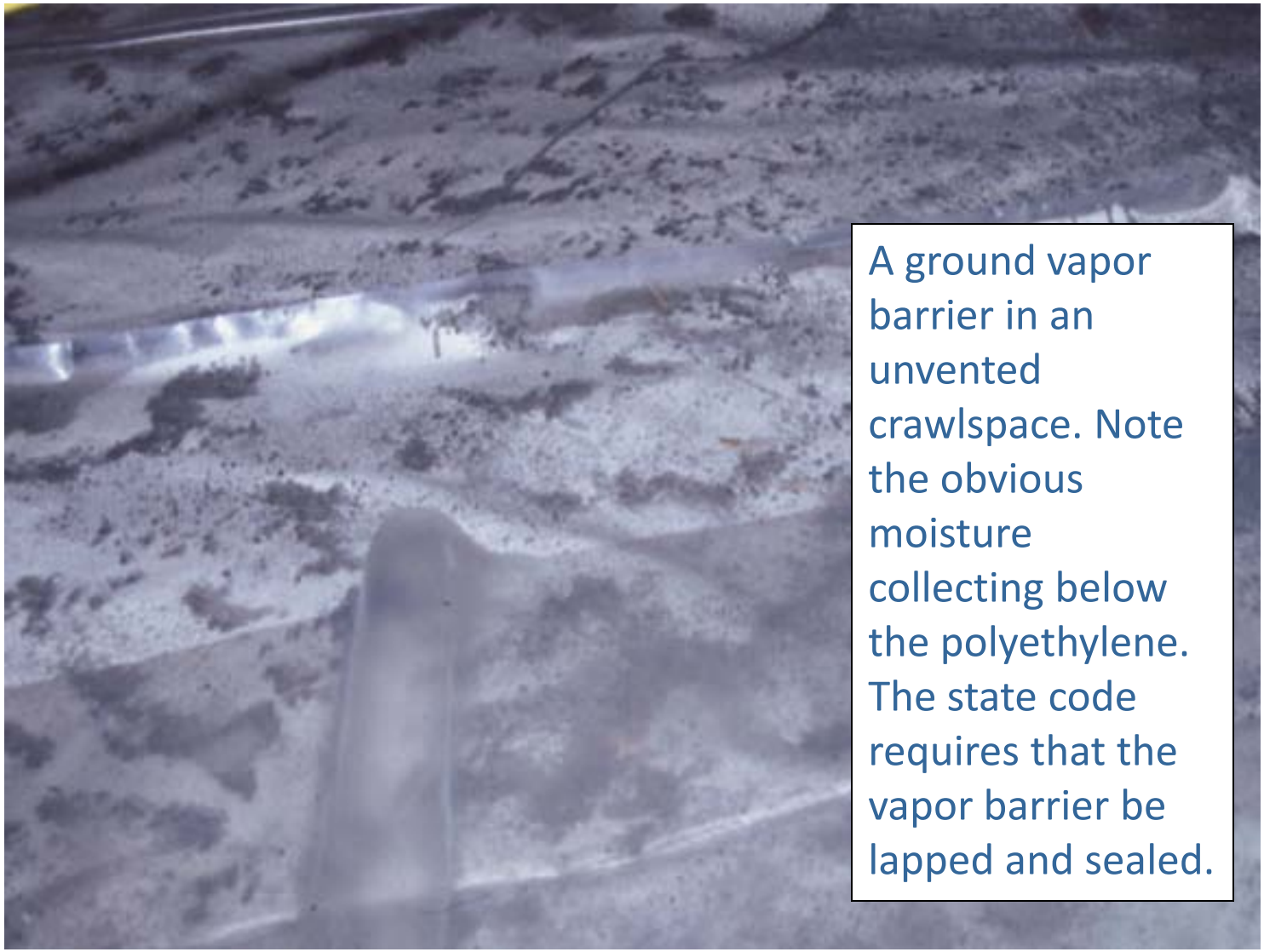
- Maximum thickness 3 ½”
- Foam density 0.5 to 2.0 lbs/CF
- Flame spread <=25 & smoke developed index <=450

Crawlspace Foundations



Source: USDOE Building Technologies Program, Introduction to Building Systems Performance: Houses That Work II

The Importance of a Continuous Vapor Barrier

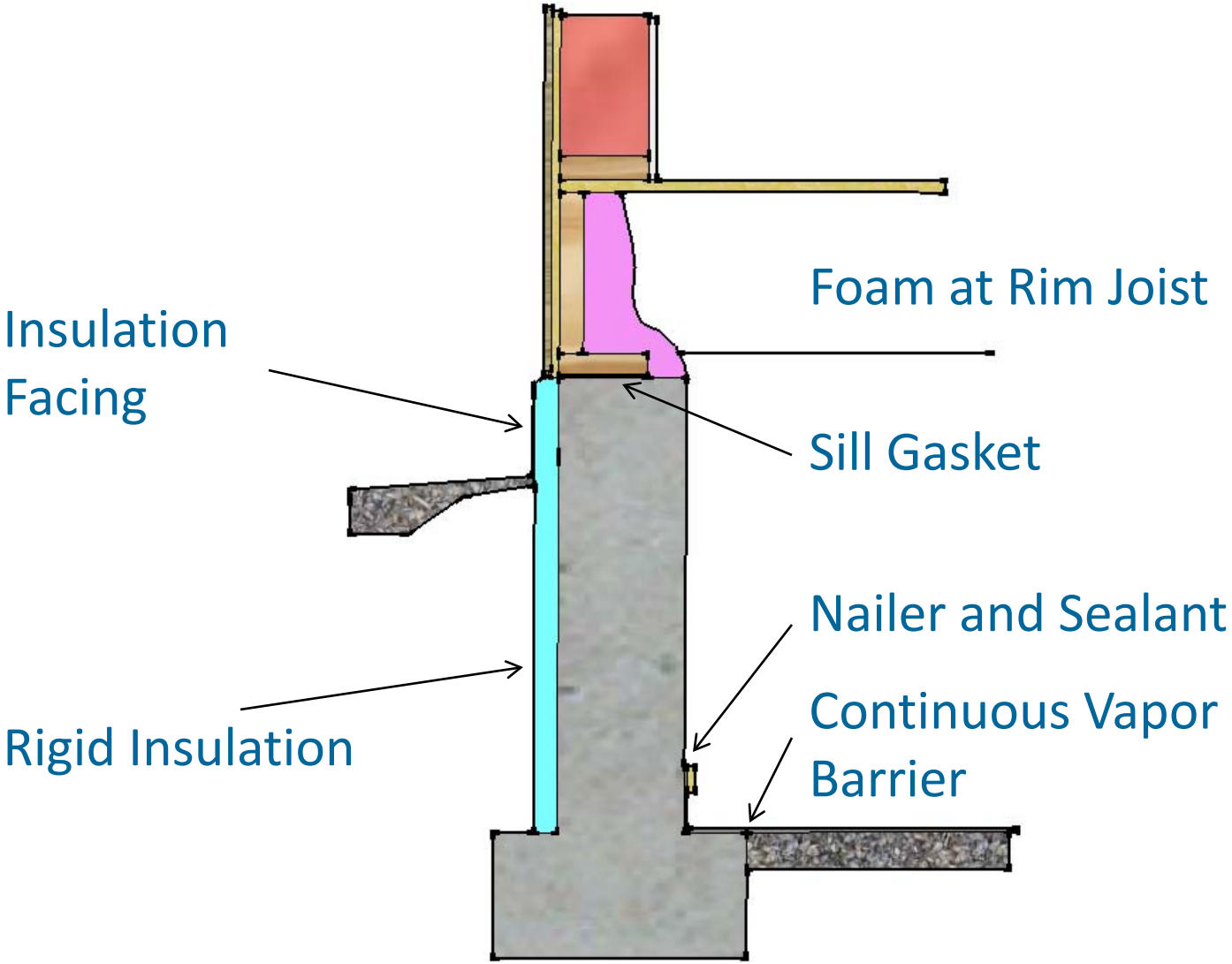


A ground vapor barrier in an unvented crawlspace. Note the obvious moisture collecting below the polyethylene. The state code requires that the vapor barrier be lapped and sealed.

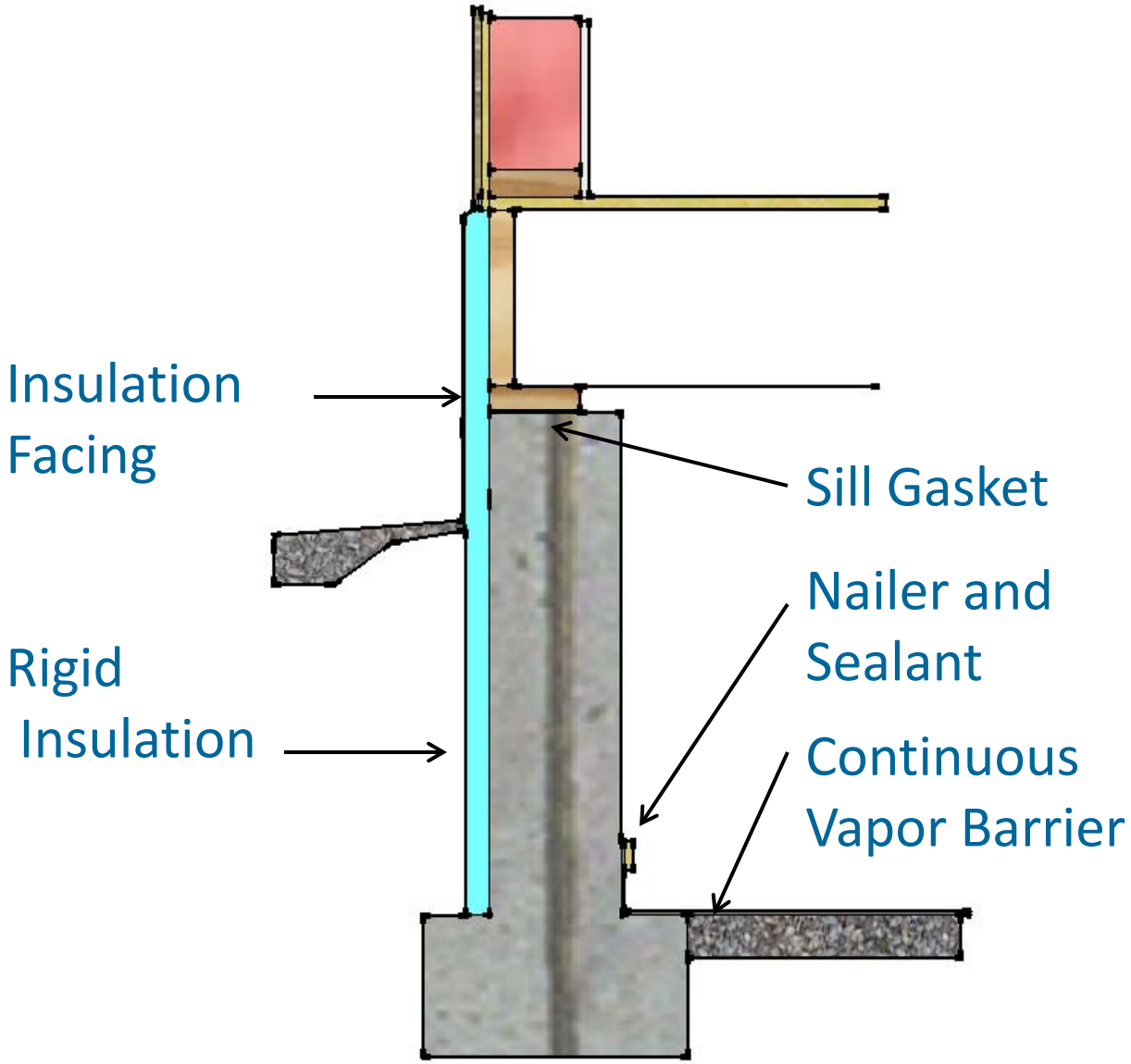
The Importance of a Continuous Vapor Barrier

Here is an example of a much better unvented crawlspace. The builder used an insulated concrete foundation (ICF) and 10 mill sealed polyethylene for ground vapor barrier. Some code officials require fire protection such as gypsum board for the exposed foam of the ICF.

