Montana Residential Energy Code Update

Funding for this presentation has been provided by the Northwest Energy Efficiency Alliance and its participating utilities in Montana.
LEED for Homes
Passive House
Energy Codes & HERS index

RESNET
HERS®
INDEX

Existing Homes

2006 IECC
2009 IECC
2012 IECC

Standard New Home

Typical ENERGY STAR Home

Builder’s Challenge
Passive House

Zero Energy Home

Less Energy

More Energy
Residential
Energy Code Evolution

- Standard 90-75
- MEC 1983/86: 10%
- MEC 1992/93: 2%
- MEC 1995
- IECC 1998: 2%
- IECC 2004/06: 2%
- IECC 2009: 15%
- IECC 2012: 15%

Energy Use Index (1975 use = 100)

Source: BECP
## 2012 IECC Economics

<table>
<thead>
<tr>
<th>Savings and cost of implementing the 2012 IECC vs the existing Montana State Energy Code</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MTDEQ and USDOE 2012 IECC Economics</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Floor Area (SF)</strong></td>
<td>USDOE</td>
</tr>
<tr>
<td>2400</td>
<td>Weighted</td>
</tr>
<tr>
<td><strong>Weighted Annual Savings</strong></td>
<td>$310</td>
</tr>
<tr>
<td><strong>Life Cycle Cost Savings</strong></td>
<td>$4,105</td>
</tr>
<tr>
<td><strong>Implementation Cost Estimate</strong></td>
<td>$2,558</td>
</tr>
<tr>
<td><strong>Simple Payback</strong></td>
<td>7.3</td>
</tr>
<tr>
<td><strong>Annual Mortgage Increase</strong></td>
<td>$130</td>
</tr>
<tr>
<td><strong>Net Annual Cash Flow Savings</strong></td>
<td>$180</td>
</tr>
</tbody>
</table>
## I-Codes Overlap and Interact

<table>
<thead>
<tr>
<th>Topic</th>
<th>IECC</th>
<th>IRC</th>
<th>IMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC Sizing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation Values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window/Skylight U-Factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House Tightening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duct Sealing and Tightening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting Efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foam Thermal Properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor Retarders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crawlspace Ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical Ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
Definitions

Residential Building
- Detached one and two family dwellings
- Multiple single family dwellings and townhouses
- Group R-2, R-3, R-4 <= 3 stories in height
Alterations, Renovations, & Repairs where permit is required. Note the exceptions!

Additions - Treat as a stand-alone building or with whole building.

Alterations, Renovations, & Repairs where permit is required. Note the exceptions!
Compliance

- Envelope Compliance
- Mandatory Provisions

Prescriptive Path
- R-Value Computation
- U-Factor Alternative
- Total UA Alternative

OR

Performance Path
R402 & R405

Compliance Paths

<table>
<thead>
<tr>
<th>Compliance Paths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory + Prescriptive</td>
</tr>
<tr>
<td>R-Value Computation</td>
</tr>
<tr>
<td>Mandatory + Prescriptive</td>
</tr>
<tr>
<td>U-Factor Alternative</td>
</tr>
<tr>
<td>Mandatory + Prescriptive</td>
</tr>
<tr>
<td>Total UA Alternative</td>
</tr>
<tr>
<td>Mandatory + Performance</td>
</tr>
<tr>
<td>Simulated Performance Alternative</td>
</tr>
<tr>
<td>Mandatory +</td>
</tr>
<tr>
<td>Above-code Program</td>
</tr>
</tbody>
</table>
Climate Specific Requirements

Table R301.1
Certificate (Mandatory)

R401.3

Place on electrical panel.

R-Values
U-Factors & SHGC
Envelope Air Leakage
Space Conditioning Efficiencies
Duct Tightness Test
Building Tightness Test
Duct R-Values
Builder Signature
The 3 Heat Transfer Mechanisms

- Conduction
- Convection
- Radiation

Source: NCAT
Conduction
Convection
Heat Transfer Through Walls

Conduction, Convection, & Radiation

Source - NCAT
Heat Transfer Through Walls

Conduction

Source - NCAT
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

\[ R = \frac{1}{U} \text{ and } U = \frac{1}{R} \]

**British Thermal Unit (Btu) = Amount of heat required to raise one pound of water 1° F.**
R-Values and Diminishing Returns

