

# DOE Challenge Home

U.S. DEPARTMENT OF  
**ENERGY** | Energy Efficiency &  
Renewable Energy



**Why Zero Energy Ready is Readily Achievable:  
Technical Specifications for DOE Challenge Home**

**Jamie Lyons, P.E.**  
DOE Challenge Home

**See Other Sessions in DOE  
Challenge Home Track!**

## Zero Energy Ready Homes:

- Defined
- The Visible Future
- Visible Future Builders
- Value Proposition
- Business Case



## Zero Energy Ready Homes:



- **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**

**5 Additional In-Depth  
Technical Sessions  
TUE & WED**



# Zero Energy Ready Homes **Defined**

**High-performance home**  
**so energy efficient,**  
all or most annual energy consumption  
can be offset by renewable energy.

Zero Energy Ready =  
Complete Systems

**Ultra-High  
Efficiency  
Systems**

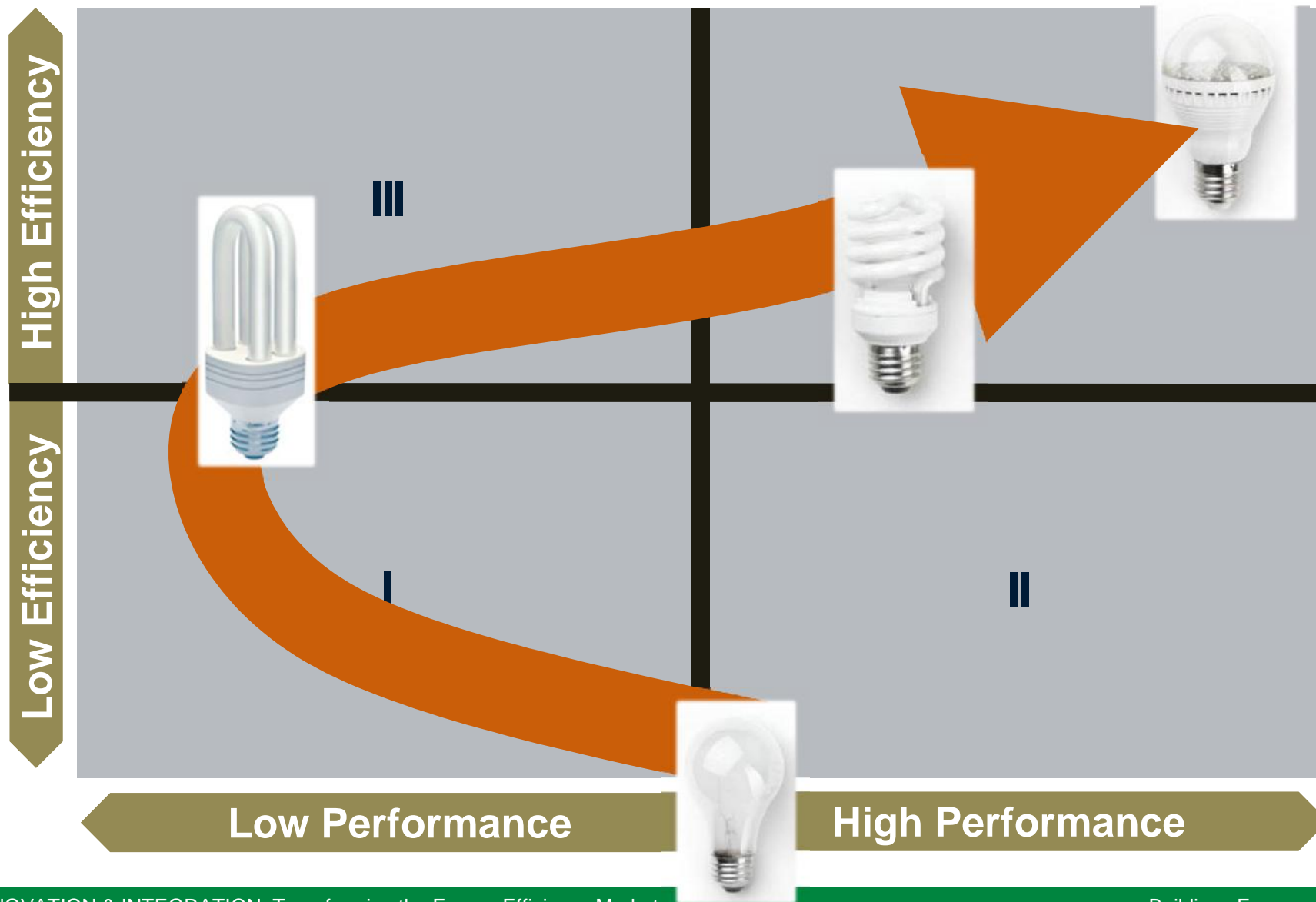
that optimizes  
cost-effectiveness



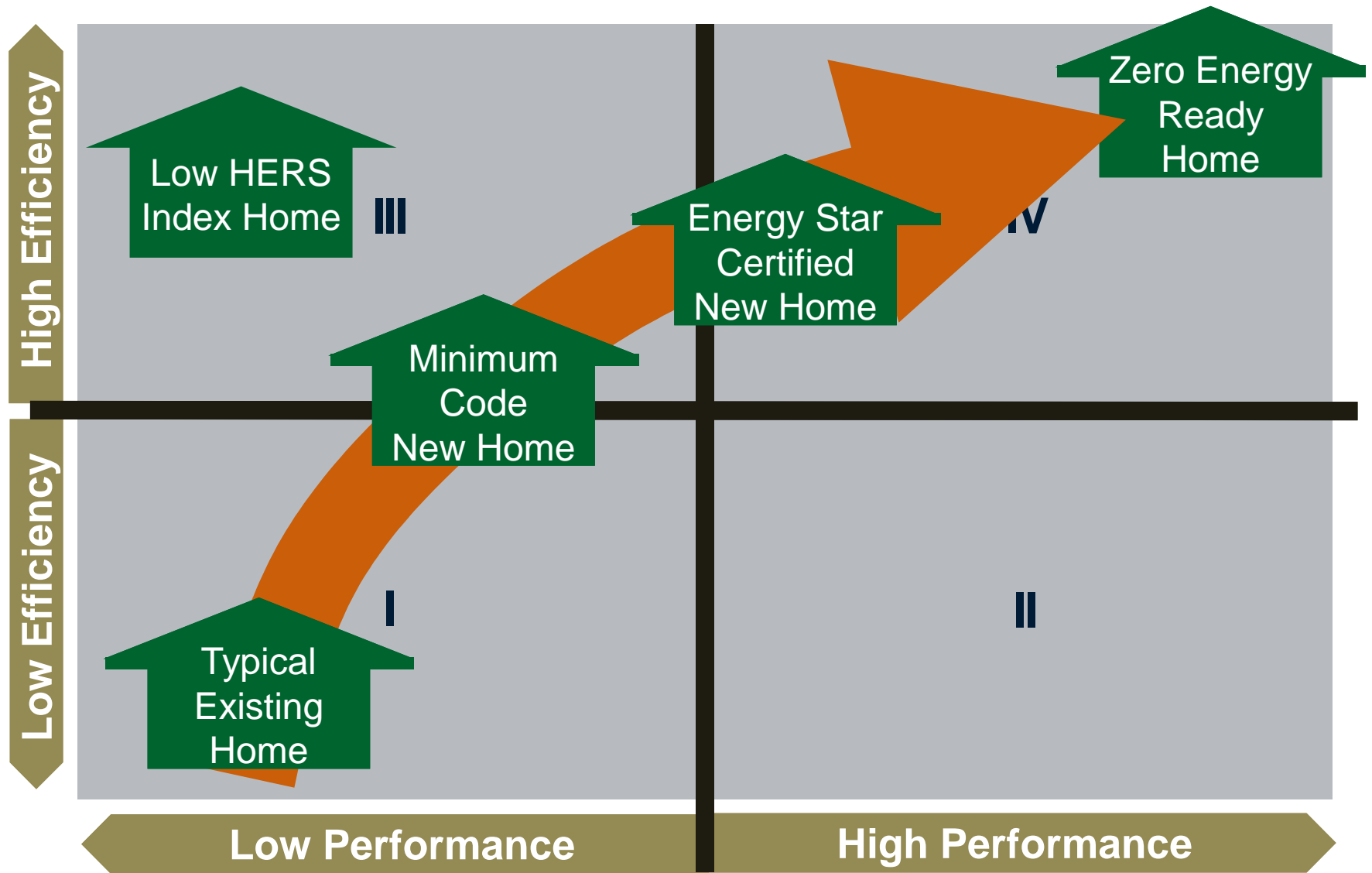
**Assured  
Performance  
Systems**

that exceeds  
consumer expectations

# Why Efficiency + Performance



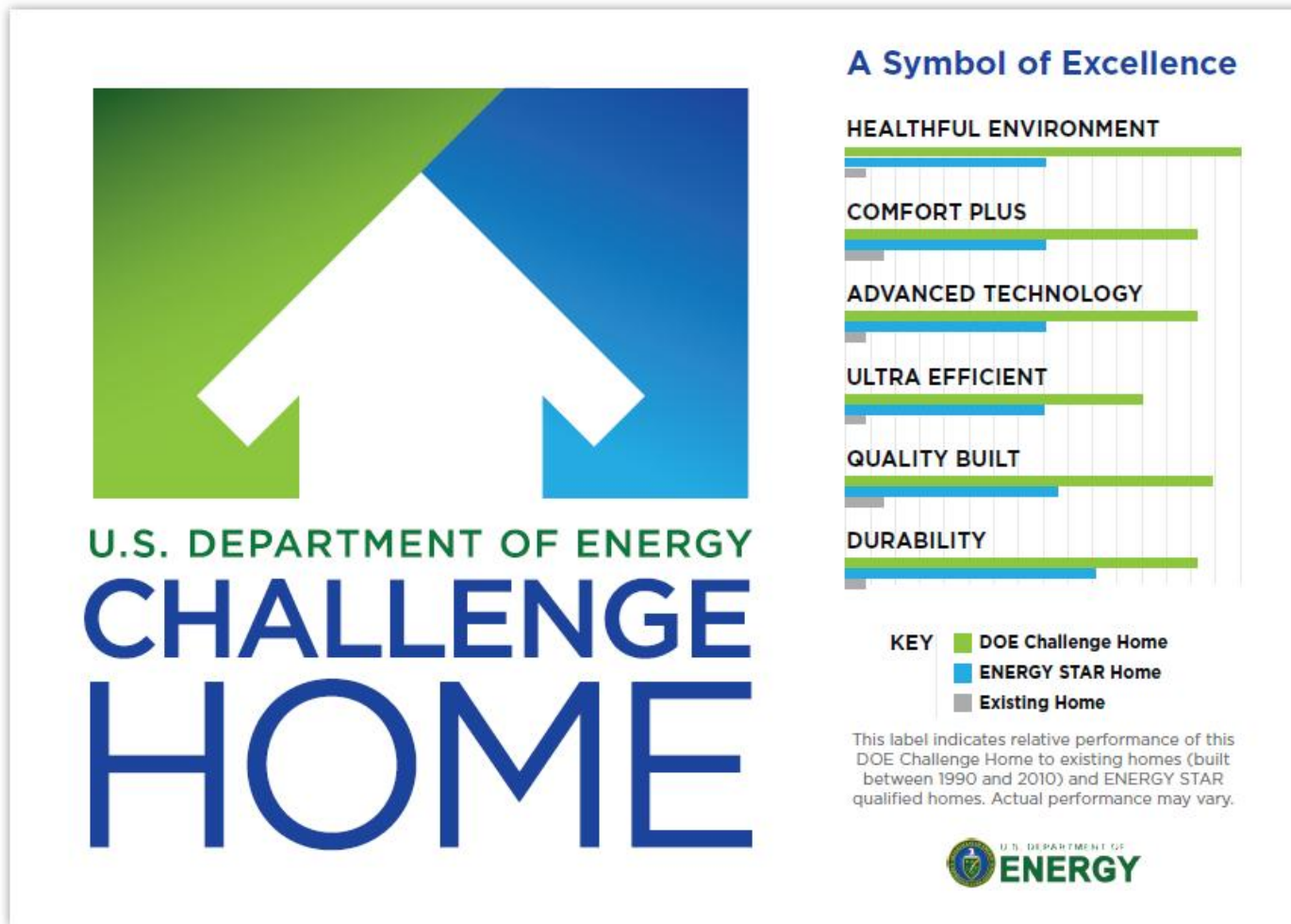
# ZERH Efficiency + Performance







# Zero Energy Ready Homes **Value Propositions**



# Innovation Leadership Example





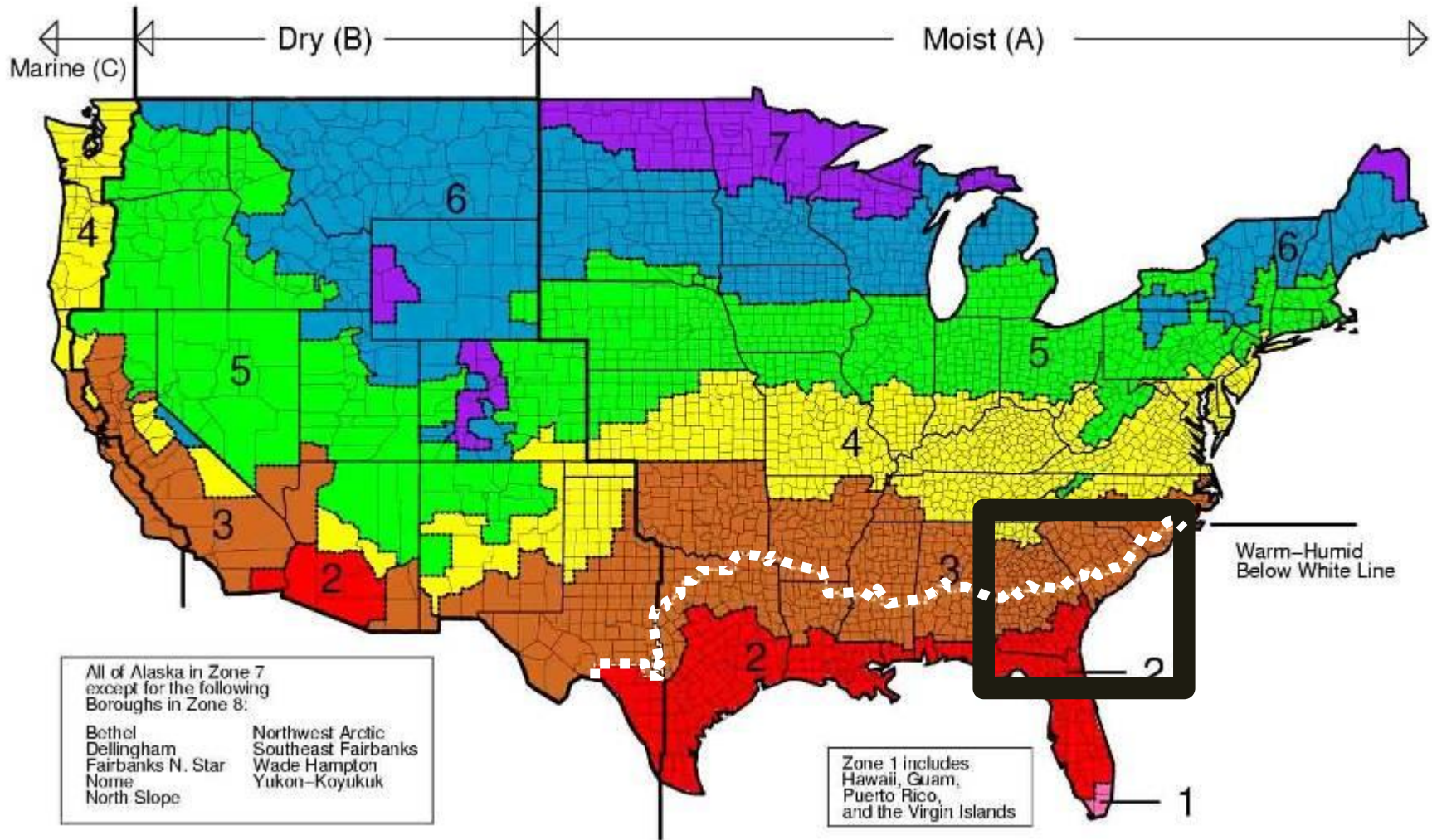
# Zero Energy Ready Homes **Technical Specifications**

## Leverage Existing Programs that Ensure Efficiency + Performance



**Don't Reinvent the Wheel**

# IECC Climate Zones



# DOE Challenge Home Framework

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

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	<input type="checkbox"/> Certified under ENERGY STAR Qualified Homes Version 3 <sup>5</sup>
2. Envelope <sup>6</sup>	<input type="checkbox"/> Fenestration shall meet or exceed latest ENERGY STAR requirements <sup>7, 8</sup> <input type="checkbox"/> Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 IECC levels <sup>9</sup>
3. Duct System	<input type="checkbox"/> Ducts located within the home's thermal and air barrier boundary <sup>10</sup>
4. Water Efficiency	<input type="checkbox"/> Hot water delivery systems shall meet efficient design requirements <sup>11</sup>
5. Lighting & Appliances <sup>12</sup>	<input type="checkbox"/> All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. <input type="checkbox"/> 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets <input type="checkbox"/> All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
6. Indoor Air Quality	<input type="checkbox"/> EPA Indoor airPLUS Verification Checklist and Construction Specifications <sup>13</sup>
7. Renewable Ready <sup>14</sup>	<input type="checkbox"/> EPA Renewable Energy Ready Home Solar Electric Checklist and Specifications <sup>15</sup> <input type="checkbox"/> EPA Renewable Energy Ready Home Solar Thermal Checklist and Specifications <sup>16</sup>

Mandatory  
Reqt.

