Conducting Plan Reviews for the 2018 IECC
Part 1

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Learning Objectives and Content

1. Significant Changes to the 2018 IECC

2. How to Review Construction Documents
   (Suggested by the MTDEQ Building Department Survey)

3. Introduce Building Science and the Energy Code
   (Suggested by discussion at the Energy Codes Working Group)

4. What’s Coming Down the Road – 2021 IECC
Introduction
Energy Codes born from Oil Crises of the 1970s
Given Second Class Status – Not Life and Safety
Current Drivers - Global Warming
How Energy Codes are Different than Other Codes

Comfort

Indoor Air Quality

Durability
The IECC Through the Years

MT Adopted the 2012 IECC in 2014
MT Will Adopt the 2018 IECC in 2020

2021 IECC Finalized
Most Model Codes
(IRC, IBC, IMC, UPC, NEC, etc.)

Listening Sessions
March 2018

State Adopted
Effective 12/7/2019

Local Jurisdictions had 90 Days to Adopt

- 2018 IECC Published by ICC [Fall 2017]
- State Listening Sessions [August 2019]
- State IECC Working Group Meeting [January 2020]
- DLI Prepares Findings – Submits for Legal Review [July 2020]
- Building Codes Council Holds Public Hearing and Makes Recommendations [Date TBD]
- DLI Prepares Rules Proposal [Date TBD]
- Rules Hearing Process [Date TBD]
  - Opportunity for Public Comment
  - Legislative Interim Committee Review
  - Publication by Secretary of State
- Local Jurisdictions had 90 Days to Adopt [Date TBD]

Where We Are Now
Why Plan Review Is Important

[R103] Construction documents must be submitted for each permit application.

[R103.3] Code official shall examine and determine compliance of construction documents.

[R103.3.1] Approved construction documents must be stamped “Reviewed for Code Compliance.”

Gets everyone on the same wavelength.

• Builder/Owner
• Plan Reviewer
• Inspector(s)

It’s easier to fix a code compliance problem with an eraser than with a sawzall.
# Building Thermal Envelope (R402)

<table>
<thead>
<tr>
<th>Value From Plans</th>
<th>Component</th>
<th>Code Provision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low-Energy Building</td>
<td>Per R402.1</td>
</tr>
<tr>
<td></td>
<td>Log Building</td>
<td>Designed in compliance with ICC400</td>
</tr>
</tbody>
</table>

**Fenestration (Windows, Doors, and Skylights, Table 402.1.2)**

<table>
<thead>
<tr>
<th>Value From Plans</th>
<th>Component</th>
<th>Code Provision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fenestration</td>
<td>Weighted average R-factor allowed</td>
</tr>
<tr>
<td></td>
<td>Windows &amp; Doors</td>
<td>Area weighted average (max. value)</td>
</tr>
<tr>
<td></td>
<td>Skylight</td>
<td>U-factor (max. value)</td>
</tr>
<tr>
<td></td>
<td>Fenestration</td>
<td>Windows, doors, and skylights certified and labeled</td>
</tr>
<tr>
<td></td>
<td>Glazing</td>
<td>15 Ft² glazed fenestration exemption</td>
</tr>
<tr>
<td></td>
<td>Doors</td>
<td>24 Ft² Opaque door exemption</td>
</tr>
<tr>
<td></td>
<td>Fenestration</td>
<td>Infiltration rate maximum for windows, skylights, and sliding doors</td>
</tr>
</tbody>
</table>

**General - Thermal Envelope Provisions Exempt**

- Low-Energy Building: Per R402.1
- Log Building: Designed in compliance with ICC400

Changes in 2018 IECC:

A "?" in the "Complies" column indicates potential changes when MT adopts the 2018 IECC based on past or proposed amendments.
Definitions [R202]

[R202] Commercial Building. All buildings not a “Residential Building.”

[R202] Residential Building. Detached one- and two-family dwellings and townhouses as well as Group R-2, R-3, and R-4 buildings three stories and less above grade.

Residential Buildings

• Detached single family dwellings and duplexes (R-3)

• Apartments, dormitories, condominiums, and townhouses (R-2) ≤ 3 stories

• (R-4) Small residential care/assisted living facilities, 6 to 16 occupants, ≤ 3 stories
Example 1. Three story (above grade) apartment building (R-2).
Example 1. Three story (above grade) apartment building (R-2).
Example 2. Four story condominium building (R-2).
Example 2. Four story condominium building (R-2).
Example 3. A 3-story mixed occupancy building

- Apartments
- Apartments
- Office/Retail
Example 3. A 3-story mixed occupancy building
Example 4. 4-story mixed occupancy building

- Condominiums
- Condominiums
- Condominiums
- Office/Retail
Example 4. 4-story mixed occupancy building

Condominiums
Condominiums
Condominiums
Office/Retail

Commercial Provisions Apply
IECC adopted by Montana
IECC addresses only energy
IECC addresses both residential and commercial buildings, in separate sections

IRC addresses all topics (*energy, structural, mechanical, etc.*)
IRC addresses subset of residential (detached one- and two-family dwellings and townhouses 3 stories or fewer)
IRC Chapter 11, the energy chapter is not adopted by Montana
“to confirm compliance with the code.” [R103.1]

“examine...construction documents and shall ascertain whether the construction indicated and described is in accordance with the requirements...” [R103.2]
1. Insulation Materials & R-values
2. Fenestration U-Factors
3. Area Weighted U-Factor Calculations
4. Mechanical Systems Design Criteria
5. Mech/DHW Types, Sizes, Efficiencies
6. Equipment Systems and Controls
7. Duct Sealing, Duct & Pipe Insulation
8. Air Sealing Details
9. Depict building thermal envelope
"All insulation levels will comply with the 2018 IECC."