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: 0.06%
- R-50 to R-51: 0.04%
### Table R402.1.3
EQUIVALENT U-FACTORS

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR</th>
<th>SKYLIGHT U-FACTOR</th>
<th>CEILING U-FACTOR</th>
<th>FRAME WALL U-FACTOR</th>
<th>MASS WALL U-FACTOR</th>
<th>FLOOR U-FACTOR</th>
<th>BASEMENTWALL U-FACTOR</th>
<th>CRAWL SPACE WALL U-FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50</td>
<td>0.75</td>
<td>0.035</td>
<td>0.082</td>
<td>0.197</td>
<td>0.064</td>
<td>0.360</td>
<td>0.477</td>
</tr>
<tr>
<td>2</td>
<td>0.40</td>
<td>0.65</td>
<td>0.030</td>
<td>0.082</td>
<td>0.165</td>
<td>0.064</td>
<td>0.360</td>
<td>0.477</td>
</tr>
<tr>
<td>3</td>
<td>0.35</td>
<td>0.55</td>
<td>0.030</td>
<td>0.057</td>
<td>0.098</td>
<td>0.047</td>
<td>0.091</td>
<td>0.136</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>0.35</td>
<td>0.55</td>
<td>0.026</td>
<td>0.057</td>
<td>0.098</td>
<td>0.047</td>
<td>0.059</td>
<td>0.065</td>
</tr>
<tr>
<td>5 &amp; Marine 4</td>
<td>0.32</td>
<td>0.55</td>
<td>0.026</td>
<td>0.057</td>
<td>0.082</td>
<td>0.033</td>
<td>0.050</td>
<td>0.055</td>
</tr>
<tr>
<td>6</td>
<td>0.32</td>
<td>0.55</td>
<td>0.026</td>
<td>0.057</td>
<td>0.060</td>
<td>0.033</td>
<td>0.050</td>
<td>0.055</td>
</tr>
<tr>
<td>7 and 8</td>
<td>0.32</td>
<td>0.55</td>
<td>0.026</td>
<td>0.048</td>
<td>0.057</td>
<td>0.028</td>
<td>0.050</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Designer is allowed to use the R-Value table for some components and U-Value table for others.
Calculating Assembly U-Factors

<table>
<thead>
<tr>
<th>Material</th>
<th>Inside air film</th>
<th>Gypsum board</th>
<th>Cavity insulation</th>
<th>5.5&quot; Stud</th>
<th>Exterior sheathing</th>
<th>Exterior siding</th>
<th>Outside Air Film</th>
<th>Total R-value</th>
<th>U-Value</th>
<th>Area Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-Value Cavity</td>
<td>0.68</td>
<td>0.68</td>
<td>21.00</td>
<td>6.80</td>
<td>0.50</td>
<td>1.00</td>
<td>0.17</td>
<td>23.80</td>
<td>0.042</td>
<td>0.80</td>
</tr>
<tr>
<td>R-Value Framing</td>
<td>0.68</td>
<td>0.45</td>
<td>......</td>
<td>6.80</td>
<td>0.50</td>
<td>1.00</td>
<td>0.17</td>
<td>9.60</td>
<td>0.104</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Area Weighted U-Factor = (Area1\_Frac × U1) + (Area2\_Frac + Area2)

Area Weighted U-Factor = (0.8 x 0.042) + (0.2 x 0.104) = 0.054

Area Weighted R-Value = (1/0.054) = 18.38
Compliance Paths

R402.1.4

Mandatory + Prescriptive
R-Value Computation

Mandatory + Prescriptive
U-Factor Alternative

Mandatory + Prescriptive
Total UA Alternative

Mandatory + Performance
Simulated Performance Alternative

UA_{Total} = (A \times U_1) + (A \times U_2) + ...
Using REScheck Software

Download http://www.energycodes.gov/rescheck
Select the Appropriate Code
Looking at the Bottom Line

