Innovation & Integration: Transforming the Energy Efficiency Market

DOE Zero Energy Ready Home

Zero Energy Ready Home Training

SAM RASHKIN
Chief Architect
Building Technologies Office
Part I: Why Build Zero Energy

Zero Energy Ready Home:

- Definition
- The Visible Future
- Visible Future Builders
- Value Proposition
- Business Case
Part II: How to Build Zero Energy

Zero Energy Ready Home:

- Technical Specs Overview
  - ENERGY STAR for Homes v3 Baseline
  - Super Air-Tight Construction
  - 2012 IECC Insulation
  - Advanced Windows
  - Ducts in Conditioned Space
  - Efficient Hot Water Distribution
  - Efficient Components
  - Indoor Air Quality
  - Renewable Ready Construction
  - Performance Threshold

- Recognition

- Local Solution
Zero Energy Ready Home

Definition
A ‘Green’ Home is…

A Home with a Package of Measures Earning a Bunch of Points Needed to Achieve One of Four Levels of Greenness.
‘Green’ vs. Zero Energy Ready

What’s Missing in Green Definition

Complete Systems that Ensure Bankable Value Propositions

What’s Included in Zero Energy Ready Definition
What Complete Systems?

Ultra-High Efficiency Systems that optimizes cost-effectiveness + Assured Performance Systems that exceeds consumer expectations
Why Efficiency + Performance
ZERH Efficiency + Performance

High Efficiency

Low Efficiency

Low Performance

High Performance

Low HERS Index Home

Minimum Code Home

Energy Star Certified Home

Zero Energy Ready Home

Low Efficiency

Typical Existing Home

Energy Star Certified Home

Zero Energy Ready Home
High-performance home so energy efficient, all or most annual energy consumption can be offset by renewable energy.
Leverage Existing Programs That Ensure Complete Systems

[Efficiency + Performance]

Don’t Reinvent the Wheel Strategy
The Visible Future
“You can predict the future accurately.
All you have to do is leave out the parts
you could be wrong about.”

“The key… is knowing how to distinguish a
soft trend from a hard trend…

It’s knowing how to recognize certainty.”

Daniel Burrus, “Flash Foresight”
Predicting the Visible Future

3 Hard Trends

- Increasing Energy Efficiency
- Increasing Performance
- Increasing Innovation

8 Complete Systems
Hard Trend: Increasing Energy Prices: Gas

> Energy Eff.  > Performance  > Innovation

Source: U.S. Energy Information Administration
Hard Trend: Increasing Energy Prices: Gas

> Energy Eff.  > Performance  > Innovation

Figure 19. Average delivered prices for natural gas in three cases, 2005-2040 (2011 dollars per million Btu)
Average electricity prices have risen 37% over the last decade... However, it’s where electricity prices are headed that will be exciting and profitable...

> Energy Eff.  > Performance  > Innovation
Hard Trend: Increasing Energy Prices

National average electric bill has increased nearly 80% over the last ten years.

Source: U.S. Energy Information Agency
Hard Trend: Increasing Rigor of Energy Codes

> Energy Eff.  > Performance  > Innovation

- 20%
- 10%
  0%
  10%
  20%
  30%
  40%
  50%
  60%


15%  30%
Hard Trend: Increasing Builder Risk

> Energy Eff. > Performance > Innovation

- Energy Prices
- Energy Efficiency
- Builder Risk

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<td>-10%</td>
<td>0%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
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Bldg. Sci. Tipping Point

2006
2009
2012
### Building Science Tipping Point:

- Homes No Longer Can Dry if They Get Wet
- Homes More Likely to Get Wet with Colder Condensing Surfaces
- Homes No Longer Ensure Fresh Air
- Greater Combustion Safety Risks
Visible Future: System #1

> Energy Eff.  > Performance  > Innovation

Comprehensive Building Science:
Control Air, Thermal and Moisture Flow.

[ENERGY STAR Certified Homes v3]
Hard Trend:  
Increasing Energy Eff. Homes

> Energy Eff.  > Performance  > Innovation

Green Growing

Green housing projects have been growing steadily, accounting for 20% of all newly built homes last year.

Base Estimate  Upper Estimate

2005: $6 billion 2% of overall value of new homes
2012: $25 billion 22-25%
2013: $32-36 billion* 29-38%
2016: $87-114 billion*

Source: McGraw Hill Construction  * Projected
The Wall Street Journal
2013

- ~220,000 HERS Ratings
- Average Score 64
Visible Future: System #2

> Energy Eff.  > Performance  > Innovation

Optimized Enclosure and HVAC:
Proven Technologies and Best Practices
[DOE’s Building America Program Innovations]

- Energy Eff.
- Performance
- Innovation

Increases in Energy Efficiency Household Appliances, 1981 to 2011

Source: Association of Home Appliance Manufacturers

Percent Increase in Energy Factor

- Room Air Conditioner: 46%
- Freezer: 65%
- Clothes Washer: 102%
- Dishwasher: 114%
- Refrigerator: 207%
Visible Future: System #3

> Energy Eff. > Performance > Innovation

Energy Efficient Components:
High-Efficiency Appliances, Lighting, Fans
[ENERGY STAR Certified Products]
### Hard Trend: Increasing Health Concerns

<table>
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<tr>
<th>Energy Eff.</th>
<th>Performance</th>
<th>Innovation</th>
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- **$40 Billion**
- **$20 Billion**
Indoor vs. Outdoor Air Pollutants:

On average 2-5 times greater

Up to 100 times greater

While Americans Spend

90% of time indoors
Visible Future: System #4

Comprehensive Indoor Air Quality:
Source Control, Dilution, and Filtration

[EPJ Indoor airPlus]
Hard Trend: Decreasing Renewable Cost

> Energy Eff. > Performance > Innovation

Average PV System Price Decline

- LBNL "Tracking the Sun IV"
- SEIA/GTM Research

Average System Price ($/W)


$12 $10 $8 $6 $4 $2 $0

Buildings.Energy.gov
Visible Future: System #5

> Energy Eff.  > Performance  > Innovation

Solar Ready Package:
Low/No-Cost Details Can Save $1,000’s in Future

[|EPA Renewable Ready checklist|]
Visible Future: System #5

Solar Energy Last Step:
Only After 100+ Year Opportunity Cost Systems
[Offset All or Most Annual Energy Consumption]
1950 – 2000:
U.S. Population Doubled
Public Supply
Water Demand
More than Tripled

Since 2011:
> Half the U.S.
Some Level of Drought.
Hard Trend: Increasing Water Crisis

> Energy Eff.  > Performance  > Innovation

U.S. Drought Monitor

July 31, 2012
Valid 7 a.m. EDT

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu/

Released Thursday, August 2, 2012
Author: Mark Svoboda, National Drought Mitigation Center
Hard Trend: Decreasing Water Fixture Flow

> Energy Eff.  > Performance  > Innovation

Shower/Faucet GPM Flow

- **Energy Efficiency**
- **Performance**
- **Innovation**

- **Decreasing Water Fixture Flow**
- **Energy Prices**
- **Energy Efficiency**
- **Builder Risk**
- **Health Concerns**
- **Renewable Cost**
- **Water Crisis**
- **Water Flow**
- **Energy Eff.**
- **Performance**
- **Innovation**

![Graph showing the decrease in shower/faucet GPM flow from 2000 to 2020.](image)
Hard Trend: Decreasing Water Fixture Flow

