

# Low-cost Construction for High-energy Savings



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# Objectives:

1. Control air & moisture in high-performance, low-cost construction
2. Basics at design stage of house
3. Material options (insulation, windows, mechanicals, etc.) for high-performing homes
4. Improve basics & modified techniques before high-tech solutions
5. ENERGY STAR for Homes process & checklists
6. Performance measures in diagnostic testing
7. Assess energy use in completed homes

# What does it take to build an energy-efficient home?

## 1) Labor

- ▶ Standard methods, OVE, new best practices
- ▶ Devil in the details

## 2) Materials

- ▶ Energy-efficient
- ▶ Durable
  - ▶ Wet/dry?
  - ▶ Over time
  - ▶ Maintaining Durability

# Materials

Durability

Heat

Moisture

Time

Fiberglass

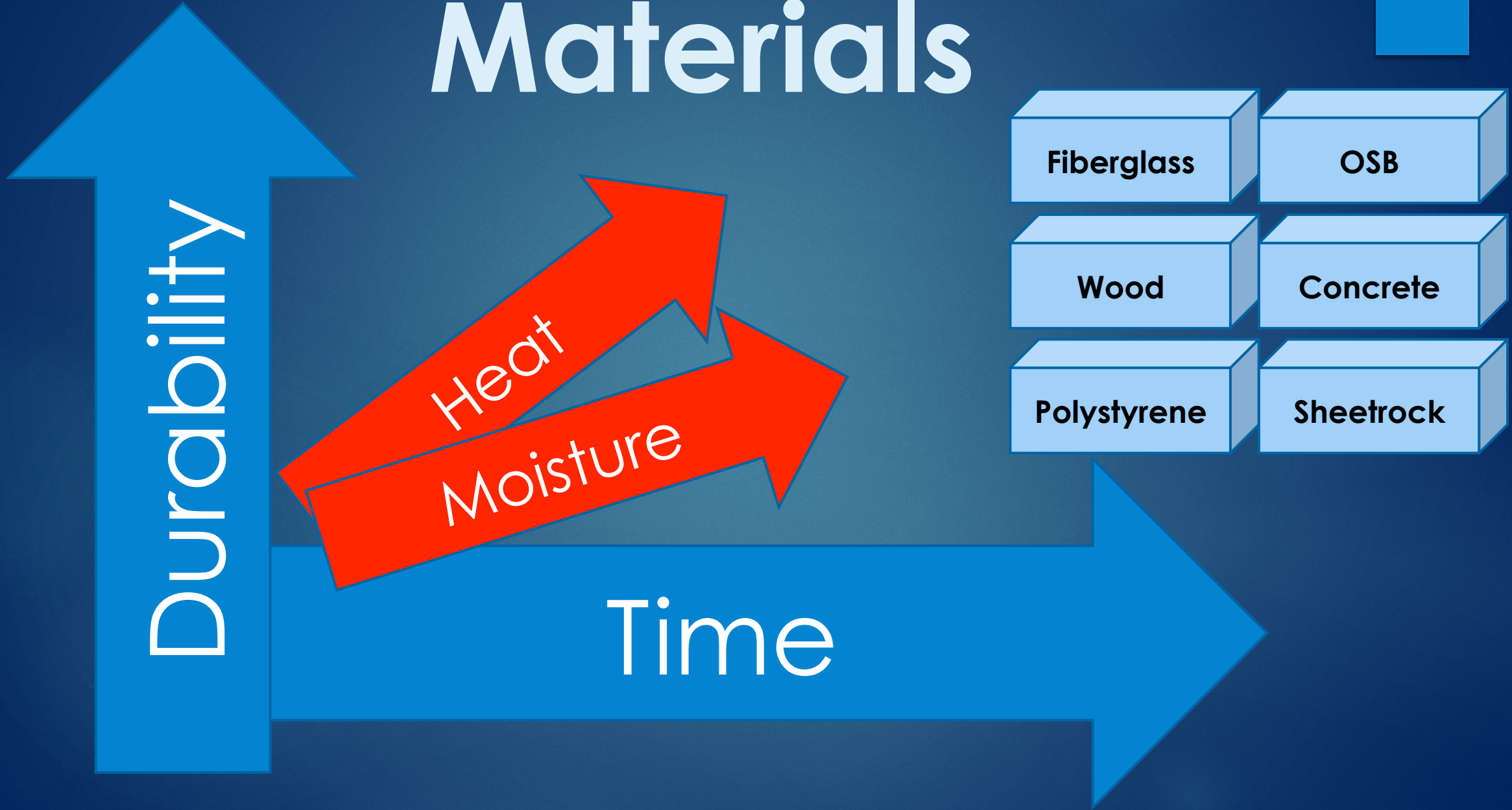
OSB

Wood

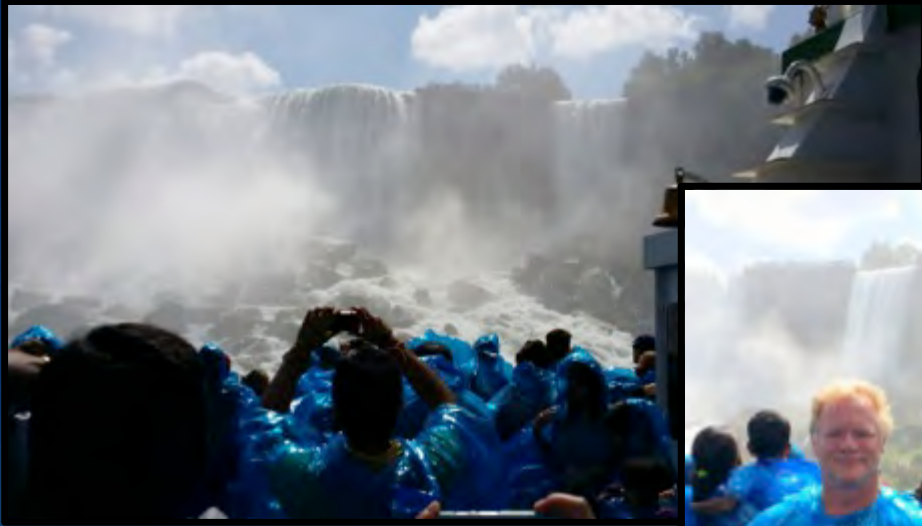
Concrete

Polystyrene

Sheetrock



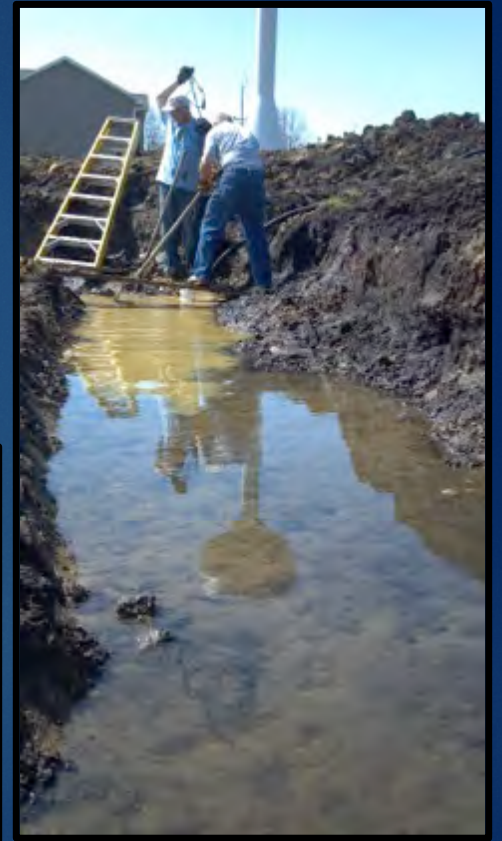
# The climate throws a lot at us...



It may make for natural beauty...