% Better Than Code

Max UA

Your UA
The log thickness is the area of the log profile divided by its stack height, rounded to the nearest inch. The inscribed rectangle may be used to establish dimensions of non-rectangular log profiles.
## INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR(^b)</th>
<th>SKYLIGHT(^b) U-FACTOR</th>
<th>GLAZED FENESTRATION SHGC(^b,e)</th>
<th>CEILING R-VALUE</th>
<th>WOOD FRAME WALL R-VALUE</th>
<th>MASS WALL R-VALUE</th>
<th>FLOOR R-VALUE</th>
<th>BASEMENT(^c) WALL R-VALUE</th>
<th>SLAB(^d) R-VALUE &amp; DEPTH</th>
<th>CRAWL SPACE(^c) WALL R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 IECC*</td>
<td>6</td>
<td>0.33</td>
<td>0.60</td>
<td>NR</td>
<td>21 or 13+5(^h)</td>
<td>15/19</td>
<td>30(^g)</td>
<td>15/19</td>
<td>10, 4 ft</td>
<td>10/19</td>
</tr>
<tr>
<td>2012 IECC*</td>
<td>6</td>
<td>0.32</td>
<td>0.55</td>
<td>NR</td>
<td>21 or 13+5(^h)</td>
<td>15/20</td>
<td>30(^g)</td>
<td>15/19</td>
<td>10, 4 ft</td>
<td>15/19</td>
</tr>
<tr>
<td>2012 IECC</td>
<td>6</td>
<td>0.32</td>
<td>0.55</td>
<td>NR</td>
<td>20+5 or 13+10(^h)</td>
<td>15/20</td>
<td>30(^g)</td>
<td>15/19</td>
<td>10, 4 ft</td>
<td>15/19</td>
</tr>
</tbody>
</table>

\(^*\) - With Montana Amendments

\(^b\) - FENESTRATION U-FACTOR
\(^c\) - WALL R-VALUE
\(^d\) - SLAB R-VALUE
\(^e\) - SHGC
Window U-Factor

from 0.32 U-Factor to 0.33

Lower means less heat loss.

Source: www.nfrc.org
Window Solar Heat Gain Coefficient

No requirement for Zone 6 (Montana)

Lower means less solar gain. Single pane glass is

Source: www.nfrc.org

<table>
<thead>
<tr>
<th>ENERGY PERFORMANCE RATINGS</th>
<th>ADDITIONAL PERFORMANCE RATINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Factor (U.S./I-P)</td>
<td>Visible Transmittance</td>
</tr>
<tr>
<td>0.35</td>
<td>0.51</td>
</tr>
<tr>
<td>Solar Heat Gain Coefficient</td>
<td>Air Leakage (U.S./I-P)</td>
</tr>
<tr>
<td>0.32</td>
<td>0.2</td>
</tr>
<tr>
<td>Condensation Resistance</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td></td>
</tr>
</tbody>
</table>

Source: www.nfrc.org
Window Visible Transmittance

R402.1.1

No code requirement.

Higher means greater potential for daylighting.

Source: www.nfrc.org
Window Condensation Chart
Energy Trusses Allow R-38

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

New: Required for air permeable insulations in vented attics

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
Wood Frame Wall R-Value

From **R21 or R13+R5** to **No Change**

R402.1.1

2012 IECC

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

**From R21 or R13+R5 to No Change**

**R20+R5 or R13+R10**
### Fiberglass Batt Insulation R-Values when Compressed

<table>
<thead>
<tr>
<th>Nominal Lumber Size</th>
<th>Cavity Depth</th>
<th>Insulation R-Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x12</td>
<td>11 1/4&quot;</td>
<td>37  38  30</td>
</tr>
<tr>
<td>2x10</td>
<td>9 1/4&quot;</td>
<td>32  35  30</td>
</tr>
<tr>
<td>2x8</td>
<td>7 1/4&quot;</td>
<td>27  30  25</td>
</tr>
<tr>
<td>2x6</td>
<td>5 1/2&quot;</td>
<td>21  22  20</td>
</tr>
<tr>
<td>2x4</td>
<td>3 1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>2x3</td>
<td>2 1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>2x2</td>
<td>1 1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>2x1</td>
<td>3/4&quot;</td>
<td></td>
</tr>
<tr>
<td>Product R-Values</td>
<td>R-38</td>
<td>R-38C   R-30</td>
</tr>
<tr>
<td>Standard Thickness</td>
<td>12&quot;</td>
<td>10 1/4&quot;  9 1/2&quot;</td>
</tr>
</tbody>
</table>
Fiberglass Batts (Real World)
Simulated Performance Alternative (Performance)

Allows credit for:

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

Standard Reference Design

Proposed Design

“Geometric Twins”
### TABLE R405.5.2(1)

**SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS**

<table>
<thead>
<tr>
<th>BUILDING COMPONENT</th>
<th>STANDARD REFERENCE DESIGN</th>
<th>PROPOSED DESIGN</th>
</tr>
</thead>
</table>
| 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 |
| 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 |
## Thermal Distribution Systems

<table>
<thead>
<tr>
<th>Standard Reference Design</th>
<th>Proposed Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untested distribution systems: DSE = 0.88</td>
<td>Untested distribution systems: DSE from Table R405.5.2</td>
</tr>
<tr>
<td>Tested Ducts: Leakage rate to outside conditioned space per R403.2.2(1)</td>
<td>Tested Ducts: Tested Leakage rate to outside conditioned space</td>
</tr>
<tr>
<td>Tested duct location: Inside thermal envelope</td>
<td>Duct location: As proposed</td>
</tr>
<tr>
<td>Tested duct insulation: in accordance with R403.2.1</td>
<td>Duct Insulation: As proposed</td>
</tr>
</tbody>
</table>
Understanding Wall Control Functions

Heat
Air
Liquid Water
Water Vapor
Relative Humidity and Dew Point

**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:
  - Raise temperature of condensation surface
  - Reduce or eliminate moisture sources
  - Provide mechanical ventilation

*When condensation appears on the glass of ice water the glass has reached the dew point temperature.*
Relative Humidity and Dew Point
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

Air Molecules

Water Molecules

Low Pressure

High Pressure

Source - NCAT
How many vapor retarders are in your assemblies?

How many air barriers are in your assemblies?
Vapor Retarder and Air Barrier Code Summary

Continuous Air Barrier in Building Envelope

Class I or II Vapor Retarder – Above Grade Walls
Vapor Retarders

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

Class III is allowed for:
- Vented cladding
- Continuous Insulation
  - R-7.5 for 2x4 wall
  - R11.25 for 2x6 wall

Source - NCAT

IRC R702.7
### Vapor Retarders

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.1 perm or less</td>
<td>Sheet polyethylene, sheet metal, non-perforated aluminum foil</td>
</tr>
<tr>
<td>II</td>
<td>Greater than 0.1 perm to less than 1.0 perm</td>
<td>Kraft-faced fiberglass batts or low-perm paint</td>
</tr>
<tr>
<td>III</td>
<td>Greater than 1.0 perm to less than 10 perm</td>
<td>Latex or enamel paint</td>
</tr>
</tbody>
</table>

**Impermeable** (vapor barrier)

**Semi-impermeable**

**Semi-permeable**

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates
## Vapor Permeability of Materials

<table>
<thead>
<tr>
<th>Building Materials</th>
<th>Thickness</th>
<th>Perms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plywood (CDX)</td>
<td>3/8&quot;</td>
<td>0.75</td>
</tr>
<tr>
<td>OSB</td>
<td>3/8&quot;</td>
<td>0.375</td>
</tr>
<tr>
<td>Foil Faced Insulation</td>
<td>1&quot;</td>
<td>0.01</td>
</tr>
<tr>
<td>XPS Insulation (Extruded)</td>
<td>1&quot;</td>
<td>0.8 - 1.2</td>
</tr>
<tr>
<td>EPS Insulation (1.5 pcf)</td>
<td>1&quot;</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Gypsum Board</td>
<td>1/2&quot;</td>
<td>40</td>
</tr>
<tr>
<td>Fiberglass (unfaced)</td>
<td>3 1/2&quot;</td>
<td>120</td>
</tr>
<tr>
<td>Low Density Spray Urethane</td>
<td>3 1/2&quot;</td>
<td>16</td>
</tr>
</tbody>
</table>

### Coatings

<table>
<thead>
<tr>
<th>Coatings</th>
<th>Perms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Retarder Primer</td>
<td>0.5</td>
</tr>
<tr>
<td>Latex Primer &amp; Sealer</td>
<td>3.5-6.1</td>
</tr>
</tbody>
</table>
Air Barrier: Material(s) assembled and joined together to provide a barrier to air leakage through and into the building envelope. An air barrier may be a single material or a combination of materials.
Envelope Control Challenges

Wind Washing
Envelop Control Challenges

Water Vapor Air Transport
Envelope Control Challenge

Water Vapor Diffusion
Drying Potential - Cold Climate

Exterior
Cooler
Lower Humidity

Semi-Permeable

Primary Drying to the Exterior

Vapor Retarder Layer Semi-Impermeable

Secondary Drying to the Interior

Interior
Warmer
Higher Humidity

Source - NCAT
Wall Drying Potential - Cold Climate

- **Cooler Lower Humidity** (Exterior)
- **Warmer Higher Humidity** (Interior)

