Zero Made Easier

Theresa Gilbride, Joe Nebbia
Pacific Northwest National Laboratory, Newport Partners
DOE ZERH is taking off!

4,245 DOE ZERH homes certified to date.

DOE ZER Homes Certified, by Year

Number of ZER Certified Homes

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100</td>
<td>250</td>
<td>350</td>
<td>500</td>
<td>1000</td>
<td>1200</td>
</tr>
</tbody>
</table>

as of 8-1-19
Zero Coming Soon to a City Near You

CA Building Code Takes Big Step Toward Net-Zero Energy

May 09, 2018  Pierre Delforge

Image courtesy of Wakeland Housing and Development Corporation
How to Achieve a DOE Zero Energy Ready Home

HERS® Index: more energy | less energy

- START WITH ENERGY STAR Certified Homes V. 3.0
- ENVELOPE meets or exceeds 2012 IECC levels
- DUCT SYSTEM located within the home’s thermal boundary
- WATER EFFICIENCY meets WaterSense hot water distribution spec.
- LIGHTING AND APPLIANCES ENERGY STAR qualified
- INDOOR AIR QUALITY meets or exceeds the EPA Indoor airPLUS Verification Checklist
- SOLAR meets PV Ready Checklist
- HVAC, HW, and ACH50 meet specs or tradeoff
- BUILD, Label, Sell
Wall Type: How Do ZERH Homes Compare?

- **2x4 16 in. o.c.**
- **2x4 24 in. o.c.**
- **2x6 16 in. o.c.**
- **2x6 24 in. o.c.**
- **Double-wall***
- **Staggered Stud***
- **Other concrete**
- **Panelized or Modular**
- **SIP**
- **ICF**
- **Log, Post & Beam**

**Percent of Homes**

*Staggered and double walls were not reported by Home Innovation Research Labs. 2x4s staggered on 2x6 plates, or 2x6s staggered on 2x8 plates.

**Participants in DOE ZERH Housing Innovation Awards 2013 to 2019.

***2016 new homes study by Home Innovation Research Labs.
A Better Stud Wall

Advanced Framing

• 2-foot grid
• Less lumber, Less time, Less waste
• More room for insulation
Advanced Framing

Advanced framing on a 2-foot grid.
Advanced Framing

Traditional Framing

Advanced Framing Techniques
More Advanced Frame

Exterior sheathing

Studs

Drywall

Exterior 2x6 wall

Ladder of 2x4s spaced vertically 24” on center

Horizontal blocking for gypsum board support and connection between interior and exterior wall

Interior 2x4 wall

Drywall clip

Drywall
An uncommon 6.55/12 roof pitch provides space for exactly 4 ½ sheets of 4-foot-wide roof sheathing with just one cut and optimal PV angle.
Stud Walls are Great - Except for Thermal Bridging

FLIR - Infra red image taken at -15 degrees Celsius

11/27/03 7:36:41 AM e=0.96
Stop Thermal Bridging – Put on a Sweater

 Builders use rigid foam exterior insulation to stop thermal bridging.
Rigid foam can serve as insulation, sheathing, and weather-resistant barrier, all exterior insulation to stop thermal bridging.
Builders use rigid foam exterior insulation to stop thermal bridging.
Extended Plate and Beam

2x4 on 2x6 Plate
Provides solid nailing surface at top and bottom plate
Staggered Studs

Staggered studs: Builders weave insulation around the studs to stop thermal bridging.
Double Walls
SIPs
SIPs

Graphite SIPs

EPS and Steel panels
It’s a Marshmallow World in the Winter
Just like Legos

Habitat Volunteers build an ICF house in Florida
DIY ICF Foundation

1. Assemble the ICF blocks.

2. Lay the foundation base with dirt or sand.

3. Fill the ICF blocks with concrete.

4. Install the final layer of the foundation.
AAC – a different kind of concrete
Modular - Modern
Modular - Traditional

Traditional Dutch colonial made from traditional materials in nontraditional factory setting.
Modular with I Beams

Panelized factory construction with 9.5-inch I-joist wall studs.
Panelized homes – Insight
Production Homes
Deltec the new Sears Roebuck House.
Insulated Concrete Panels
Concrete Panel House

Insulated concrete panels assemble quickly on site, sit on gravel, no foundation is poured.
Spray Foam Slab Edge

2" overhung wall

Slab edge before spray foam application

Finished wall and slab edge insulated detail once painted, graded and hardscaped.
Spray Foam Just where you need it.