*Are we building ships?*

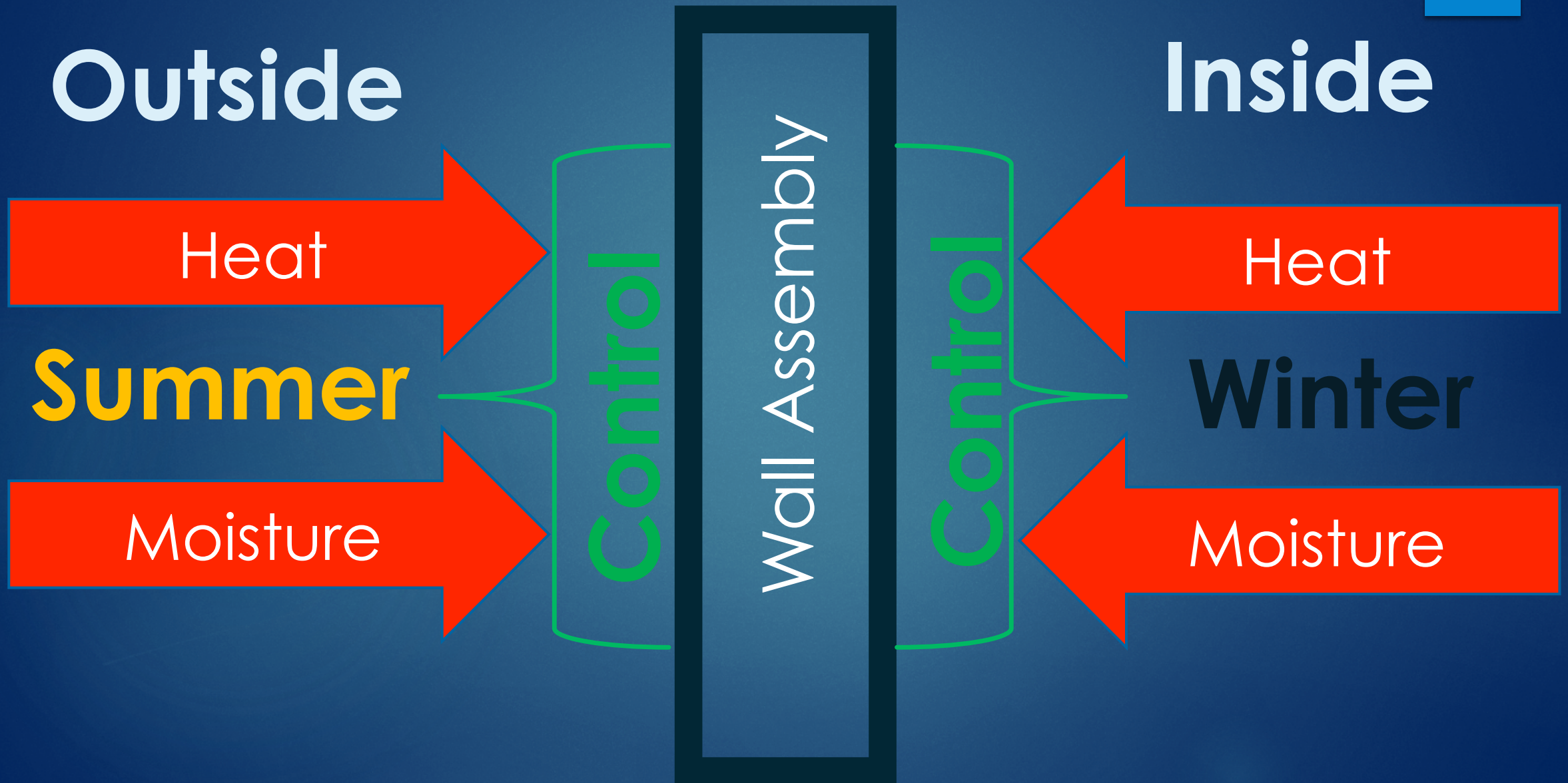


...but in our homes it conspires to undo our work!

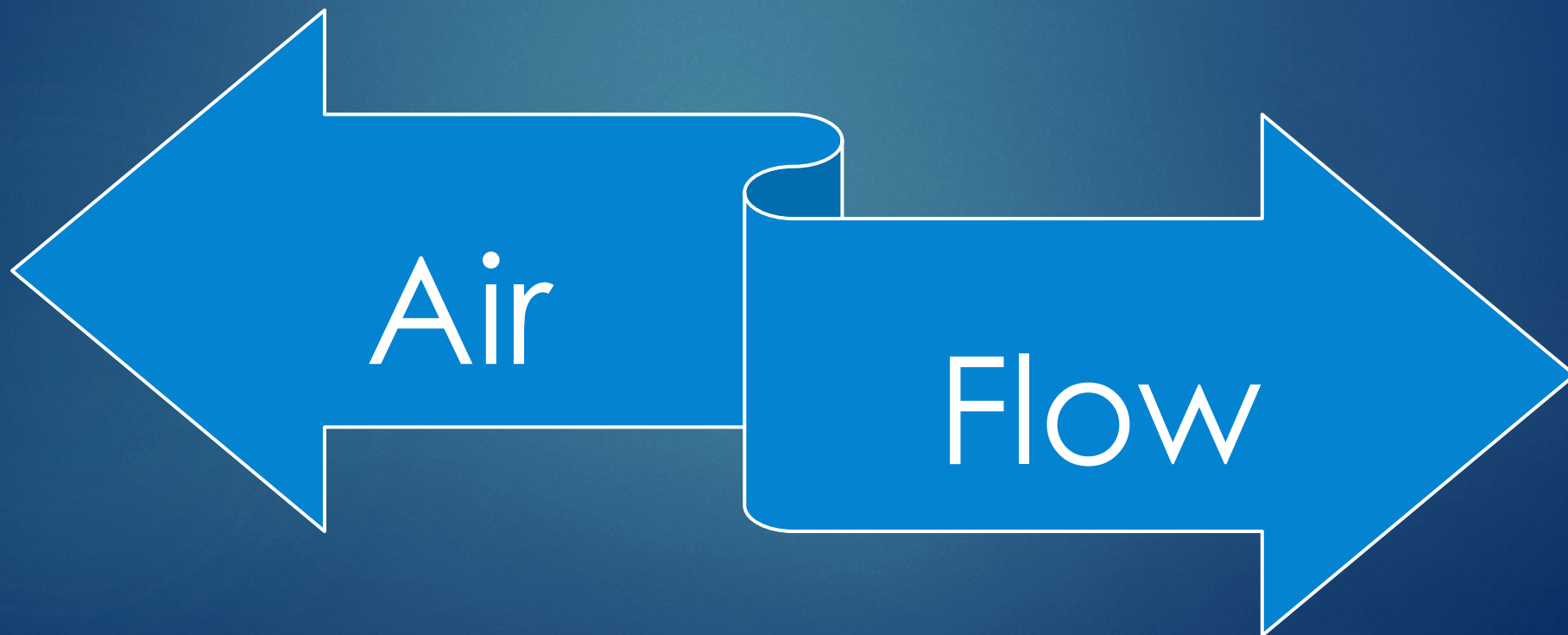
# Control air & moisture in high-performance, low-cost construction

- ▶ **Top cause of heat and moisture movement is air flow**
- ▶ Preventing heat and moisture flow through the foundation system
- ▶ Preventing heat and air flow through the building envelope
- ▶ Follow up after sheetrock installation, attic and walls
- ▶ Sealing doors and window openings
- ▶ Air-tight framing methods
- ▶ Framing to foundation transition
- ▶ Air-sealing the attic

# Control in the wall assembly



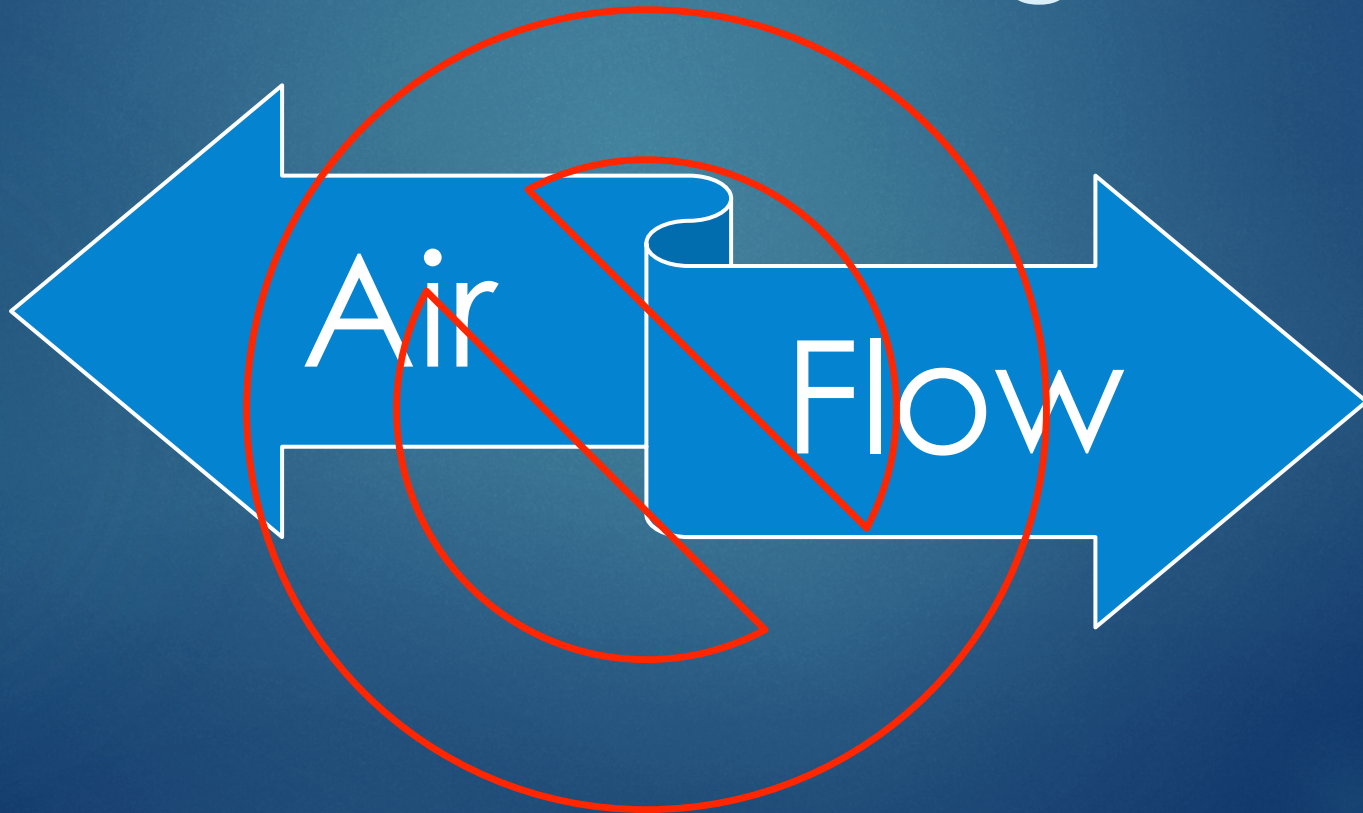
**#1 Means of heat & moisture transfer in wall assemblies is:**