Must  
Comply

Exhibit 2: DOE Challenge Home Target Home<sup>3, 17</sup>

HVAC Equipment <sup>18</sup>			
	Hot Climates (2012 IECC Zones 1,2) <sup>19</sup>	Mixed Climates (2012 IECC Zones 3, 4 except Marine)	Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10 <sup>20</sup>
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House Mechanical Ventilation System	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 60% SR <sub>50</sub>
<b>Insulation and Infiltration</b>			
<ul style="list-style-type: none"> <li>Insulation levels shall meet the 2012 IECC and achieve Grade 1 Installation, per RESNET standards.</li> <li>Infiltration<sup>21</sup> (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</li> </ul>			
<b>Windows<sup>22, 23, 24</sup></b>			
	Hot Climates (2012 IECC Zones 1,2,)	Mixed Climates (2012 IECC Zones 3, 4 except Marine)	Cold Climates (2012 IECC Zones 4 Marine 5,6,7,8)
SHGC	0.25	0.27	any
U-Value	0.4	0.3	0.27
Homes qualifying through the Prescriptive Path with a total window-to-floor area greater than 15% shall have adjusted U-values or SHGCs. <sup>25</sup>			
<b>Water Heater</b>			
ENERGY STAR minimum; for heating oil water heaters use EF = 0.60			

'Target  
Home'  
Specs

Trade-Off  
Flexibility

Effective for Homes Permitted Starting 8/1/2012 Revised 07/01/2012 Page 2 of 8

Exhibit 3: Benchmark Home Size<sup>26</sup>

Bedrooms in Home to be Built	1	2	3	4	5	6	7	8
Conditioned Floor Area <sup>27</sup> Benchmark Home	1,000	1,600	2,200	2,800	3,400	4,000	4,600	5,200

Size Adjust.  
Factor

Identical to  
Energy Star



Zero Energy Ready Homes

# Technical Specifications Mandatory Requirements:



# Mandatory Requirements

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## Encouraged:

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



Zero Energy Ready Homes

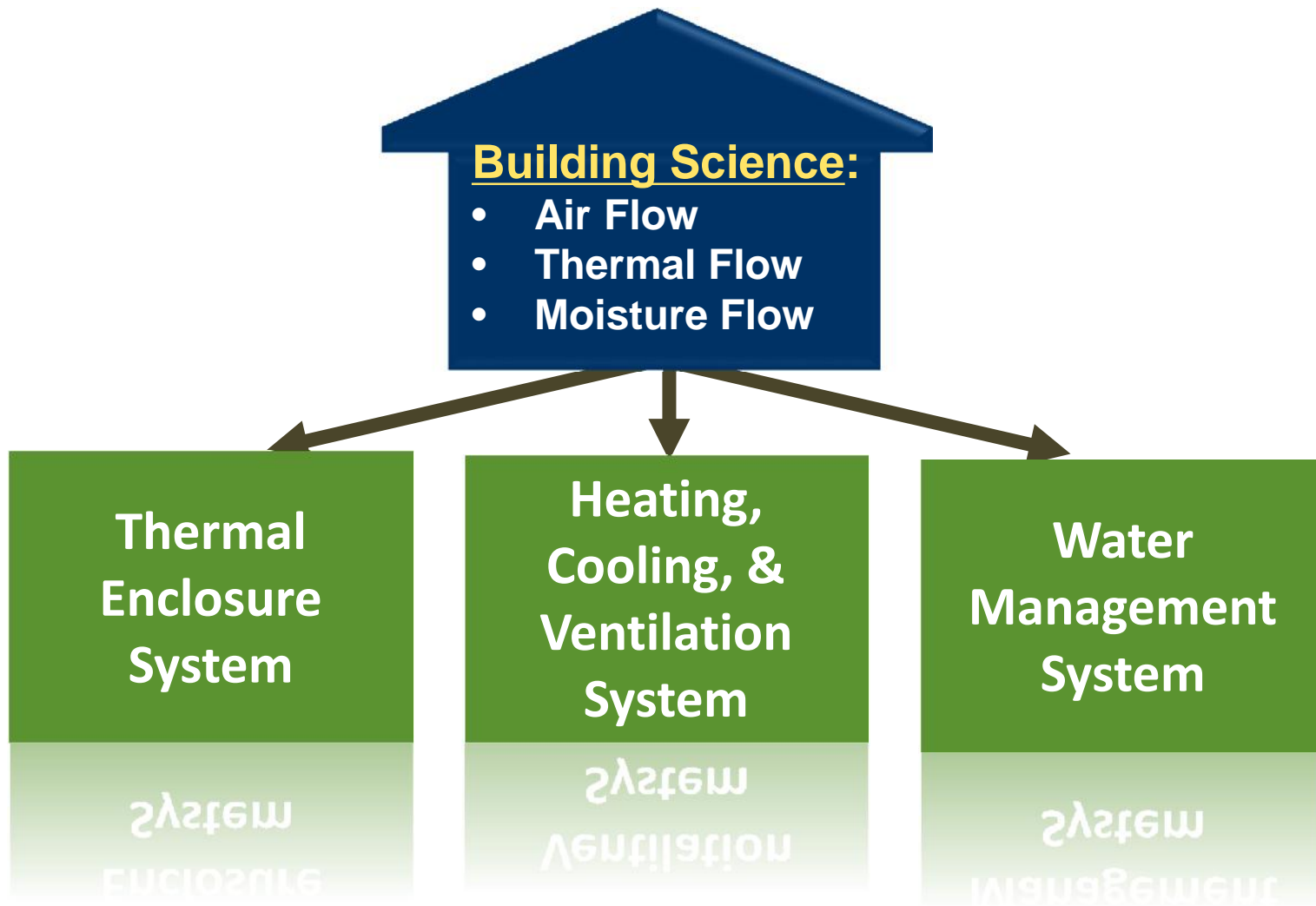
# Technical Specifications Mandatory Requirements: **ENERGY STAR for Homes Version 3 Baseline**

## **Align with ENERGY STAR for Homes v3:**

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



# What is Building Science



System 1:  
Thermal enclosure system

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

A well-insulated and air-sealed home,  
with good windows and doors,  
reduces the amount of energy needed  
to keep the home comfortable.

# System 1: Thermal Enclosure System Basic Concepts

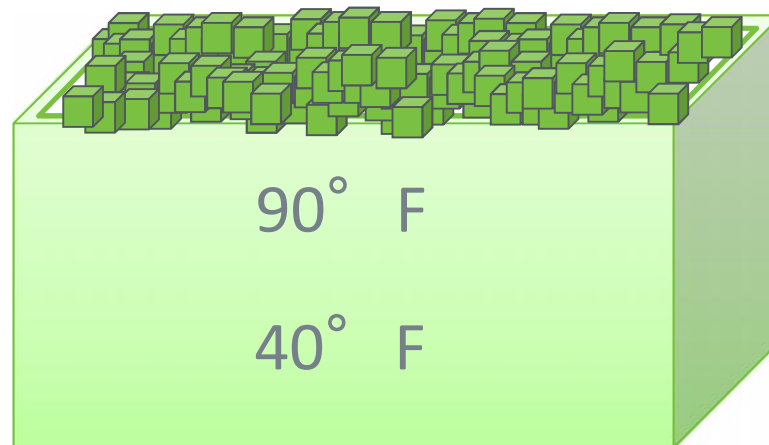
**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

1. Energy moves from more to less.

90° F - Outside



**Cooler with Ice**

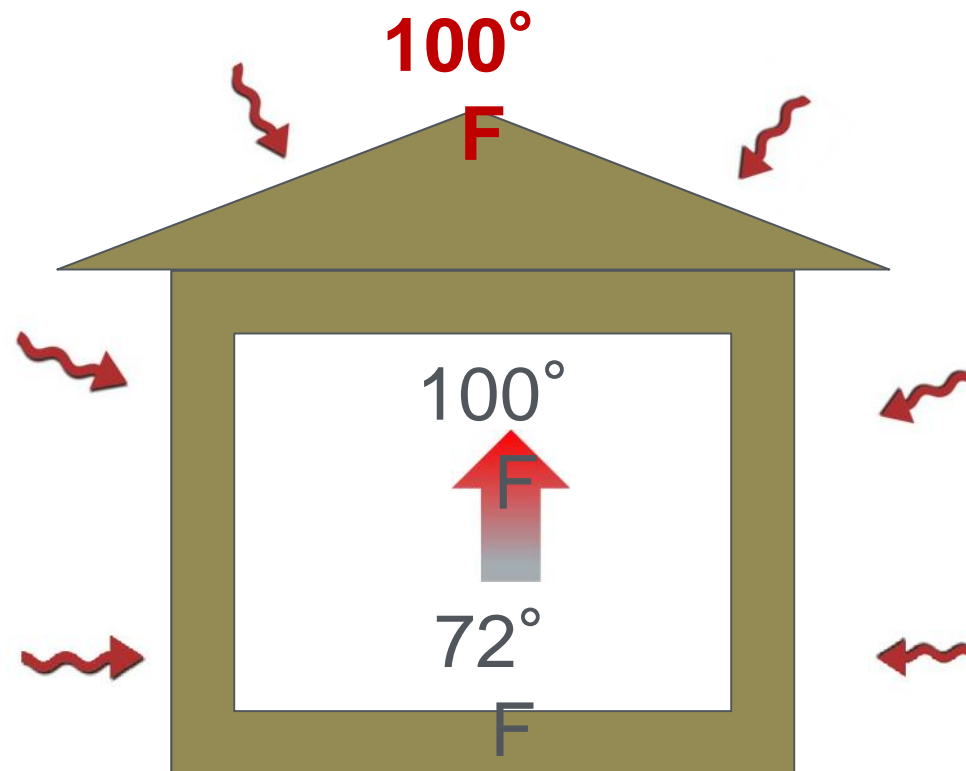
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# System 1: Thermal Enclosure System Basic Concepts

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

1. Energy moves from more to less.

**20 F**





# System 1: Thermal Enclosure System

## Basic Concepts

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**



- Heat transfer can be quantified in British Thermal Units (Btu's)
- 1 Btu is approximately equal to the energy in a single match.

# System 1: Thermal Enclosure System

## What We're Trying to Avoid

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**



Attic air infiltration into the wall

# System 1: Thermal Enclosure System Drywall Sealed at Top Plates

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

**Foam**



**Sill sealer**



**Constr. Adhesive**



# System 1: Thermal Enclosure System Attic/Ceiling Air Sealing Details

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

**Default:  
Insulation at Ceiling**



**Alternative:  
Insulation Roof Deck**



**Ducts in conditioned space**

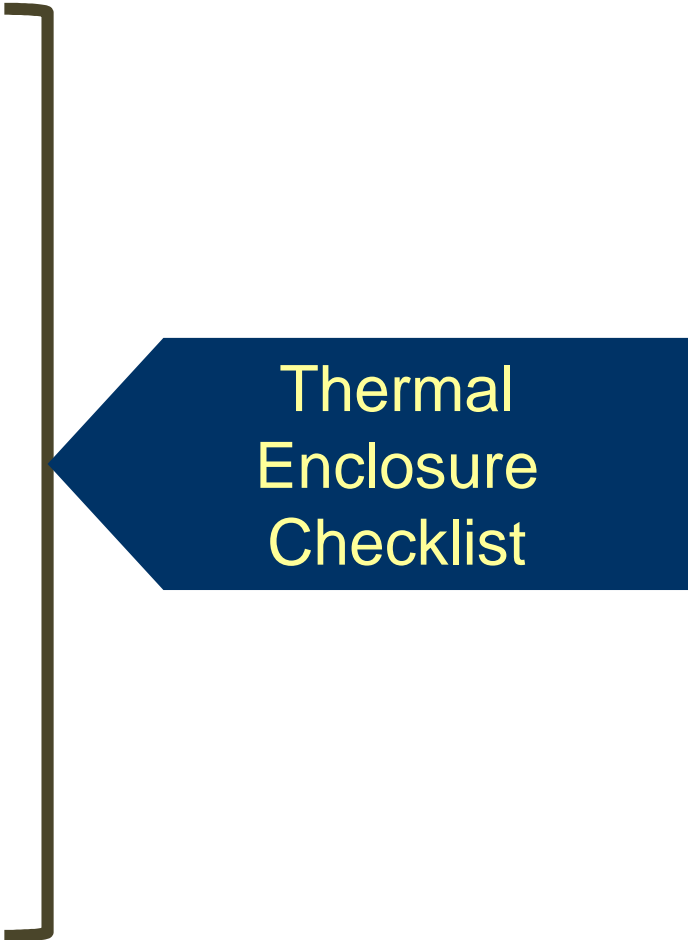
# System 1: Thermal Enclosure System Air and Thermal Flow Control

## Thermal Enclosure

## Heating, Cooling & Ventilation

## Water Management

- **Air Sealing**
- **Air Barriers**
  - Thermal Bypass
  - Wind Intrusion
- **Insulation**
  - Adequate Quantity
  - Proper Installation
  - Minimum Thermal Bridging
- **Adv. Windows**



Thermal  
Enclosure  
Checklist

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

- **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

# System 2: HVAC System

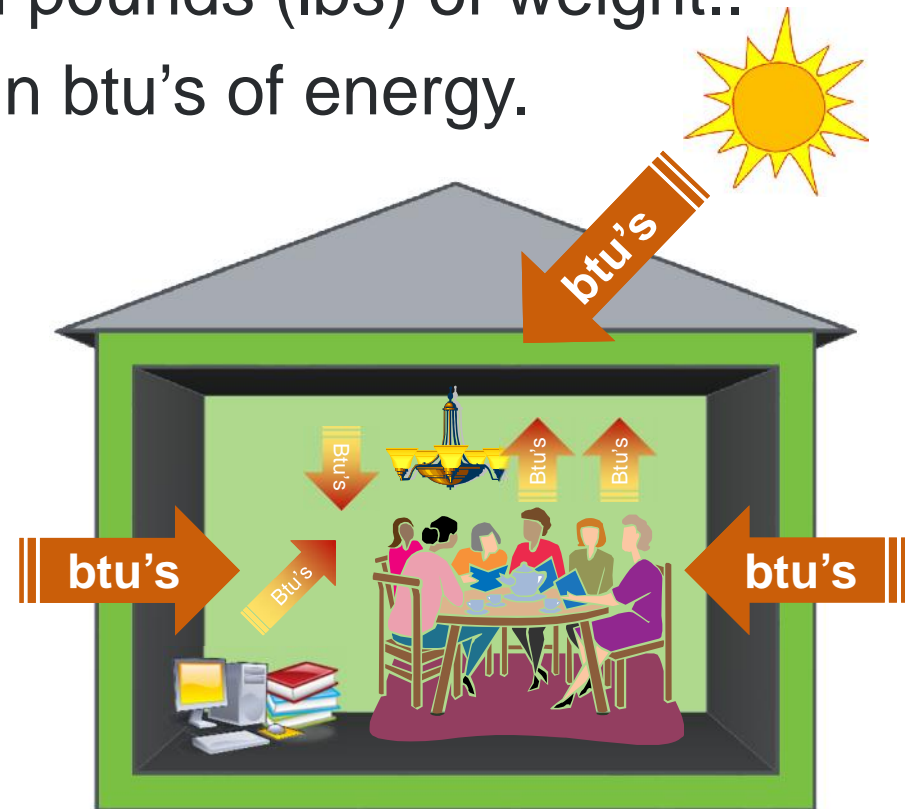
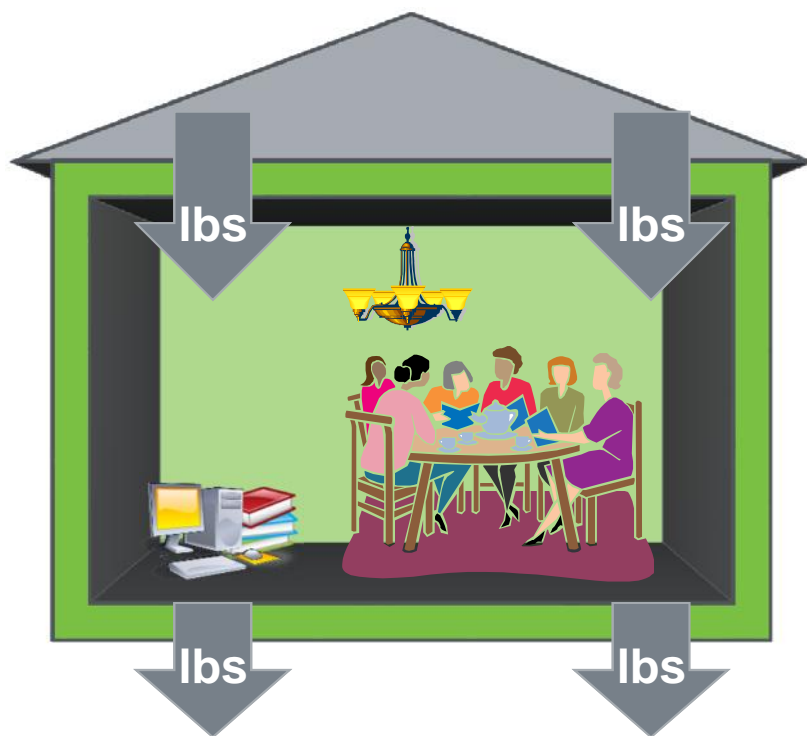
## Calculating Heating & Cooling Load

Thermal Enclosure

Heating, Cooling & Ventilation

Water Management

Structural load measured in pounds (lbs) of weight..  
..Cooling load measured in btu's of energy.