Not Acceptable!

(according to the IECC Code and Commentary)
“drawn to scale...sufficient clarity to indicate the location, nature, and extent of the work proposed.”
Footing and Foundation Inspection

- R-value
- Location
- Thickness
- Depth of Burial
- Protection

Framing and Rough-in Inspection

- Before interior finish
- R-values (Location and Installation)
- Fenestration U-factor
- Air leakage controls
- Types of Insulation
- R-values & Protection
Plumbing Rough-in
- Types of Insulation
- R-values & Protection
- Required Control

Mechanical Rough-in Inspection
- HVAC Equipment Type & Size
- Required Controls
- Duct System Insulation & R-value
- System Air Leakage Control
- Programmable Thermostats
- Dampers
- Whole House Ventilation
- Minimum Fan Efficiency
Final Inspection

- Required Building Systems
- Equipment & Controls (Proper Operation)
- Number of High-Efficacy Fixtures
Approved Inspection Agencies

Code official authorized to accept reports of approved third-party inspection agencies.

As an alternative to the building department conducting the inspection.
Definition: Conditioned Space [R202]

- Enclosed within Building Thermal Envelope
- Directly or Indirectly Heated or Cooled

Indirectly Heated or Cooled Spaces:

- Contain Uninsulated Ducts, Piping, or Other Sources of Heating or Cooling
- Separated by Uninsulated walls, Floors, or Ceilings
- Communicate through Openings with Conditioned Spaces

Why Important?
Duct Tightness Limit Calculation
3 Thermal Envelope

Compliance Paths
<table>
<thead>
<tr>
<th>Prescriptive</th>
<th>Performance</th>
<th>Energy Rating Index</th>
</tr>
</thead>
</table>
Prescriptive Compliance Path Options

Prescriptive Compliance Path Options

- Insulation/Fenestration Table
- U-Factor Alternative
- Trade-off Alternative (REScheck)

REScheck is based on un-amended 2018 IECC
Energy Code Compliance Path Options

Prescriptive
+ Mandatory Provisions

Performance
+ Mandatory Provisions

Energy Rating Index
+ Mandatory Provisions

Must comply with all **provisions** R402 through R404

Must also comply with all “Mandatory” **provisions** in R402 through R404
REScheck™

DOE’s Building Energy Codes Program
Internet Address: www.energycodes.gov

Energy Efficiency and Renewable Energy • U.S. Department of Energy

REScheck Web™ simplifies residential energy code compliance by automating the trade-off calculations for the International Energy Conservation Code (IECC) and a number of state-specific codes. It performs just like REScheck, the desktop version, but you don’t need to download or install any software on your computer.
REScheck Software

Great for Total UA Tradeoffs but Not For ERI

http://www.energycodes.gov/rescheck
REScheck™ for Windows and REScheck™-Web

1. Two Versions: REScheck for Windows and REScheck-Web
2. 2018 IECC only available on REScheck-Web
3. Also has Performance based compliance path but does not allow HVAC or air tightness tradeoffs. ERI has more flexibility.
4. REScheck not customized for Montana Amendments (i.e., frame wall insulation)

**In other words, to get a ”Pass” must meet un-amended 2018 IECC envelope requirements.**
<table>
<thead>
<tr>
<th>Project</th>
<th>Last Updated</th>
<th>Energy Code</th>
<th>Status</th>
<th>Sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill Street House</td>
<td>Feb 12, 2020 8:54:02 AM</td>
<td>2018 IECC</td>
<td>Draft</td>
<td></td>
</tr>
<tr>
<td>A Sample Project</td>
<td>Feb 11, 2020 3:35:34 PM</td>
<td>2015 IECC</td>
<td>Draft</td>
<td></td>
</tr>
<tr>
<td>Horton test 1</td>
<td>Feb 11, 2020 3:33:04 PM</td>
<td>2018 IECC</td>
<td>Draft</td>
<td></td>
</tr>
</tbody>
</table>
REScheck Software

- Code Selection
- Building Characteristics
### Building Inputs

#### Ceilings / Skylights (1 assembly)

<table>
<thead>
<tr>
<th>Ceiling</th>
<th>Assembly</th>
<th>Gross Area</th>
<th>R-Value</th>
<th>U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>Flat Ceiling or Scissor Truss</td>
<td>1376</td>
<td>13</td>
<td>0.02</td>
</tr>
</tbody>
</table>

#### Walls / Windows / Doors (4 assemblies)

<table>
<thead>
<tr>
<th>Walls</th>
<th>Assembly</th>
<th>Gross Area</th>
<th>Orientation</th>
<th>R-Value</th>
<th>U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front E Wall</td>
<td>Wood Frame, 24&quot; o.c.</td>
<td>240</td>
<td>Front side</td>
<td>21</td>
<td>0.042</td>
</tr>
<tr>
<td>Doors</td>
<td>Solid Door (under 50% glazing)</td>
<td>21</td>
<td></td>
<td>21</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Requirements Checklist

Plan Review (2)

   - Requirement resolution
   - Resolution will be met
   - Plans reference page / section:

2. [302.1, 403.7] Heating and cooling equipment is sized per ACCA Manual S based on loads calculations.
### Inspection Checklist

**Energy Code: 2018 IECC**

Requirements: 0.0% were addressed directly in the REScheck software.

Text in the “Comments/Assumptions” column is provided by the user in the REScheck Requirements screen. For each requirement, the user certifies that a code requirement will be met and how that is documented, or that an exception is being claimed. Where compliance is itemized in a separate table, a reference to that table is provided.