Judicious use of spray foam
Paint-on flashing and weather-resistant barrier.
No Holes Up There

Zero roof penetrations on all our roofs. Gable vents for air systems and studor vents for all plumbing vents are used.

Exhaust fan, ERV, dryer and range hood venting all in gables and not run through the roof system.
Aerosol Sealing

Air seal everywhere all at once.
Aerosol sealant seals off every nook and cranny.
Air Sealing

Buy your own or build your own blower door.
HVAC: How Do ZERH Homes Compare?

- Mini-Split Heat Pump: 25%
- Central Heat Pump: 28%
- Ground-Source Heat Pump: 14%
- Air-to-Water Heat Pump: 8%
- Gas Furnace: 24%
- Electric Furnace & Baseboard: 2%
- Oil Furnace or Boiler: 6%
- Gas: Radiant or Combi: 6%
- Other: 3%
- No Heating System: 0.5%

**Notes:**
*Participants in DOE ZERH Housing Innovation Awards 2013 to 2019.
**2016 new homes study by Home Innovation Research Labs.
***DOE Energy Information Administration 2015.
****Does not add to 100%. Homes with multiple heating systems are counted twice.
HVAC* (DOE ZERH Builders 2013-19)

- 23% Mini-Split Heat Pump
- 25% Central Heat Pump
- 13% Ground-Source Heat Pump
- 7% Air-to-Water Heat Pump
- 6% Gas: Radiant or Combi
- 2% Electric Furnace & Baseboard
- 2% Other & No Heating System

*Percents are calculated out of the total number of system installed as some builders install multiple types of HVAC systems.
Mini-Split Heat Pumps: Ducted vs Ductless
(DOE ZERH Builders 2013-19)

- 60% Ductless Mini-Split
- 32% Ducted Mini-Split
- 9% Ducted & Ductless Mini-Splits
Heat Pumps

Type of Heat Pump Installed
(DOE ZERH Builders 2013-19*)

- Air-to-Water Heat Pump: 11%
- Ground-Source Heat Pump: 19%
- Central Heat Pump: 38%
- Mini-Split Heat Pump: 34%

Percent of Homes with Heat Pump Installed

*Does not add to 100%. Homes with multiple heat pumps are counted twice.
Where’s the minisplit?

Find the mini-split.
Just one ductless

Maximizing mini-splits, with exhaust fans?!
Air Sealed Chase

Trunk ducts are inside conditioned space in a dropped ceiling chase.
Tucked in Ducts

Trunk ducts are inside conditioned space in a dropped ceiling chase.
Attic Chase for Ducts
Water Heating

Type of Primary Water Heating System Installed
(DOE ZERH Builders 2013-19)

- Tankless: 30%
- Electric Tank: 7%
- Gas Tank: 2%
- Gas-Fired Boiler: 5%
- Air-Source Heat Pump: 28%
- Air-to-Water Heat Pump: 7%
- Ground-Source Heat Pump: 10%
- Solar Thermal Plus Other: 10%
- Other: 0.5%
Combined Heat and Hot Water
(DOE ZERH Builders 2013-19)

26%
Combined Heat and Hot Water

74%
Domestic Hot Water Only
Ground Source Water Heater

Ground source heat pump plumbed to heat for domestic water first then space heat
Ventilation

Ventilation Type
(DOE ZERH Builders 2013-19)

- 43% ERV
- 20% HRV
- 23% Balanced and Supply-Only
- 13% Exhaust-Only
- 1% Unknown
Ventilation

Type of Ventilation System by IECC Climate Zone

(DoE ZERH Builders 2013-19)

Percent of Builders in Each Climate Zone

- ERV
- HRV
- Exhaust
- Balanced and Supply-Only
- Unknown

IECC Climate Zone:
- 2A
- 2B
- 3A
- 3B
- 3C
- 4A
- 4B
- 4C
- 5A
- 5B
- 6A
HRV vs ERV

Percent of Builders in Each IECC Climate Zone Who Use an ERV or HRV
(DOE ZERH Builders 2013-19)