Exterior Crawlspace Insulation

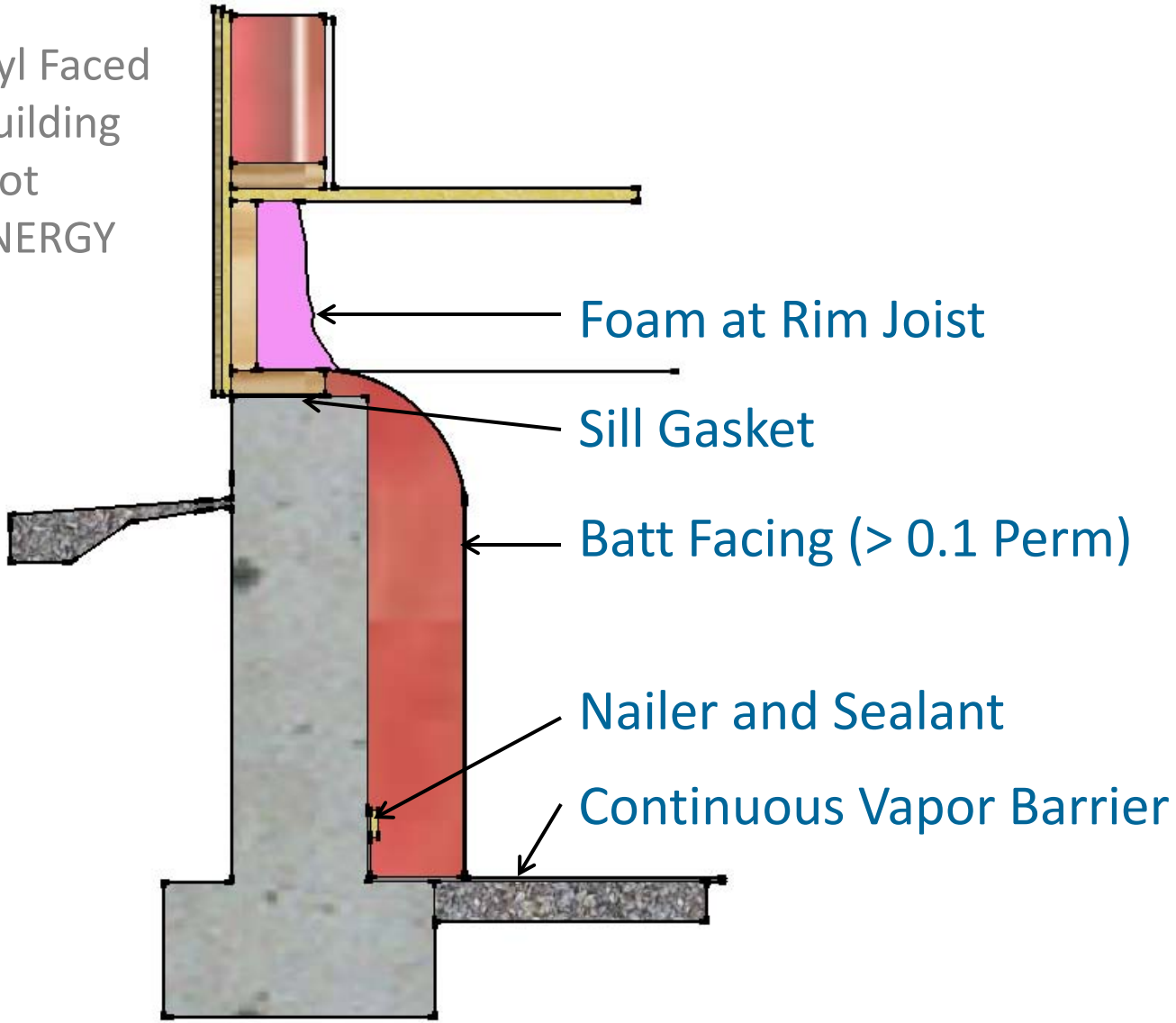


Exterior Crawlspace Insulation

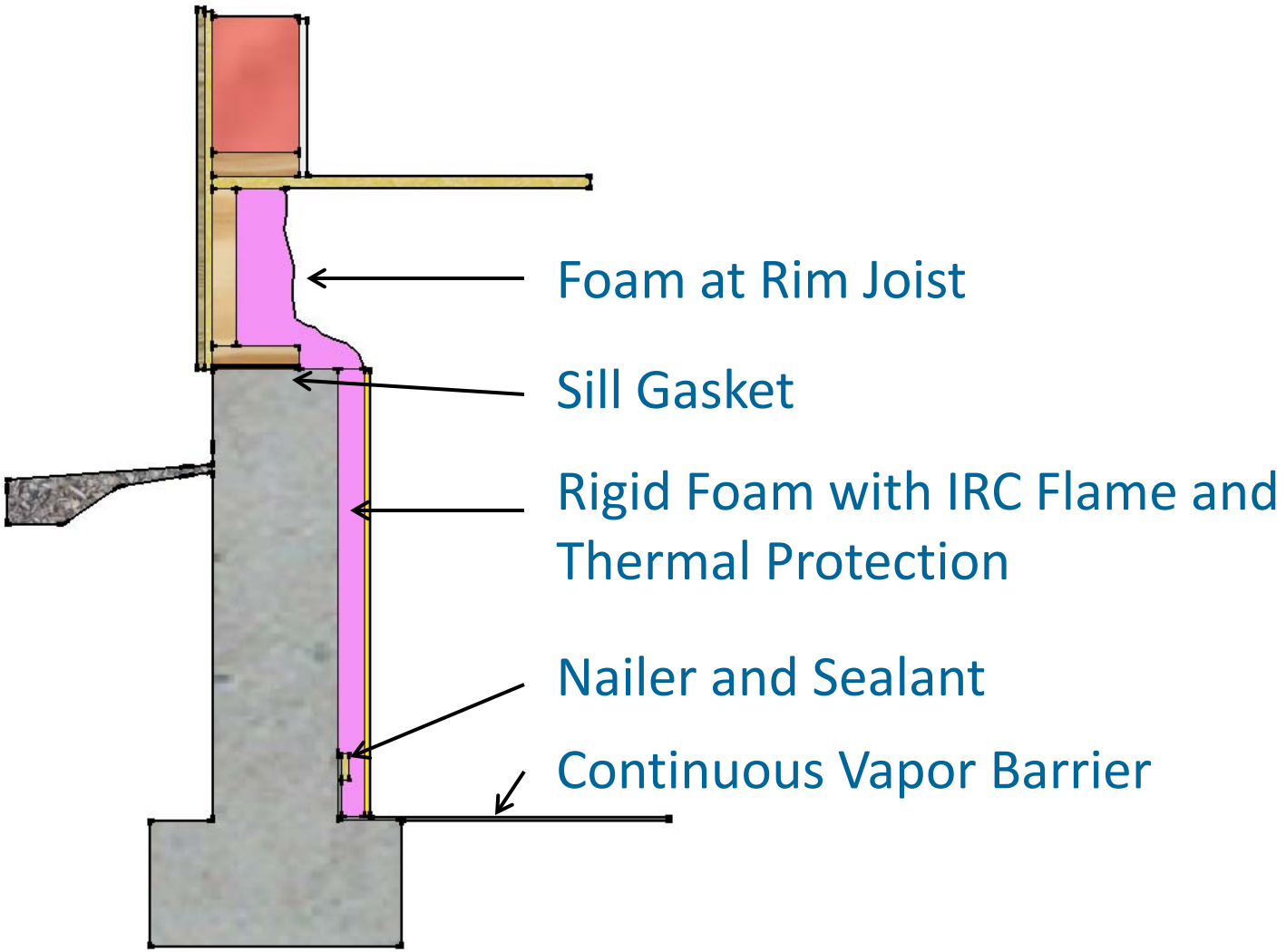


Interior Crawlspace Batt Insulation

Traditional Vinyl Faced Batts (Metal Building Insulation) is not accepted by ENERGY STAR.



Interior Crawlspace Rigid Board Insulation

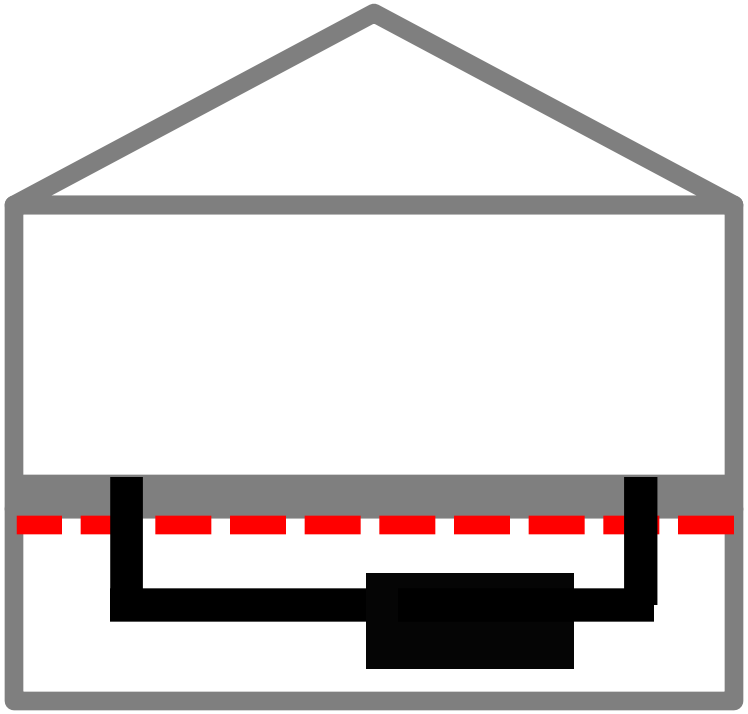


Fire Protection for Floors

R501.3

Floor assemblies shall be provided with a ½ gypsum board membrane.

Exception 2: Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.



Air Leakage (Mandatory)

R402.4

Thermal envelope must comply with both:

Testing (402.4.1.2)

+

Table R402.4.1
Air Barrier and Insulation **Installation**

COMPONENT	CRITERIA*
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
Windows, skylights and doors	The space between windows/door jambs and framing and skylights and framing shall be sealed.
Rim joists	Rim joists shall be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the sub-floor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

"Where required by the code official, testing shall be conducted by an *approved* ~~third~~ party."

Typical House Tightness Levels

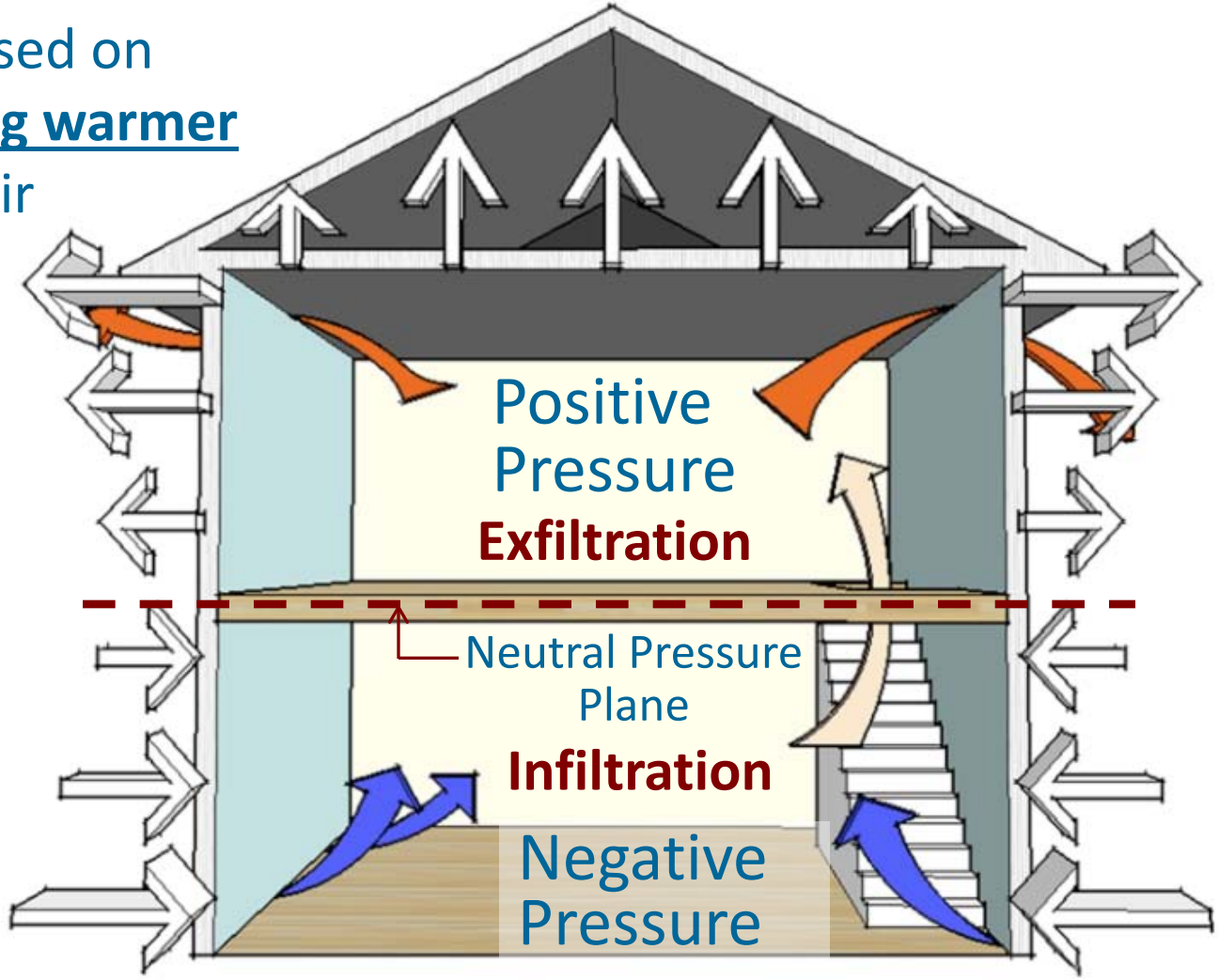
	ACH50	CFM 2000 SF
Older Homes	10+	>2600
Typical New Home ~2000	7	1800
2009 IECC Tightness Limit Zone 6	7	1800
Montana State Energy Code	4	1050
Proposed MT State Energy Code	4	1050
Energy Star Homes	4	1050
Idaho New Homes 2013	3.6	930
2012 IECC Tightness Limit Zone 6	3	800

Example based on 2,000 Ft^2 house with n = 14.5.