A **Semi-Permeable** layer allows water vapor to pass through, facilitating drying primarily to the exterior.
Effective R-Value of Typical Wall Assemblies

R-Value

R-19
R-10
R-5

R-14.4  R-19.4  R-18.8  R-23.8
Exterior Insulated Sheathing & Condensation Resistance

- 70 F
- 32 F
- 33 F
- 40 F
- 44 F
What We Can’t Control:
- Outdoor Temperature
- Outdoor Humidity
- Wind
What we can control:

- Indoor Temperature (sort of)
- Indoor Humidity (sort of)
- Thermal Resistance of Components
- Vapor Permeability of Components
- Air Permeability of Components
Continuous Insulated Sheathing

Not in the MT Code

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

Concrete block
Concrete
ICF
Masonry Cavity

Brick
Earth
Solid Timber/Logs
Mass Walls

R-15

R-8

R-7

R-15 If More Than Half of Insulation on the Exterior

R-20

R-9

R-11

R-20 More Than Half of Insulation on the Interior
Slab Insulation

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

Source: USDOE Building Energy Codes University
Slab Insulation

Source: USDOE Building Energy Codes University
Unvented Crawlspace Wall

(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 – Two Design Options

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
The Importance of a Continuous Class I Vapor Retarder
Do the characteristics shown comply with the new energy code?

- $U = 0.55$
- $R = 38$
- $U = 0.33$
- $R = 21$
- $R = 21$
- $R = 10$

Crawl Space
Do the characteristics shown comply with the new energy code?

U = 0.55
R = 38

U = 0.33
R = 21

R = 10
Do the characteristics shown comply with the energy code?

R = 49

Windows
100 SF U-0.33
100 SF U-0.30

R = 21

R = 15
Continuous

Basement
Air Leakage (Mandatory)

Thermal envelope must comply with both:

Testing (402.4.1.2)  Air Barrier and Insulation Installation (Table R402.4.1)

“Where required by the code official, testing shall be conducted by an approved third party.”
# 16 Installation Components

## Table R402.4.1.1: Air Barrier and Insulation Installation Components

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air barrier and thermal barrier</td>
<td>A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Streaks or joints in the air barrier shall not be sealed. Air-permeable insulation shall not be used as a sealing material.</td>
</tr>
<tr>
<td>Ceiling/plaster</td>
<td>The air barrier in any dropped ceiling/walls shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, i.e., door, window, or die cut wall doors to unconditioned attic spaces shall be sealed.</td>
</tr>
<tr>
<td>Walls</td>
<td>Corners and headers shall be insulated and the junction of the foundation and sill plane shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.</td>
</tr>
<tr>
<td>Windows, skylights and doors</td>
<td>The space between window/door jams and framing and skylights and framing shall be sealed.</td>
</tr>
<tr>
<td>Rim joints</td>
<td>Rim joints shall be insulated and include the air barrier.</td>
</tr>
<tr>
<td>Floors (including above-garage and cantilevered floors)</td>
<td>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.</td>
</tr>
<tr>
<td>Crawl space walls</td>
<td>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.</td>
</tr>
<tr>
<td>Shafts, penetrations</td>
<td>Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.</td>
</tr>
<tr>
<td>Narrow cavities</td>
<td>Barriers in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation fully conforms to the available cavity space.</td>
</tr>
<tr>
<td>Garage separation</td>
<td>Air sealing shall be provided between the garage and conditioned spaces.</td>
</tr>
<tr>
<td>Recessed lighting</td>
<td>Recessed light fixtures installed in the building thermal envelope shall be air-tight, IC rated, and sealed to the drywall.</td>
</tr>
<tr>
<td>Plumbing and wiring</td>
<td>Bath insulation shall be cut to size to fit around wiring and plumbing in exterior walls, or installation that on installation fully conforms to the available space shall extend behind wiring and wiring.</td>
</tr>
<tr>
<td>Showerhead on exterior wall</td>
<td>Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.</td>
</tr>
<tr>
<td>Electrical/phone box on exterior walls</td>
<td>The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.</td>
</tr>
<tr>
<td>HVAC register boots</td>
<td>HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.</td>
</tr>
<tr>
<td>Fireplace</td>
<td>An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.</td>
</tr>
</tbody>
</table>
1. Air Barrier and Thermal Barrier

Table R402.4.1.1

- Continuous air barrier shall be installed.
- Breaks or joints in the air barrier shall be sealed.