<table>
<thead>
<tr>
<th>IECC Climate Zone</th>
<th>ERV</th>
<th>HRV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>3A</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>3B</td>
<td>20%</td>
<td>50%</td>
</tr>
<tr>
<td>3C</td>
<td>50%</td>
<td>13%</td>
</tr>
<tr>
<td>4A</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>4B</td>
<td>82%</td>
<td>9%</td>
</tr>
<tr>
<td>4C</td>
<td>45%</td>
<td>50%</td>
</tr>
<tr>
<td>5A</td>
<td>55%</td>
<td>19%</td>
</tr>
<tr>
<td>5B</td>
<td>52%</td>
<td>16%</td>
</tr>
<tr>
<td>6A</td>
<td>39%</td>
<td></td>
</tr>
</tbody>
</table>
Stained concrete - Fashion statement or heating system?
Earth Tubes

Now for something completely different...
Attics

Attic: Vented vs Unvented
(DOE ZERH Builders 2013-19)

40% Vented Attic
60% Unvented Attic
Windows: Double vs Triple Pane

(DOE ZERH Builders 2013-19)

41% Triple-Pane

59% Double-Pane
Windows

Windows: Single, Double, or Triple Pane

<table>
<thead>
<tr>
<th></th>
<th>EIA 2015*</th>
<th>DOE ZERH 2013-2019**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Pane</td>
<td>41%</td>
<td>0%</td>
</tr>
<tr>
<td>Double Pane</td>
<td>58%</td>
<td>59%</td>
</tr>
<tr>
<td>Triple Pane</td>
<td>41%</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Data from 2015 EIA Residential Energy Consumption Survey (RECS).
**Participants in DOE ZERH Housing Innovation Awards 2013 to 2019.
**Lighting**

**Percent of Homes with Half or More LED, CFL, or Incandescent Bulbs**

<table>
<thead>
<tr>
<th></th>
<th>EIA 2015*</th>
<th>ZERH 2013-19**</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incandescent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Data from 2015 EIA Residential Energy Consumption Survey (RECS).
**Participants in DOE ZERH Housing Innovation Awards 2013 to 2019. 45% or more equals about half of bulbs in ZERH data.
*** Does not add to 100%. Homes with a 50/50 split between bulbs are counted twice.
Lighting

Lighting (DOE ZERH Builders 2013-19)

- 66% LED (≥ 95%)
- 16% Mostly LED
- 10% Mostly CFL
- 9% CFL (≥95%)

Percent of Homes with Over 95% LED Lights

(DOE ZERH Builders 2013-18)

- 2013: 25%
- 2014: 17%
- 2015: 44%
- 2016: 67%
- 2017: 89%
- 2018: 100%
Pseudo Can Lights
Photovoltaics

(DOE ZERH Builders 2013-19)

- 63% With Solar PV
- 37% Without Solar PV
Clever Hacks – Solar

Tip the hat to solar.
Solar Slope

Asymmetrical for more solar access. PV tray is water proof and vented.
Clever Hacks – Solar

Solar shingles blend in with the roof tiles.

Asymmetrical garden shed houses solar panels.
PV Roofs

PV IS the roof for this back porch and covered roof-top deck.
Battery storage = more net zero with less PV

For example:

6.2-kW PV = Net Zero

3.6-kW PV = Net Zero

+ 10-kW battery
PV + Battery Storage

The graph shows the power output over a 3.5-day period, focusing on the period from 08:00 to 04:00. The graph includes data on charge, consumption, PV production, discharge, and SOC (State of Charge). The time frame is set to go to: Now 11.09.2019.
Clever Hacks –
Expect what you Inspect

Good performance
= good materials +
good installation
Questions?

For more information contact

Theresa Gilbride
Pacific Northwest National Laboratory
Theresa.Gilbride@pnnl.gov
office: 509-371-6047
Production Builders

Wall Type Choices for all ZERH Builders
- Staggered: 17%
- 2x6, 24" oc: 33%
- Other: 28%
- Double: 13%
- ICF: 9%

Production Builder Wall Type Choices
- 2x6, 24" oc: 65%
- Double: 20%
- ICF: 10%
- Staggered: 5%