# System 2: HVAC System

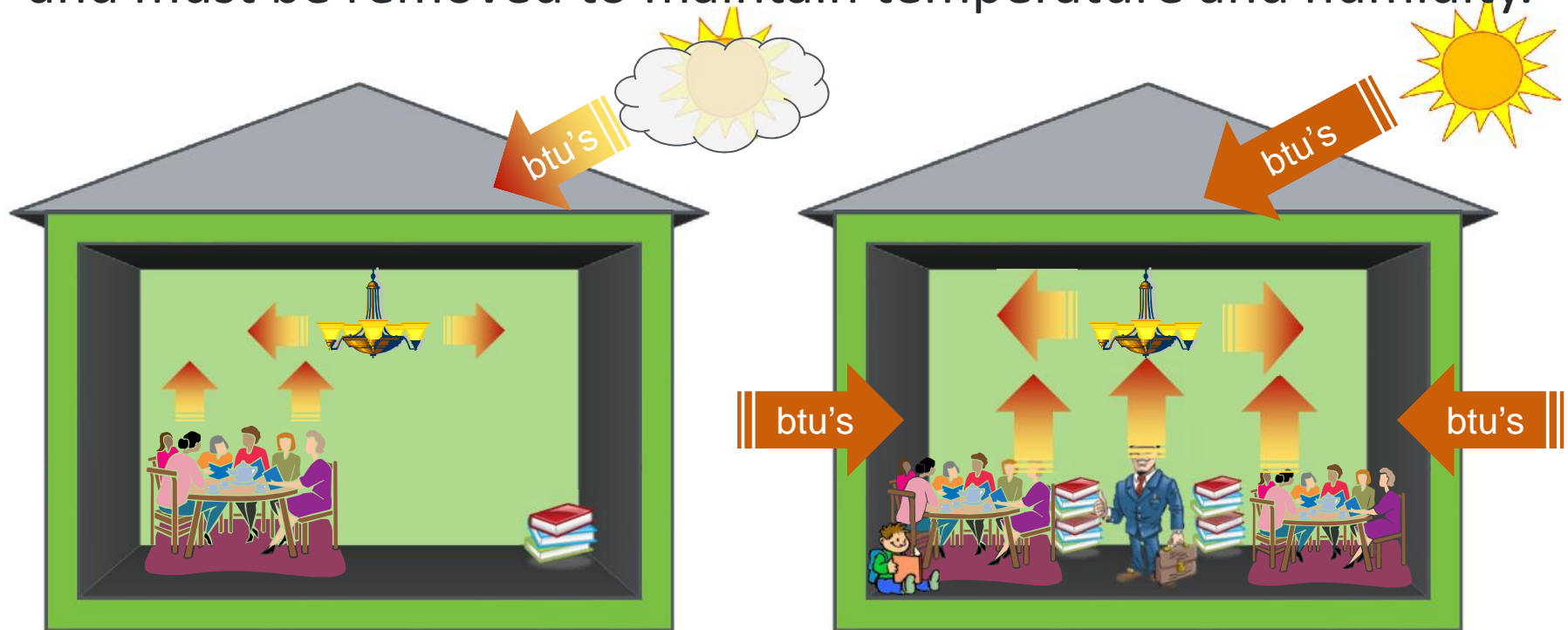
## Calculating Heating & Cooling Load

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

- 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

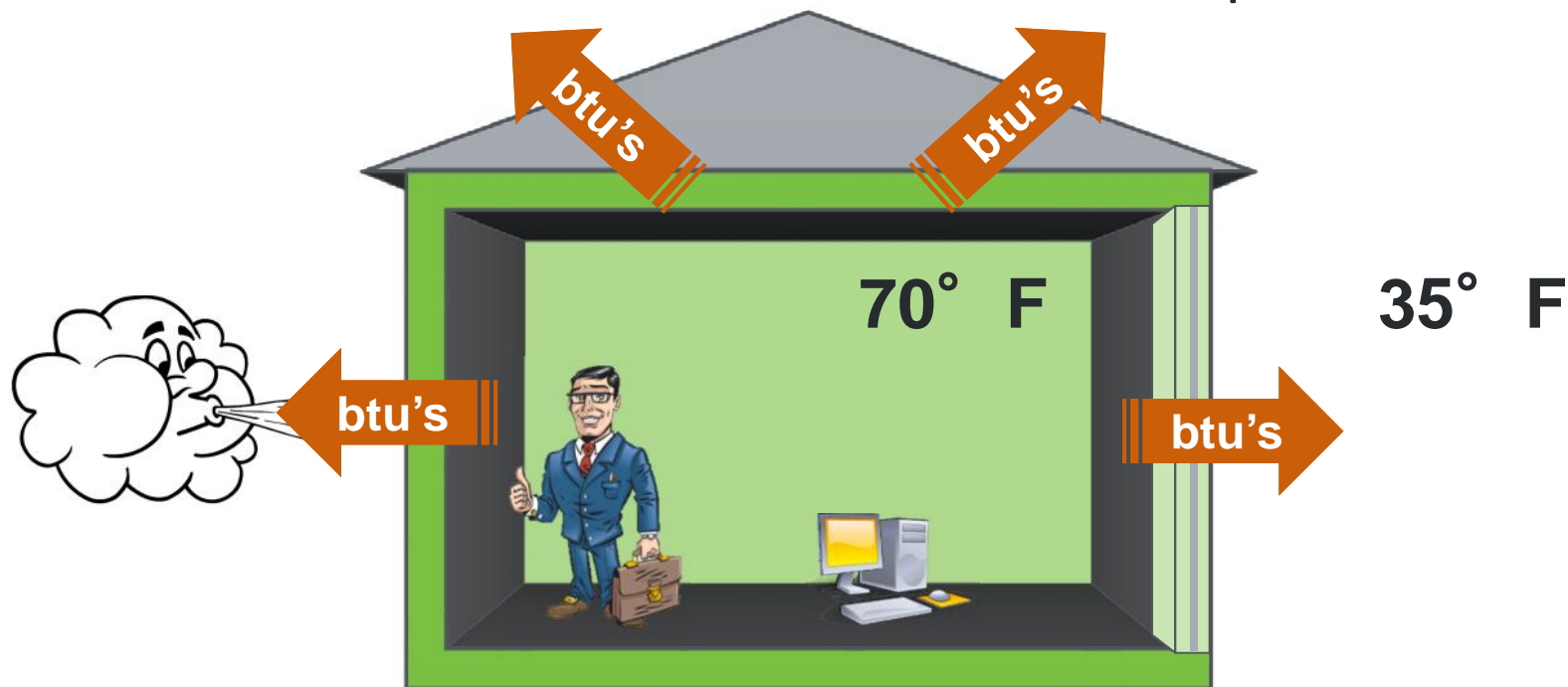
## Calculating Heating & Cooling Load

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

- 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

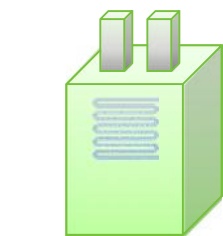
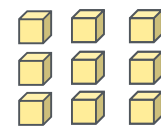
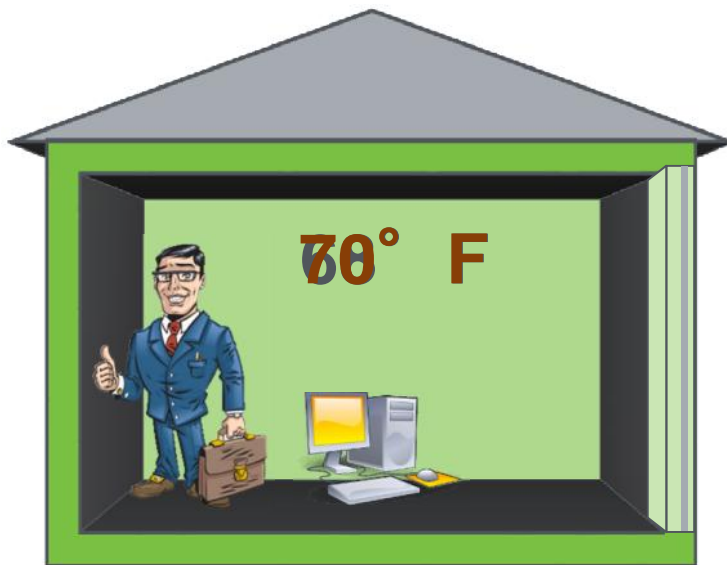
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Enclosure

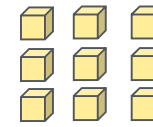
Heating, Cooling  
& Ventilation

Water  
Management

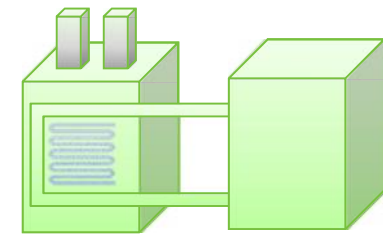
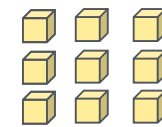
- Cooling & heating equipment are “btu machines” that add or remove btu’s to offset the load
- Load = number of btu’s equipment has to remove or add
- Load independent of type of equipment used



Furnace



Boiler



HP

# System 2: HVAC System

## What We're Trying to Avoid

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

### Random Acts of Sizing



# System 2: HVAC System HVAC-C (Sect 2); HVAC-R (Sect. 1)

Thermal Enclosure

Heating, Cooling & Ventilation

Water Management

Input Type				Cooling Load			
				kbtu		%	
	Low Input	Correct Input	High Input	Low	High	Low	High
Baseline	-	-	-	35.1		-	-
1 Outdoor Design Temperature	103 F	108 F	113 F	32.4	38.0	-8%	8%
2 Home Orientation	N	E	W	31.7	36.1	-9%	3%
3 Number of Occupants	1	4	7	34.4	36.3	-2%	4%
4 Conditioned Floor Area (Sq. Ft.)	2,160	2,400	2,640	33.9	36.3	-3%	3%
5 Window Area (Sq. Ft.)	324	360	396	33.7	36.4	-4%	4%
6 Predominant Window SHGC	0.20	0.30	0.40	32.8	36.4	-6%	4%
<b>Combined Impact From First Six Parameters</b>				<b>25.1</b>	<b>43.0</b>	<b>-29%</b>	<b>23%</b>

# System 2: HVAC System Basic Concepts

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

## 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

HVAC QI  
Contractor  
Checklist

HVAC QI  
Rater  
Checklist

# System 3: Water Management

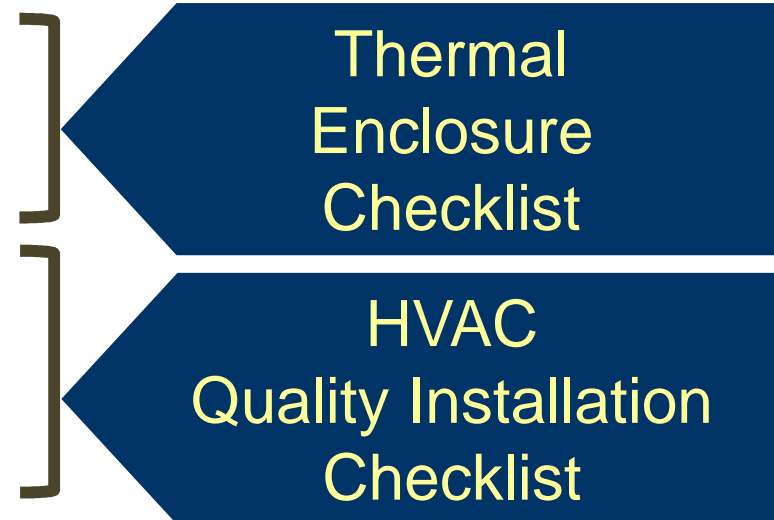
Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

## Moisture Vapor (Air Flow)

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

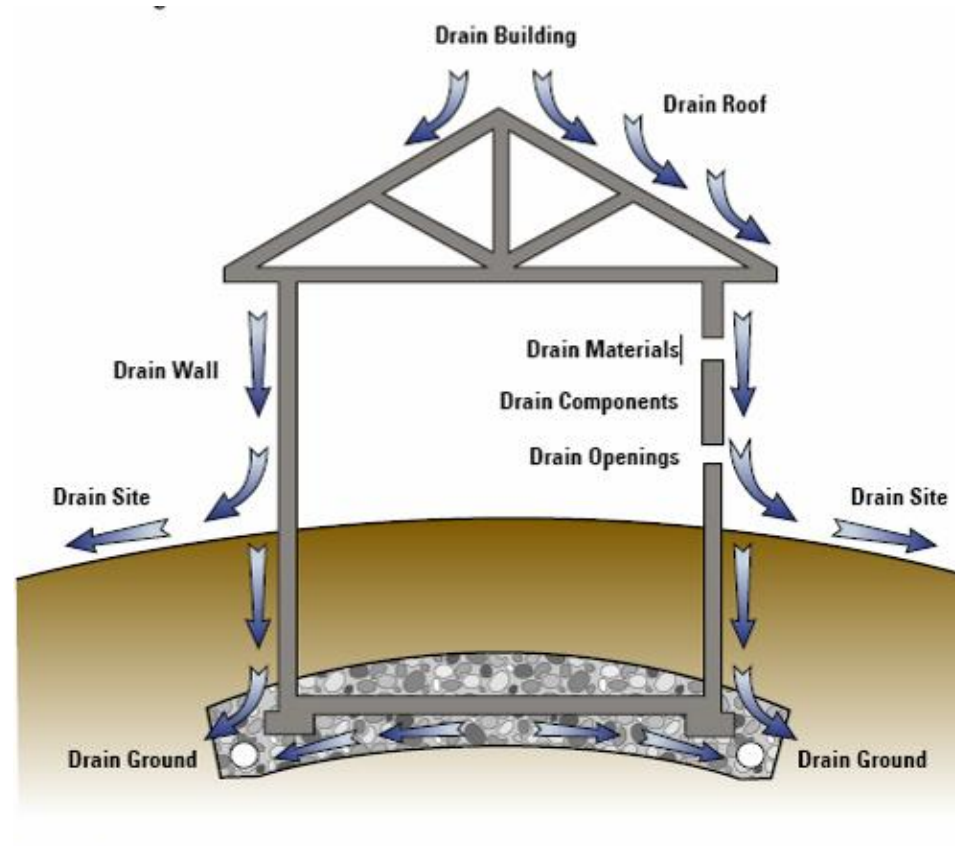


# System 3: Water Management Basic Concept

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management



## System 3: Water Management Basic Concept

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

- Many materials used in building homes are not durable when wet.
- Especially important in high performance homes, regardless of whether ENERGY STAR certified.



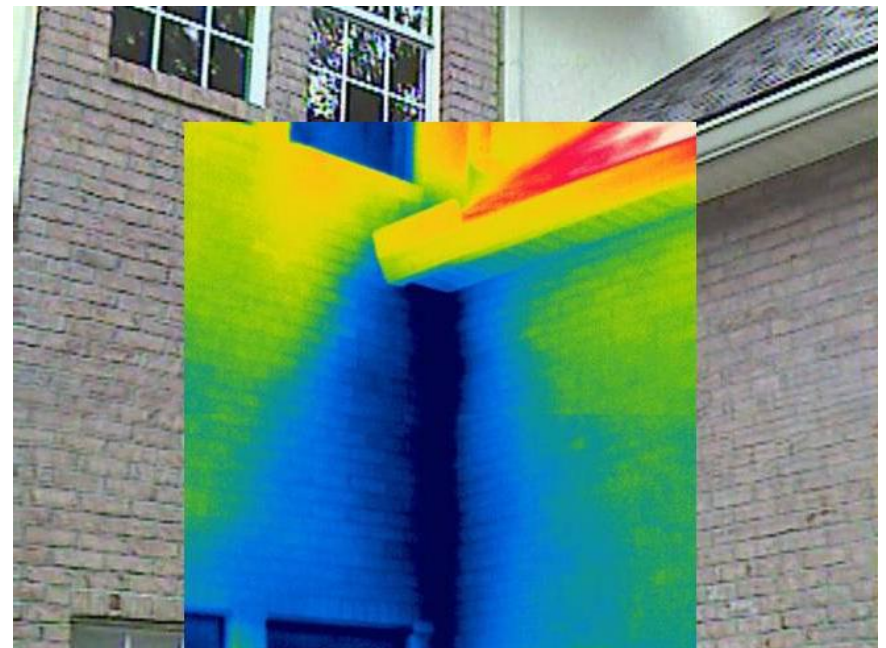


# System 3: Water Management What We're Trying to Avoid

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management



Missing step & kick-out flashing

## System 3: Water Management

### Step and Kick-Out Flashing (3.1)

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

- 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.