**Stop the air flow!**  
**And stop the heat loss & the  
moisture damage**

**Control**



**Control**

# From [constructioninstruction.com](http://constructioninstruction.com)

- ▶ **“The reality:** Many walls have too little insulation and too many leaks. This means that warm moist air can get in, find a cool surface, and condense. Result: The wall gets wet, mold and mildew begin to grow.”
- ▶ “Moisture can be carried by the flow of air into or out of the home through holes and cracks in the building envelope. This airflow is caused by a variety of forces including stack effect, the wind, and mechanical systems.”
- ▶ “By building a tight envelope and controlling mechanical pressures, we can reduce moisture flow through a building.”

# Preventing heat, moisture & air flow through the building envelope

- ▶ Start with “air-tight framing”
  - ▶ Testing at insulation stage (we found biggest leaks due to framing)
- ▶ WRB barrier, taped top, bottom, edges
  - ▶ Stopping wind pressure from producing air infiltration
- ▶ Interior barrier methods
  - ▶ Poly/air-tight drywall, “smart vapor retarders” (vapor retarders whose vapor permeability changes based on the humidity conditions)
- ▶ Connecting the interior and exterior barriers
  - ▶ Sealed to framing for complete air block
- ▶ Under slab control of moisture & radon
  - ▶ Poly film, polystyrene board

# Start with air-tight framing



Caulking the framing



Caulking the framing

# Rim joist areas



# Sealing the gaps



Penetrations such as electrical boxes



Bottom plate

Foundation to wood connections

# WRB barrier, taped top, bottom, edges, window & door openings



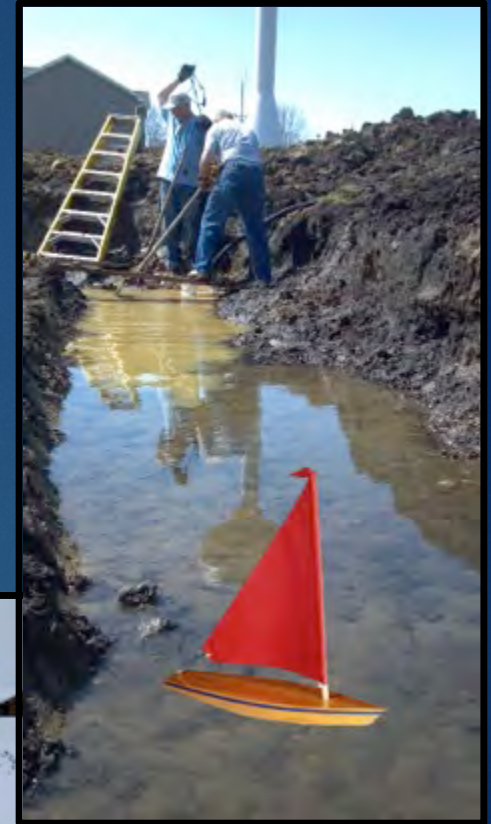
Follow up after sheetrock installation, attic & walls, etc.



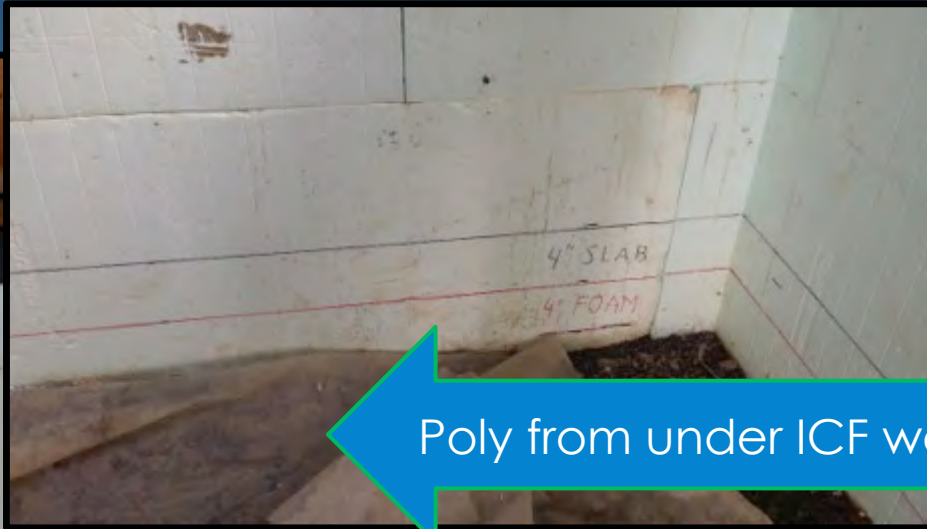


# Preventing heat & moisture flow through the foundation system

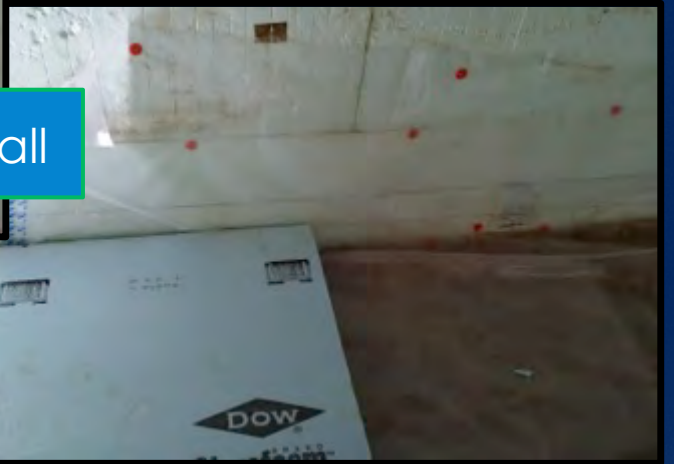
- ▶ Build foundation like a boat hull underwater
- ▶ Capillary break between footing & foundation wall (radon control)
- ▶ Connecting the capillary break to under slab radon control
- ▶ Insulating under the slab (new energy code)
- ▶ Use of ICF
- ▶ Capping the foundation top with waterproof membrane
- ▶ Connection between foundation and framing



# Under Slab Poly & Foam Board



Poly from under ICF wall



Sealing around plumbing



# Connection between foundation wall & framing



# Connection between foundation wall & framing

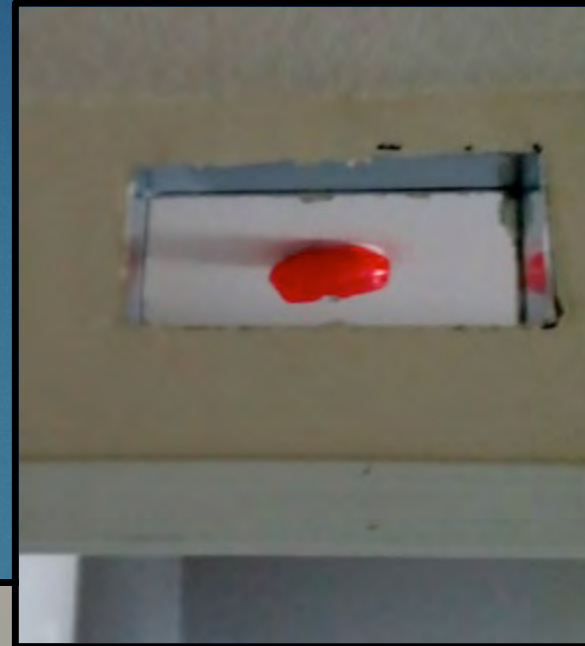


# Basics at design stage of house

- ▶ Planning for minimal ductwork
  - ▶ Keeping ducts inside the thermal envelope
  - ▶ Pass-through instead of ducted returns when possible to minimize ducts
- ▶ Simplified design of home
- ▶ OVE framing
  - ▶ Line up floor trusses, wall studs, roof trusses (24: o.c.)
  - ▶ Reduce thermal transfer



