Zero Specifications
DOE ZERH Eligible Building Types

**Single-Family Detached**

**Single-Family Attached**

**Multi-Family Dwelling Units**
- ≤ 5 Stories Above-Grade
- Individual HVAC
- Dwelling Units Occupy ≥ 80% Occupiable SF
- Individual or Central DHW (no solar required)
IECC Climate Zones

All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
- Bethel
- Dillingham
- Fairbanks N. Star
- Nome
- North Slope
- Northwest Arctic
- Southeast Fairbanks
- Wade Hampton
- Yukon-Koyukuk

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands.
Align with ENERGY STAR for Homes v3:

- Comprehensive Building-Science System
- Variable vs. Fixed HERS Index Score
- House Size Adjustment to HERS Score
### DOE Challenge Home Mandatory Requirements for All Labeled Homes

<table>
<thead>
<tr>
<th>Area of Improvement</th>
<th>Mandatory Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ENERGY STAR for Homes Baseline</td>
<td>Certified under ENERGY STAR Qualified Homes Version 3&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>2. Envelope&lt;sup&gt;®&lt;/sup&gt;</td>
<td>Fenestration shall meet or exceed latest ENERGY STAR requirements&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>3. Duct System</td>
<td>Ducts located within the homes thermal and air-tight boundary&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>4. Water Efficiency</td>
<td>Hot water deliver systems shall meet efficient design requirements&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>5. Lighting &amp; Appliances&lt;sup&gt;®&lt;/sup&gt;</td>
<td>All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified.</td>
</tr>
<tr>
<td></td>
<td>80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (tubes) in minimum 60% of sockets</td>
</tr>
<tr>
<td>6. Indoor Air Quality</td>
<td>EPA indoor airPLUS Verification Checklist and Construction Specifications&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
<tr>
<td>7. Renewable Ready&lt;sup&gt;®&lt;/sup&gt;</td>
<td>EPA Renewable Energy Ready Home for Electric Checklist and Specifications&lt;sup&gt;®&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### DOE Challenge Home Target Home<sup>®</sup>

#### HVAC Equipment<sup>®</sup>

<table>
<thead>
<tr>
<th>Area</th>
<th>Hot Climates (2012 IECC Zones 1,2)&lt;sup&gt;®&lt;/sup&gt;</th>
<th>Mixed Climates (2012 IECC Zones, 4 except Maine)</th>
<th>Cold Climates (2012 IECC Zones 4, Marine 5,6,7,8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFUE</td>
<td>80%</td>
<td>90%</td>
<td>94%</td>
</tr>
<tr>
<td>SEER</td>
<td>15</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>HSPF</td>
<td>15</td>
<td>20</td>
<td>115</td>
</tr>
</tbody>
</table>

#### Insulation and Infiltration

- Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standard.
- Infiltration<sup>®</sup> (ACH50):
  - Hot Climates: 0.4 in CFT 1.2
  - Mixed Climates: 0.3 in CFT 1.2
  - Cold Climates: 0.3 in CFT 1.2

#### Windows<sup>®</sup>

<table>
<thead>
<tr>
<th>Area</th>
<th>Hot Climates (2012 IECC Zones 1,2)</th>
<th>Mixed Climates (2012 IECC Zones, 4 except Maine)</th>
<th>Cold Climates (2012 IECC Zones 4, Marine 5,6,7,8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHGC</td>
<td>0.23</td>
<td>0.27</td>
<td>Any</td>
</tr>
<tr>
<td>U-value</td>
<td>0.4</td>
<td>0.3</td>
<td>0.17</td>
</tr>
</tbody>
</table>