## System 3: Water Management Bulk Moisture Control

Thermal  
Enclosure

Heating, Cooling  
& Ventilation

Water  
Management

# Bulk Moisture

- weather resistant barriers
- flashing
- capillary breaks

Water  
Management  
Checklist

**Thermal  
Enclosure**

**Heating, Cooling  
& Ventilation**

**Water  
Management**

## **ENERGY STAR for Homes v3:**

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



Zero Energy Ready Homes

# Technical Specifications Mandatory Requirements

## **Envelope: 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

ENERGY STAR® Qualified in All 50 States



World's Best Window Co.  
Millennium 2000+  
Vinyl-Clad Wood Frame  
Double Glazing • Argon Fill • Low E  
Product Type: Vertical Slider  
(per NFRC 100-97)

**ENERGY PERFORMANCE RATINGS**

U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
<b>0.30</b>	<b>0.27</b>

**ADDITIONAL PERFORMANCE RATINGS**

Visible Transmittance	Air Leakage (U.S./I-P)
<b>0.51</b>	<b>0.2</b>

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information.  
www.nfrc.org

# Good, Better, Best Windows

	Hot Climates IECC CZ 1-2		Mixed Climates IECC CZ 3-4 except Marine		Cold Climates IECC CZ 5-8 and 4 Marine	
	SHGC	U-value	SHGC	U-value	SHGC	U-value
<b>Mandatory:</b> ENERGY STAR	0.27	0.60	[4] 0.40 [3] 0.30	[4] 0.32 [3] 0.35	Any 0.35 0.40	0.30 0.31 0.32
<b>Performance:</b> Target Home	0.25	0.4	0.27	0.3	Any	0.27
<b>Encouraged:</b> R-5	0.22	0.21	0.25	0.21	Any	0.21



Zero Energy Ready Homes

# **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

	ACH50 Requirements/Targets			
Climate Zones	DOE Challenge Home	ENERGY STAR V3	2012 IECC	Passive House
1-2	3.0	6.0	5.0	0.6
3-4	2.5	5.0	3.0	0.6
5-7	2.0	4.0	3.0	0.6
8	1.5	3.0	3.0	0.6

# 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



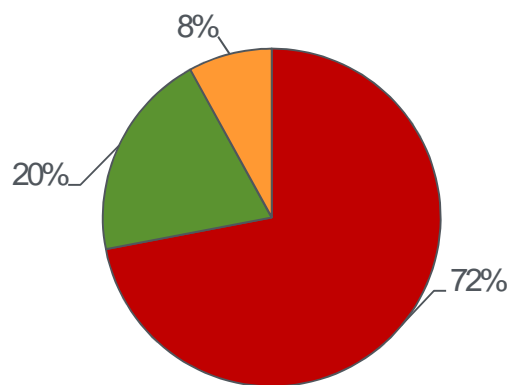
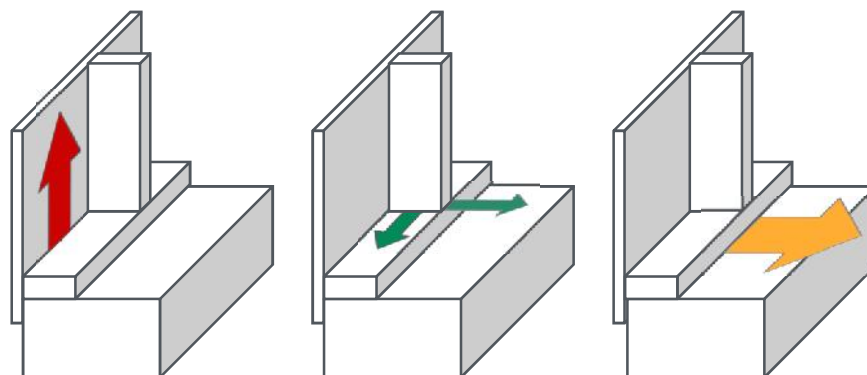
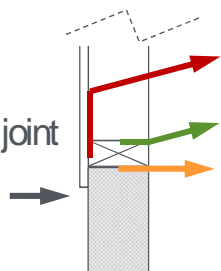
## Odd Geometry:

- Cantilevers
- Knee-walls

# Air Leakage Distribution

Exterior air barrier

Sheathing / foundation joint  
1.1 cfm/ft @ 50 Pa



- Sheathing / bot plate
- Stud / bot plate
- Bot plate / floor

2-Story house (Floor area = 2,000 ft<sup>2</sup>)

Sheathing / foundation joint unsealed  $\cong 0.5 ACH_{50}$

Zone	DOE Challenge Home		IECC 2012	
	Requirement	Contribution to requirement (%)	Requirement	Contribution to requirement (%)
1 – 2	3	17	5	10
3 – 4	2.5	20	3	17
5 – 7	2	25	3	17
8	1.5	33	3	17

# Examples

## Building America Solution Center

[www.basc.pnnl.gov](http://www.basc.pnnl.gov)





Zero Energy Ready Homes

**Technical Specifications**  
**Mandatory Requirements:**  
**Envelope:**  
**2012 IECC Insulation**

- Compliance with next generation code
- Three Options:
  - ✓ Prescriptive
  - ✓ Alternative equivalent U-factor
  - ✓ Total UA calculation [including windows]
    - Done automatically in Rating Software

# Prescriptive Requirements

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Glazed Fenestration SHGC	Ceiling R-Value	Wood Frame Wall R-Value
1	NR	0.75	0.25	30	13
2	0.40	0.65	0.25	38	13
3	0.35	0.55	0.25	38	20 or 13+5 <sup>h</sup>
4 except Marine	0.35	0.55	0.40	49	20 or 13+5 <sup>h</sup>
5 & Marine 4	0.32	0.55	NR	49	20 or 13+5 <sup>h</sup>
6	0.32	0.55	NR	49	20+5 or 13+10 <sup>h</sup>
7 & 8	0.32	0.55	NR	49	20+5 or 13+10 <sup>h</sup>



# Prescriptive Requirements (cont.)

Climate Zone	Mass Wall R-Value <sup>i</sup>	Floor R-Value	Basement <sup>c</sup> Wall R-Value	Slab <sup>d</sup> R-Value, Depth	Crawl Space <sup>c</sup> Wall R-Value
1	3/4	13	0	0	0
2	4/6	13	0	0	0
3	8/13	19	5/13 <sup>f</sup>	0	5/13
4 except Marine	8/13	19	10 /13	10, 2 ft	10/13
5 & Marine 4	13/17	30 <sup>g</sup>	15/19	10, 2 ft	15/19
6	15/20	30 <sup>g</sup>	15/19	10, 4 ft	15/19
7 & 8	19/21	38 <sup>g</sup>	15/19	10, 4 ft	15/19



Zero Energy Ready Homes

# Technical Specifications Mandatory Requirements: Ducts in Conditioned Spaces

- **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

- **Short Duct Run**

up to 10' of total length is permitted to be outside of the home's thermal and air barrier boundary.

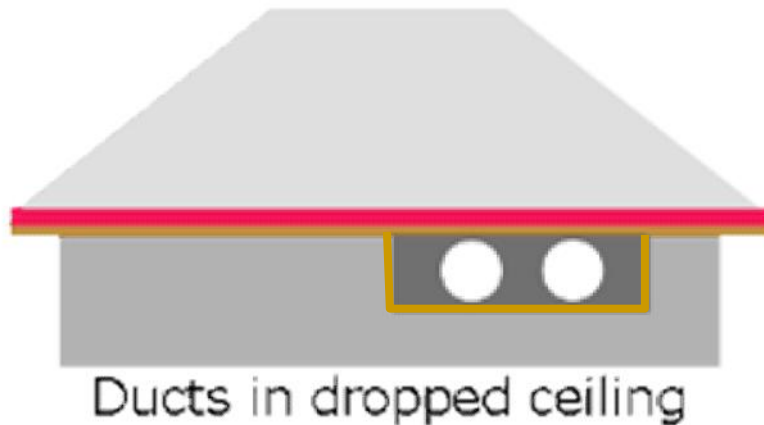
- **Jump Ducts**

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

- **Ductless HVAC system**

- **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

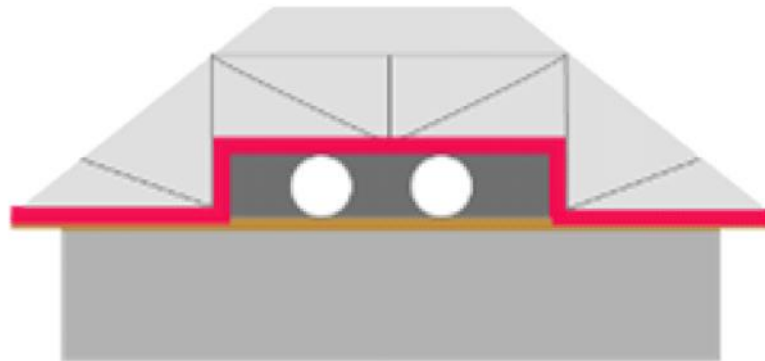


## Issues:

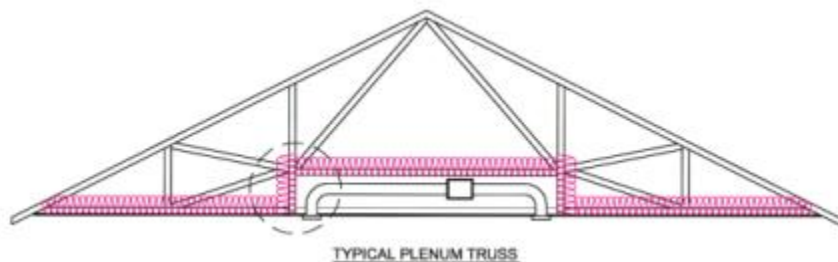
- Architectural Integration
- Good Fit w/Simple Plans
- Longer Throws  
(ACCA Man T)



# Ducts in Conditioned Floor Space Option 2: Modified Attic Truss



Ducts in modified truss  
in attic



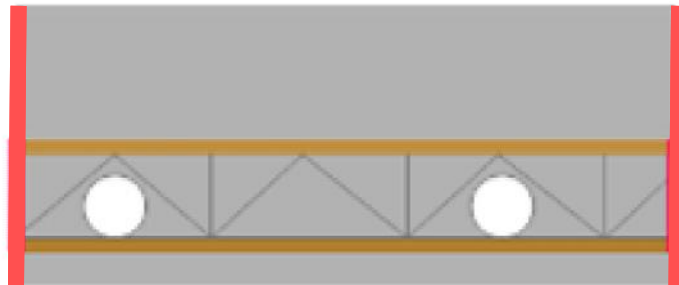
TYPICAL PLENUM TRUSS

## Issues:

- Design Integration
- Good Fit w/Narrow Plans
- Sealed Air Barrier Critical



# Ducts in Conditioned Floor Space Option 3: Ducts Between Floors



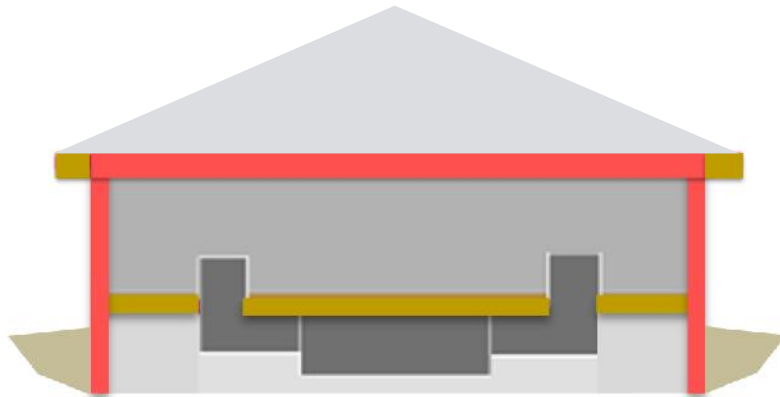
Ducts between floors

## Issues:

- Simple Installation
- Design Flexibility
- Cost-Effective
- Floor Registers Likely







Ducts in unvented crawl space  
or basement

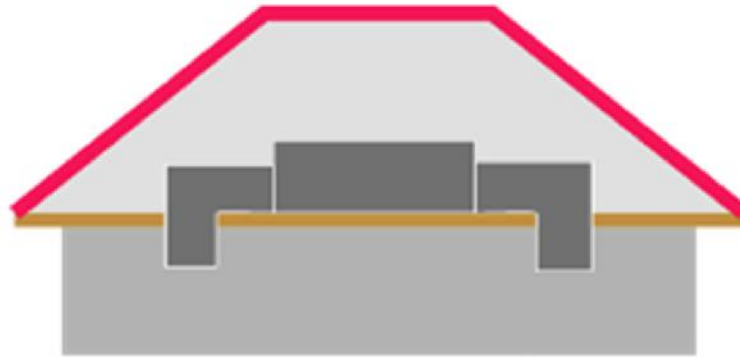
Insulation at  
Walls

## Issues:

- Simple Installation
- Design Flexibility
- Cost-Effective
- Floor Registers Likely



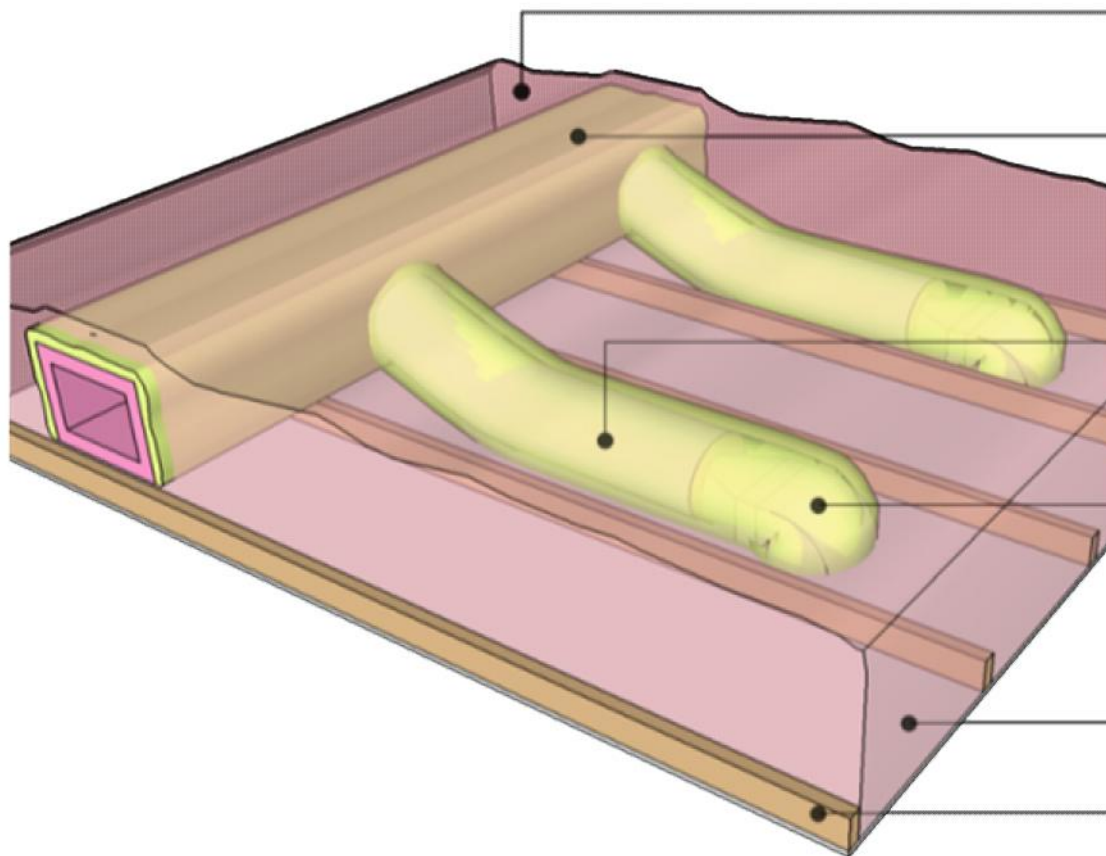
# Ducts in Unvented Attic



Ducts in unvented attic



# Ducts in a *Vented* Attic: Buried/Encapsulated Ducts



Ducts buried under loose-fill insulation

R-8 ducts encapsulated in 1.5" ccSPF

R-8 flex duct encapsulated in 1.5" ccSPF

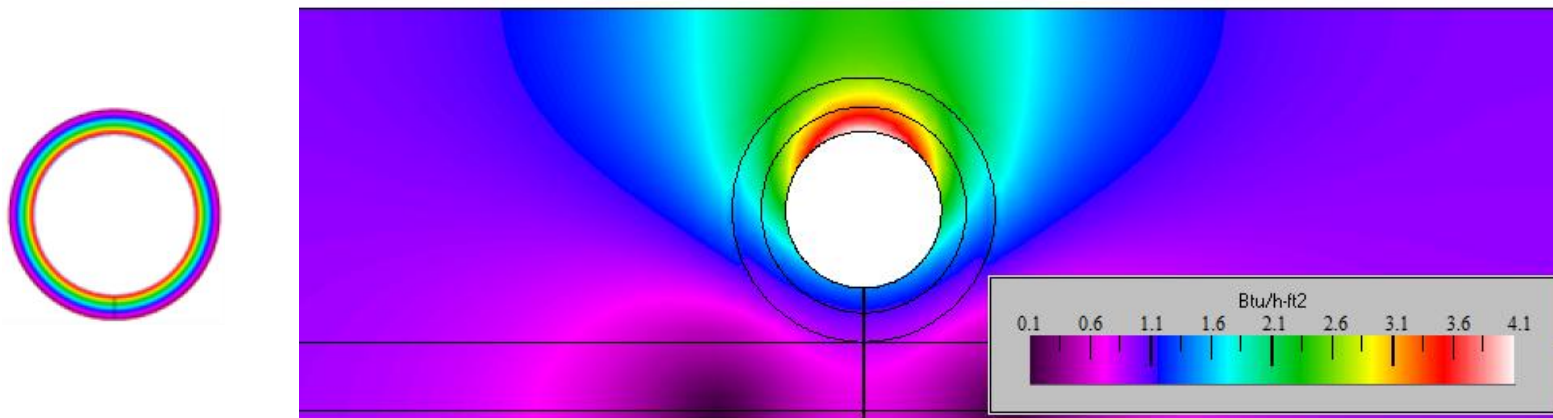
Duct boot connection encapsulated in 1.5" ccSPF

Drywall ceiling

Truss lower chords

# Effective R-values

- R-value metrics:
  - Nominal – listed values for duct insulation
  - Effective – heat loss/gain from duct to attic
- Buried duct effective R-values calculated using FEA



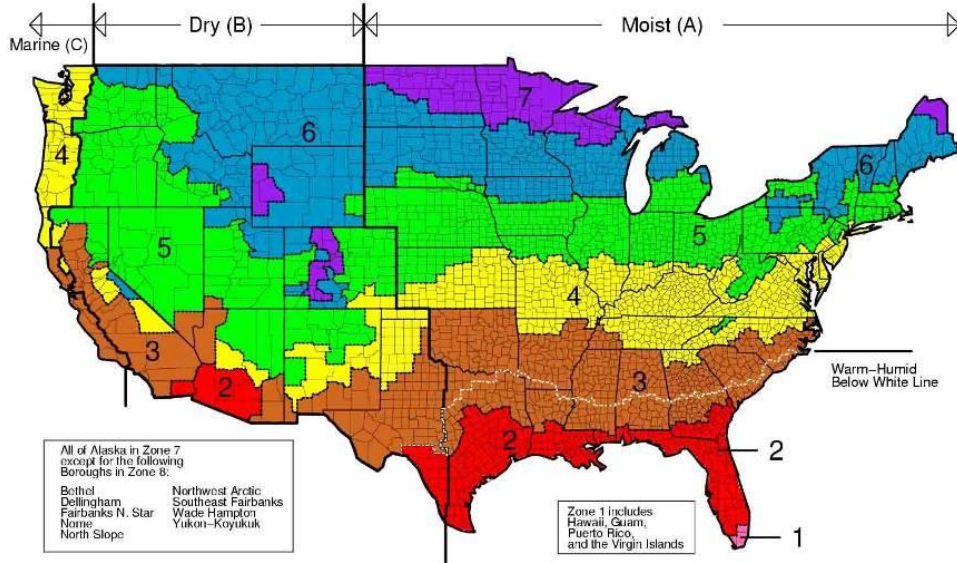
Heat flux magnitude through a hung duct, and an encapsulated and fully-buried 8-in diameter duct