Energy Eff. > Performance > Innovation

“OK, there! I don’t want to hear anyone whining about how long it takes for the water to get hot!”
Water Efficiency:
Fixtures, Hot Water Distribution, & Landscaping
[EPA WaterSense specifications]
2013 Highlights

**Tornadoes:**

- Moore, OK: 200 mph winds
  25 killed, 100’s injured, 1,000+ homes destroyed
- El Reno, OK: widest tornado ever
Hard Trend: Increasing Extreme Weather

2013 Highlights

**Hurricane Sandy:**

- 285 killed
- 115 mph winds
- Record largest spanning 1,100 miles
- $65 billion damage in the U.S.
Hard Trend: Increasing Extreme Weather

> Energy Eff.  > Performance  > Innovation

2013 Highlights

**Colorado Flooding:**

- 5 killed
- Biggest civilian airlift since Katrina
- 1,200 missing or stranded
- 9+ inches rain in Boulder over 24 hrs.
2011-13 Highlights

Wild Fires:

- Largest in AZ (Wallow 2011)
- Largest and most destructive in NM (Black Forest, Waldo Canyon 2012)
- Most destructive in TX (2011)
- 3rd largest in CA (Rim 2013)
Hard Trend: Increasing Disaster Risk

> Energy Eff.  > Performance  > Innovation

Tornado Risk
Lower  Higher

Hurricane Risk
Lower  Higher

Earthquake Risk
Lower  Higher

New York Times, April 30, 2011
Hard Trend: Increasing Disaster Risk

> Energy Eff. > Performance > Innovation

Severe Winter Weather

Termite Risk

Flood Risk

Wild Fire Risk
Visible Future: System #7

Disaster Resistance:
Weather, Natural Events, and Pests
[IBHS Fortified Homes plus Termite Protection]
Hard Trend: Increasing Innovation Expectation

> Energy Eff.   > Performance   > Innovation

78 Million Innovation Junkies
Hard Trend: Increasing Innovation Expectation

> Energy Eff.   > Performance   > Innovation

Electric Detail: 6300 HINMAN DR, CLINTON

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<th>Meter Number</th>
<th>Pres Read</th>
<th>Prev Read</th>
<th>Pres Date</th>
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11/22/13 12/23/13 Basic Charge
11/22/13 12/23/13 Electric Energy Charge
11/22/13 12/23/13 Energy Exchange Credit
11/22/13 12/23/13 Electric Cons. Program Charge
11/22/13 12/23/13 Power Cost Adjustment
11/22/13 12/23/13 Merger Credit
11/22/13 12/23/13 Federal Wind Power Credit
11/22/13 12/23/13 Regulatory Asset Tracker
11/22/13 12/23/13 Renewable Energy Credit

Current Electric Charges

0 kWh @ $0.091414 Per kWh
0 kWh @ $0.008279CR Per kWh
0 kWh @ $0.004632 Per kWh
0 kWh @ $0.000528CR Per kWh
0 kWh @ $0.000335CR Per kWh
0 kWh @ $0.000323CR Per kWh
0 kWh @ $0.000030 Per kWh
0 kWh @ $0.000348CR Per kWh

$7.87
“This accelerating rate of change is as certain as the sun rising in the east…
It will disrupt catastrophically every aspect of every industry and every aspect of human activity — except for those who see it coming.”

Daniel Burrus, “Flash Foresight”
New Innovation Business Model:
Exceed Customer Expectations

New Rules*:
1. If it can be done, it *will* be done.
2. If you don’t do it, *someone else* will.

* Daniel Burrus, “*Flash Foresight*”
### Disruption with Someone Else Doing It:

- Kodak
- Polaroid
- Motorola
- Palm
- American Car Manufacturers
- TWA and other Legacy Airlines
- Converse Sneakers
- and the list goes on…
Visible Future: System #8

> Energy Eff.  > Performance  > Innovation

**Quality Assurance:**
Integrated Design, Contract Docs, and QM Plan

[Building America QA Best Practices]

- Water Efficient
- Disaster Resistant
- Quality Management
- Energy Efficient Components
- Complete Indoor Air Quality
- Solar Ready
- Comprehensive Building Science
- Optimized Enclosure and HVAC
Real Estate Web Searches Climb 253% in Four Years as 90% of Homebuyers Use Internet as Primary Research

Jan 7 2013, 3:50PM

Home-shopping consumers are not only exponentially increasing their reliance on the Internet but are also developing distinct patterns for using it in their housing searches. Google and the National Association of Realtors® are all trying to anticipate how it will unfold.
Hard Trend: More Informed Consumers

- Energy Eff.
- Performance
- Innovation

SOURCE: National Association of Realtors® - Profile of Home Buyers and sellers 2010
Hard Trend: Aging Housing Stock

> Energy Eff.  > Performance  > Innovation

Median Age of Owner-Occupied Housing

Source: U.S. Census Bureau - 2011 AHS
Hard Trend: Aging Housing Stock

> Energy Eff. > Performance > Innovation

Share of Owner-Occupied Housing Years Structure Built - 2011

- 41% 1969 or earlier
- 15% 1970 to 1979
- 14% 1980 to 1989
- 13% 1990 to 1990
- 17% 2000 to 2009

Source: U.S. Census Bureau - 2011 AHS
Existing Homes with:

- High Utility Bills
- Poor Comfort
- Health Risks
- Moisture Problem Risks
- Excessive Bugs/Pests
- Durability Issues
- Obsolete Technology

Meet 85% of Your Competition
Visible Future: Bundled Systems

> Energy Eff.  > Performance  > Innovation

- Water Efficient
- Disaster Resistant
- Quality Management

- Energy Efficient Components
- Complete Indoor Air Quality
- Solar Ready

- Comprehensive Building Science
- Optimized Enclosure and HVAC
Zero Net-Energy Ready Home

Visible Future Builders
Welcome:
Zero Energy Ready Home

Value Propositions
Zero Energy Ready Home

> Energy Eff.  > Performance  > Innovation

Water Efficient  Disaster Resistant  Quality Management

Energy Efficient Components  Complete Indoor Air Quality  Solar Ready

Comprehensive Building Science  Optimized Enclosure and HVAC

62 | INNOVATION & INTEGRATION: Transforming the Energy Efficiency Market
Zero Energy Ready Home Value

Lives Better
- Engineered Comfort
- Healthier Living
- Solar Ready
- Long-Term Warranty

Works Better
- Ultra-Low Utility Bills
- Advanced Technology
- Water Efficient
- Black-Out Power

Lasts Better
- Quality Construction
- More Durability
- Disaster Resistant
- Lower Cost Insur./Mort.
Someone Else Doing It…
DOE Zero Energy Ready Home

- **Water Efficient (Encouraged)**
- **Disaster Resistant (Encouraged)**
- **Quality Management (Encouraged)**

- **Energy Efficient Components**
- **Complete Indoor Air Quality**
- **Solar Ready**

- **Comprehensive Building Science**
- **Optimized Enclosure and HVAC**
DOE ZERH Bankable Value

**Lives Better**
- Engineered Comfort
- Healthier Living
- Solar Ready
- Long-Term Warranty

**Works Better**
- Ultra-Low Utility Bills
- Advanced Technology
- Water Efficient
- Black-Out Power

**Lasts Better**
- Quality Construction
- More Durability
- Disaster Resistant
- Lower Cost Insur./Mort.
A Symbol of Excellence

- Healthful Environment
- Comfort Plus
- Advanced Technology
- Ultra Efficient
- Quality Built
- Durability

KEY
- DOE Zero Energy ReadyHome
- ENERGY STAR Certified Home
- Existing Home

This label indicates relative performance of this DOE Zero Energy Ready Home to existing homes (built between 1990 and 2010) and ENERGY STAR Certified Homes. Actual performance may vary.
Value Proposition Transparency

DOE Challenge Home Label Methodology

October 2012
Translating ZERH Value Proposition

Lives Better

HEALTHFUL ENVIRONMENT
Every DOE Zero Energy Ready Home has a comprehensive package of measures to minimize dangerous pollutants, provide continuous fresh air, and effectively filter the air you breathe.