#### Water Heater

ENERGY STAR minimum for heating oil water heaters use EF = 0.60

#### Benchmark Home Size<sup>®</sup>

<table>
<thead>
<tr>
<th>Bedrooms in Home to be Built</th>
<th>Conditioned Floor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,000</td>
</tr>
<tr>
<td>2</td>
<td>1,000</td>
</tr>
<tr>
<td>3</td>
<td>2,200</td>
</tr>
<tr>
<td>4</td>
<td>2,500</td>
</tr>
<tr>
<td>5</td>
<td>3,400</td>
</tr>
<tr>
<td>6</td>
<td>4,000</td>
</tr>
<tr>
<td>7</td>
<td>4,000</td>
</tr>
<tr>
<td>8</td>
<td>5,200</td>
</tr>
<tr>
<td>Area of Improvement</td>
<td>Mandatory Requirements</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1. ENERGY STAR for Homes Baseline</td>
<td>Certified under ENERGY STAR Qualified Homes Version 3 or 3.1¹⁹,¹⁰</td>
</tr>
<tr>
<td>2. Envelope¹¹</td>
<td>□ Fenestration shall meet or exceed ENERGY STAR requirements¹²,¹³</td>
</tr>
<tr>
<td></td>
<td>□ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 or 2015 IECC levels¹⁴,¹⁵</td>
</tr>
<tr>
<td>3. Duct System</td>
<td>□ Duct distribution systems located within the home's thermal and air barrier boundary or optimized to achieve comparable performance¹⁶</td>
</tr>
<tr>
<td>4. Water Efficiency</td>
<td>□ Hot water delivery systems shall meet efficient design requirements¹⁷</td>
</tr>
<tr>
<td>5. Lighting &amp; Appliances¹⁸</td>
<td>□ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified.</td>
</tr>
<tr>
<td></td>
<td>□ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets</td>
</tr>
<tr>
<td></td>
<td>□ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified</td>
</tr>
<tr>
<td>6. Indoor Air Quality</td>
<td>□ Certified under EPA Indoor airPLUS¹⁰</td>
</tr>
<tr>
<td>7. Renewable Ready</td>
<td>□ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed; (Solar Hot Water Ready provisions are encouraged but not required)¹⁹</td>
</tr>
</tbody>
</table>

**Encouraged:**

- WaterSense Label (indoor and outdoor)
- Disaster Resistance (IBHS Fortified Home)
- Quality Management
### Exhibit 2: DOE Zero Energy Ready Home Target Home

<table>
<thead>
<tr>
<th>HVAC Equipment</th>
<th>Hot Climates (2012 IECC Zones 1.2)</th>
<th>Mixed Climates (2012 IECC Zones 3, 4 except Marine)</th>
<th>Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFUE</td>
<td>80%</td>
<td>90%</td>
<td>94%</td>
</tr>
<tr>
<td>SEER</td>
<td>18</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>HSPF</td>
<td>8.2</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Geothermal Heat Pump</td>
<td>1.4 cfm/W; no heat exchange</td>
<td>1.4 cfm/W; no heat exchange</td>
<td>1.2 cfm/W; heat exchange with 60% SRE</td>
</tr>
<tr>
<td>ASHRAE 62.2 Whole-House Mechanical Ventilation System</td>
<td>Infiltration^24 (ACH50): 3 in CZ's 1-2</td>
<td>2.5 in CZ's 3-4</td>
<td>2 in CZ's 5-7</td>
</tr>
</tbody>
</table>

### Insulation and Infiltration
- Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards.
- Infiltration^24 (ACH50): 3 in CZ's 1-2 | 2.5 in CZ's 3-4 | 2 in CZ's 5-7 | 1.5 in CZ 8

### Windows
- SHGC
- U-Value

### Water Heater
ENERGY STAR levels for the system Energy Factor, as follows:
- Gas/propane systems of ≤ 55 gallons, EF = 0.67
- Gas/propane systems of > 55 gallons, EF = 0.77
- Electric systems, EF = 2.0
For heating oil water heaters use EF = 0.60

### Thermostat
- Programmable thermostat (except for zones with radiant heat)

### Lighting & Appliances
- For purposes of calculating the DOE Zero Energy Ready Home Target Home HERS Index, homes shall be modeled with an ENERGY STAR dishwasher, ENERGY STAR refrigerator, ENERGY STAR ceiling fans, and ENERGY STAR lamps (bulbs) in 80% of sockets or 80% of lighting fixtures are ENERGY STAR Qualified.
Based on 1800, 2400, and 3600 ft$^2$ prototypes on climate-appropriate foundations.
Homes larger than the benchmark home size must use the size adjustment factor to determine the target HERS index.