# Effective R-values

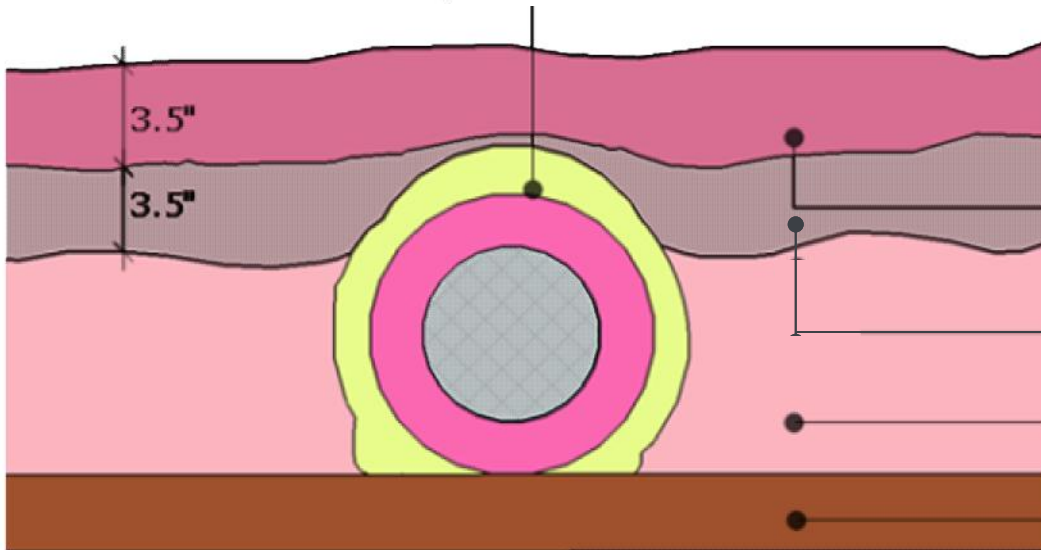


Duct Configuration	R-4.2 Ducts	R-6 Ducts	R-8 Ducts
Traditional hung ducts	4.6	5.9	7.2
Hung ducts encapsulated in 1.5" of ccSPF	11.3	12.0	12.7
Partially-buried	8.1	10.2	12.3
Fully-buried	12.0	14.1	16.2
Deeply-buried	20.7	22.1	23.5
Encapsulated in 1.5" of ccSPF and partially-buried	18.4	19.7	21.0
Encapsulated in 1.5" of ccSPF and fully-buried	22.6	23.8	25.0
Encapsulated in 1.5" of ccSPF and deeply-buried	29.6	30.3	31.1

# Ducts in Vented Attic: Moist CZs



## Buried Encapsulated Ducts (BEDs)

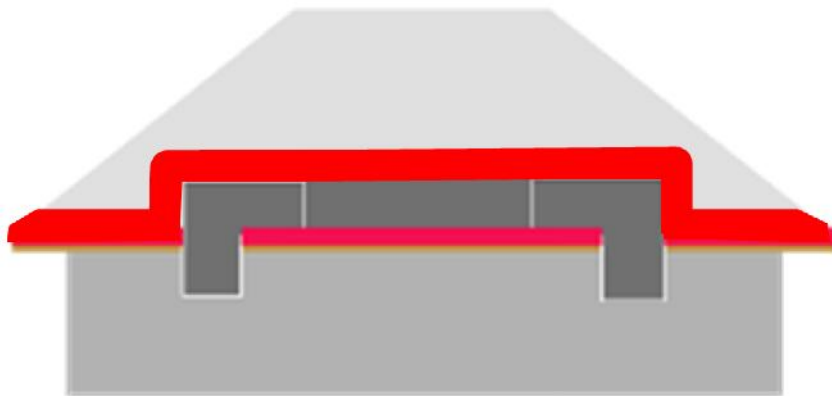


Ducts with R-8 insulation encapsulated in 1.5 in of ccSPF

Leakage 3 CFM25 per 100 ft<sup>2</sup> CFA

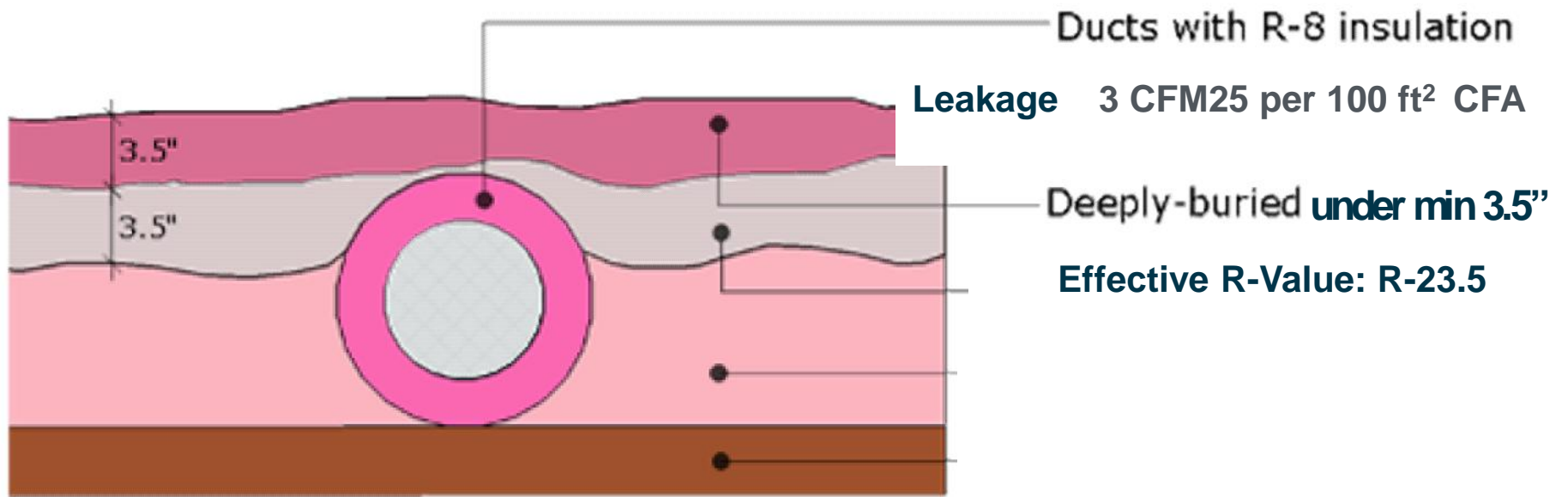
Fully-buried under min 2" (~R-25)

# Ducts in Vented Attic: Dry CZs



Ducts in vented attic

## Buried Ducts





Zero Energy Ready Homes

# Technical Specifications Mandatory Requirements: Efficient Hot Water Distribution



- **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)



# Energy Intensity of Hot Water

- Energy Intensity of Indoor Cold Water
  - Range from 5 to 25 kWh per 1000 gallons
- Energy Intensity of Hot Water

	Electric		Natural Gas	
	Resistance (85 % Efficient)	Heat Pump (COP = 2)	(50% Efficient)	(95% Efficient)
kWh/1,000 Gallons	201	85	342	180
Relative Energy Intensity compared to 5 kWh/1,000 gallons	40	17	68	36

- Typically 40-68 times more energy intensive than indoor cold water.

**Slide Source: Gary Klein**

# Hot Water Distribution

Built for when water was free and energy was cheap!

Copper L piping:

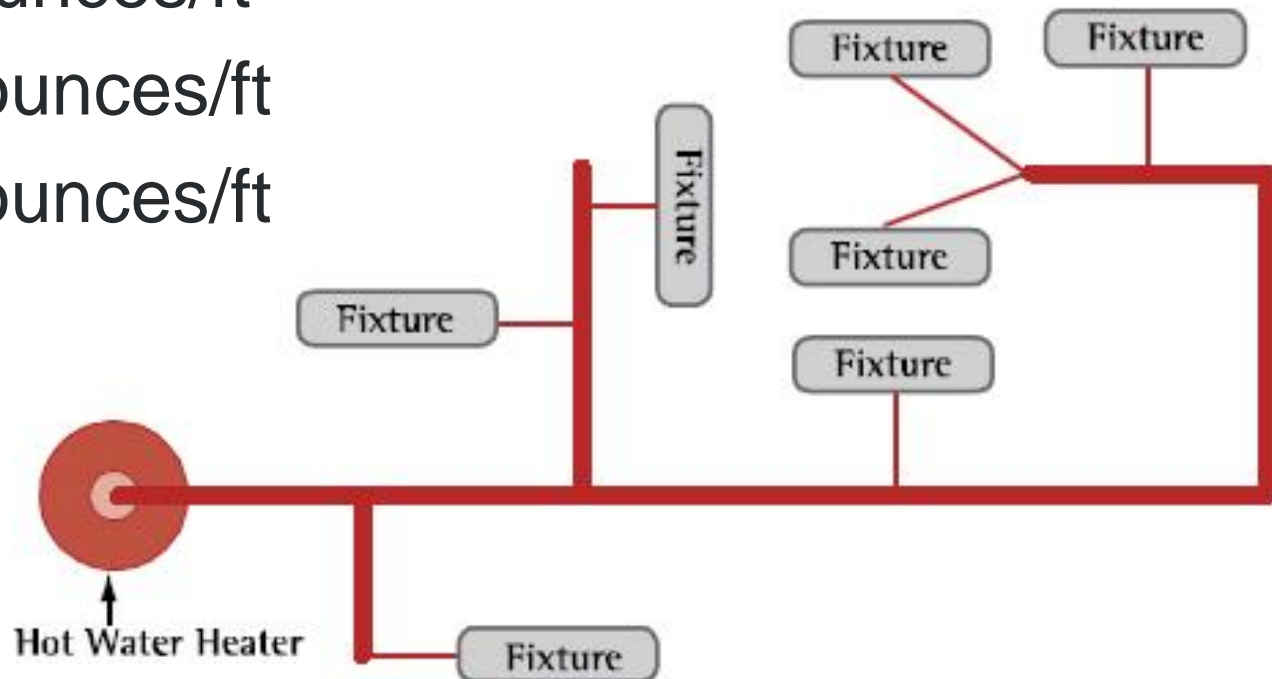
- 1" = 5.53 ounces/ft
- $\frac{3}{4}$ " = 3.22 ounces/ft
- $\frac{1}{2}$ " = 1.55 ounces/ft

**Sample Volume:**

**16 gallons**

**30 tank**

**10' branch**  
**Wait Time: 1 – 1.5**  
**minutes**  
**2 GPM showerhead**



# How Long Should We Wait?

Volume in the Pipe (ounces)	<u>Minimum</u> Time-to-Tap (seconds) at Selected Flow Rates					
	0.25 gpm	0.5 gpm	1 gpm	1.5 gpm	2 gpm	2.5 gpm
2	4	1.9	0.9	0.6	0.5	0.4
4	8	4	1.9	1.3	0.9	0.8
8	15	8	4	2.5	1.9	1.5
16	30	15	8	5	4	3
24	45	23	11	8	6	5
32	60	30	15	10	8	6
64	120	60	30	20	15	12
128	240	120	60	40	30	24

## ASPE Time-to-Tap Performance Criteria

	<b>Acceptable Performance</b>	1 – 10 seconds
	<b>Marginal Performance</b>	11 – 30 seconds
	<b>Unacceptable Performance</b>	31+ seconds

Source: Domestic Water Heating Design Manual – 2<sup>nd</sup> Edition, ASPE, 2003, page 234

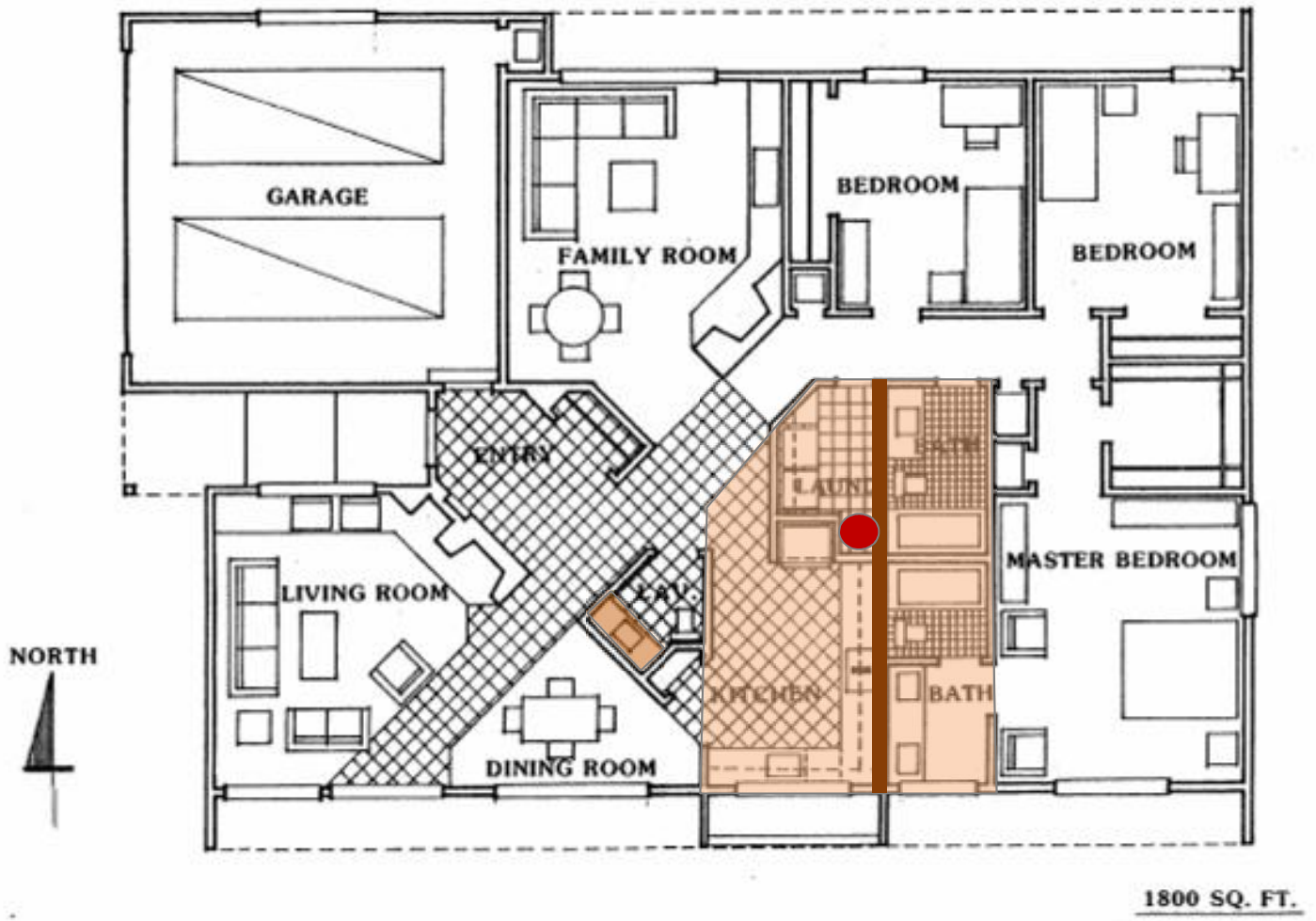
Slide Source: Gary Klein

- “Must Have” for zero net-energy ready homes
- Based on EPA WaterSense Specifications:
  - No more than 0.5 gallons (64 oz.) 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.
  - Recirculating systems based solely on a static timer- or temperature-based control shall not be used to meet the criteria
  - ***Recirculation systems based on “adaptive” controls are currently eligible to meet this criteria***