COMFORT PLUS
Superior insulation, windows, air sealing and space-conditioning systems included in every DOE Zero Energy Ready Home surround you with even temperatures, low-humidity, and quiet in every room on every floor.

KEY
- DOE Zero Energy Ready Home
- ENERGY STAR Certified Home
- Existing Home

Works Better

ADVANCED TECHNOLOGY
Every DOE Zero Energy Ready Home begins with solid building science specified by ENERGY STAR for Homes, and then adds advanced technologies and practices from DOE’s world-class research program, Building America.

ULTRA EFFICIENT
Compared to a typical home, an ultra efficient Zero Energy Ready Home is inexpensive to own. In fact, every DOE Zero Energy Ready Home is so energy efficient, a small solar electric system can easily offset most, or all, of your annual energy consumption. We call this Zero Net-energy Ready.

DURABILITY
The advanced levels of energy savings, comfort, health, durability, quality and future performance in every DOE Zero Energy Ready Home provide value that will stand the test of time, and will meet and exceed forthcoming code requirements.

Lasts Better

QUALITY BUILT
Advanced construction practices and technologies are specified for every DOE Zero Energy Ready Home. These are enforced by independent verifiers with detailed checklists and prescriptive diagnostics.

A Symbol of Excellence

HEALTHFUL ENVIRONMENT

COMFORT PLUS

ADVANCED TECHNOLOGY

ULTRA EFFICIENT

QUALITY BUILT

DURABILITY

Call us at:
303-231-4567
NewTown@net.com
Translating ZERH Value Proposition

My power bill is $5. What’s yours?
- Heather Robbins, Garbett Homeowner

garbettHOMES.com
Now you’re living.
“My Cool Mom’s August Electric Bill Was $–57.97! What Was Yours?”

- Ali Domino
  Resident of a De Young Net Zero EnergySmart™ Home

Ali and her mother Leah are enjoying the savings and comfort of their De Young Net Zero EnergySmart™ home. De Young homes,....
Translating ZERH Value Proposition

YOU DON’T NEED TO
Imagine
A HOME IN THE YEAR 2020...

IT’S ALREADY HERE!
Translating ZERH Value Proposition

Compare and Contrast
### 30-Year Warranty...

**Lives Better Warranty**
- Lead-Free*
- Asbestos-Free*
- Particulates Filtered to 3 Microns*
- Mold-Free*
- Combustion Safety *
- 100,000+ CF per Day Fresh/Filtered Air*
- VOC-Free*
- Formaldehyde-Free*
- Pest-Free*
- Radon-Free*

**Works Better Warranty**
- $40/Month Average Heating/Cooling Bill*
- Even Room-by-Room Temperatures*
- No Outdoor Drafts*
- Outside Noise Reduction*
- No Excessive Humidity*

**Lasts Better Warranty**
- Structural Integrity *
- No Moisture Damage* 
- Dry Basements*
- No Thermal Defects* 
- 90% UV Sunlight Blocked
- No Window Condensation*
- Roofing
- Siding*
- Windows
- Termite Damage *
Why * in 30-Year Warranty…

- Specified operating conditions
- Specified weather assumptions
- Specified number of occupants
- Specified limitations
- Requirement for warranty service!
Zero Energy Ready Home

Business Case
Minimize Cost

NAHB estimates for every $1,000 increase in sales price, nearly 250,000 households fail to qualify for a mortgage on a typical new home.
Maximize Value

with proven innovations

homebuyers have to have once they try them
(e.g., make new housing compelling again).
Innovation/Value Premium Example

Willingness to Pay for Valued Services

Price Based on ‘Value’, NOT Cost

New Revenue

Innovation/Value Premium

Profit

Old Cell Phone Cost

i-Phone Cost

Profit

Willingness to Pay for Valued Services

Price Based on ‘Value’, NOT Cost

Innovation/Value Premium

Profit

Old Cell Phone Cost

i-Phone Cost

VS.
# ZERH Real Cost

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<th>Marketing Cost</th>
<th>Call-Back Cost</th>
<th>Hard Cost</th>
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<td>Standard Home</td>
<td>VS.</td>
<td>ZERH</td>
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<th>Call-Back Cost</th>
<th>Hard Cost</th>
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ZERH Innovation/Value Premium

Standard Home VS. ZERH

Willingness to Pay for Valued Services

Price Based on ‘Value’, NOT Cost

New Revenue

Innovation/Value Premium

Profit

Cost

Home

ZERH

Willingness to Pay

For Valued Services

Price Based on ‘Value’, NOT Cost

New Revenue

Innovation/Value Premium

Profit

Cost

Home

ZERH

Willingness to Pay

For Valued Services

Price Based on ‘Value’, NOT Cost

New Revenue

Innovation/Value Premium

Profit

Cost

Home

ZERH
Independent Voice of Authority vs. “Trust me.”
Nearly 1 in 3 consumers indicated they **do not trust** home building and real estate companies.

Source: The business of Trust – The Most Trusted Builders in America, Lifestory Research, January 2013
“They didn’t have this [model] when we purchased our home” three doors down the street in October, said Nickiea Youmans, who along with her husband, Linzy, walked into the back yard to check out the house. “We would have been very interested in this,” she added.
Pent-up ZERH Demand

= 8,000 Requests for ZERH
Sensing Pent-up ZERH Demand

~8,000
ZERH’s Committed

~1/4
Staff/Budget/Time
Zero Energy Ready Home

Technical Specifications
Align with ENERGY STAR for Homes v3:

- Comprehensive Building-Science System
- Variable vs. Fixed HERS Index Score
- House Size Adjustment to HERS Score
**DOE ZERH Framework**

### Exhibit 1: 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[^3]</td>
</tr>
<tr>
<td></td>
<td>Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels</td>
</tr>
<tr>
<td>3. Duct System</td>
<td>Ducts located within the homes thermal and air barrier boundary[^7]</td>
</tr>
<tr>
<td>4. Water Efficiency</td>
<td>Hot water delivery systems shall meet efficient design requirements[^3]</td>
</tr>
<tr>
<td>5. Lighting &amp; Appliances[^1]</td>
<td>All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified</td>
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<tr>
<td></td>
<td>80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 60% of sockets</td>
</tr>
<tr>
<td></td>
<td>All installed bathroom venting and ceiling fans are ENERGY STAR qualified</td>
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### Exhibit 2: DOE Challenge Home Target Home[^1-17]

#### HVAC Equipment[^11]

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<td>90%</td>
<td>94%</td>
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<tr>
<td>HSPF</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
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#### Geothermal Heat Pump

- ASHRAE 62.2 Whole-House mechanical ventilation system
- ENERGY STAR EER and COP criteria
- 1.4 cfm/W no heat exchange
- 1.2 cfm/W heat exchange with 60% EER