**Note:** Renewable energy systems may not be used to qualify for the ZERH HERS Index Target Score, but may be used for the *incremental* HERS Index points needed for the Size Adjustment Factor.

\[
\text{Size Mod. Factor} = \left[ \frac{\text{CFA}_{\text{Benchmark Home}}}{\text{CFA}_{\text{Home to Be Built}}} \right]^{0.25} \text{[Not to Exceed 1.0]}
\]
## Performance Path Example

**CZ5 Prototype - 4 BR, 2400 SF**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Target Home Spec</th>
<th>Design Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGW Insulation</td>
<td>R20 or R13+5</td>
<td>R20</td>
</tr>
<tr>
<td>Attic Insulation</td>
<td>R49 (U=0.026)</td>
<td>R50</td>
</tr>
<tr>
<td>Basement Walls</td>
<td>R15/19</td>
<td>R10</td>
</tr>
<tr>
<td>Windows</td>
<td>U=0.27; SHGC=0.40</td>
<td>U=0.32; SHGC=0.30</td>
</tr>
<tr>
<td>Infiltration</td>
<td>2.0 ACH50</td>
<td>2.0 ACH50</td>
</tr>
<tr>
<td>Ducts</td>
<td>Total ≤ 8 CFM25 per 100 SF of CFA; Leakage to outdoors ≤ 4 CFM25 per 100 SF of CFA</td>
<td>Total leakage 288 CFM25 In Conditioned Space w/ ½ ACH50 (Req.’d by ENERGY STAR) – Exempt</td>
</tr>
<tr>
<td>Furnace AFUE</td>
<td>94</td>
<td>90</td>
</tr>
<tr>
<td>A/C SEER</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Whole-House Mech. Vent.</td>
<td>77 cfm; 1.2cfm/W balanced;</td>
<td>77 cfm; 8.0 cfm/W exhaust-only</td>
</tr>
<tr>
<td>Water Heater</td>
<td>ENERGY STAR</td>
<td>Gas storage 0.67 EF</td>
</tr>
<tr>
<td>HERS Index</td>
<td>52</td>
<td>52 <strong>COMPLIES!</strong></td>
</tr>
</tbody>
</table>
Rating & Verifying Homes

• Same: ENERGY STAR Homes framework

• New:
  – Indoor airPLUS Checklist;
  – Renewable Energy Ready Home Checklists (if req’d.)
  – Hot Water Distribution test

• Submissions:

  **Current**: Send “DOE ZERH Verification Summary” electronically to zero@newportpartnersllc.com

  **Future**: Automatically submitted as part of rating to RESNET National Homes Registry
ZERH Resources: Technical

- Technical Webinars
- Webinar Meetings
- Building America Solution Center (BASC)
- Building America Research Studies
- Leading Builder Round-Table Meetings

For Info: www.buildings.energy.gov/zero/
Zero Specifications:

Optimized Enclosure System
Zero Energy Ready Home Spec

Optimized Enclosure System

2012 / 2015 IECC Envelope Insulation + Tighter Construction = ENERGY STAR Windows
Optimized Enclosure is Part of Complete Building Science System

Building Science:
- Air Flow
- Thermal Flow
- Moisture Flow
- Vapor Flow

Thermal Enclosure System
Heating, Cooling, & Ventilation System
Water Management System
A well-insulated and air-sealed home, with good windows and doors, reduces the amount of energy needed to keep the home comfortable.
1. Energy moves from more to less.

90°F - Outside

90°F

40°F

Cooler with Ice
1. Energy moves from more to less.
1. Energy moves from more to less.
Thermal Holes Are a Big Deal

1,000 sq. ft. R-38 Attic
U = .026

Drop-Down Stair = R-1
R-1, U = 1.0

10 sq. ft. = 1% of area

What Percent Loss in Attic R-Value?
Thermal Holes Are a Big Deal

Avg. $U = \frac{U_1 \times A_1 + U_2 \times A_2 + \ldots}{\text{Total Area (A)}}$

$= \frac{(0.026 \times 990) + (1 \times 10)}{1,000}$

$= \frac{35.74}{1,000} = 0.036$

$= R-28 = 27\% < R-38$

1% Hole Results in 27% Loss of R-Value
Assume 50°F temperature difference across attic ceiling

Heat Flow = U x A x ΔT

Heat Flow w/o Hole = .026 x 1,000 x 50 = 1316 Btu/hr

Heat Flow w/Hole = .036 x 1,000 x 50 = 1786 Btu/hr

33%+ Greater Heat Flow with 1% Hole
Thermal Holes Are a Big Deal
Optimized Enclosure System