<table>
<thead>
<tr>
<th>Section &amp; Req.ID</th>
<th>Pre-Inspection/Plan Review</th>
<th>Plans Verified Value</th>
<th>Field Verified Value</th>
<th>Complies?</th>
<th>Comments/Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>103.1, 103.2</td>
<td>Construction drawings and documentation demonstrate energy code compliance for the building envelope. Thermal envelope represented on construction documents.</td>
<td></td>
<td></td>
<td>Complies</td>
<td></td>
</tr>
<tr>
<td>[PR1]^1</td>
<td></td>
<td></td>
<td></td>
<td>Does Not</td>
<td>Not Observable</td>
</tr>
<tr>
<td>103.1, 103.2, 403.7</td>
<td>Construction drawings and documentation demonstrate energy code compliance for lighting and mechanical systems. Systems serving multiple dwelling units must demonstrate compliance with the IECC Commercial Provisions.</td>
<td></td>
<td></td>
<td>Complies</td>
<td></td>
</tr>
<tr>
<td>[PR3]^1</td>
<td></td>
<td></td>
<td></td>
<td>Does Not</td>
<td>Not Observable</td>
</tr>
<tr>
<td>302.1, 403.7</td>
<td>Heating and cooling equipment is sized per ACCA Manual S based on loads calculated per ACCA Manual J or other methods approved by the code official.</td>
<td>Heating: Btu/hr</td>
<td></td>
<td>Complies</td>
<td></td>
</tr>
<tr>
<td>[PR2]^2</td>
<td></td>
<td></td>
<td></td>
<td>Does Not</td>
<td>Not Observable</td>
</tr>
</tbody>
</table>

Inspection checklist is limited and does not auto-fill values.
Energy Analysis and Plan Review Calculations

**Energy Code Envelope Compliance**

- **Prescriptive Values**
  - Tables R402.1.2 & R402.1.4 [Area Weighted Calculations]

- **Prescriptive Envelope Tradeoff**
  - Total UA Alternative – Manual Calc. or Spreadsheet
  - Total UA Alternative – REScheck

- **Performance or ERI**
  - Energy Modeling – Simulated Performance [R405]
  - ERI Alternative [R406] – REMRate™, EnergyGauge™, Ecotrope™

**Important Plan Review Note:** Values on Construction Drawings must Match Energy Analysis. Verify that information on the schedules matches what is on the energy analysis.
The average U-value and R-value if a surface area having two different areas of differing insulation characteristics can be calculated as follows:

\[ U = (A_1 \times U_1) + (A_2 \times U_2) + \ldots \]

- U is area-weighted average U-value
- \( A_1 \) is the decimal fraction of wall represented by framing
- \( U_1 \) is the U-value of the framing members
- \( A_2 \) is the decimal fraction of the wall represented by insulation within the cavity
- \( U_2 \) is the U-value of the insulated cavity
- R is the area-weighted R-value of the wall

This formula can be extended for more than two different areas:
Attic Hatch Area Weighted U-Factor Calculation

Find the overall U-value of the attic/hatch assembly

\[ U_{\text{attic}} = \frac{1}{R_{30}} = 0.033 \text{ Btu/Hr} \cdot \text{ft}^2 \cdot \circ F \]
\[ U_{\text{hatch}} = \frac{1}{R_2} = 0.5 \text{ Btu/Hr} \cdot \text{ft}^2 \cdot \circ F \]

\[ A_{\text{atticfraction}} = \frac{(1000 - 8)}{1000} = 0.992 \]
\[ A_{\text{hatchfraction}} = \frac{8}{1000} = 0.008 \]

\[ U_{\text{assembly}} = (A_{\text{frac}} \times U_1) + (A_{\text{frac}} \times U_2) \]
\[ U_{\text{assembly}} = (0.992 \times 0.033) + (0.008 \times 0.5) = 0.0367 \text{ Btu/Hr} \cdot \text{ft}^2 \cdot \circ F \]

\[ R_{\text{average}} = \frac{1}{0.0367} = 27.22 \]
### U-Factor Alternative [R402.1.4]

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value Cavity</th>
<th>R-value Stud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside air film</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Cavity insulation</td>
<td>21</td>
<td>5.5” Stud</td>
</tr>
<tr>
<td>Exterior sheathing</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Exterior siding</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Outside Air Film</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Total R-value</strong></td>
<td><strong>23.8</strong></td>
<td><strong>9.68</strong></td>
</tr>
</tbody>
</table>

| U-value (1/R)             | 0.042          | 0.103        |
| **Area Fraction**         | **0.8**        | **0.2**      |

\[
U_{\text{areaweighted}} = (A_{1\text{ fract}} \times U_1) + (A_{2\text{ fract}} \times U_2)
\]

\[
U_{\text{areaweighted}} = (0.8 \times 0.042) + (0.2 \times 0.103) = \mathbf{0.0542}
\]

\[
R_{\text{average}} = \frac{1}{0.0542} = 18.45
\]
Blank printable copies are available on the DEQ website at:
deq.mt.gov/Energy/eec/EnergyCode

Can Serve as Self-Certification Notice to Homeowner
Exception 1. Low-Energy Buildings

A. Peak design rate of energy usage less than 3.4 Btu/h or 1.0 watt/ft² for space-conditioning
B. No conditioned spaces

Exception 2. ICC 400
ICC 400 Includes:

- Log Grading
- Moisture Content
- Structural Design
- Settling Allowances
- Fire Resistance
- Thermal Performance