#### Insulation and Infiltration

- Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards.
- Infiltration[^12] (ACH60): 3 in CFI 1-2 | 3.0 in CFI 3-4 | 3.0 in CFI 5-7 | 3 in CFI 8

#### Windows[^8] (R-26)

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<td>0.17</td>
</tr>
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#### Water Heater

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

---

[^3]: Must Comply
[^4]: Trade-Off Flexibility
[^5]: Size Adjust. Factor
[^6]: Identical to Energy Star
[^7]: ‘Target Home’ Specs
[^8]: Mandatory Reqs.
Zero Energy Ready Home

Technical Specifications

Mandatory Requirements:
### Mandatory Requirements

#### Exhibit 1: DOE Challenge Home Mandatory Requirements for All Labeled Homes

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| 2. Envelope⁶ | Fenestration shall meet or exceed latest ENERGY STAR requirements⁷ ⁸  
  Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels⁹ |
| 3. Duct System | Ducts located within the home’s thermal and air barrier boundary¹⁰ |
| 4. Water Efficiency | Hot water delivery systems shall meet efficient design requirements¹¹ |
| 5. Lighting & Appliances¹² | All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified.  
  80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets  
  All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified |
| 6. Indoor Air Quality | EPA Indoor airPLUS Verification Checklist and Construction Specifications¹³ |
  EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications¹⁶ |

### Encouraged:

- WaterSense Label (indoor and outdoor)
- Disaster Resistance (IBHS Fortified Home)
- Quality Management
Zero Energy Ready Home

Technical Specifications

Mandatory Requirements:
ENERGY STAR for Homes Version 3 Baseline
What is Building Science

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

<table>
<thead>
<tr>
<th>System 1:</th>
<th>Thermal enclosure system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal Enclosure</strong></td>
<td><strong>Heating, Cooling &amp; Ventilation</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Water Management</strong></td>
</tr>
</tbody>
</table>
1. Energy moves from more to less.

90°F - Outside

90°F

40°F

Cooler with Ice
1. Energy moves from more to less.

![Diagram showing energy movement from 70°F to 30°F within a thermal enclosure system.](image-url)
## System 1: Thermal Enclosure System

### Basic Concepts

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

2. Heat Transfer is quantified in British Thermal Units (BTU’s)

1 Btu is approximately equal to the energy in a single match.
<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

Attic air infiltration into the wall
### System 1: Thermal Enclosure System

**Air and Thermal Flow Control**

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Sealing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Air Barriers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Thermal Bypass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Wind Intrusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insulation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Adequate Quantity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Proper Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Minimum Thermal Bridging</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Adv. Windows</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Thermal Enclosure Checklist**
### Heating, Cooling & Ventilation

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

#### Heating and Cooling Equipment:
- High efficiency
- Properly designed and installed
- Combined with a duct system that’s insulated, sealed, and balanced

... Maintain comfort with less energy.

#### Ventilation System:
- Remove low-quality air
- Provide outdoor air
- Filter contaminants to improve IAQ
Structural load measured in pounds (lbs) of weight.

Cooling load measured in btu’s of energy.
System 2: HVAC System
Calculating Heating & Cooling Load

- **Cooling Load** varies for each hour of the year.
- **Cooling Peak Load**: Maximum energy added in a single hour, and must be removed to maintain temperature and humidity.
System 2: HVAC System
Calculating Heating & Cooling Load

- Heating Load varies for each hour of the year.
- Heating Peak Load: Maximum energy lost in a single hour, which must be added back to maintain temperature.
**System 2: HVAC System**

Calculating Heating & Cooling Load

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
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</tr>
</thead>
</table>

- Cooling & heating equipment are “btu machines” that add or remove btu’s to offset the load.
- Load = number of btu’s equipment has to remove or add.
- Load independent of *type* of equipment used.

**°F**

- Furnace
- Boiler
- HP
### System 2: HVAC System

#### What We’re Trying to Avoid

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

#### Random Acts of Sizing
<table>
<thead>
<tr>
<th>Input Type</th>
<th>Low Input</th>
<th>Correct Input</th>
<th>High Input</th>
<th>Cooling Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Baseline</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 Outdoor Design Temperature</td>
<td>103 F</td>
<td>108 F</td>
<td>113 F</td>
<td>32.4</td>
</tr>
<tr>
<td>2 Home Orientation</td>
<td>N</td>
<td>E</td>
<td>W</td>
<td>31.7</td>
</tr>
<tr>
<td>3 Number of Occupants</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>34.4</td>
</tr>
<tr>
<td>4 Conditioned Floor Area (Sq. Ft.)</td>
<td>2,160</td>
<td>2,400</td>
<td>2,640</td>
<td>33.9</td>
</tr>
<tr>
<td>5 Window Area (Sq. Ft.)</td>
<td>324</td>
<td>360</td>
<td>396</td>
<td>33.7</td>
</tr>
<tr>
<td>6 Predominant Window SHGC</td>
<td>0.20</td>
<td>0.30</td>
<td>0.40</td>
<td>32.8</td>
</tr>
<tr>
<td><strong>Combined Impact From First Six Parameters</strong></td>
<td><strong>25.1</strong></td>
<td><strong>43.0</strong></td>
<td><strong>-29%</strong></td>
<td><strong>23%</strong></td>
</tr>
</tbody>
</table>
### System 2: HVAC System

**Select Equipment That Meets Loads**

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

Heating and cooling equipment generally two modes – on & off.

- **Equipment < Load**
- **Equipment > Load**
### System 2: HVAC System
### What We’re Trying to Avoid

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
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</thead>
</table>

Which boat would you want - the one with the **small** pump or the **big** pump?
Verify that the equipment capacity is right-sized relative to the heating and cooling load.

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 2: HVAC System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC-C (3.12); HVAC-R (1.2.9)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Air follows the path of least resistance.

Equal resistance, equal flow

Higher resistance, less flow
Factors that influence the airflow of the ducts:

- Duct Length
- Duct Size
- Duct Shape
- Duct Type
- Duct Turns
- Other Components (e.g., Filters)
System 2: HVAC System

What We Are Trying to Avoid

<table>
<thead>
<tr>
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</thead>
</table>

![Image of HVAC system]

![Image of water management]

U.S. DEPARTMENT OF
Energy Efficiency & Renewable Energy

Buildings.Energy.gov
Verify that the ducts are balanced, insulated, tight, and installed without major defects.
System 2: HVAC System
Basic Concepts

Design:
1. Calculate Heating/Cooling Loads
2. Select Equipment that Meets Loads
3. Design Duct System that Gets Air from Equipment to Rooms and Back

Commission:
A. Check Airflow at Air Handler
B. Check Refrigerant Charge
C. Measure Airflow at Registers/Exhaust
Moisture Vapor (Air Flow)

- Air Sealing
- Air Barriers
- Vapor Barriers/Retarders
- HVAC Quality Installation
- Whole-House Ventilation
- Spot Ventilation

Thermal Enclosure Checklist

HVAC Quality Installation Checklist
System 3: Water Management
Basic Concept

Thermal Enclosure

Heating, Cooling & Ventilation

Water Management
### System 3: Water Management

#### Basic Concept

<table>
<thead>
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<th>Thermal Enclosure</th>
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</tr>
</thead>
</table>

- Many materials used in building homes are not durable when wet.
- Especially important in high performance homes, regardless of whether ENERGY STAR certified.
<table>
<thead>
<tr>
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<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>

**System 3: Water Management**

**What We’re Trying to Avoid**

- Missing step & kick-out flashing
Step and kick-out flashing at all roof-wall intersections, extending ≥ 4” on wall surface about roof deck and integrated with drainage plane above.