Gypsum Board vs. Polyethylene

Unchanged.
Seal at bottom plate
1. Air Barrier and Thermal Barrier

Source: USDOE Vol. 10 Building America
Best Practices Series - Air Sealing
1. Air Barrier and Thermal Barrier

Source: USDOE Vol. 10 Building America
Best Practices Series - Air Sealing
1. Air Barrier and Thermal Barrier

Table R402.4.1.1
2. Ceiling/attic

Unchanged.

Table R402.4.1.1
3. Walls

Unchanged. Table R402.4.1.1

Source: ENERGY STAR New Homes
3. Walls

Table R402.4.1.1

Air sealing key points continued

Source: USDOE Vol. 10 Building America
Best Practices Series - Air Sealing

Appendix 2009 IECC
4. Windows, Skylights, and Doors

Source: USDOE Building Energy Codes University

Unchanged.

Source: ENERGY STAR New Homes

Image: Sprayfoam.com
5. Rim Joists

Table R402.4.1.1

Unchanged.
5. Rim Joists

Table R402.4.1.1
6. Floors

Unchanged. 

Table R402.4.1.1
7. Crawl Space Walls

Unchanged. Table R402.4.1.1
8. Shafts, Penetrations

Unchanged.

Table R402.4.1.1

Source: USDOE Building Energy Codes University

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

Unchanged.

Table R402.4.1.1
10. Garage Separation

Unchanged.

Table R402.4.1.1

Source: ENERGY STAR New Homes

Source: USDOE Vol. 10 Building America
Best Practices Series - Air Sealing
11. Recessed Lighting

Recessed light fixtures should be rated for insulation contact and air tight (ICAT).

Airtight can
Airtight wire connection from junction box

Caulk or Gasket
Decorative cover

Source: USDOE Vol. 10 Building America Best Practices Series - Air Sealing

Source: ENERGY STAR New Homes
12. Plumbing and Wiring

Does Not Comply with Code

Table R402.4.1.1

Source: USDOE Vol. 10 Building America - Best Practices Series - Air Sealing
13. Shower/Tub on Exterior Wall

Source: ENERGY STAR New Homes

Table R402.4.1.1

Unchanged.

Source: ENERGY STAR New Homes
Seal all electric outlets and switches with foam sealant, or select boxes with built-in sealant or gaskets.

Source: USDOE Vol. 10 Building America
Best Practices Series - Air Sealing
15. HVAC Register Boots

Unchanged.

Table R402.4.1.1

Source: ENERGY STAR New Homes
16. Fireplace

Gasketed doors is new.

Source: ENERGY STAR New Homes
• New wood-burning fireplaces shall have tight fitting flue dampers or doors, and outdoor combustion air
• Tight fitting doors on fireplaces that are:
  – Factory built – listed and labeled per UL 127
  – Masonry – listed and labeled per UL 907
Visual Checklist Quiz
Which sealing installation complies with the energy code?
Which sealing installation complies with the energy code?

A

B
Which sealing installation complies with the energy code?

A

B
Which sealing installation complies with the energy code?

A

B
Which recessed lighting fixture complies with the Air Barrier and Insulation Installation Table?

A

B
Which sealing detail complies with the Air Barrier and Insulation Installation Table?
Which duct return installation complies with the energy code?
Which insulation complies with the Air Barrier and Insulation Installation Table?
Which insulation complies with the Air Barrier and Insulation Installation Table?
Which insulation complies with the Air Barrier and Insulation Installation Table?
Which insulation complies with the Air Barrier and Insulation Installation Table?
Which eave installation complies with the energy code?