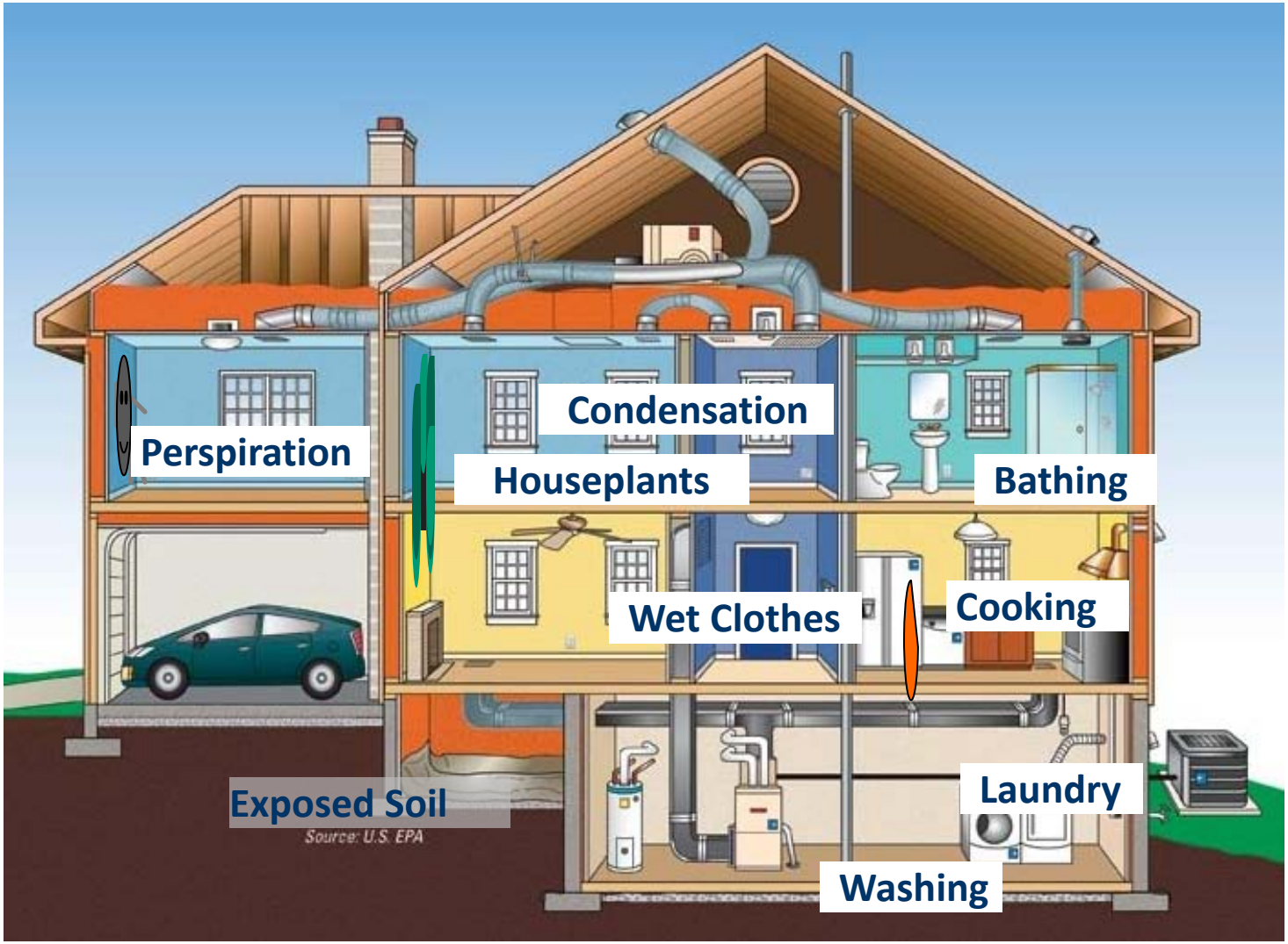
Stack Effect

Diagram is based on **inside air being warmer** than outside air

When **outside air is warmer** than inside air, this process is reversed.



Sources of Household Water Vapor



How Much Water?

Daily water vapor produced by family of 4:

• Respiration and perspiration	14 lb
• Showers & bathing	3 lb
• Cooking	2 lb
• Other activities	2 lb
Total	**21 lb = 2.5 gal**

US. Forest Products Lab estimated 12 gallons per day in a high ground water area

Options for Controlling Mold

- Eliminate mold spores (can't do it!)
- Freeze or burn them (and drive us out too!)
- Control nutrient sources - Elimination is difficult
- **Control moisture - Best strategy**

Source: Paul Tschida, MT DEQ

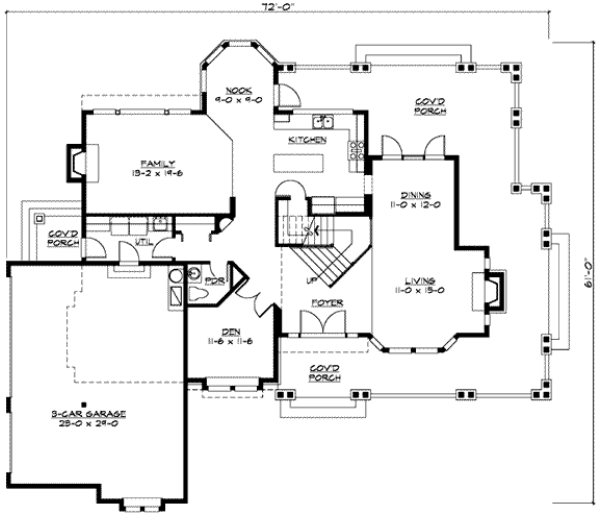
Vapor Retarder Recommendations

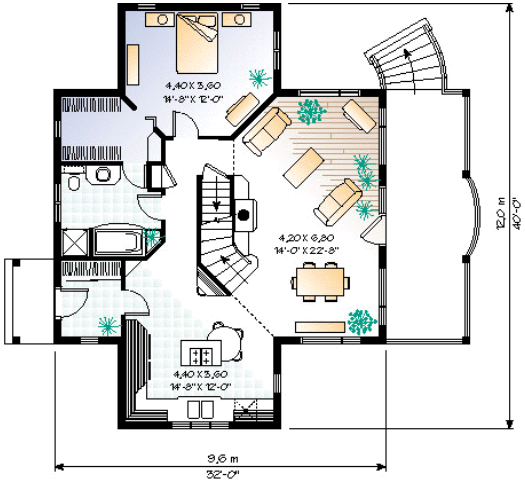
1. Allow building assemblies to dry to either the exterior or the interior or both.
2. Avoid use of a less permeable vapor retarder where a more permeable retarder will provide satisfactory performance, to encourage drying.
3. Avoid installing vapor barriers on both sides of assemblies, i.e., double vapor barriers, to facilitate assembly drying in at least one direction.
4. Avoid installing Class I vapor barriers (polyethylene sheet, foil-faced batt) on the interior of air conditioned assemblies.
5. Avoid vinyl wall coverings on the inside of air conditioned assemblies.
6. Ventilate to ASHRAE 62.2.

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates, from *Lstiburek 2006c*

“Build it tight and ventilate it right”

A tight house starts with a basic and simply floor and roof plan. This makes detailing the continuous air and thermal barrier much easier.





Air Barrier and Insulation Installation

Table R402.4.1.1

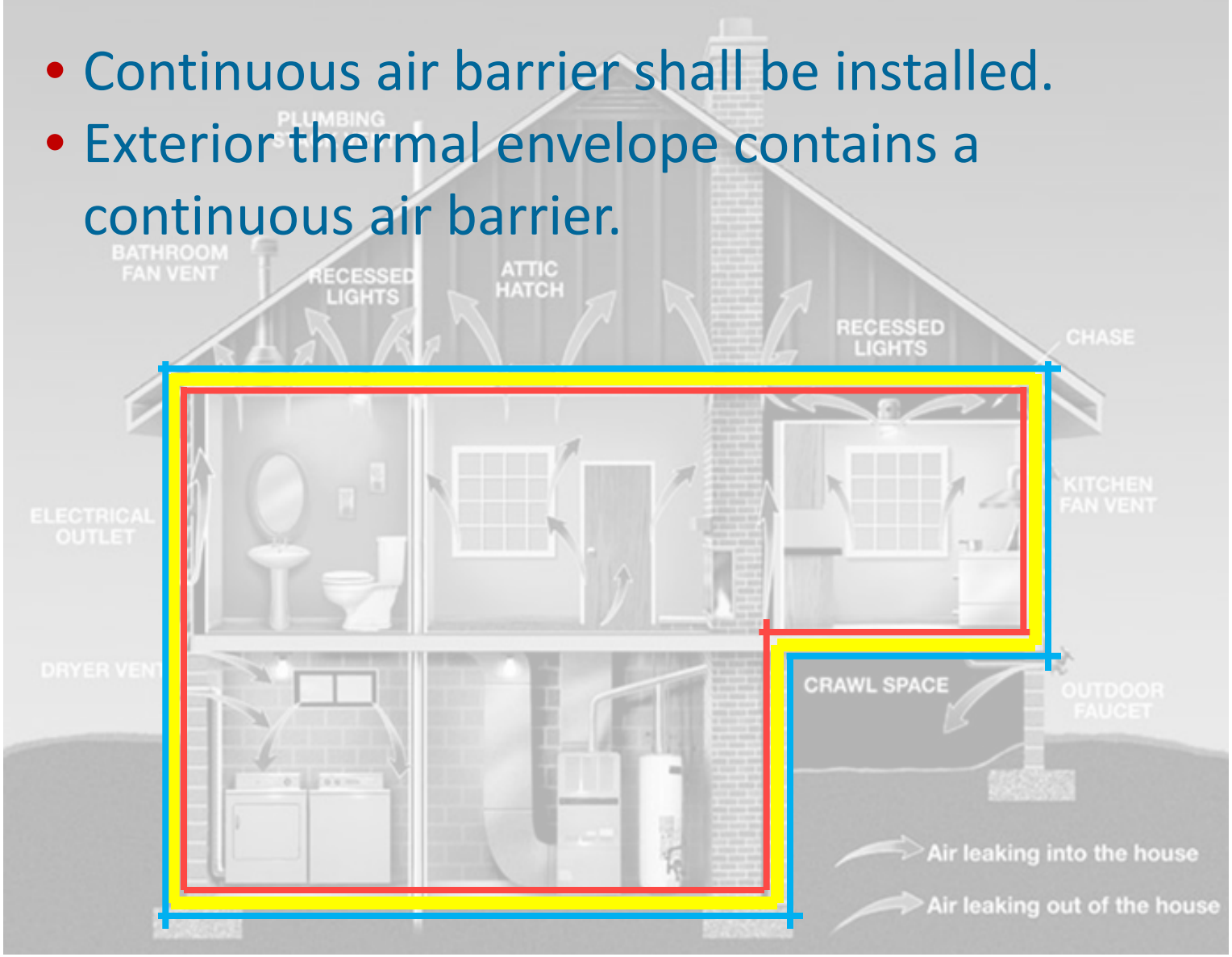
16 Installation Components

COMPONENT	CRITERIA*
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
Rim joists	Rim joists shall be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the sub-floor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

1. Air Barrier and Thermal Barrier

Table R402.4.1.1

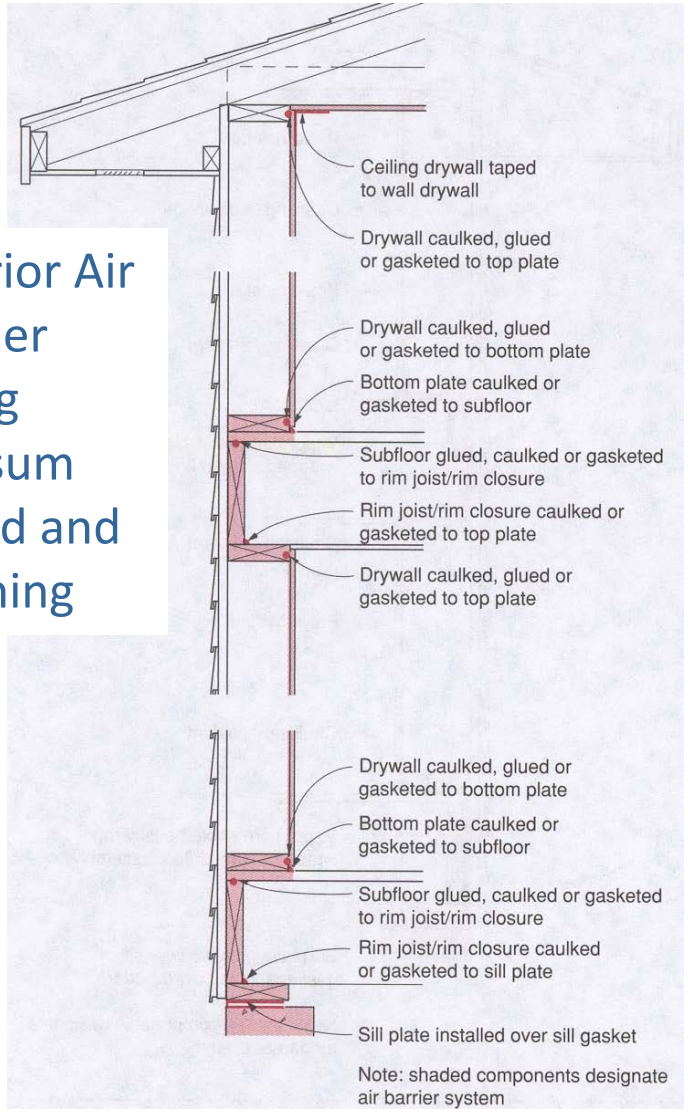
- Continuous air barrier shall be installed.
- Exterior thermal envelope contains a continuous air barrier.