Step flashing goes behind water barrier on wall and under shingles on the roof.
### Bulk Moisture Control

- weather resistant barriers
- flashing
- capillary breaks

---

**System 3: Water Management**

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>
### ENERGY STAR for Homes v3:

- ✔ Thermal Enclosure Checklist
- ✔ HVAC QI Checklist - Contractor
- ✔ HVAC QI Checklist - Rater
- ✔ Water Management Checklist

<table>
<thead>
<tr>
<th>Thermal Enclosure</th>
<th>Heating, Cooling &amp; Ventilation</th>
<th>Water Management</th>
</tr>
</thead>
</table>
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</th>
<th>Mixed Climates</th>
<th>Cold Climates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IECC CZ 1-2</td>
<td>IECC CZ 3-4 except Marine</td>
<td>IECC CZ 5-8 and 4 Marine</td>
</tr>
<tr>
<td><strong>Mandatory:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| ENERGY STAR          | 0.27         | 0.40 | Any
| **Performance:**     |              |     |                     |
| Target Home          | 0.25         | 0.30 | ≥0.35
| Home                 | 0.27         | 0.35 | ≥0.40
| **Encouraged:**      |              |     |                     |
| R-5                  | 0.22         | 0.30 | Any

SHGC: Solar Heat Gain Coefficient
U-value: Thermal Transmittance Coefficient

[1] Good
[2] Better
[3] Best
Zero Energy Ready Home

Technical Specifications:
Best Practices
Super Air-Tight Construction
Why Air-Tight Construction

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

<table>
<thead>
<tr>
<th>Climate Zones</th>
<th>DOE Challenge 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 (boxed)</td>
<td>4.0 (boxed)</td>
<td>3.0 (boxed)</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

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

**Shafts:**
- Flues
- Ducts
- Plumbing

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

Exterior air barrier
Cathedral ceiling

Sheathing / roof joint
1.1 cfm/ft @ 50 Pa

- 93%
- 6%
- 1%

- Sheathing / top plates
- Stud / top plates
- Top plates

2-Story house (Floor area = 2,000 ft²)
Sheathing / roof joint unsealed ≈ 0.5 ACH<sub>50</sub>

<table>
<thead>
<tr>
<th>Zones</th>
<th>Requirement</th>
<th>Contribution to requirement (%)</th>
<th>Requirement IECC 2012</th>
<th>Contribution to requirement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 2</td>
<td>3</td>
<td>17</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>3 – 4</td>
<td>2.5</td>
<td>20</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>5 – 7</td>
<td>2</td>
<td>25</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>1.5</td>
<td>33</td>
<td>3</td>
<td>17</td>
</tr>
</tbody>
</table>
Air Sealing with Aerosol

You’ve probably seen this:
Air Sealing with Aerosol

But now we are going to investigate this…

Engineer Curtis Harrington taping off areas in preparation for sealing.

Connecting controls for blower door, setting up compressor for aerosol injection and monitoring software.

Aerosol sealant sealed this leak between this electrical outlet and the wall.

Photos from wcec.ucdavis.edu
Zero Energy Ready Home

Technical Specifications

Mandatory Requirements:

Envelope:

2012 IECC Insulation
• 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]
Climate Zone 5:
Walls: R-20 or R-13+5
Ceiling: R-49
Floor: R-30
Basement: R-15/19
Crawl Space: R-15/19
Slab: R-10 for 2 ft. depth
Zero Energy Ready Home

High-R Walls
High-R Wall Options

• Advanced Framing with Thicker Wall
• Rigid Insulation Exterior Sheathing
  – Continuous Rigid Insulation w/Sheathing
  – Continuous Rigid Insulation w/o Sheathing
  – Continuous Rigid Insulation w/Recessed Studs
• Structural Insulated Panels (SIPs)
• Insulated Concrete Forms (ICFs)
• Double Wall
Adv. Framing w/Thicker Walls

• R-17 – R-21
• Higher Framing Factor (~12-15%)
• Blanket Insulation Issues:  
  R-19 is 6” Thick, which results in  
  R-17 Compressed in 2x6 Wall  
  R-21 is 5.5” Thick, which results in  
  R-21 in 2x6 Wall
• Blown-In Insulation Issues:  
  Settling and Proper Density (Bag Count)
• Spray Foam Issues:  
  High Cost  
  Closed Cell Enhances Structure Perf.  
  Still Need to Ensure Quality installation
Rigid Insulation w/Sheathing

- R-18 Wall
- Complete Thermal Break
- Exterior Condensation Surface
- Can Combine Sheathing w/ Weather Resistant Barrier
- Installation Issues:
  - ≤ 1.5” Thick, Nails Okay
  - > 1.5” Thick, Screws Needed
**BASF Patented Wall Assembly:**

- R-17 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
- BASF Claims Net Cost Competitive with Conventional Wall
Rigid Insulation w/Recessed Studs

- 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
- Much Easier Installation of Cladding
Structural Insulated Panels (SIPs)

- R-20 Walls (6”)
- Substantial Thermal Break (5 – 8% Framing Factor)
- Special Construction Practices Required
- Foundation has to be Perfectly Level
- Significantly Reduced Time-of-Construction
- Reduced Dimensional Variation Corrections
Insulated Concrete Forms (ICFs)

- ~R-24 Walls
- 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
Double-Wall

• R-26 Walls
• Studs Offset to Ensure Complete Thermal Break
• Coldest Outside Sheathing Surface Suggests Plywood Rather Than OSB to Ensure Drying
• Uses Exact Same Framing Techniques Already Understood by Trade Partners
Zero Energy Ready Home

High-R Roofs
5.1 AIR-IMPERMEABLE: In direct contact with the underside of the sheathing
### 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 allowing insertion tube techniques described in BPI RBE-WHALCI 2012.

---

**Structural sheathing as required to attach roof cladding.**

**Water control layer and cladding as per project.**

**Rigid foam plastic insulation sheathing.**

**Roof sheathing (air barrier at this layer).**

**Rafter.**

**Cavity insulation.**

**Interior ceiling covering.**
Sequence of Retrofit:

1) If keeping existing roofing, identify and repair any roof leaks prior to proceeding with retrofit; Otherwise, remove existing roofing and underlayment; Inspect existing roof deck and framing and repair as necessary.

2) Remove existing soffit and install rigid blocking to prevent loose-fill fiber insulation from blowing into soffit; Replace soffit.

3) Remove existing ceiling and insulation (if any) and install ccSPF insulation directly to underside of roof deck; Create air seal at bottom of cavity space by ensuring that foam seals to top plates, blocking, framing and roof deck.

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 Spray Foam Under Roof Decks

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.

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
- 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 Energy Ready Home

Technical Specifications

Mandatory Requirements:

Ducts in Conditioned Spaces
Why Ducts in Conditioned Space?

• **Significant Thermal Losses:**
  – Thermal losses triple for ducts in unconditioned vs. conditioned space
  – Total thermal losses can range from 10-45%
  – Extensive unconditioned space penetrations

• **Significant Performance Impacts:**
  – IAQ
  – Comfort
  – Durability
Ducts in Condit. Space Exemptions

- **Short Duct Run**
  up to 10’ of total length is permitted to be outside of the home’s thermal and air barrier boundary.