3 Compliance Methods
- Prescribed
- Test Method
- Calculation Method
IECC Section R402 Building Thermal Envelope

R402.1 General (Prescriptive) Exceptions

2. Log homes designed in accordance with ICC 400.

ICC 400 Section 305 Thermal Envelope

305.2 Buildings must comply with the IECC.

Exception: Compliance with Section 305.3 (Thermal Properties of Log Walls) of this standard shall be permitted to satisfy Section 402.1 of the IECC.
### Thermal Envelope Prescribed Method (305.1.1.2)

Insulation and Fenestration Requirements by Component Table 305.3.1.2

<table>
<thead>
<tr>
<th>Log Wall $W_L$</th>
<th>Fenestration U-Factor</th>
<th>Skylight U-Factor</th>
<th>Ceiling U-factor</th>
<th>Wood Frame Wall R-Value</th>
<th>Floor R-Value</th>
<th>Basement/Crawl Wall R-Value</th>
<th>Slab R-Value &amp; Depth</th>
<th>Heated Slab R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5” if SG ≤ 0.50</td>
<td>0.33</td>
<td>0.60</td>
<td>49</td>
<td>20 or 13+5</td>
<td>30</td>
<td>15/19</td>
<td>15, 4'</td>
<td>15</td>
</tr>
<tr>
<td>7” if SG &gt; 0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$W_L$ is Average Width

- Ponderosa Pine SG=0.4
- Western Larch SG=0.52
- Lodgepole Pine SG=0.41
Building Envelope Air Tightness
The same testing and air tightness requirements apply to log walls as for any other method of construction.

Vapor Retarder (within R402.1)
As noted in Exception 3 of IRC Section R702.7
Not required in “construction where moisture or its freezing will not damage the materials.”
There is no cavity to protect in a log wall…….
Why will building tightness testing be required of log homes?

The thermal envelope exception in R402.1 for log buildings applies only to the thermal envelope provisions R402.1.1 through R402.1.5.

Building tightness testing requirements are in provision R402.4 and therefore not affected by the ICC 400 exception.
4 Building Science
Building Science (BS) is what we know now about how buildings work.
Heat Transfer Mechanisms

Conduction, Convection, & Radiation

Source: NCAT

Radiation
Heat Transfer Through Walls

Only Conduction

Cold

Hot

Source: NCAT
R-values is the measure thermal resistance

U-value is the rate of heat transfer

R-value is the inverse of U-value (Btu/Hr • ft² • °F): \[ R = \frac{1}{U} \text{ and } U = \frac{1}{R} \]

R-values are additive, U-values are not additive

R-values of a series of components can be added; the inverse of this sum will be the U-value.

- \[ R_1 + R_2 = R \text{ total} \]
- \[ U_1 + U_2 = \text{Garbage} \]
- \[ R = \frac{1}{U} \text{ and } U = \frac{1}{R} \]
### Common Insulating Materials

<table>
<thead>
<tr>
<th>INSULATING MATERIAL</th>
<th>Avg. R-Value per inch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiberglass</strong></td>
<td></td>
</tr>
<tr>
<td>Unfaced batt, standard density</td>
<td>R-2.9 to R-3.8</td>
</tr>
<tr>
<td>Unfaced batt, high density</td>
<td>R-3.7 to R-4.3</td>
</tr>
<tr>
<td>Blown fiberglass</td>
<td>R-2.2 to R-2.7</td>
</tr>
<tr>
<td><strong>Expanded Polystyrene (EPS)</strong></td>
<td></td>
</tr>
<tr>
<td>Rigid foam board</td>
<td>R-3 to R-4</td>
</tr>
<tr>
<td>Beads</td>
<td>R-2.3</td>
</tr>
<tr>
<td><strong>Extruded Polystyrene (XPS)</strong></td>
<td></td>
</tr>
<tr>
<td>Rigid foam board</td>
<td>R-5</td>
</tr>
<tr>
<td><strong>Polyisocyanurate</strong></td>
<td></td>
</tr>
<tr>
<td>Rigid board</td>
<td>R-5.6 to R-8</td>
</tr>
<tr>
<td>With foil facing</td>
<td>R-7.1 to R-8.7</td>
</tr>
<tr>
<td><strong>Polyurethane</strong></td>
<td></td>
</tr>
<tr>
<td>Spray foam or foam board</td>
<td>R-7 to R-9</td>
</tr>
<tr>
<td>Foam board with foil facing</td>
<td>R-7.1 to R-8.7</td>
</tr>
<tr>
<td>Soy-based polyurethane spray foam</td>
<td>R-3.7</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td>Cellulose, blown</td>
<td>R-3.6 to 3.8</td>
</tr>
<tr>
<td>Mineral wool, rock or slag, batt or loose</td>
<td>R-3.7</td>
</tr>
<tr>
<td>Cotton batt</td>
<td>R-3.4</td>
</tr>
<tr>
<td>Sheep’s wool batt</td>
<td>R-3.5</td>
</tr>
<tr>
<td>Strawbale</td>
<td>R-2.4</td>
</tr>
<tr>
<td>Plastic PET</td>
<td>R-3.8 to R-4.3</td>
</tr>
</tbody>
</table>

Source: DOE Energy Savers website: www.energysavers.gov/your_home/insulation_airsealing/index.cfm/mytopic=11510

Source: USDOE Building Technologies Program, Whole-House Energy Savings in Cold and Very Cold Climates
Fiberglass Batts (Real World)

- Rated R-value
- "Best Practice***"
- Typical Installation*
- Steel Stud wall

Graph showing the comparison of different installation methods for fiberglass batts.
Effective R-Value of Wall Types