1. Air Barrier and Thermal Barrier

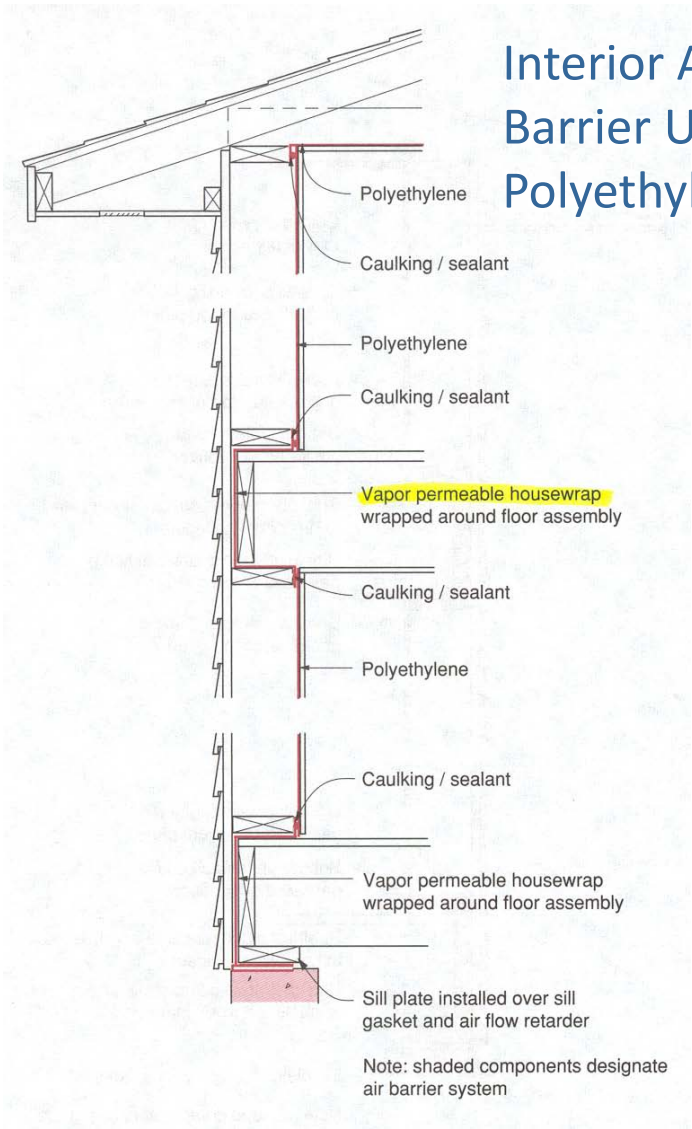
Table R402.4.1.1

Interior Air Barrier Using Gypsum Board and Framing



Source - Builder's Guide to CC

Interior Air Barrier Using Polyethylene



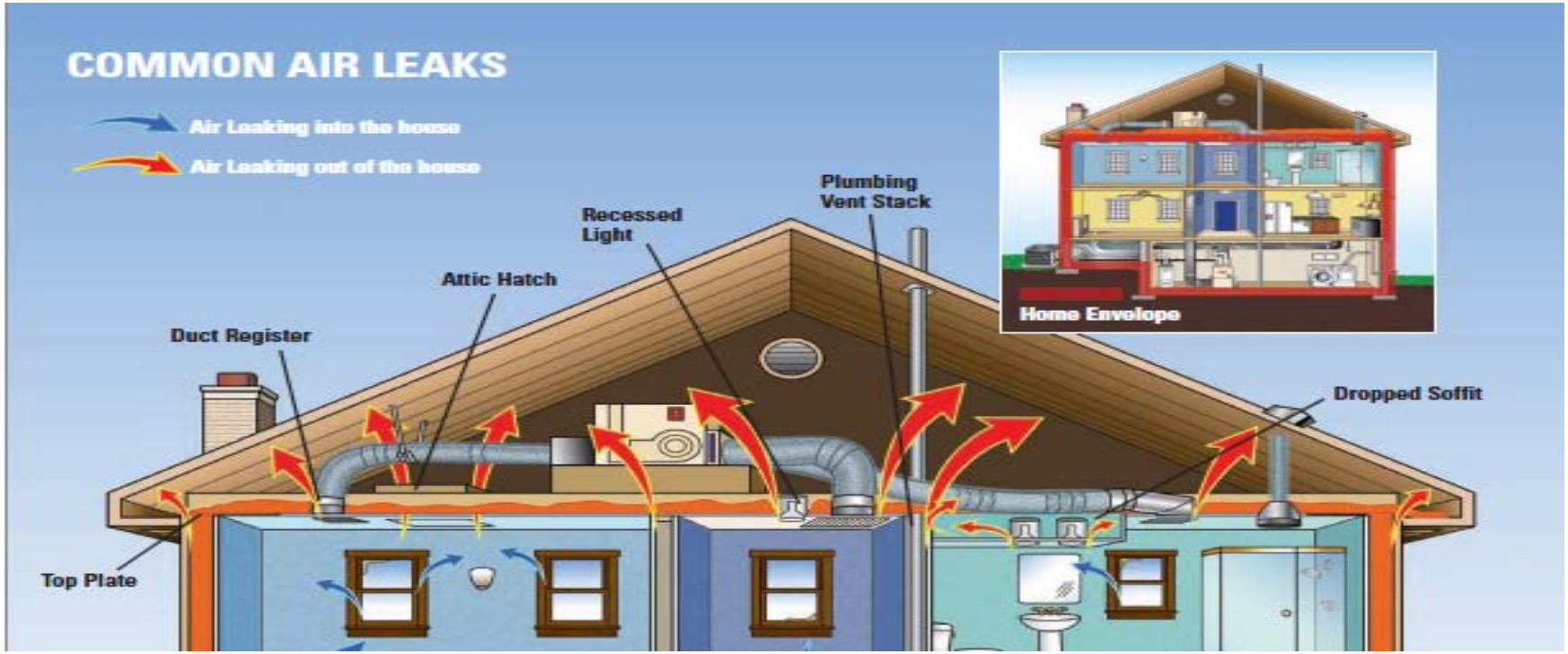
Source - Builder's Guide to CC

1. Air Barrier and Thermal Barrier

Table R402.4.1.1

2. Ceiling/attic

Table R402.4.1.1



2. Ceiling/attic

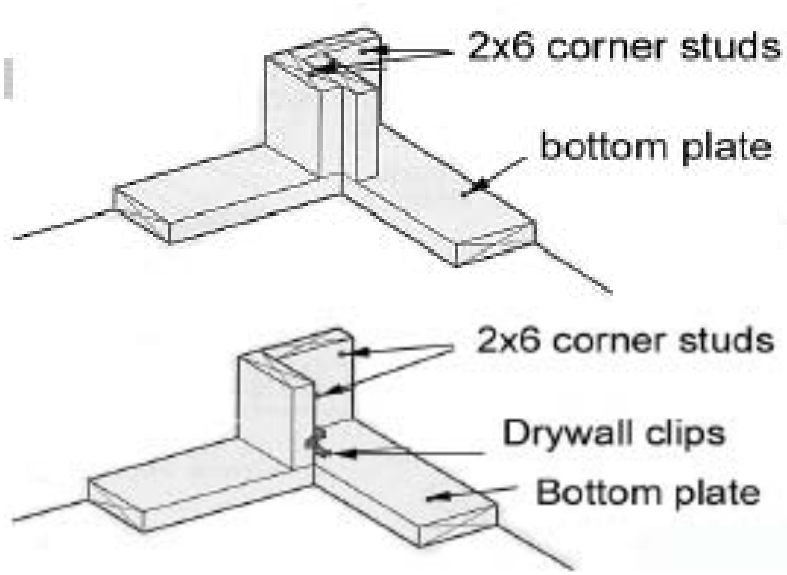
Table R402.4.1.1

Holes in the top plate for wiring are sealed with foam.

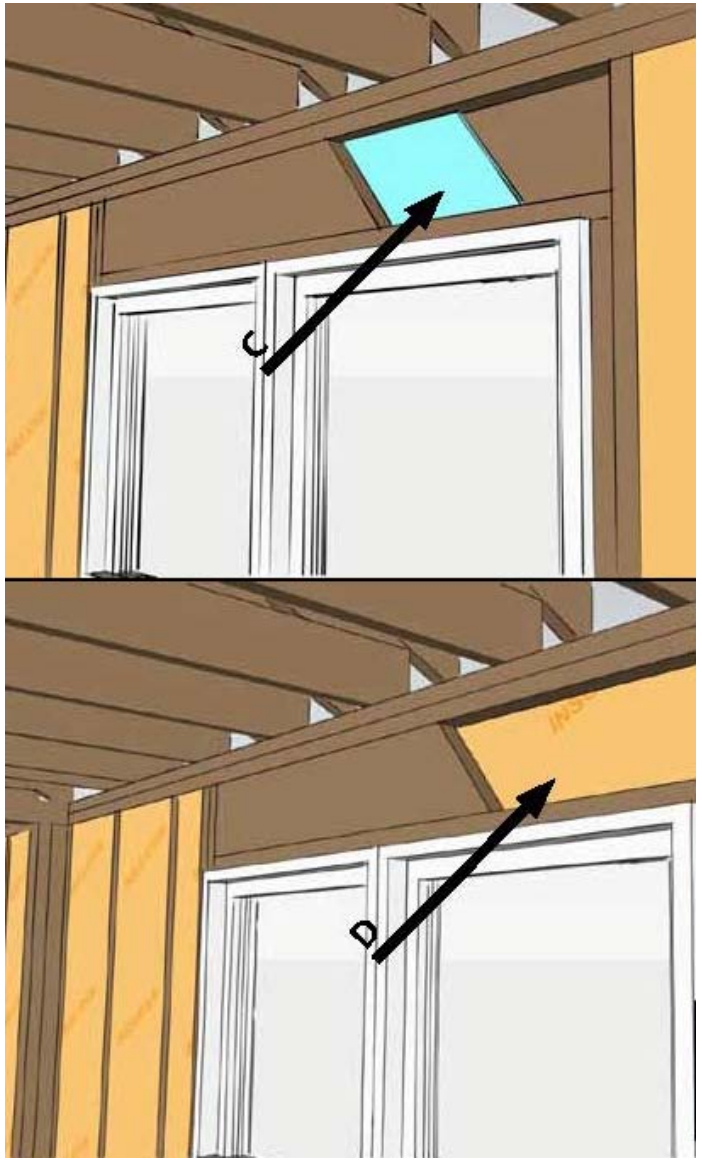
Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates

3. Walls

Table R402.4.1.1



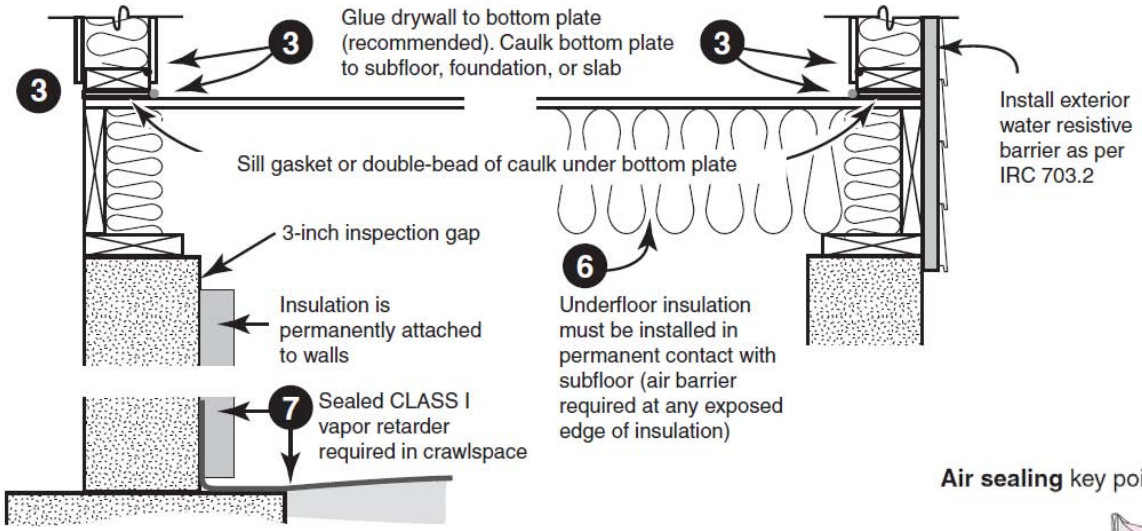
Source: ENERGY STAR New Homes

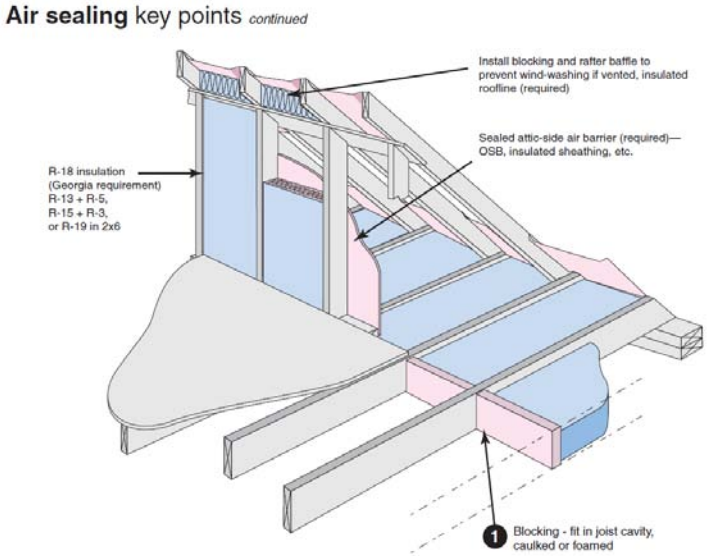


Source: ENERGY STAR New Homes

3. Walls

Table R402.4.1.1

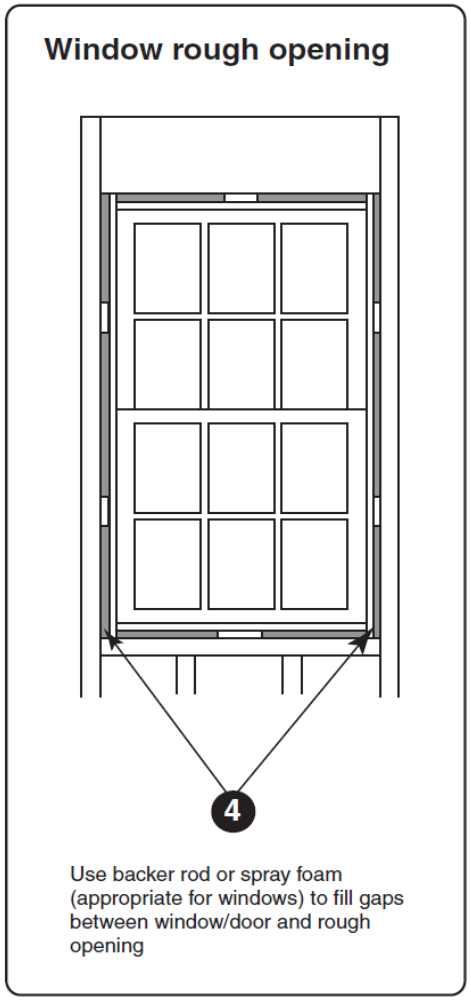




Appendix 2009 IECC

4. Windows, Skylights, and Doors

Table R402.4.1.1



Appendix 2009 IECC

Source: USDOE Building Energy Codes University

Source: ENERGY STAR New Homes

5. Rim Joists

Table R402.4.1.1

5. Rim Joists

Table R402.4.1.1

6. Floors

Table R402.4.1.1

7. Crawl Space Walls

Table R402.4.1.1

8. Shafts, Penetrations

Table R402.4.1.1

Source: USDOE Building Energy Codes University

9. Narrow Cavities

Table R402.4.1.1

10. Garage Separation

Table R402.4.1.1

Source: ENERGY STAR New Homes

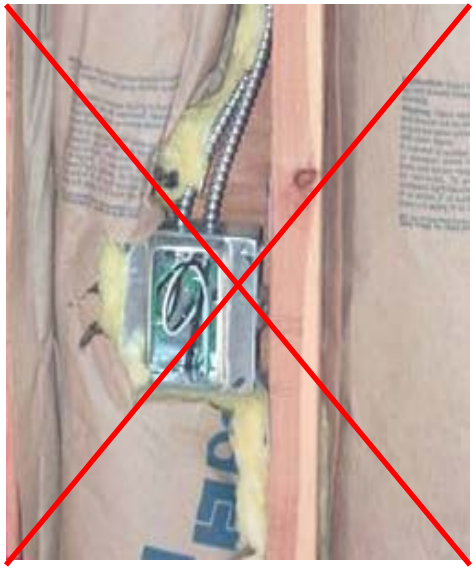
11. Recessed Lighting

Table R402.4.1.1

Source: ENERGY STAR New Homes

12. Plumbing and Wiring

Table R402.4.1.1



Does Not Comply with Code

13. Shower/Tub on Exterior Wall

Table R402.4.1.1

Source: ENERGY STAR New Homes

Source: ENERGY STAR New Homes

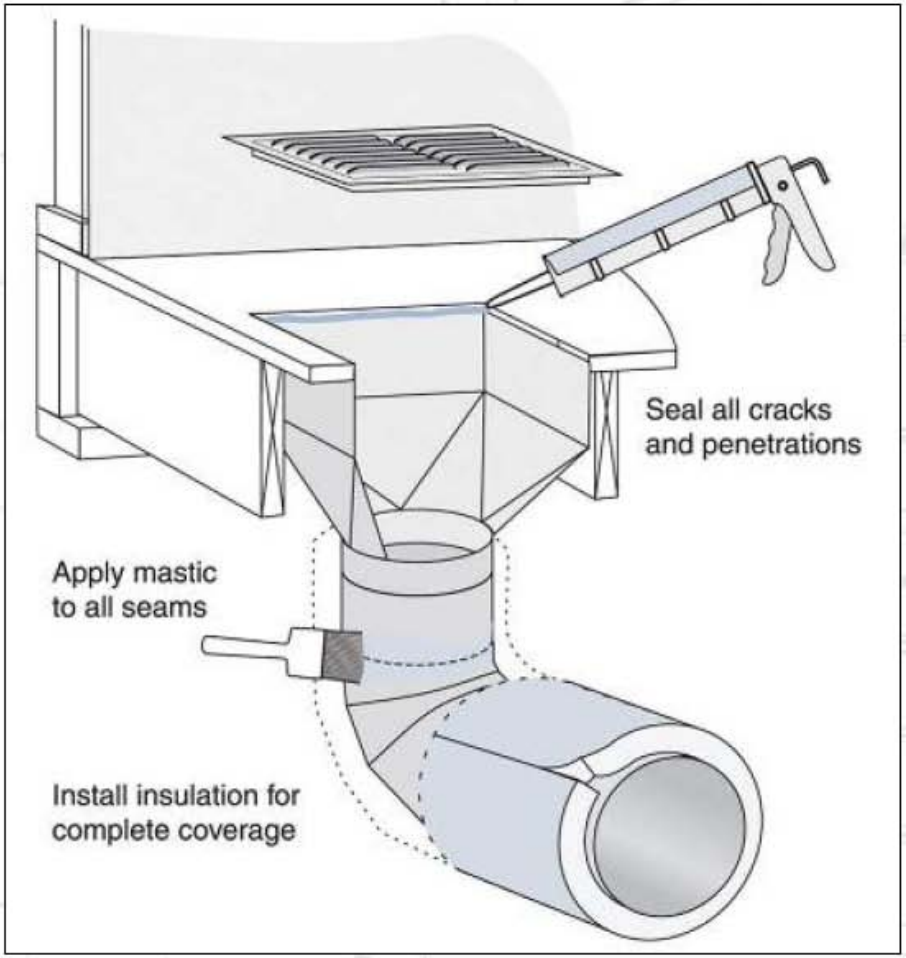
14. Electrical/Phone Box

Table R402.4.1.1

Source: USDOE Building Energy Codes University

15. HVAC Register Boots

Table R402.4.1.1



DUCT BOOTS & SEAMS
SEALED WITH MASTIC

Source: ENERGY STAR New Homes

16. Fireplace

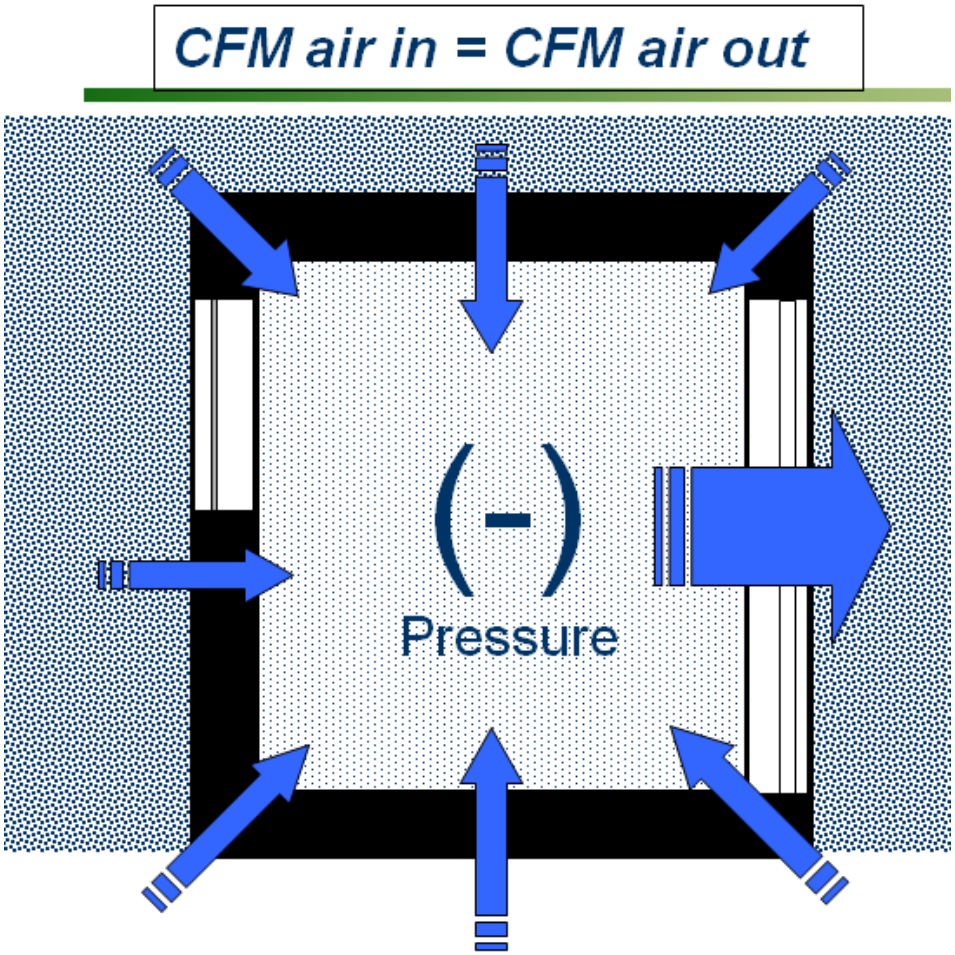
Table R402.4.1.1

Source: ENERGY STAR New Homes

Air Leakage Test (Mandatory)

R402.4.1.2

MT Amendment: Less than 4 ACH50



Applying Mastic

R403.2.2

Duct Tightness Testing

R403.2.2

Postconstruction Test

Total Leakage **or Leakage to the Outside** <= 4 cfm/100 SF (at 25 PA)

Formerly Leakage to Outside limit was 8 cfm/100 SF

Formerly Total Leakage limit was 12 cfm/100 SF

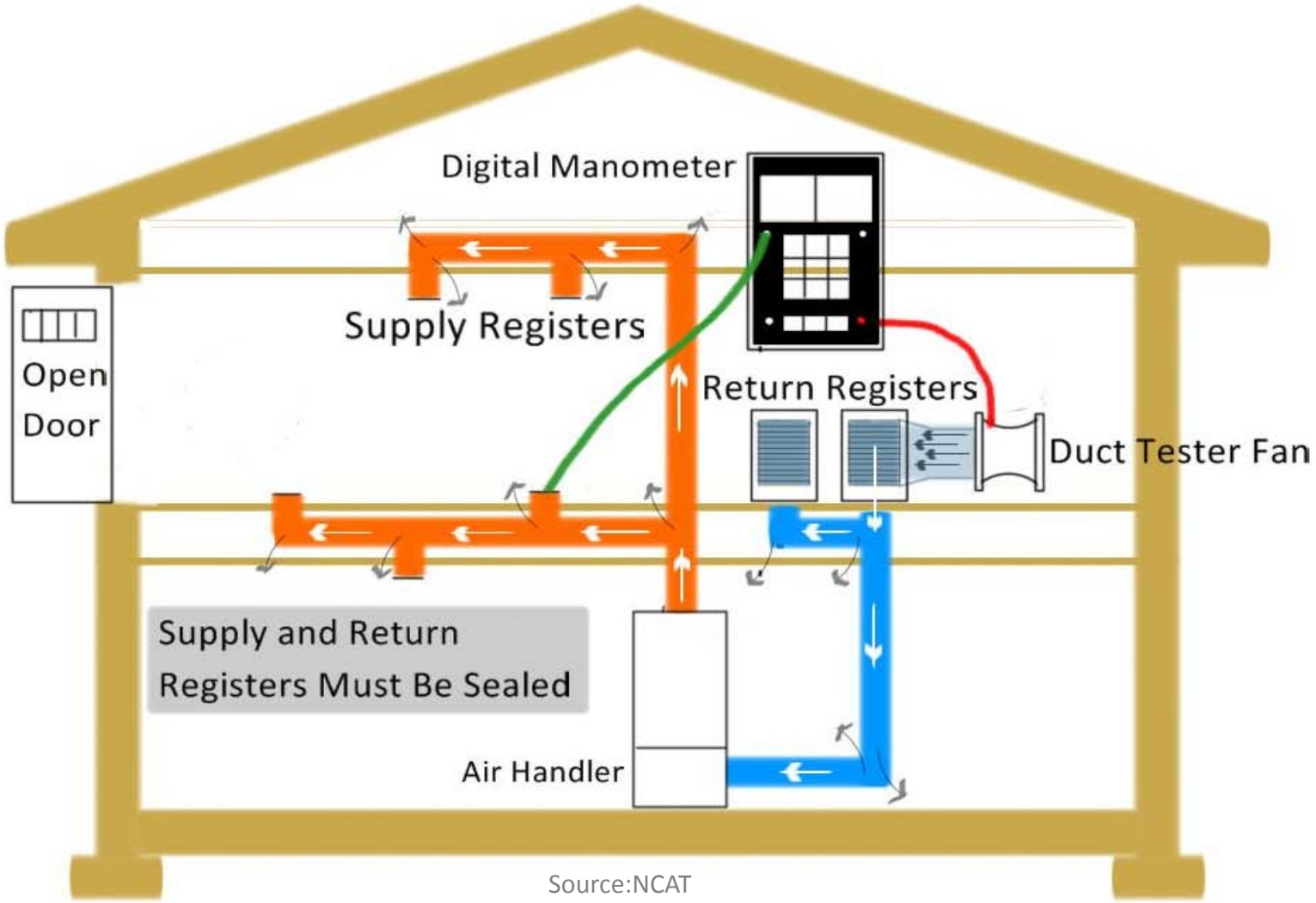
Rough-in Test

Total Leakage <= 4 cfm/100 SF (at 25 PA)

Formerly Total Leakage limit was 6 cfm/100 SF

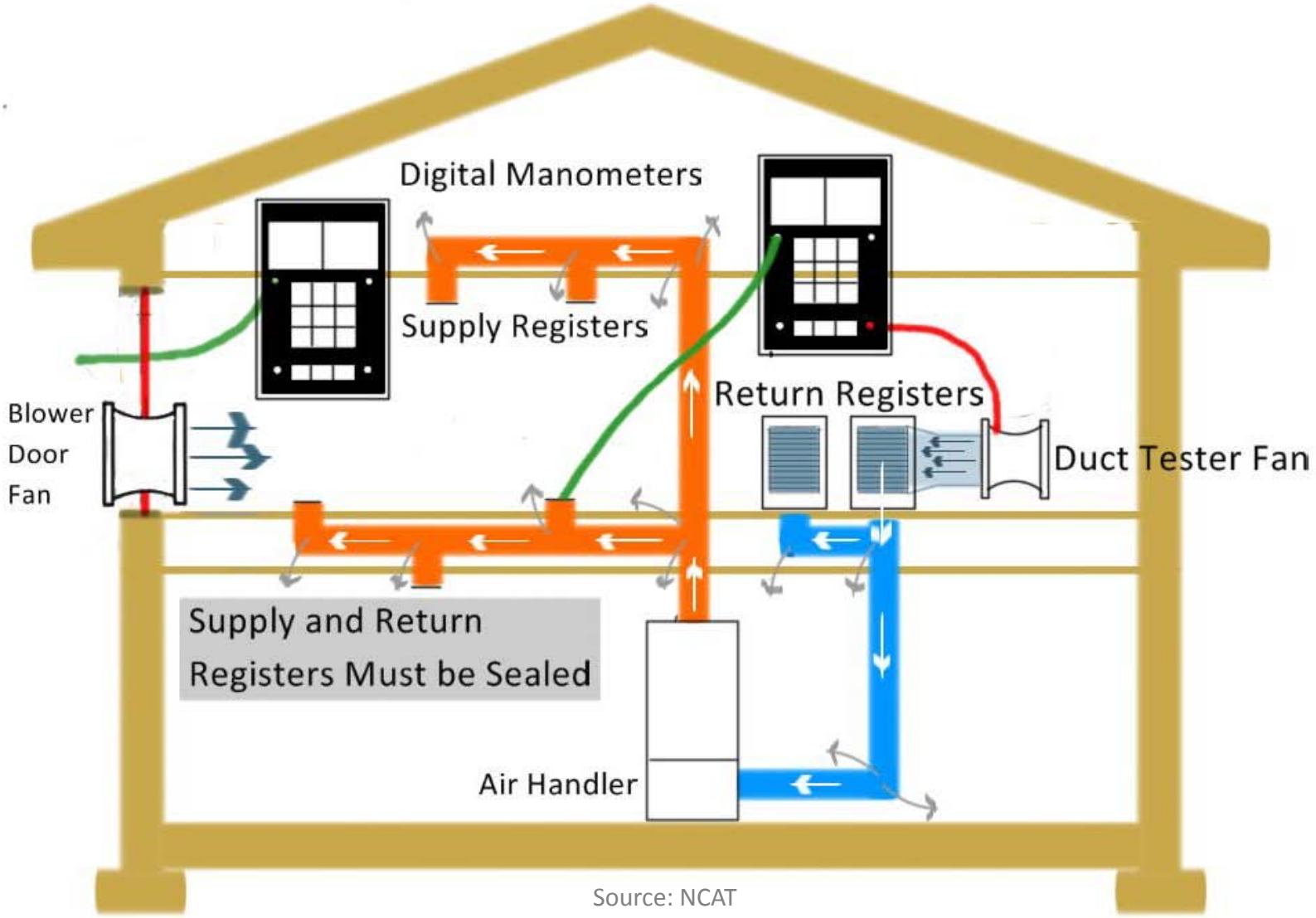
Testing not required if ducts and air handler entirely within building thermal envelope.