- **Jump Ducts**
  may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic

- **Ductless HVAC system**
Ducts in Condit. Space Options

• **Conditioned Floor Space [3 options]**
  within the thermal boundary

• **Unvented Crawl Space/Basement**
  which is within the home’s thermal boundary

• **Unvented Attic**
  regardless of whether conditioned with a supply register

• **Vented Attic**
  equivalent option where other locations in conditioned space are impractical, expensive, don’t work well in specific climates, or increase envelope loads
Ducts in Conditioned Floor Space Option 1: Dropped Ceiling

Issues:

- Architectural Integration
- Good Fit with Simple Plans
- Longer Throws (ACCA Man T)
Issues:

- Design Integration
- Good Fit w/Narrow Plans
- Sealed Air Barrier Critical
Ducts in Conditioned Floor Space Option 3: Ducts Between Floors

Issues:

• Simple Installation
• Design Flexibility
• Cost-Effective
• Floor Registers Likely
Unvented Crawl Space/Basement

Ducts in unvented crawl space or basement

Insulation at Walls

Issues:
- Simple Installation
- Design Flexibility
- Cost-Effective
- Floor Registers Likely
Ducts in Unvented Attic

Issues:

• CZ 5+, air impermeable plus a Class II VT or Class III VT in direct contact
• No Class I VR on attic floor
Ducts in Vented Attic: Dry CZs

Buried Ducts

Ducts with R-8 insulation

Deeply-buried

Fully-buried

Partially-buried

Truss lower chords
Ducts in Vented Attic: Humid CZs

Buried Encapsulated Ducts (BEDs)

- Ducts in vented attic
- Ducts with R-8 insulation encapsulated in 1.5 in of ccSPF = R-31
- Deeply-buried = R-31
- Fully-buried = R-25
- Partially-buried
- Truss lower chords
Zero Energy Ready Home

Technical Specifications

Mandatory Requirements:

Efficient Hot Water Distribution
Water Efficiency as a System

- **Indoor Fixtures**
  - Plumbing Fixtures
  - Appliances and Other Equipment

- **Distribution**
  - Service Pressure
  - Metering (for Multi-Family Homes)
  - Leak Prevention
  - Hot Water Distribution

- **Outdoor**
  - Landscape Design
  - Irrigation (if installed)
Efficient Hot Water Distribution

• “Must Have” for zero net-energy ready homes

• Based on EPA WaterSense Specifications:
  – No more than 0.5 gallons of water in any piping/manifold between the hot water source and any hot water fixture.
  – No more than 0.6 gallons of water shall be collected from the hot water fixture before hot water delivered.
  – Timer- and temperature-based recirculating systems shall not be used to meet the criteria.
Built for when water was free and energy was cheap!

Copper L piping:
- 1” = 5.53 ounces/ft
- ¾” = 3.22 ounces/ft
- ½” = 1.55 ounces/ft

Stored Volume: 306 gallons
10’ branch Wait Time: 1 – 1.5 minutes
2 GPM showerhead
Hot Water Distribution Options

• Core Plumbing Layout (wet wall)
• Manifold System
• Demand Pumping System
Core Plumbing Layout
Manifold Plumbing System
Demand Pumping System

- Sensor or Controls
- Demand Pump
- Dedicated Return
Zero Energy Ready Homes

Technical Specifications

Mandatory Requirements:

Efficient Components:
Lighting, Appliances, & Fans
Components and MEL’s are increasingly important in Low-Load Homes (~25 to 40%). Therefore, Challenge Home requires:

- **ENERGY STAR Certified Appliances**: refrigerators, dishwashers, clothes washers
- **ENERGY STAR Certified Fans**: bathroom ventilation, ceiling fans
- **ENERGY STAR Certified Lighting**: Min. 80% of fixtures or lamps (CFL or LED)

*Only where installed by builder*
Zero Energy Ready Home

Technical Specifications
Mandatory Requirements: Indoor Air Quality
Why IAQ is NOT A La Carte?

- 5 Pa depressurization

- 2000 SF Home
- 8.5’ Ceilings
- 3 ACH50 Air Tightness
- 200 cfm Exhaust (e.g. dryer, range hood)
- Dust Mites –asthma
- ~40% households with significant respiratory issue
- Radon Control
Indoor Air Quality as a System

- Source Control
- Dilution
- Filtration

Practices & Product Selection That Limit Moisture, Radon, Chemicals, Combustion By-Products, Biological Contaminants

HVAC Quality Installation System
Source Control: Moisture

Moisture Control System

• Moisture Vapor:
  – Air Sealing
  – Air Barriers

• Bulk Moisture:
  – Water-Managed Roofs
  – Water-Managed Walls/Openings
  – Water Manage Foundation/Site
  – Water Managed Materials

• Dehumidification [Warm-Humid Climates]
Note: these maps indicate average risk by county. However, **High levels of Radon can be found in any home.**
Source Control: Radon

Radon Resistant Construction

Required for Moisture Control:

A. Gas Permeable Layer
   (min. 4” clean gravel)

B. Plastic Sheeting
   (under slab)

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 Test Kits Not Required
Corrosion-proof rodent/bird screens for openings (e.g., copper or stainless steel mesh)

Exception: clothes dryer vent
Source Control: Biological Contaminants/Moisture

Foundation Sealing

Sealed Sump Pump

Air Sealing
Source Control: Combustion By-Products
Power/Direct Vent Equipment

Power Vented Water Heater  Direct-Vent Furnace
Source Control: Combustion By-Products
Certified Fireplaces & Stoves

- Vented to outdoors
- Adequate Combustion and Ventilation Air
- Gas fireplace power or direct vented
- Meet Specified Standards
CO Alarm in each bedroom area

CO Alarm

Combined CO & Smoke Alarm

Enforceable policy in Multi-family buildings

Certified CO Alarms

Source Control: Combustion By-Products
Source Control: Combustion By-Products
Attached Garage Isolation

Exhaust Fan
Optional

Air Sealing & Gasketed Door
Source Control: Chemicals
Low Formaldehyde Pressed Wood

MDF & Particleboard

Sample Industrial Board Bundle Tag For Particleboard Certified to 0.20 PPM Standard. Tag Size 4"x5"

CONFORMS TO PARTICLEBOARD FORMALDEHYDE EMISSION REQUIREMENTS OF BOTH ANSI A208.1-1999, TABLE B AND HUD 24 CFR 3280

MILL 000

COMPANY LOCATION

PRODUCTION DATE/SHIFT
Source Control: Chemicals
Why Low VOC

Health Hazards of VOCs
VOLATILE Organic Compounds

Immediate
- Eye & Respiratory Tract Irritation
- Headaches
- Dizziness
- Visual Disorders
- Memory Impairment

Up to 6 years
- Eye, Nose, and Throat Irritation
- Headaches
- Loss of Coordination
- Nausea
- Damage to Liver, Kidney, and Central Nervous System
- Cancer
Interior paints and finishes, including 90% or more of such products applied to interior surfaces of homes, shall be certified low-VOC or no-VOC by one of the following:

- Green Seal Standard GS-11, OR
- Greenguard Certification for Paints and Coatings, OR
- Master Painters Institute (MPI) Green Performance Standards GPS-1 or GPS-2, OR
- A third-party low-emitting product list based on CA Section 01350, e.g., the CHPS List at chps.net/manual/lem_table.htm.
Carpets and carpet adhesives shall be labeled with, or otherwise documented as meeting, the Carpet & Rug Institute (CRI) Green Label Plus or Green Label testing program criteria. Carpet cushion (i.e., padding) shall similarly be certified to meet the CRI Green Label testing program criteria.
Dilution:
Whole-House Ventilation

Three Options:
• Exhaust-Only
• Supply-Only
• Balanced

ASHRAE 62.2 2010 Continuous Ventilation Rate:
\[7.5 \text{ cfm} \times (\# \text{ bedrooms} + 1) + [0.01 \times \text{Sq. Ft.}]\]

2,000 sq. ft., 3 Bedroom Home Example:
\[7.5 \times (3+1) + [0.01 \times 2,000] = [30 + 20] = 50 \text{ cfm}\]
Dilution: Whole-House Ventilation
Exhaust-Only Ventilation
Dilution: Whole-House Ventilation
Supply-Only Ventilation
Dilution: Whole-House Ventilation
Balanced Ventilation

ERV or HRV
Simple Thru-Wall ERV

• 90+% Heat Recovery
• 20-30% Humidity Recovery
• 1.4 – 2.8 W for 10/18/22 CFM
Dilution: Spot Ventilation

• Kitchen:
  – 100 CFM Intermittent
  – 5 ACH Continuous

• Bathrooms:
  – 50 CFM Intermittent
  – 20 CFM Continuous
Filtration:
High-MERV HVAC Filter

8 MERV Filter Minimum
Zero Energy Ready Home

Technical Specifications

Mandatory Requirements:

Renewable Ready
[Where Applicable]
Exemptions

- Not required in areas lacking significant solar resources or shaded
- Recognition of high performance water heating systems
RERH Applicability

Average Daily Solar Radiation Per Month

ANNUAL

Solar Ready Encouraged

Solar Ready Required
Screen for RERH Applicability

- **Renewable Energy Ready Checklists**
  - Determine applicability by zip code
  - In this Mid-Atlantic example, solar resources $= 4.8 \text{ kWh/m}^2/\text{day}$
Documentation of the maximum allowable dead load and live load ratings of the existing roof (Rec DL.: 6 lbs./sq. ft.)

Conduit to run DC wire from roof to inverter

Dedicated Area for installing inverter and balance of system

Conduit to run AC wire from inverter location to electric panel

Circuit Breaker designated and/or installed for use by the PV system in the electric panel
Documentation of the maximum allowable dead load and live load ratings of the existing roof (Rec DL.: 6 lbs./sq. ft.)

Chases (a single 4” or 2–2”) from utility room to the attic space below designated array location. Cap and label both ends.
* Homes equipped with an ENERGY STAR whole-house tankless gas water heater or heat pump water heater are exempt from these requirements.

**Solar Bypass Valve** on the cold water feed of the water heater (cap and label both ends).

**Dedicated Area** (3’ x 3’ x 7’) in the utility room adjacent to the existing water heater for a solar hot water tank.

**Dedicated Area** (3’ x 2’ plywood panel) adjacent to the solar hot water tank for the balance of system components/pumping package.

**Electrical Outlet** within 6’ of the designated wall area.
Above: The cold water feed of the existing water heater should have a code-compliant valve assembly installed to connect to the future solar storage tank. Solar bypass valve assembly includes shut-off valves on each of the stubbed and capped “T” fittings, and one shut off valve in the main pipe between the two “T” fittings.
Zero Energy Ready Home

Technical Specifications: Putting It All Together
Zero Energy Ready Home Systems

Building Science
- Thermal Enclosure
- HVAC QI
- Water Management

Best Practices
- Ducts in Condit. Sp.
- 2012 IECC Insulation
- Super Air-Tight
- Super Windows
- Low-Load Eff. HVAC

Efficient Components
- HVAC System
- Water Htg. System
- Lighting/Appliances

Indoor Air Quality
- Source Control
- Dilution
- Filtration

Solar Ready
- Solar Electric
- Solar Thermal

Water Efficiency
- Hot Water Distribution
- Indoor Fixtures
- Outdoor Irrigation

Disaster Resistance
- Weather
- Natural Events
- Pests

Quality Management
- Int. Design Process
- Construction Documents
- QM Program

Encouraged in Challenge Home
Zero Energy Ready Home

Performance Threshold
### Exhibit 2: DOE Challenge 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)</th>
<th>Cold Climates (2012 IECC Zones 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>
</tbody>
</table>

### Insulation and Infiltration
- Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards.
- Infiltration $^{22}(\text{ACH50})$: 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

<table>
<thead>
<tr>
<th></th>
<th>Hot Climates (2012 IECC Zones 1,2)</th>
<th>Mixed Climates (2012 IECC Zones 3,4)</th>
<th>Cold Climates (2012 IECC Zones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHGC</td>
<td>0.25</td>
<td>0.27</td>
<td>any</td>
</tr>
<tr>
<td>U-Value</td>
<td>0.4</td>
<td>0.3</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Homes qualifying through the Prescriptive Path with a total window-to-floor area greater than 15% shall have adjusted U-values or SHGCs.

### Water Heater
- ENERGY STAR minimum

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

### Lighting & Appliances
- For purposes of calculating the DOE Challenge 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.
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 Challenge Home HERS Index Target Score, but may be used for the incremental HERS Index points needed for the Size Adjustment Factor.

Size Mod. Factor = \[
\left(\frac{\text{CFA}_{\text{Benchmark Home}}}{\text{CFA}_{\text{Home to Be Built}}}\right)^{0.25}
\] [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 COMPLIES!</td>
</tr>
</tbody>
</table>
Rating & Verifying Homes

• Same: ENERGY STAR Homes framework

• New:
  – Indoor airPLUS Checklist;
  – Renewable Energy Ready Home Checklists (where applicable)
  – Hot Water Distribution test

• Submissions:
  – Send “DOE Challenge Home Verification Summary” electronically to doechallengehome@newportpartnersllc.com
  – Otherwise builders will not receive “credit” on DCH website
  – Considering RESNET National Homes Registry for future
Verifying Homes – Indoor airPLUS

• 1-page checklist
• Builder or Rater may verify
• Permissible methods:
  – Visual verification on site during construction
  – Reviewing photos taken during construction
  – Checking documentation
  – Equivalent methods as appropriate
• Sampling permitted per RESNET protocol
Verifying Hot Water Distribution

1. Initiate operation of occupant-controlled or occupancy sensor-based recirculation systems, if present,

2. Place bucket or flow measuring bag (pre-marked for 0.6 gallons) under the hot water fixture. Only fixture with greatest stored volume of hot water needs to be tested.

3. Turn on hot water; place digital thermometer into the stream of water just where it meets the water being collected; record starting temperature.