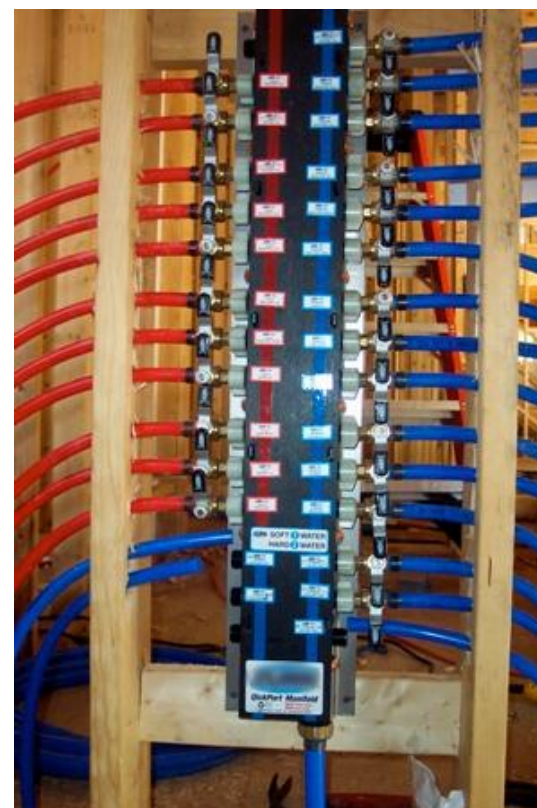
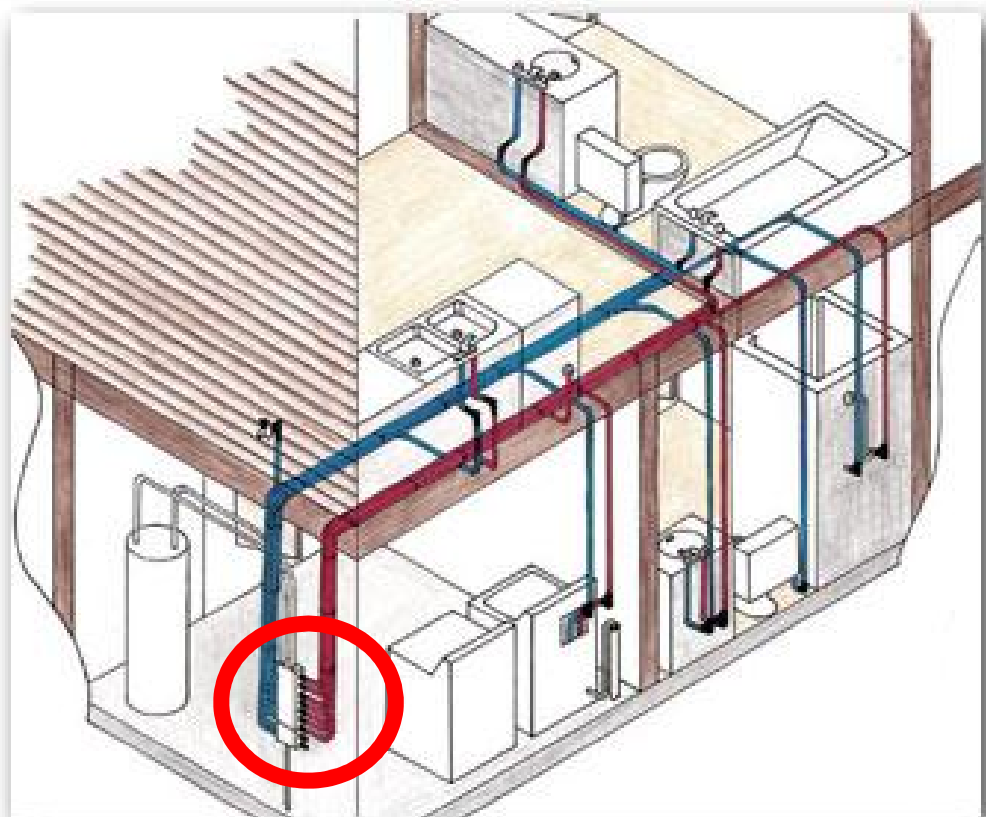
# Hot Water Distribution Options

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

# Core Plumbing Layout

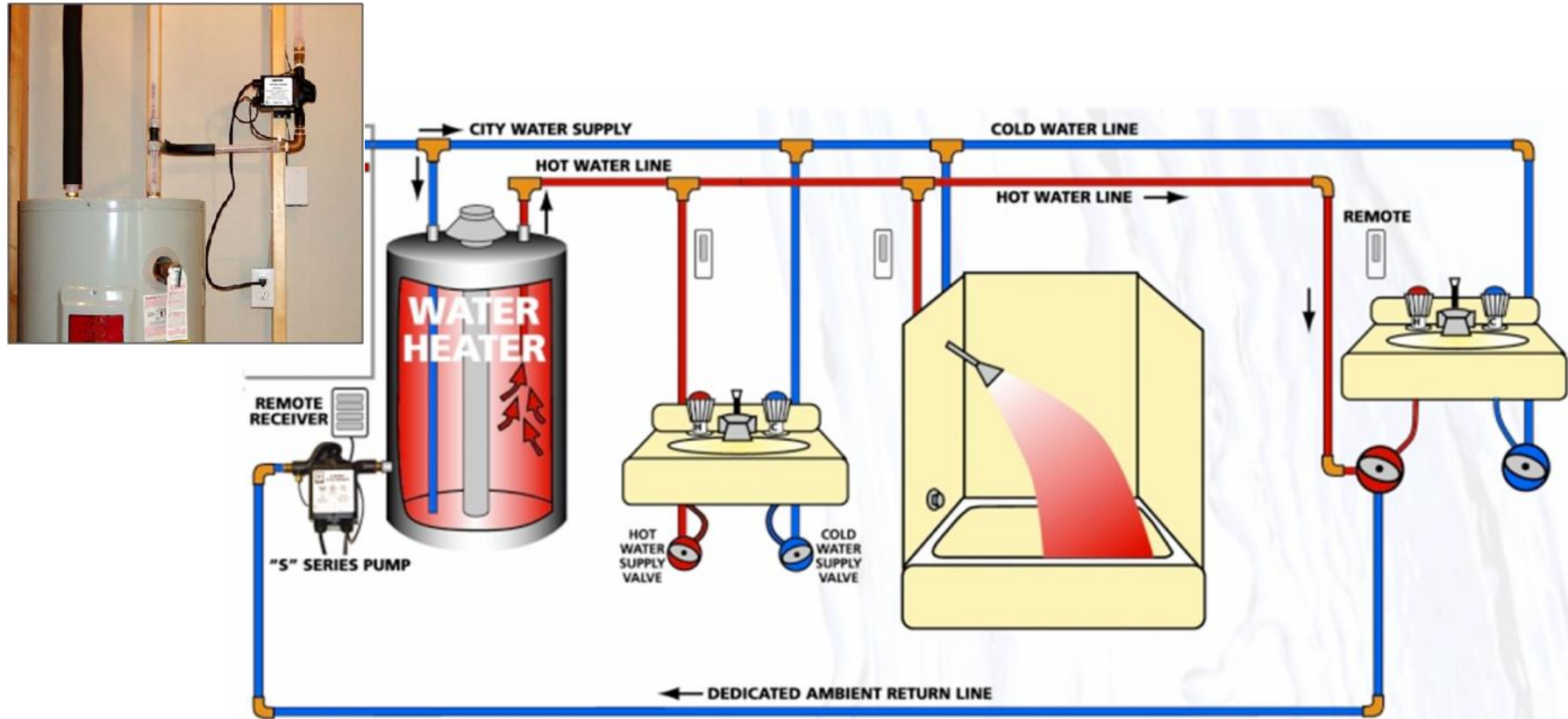


# Manifold Plumbing System





# Demand Pumping System





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 Homes

# Technical Specifications Mandatory Requirements: Indoor Air Quality

# Why IAQ as a System?

- 2000 SF Home
- 8.5' Ceilings
- 3 ACH50 Air Tightness
- 200 cfm Exhaust  
(e.g. dryer, range hood)

**- 5 Pa depressurization**

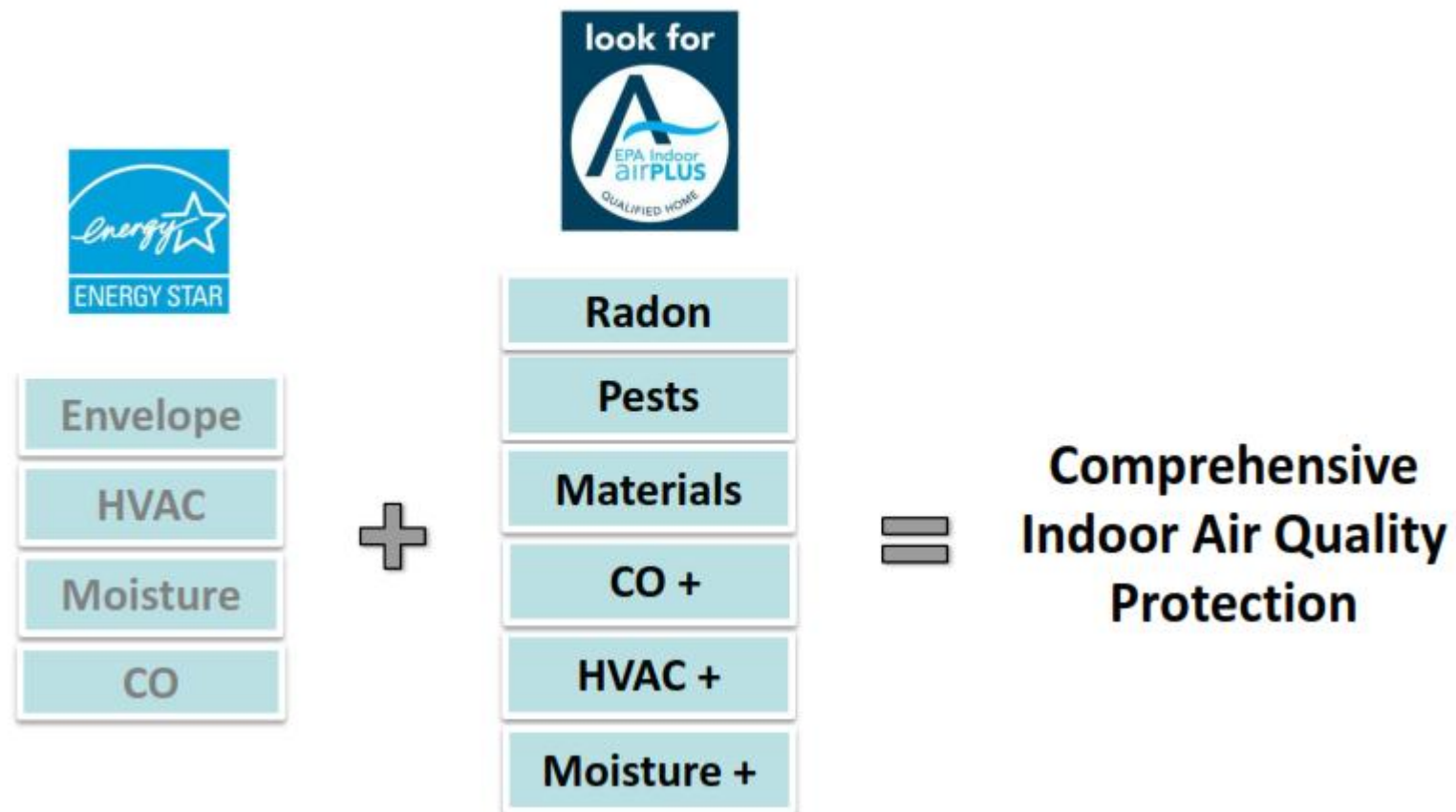


## Other Examples:

- Dust Mites –asthma
- ~40% households with  
significant respiratory issue

# Comprehensive Indoor Air Measures through ENERGY STAR + IAP

## ENERGY STAR + Indoor airPLUS



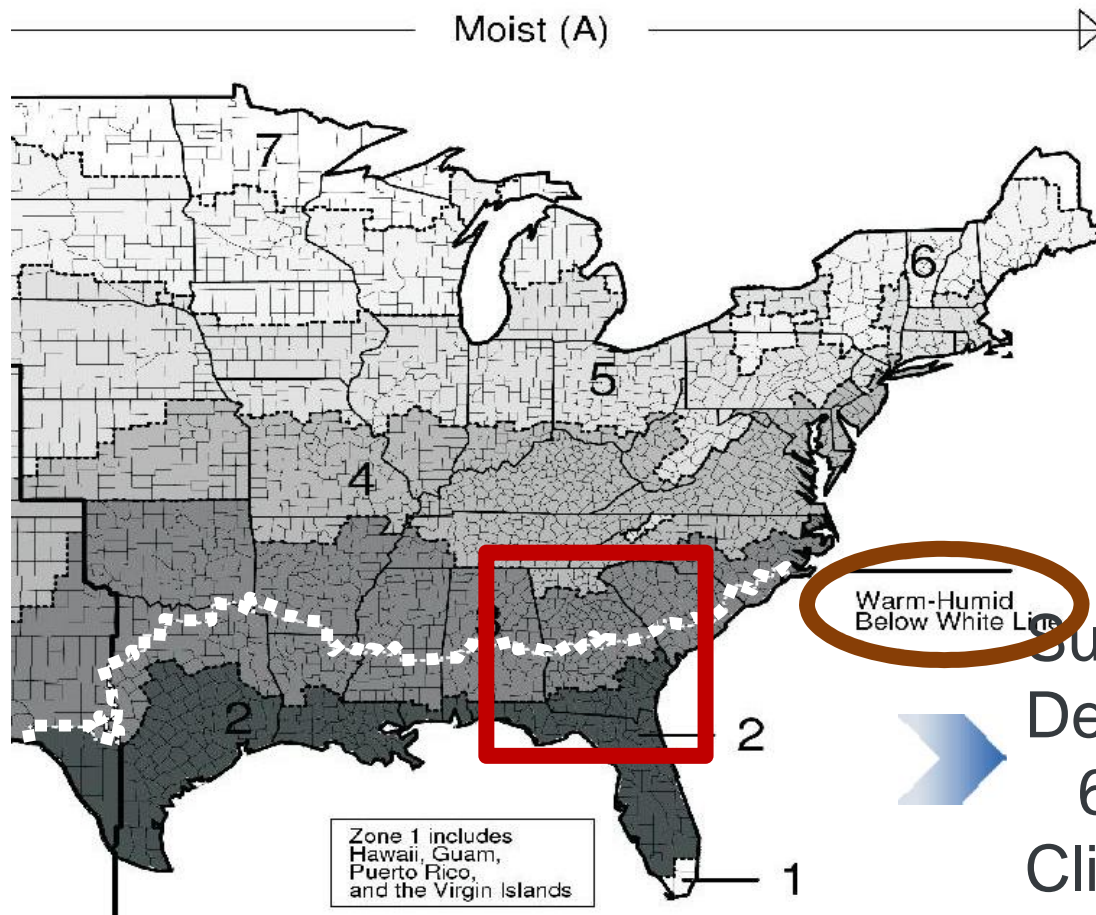
**Source Control**

**Dilution**

**Filtration**

# Source Control: Moisture Dehumidification in Warm-Humid CZs

Defined by 2009 IECC Figure 301.1 (i.e., Climate Zone 1 and portions of Zones 2 and 3A below the white line),



Dust mites in the billions at 60% RH or high

Supplemental Dehumidification to Ensure 60% RH in Warm-Humid Climates

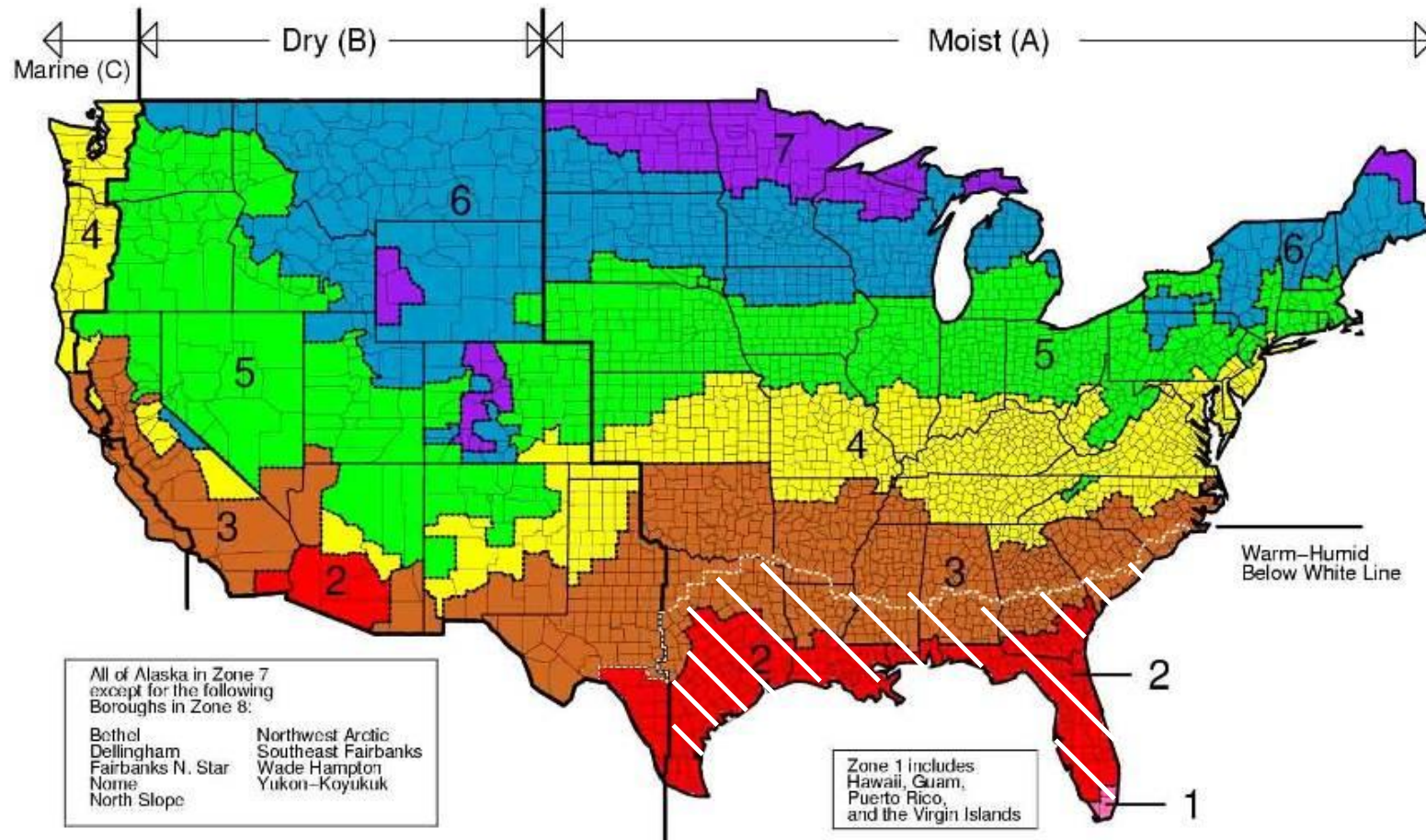
Equipment shall be installed with sufficient latent capacity to maintain indoor relative humidity (RH) 60%. This requirement shall be met by either:

- Additional dehumidification system(s), OR
- A central HVAC system equipped with additional controls to operate in dehumidification mode.