# Pass-throughs, returns



# Material options (insulation, windows, mechanicals, etc.) for high-performing homes

- ▶ Polystyrene board
- ▶ Fiberglas batts
- ▶ New energy code/no interior vapor barrier required?
- ▶ Foam fill around windows
- ▶ Inexpensive caulk & air-tight framing
- ▶ WRB, tape and sealing the entire envelope
- ▶ All sealed ducting
- ▶ Triple-glazed window costs



# Polystyrene + Fiberglass

TABLE N1102.1.1 (R402.1.1)  
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT<sup>g</sup>

CLIMATE ZONE	FENESTRATION U-FACTOR <sup>b</sup>	SKYLIGHT <sup>b</sup> U-FACTOR	GLAZED FENESTRATION SHGC <sup>h, o</sup>	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	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>e</sup> WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5 <sup>h</sup>	8/13	19	5/13 <sup>f</sup>	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13 + 5 <sup>h</sup>	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13 + 5 <sup>h</sup>	13/17	30 <sup>g</sup>	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 13 + 10 <sup>h</sup>	15/20	30 <sup>g</sup>	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20 + 5 or 13 + 10 <sup>h</sup>	19/21	38 <sup>g</sup>	15/19	10, 4 ft	15/19

# Improve basics & modified techniques before high-tech solutions

- ▶ Details, details, details. The Devil is in there!
  - ▶ Focus on the details to achieve maximum performance of materials through best practices
- ▶ OVE framing practices
  - ▶ Two-stud corners, ladder pocket, alignment of components
- ▶ Pre-poly and poly connection to WRB
- ▶ Complexity and cost of generating power—lower use first.
- ▶ PV is a rapidly changing industry and current equipment will continue to drop in cost and go up in efficiency (a changing variable)

# Ducts/plumbing in unconditioned space

## Floor over garage blocking

In floors over garages, air from unconditioned spaces can easily pass into the floor assembly if solid blocking (rim joist) is left out or inadequately sealed. This degrades insulation performance, leads to uneven floor temperatures, and decreases occupant comfort and safety. Enclose all cavities by installing and sealing solid blocking around the entire perimeter at the rim joist location.



Figure 8.2



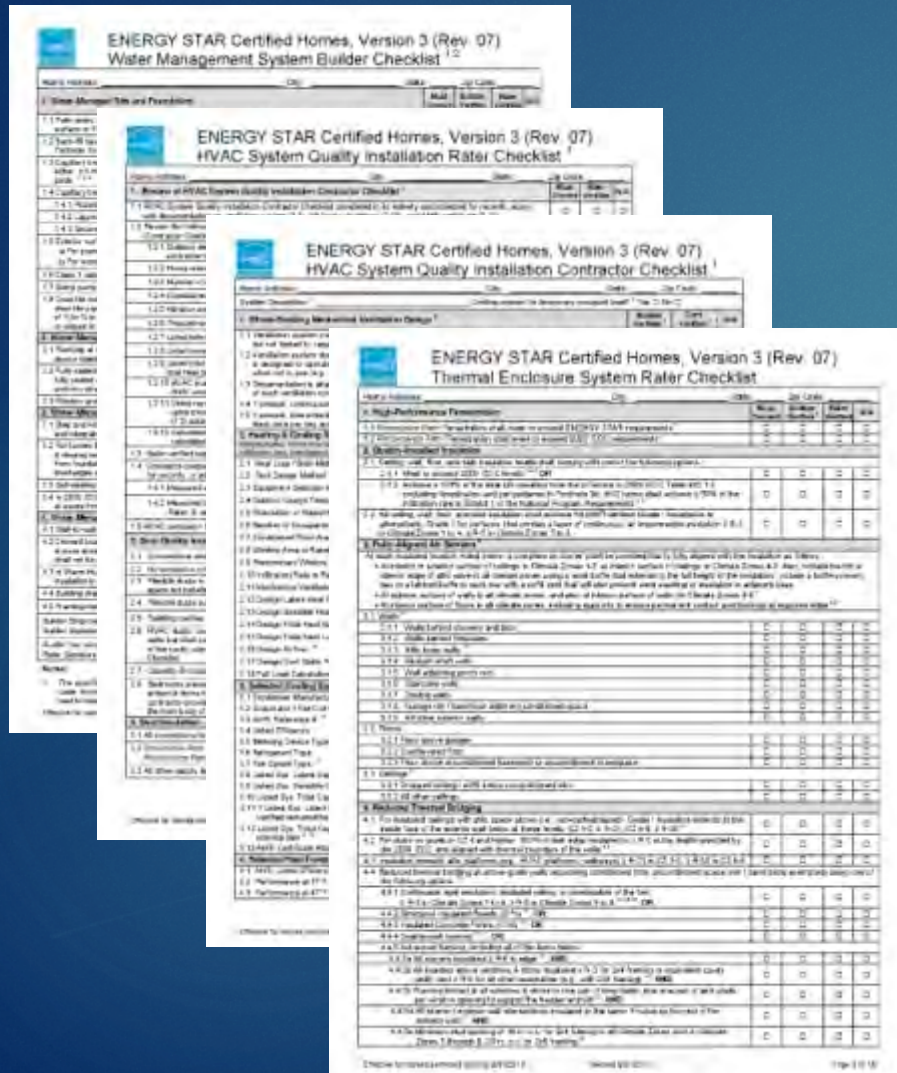
### Exceptional Building Practices

The following items are demonstrative of exceptional construction practices and details. Not only have you exceeded standard building practices, it has been done so in an exceptional manner.

# ENERGY STAR for Homes process & checklists

- ▶ Checklists:
  - ▶ Thermal Enclosure System Rater Checklist
  - ▶ HVAC System Quality Installation Contractor Checklist
  - ▶ HVAC System Quality Installation Rater Checklist
  - ▶ Water Management System Builder Checklist
- ▶ Hiring a qualified HVAC contractor
  - ▶ Must

# Checklists



- ▶ Thermal Enclosure
- ▶ HVAC Contractor
- ▶ HVAC Rater
- ▶ Water Management

# Performance measures in diagnostic testing

- ▶ Energy rater three stages of evaluation
  - ▶ Site Visit 1 (SV1) Completion of framing
  - ▶ SV2 after HVAC, Plumbing, Electrical & insulation & poly VB
- ▶ Blower door and duct leakage testing numbers SV3
  - ▶ Duct leakage testing at SV2

# Site Visit

## Voids/gaps/compressions in fiberglass

Insulation performance is reduced by misalignment, voids, gaps and compressions and leads to building durability issues, uneven interior surface temperatures, occupant discomfort, and high utility costs. Completely fill cavities without voids, gaps, and compressions with the insulation in full contact with the vapor barrier.



Figure 1.2

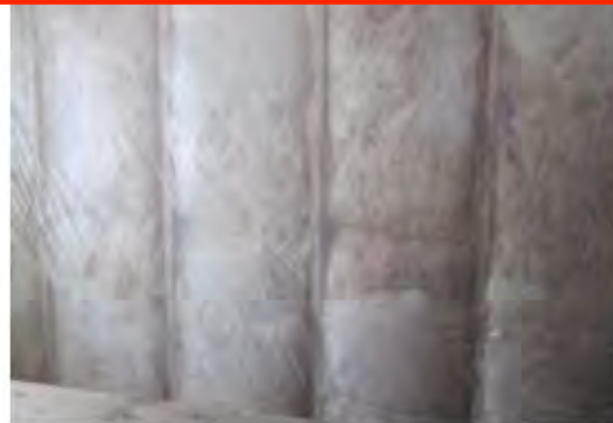


Figure 1.3



Figure 1.4

## ! Opportunities for Quality Improvement

Items and pictures listed in this section do not require corrective action. These items are opportunities for additional improvement.

# Site Visit

## Voids/gaps/compressions in fiberglass

Insulation performance is reduced by misalignment, voids, gaps and compressions and leads to building durability issues, uneven interior surface temperatures, occupant discomfort, and high utility costs. Completely fill cavities without voids, gaps, and compressions with the insulation in full contact with the vapor barrier.



Figure 1.2



## Exceptional Building Practices

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Figure 1.3



# Site Visit



## Exceptional Building Practices

The following items are demonstrative of exceptional construction practices and details. Not only have you exceeded standard building practices, it has been done so in an exceptional manner.