- **Air-Tight Construction**
- **Complete Air Barriers**
  - Thermal Bypass
  - Wind Intrusion
- **Insulation System**
  - Next Code Quantity
  - Proper Installation
  - Minimum Thermal Bridging
- **Advanced Windows**
Zero Specifications
Optimized Enclosure System
Air-Tight Construction
Why Air-Tight Construction

- 16 to 50% of HVAC Loads
- Moisture Problems
- Comfort Problems
- Indoor Air Quality
### Target Home Air-Tightness

#### ACH50 Requirements/Targets

<table>
<thead>
<tr>
<th>Climate Zones</th>
<th>Zero Energy Ready Home</th>
<th>ENERGY STAR V3</th>
<th>2012 IECC</th>
<th>Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>3.0</td>
<td>6.0</td>
<td>5.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3-4</td>
<td>2.5</td>
<td>5.0</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>5-7</td>
<td>2.0</td>
<td>4.0</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>8</td>
<td>1.5</td>
<td>3.0</td>
<td>3.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Seal Usual Suspects

Cracks:
- Sill Plates
- Windows & Doors
- Drywall at Top Plate
- Access Panels
- Sheathing Joints
- Foundation/Framing

Penetrations:
- Plumbing
- Wiring
- Recessed Lights
- Vents
- HVAC Duct Boots

Shafts:
- Flues
- Ducts
- Plumbing

Odd Geometry:
- Cantilevers
- Knee-walls
What We’re Trying to Avoid

Attic Air Infiltration Between Drywall and Top Plate
Drywall Sealed to Top Plate

Default: Spray Foam

Alternative: Sill sealer

Alternative: Constr. Adhesive
Air Leakage Distribution

Exterior air barrier
Cathedral ceiling

Sheathing / roof joint
1.1 cfm/ft @ 50 Pa

2-Story house (Floor area = 2,000 ft²)
Sheathing / roof joint unsealed ≅ 0.5 ACH₅₀

<table>
<thead>
<tr>
<th>Zones</th>
<th>DOE Zero Energy Ready Home</th>
<th>IECC 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Requirement</td>
<td>Contribution to requirement (%)</td>
</tr>
<tr>
<td>1 – 2</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>3 – 4</td>
<td>2.5</td>
<td>20</td>
</tr>
<tr>
<td>5 – 7</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>1.5</td>
<td>33</td>
</tr>
</tbody>
</table>
- 1/8” to 1/4” perimeter gap
- ~ 12 cfm @ 50 Pa
- Perimeter gap sealed
  - Somewhat effectively with one-component polyurethane foam
  - Effectively with caulk
- Wire holes ≥ 50% of leakage
**Fasteners**

Air leaked at nailed fasteners

Repeat test with screwed fasteners
Exterior Air Barrier:
2-Story House (2,000 sq. ft.)

(4) Elect. Outlets = 0.17 ACH$_{50}$

Exterior Sheathing/Foundation = 0.51 ACH$_{50}$

1. Sheathing/Foundation Joint Unsealed = 0.51
2. Sheathing/Roof Joint Unsealed = 0.51
3. (4) Electrical Outlets = 0.17
4. (5) Ceiling Lights = 0.29
5. Return Duct = 0.22

1.7 ACH$_{50}$
Sealing HVAC Ducts with Aeroseal
Zero Specifications
Optimized Enclosure System
Insulation System
### Changes Between the 2012 IECC and 2015 IECC

<table>
<thead>
<tr>
<th></th>
<th>Change</th>
<th>No Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prescriptive R-Value</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>U-Value Alternative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total UA Alternative</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ONLY Change in U-Value is for Above-Grade Framed Walls**