Exception: Climate Zones 4-8, 3B, 3C and the portions of 3A and 2B above the white line as shown by 2009 IECC Figure 301.1.



# Applicability



# The Need for Dehumidification in High Performance Homes

- High performance homes with well air-sealed and insulated envelopes have longer cooling system off-times due to less sensible heat gain
  - This is good: significant energy & cost savings
- Latent (moisture) loads are still present however, from, from:
  - ventilation load
  - resident-generated moisture

- **Effective System Solutions** for maintaining indoor RH < 60% along with relatively low operating costs:
  - Stand-alone dehumidifier with central fan system providing mixing
  - Ducted dehumidifier
  - Full condensing dehumidifier with modulating reheat, integrated with the central A/C system
  - Central variable speed A/C system with dehumidification mode
- **Energy Consumption:**
  - About 170 kWh/yr could be expected for a HERS 50 house (~ DOE Challenge Home level) with a 60% RH setpoint.
  - With a 50% RH setpoint – energy consumption is **about 5X**

2. Supplemental Dehumidification for Humid Climates. Presented by Armin Rudd, Building Science Corp, at ACI National Conference May 2013. Supported in part by DOE Building America

- **Stand-alone Dehumidifiers**
  - Specify ENERGY STAR qualified (efficacy 1.5 Liters/kWh)
  - Integrate with central fan for mixing throughout house
  - Provide remote dehumidistat control
  - Add small central HVAC return duct to dehumidifier closet to increase circulation
- **Ducted Dehumidifiers**
  - The dehumidifier's fan draws in house air, then delivers this air to the central supply plenum/trunk; controls cycle on central AHU
  - Unit is controlled by a remote dehumidistat in the living space.
- **Variable Speed Central A/C Systems**
  - Include dehumidification mode to operate when no cooling call
  - Variable speed operation for enhanced latent removal
  - Controls limit extent of dehumidification operation below cooling set point

## Dilution: Whole-House Ventilation

### Three Options:

- Exhaust-Only
- Supply-Only
- Balanced

ASHRAE 62.2 2010 Continuous Ventilation Rate:

$[7.5 \text{ cfm} * (\# \text{ bedrooms} + 1)] + [.01 * \text{Sq. Ft.}]$

2,000 sq. ft., 3 Bedroom Home Example:

$[7.5 * (3+1)] + [.01 * 2,000] = [30 + 20] = 50 \text{ cfm}$

- WHMV Fan Efficiency
  - For an example home of 4 BR and 2500 SF in CZ5:
    - $Q_{fan} = 0.01 * A_{floor} + 7.5(Nbr + 1)$
    - $= 0.01 * (2500) + 7.5 * (5) = 63 \text{ cfm}$

## DOE Challenge Home Target Home Specs for WHMV Fans

CZ 1-2	CZ 3, 4 (except Marine)	CZ 4 Marine, 5-8
1.4 cfm/W	1.4 cfm/W	1.2 cfm/W
No heat exchange	No heat exchange	HX with 60% SRE

- $63 \text{ cfm} / (1.2 \text{ cfm/W}) = \mathbf{53 \text{ Watts BALANCED w/ 60\% SRE}}$

# Dilution: Whole-House Ventilation Exhaust-Only Ventilation

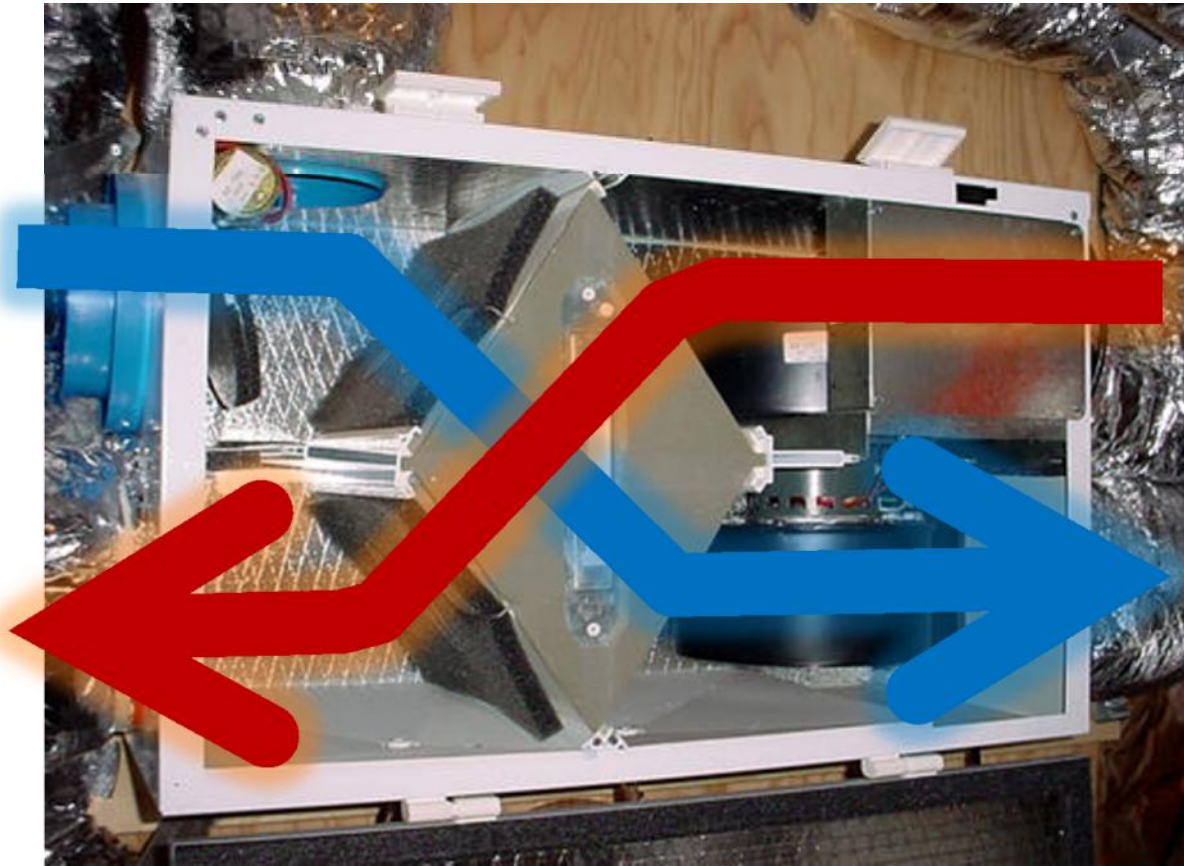


# Dilution: Whole-House Ventilation Supply-Only Ventilation





# 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

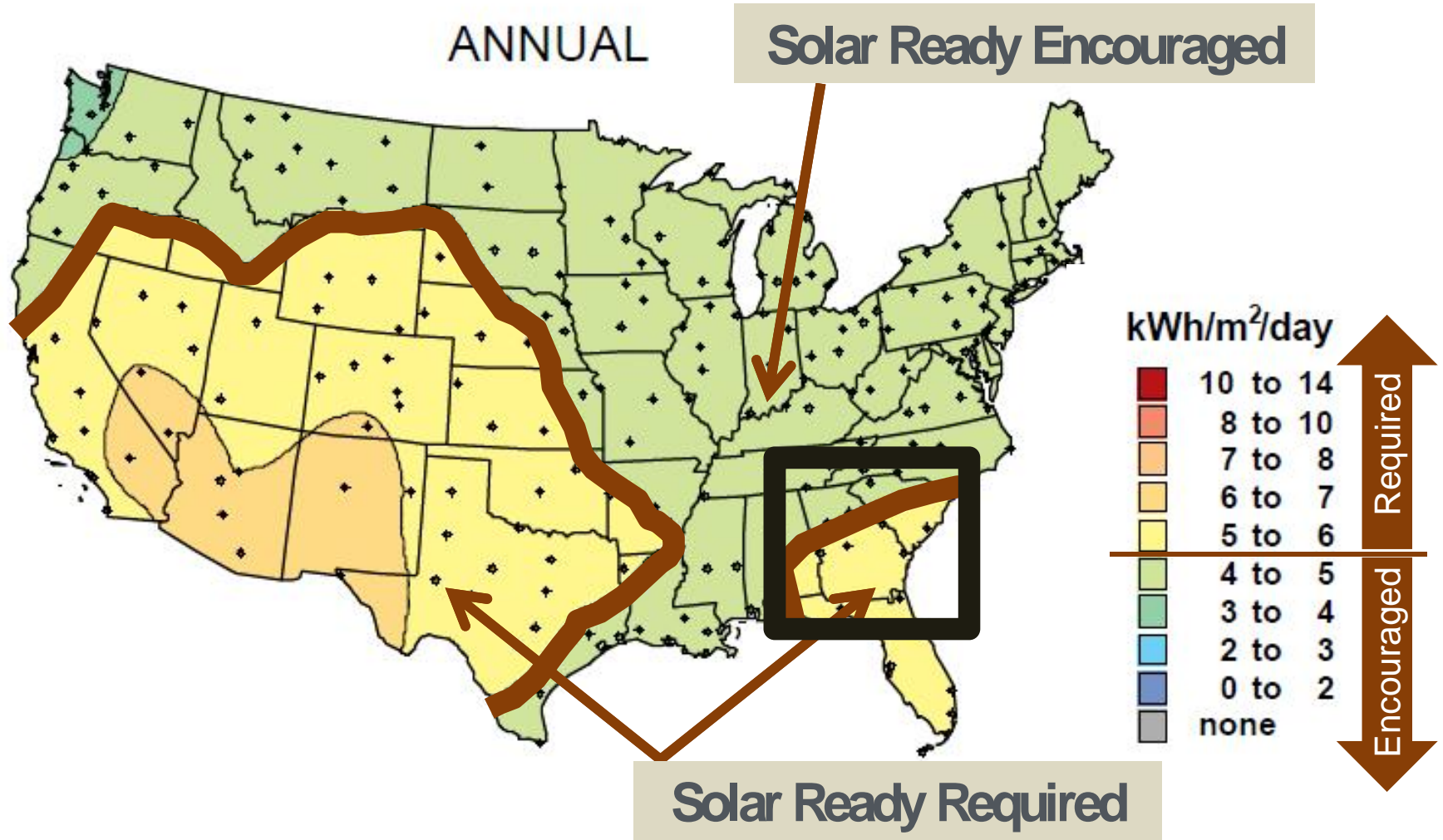


Zero Energy Ready Homes

# Technical Specifications Mandatory Requirements: **Renewable Ready** [Where Applicable]

# RERH Applicability

## Average Daily Solar Radiation Per Month



# Screen for RERH Applicability

- **Renewable Energy Ready Checklists**
  - Determine applicability by zip code
  - [http://gisatnrel.nrel.gov/PVWatts\\_Viewer/index.html](http://gisatnrel.nrel.gov/PVWatts_Viewer/index.html)
  - In this Mid-Atlantic example, solar resources = 4.8 kWh/m<sup>2</sup>/day



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





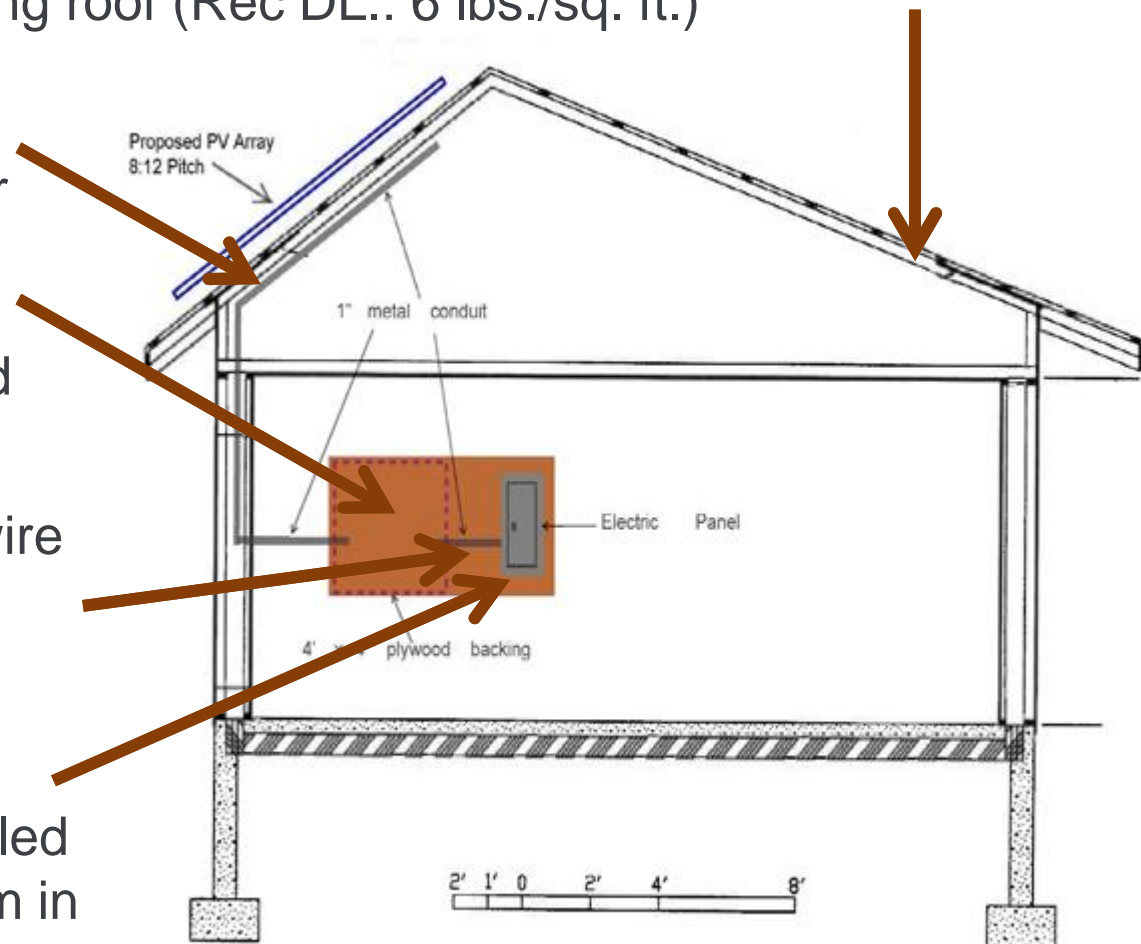
**Documentation** of the maximum allowable dead load and live load ratings of the existing roof (Rec DL.: 6 lbs./sq. ft.)

**Conduit** to run DC wire from roof to inverter

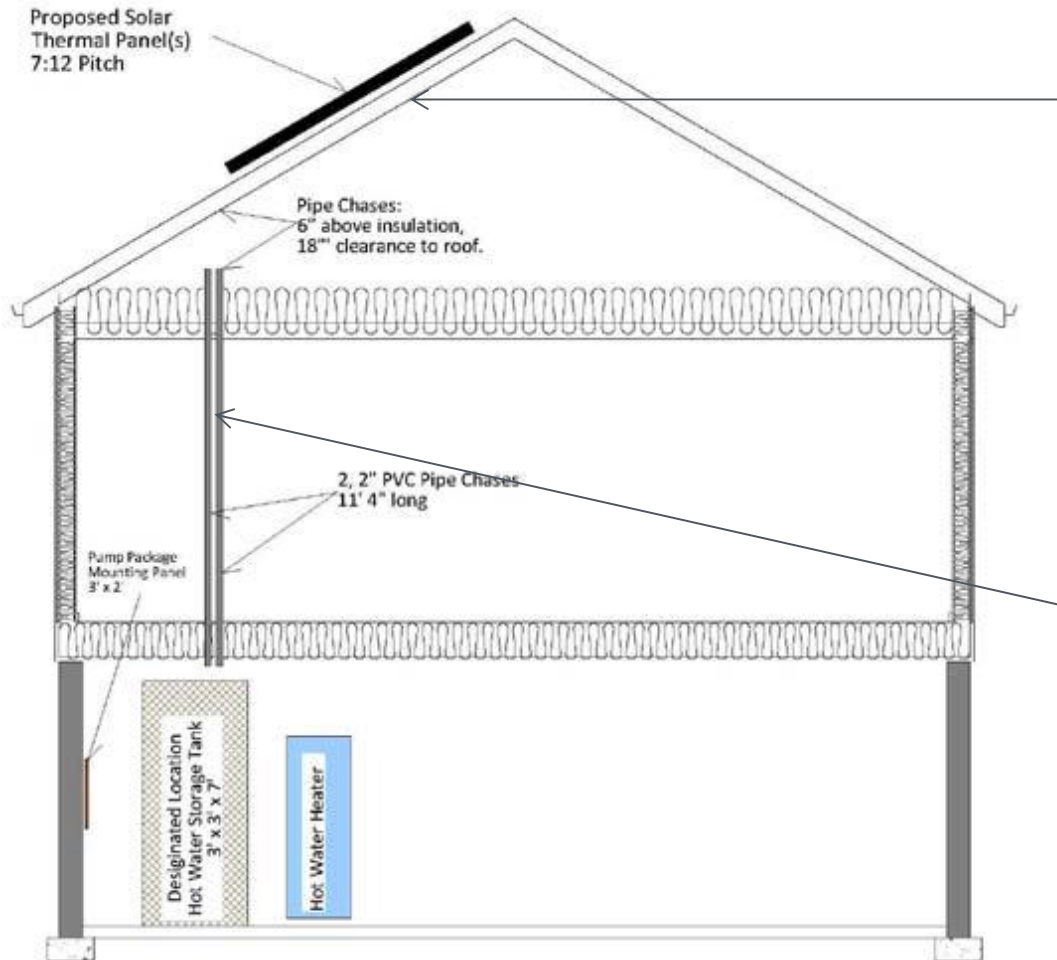
**Dedicated Area** for installing inverter and balance of system

**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



# Solar Hot Water Ready Reqts.



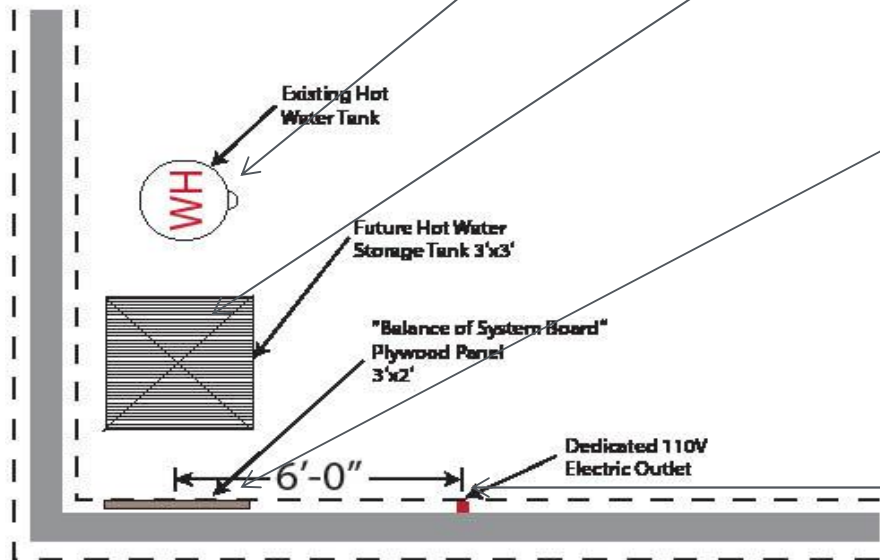
## Documentation

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.