Figure 5.1



Figure 5.2

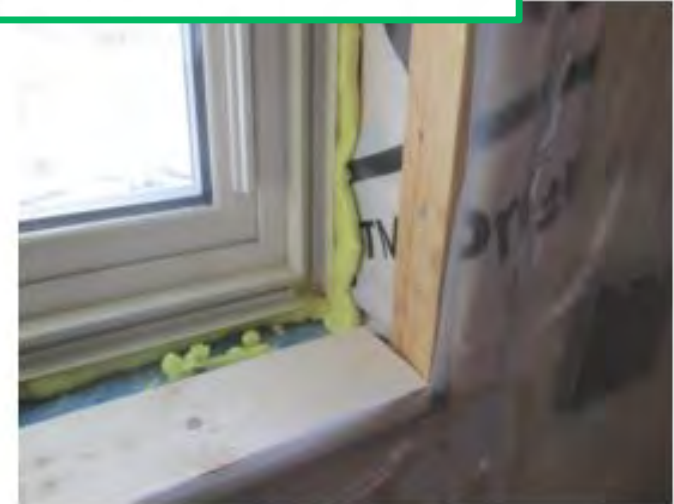


Figure 5.6



Figure 5.3



Figure 5.4



Figure 5.5

# Duct Leakage Test... Missed it!

Main Level SF - 940.4

Lower Level SF - 940.4

Total SF = 1,880.8

$1,880.8 \text{ SF} / 100 = 18.808$

$18.808 \times 8 \text{ CFM25} = 150.464$

Your allowable total duct leakage is **150.464**. Your test results were **151....this does not meet the requirements.**

# HVAC System

- ▶ NO un-ducted cavity returns
- ▶ Seal ALL seams
- ▶ Seal cabinet
- ▶ Seal boots to subfloor/wall/ceiling
- ▶ Credentialed through ACCA OR Advanced Energy



# Performance Measures & Testing

- ▶ Blower door:  $\leq 4$  ACH50
  - ▶ Air changers/hour @ induced pressure of -50 Pascals
  - ▶ Meant to simulate a “stiff wind” perhaps 15 -20 mph
- ▶ Ducts – total:  $\leq 8$  CFM / 100 SF finished
  - ▶ Total of all ductwork
- ▶ Ducts – outside:  $\leq 4$  CFM / 100 SF finished
  - ▶ Total leakage in ductwork in unconditioned space
- ▶ [Just Right & Airtight, Joe Lstiburek](#)  
BuildingScience.com



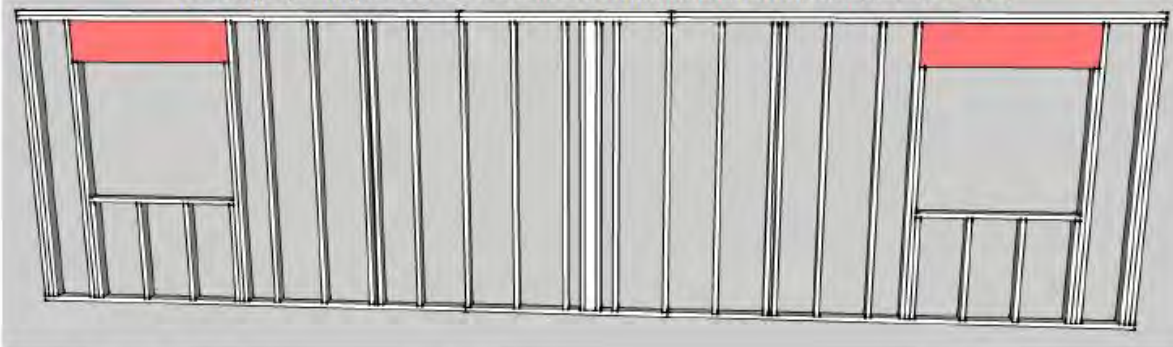
# OVE Framing Practices



ENERGY STAR Certified Homes, Version 3  
Cost & Savings Estimates

To estimate the impact on framing fraction from these details, a 30'x8' wall was modeled with and without these details. The wall below was modeled without these features and has a framing fraction of 23%.

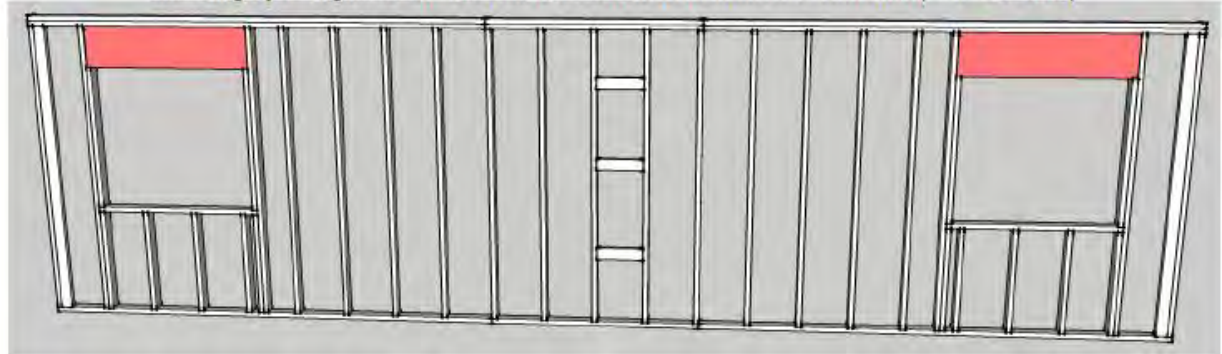
30' Long by 8' High 2x4 16" OC Standard Wall with Two Windows (4'-1" x 3'-8.5")



Top & Bottom Plates:	3 * 30' * 1.5"	= 11.3 sqft
King Studs:	23 * 7'-7.5" * 1.5"	= 21.9 sqft
Int. / Ext. Wall Intersection:	7'-7.5" * 3.5"	= 2.2 sqft
Exterior Wall Corner:	4 * 7'-7.5" * 1.5"	= 3.8 sqft
Window Header:	2 * 4'-4" * 11.5"	= 8.3 sqft
Jacks / Trimmers:	4 * 6'-8" * 1.5"	= 6.0 sqft
Window Sills:	2 * 4'-1" * 1.5"	= 1.0 sqft
Cripples:	8 * 2'-8.5" * 1.5"	= 2.7 sqft
<b>Total Wood Area</b>		<b>= 54.6 sqft</b>
<b>Total Wall Area</b>		<b>= 240 sqft</b>
<b>Framing Fraction</b>	<b>= 54.6 / 240</b>	<b>= 23%</b>

The wall below was modeled with these features and has a framing fraction of 18%.

30' Long by 8' High 2x4 16" OC ENERGY STAR Wall with Two Windows (4'-1" x 3'-8.5")



Top & Bottom Plates:	3 * 30' * 1.5"	= 11.3 sqft
King Studs:	19 * 7'-7.5" * 1.5"	= 18.1 sqft
Int. / Ext. Wall Intersection:	(Insulated Ladder Wall)	= 0 sqft
Exterior Wall Corner:	(Insulated 3-Stud Corner)	= 0 sqft
Window Header:	2 * 4'-4" * 11.5"	= 8.3 sqft
Jacks / Trimmers:	4 * 3'-10" * 1.5"	= 1.9 sqft
Window Sills:	2 * 4'-4" * 1.5"	= 1.1 sqft
Cripples:	10 * 2'-8.5" * 1.5"	= 3.4 sqft
<b>Total Wood Area</b>		<b>= 44.1 sqft</b>
<b>Total Wall Area</b>		<b>= 240 sqft</b>
<b>Framing Fraction</b>	<b>= 44.1 / 240</b>	<b>= 18%</b>

# Advanced Framing: An Examination of its Practical Use in Residential Construction



“Based on the case study, some OVE techniques were practical to implement (when visibly marked on the construction plans) and had noticeable material savings, thermal benefits, and positively affected the quality of framing. Other practices were found to be problematic, either from a technical or logistical standpoint, or had minimal energy or lumber saving benefits (considering that **exterior foam sheathing** was employed on the home).”

“On a first-time home, these added “soft costs” associated with the implementation of even the most basic OVE practices are likely to offset any savings accrued from reduced lumber use. Furthermore, the energy efficiency gains associated with using **continuous exterior insulating sheathing** overshadow the efficiency gains from employing OVE framing techniques.”

# Reducing backing requirements



## ◀ **Corner-backs**

Prest-on Corner-back fasteners eliminate wood or steel stud backup at corners and ceilings. The result is faster framing and faster, easier drywall installation. Also great for **Truss Uplift**.

[view >](#)



## ◀ **Framer-backs**

Framer-back drywall fastener eliminates the need for wood blocking at interior drywall corners and ceilings.