Based on % Framing and Insulation Grade

- 2x6, 24", R21+5 (15%)
- 2x6, 16", R21+5 (23%)
- 2x4, 24", R13+10 (15%)
- 2x4, 16", R13+10 (23%)
- 2x6, 24", R21 (15%)
- 2x6, 16", R21 (23%)

Annual Consumption MMBtu/Yr

Grade III
Grade II
Grade 1
R-Values and The Law of 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%

R-Value vs. Btu/Deg F/SF
Temperature Gradients - Three Exterior Insulation Alternatives

- **Nominal:** R19
- **Effective:** R14.4
- R19 + R5
  - **Effective:** R-19.4
- R19 + R10
  - **Effective:** R-23.8

**Outside Temperatures:**
- 32° Outside
- 0° Outside

**Inside Temperature:**
- 70° Inside
Diagram is based on **inside air being warmer** than outside air (Winter).

When **outside air is warmer** than inside air, this process is reversed (Summer).
Wind creates positive and negative pressures within the house.
At 100% relative humidity the dew point temperature is the same as the air temperature.
Relative Humidity and Dew Point
Daily water vapor produced by family of 4:

- Respiration and perspiration: 14 lbs
- Showers & bathing: 3 lbs
- Cooking: 2 lbs
- Other activities: 2 lbs

Total: 21 lbs = 2.5 gallons
Indoor Humidity

Optimal Temperature and Humidity Ranges for People with Respiratory Issues

2015 National Asthma Council Australia
Vapor Movement by Air Transport

Air Molecules

Water Vapor Molecules

Direction of Heating Season Air and Water Vapor Movement
Air movement is typically far more important than vapor diffusion.

- **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*
Common Household Air Leaks

A. Behind Kneewalls
B. Attic Hatch
C. Wiring Holes
D. Plumbing Vent
E. Open Soffit (the box that hides recessed lights)
F. Recessed Light
G. Furnace Flue or Duct Chaseways (the hollow box or wall feature that hides ducts)
H. Basement Rim Joists (where the foundation meets the wood framing)
I. Windows and Doors

Source: USEPA, A DO-IT-YOURSELF GUIDE TO SEALING AND INSULATING WITH ENERGY STAR® SEALING AIR LEAKS AND ADDING ATTIC INSULATION
House Tightness and Interior Humidity

Tighter Building Envelope \rightarrow Increased Interior Relative Humidity

The higher the RH the greater likelihood of condensation
House Tightness and Interior Humidity

Tighter Building Envelope Increases Interior Relative Humidity

Exhaust Decreases Interior Relative Humidity

Could reduce or eliminate moisture sources
Continuous Air Barrier in Building Envelope

Class I or II
Vapor Retarder – Above Grade Walls
Water is related to 90% of building and material failures (ASHRAE)

Estimated $9 Billion/year in repairs for water related failures
Mold and Rot

Courtesy of Building Science Corp.
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**
Window Condensation

Is it Magic?

Source: Lawrence Berkeley National Laboratory
Exterior Sheathing Temperature – No Insulation

**Inside**
- 70°F
- 45°F Dew Point

**Outside**
- 30°F
- 55°F Sheathing Surface Temperature
Exterior Sheathing Temperature – With Insulation

**Inside**
- 70°F
- 45°F Dew Point

**Outside**
- 30°F
- 32°F Sheathing Surface Temperature
Pre-enlightenment Wall (No Vapor Retarder, No Air Barrier, No WRB)

Vapor Movement
From Warm Moist to Cool Dry

Air Transport

Diffusion

Bulk Moisture

Wind Washing
Enhanced Wall: With Vapor Retarder, With Air Barrier, with WRB

- Drainage Plane Gap
- Water Resistant Barrier
- Warm Side Class II or III
- Vapor Retarder
- Sealed Air Barrier
- Exterior Insulation
Does the code allow the air barrier and vapor retarder to be the same material(s)?

YES
Does the code allow two air barriers? YES
Is that a good idea? Depends
Does the code allow two vapor retarders?  
YES

Is that a good idea?  
Depends
Does the IECC require house wrap?

No, but the IRC requires a water-resistive barrier. [IRC R703.2]
5 Thermal Envelope Code Provisions
## Prescriptive Component Requirements [R402.1.2]

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirements</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows &amp; Doors</td>
<td>U-0.30</td>
<td></td>
</tr>
<tr>
<td>Skylights</td>
<td>U-0.55</td>
<td></td>
</tr>
<tr>
<td>Ceiling</td>
<td>R-49</td>
<td>R-38 complies if uncompressed insulation extends over top of exterior wall top plates.</td>
</tr>
<tr>
<td>Wood Frame Wall</td>
<td>R-21 or R-13+5</td>
<td>First value is cavity insulation; second value, if present, is continuous insulation.</td>
</tr>
<tr>
<td>Mass Wall</td>
<td>R-15/R-20</td>
<td>Second value applies when more than half of R-value is on interior if mass wall.</td>
</tr>
<tr>
<td>Floor</td>
<td>R-30</td>
<td>Insulation that fills cavity (R-19 minimum) also complies.</td>
</tr>
<tr>
<td>Basement Wall</td>
<td>R-15/R-19</td>
<td>First value is continuous; second value is for framing cavity</td>
</tr>
<tr>
<td>Slab</td>
<td>R-10, 4'</td>
<td>Insulation must extend downward continuously from top of slab for 4 feet vertically or horizontally. R-15 if radiant heat is installed in floor.</td>
</tr>
<tr>
<td>Crawlspace Wall</td>
<td>R-15/R-19</td>
<td>First value is continuous inside or outside; second value is for insulation in framing cavity</td>
</tr>
</tbody>
</table>
Window U-Factor [R402.3.2] National Fenestration Rating Council [R301.1.3]

Lower means less heat loss.