A

B

Baffle
Air Leakage Test
Depressurization Blower Door Test

Air In = Air Out

\( \leq 4 \text{ ACH50} \)

Source: Energy Conservatory
Pressurization Blower Door Test

Air In = Air Out

Source: NCAT
Typical Performance Testing Equipment

- Duct Blaster
- Blower Door Fan
- Digital Manometer
- Exhaust Flow Hood
- Pressure Pan
- Blower Door Frame
The Blower Door Parts - Rings

- Ring A
- Ring B
- Fan Cover
- Fan (no ring = open config)
The Blower Door – The Skin

Hose Eyelets
The Measurement
Blower Door Test
Depressurizing a House

**STEPS**

1. Install blower door with fan exhausting air from house. Rings must be to the inside of the house.
2. Connect hoses as shown.
3. Manometer **MODE** should read PR/FL, **CONFIG** should reflect ring used (open, A, B, or C), and **DEVICE** should reflect BD3.
4. Open all interior doors. Close all exterior doors and windows.
5. Turn OFF airhandler, dryer, all fans and combustion equipment.
6. Turn on blower door, depressurize house to -50 Pascals (side A reading), +/- 0.5 Pa. (hint: canvas should be bulging inward). Use the smallest ring possible to get to -50 Pa. If you have to change the ring, be sure to reflect that in the manometer **CONFIG** setting.
7. Record reading on side B. This is your house cfm leakage at 50 Pa.

<table>
<thead>
<tr>
<th>PR/FL</th>
<th>CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD3</td>
<td>1200</td>
</tr>
<tr>
<td>A1</td>
<td>1</td>
</tr>
</tbody>
</table>
To calculate air changes per hour at 50 Pa:

\[
ACH_{50} = \frac{\text{CFM}_{50} \times 60}{\text{House Volume}}
\]

House volume is cubic feet enclosed by the conditioned space boundary including exterior walls.
Applying Mastic

PLUG, don’t paint!
THICK AS A NICKEL

R403.2.2
Are ducts in exterior walls allowed?
Duct Tightness Testing

**Postconstruction Test**
Total Leakage or Leakage to the Outside
\[ \leq 4 \text{ cfm/100 SF (at 25 PA)} \]
Former leakage to outside limit was 8 cfm/100 SF
Former total leakage limit was 12 cfm/100 SF

**Rough-in Test**
Total Leakage
\[ \leq 4 \text{ cfm/100 SF (at 25 PA)} \]
Former total leakage limit was 6 cfm/100 SF

*Testing not required if ducts and air handler entirely within building thermal envelope.*
Duct Tightness Testing
Total Duct Leakage Test

Source: NCAT
Duct Leakage to the Outside

Source: NCAT
What do plumbers call flex duct?

Source: PTCS
Building Cavities as Return Ducts

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

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
IRC R303.4 Whole house mechanical ventilation mandatory when house is tighter than 5 ACH50.
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

<table>
<thead>
<tr>
<th>FAN LOCATION</th>
<th>AIR FLOW RATE MINIMUM (CFM)</th>
<th>MINIMUM EFFICACY (CFM/WATT)</th>
<th>AIR FLOW RATE MAXIMUM (CFM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range hoods</td>
<td>Any</td>
<td>2.8</td>
<td>Any</td>
</tr>
<tr>
<td>In-line fan</td>
<td>Any</td>
<td>2.8</td>
<td>Any</td>
</tr>
<tr>
<td>Bathroom, utility room</td>
<td>10</td>
<td>1.4</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>Bathroom, utility room</td>
<td>90</td>
<td>2.8</td>
<td>Any</td>
</tr>
</tbody>
</table>
Continuous Mechanical Ventilation

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

<table>
<thead>
<tr>
<th>DWELLING UNIT FLOOR AREA (square feet)</th>
<th>0-1</th>
<th>2-3</th>
<th>4-5</th>
<th>6-7</th>
<th>&gt; 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,500</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>1,501 - 3,000</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>3,001 - 4,500</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
</tr>
<tr>
<td>4,501 - 6,000</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>135</td>
</tr>
<tr>
<td>6,001 - 7,500</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>135</td>
<td>150</td>
</tr>
<tr>
<td>&gt; 7,500</td>
<td>105</td>
<td>120</td>
<td>135</td>
<td>150</td>
<td>165</td>
</tr>
</tbody>
</table>

Note: Manual override required.
### CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE REQUIREMENTS

<table>
<thead>
<tr>
<th>DWELLING UNIT FLOOR AREA (square feet)</th>
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<td>&lt; 1,500</td>
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<td>105</td>
</tr>
<tr>
<td>3,001 - 4,500</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
</tr>
</tbody>
</table>
### Intermittent Whole-House Mechanical Ventilation Rate Factors

<table>
<thead>
<tr>
<th>Run-Time Percent in Each 4-Hour Segment</th>
<th>25%</th>
<th>33%</th>
<th>50%</th>
<th>66%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Exhaust Ventilation**