[view >](#)

# Assess energy use in completed homes

- ▶ Energy rater
- ▶ Blower door test and understanding the results
- ▶ Duct leakage test and understanding the results and why it's important





# Final Testing and Completion Report (SV3)

Site Walk Date: 2014-12-22

Building Code MN Code  
File Number #43254  
Site Walk Date 2014-12-22



**Home**  
801 3rd St SE  
Kasson, MN 55944

**Builder**  
Habitat for Humanity -  
Rochester Area  
1530 Greenview Drive SW  
Suite 107  
Rochester, MN 55902

**Model**  
Production  
Type: Single-family detached  
Size: 1881 ft<sup>2</sup>

## ENERGY STAR Requirements

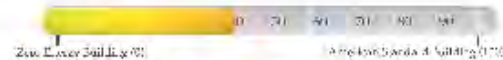
NO

Checklists Completed No  
Checklists Signed No  
Meets Testing Standards Yes

0  
TBC Failures need correcting

## HERS Index

45



RESNET Ratings provide a relative energy use index called the HERS Index, which represents the home's energy usage as a percentage of the energy usage of the "American Standard Building."

Beats 2006 IECC standard by 66.27%

2  
Issues could use improvement

0  
Exceptional building practices identified

### Insulation Features

Worst Insulation Grade	III/NR
Rim	Grade: I
Ceiling Flat	R = 50.0 (Grade I)
Vaulted Ceiling	n/a
Above Grade Walls	R = 24.0 (Grade I)
Foundation Walls	R = 23.0 (Grade I)
Framed Floor	n/a
Slab	R = 23.0 Edge, 23.0 Under (Grade III/NR)
Duct	Uninsulated
Window	U = 0.270, SHGC = 0.290

### Blower Door Test Results

Tested CFM50	477
CFM50 / ft <sup>2</sup> surface area	0.11
CFM50 / ft <sup>2</sup> floor area	0.25
ACH50	1.72

### Ventilation Flow Test Results

Target Flow (CFM)	Unknown
Actual Flow (CFM)	100
Rated Flow (CFM)	0.0
Duct Leakage to Outside	122

<b>Efficiency</b>	<b>Heat</b>	<b>Cooling</b>	<b>Hot Water</b>	<b>Ventilation</b>	<b>Thermostat</b>
<b>Brand / Make</b>	96.5 (AFUE)	13.0 (SEER)	0.67		
<b>Model</b>	Carrier	Not Installed	Rheem	Venmar	Pro1
<b>Size</b>	59TP5A040E14110	NA	PROG40-40N RH67 PV	Venmar	Pro1
	39.0 BTU	BTU	40 Gal		



# Final Testing and Completion Report (SV3)

Site Walk Date: 2011-11-04

Building Code MN Code  
File Number #4670  
Site Walk Date 2011-11-04



**Home**  
2011 Petersen Dr NW  
Stewartville, MN 55976

**Builder**  
Habitat for Humanity -  
Rochester Area  
1530 Greenview Drive SW  
Suite 107  
Rochester, MN 55902

**Model**  
Custom  
Type: Single-family detached  
Size: 1758 ft<sup>2</sup>

## Meets ENERGYSTAR Requirements

YES

AC Sizing On File  
Duct Leakage Does not meet  
Thermal Bypass Checklist (TBC) Pass

0  
TBC Failures need correcting

## HERS Index

57



RESNET Ratings provide a relative energy use index called the HERS Index, which represents the home's energy usage as a percentage of the energy usage of the "American Standard Building."

Beats 2004 IECC standard by 62.34%

4  
Issues could use improvement

0  
Exceptional building practices identified

### Insulation Features

Worst Insulation Grade	III/NR
Rim	Grade: III/NR
Ceiling Flat	R = 44.0 (Grade III/NR)
Vaulted Ceiling	n/a
Above Grade Walls	R = 24.0 (Grade I)
Foundation Walls	R = 22.0 (Grade I)
Framed Floor	n/a
Slab	R = 22.0 Edge, 22.0 Under (Grade III/NR)
Duct	Uninsulated
Window	U = 0.310, SHGC = 0.330

### Blower Door Test Results

Tested CFM50	742
CFM50 / ft <sup>2</sup> surface area	0.20
CFM50 / ft <sup>2</sup> floor area	0.42
ACH50	3.03

### Ventilation Flow Test Results

Target Flow (CFM)	Unknown
Actual Flow (CFM)	0
Rated Flow (CFM)	153.0
Duct Leakage to Outside	0

<b>Efficiency</b>	<b>Heat</b>	<b>Cooling</b>	<b>Hot Water</b>	<b>Ventilation</b>	<b>Thermostat</b>
<b>Brand / Make</b>	95.0 (AFUE)	13.0 (SEER)			
<b>Model</b>	Trane	Trane	AO Smith	RenewAire	Honeywell
<b>Size</b>	TUHI B060A9361AA	4TTB3018D1000AA	GPVH 40 100	RenewAire	Honeywell
<b>Serial Number</b>	57.0 BTU	18.0 BTU	49 Gal		
	11234KNN7G		1114A025442		

# Fuel Summary for Kasson House

## Fuel Summary

Property  
801 3rd St SE  
Kasson, MN 55944

Organization  
XRG Concepts, LLC  
507-258-6500  
Brandon Vagt

HERS  
Confirmed  
12/22/2014  
Rating No:14-XRG-192-09  
Rater ID:8188958

Weather:Rochester, MN  
14-XRG-192-09  
14-XRG-192-09 801 3rd St SE  
Kasson MN 55944 REM.Fnl  
010915.blg

Builder  
Habitat for Humanity - Roch

Annual Energy Cost	\$/yr
Natural gas	399
Electric	551

Annual End-Use Cost	\$/yr
Heating	236
Cooling	0
Water Heating	177
Lights & Appliances	538
Photovoltaics	-0
Service Charge	222
<b>Total</b>	<b>1173</b>

Annual End-Use Consumption	
Heating (Therms)	267
Heating (kWh)	166
Water Heating (Therms)	211
Lights & Appliances (kWh)	6230
<b>Total (Therms)</b>	<b>478</b>
<b>Total (kWh)</b>	<b>6396</b>

Annual Energy Demands	kW
Heating	0.1
Cooling	0.0
Water Heating (Winter Peak)	0.0
Water Heating (Summer Peak)	0.0
Lights & Appliances (Winter Peak)	0.5
Lights & Appliances (Summer Peak)	1.2
<b>Total Winter Peak</b>	<b>0.5</b>
<b>Total Summer Peak</b>	<b>1.2</b>

Utility Rates	
Electricity	City of Kasson 2014**
Natural Gas	MERC 2014 10/21/14**

REM/Rate - Residential Energy Analysis and Rating Software v14.5.1

This information does not constitute any warranty of energy cost or savings.

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# Utility use in RAHH Homes

## Utility Data Report ROCHESTER AREA HABITAT FOR HUMANITY, 2013-2014

### Utility use summary

Total annual natural gas* cost:	\$839
Highest annual ng cost:	\$1196
Lowest annual ng cost:	\$637
Average per winter month:	\$105
Average per summer month:	\$40

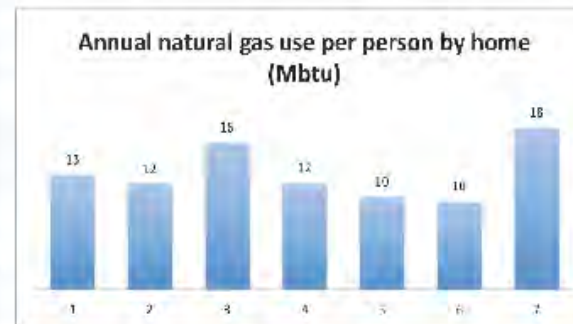
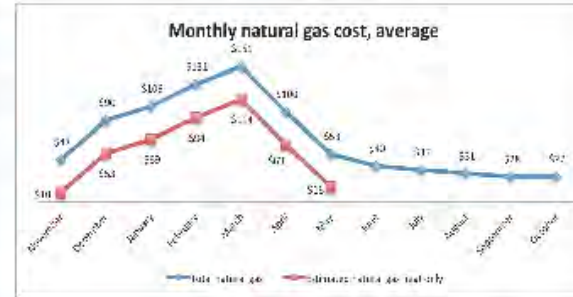
### How to use this report

**Monthly utility cost** - this data can be helpful for future Habitat for Humanity homeowners in planning for anticipated monthly expenses.

**Annual cost by home** - this data can be used to help gauge the performance of the methods and materials used to build different homes. But use with caution - it's as much about behavior as construction!

**Annual energy use per person** - this data can be practical in looking at differences in household energy use patterns regardless of family size or utility rates. It is measured in MBTUs - meaning million British Thermal Units, which is a standard energy measurement.

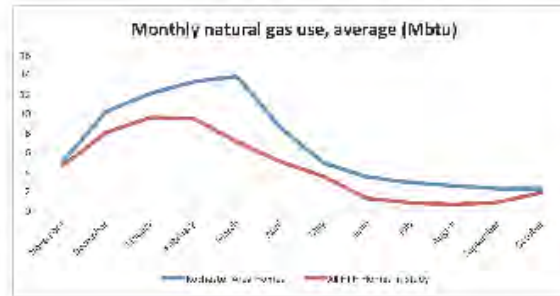
**Digging deeper...** While all homes in your sample set are similar in size and climate location, further analysis can be done upon request to account for square footage or regional temperature differences. For more information, contact Molly Berg, Sustainable Building Program Manager, Habitat for Humanity of Minnesota, at [molly@hfhmn.org](mailto:molly@hfhmn.org).