Source: www.nfrc.org
Solar Heat Gain Coefficient (SHGC) measures how well a product blocks heat from the sun. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Assumes the sun strikes the glass at 90 degrees.

Visible Transmittance (VT) measures how much light comes through a glazing. VT is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.
## Default Fenestration U-Factors [R303.1.3]

<table>
<thead>
<tr>
<th>Frame Type</th>
<th>Labeled</th>
<th>Default</th>
<th>Skylight U-Factors</th>
<th>Labeled</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
<td>2018</td>
<td>Single Pane</td>
<td>Double</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pane</td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>0.32</td>
<td>0.30</td>
<td>1.2</td>
<td>0.8</td>
<td>0.55</td>
</tr>
<tr>
<td>Metal with Thermal Break</td>
<td>0.32</td>
<td>0.30</td>
<td>1.1</td>
<td>0.65</td>
<td>0.55</td>
</tr>
<tr>
<td>Nonmetal or Metal Clad</td>
<td>0.32</td>
<td>0.30</td>
<td>0.95</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Glazed Block</td>
<td>0.32</td>
<td>0.30</td>
<td>0.6</td>
<td>0.6</td>
<td>0.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Door Type</th>
<th>Labeled U-Factor</th>
<th>Default U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uninsulated Metal</td>
<td>0.32</td>
<td>0.30</td>
</tr>
<tr>
<td>Insulated Metal</td>
<td>0.32</td>
<td>0.30</td>
</tr>
<tr>
<td>Wood</td>
<td>0.32</td>
<td>0.30</td>
</tr>
<tr>
<td>Insulated, nonmetal edge, max. 45% glazing double pane</td>
<td>0.32</td>
<td>0.30</td>
</tr>
</tbody>
</table>
### Doors [R402.5]

**Typical Door R-values**

- **Solid Core Wood Doors**
  - $R=2.5$ ($U=0.40$)
- **Wood Panel Doors w/ Recessed Areas**
  - $R=1.75$ ($U=0.57$)
- **Insulated Panel Doors**
  - $R=5-7$ ($U=0.20-0.14$)

### Energy Performance Ratings

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Default Frame **</th>
<th>U-Factor/Solar Heat Gain Coefficient (SHGC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Wood</strong></td>
<td>1/4 Lit $\leq 40\text{ft}$</td>
</tr>
<tr>
<td>2&quot;x1/na/AIR/0.250</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>2&quot;x1/.0203/ARG/0.750</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>2&quot;x1/na/AIR/0.675</td>
<td></td>
<td>0.28</td>
</tr>
<tr>
<td>3&quot;5/na/AIR/0.250</td>
<td>0.21</td>
<td>0.25</td>
</tr>
<tr>
<td>Flush/Embossed</td>
<td><strong>U-Factor 0.19</strong></td>
<td>SHGC 0.04</td>
</tr>
</tbody>
</table>

*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-emissivity (surface) / gap fill / gap width (na-not applicable)**

**per NFRC 100 Section B3.24**

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**www.nfrc.org**

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96
No Solar Heat Gain Coefficient (SHGC) Requirement in Montana climate zone.

May Use Area Weighted U-factor Calculation for prescriptive U-factor.

Up to 15 Ft$^2$ of Glazed Fenestration per Dwelling Unit is Exempt from Prescriptive U-factor Requirements.

One Side-hinged Opaque Door up to 24 Ft$^2$ Exempted from the Prescriptive U-Factor Requirement.
<table>
<thead>
<tr>
<th>WOOD FRAME  R-VALUE REQUIREMENT</th>
<th>COLD-FORMED STEEL EQUIVALENT R-VALUE(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Steel Truss Ceilings(^b)</strong></td>
</tr>
<tr>
<td>R-30</td>
<td>R-38 or R-30 + 3 or R-26 + 5</td>
</tr>
<tr>
<td>R-38</td>
<td>R-49 or R-38 + 3</td>
</tr>
<tr>
<td>R-49</td>
<td>R-38 + 5</td>
</tr>
<tr>
<td></td>
<td><strong>Steel-Framed Wall, 16” on center</strong></td>
</tr>
<tr>
<td>R-21</td>
<td>R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or</td>
</tr>
<tr>
<td></td>
<td>R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Framed Wall, 24” on center</strong></td>
</tr>
<tr>
<td>R-21</td>
<td>R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or</td>
</tr>
<tr>
<td></td>
<td>R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9</td>
</tr>
</tbody>
</table>

### Walls - Table R402.2.6

**R-21 Wood Frame 16” o.c.**
- R-0 + R-14.6
- R-13 + R-9.5
- R-15 + R-9.1
- R-19 + R-8.4
- **R-21 + R-8.1**

**R-21 Wood Frame 24” o.c.**
- R-0 + R-14.6
- R-13 + R-8.3
- **R-15 + R-7.7**
- R-19 + R-6.9
- **R-21 + R-6.5**
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.
Vented attics with air permeable insulation must include baffle adjacent to soffit and eave vents that extends over insulation.
Ice Dams Extra Credit

Source: USDOE Building Technologies Program, *Whole-House Energy Savings in Cold and Very Cold Climates*
When might the code provision not solve the ice dam problem?
Where not enough room in joist space to achieve prescribed R-value:

**IECC**

R-30 is allowed for up to 500 $\text{Ft}^2$ for 20% of ceiling area, whichever is less.

**Montana Amendment**

R-30 is allowed for up to 250 $\text{Ft}^2$ for 10% of ceiling area, whichever is less.
Access Hatches
Insulated to adjoining area and **weather-stripped**.