- Central exhaust fan
- Exhaust air outlet
- Air flow
- Positive air pressure
- Air infiltration
- Negative air pressure

**Balanced Ventilation**

- Room air exhaust ducts
- Exhaust air outlet
- Air flow
- Positive air pressure
- Air infiltration
- Negative air pressure
- Fresh air inlet

**TABLE M1507.3.3(2)**

Intermittent Whole-House Mechanical Ventilation Rate Factors
### Table M1507.4
Minimum Required Local Exhaust Rates for One- and Two-Family Dwellings

<table>
<thead>
<tr>
<th>Area to Be Exhausted</th>
<th>Exhaust Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchens</td>
<td>100 cfm intermittent or 25 cfm continuous</td>
</tr>
<tr>
<td>Bathrooms-Toilet Rooms</td>
<td>Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous</td>
</tr>
</tbody>
</table>
Whole House Ventilation Example

3BR, 2000 SF House = 60 CFM
Whole House Ventilation Example

4BR, 3600 SF House = 90 CFM
What is the best strategy for preventing mold?

A. Eliminate mold spores
B. Freeze or burn spores
C. Control nutrient source
D. Control moisture
Heating and Cooling Equipment

- Sized according to **ACCA Manual S**
- Based on loads calculated per **ACCA Manual J** (or other approved calculation methodology)
75% High Efficacy either:
1. Lamps or
2. Permanently Installed Fixtures

High Efficacy Lamps
1. Compact Fluorescent Lamps (CFL)
2. T-8 or small Diameter Linear Fluorescent Lamps
3. Lamps that meet the minimum lumens/watt

Low-wattage do not count. Interior and exterior count.
High Efficacy Lamp Values

- 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

<table>
<thead>
<tr>
<th>Lamp Efficacy</th>
<th>Lum/Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent Tungsten Filament</td>
<td>7-18</td>
</tr>
<tr>
<td>Incandescent Tungsten Halogen</td>
<td>12-26</td>
</tr>
<tr>
<td>Linear Fluorescent</td>
<td>45-104</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td>33-75</td>
</tr>
<tr>
<td>LED</td>
<td>70-140</td>
</tr>
</tbody>
</table>
Radon Not Addressed in Codes
EPA recommends that all homes built in Zone 1 have radon reduction systems.
Radon Mitigation

Is there a safe level of radon?

Can you test for radon before construction?

Comparison of Death Risks

Deaths per Year

- Home Fires: 3,700
- Drowning: 4,000
- Radon: 20,000
- Motor Vehicle Accidents: 41,000

100 pCi/L
1.25 pCi/L
Is there a safe level of radon? No.

Can you test for radon before construction? No.
Radon enters a home through cracks in concrete, joints in construction below grade, and through poorly sealed crawl space construction.
Radon Mitigation

A. Gas Permeable Layer
   (4” clean gravel)

B. Plastic Sheeting
   (under slab or over crawl space)

C. Sealing and Caulking
   (all openings in concrete floor)

D. Vent Pipe
   (3 or 4 inch PVC pipe)

E. Junction Box
   (if fan needed later)
Radon Mitigation
2015 IECC Residential Changes

- New Chapter on Existing Buildings
- Specifics about inspections
- Historic Buildings must do as much as possible
- Improved Visual Checklist
- Atmospheric Vented Appliances in Sealed Closet
- New Appendices:
  - Energy Rating Index Compliance Path
  - Worst Case Pressurization Testing
  - Solar Ready Provisions
<table>
<thead>
<tr>
<th>Component</th>
<th>Air Barrier Criteria</th>
<th>Insulation Installation Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>General requirements</td>
<td>A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.</td>
<td>Air-permeable insulation shall not be used as a sealing material.</td>
</tr>
<tr>
<td>Ceiling/attic</td>
<td>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.</td>
<td>The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.</td>
</tr>
<tr>
<td>Walls</td>
<td>The junction of the foundation and sill plate shall be sealed.</td>
<td>Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of R-3 per inch minimum. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.</td>
</tr>
<tr>
<td>Windows, skylights and doors</td>
<td>The space between window/door jambs and framing and skylights and framing shall be sealed.</td>
<td>(partial table)</td>
</tr>
</tbody>
</table>
Energize Montana deq.mt.gov/energy

energycodes.gov