**No Changes to Prescriptive R-Value Requirements**
### U-Factors for Above-Grade Framed Walls

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>2012 U-Factor Equivalent Above-Grade Frame Wall (Table 402.1.3)</th>
<th>2015 U-Factor Equivalent Above-Grade Frame Wall (Table 402.1.4)</th>
<th>Change (% and Direction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.082</td>
<td>0.084</td>
<td>2% Decrease in Stringency ▼</td>
</tr>
<tr>
<td>2</td>
<td>0.082</td>
<td>0.084</td>
<td>2% Decrease in Stringency ▼</td>
</tr>
<tr>
<td>3</td>
<td>0.057</td>
<td>0.060</td>
<td>5% Decrease in Stringency ▼</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>0.057</td>
<td>0.060</td>
<td>5% Decrease in Stringency ▼</td>
</tr>
<tr>
<td>5 and Marine 4</td>
<td>0.057</td>
<td>0.060</td>
<td>5% Decrease in Stringency ▼</td>
</tr>
<tr>
<td>6</td>
<td>0.048</td>
<td>0.045</td>
<td>6% Increase in Stringency ▲</td>
</tr>
<tr>
<td>7 and 8</td>
<td>0.048</td>
<td>0.045</td>
<td>6% Increase in Stringency ▲</td>
</tr>
</tbody>
</table>
• No additional burden for most designs

• In Climate Zones 1 – 5, meeting 2015 IECC via a whole-building UA tradeoff will be *very slightly* less stringent
  – Required Frame Wall U-Factor is 2 to 5% less stringent
  – Frame Walls might comprise ~ 20% – 40% of total shell area...
• Compliance with next generation code
• Three Options:
  ✓ Prescriptive
  ✓ Alternative equivalent U-factor
  ✓ Total UA calculation
    [allows window to be included]
• Allowances for ceilings without attic spaces
  [up to 500 square feet or 20% of roof area, whichever is smaller]
<table>
<thead>
<tr>
<th>Component</th>
<th>CZ 5</th>
<th>CZ 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls</td>
<td>R-20 or R-13+5</td>
<td>R-20+5 or R-13+10</td>
</tr>
<tr>
<td>Ceiling</td>
<td></td>
<td>R-49</td>
</tr>
<tr>
<td>Floor</td>
<td></td>
<td>R-30</td>
</tr>
<tr>
<td>Basement</td>
<td></td>
<td>R-15/19</td>
</tr>
<tr>
<td>Crawl Space</td>
<td></td>
<td>R-15/19</td>
</tr>
<tr>
<td>Slab</td>
<td>R-10/2’ Deep</td>
<td>R-10/4’ Deep</td>
</tr>
</tbody>
</table>
Insulation Proper Installation

- Void
- Gap
- Compression
- Misalignment
Insulation Thermal Bridging
<table>
<thead>
<tr>
<th>High-R Wall Options (Climate Zones 6-8)</th>
<th>Condensation Inside the Wall Cavity</th>
<th>Bulk Moisture Control</th>
<th>Disaster Resistance</th>
<th>Structural Support for Cladding</th>
<th>Installation Quality Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulated Framed Cavity Wall (Single or Double)</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
<tr>
<td>Insulated Framed Cavity Wall with ≤ 60% Insulation Outboard</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
<tr>
<td>Framed Assembly with &gt; 60% Insulation Outboard</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
<tr>
<td>Structural Insulated Panel (SIP) System</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
</tr>
<tr>
<td>Exterior Insulated Concrete/Masonry Wall System</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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</tr>
<tr>
<td>Interior Insulated Concrete/Masonry Wall System</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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<tr>
<td>Insulated Concrete Form (ICF) System</td>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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</tbody>
</table>
**Innovation & Integration: Transforming the Energy Efficiency Market**

**Buildings.Energy.gov**

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**Framing Options**
- Advanced Framing
- TJI Studs
- Double-Wall Framing

**Insulation Options**
- Fibrous Insulation Blown-in
- Fibrous Insulation Batt
- Open-Cell Spray Foam
- Closed-Cell Spray Foam
- Flash and Blow/Batt

**Risk Management Guidance**
- Condensation Inside Cavity
- Bulk Moisture Control
- Disaster Resistance
- Quality Installation

---

**Risk Managed Insulated Framed Cavity Wall**
Zero Specifications
Optimum Enclosure System
Insulation System:
Complete Air Barriers
Complete Air Barriers

**Walls**
- Showers and Tubs
- Fireplaces
- Attic Knee Walls
- Skylight Shaft Walls
- Adjoining Porch Roof
- Staircase Exterior Walls
- Double Walls
- Rim/Band Joists
- Other Exterior Walls

**Floors**
- Floors Above Garage
- Cantilevered Floor
- Unconditioned Floor (Basement/Crawl Sp.)

**Ceilings**
- Dropped Ceiling/Soffit at Unconditioned Attic
- Other Ceilings
Air Barrier Example: Attic Knee Wall

No rigid backing on knee wall.