\*Only natural gas data available for these homes. Totals do NOT include electric utility use and costs. See page 2 for electric cost estimate.  
\*\*Addresses removed for privacy, available to affiliate upon request.

# Utility use in RAHH Homes

## ROCHESTER AREA HABITAT FOR HUMANITY, 2013-2014

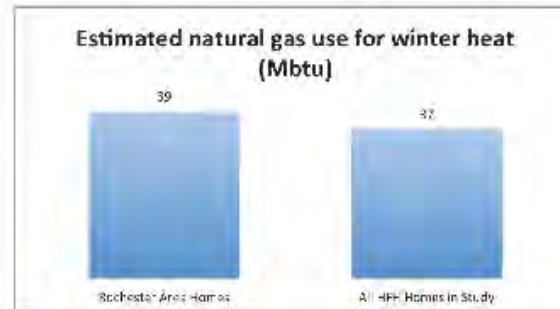


### Utility use comparison

Average annual natural gas **cost** in MN  
 HFH homes: \$567  
 Rochester: **\$272 more**

Average annual natural gas **use** in MN HFH homes: 52 Mbtu  
 Rochester: **28 Mbtu more**

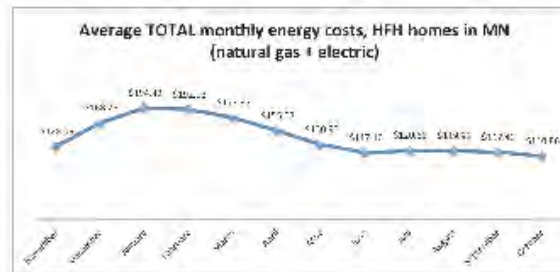
Average annual utility **cost** in MN HFH homes with electric & gas: \$1,285  
 Rochester: **Not available**



### Results

The Rochester Area homes spend more money on natural gas fuel than the average HFH home in Minnesota. Rochester Area homes use about 28 Mbtu more in natural gas than the average HFH home in Minnesota; this is the equivalent of 2-3 winter months' worth of natural gas fuel.

This may be due, in part, to the use of natural gas for water heating and cooking. Analysis indicates nearly identical natural gas use estimates for winter heat when comparing Rochester Area homes to all HFH homes in the study.



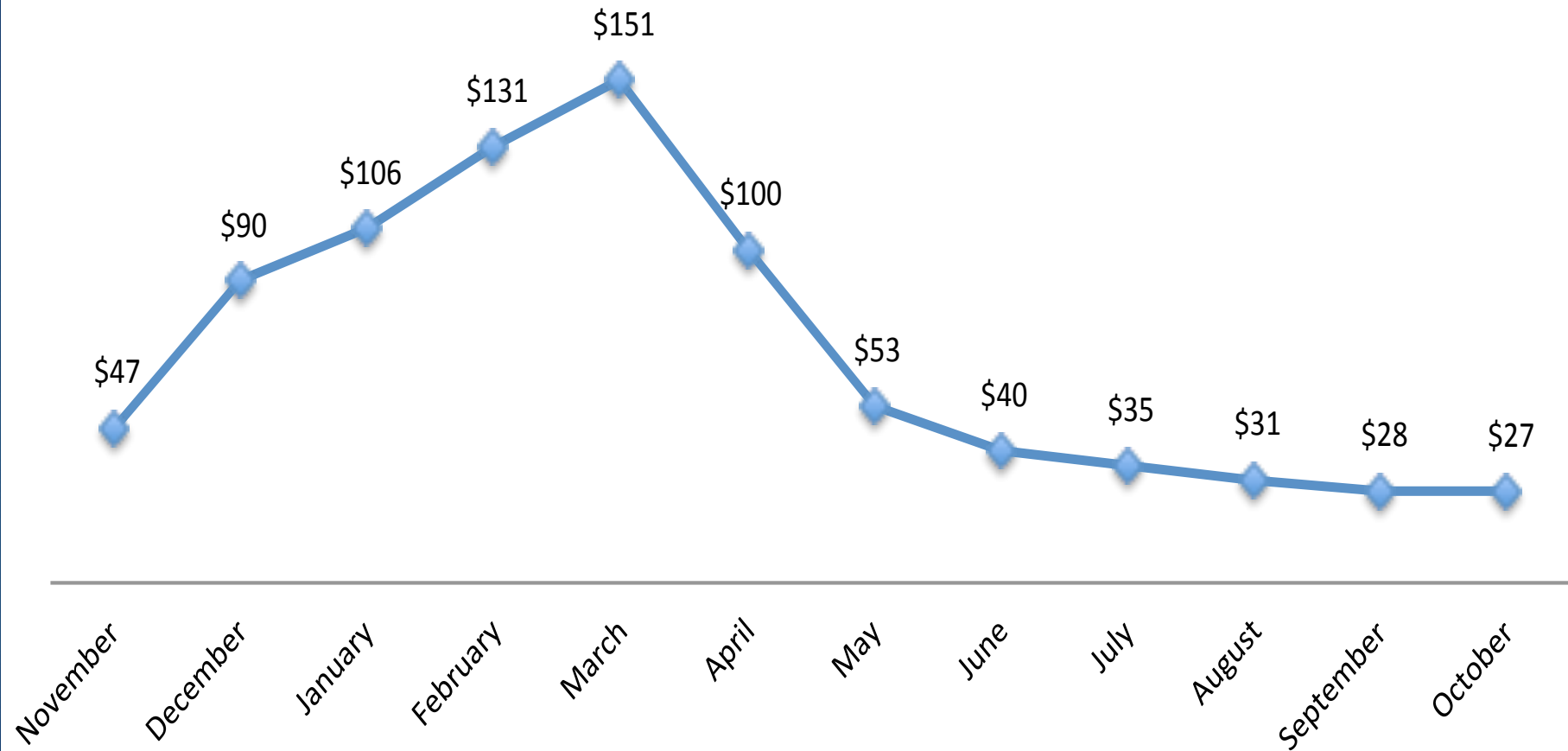
Most Rochester Area homes are supplied by Rochester Public Utilities, which charges a data fee not supported by this study. The final graph on the left represents the average TOTAL (electric & gas) monthly energy costs of HFH homes in Minnesota.

### Methodology

All data reflects November, 2013 - October, 2014. Data is obtained for homes with signed data release forms. Winter data range (Nov-Mar) is determined based on available comparison data from Centerpoint Energy. Winter heat estimate - when used - is determined by subtracting the heat fuel cost May-Sept from the heat fuel cost Nov-Mar. For more information, contact Molly Berg, Sustainable Building Program Manager, at [molly@hhmn.org](mailto:molly@hhmn.org).