# Solar Hot Water Ready Reqts.\*

- \* 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.

- IAP: formaldehyde free OSB is the more limiting of the 2 criteria for structural wood products;
- Low VOC paints – coverage might be a small issue;
- Carpets – generally widely available with the required ratings



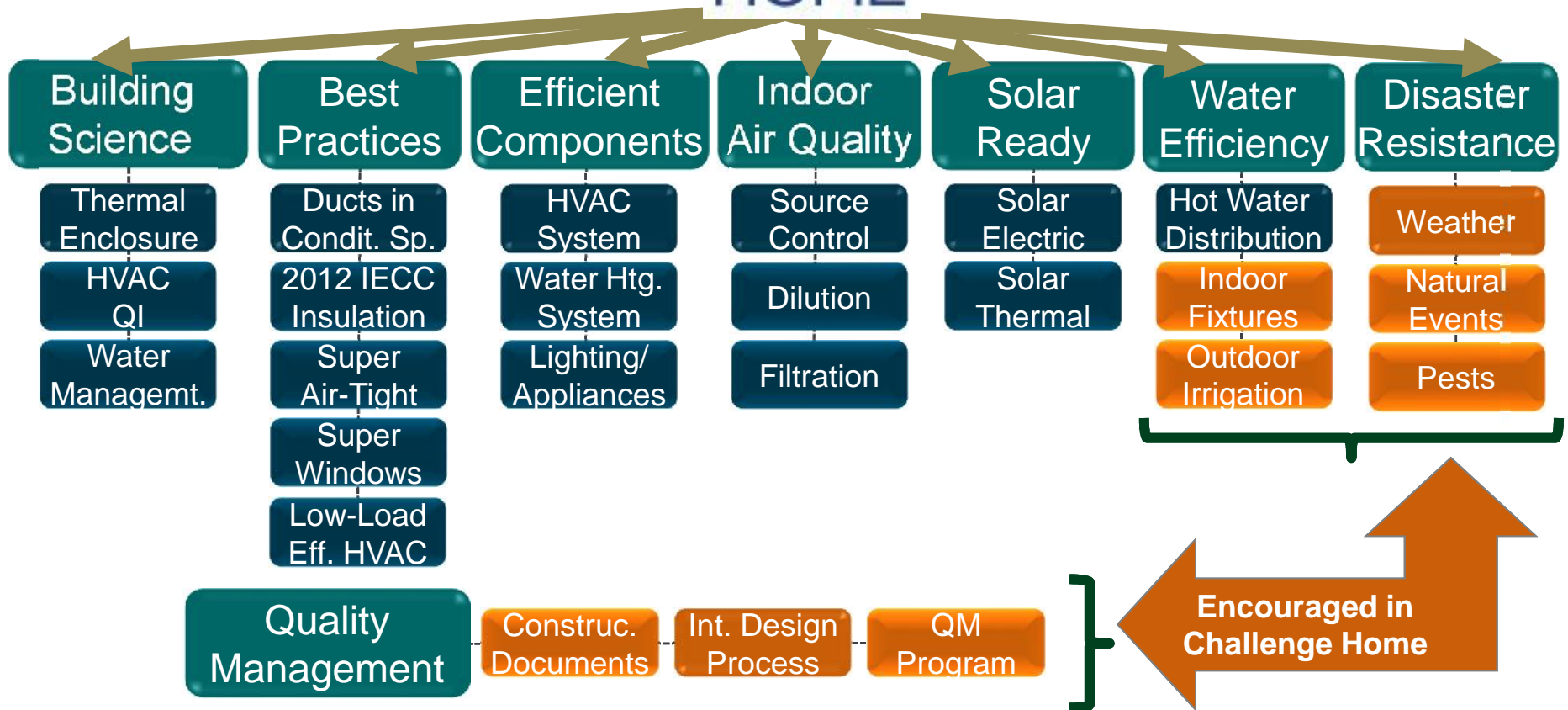
Zero Energy Ready Homes

# Technical Specifications: Putting It All Together

# Zero Energy Ready Home Systems



Energy Efficiency & Renewable Energy





# Zero Energy Ready Homes **Performance Threshold**

# 'Target Home' vs. Energy Star Spec

Exhibit 2: DOE Challenge Home Target Home 3-17

HVAC Equipment			
	Hot Climates (2012 IECC Zones 1,2) <sup>18</sup>	Mixed Climates (2012 IECC Zones 3,4)	Cold Climates (2012 IECC Zones 5,6,7,8)
AFUE	80%	90%	94%
SEER	18	15	13
HSPF	8.2	9	10 <sup>19</sup>
Geothermal Heat Pump	ENERGY STAR EER and COP Criteria		
ASHRAE 62.2 Whole-House MV System Performance	1.4 cfm/W; no heat exchange	1.4 cfm/W; no heat exchange	1.2 cfm/W; heat exchange with 80% SRF
Insulation and Infiltration			
<ul style="list-style-type: none"> <li>Insulation levels shall meet the 2012 IECC and achieve Grade 1 installation, per RESNET standards.</li> <li>Infiltration<sup>20</sup> (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</li> </ul>			
Windows <sup>21, 22, 23</sup>			
	Hot Climates (2012 IECC Zones 1,2,)	Mixed Climates (2012 IECC Zones 3,4)	Cold Climates (2012 IECC Zones 5,6,7,8)
SHGC	0.25	0.27	any
U-Value	0.4	0.3	0.27
Homes qualifying through the Prescriptive Path with a total window-to-floor area greater than 15% shall have an integrated U-values or SHGCs. <sup>24</sup>			
Water Heater			
ENERGY STAR minimum			
Thermostat <sup>25</sup> & Ductwork			
<ul style="list-style-type: none"> <li>Programmable thermostat (except for zones with radiant heat)</li> </ul>			
Lighting & Appliances			
<ul style="list-style-type: none"> <li>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.</li> </ul>			

Higher Eff.  
HVAC  
Equip.

2012 vs.  
2009 IECC  
Insul.

More Eff.  
Windows

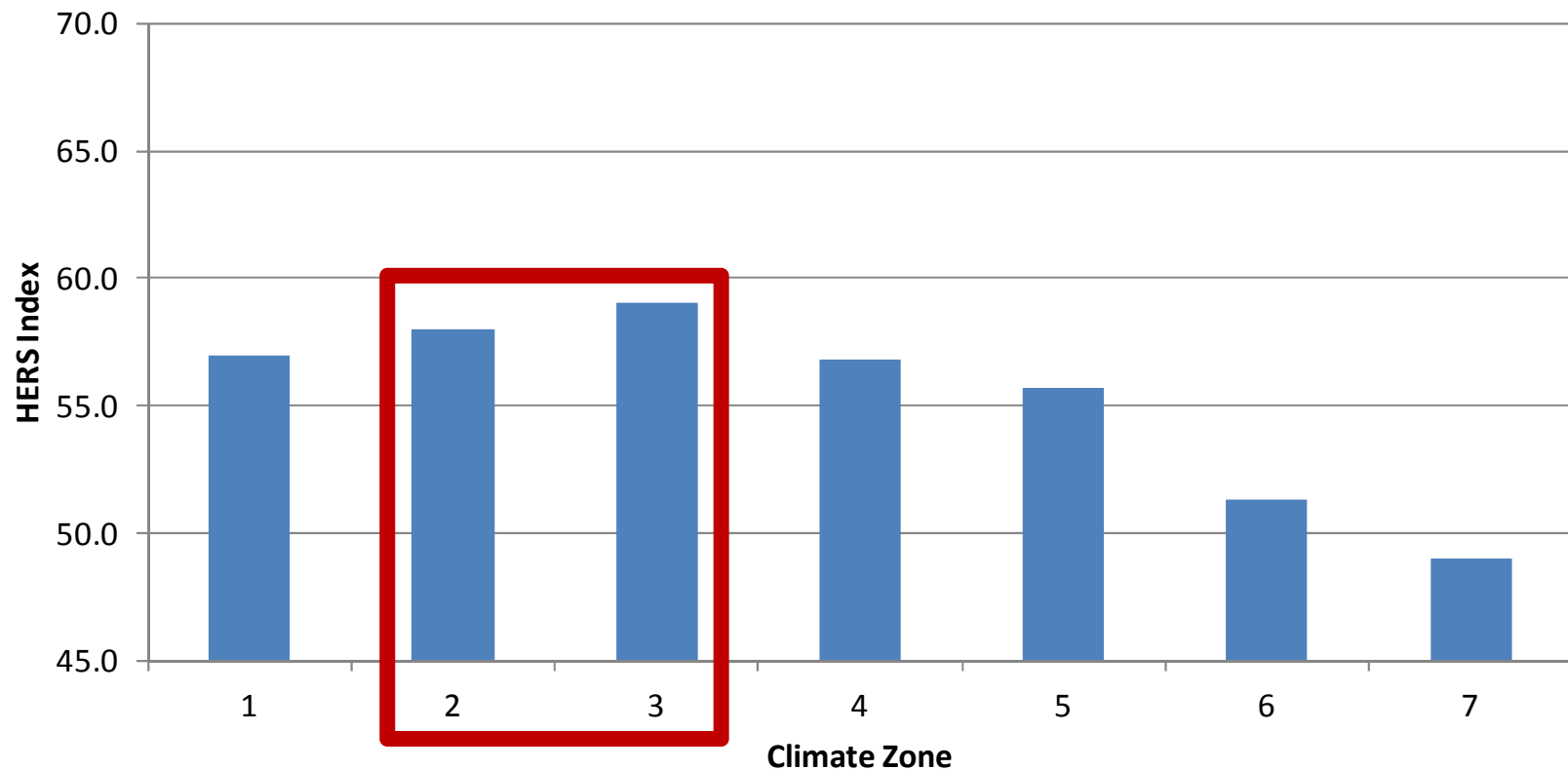
Half ACH50

ENERGY  
STAR Water  
Htg.



# Target Home Avg. HERS Scores

**Average DOE Challenge Home HERS Index by Climate Zone  
(Overall Average = 55.5)**



Based on 1800, 2400, and 3600 ft<sup>2</sup> prototypes on climate-appropriate foundations.

# Size Adjustment Factor

Homes larger than the benchmark home size must use the size adjustment factor to determine the target HERS index

Exhibit 3: Benchmark Home Size<sup>29</sup>

Bedrooms in Home to be Built	1	2	3	4	5	6	7	8
Conditioned Floor Area <small>Benchmark Home</small>	1,000	1,600	2,200	2,800	3,400	4,000	4,600	5,200

**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.

$$\text{Size Mod. Factor} = \left[ \frac{\text{CFA}_{\text{Benchmark Home}}}{\text{CFA}_{\text{Home to Be Built}}} \right]^{0.25}$$

[Not to Exceed 1.0]

# Performance Path Example

## CZ3 Prototype - 3 BR, 2300 SF

Specification	Target Home Spec	Design Home
Mandatory Items: ducts in conditioned space; 2012 IECC insulation; etc.		Meets all mandatory items; uses prescriptive R values to meet insulation reqmnt.
Windows	U=0.30; SHGC=0.27	U=0.30; SHGC=0.27
Infiltration	2.5 ACH50	<b>3.0 ACH50</b>
Duct Leakage	Total $\leq$ 8 CFM25 per 100 SF of CFA; Leakage to outdoors $\leq$ 4 CFM25 per 100 SF of CFA	Total leakage: 90 CFM25 Leakage to outdoors: 25 CFM25
Furnace AFUE	90	92
A/C SEER	15	<b>13</b>
Whole-House Mech. Vent.	54 cfm; 1.4 cfm/W;	108 cfm (50% duty cycle); <b>0.6 cfm/W (balanced)</b>
Water Heater	ENERGY STAR (0.67 EF gas)	0.67 EF Gas Storage WH
Target Home HERS Index	53	
HERS Index – Design Home		50 – <b>COMPLIES!</b>

- 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](mailto:doechallengehome@newportpartnersllc.com)
  - Otherwise builders will not receive “credit” on DCH website
  - Considering RESNET National Homes Registry for future



# Zero Energy Ready Homes **Recognition**

# Lots of Recognition Choices...



- **Review**
  - Technical Guidelines
  - Partnership Agreement Terms
- **Register**
  - Electronically Sign Agreement
- **Choose Optional Commitments:**
  -  100% of homes meet DOE Challenge Home Guidelines
  -  Homes meet EPA's WaterSense Guidelines
  -  Homes meet IBHS's Fortified Home Guidelines
  -  Meet DOE Challenge Home Quality Management Program

- **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 Challenge Home Web Site Locator Tool
- Case Studies/Virtual Parade of Home [coming]



## Links Buyers to Leading Edge Builders:

- Contact Information
- Optional Commitments



- # Labeled Homes
- Website link

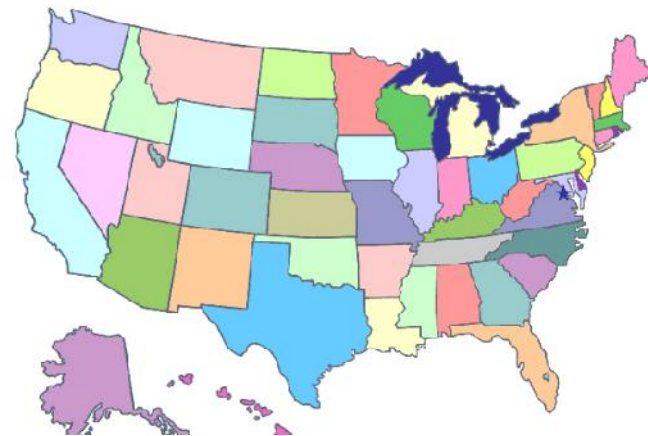
For All Active Partners

### DOE Challenge Home Partner Locator

Find out who is taking the challenge. Locate [DOE Challenge Home](#) partners near you! First choose a partner type and select a state. You can also enter a company name and find DOE Challenge Home partners that match your search.

*Please note: Partners began registering for the new DOE CHALLENGE HOME on April 2, 2012. The locator will not produce large results of partners in the program for several weeks. Please check back to watch our progress.*

Organization Type:  Choose a State:  [See Results](#)



# CH Partner Locator Tool

W Monsanto House x Indoor Air Quali x Building Technol x TeamSportsInfo. x US EPA Construction Spe x SAC/HC | New Pi x

www4.eere.energy.gov/buildings/residential/results/verifier/mn

About  
Take Action to Save Energy  
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Building America  
Home Energy Score  
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- Become a Partner  
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- Partner Locator  
- Events  
Guidelines for Home Energy Professionals  
Technology Research, Standards, & Codes

## DOE Challenge Home: Results

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

[\[Modify Search\]](#) [\[New Search\]](#)

First Prev 1 2 Next Last

100% Partners					
Name	Commitments	City	State	# of DOE Challenge Home Projects	
<a href="#">Building Science Institute Inc.</a>		HINSDALE	IL		
<a href="#">Habitat for Humanity of Ohio-Ky</a>		HAMILTON	OH		
<a href="#">Midwestern Energy Solutions, LLC</a>		OELWEIN	IA		
<a href="#">SustainMax, LLC</a>		MINNEAPOLIS	MN		
Name	Commitments	City	State	# of DOE Challenge Home Projects	
<a href="#">Bluegill Energy Management</a>		KATY	TX		
<a href="#">Building Efficiency Resources</a>		HOLCOMBVILLE	NY		

# CH Housing Innovation Awards



- **‘Test Drive’ Challenge Home**  
[1- 5 homes; most not ready for wholesale change]  
Offer Challenge Home upgrade as *‘Limited Edition’*
- **Measure Profit Metrics:**
  - Cost
  - Marketing
  - Performance
- **High-Performance Looks Different!**
  - Architectural Appearance
  - ‘Mark of Excellence’

# Questions?

## RELATED SESSIONS

**Indoor Air Plus & Challenge Home**  
2/25 @ 1:30 pm

**High R Assemblies**  
2/25 @ 3:30 pm

**Low Load HVAC**  
2/26 @ 8:30 am

**Ducts in Conditioned Space**  
2/26 @ 10:30 am

**WaterSense, Disaster Resistance,  
& Renewable Ready**  
2/26 @ 1:30

# Thank You



## For More Information:

[www.buildings.energy.gov/challenge/](http://www.buildings.energy.gov/challenge/)

## e-mail Contact:

[doechallengehome@newportpartnersllc.com](mailto:doechallengehome@newportpartnersllc.com)