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Ceiling R-Value</th>
<th>Wood Frame Wall R-Value</th>
<th>Mass Wall R-Value(^b) (2009) (IRC: k)</th>
<th>Floor R-Value</th>
<th>Basement 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>1</td>
<td>30</td>
<td>30</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>38</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>38</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>38</td>
<td>49</td>
<td>13</td>
<td>20 or 13+5(^h)</td>
<td>5/8</td>
<td>5/13(^i)</td>
<td>0</td>
</tr>
<tr>
<td>5 and Marine 4</td>
<td>38</td>
<td>49</td>
<td>20 or 13+5(^h)</td>
<td>20 or 13+5(^h)</td>
<td>13/17</td>
<td>30(^g)</td>
<td>10, 2 ft</td>
</tr>
<tr>
<td>6</td>
<td>49</td>
<td>49</td>
<td>20 or 13+5(^h)</td>
<td>20 or 13+5(^h)</td>
<td>15/19</td>
<td>30(^g)</td>
<td>10, 4 ft</td>
</tr>
<tr>
<td>7 and 8</td>
<td>49</td>
<td>49</td>
<td>21</td>
<td>20+5(^h) or 13+10(^h)</td>
<td>19/21</td>
<td>38(^e) IRC: 30(^e)</td>
<td>10, 4 ft</td>
</tr>
</tbody>
</table>

\(^a\) For SI: 1 foot = 304.8 mm
### Insulation Reqs IECC

**IECC code table footnotes**

For SI: 1 foot = 304.8 mm.

*The IRC code requirement differs from the IECC code requirement, as noted.

**a.** Table adapted from Table R402.1.1 in the 2009 and 2012 IECC and Table R402.1.2 in the 2015 and 2018 IECC (Table N1102.1 in 2009 IRC, Table N1102.1.1 in 2012 IRC, and Table N1102.1.2 in 2015 and 2018 IRC).

2012, 2015, and 2018 IECC: R-values are minimums. When insulation is installed in a cavity which is less then the label or design thickness of the insulation, the installed R-value of the insulation shall not be less than the R-value specified in the table.

2009 IECC: R-values are minimums. R-19 batts compressed into a nominal 2x6 framing cavity such that the R-value is reduced by R-1 or more shall be marked with the compressed batt R-value in addition to the full thickness R-value.

b. Refers to fenestration requirements not shown on this excerpted table.

c. 2009-2018 IECC: “10/13” means R-10 continuous insulation (called “insulated sheathing” in 2009 IECC) on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall. “15/19” means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. Alternatively, compliance with “15/19” shall be R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home.

2009 IRC Only: The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.

d. 2018 IECC: R-5 insulation shall be provided under the full slab area of a heated slab in addition to the required slab edge insulation R-value for slabs, as indicated in the table. The slab edge insulation for heated slabs shall not be required to extend below the slab.

2009, 2012, and 2015 IECC: R-5 shall be added to the required slab edge R-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.

e. Refers to fenestration requirements not shown on this excerpted table.

f. 2009-2018 IECC: Basement wall insulation is not required in warm-humid locations as defined by Figure R301.1 and Table R301.1 (Figure/Table N1101.2 in 2009 IRC and Figure/Table N1101.10 in 2012, 2015, and 2018 IRC).

g. 2009-2018 IECC: Alternatively, insulation sufficient to fill the framing cavity and providing not less than an R-value of R-19.

h. 2015 and 2018 IECC: The first value is cavity insulation, the second value is continuous insulation. Therefore, as an example, “13+5” means R-13 cavity insulation plus R-5 continuous insulation.

2012 IECC: First value is cavity insulation, second value is continuous insulation or insulated siding, so “13+5” means R-13 cavity insulation plus R-5 continuous insulation or insulated siding. If structural sheathing covers 40 percent or less of the exterior, continuous insulation R-value shall be permitted to be reduced by no more than R-3 in the locations where structural sheathing is used — to maintain a consistent total sheathing thickness.

2009 IECC: “13+5” means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, insulated sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

i. 2018 IECC: Mass walls shall be in accordance with Section R402.2.5 (N1102.2.5 in 2018 IRC). The second R-value applies where more than half of the insulation is on the interior of the mass wall.

2009, 2012, and 2015 IECC: The second R-value applies where more than half of the insulation is on the interior of the mass wall.

(In the 2009 IRC, footnote “k” addresses mass wall insulation while footnote “I” and “J” address fenestration.)

j. 2009 IECC Only: Refers to fenestration requirements not shown on this excerpted table.