Total Duct Leakage Test



Source:NCAT

Duct Leakage to the Outside



Source: NCAT

Duct Tightness Testing

Sealed Air Handler

R403.2.2.1

Air handlers to have a manufacturer's designation for an air leakage of ≤ 2% of design air flow rate per ASHRAE 193

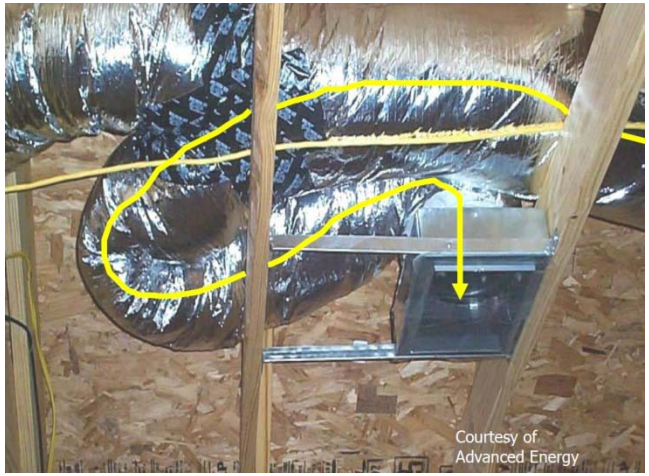
Source: USDOE Building Energy Codes University

Moving Air Hates to Make Hard Turns

Photo credit: http://www.masterfile.com/stock-photography/image/600-01791391/Aerial-View-of-Freeway-Intersection-Highway-404-and-Finch-Avenue-Willowdale-Ontario-Canada

Source: PTCS

Many Causes of Low Air Flow



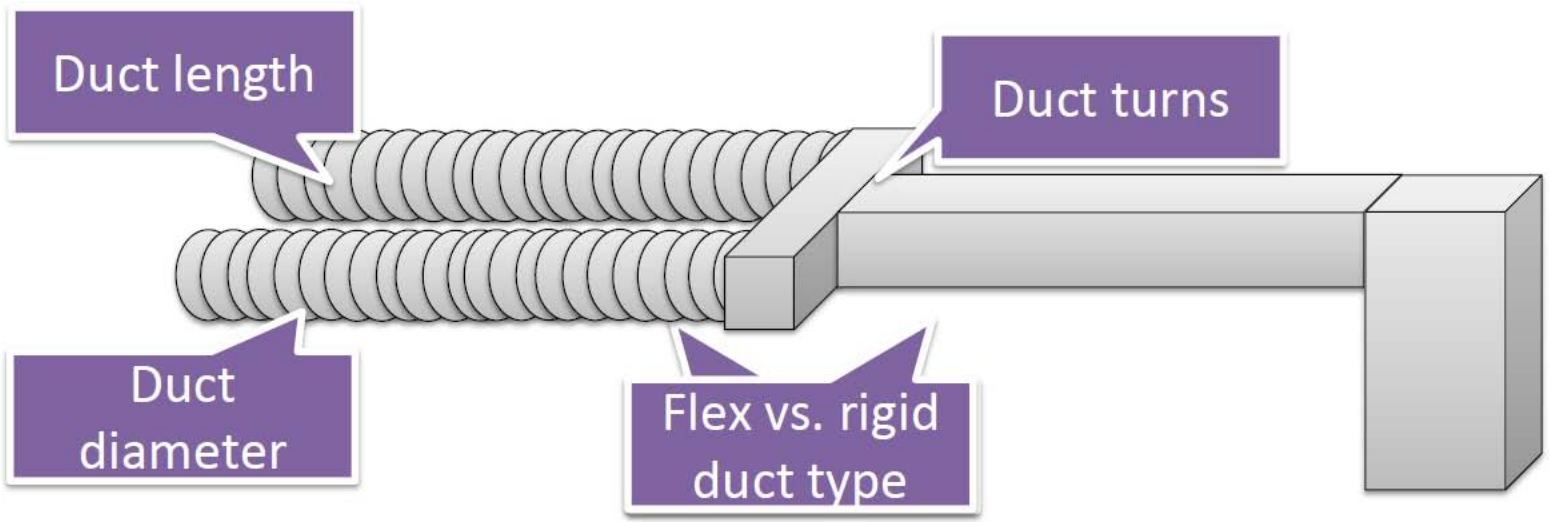
Source: PTCS

Many Causes of Low Air Flow

Source: PTCS

Designing the Duct System

- Factors that influence the static pressure of the ducts:
  - Duct length
  - Duct diameter
  - Duct type
  - Duct turns
  - Other components, like filters



Source: EPA

The Never Connected and the Disconnected

Source: PTCS

Building Cavities as Return Ducts (Mandatory) R403.2.3

2012 IECC prohibits use of building cavities for either supply or return.

Montana amended to allow use of building cavities for return.

Source: USDOE Building Energy Codes University

Service Hot Water Systems

R403.4.2

R-3 Insulation on:

- Piping > ¾ in. nominal diameter
- Piping serving more than one dwelling unit
- ~~Piping from the water heater to kitchen outlets~~
- Piping located outside the conditioned space
- Piping from the water heater to a distribution manifold
- Piping under a floor slab
- Buried piping
- Supply and return piping in recirculating systems other than demand recirculation systems
- ~~Piping with run lengths > maximum run lengths for nominal pipe diameter in Table R403.4.2~~

~~All remaining piping to be at least R-3 or meet run length requirements in Table R403.4.2~~

Mechanical Ventilation Fan Efficacy

R403.5.1

Table R403.5.1

Whole-house mechanical ventilation system fans to meet efficacy in Table R403.5.1

Exception When fans are integral to tested and listed HVAC equipment, powered by electronically commutated motor

Continuous Mechanical Ventilation

IRC M1507.3.3

TABLE M1507.3.3(1)
CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE REQUIREMENTS

DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0-1	2-3	4-5	6-7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 - 3,000	45	60	75	90	105
3,001 - 4,500	60	75	90	105	120
4,501 - 6,000	75	90	105	120	135
6,001 - 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

Intermittent Mechanical Ventilation

IRC M1507.3.3

TABLE M1507.3.3(2)
Intermittent Whole-House Mechancial Ventilation Rate Factors

Run-Time Percent in Each 4-Hour Segment	25%	33%	50%	66%	75%	100%
Factor	4	3	2	1.5	1.3	1.0

Table M1507.4
Minimum Rquired Local Exhaust Rates for One- and Two-Family Dwellings

Area to Be Exhausted	Exhaust Rates
Kitchens	100 cfm intermittent or 25 cfm continuous
Bathrooms-Toilet Rooms	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous

Continuous Mechanical Ventilation

IMC M403.3

IMC Table 403.3
Minimum Ventilation Rates - Private Dwellings, single and multiple

Occupancy Classification	Occupant Density	Airflow Rate in Breathing Zone, R*p* CFM/Person	Exhaust Airflow Rate CFM/SF
Garages, common for multiple units	----------		0.75
Garages, separate for each dwelling	----------		100 cfm per car
Kitchens	----------		50/100*
Living Areas	Based on number of bedrooms. First Bedroom 2, each additional bedroom	0.35 ACH but not less than 15 cfm/person	
Toilet Rooms and Bathrooms	----------		20/50*
* - Continuous / Intermittent			

Do Homebuyers Care about IAQ?

- **Moisture and mold litigation – Up**
  [~9,000 moisture and mold court cases - American Banker, 1/03]
- **Home moisture problem inquiries – High**
  [30%, double the next closest subject - NAHB Research Center]
- **Asthma prevalence – High**
  [19% of US households have at least 1 person with asthma - EPA]
- **Air cleaner product sales – Up**
  [$1.2 Billion annual sales - Levin, 2005]
- **Radon mitigation sales – Up**
  [300% increase in home radon mitigations since 1990 - EPA]

IAQ Risk Reduction Principles

1. **Source Control** — Should be highest priority!

   eliminate, substitute, or modify pollutant sources

2. **Dilution** — The role of mechanical ventilation!

   ventilate to dilute unavoidable pollutants

3. **Filtration**

   remove targeted pollutants,
   last resort after source control & dilution

Both difficult and expensive in residential applications.

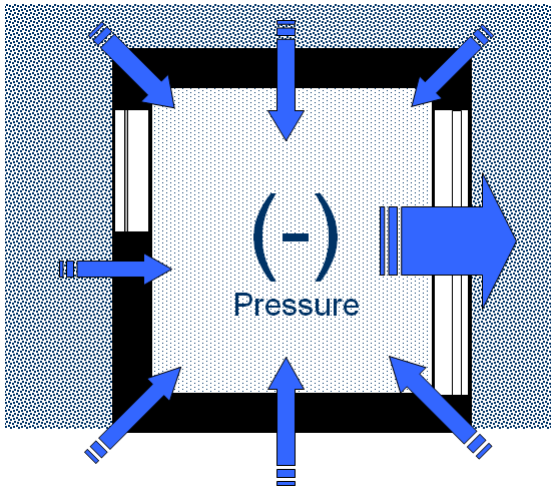
Infiltration versus Mechanical Ventilation

	Infiltration	Mechanical Ventilation
Reliable appropriate quantity of air	NO	Yes
Air delivered to appropriate spaces	NO	Yes
Can be shut off if house is unoccupied	NO	Yes
Quality of air good as outdoor air	NO	Yes

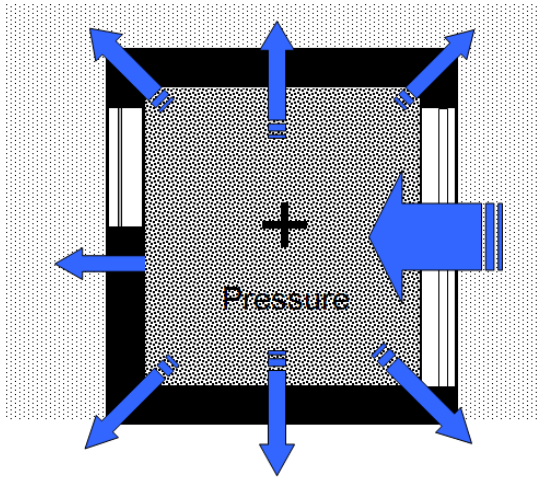
Note: This assumes mechanical system is properly designed.