Rigid backing installed prior to insulation.
Air Barrier Example: Garage Rim Joist

No air barrier is present between garage and conditioned space.

Air barrier is present between garage and conditioned space.
No air barrier between porch attic and conditioned space.

Air barrier is installed prior to porch attic framing.
Zero Specifications
Optimized Enclosure System
Insulation System:
High-R Walls
High-R Wall Options

• **Advanced Framing**
  – Thicker Wall
  – Staggered Studs
  – Double Wall

• **Rigid Insulation Exterior Sheathing**
  – With Sheathing
  – Without Sheathing
  – With Extended Plate and Beam
  – With Structural Engineered Panel

• **Systems Building**
  – Structural Insulated Panels (SIPs)
  – Insulated Concrete Forms (ICFs)
  – Insulated Concrete Panels (ICPs)
  – Precast Concrete
Adv. Framing w/Thicker Walls

- R-17 – R-21 (U 0.052-0.060)
- Higher Framing Factor (~12-15%)
- Blanket Insulation Issues:
  - R-19 is 6” Thick, Compressed is R-17
  - R-21 is 5.5” Thick, Uncompressed is R-21
- Blown-In Insulation Issues:
  - Settling
  - Proper Density (Bag Count)
- Spray Foam Issues:
  - High Cost
  - Closed Cell Enhances Structure Perf.
  - Still Need to Ensure Quality installation
Adv. Framing: Staggered Studs

- 2x6 plates with 2x4 staggered studs at 12”/24” o.c.
- Reduces thermal bridging by 80-90%
- Cost competitive with traditional 2x6 wall
- Need to ensure spacing between studs okay for deflection
Adv. Framing: Double-Wall

• R-26 Walls (U ~ 0.034)
• Studs Offset or Separated to Ensure Complete Thermal Break
• Coldest Outside Sheathing Needs to Ensure Drying
  – Vapor-open designs use higher-perm sheathing such as plywood or exterior-grade gypsum board
  – Modeling needed to assure moisture control
• Same Framing Techniques Already Understood by Trades
Rigid Insulation w/Sheathing

• R-18 Wall (U 0.054)
• Complete Thermal Break
• Condensation Surface Outboard Structure
• Can Combine Sheathing w/ Weather Resistant Barrier
• Installation Issues:
  ≤ 1.5” Thick, Nails Okay
  > 1.5” Thick, Screws Needed
Rigid Insulation w/o Sheathing

- R-17-R-28 Wall
- Complete Thermal Break
- Enhanced Racking Strength and Impact Resistance with CCSpf Enables No Sheathing
- Rigid Insulation Sheathing serves as Weather Resistant Barrier w/Liquid Membrane at Joints and Pan Flashing
- Substantially Reduced Framing including Single Plates
- Engineered Stamped System
- Cost Competitive
Rigid Insulation w/Extended Plate

- R-18 Wall
- 2x4 Studs with 2x6 Plates
- Sheathing Attached to Plates for Near Full Racking Strength
- Complete Thermal Break Except for Top and Bottom Plates
- Condensation Surface Inside Assembly, so Must Control Air Flow
- Cladding Attachment Simplified if Permissible to Nail to Sheathing
Rigid Insulation w/Engineered Panel

- Innovative & Affordable
- Based on the perfect wall, using a “studless” structural engineered panel
- Single water, air, and vapor control layer
- Recent experience has demonstrated it can be built for less than a standard wood-frame wall system
Step 1: Build the entire structure including foundation, floor systems, walls, and roof.
Step 2: Wrap the entire envelope with a “peel & stick” membrane integrated with openings / penetration
Step 3: Add rigid foam insulation
2 to 3” on foundation
3 to 4” on walls
6 to 8” on the roof
Step 4: Add furring strips, overhangs, etc.
Step 5: Install trim; siding; roof sheathing and roofing
Rigid Insulation w/Engineered Panel
Rigid Insulation w/Engineered Panel
Structural Insulated Panels (SIPs)