Vertical Access Doors
Allows vertical doors to meet the fenestration requirements.
Unvented Attic
Air Impermeable Insulation Only

Wood Shingles and Shakes Require ¼” Vented Air Space

1. Air Impermeable Insulation in Direct Contact with Sheathing

2. Air Impermeable Insulation must be Class II Vapor Retarder or Have a Class II Vapor Retarder on the Underside.

3. Class I Vapor Retarder Not Allowed
Unvented Enclosed Rafter Assembly [IRC R806.5.5.1]
Air Impermeable Insulation Only

Wood Shingles and Shakes Require ¼” Vented Air Space

1. Air Impermeable Insulation in Direct Contact with Sheathing

2. Air Impermeable Insulation must be Class II Vapor Retarder or Have a Class II Vapor Retarder on the Underside. Class I Vapor Retarder Not Allowed
Unvented Attic [IRC R806.5.5.2]
Air Impermeable Insulation Above Sheathing, Air Permeable Insulation Below

1. Rigid Board Insulation Above Sheathing ≥ R-25

2. Air Permeable Insulation in Direct Contact with the Roof Sheathing (≥ R-24), must be Class II Vapor Retarder or have a Class II Vapor Retarder directly applied to the underside

3. Class I Vapor Retarder Not Allowed

Wood Shingles and Shakes Require ¼” Vented Air Space
Unvented Attic [IRC R806.5.5.3]

Air-Impermeable Insulation in Contact with Sheathing, Air-Permeable Insulation Below

1. Air-Impermeable Insulation in Direct Contact with Sheathing Min. R-25
2. Air Permeable Insulation (≥ R-24), in Direct Contact with the Air Impermeable Insulation must be Class II Vapor Retarder or have a Class II Vapor Retarder directly applied to the underside
3. Class I Vapor Retarder Not Allowed

Wood Shingles and Shakes Require ¼” Vented Air Space
<table>
<thead>
<tr>
<th>IECC</th>
<th>Fenestration U-Factor</th>
<th>Skylight U-Factor</th>
<th>Ceiling U-factor</th>
<th><strong>Wood Frame Wall R-Value</strong></th>
<th>Mass Wall R-Value</th>
<th>Floor R-Value</th>
<th>Basement Wall R-Value</th>
<th>Slab R-Value &amp; Depth</th>
<th>Crawl Space Wall R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0.33 [0.33]</td>
<td>0.60</td>
<td>49</td>
<td>20 or 13+5 [21 or 13+5]</td>
<td>15/19</td>
<td>30</td>
<td>15/19</td>
<td>10, 4'</td>
<td>10/13 [10/19]</td>
</tr>
<tr>
<td>2012</td>
<td>0.32</td>
<td>0.6</td>
<td>49</td>
<td>20+5 or 13+10 [21 or 13+5]</td>
<td>15/20</td>
<td>30</td>
<td>15/19</td>
<td>10, 4'</td>
<td>15/19</td>
</tr>
<tr>
<td>2015</td>
<td>0.32</td>
<td>0.6</td>
<td>49</td>
<td>20+5 or 13+10</td>
<td>15/20</td>
<td>30</td>
<td>15/19</td>
<td>10, 4'</td>
<td>15/19</td>
</tr>
<tr>
<td>2018</td>
<td>0.30</td>
<td>0.6</td>
<td>49</td>
<td>20+5 or 13+10</td>
<td>15/20</td>
<td>30</td>
<td>15/19</td>
<td>10, 4'</td>
<td>15/19</td>
</tr>
</tbody>
</table>
Continuous Insulation

- Continuous Across All Structural Members
- Without Thermal Bridges Other Than Fasteners and Service Openings
- May Be Installed on Interior or Exterior
- May Be Integral to Building Envelope Component
Common Insulation Materials

Batt Insulation

Spray Foam

Blown-in Air Permeable Insulation

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
High Density Foam is one of the best solutions for insulating the rim joist.
Foam with a density greater than about 1 1/2 pounds per cubic foot is considered high-density. Foam with a density less than 1 ½ pounds per cubic foot is considered low-density foam. Low-density foam does not make a good vapor retarder.
Why can fiberglass batt insulation perform so poorly?

• The gaps and spaces dominate the heat loss
• No matter how much insulation you pile up next to a gap, the heat loss through the gap is not reduced
• The larger the initial R-value, the greater the effect
Vapor Retarders [R402.1.1] [IRC R702.7]
## Vapor Retarders [R402.1.1] [IRC R702.7]

<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 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
<table>
<thead>
<tr>
<th>Zone</th>
<th>Class III vapor retarders permitted for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>• Vented cladding over fiberboard</td>
</tr>
<tr>
<td></td>
<td>• Vented cladding over gypsum</td>
</tr>
<tr>
<td></td>
<td>• Insulated sheathing with R-value</td>
</tr>
<tr>
<td></td>
<td>≥ R-7.5 over 2x4 wall</td>
</tr>
<tr>
<td></td>
<td>• Insulated sheathing with R-value</td>
</tr>
<tr>
<td></td>
<td>≥ R-11.25 over 2x6 wall</td>
</tr>
</tbody>
</table>
Minimum Exterior Insulation Zone 6 [IRC R702.7]

2 x 6 Wall R-11.25 Exterior Insulation

2 x 4 Wall R-7.5 Exterior Insulation

2 x 6 Wall R-11.25 Exterior Insulation

R-21 Air Permeable Insulation

R-13

2 x 4 Wall R-7.5 Exterior Insulation
Minimum Exterior Insulation Zone 6 [IRC R702.7]