Mechanical Ventilation Strategies

Exhaust Only



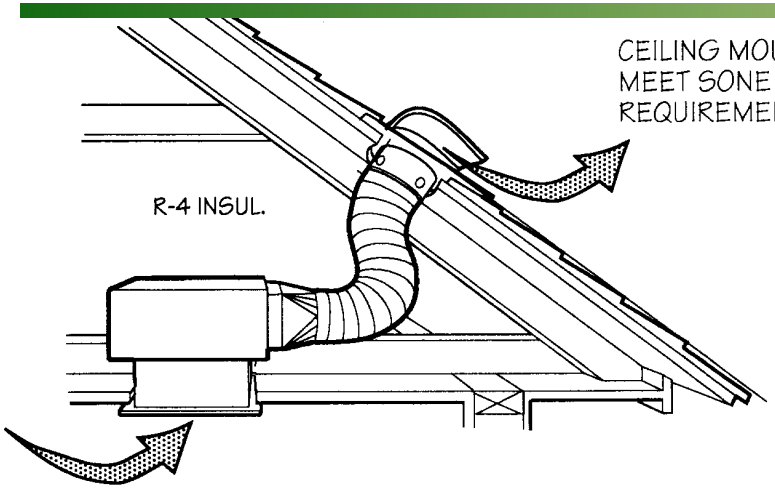
Supply Only



Balanced without Heat Recovery

Balanced with Heat Recovery

Exhaust and Supply Ventilation Systems

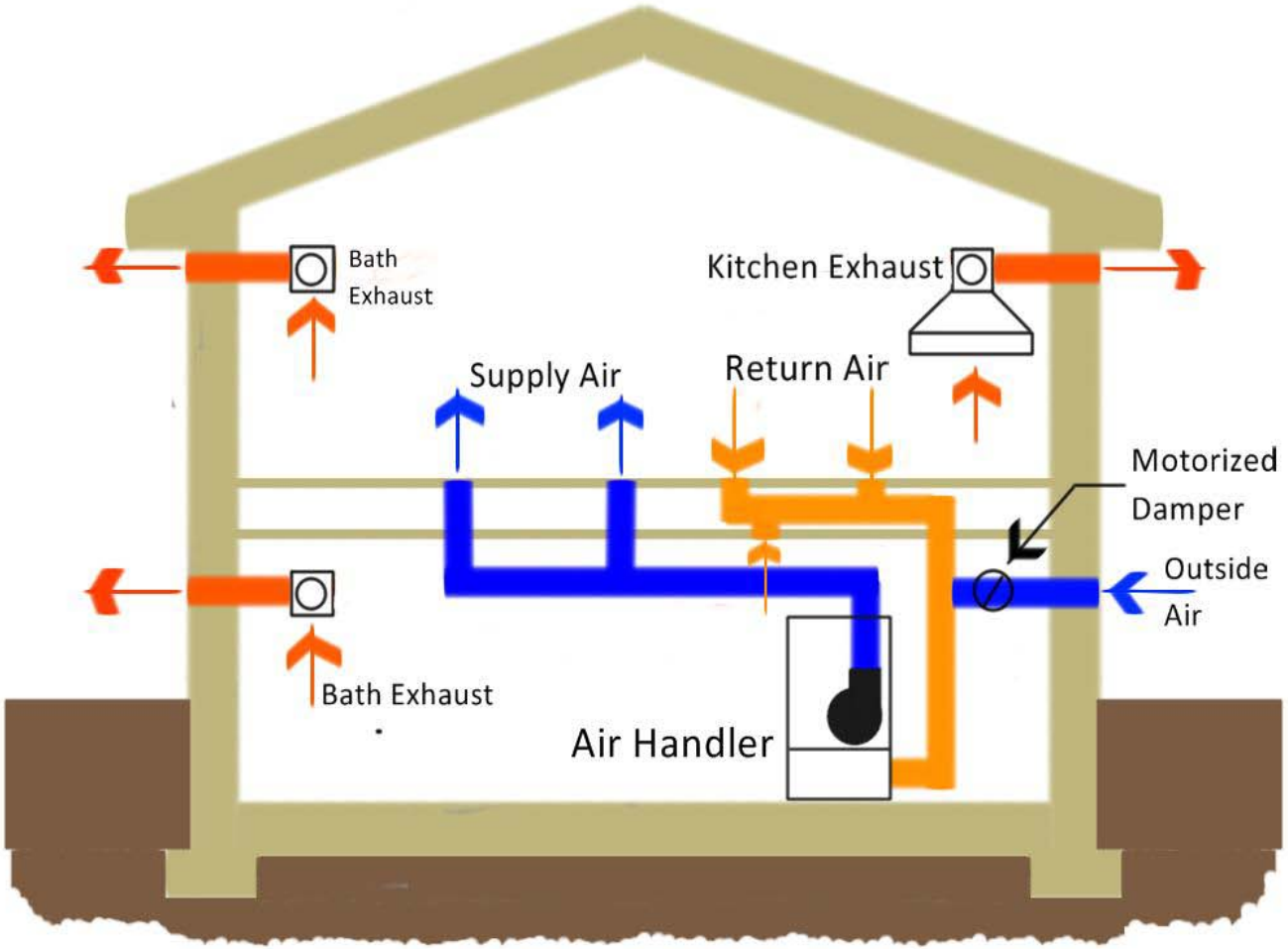


Arguments for Balanced Mechanical Ventilation Systems

1. Avoids problems of creating positive and negative pressures
2. More likely to actually provided design air quantities
3. Provides air through planned pathways, improves air quality
4. Many systems provide option for heat recovery

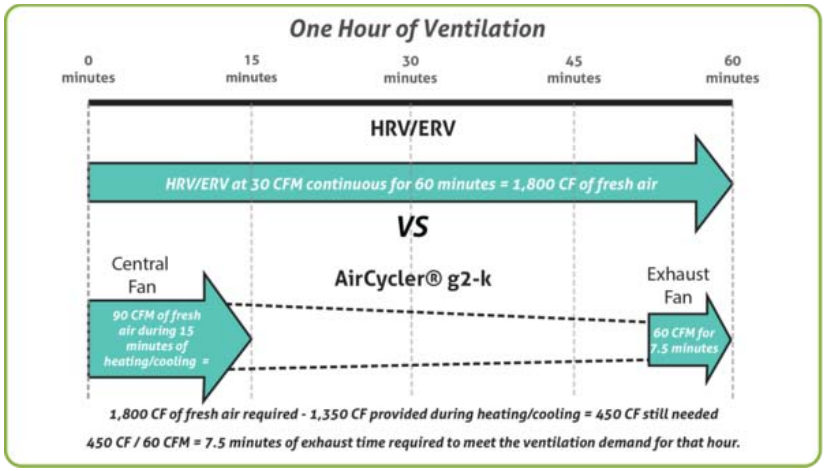
A simple controller for intermittent use of mechanical ventilation systems.

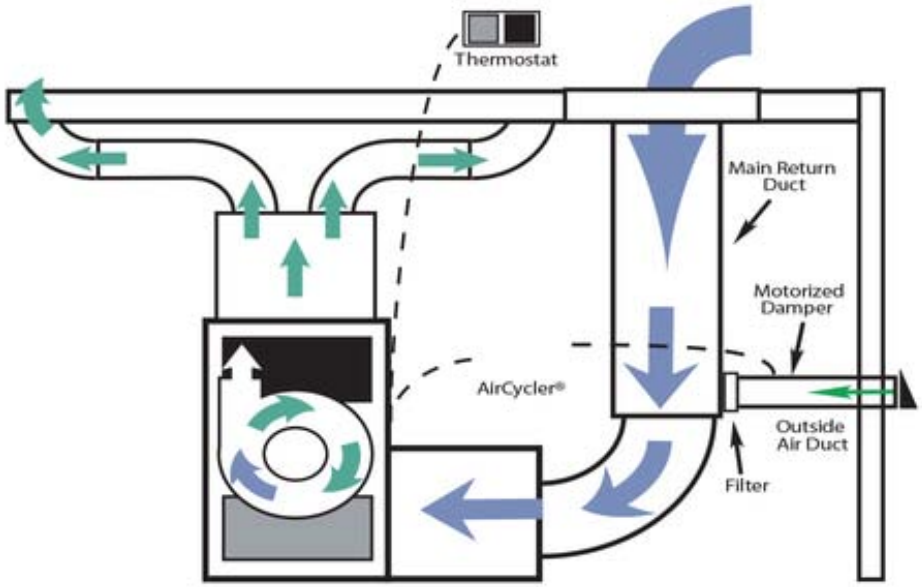
Central Balanced Exhaust without Heat Recovery



Balanced ventilation system with fresh air intake integrated with air handler and exhaust fan(s).

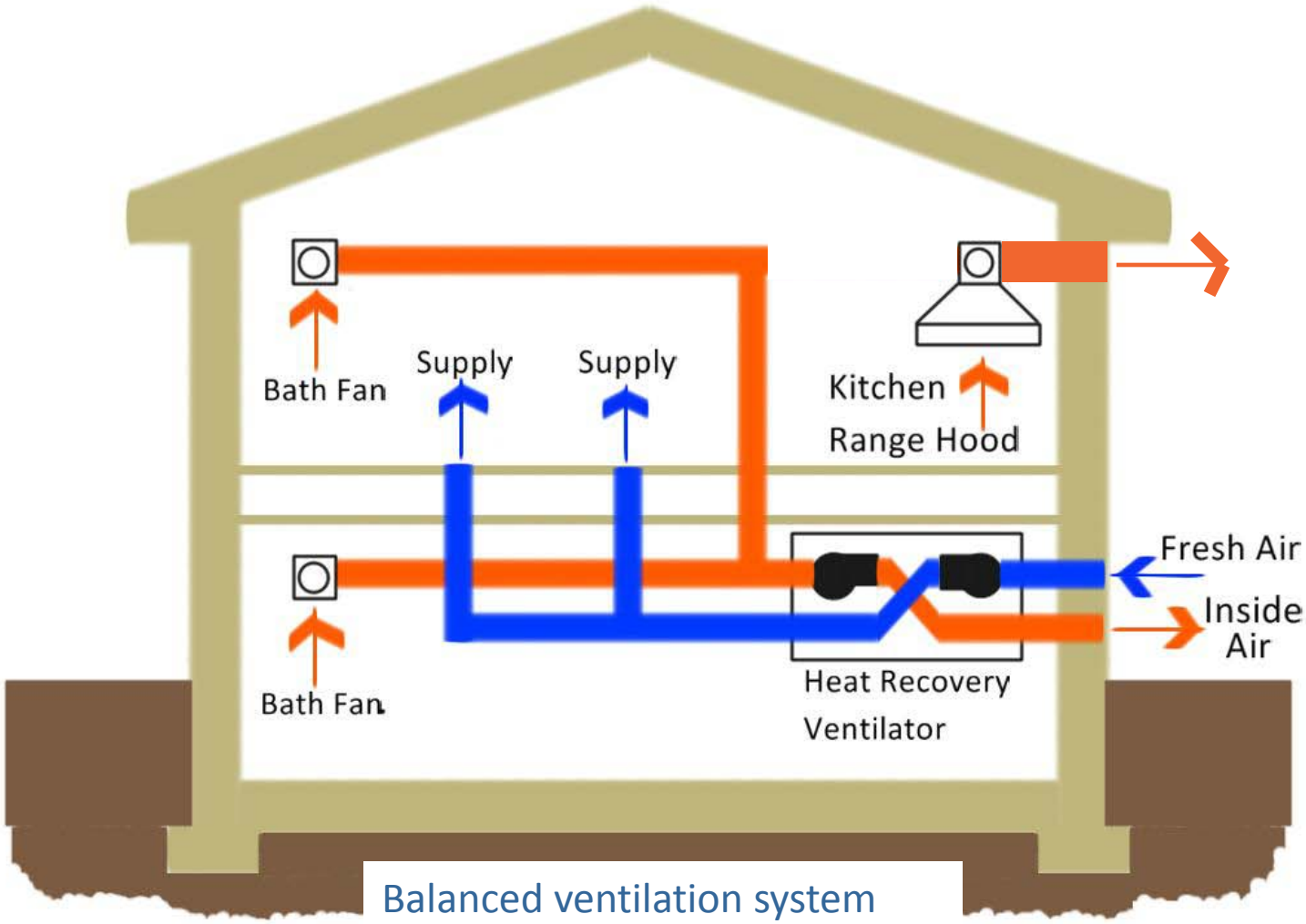
Fresh Air Intake Interconnected to Exhaust Fan