- R-26 Walls (6") (U 0.034)
- Substantial Thermal Break (3 – 8% Framing Factor)
- Special Construction Practices Required
- Foundation has to be Perfectly Level
- Significantly Reduced Time-of-Construction
- Reduced Dimensional Variation Corrections
- Killer Applications
Insulated Concrete Forms (ICFs)

- ~R-24 Walls (U 0.038)
- Complete Thermal Break
- Useful Thermal Mass
- Foundation has to be Perfectly Level
- Longer Time-of-Construction
- Maximum Disaster Resist.
- Termite Resistant
- Reduced Dimensional Variation Corrections
- Much More Costly
Insulated Concrete Panels (ICPs)

- ~R-24 Walls (U 0.038)
- Complete Thermal Break
- Useful Thermal Mass
- Foundation has to be Perfectly Level
- Significantly Reduced Time-of-Construction
- Maximum Disaster Resist.
- Termite Resistant
- Reduced Dimensional Variation Corrections
- Cost Competitive
ICP Installation Steps

1. Panels As Delivered
2. Panels Inserted into Base Track
3. Horizontal Rebar Added
4. Top C-Channels Inserted
5. Concrete Poured
6. Poured Concrete Inside Panel
Zero Specifications
Optimized Enclosure System
Insulation System
High-R R Foundations
High-R Foundation: Exterior Insulation

Source: Oak Ridge National Laboratory
High-R Foundation: Interior Insulation

Figure 2-15: Basement Wall with Interior Insulation

Source: Oak Ridge National Laboratory
High-R Foundation: Interior Insulation

Source: Building Science Corporation
Zero Specifications
Optimum Enclosure System
Insulation System:
High-R Roofs
High-R Roof Insulation at Flat
High-R Roof Insulation at Slope

5.1 AIR-IMPERMEABLE: In direct contact with the underside of the sheathing

Humid Air Cannot Reach Underside of Cold Roof Sheathing

Humid Outdoor Air Denied Entry

Humid Indoor Air Denied Entry

What R-value?

Building Science Corporation
# Insulation for Condensation Control

## Minimum R-value of Impermeable Insulation

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Minimum Impermeable Insulation R-Value*</th>
<th>2012 IECC Ceiling R-Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>2B and 3B Tile Roof</td>
<td>None Required</td>
<td>30</td>
</tr>
<tr>
<td>1, 2A, 2B, 3A, 3B, 3C</td>
<td>R-5</td>
<td>38</td>
</tr>
<tr>
<td>4C</td>
<td>R-10</td>
<td>38</td>
</tr>
<tr>
<td>4A, 4B</td>
<td>R-15</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>R-20</td>
<td>49</td>
</tr>
<tr>
<td>6</td>
<td>R-25</td>
<td>49</td>
</tr>
<tr>
<td>7</td>
<td>R-30</td>
<td>49</td>
</tr>
<tr>
<td>8</td>
<td>R-35</td>
<td>49</td>
</tr>
</tbody>
</table>

*contributes but doesn’t supersede 2012 IECC insulation requirements
Top Insulated Roof Deck

**Sequence of Retrofit:**

1) Remove existing roofing and underlayment; inspect existing roof deck and framing and repair as necessary.

2) Install new exterior foam board insulation, roof sheathing, underlayment, flashings and roofing.

3) Remove existing soffit and install rigid blocking to prevent loose-fill fiber insulation from blowing into soffit; install continuous air seal at all joints and interfaces in blocking; replace soffit.

4) Dense-pack rafter cavities using approved cellulose or glass fiber insulation and following insertion tube techniques described in BPI RBE-WHALCI 2012.
Guidance for Dense Pack Roof

- Roofing (e.g. asphalt shingles)
- Underlayement (e.g. roofing paper)
- Existing Roof Sheathing
- Closed-cell Sprayed Polyurethane Foam Insulation (ccSPF)
- Existing Roof Framing
- Drip Edge
- Fascia
- Vented Soffit
- Rigid Blocking
- Ceiling Finish (e.g. painted drywall)
- Dense-packed fiber insulation (e.g. cellulose or glass fiber)
Spray Foam Under Roof Decks

Figure 1 – New Orleans, LA – June 2012 Collection of Sample of Spray Foam Under Roof Assembly in an Attempt to Compare Actual Performance with Idealized Performance