4. When water reaches 0.6 gallons record temperatures again. The temperature must increase by 10 F.
Verifying Homes – RERH

- RERH checklist for DOE ZERH Home
  - builder or rater may verify
Zero Energy Ready Home Recognition
Lots of Recognition Choices…
ZERH Partner Registration

• **Review**
  – Technical Guidelines
  – Partnership Agreement Terms

• **Register**
  – Electronically Sign Agreement

• **Choose Optional Commitments:**
  1. 100% of homes meet DOE Challenge Home Guidelines
  2. Homes meet EPA’s WaterSense Guidelines
  3. Homes meet IBHS’s Fortified Home Guidelines
  4. Meet DOE Challenge Home Quality Management Program
ZERH Partner Benefits

• Resources
  - Customizable Homebuyer Brochures
  - Branding [Logos, Home Certificates and Labels]
  - Electronic Newsletter [updates, policy changes, new innovations]
  - Appraisal Guidance

• Technical Support
  - Building America Solution Center
  - Building America Stakeholder Meetings
  - Building America Research Studies

• Recognition
  - DOE Housing Innovation Awards
  - DOE Zero Energy Ready Home Web Site Locator Tool
  - Case Studies/Virtual Parade of Home [coming]
ZERH Partner Locator Tool

Links Buyers to Leading Edge Builders:
• Contact Information
• Optional Commitments
• # Labeled Homes
• Website link

For All Active Partners
**ZERH Partner Locator Tool**

---

**DOE Challenge Home: Results**

These are all verifiers who are located (or do business) in Minnesota.

[Modify Search] [New Search]

<table>
<thead>
<tr>
<th>Name</th>
<th>City</th>
<th>State</th>
<th># of DOE Challenge Home Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Science Institute Inc.</td>
<td>HINSDALE</td>
<td>IL</td>
<td></td>
</tr>
<tr>
<td>Habitat for Humanity of Ohio-Ky</td>
<td>HAMILTON</td>
<td>OH</td>
<td></td>
</tr>
<tr>
<td>Midwestern Energy Solutions, LLC</td>
<td>OELWEIN</td>
<td>IA</td>
<td></td>
</tr>
<tr>
<td>SustainMax, LLC</td>
<td>MINNEAPOLIS</td>
<td>MN</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Name</th>
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<th>State</th>
<th># of DOE Challenge Home Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluegill Energy Management</td>
<td>KATY</td>
<td>TX</td>
<td></td>
</tr>
<tr>
<td>Building Efficiency Resources</td>
<td>HOLCOMBVILLE</td>
<td>NY</td>
<td></td>
</tr>
</tbody>
</table>
CH Housing Innovation Awards
• **Take Orientation Training**
  after registering and renew training every year

• **Provide Certificate**
  for DOE Zero Energy Ready Home to each home owner

• **Adhere to Brand Identity Guidelines**
  for proper use of the DOE Zero Energy Ready Home name and logo

• **Build/Verify at Least One Home/Year**
  to maintain active partnership

To view the full Agreement terms and disclaimers, visit:

• Rater Prints Certificate directly from rating software

• Certificate Includes:
  – Rating Details
  – Graphic HERS Index
  – Optional Programs
Case Study Example

The Nation's First Certified DOE Challenge Home Leaves a BIG Impression with a SMALL Footprint

The first certified DOE Challenge Home—the "Wilson Residence" in Winter Park, Florida—produces more energy than it uses with construction costs considerably less than originally proposed. Completed in May 2012, this 4-bedroom, 4,064 sq ft (381 sq m) in conditioned space custom home scores a HERS 57, which is well below the HERS 100 for a standard home built to code. With its photovoltaic system, the home produces more than net-zero energy, with a score of HERS -7, which translates into no electric utility bills and even $124 annually in the homeowner's pocket from the utility.

The homeowner, Mr. Wilson, hired e2 Homes to build his dream home. From the start, Rob Smith (the president of e2 Homes) worked with the homeowner, his HERS rater, and his mechanical contractor to study how differing efficiency measures would impact cost, energy efficiency, comfort, and durability. The DOE Challenge Home is data driven and performance driven, based on all the standards... and it addresses concerns of different climates,” said Smith. The team used the Challenge Home requirements along with specifications from LEED for Homes, the Florida Green Building Coalition, the Florida Water Star Gold, and other programs to analyze the best practices in their climate zone compared to code.

As specified in the Challenge Home requirements, the envelope was designed to meet all ENERGY STAR Version 3.0 criteria and 2012 IECC insulation levels. Final home door tests show a tight envelope at 1.77 ACH 50.

The exterior walls were constructed of Aercon Autoclaved Aerated Concrete (AAC) blocks. "My clients wanted AAC to avoid using drywall in this hot humid climate," said Smith. Like concrete blocks, AAC is also mold-resistant, non-combustible, and not penetrable by termites or pests, but the unique block-like structure of the AAC also makes it mistakeable (like for a brick block), sound-resistant, lightweight (about one-third the weight of concrete), easy to saw or drill, and strong (AAC blocks and panels have structural reinforcement added). The window package they ultimately selected is ENERGY STAR, low-E 366 glass blocks 95% of ultraviolet and infrared light, double-pane, and vinyl with a U-factor of 0.27.

The roof is light-colored Galvalume standing-seam metal assembled over engineered roof joists that are energy-foamed underneath to R-50, to create a sealed, conditioned attic that keeps summer temperatures down to 85°F instead of a typical 150°F.

As required by the Challenge Home, the ducts and air handler are located within conditioned space in the unvented, insulated attic. The home is heated and cooled by three systems on the first floor: a heat pump (SEER 18, HSPF 9.5), in the master bedroom; a ductless mini-split heat pump (SEER 16, HSPF 12); and on the second floor, another heat pump (SEER 16, HSPF 9). The team designed the ventilation system to create a slight pressure positive in the home to help control humidity. The "outdoor ventilation system" includes fresh air ducts to the outside of the home that is set to an electric damper regulated by the thermostat to meet AERIA ventilation standards.

The home is water efficient in several ways. Two tankless, propane-fed water heaters are located close to their points of use as possible to minimize water and energy waste, reaching, one near the master bedroom and the other near the kitchen, laundry room, and office/bathroom. Also, the house is double-piped so that a 7,000 gallon cistern collects and supplies rain water to all toilets, urinals, and plants in the backyard.

With the home designed for maximum energy and water conservation, the 13.5 kW Sungrow photovoltaic system completes the house. Rather than treating the off solar panels on the roof, the company Superior Solar, fit them together to form a watertight structure that is the roof of the home. "We loaded the roof with 12,600 solar panels on the second floor; the 12,600 solar panels on the first floor; the company Superior Solar, fit them together to form a watertight structure that is the roof of the home". The Sungrow HIT Double 192 Watt solar panels are bifacial, meaning they can generate more electricity from reflected light that hits the bottom side of the panels. The panels also allow about 15% of the daylight to filter through them, lighting the porch area beneath. The hybrid inverter, a SolarEdge Power Optimizer and Inverter system, converts the panel-produced direct current power into a utility-compatible alternating current, using a unique technology that overcomes the limitations of traditional central string inverter systems but at a much lower cost than micro-inverter systems.

"At the end of the day, my message for builders considering [building to] Challenge Home is that this program is very rigorous, so it should help builders stand out from the crowd," said Smith. "If you start early in the process, there doesn't have to be a cost differential to implement high performance building."
ZERH Builder Recommendations

- **‘Test Drive’ Challenge Home**
  [1-5 homes; most not ready for wholesale change]
  Offer Zero Energy Ready Home as *‘Limited Edition’*

- **Measure Profit Metrics:**
  - Cost
  - Marketing
  - Performance

- **High-Performance Looks Different!**
  - Architectural Appearance
  - ‘Mark of Excellence’
Zero Energy Ready Home

Local Solution
Meet Local HERS Raters...
Thank You

For More Information:
www.buildings.energy.gov/zero/

e-mail Contact:
doechallengehome@newportpartnersllc.com