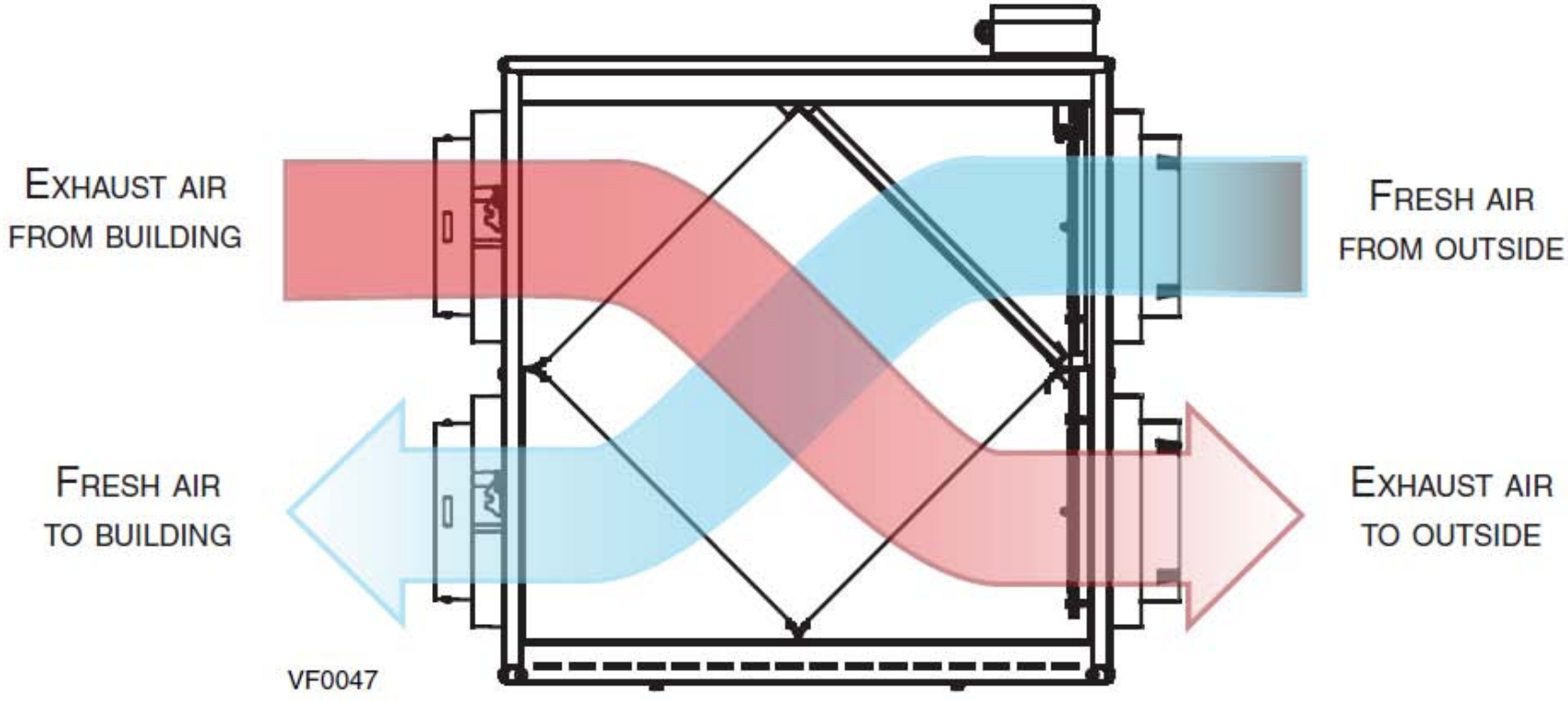
Source: www.aircycler. com

Central Balanced Exhaust with Heat Recovery



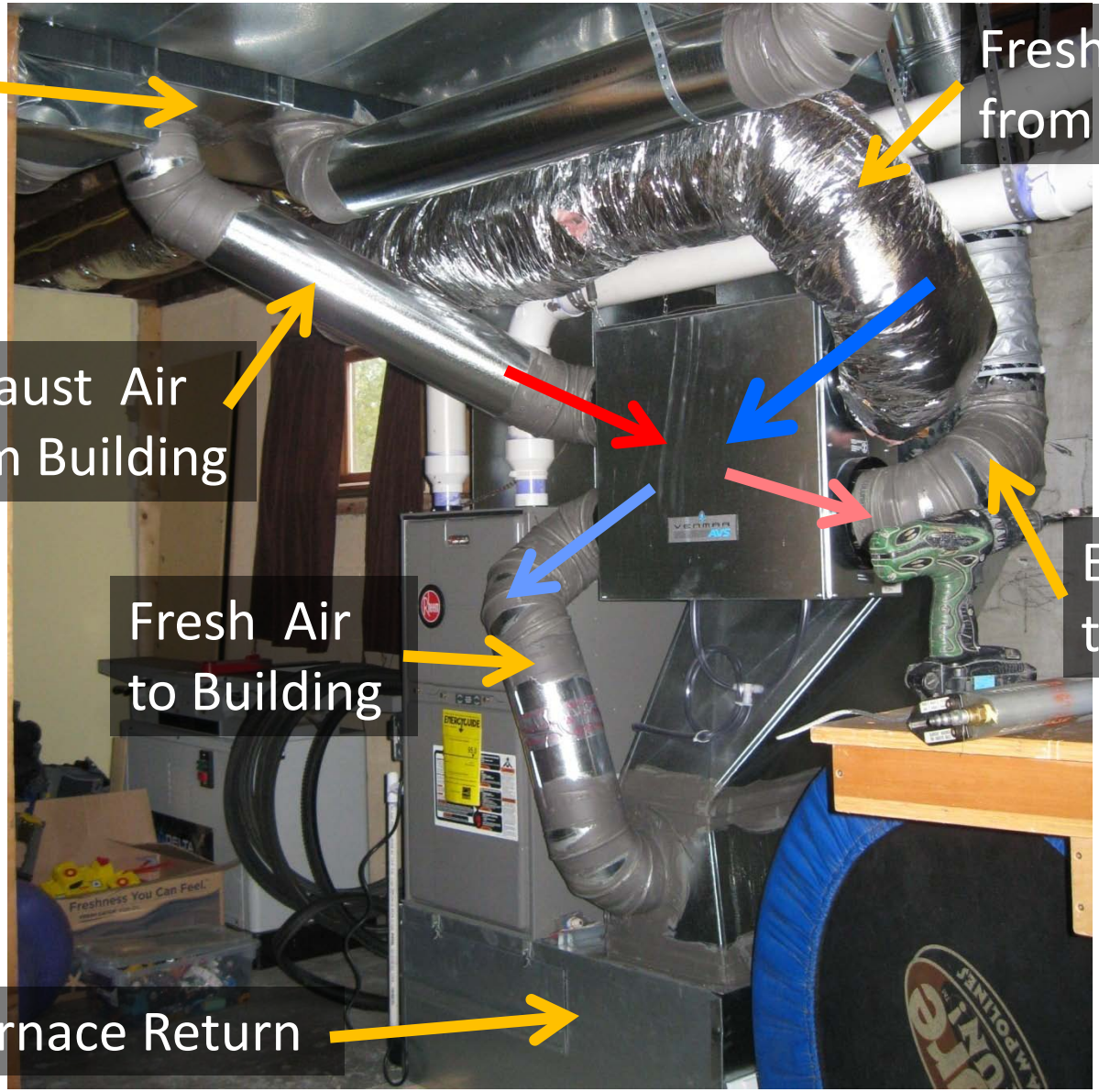
Balanced ventilation system with heat recovery ventilator.

Heat Recovery Ventilator (HRV)



Source: Venmar FAE 125M

Heat Recovery Ventilator (HRV)



Mechanical Ventilation

Some interesting stuff:

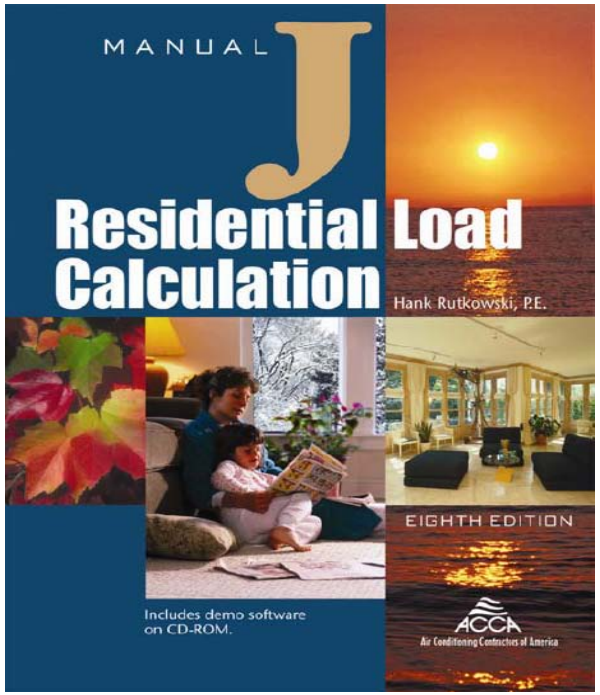
- Designer range hoods can be 500-1200 CFM
- Older clothes dryers are about 150 CFM
- New clothes dryers are 150-300 CFM
- Some jurisdictions in Canada required ducted fresh air to bedrooms
- In a typical bathroom 70 CFM fan must operate for 45 minutes to exhaust moisture from a shower.

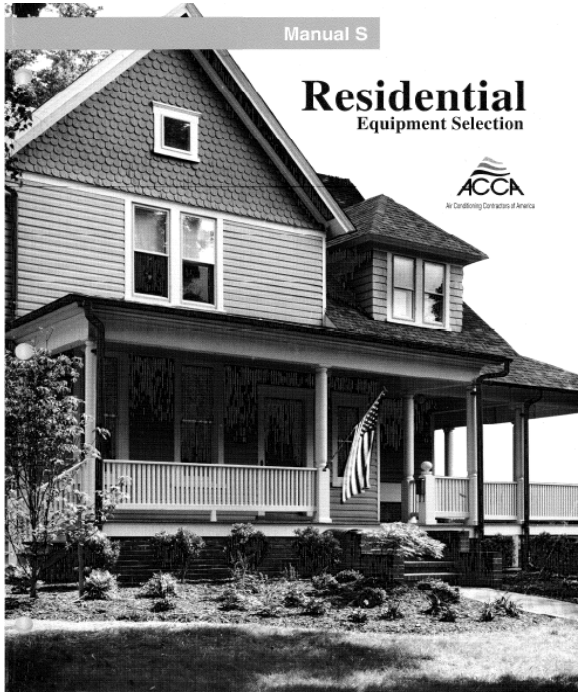
Equipment Sizing (Mandatory)

R403.6

Heating and Cooling Equipment

- Sized according to **ACCA Manual S**
- Based on loads calculated per **ACCA Manual J**
  (or other approved calculation methodology)





ACCA Manual J Room by Room Heat Load Calculations

Manual J Computer Calculation of Room Heat Flows and Air-Handler Airflows

Room	Area (ft^2)	Heating load (Btuh)	Cooling load (Btuh)	Heating Airflow (cfm)	Cooling Airflow (cfm)
Living room	255	4670	4568	188	221
Dining room	224	4219	2271	195	188
Kitchen	144	3201	2456	91	119
Bedroom 1	158	4410	1799	142	98
Bedroom 2	106	1730	771	53	41
Bedroom 3	99	3941	2492	151	136
Bathroom 1	80	1532	1206	65	78
Bathroom 2	60	771	521	29	39
Totals	**1126**	**24,474**	**16,084**	**914**	**920**

Source - **Residential Energy**

Variation in AC Capacity Per Ton

	System size sf/ton	Air flow cfm/sf	Air exchange rate ACH nat
Historic "Rule of Thumb"	**400**	**1.0**	**0.5 - 0.75**
Energy Star – Cold Climate	**1107**	**0.35**	**0.31**
Energy Star – Mixed Humid Climate	**1124**	**0.34**	**0.34**
40% BA – Cold Climate	**1476**	**0.26**	**0.10**
40% BA – Mixed Humid Climate	**1311**	**0.27**	**0.19**

Effects of Oversizing Air-conditioning Equipment

Oversizing results in <u>short cycling</u>……

- Reduces equipment life
- Reduces efficiency
- Results in poor humidification
- Reduces filter effectiveness

Lighting (Mandatory)

R404.1

75% of lamps in permanently installed fixtures shall be high efficacy lamps

- 60 lumens per watt if over 40 W
- 50 lumens per watt if between 40 and 15 W
- 40 lumens per watt if 15 W less

Lamp Efficacy	
	Lum/Watt
Incandescent Tungsten Filament	7-18
Incandescent Tungsten Halogen	12-26
Linear Fluorescent	45-104
Compact Fluorescent	33-75
LED	70-140

Simulated Performance Alternative (Performance) R405

Allows credit for:

- Exterior Shading
- Solar Heat Gain
- Innovative Framing Techniques
- Cool Roofing Systems
- Thermal Mass
- Solar Energy Systems
- Low Infiltration

REM/Design™

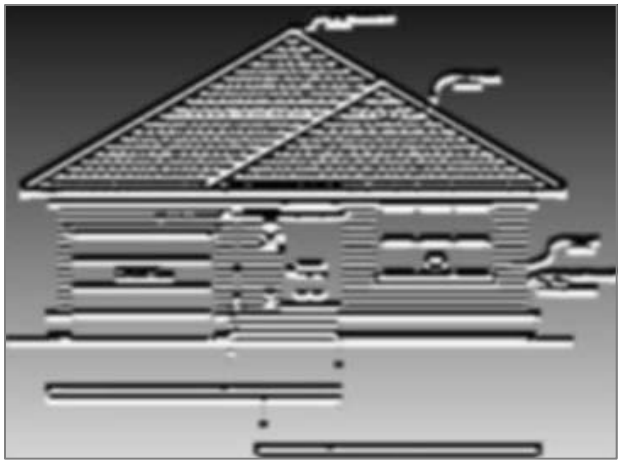
EnergyGauge®

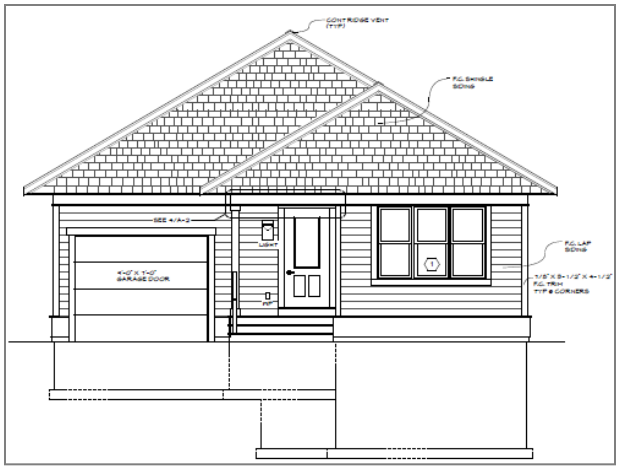
Performance Compliance

R405

Standard Reference Design Proposed Design

"Geometric Twins"





- Proposed design must have annual energy cost less or equal to reference design.
- Mandatory provisions are required.
- Characteristics based on Table R405.5.2(1)
- U-Factors of Table R402.1.3

Performance Compliance

R405.5.2(1)

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Above-grade walls	Type: Mass wall if proposed wall is mass; otherwise wood frame. Gross area: Same as proposed *U*-factor: From Table R402.1.3 Solar absorptance = 0.75 Remittance = 0.90	As proposed As proposed As proposed As proposed As proposed
Below-grade walls	Type: Same as proposed Gross area: Same as proposed *U*-factor: From Table R402.1.3, with insulation layer on interior side of walls.	As proposed As proposed As proposed
Above-grade floors	Type: Wood frame Gross area: Same as proposed *U*-factor: From Table R402.1.3	As proposed As proposed As proposed
	orientations (N, E, S & W). *U*-factor: From Table R402.1.3 SHGC: From Table R402.1.1 except that for climates with no requirement (NR) SHGC = 0.40 shall be used. Interior shade fraction: 0.92 - (0.21 × SHGC for the standard reference design) External shading: None	 As proposed As proposed 0.92 - (0.21 × SHGC as proposed) As proposed

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Above-grade walls	Type: Mass wall if proposed wall is mass; otherwise wood frame. Gross area: Same as proposed *U*-factor: From Table R402.1.3 Solar absorptance = 0.75 Remittance = 0.90	As proposed As proposed As proposed As proposed As proposed

Performance Compliance

R405.5.2(1)

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
	U-factor: From Table R402.1.3	As proposed
	SHGC: From Table R402.1.1 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Interior shade fraction: 0.92 - (0.21 × SHGC for the standard reference design) External shading: None	0.92 - (0.21 × SHGC as proposed) As proposed

TABLE R405.5.2(1)
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Glazing[a]	Total area[b] = (a) The proposed glazing area; where proposed glazing area is less than 15% of the conditioned floor area. (b) 15% of the conditioned floor area; where the proposed glazing area is 15% or more of the conditioned floor area.	As proposed
	Orientation: Equally distributed to four cardinal compass orientations (N, E, S & W).	As proposed
	U-factor: From Table R402.1.3	As proposed
	SHGC: From Table R402.1.1 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Interior shade fraction: 0.92 - (0.21 × SHGC for the standard reference design) External shading: None	0.92 - (0.21 × SHGC as proposed) As proposed

Montana Amendment to Reference Design R405.5.2(1)

Thermal Distribution Systems

Standard Reference Design	Proposed Design
Untested distribution systems: DSE = 0.88 Tested Ducts: Leakage rate to outside conditioned space per R403.2.2(1) Tested duct location: Inside thermal envelope Tested duct insulation: in accordance with R403.2.1	Untested distribution systems: DSE from Table R405.5.2 Tested Ducts: Tested Leakage rate to outside conditioned space Duct location: As proposed Duct Insulation: As proposed