Figure 2 – Minneapolis, MN – July 2012

Description
- Built 2009
- Cathedralized attic
- R21 - ~3.5" ccSPF below OSB roof sheathing

Exploration Findings
- All sheathing locations investigated are within safe moisture content readings

Exploration Location 1 – North Lower
- 6% moisture content reading
- No visible signs of moisture damage

Exploration Location 2 – West Upper
- 7.5% moisture content reading
- No visible signs of moisture damage

Exploration Location 3 – East Upper
- 6.5% moisture content reading
- No visible signs of moisture damage

Exploration Location 4 – West Lower
- 7.0% moisture content reading
- No visible signs of moisture damage

This information correlates well to modeling of warm locations with drives that enhance drying and have limited wetting.

Description
- 1941, Retrofit 2012
- Cathedralized attic
- R21 - ~3.5" ccSPF below 1x board roof

Exploration Findings
- All sheathing locations investigated are within safe moisture content readings

Exploration Location 1 – North West Lower
- 9.2% moisture content reading
- No visible signs of moisture damage

Exploration Location 2 – South West Lower
- 6.9% moisture content reading
- No visible signs of moisture damage
Zero Specifications
Optimized Enclosure System
Advanced Windows
ENERGY STAR Windows

- Assures beyond-code window performance
- Fenestration used for passive solar design are exempt from the U-factor and SHGC requirements
- Area-weighted averages for U-factor, SHGC permitted
## Good, Better, Best Windows

<table>
<thead>
<tr>
<th></th>
<th>Hot Climates IECC CZ 1-2</th>
<th>Mixed Climates IECC CZ 3-4 except Marine</th>
<th>Cold Climates IECC CZ 5-8 and 4 Marine</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-value</td>
<td>SHGC</td>
<td>U-value</td>
<td>SHGC</td>
</tr>
<tr>
<td><strong>Mandatory:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENERGY STAR</td>
<td>0.40</td>
<td>0.30 [3] 0.25 [4]</td>
<td>0.27 [3] 0.28 [4]</td>
</tr>
<tr>
<td><strong>Performance:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target Home</td>
<td>0.40</td>
<td>0.30</td>
<td>0.27</td>
</tr>
<tr>
<td>Encouraged:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-R</td>
<td>--</td>
<td>0.21</td>
<td>0.18 - 0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Any</td>
</tr>
</tbody>
</table>

### Notes:
- [3] Any ≥0.37
- [4] Any ≥0.42
**Why Go Beyond ENERGY STAR***

<table>
<thead>
<tr>
<th>Window 15% of Wall Area</th>
<th>Wall R-Value with Windows w/Varied Wall Insulation Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Value</td>
<td>R-0</td>
</tr>
<tr>
<td>0.30</td>
<td>R-5</td>
</tr>
<tr>
<td>0.20</td>
<td>R-5</td>
</tr>
<tr>
<td>0.15</td>
<td>R-5</td>
</tr>
<tr>
<td>0.10</td>
<td>R-5.5</td>
</tr>
</tbody>
</table>

* In Cold Climates

**Sources:**

“*Holes in the Wall: To Improve the Energy Performance of Walls, Look at the Total R-Value,*” Journal of Light Construction, February 2014;
Multi-Assembly R-Value / U-Value Calculator – Cascadia Windows and Doors;
Michael Blasnik Presentation, 2014 ACI Conference
The Biggest Thermal Hole....
Zero Specifications: Water Protection System
Zero Energy Ready Home Spec

- Sump Pumps
- Flooring Materials
- Sub-Slab Aggregate

Water Protection System

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy
Moisture Vapor (Air Flow) Control

- Air Sealing
- Air Barriers
- Vapor Barriers/Retarders
- HVAC Quality Installation
- Whole-House Ventilation
- Spot Ventilation
Bulk Moisture Control Concept
Bulk Moisture Control

- Weather Resistant Barriers
- Flashing
- Capillary Breaks

Water Management Checklist
• Many materials used in building homes are not durable when wet.
• Especially important in high performance homes, regardless of whether ENERGY STAR certified.
What We’re Trying to Avoid

Missing step & kick-out flashing
Step & Kick-Out Flashing

- Step flashing extend 4" up wall
- Step flashing goes under shingles
- Counter flashing tape over step flashing
- Provide kick out flashing at roof edge termination