2 x 6 Wall R-11.25 Exterior Insulation

R-21 Air Permeable Insulation

R-13

R-42

2 x 4 Wall R-7.5 Exterior Insulation

Double Stud Wall - Exterior Insulation Not Recommended
Minimum Exterior Insulation  Zone 6 [IRC R702.7]

- **R-11.25**
  - 2 x 6 Wall R-11.25 Exterior Insulation

- **R-7.5**
  - 2 x 4 Wall R-7.5 Exterior Insulation

- **?**
  - Double Stud Wall - Exterior Insulation Not Recommended

Variables
- Outdoor Temperature
- Indoor Temperature
- Indoor Relative Humidity
Above-ground Walls
Concrete Block
Insulated Concrete Form (ICF)
Masonry Cavity
Brick (not brick veneer)
Compressed Earth Block
Solid Timber or Solid Logs
Rammed Earth
Adobe

Heat Capacity ≥ 6 Btu/ft² °F
More Than Half of Insulation R-value is on the Interior

R-20

R-9

R-11

R-15 If Half or Less Than Half of Insulation R-value is the Interior

R-15

R-8

R-7

Mass Wall Provisions [R402.2.5]
Floors [R402.2.8]

R = 30

Vented Crawl Space
R = 15
Continuous

R = 19
Cavity

Basement
Minimum R-10 for 4’ combined vertical and horizontal insulation.
Conventional Slab-On-Grade Insulation Options [R402.2.10]

Minimum R-10 for 4’ combined vertical and horizontal insulation.

- Insulation Protection (IECC R303.2.1)
- Slope of Final Grade 6” in 10’ (IRC R401.3)
- Minimum 10”
Minimum R-10 for 4’ combined vertical and horizontal insulation.

45° Angle of Insulation Allowed at Interior Foundation Wall
2” Vertically from Concrete Porch or Patio Slabs Exposed to Weather (IRC R317.1)

Impervious Surfaces Slope Minimum 2% Away from Building (IRC R401.3)

Minimum R-10 for 4’ combined vertical and horizontal insulation.
Conventional Slab-On-Grade Insulation Options [R402.2.10]

Source: USDOE Building Energy Codes University
Frost Protected Shallow Foundations

1: Building maintained 64° min.

2: Insulation materials used below grade must be labeled as complying with ASTM C 578.

3: This discussion addresses a standalone structure. The IRC includes more details and requirements when a FPSF is adjacent to structures. Refer to 2018 IRC R403.2.
Frost Protected Shallow Foundations [IRC R403.3]

- Flashing per IRC R703.4
- Insulation Protection per IECC R303.2.1
- Slope Final Grade per IRC R401.3

D = 16” Min.

12” Maximum

4” Base Course of Clean Graded Sand, gravel, or Crushed Stone Per IRC R506.2.2

Slab-On-Grade Floor per IRC Sections R403.1 and R506
<table>
<thead>
<tr>
<th>Montana Air Freezing Index by County (°F-days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1500 or less</strong></td>
</tr>
<tr>
<td>Mineral</td>
</tr>
<tr>
<td>Golden Valley</td>
</tr>
<tr>
<td>Granite</td>
</tr>
<tr>
<td>Lake</td>
</tr>
<tr>
<td>Lincoln</td>
</tr>
<tr>
<td>Missoula</td>
</tr>
<tr>
<td>Ravalli</td>
</tr>
<tr>
<td>Sanders</td>
</tr>
<tr>
<td>Sweet Grass</td>
</tr>
<tr>
<td>Silver Bow</td>
</tr>
<tr>
<td>Stillwater</td>
</tr>
<tr>
<td>Westland</td>
</tr>
<tr>
<td>Rosebud</td>
</tr>
<tr>
<td>Teton</td>
</tr>
<tr>
<td>Treasure</td>
</tr>
<tr>
<td>Yellowstone</td>
</tr>
</tbody>
</table>
## Minimum Footing Depth and Insulation Requirements for FPSF in Heated Buildings

<table>
<thead>
<tr>
<th>Air Freezing Index (°F-days)</th>
<th>Minimum Footing Depth D (Inches)</th>
<th>Vertical Insulation R-Value</th>
<th>Horizontal Insulation R-Value</th>
<th>Combined Vertical &amp; Horizontal Insulation Dimension (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 4,000</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>48</td>
</tr>
</tbody>
</table>

*The combined vertical and horizontal insulation dimension must be at least 48 inches.*
Horizontal Insulation Requirements Plan
Applicable only if County has an Air Freezing index of 4,000.
Dehumidification is another option providing 70 pints of moisture removal per 1,000 Ft² of Crawlspace Area.
Crawlspace [R402.2.11]

Unvented Crawl Space

R = 15
Continuous

R = 19
Cavity
Crawlspace Exhaust – Related Issues [IRC R408.1]

 Mech. Ventilation?
 Backdrafting?
Continuous Class I Vapor Retarder on Crawlspace Floor [IRC R408.3]
<table>
<thead>
<tr>
<th>Sunroom (Thermally Isolated Enclosing Conditioned Space)</th>
<th>Ceiling Insulation</th>
<th>R-24</th>
<th>R402.2.13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wall Insulation</strong></td>
<td><strong>R13</strong></td>
<td><strong>R402.2.13</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Glazing U-factor</strong></td>
<td><strong>U-0.45</strong></td>
<td><strong>R402.3.5</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Skylight U-factor</strong></td>
<td><strong>U-0.70</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wall insulation at exterior</strong></td>
<td><strong>R-13</strong></td>
<td><strong>R402.2.13</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Wall insulation at conditioned space</strong></td>
<td><strong>R-21 or R-13+5</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ceiling insulation</strong></td>
<td><strong>R-24</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>