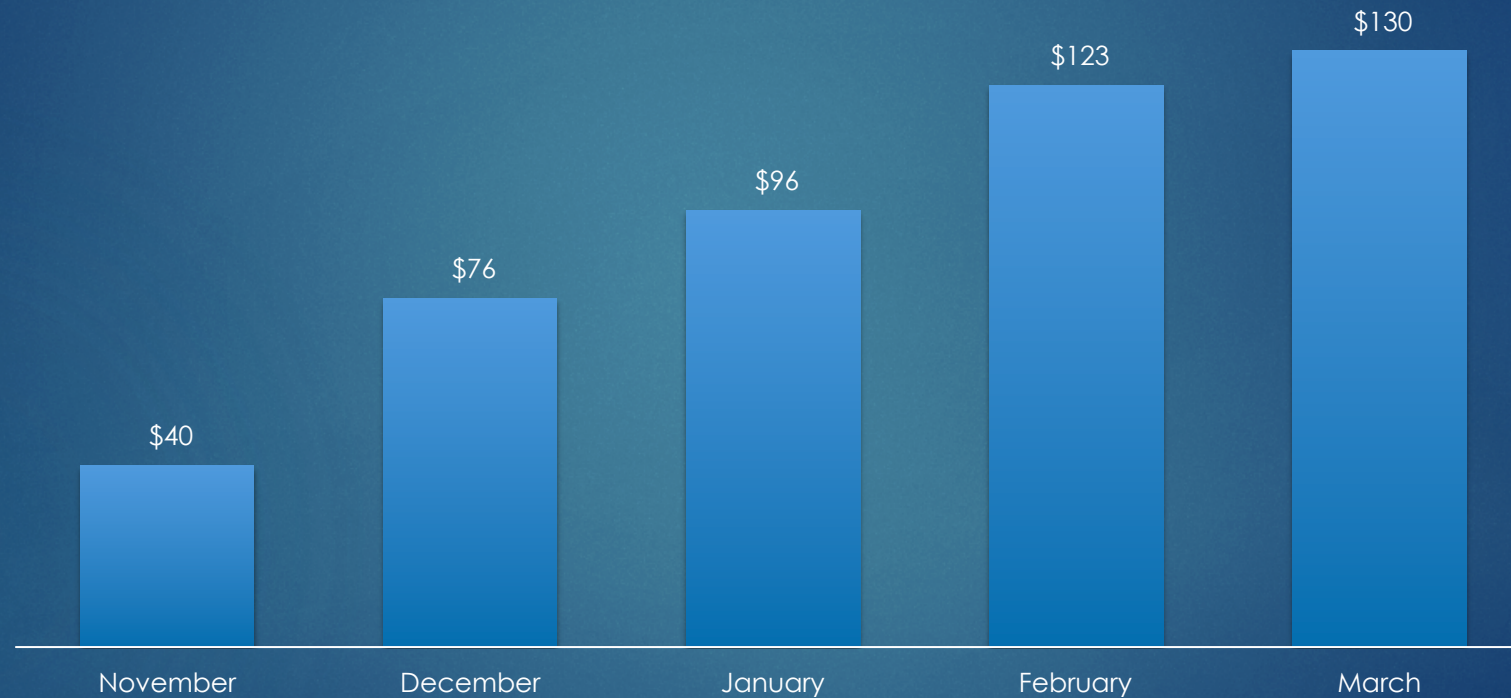
# Utility Use Assessments

## Average Monthly Total Natural Gas Cost, 2013-2014



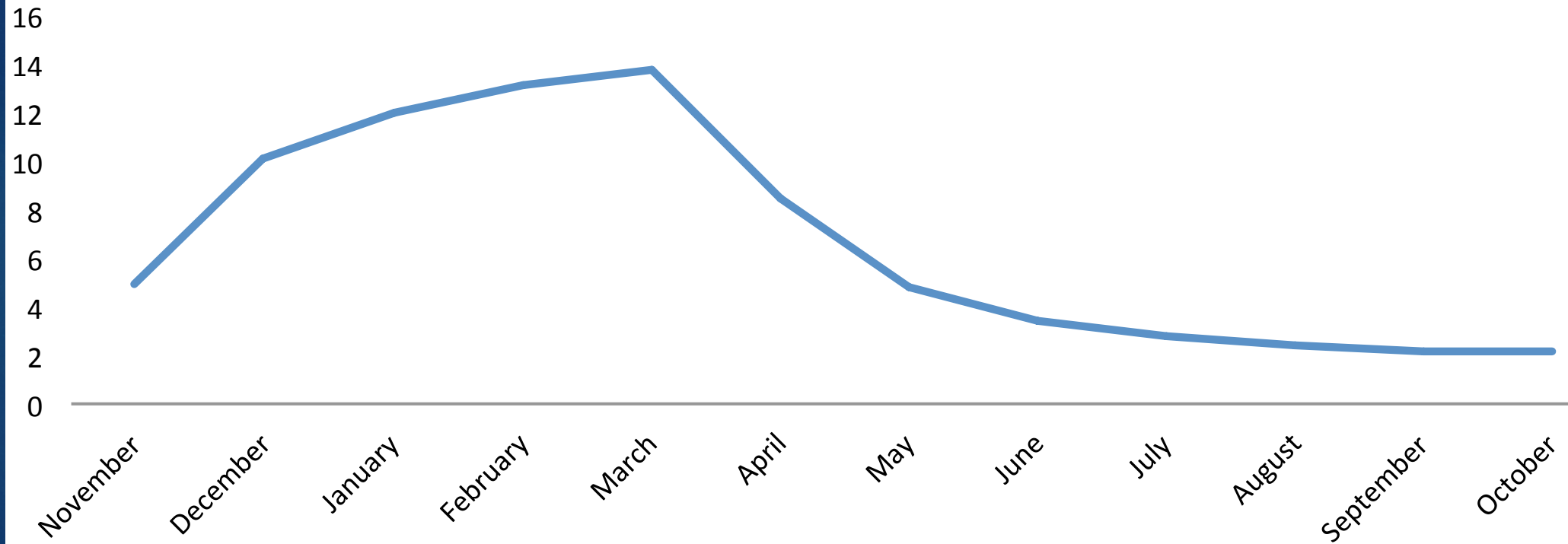
# Utility Use Assessments

## Average Monthly Winter Heat Cost - Rochester



# Utility Use Assessments

**Average Monthly Total Natural Gas Use, 2013-2014  
(MBtus)**



# Is Energy Star 3 Worth the Cost?

**Exhibit 3: ENERGY STAR v3 Certified Home vs 2009 IECC Home, Illustrative Cost & Savings Summary**

#	CZ	Location	Found.	HVAC Equipment Type	2009 IECC	ENERGY STAR Version 3						
					Annual Purchased Energy Costs	Annual Purchased Energy Costs	Annual Purchased Energy Savings	Total Upgrade Cost	Monthly Purchased Energy Savings	Monthly Mortgage Upgrade Cost	Net Cash Flow	
1	1	Miami, FL	Slab	Elec. Air-Source HP	\$1,911	\$1,589	\$322	17%	\$2,187	\$27	\$12	\$15
2	1	Miami, FL	Slab	Gas Furnace / Elec. AC	\$1,749	\$1,428	\$321	18%	\$2,124	\$27	\$11	\$15
3	2	Tampa, FL	Slab	Elec. Air-Source HP	\$1,923	\$1,615	\$308	16%	\$2,187	\$26	\$12	\$14
4	2	Tampa, FL	Slab	Gas Furnace / Elec. AC	\$1,750	\$1,435	\$315	18%	\$2,124	\$26	\$11	\$15
5	3	Fort Worth, TX	Slab	Elec. Air-Source HP	\$2,326	\$1,780	\$546	23%	\$2,421	\$45	\$13	\$32
6	3	Fort Worth, TX	Slab	Gas Furnace / Elec. AC	\$1,998	\$1,622	\$376	19%	\$2,358	\$31	\$13	\$19
7	4	St. Louis, MO	Bsmt.	Elec. Air-Source HP	\$2,868	\$2,294	\$574	20%	\$2,176	\$48	\$12	\$36
8	4	St. Louis, MO	Bsmt.	Gas Furnace / Elec. AC	\$2,129	\$1,762	\$366	17%	\$2,145	\$31	\$12	\$19
9	5	Indianapolis, IN	Bsmt.	Elec. Air-Source HP	\$2,917	\$2,197	\$720	25%	\$2,571	\$60	\$14	\$46
10	5	Indianapolis, IN	Bsmt.	Gas Furnace / Elec. AC	\$2,089	\$1,674	\$415	20%	\$2,350	\$35	\$13	\$22
11	6	Burlington, VT	Bsmt.	Elec. Air-Source HP	\$3,803	\$2,686	\$1,117	29%	\$2,667	\$93	\$14	\$79
12	6	Burlington, VT	Bsmt.	Gas Furnace / Elec. AC	\$2,399	\$1,852	\$547	23%	\$2,350	\$46	\$13	\$33
13	7	Duluth, MN	Bsmt.	Gas Furnace / Elec. AC	\$2,696	\$2,023	\$673	25%	\$2,350	\$56	\$13	\$43



# Special thanks to Molly Berg, Sustainable Building Program Manager at Habitat for Humanity of Minnesota

## Contributions:

Cost analysis, assistance with Energy Rating, filling out the forms, etc.



Molly Berg



In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

“This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials and Residential Contractors** continuing education requirements.”

For additional continuing education approvals, please see your credit tracking card.

# Links:

**OVE:**

<http://www.toolbase.org/Building-Systems/Whole-House-Systems/advance-framing-techniques>

**Building Science:** [http://www.buildingscience.com/index\\_html](http://www.buildingscience.com/index_html)

**Construction Instruction:** <http://www.constructioninstruction.com/>



Time-permitting: Exterior foam board/ new energy code.

# Incorporating Thick Layers of Exterior Rigid Insulation on Walls

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November 2014

# Incorporating Thick Layers of Exterior Rigid Insulation on Walls

“Wall assemblies are one portion of the building that provide a separation between the inside environment and the outside environment. This separation is often referred to as a building enclosure or a building envelope. For wall assemblies, control of rainwater, airflow, water vapor flow, and heat flow are key factors to providing a durable enclosure. The control of these elements can be separated into four principle control layers. They are presented in order of importance:

- ▶ A water control layer
- ▶ An air control layer
- ▶ A vapor control layer
- ▶ A thermal control layer

**The best place for the control layers is to locate them on the outside of the structure in order to protect the structure.”**

# Incorporating Thick Layers of Exterior Rigid Insulation on Walls

- ▶ “There are three principle control approaches to dealing with water in the vapor form. The first is to let the water vapor pass through the assembly from the inside out and from the outside in. This type of wall assembly is called a **“flow-through” assembly** and can dry to both sides.
- ▶ The second is to locate a distinctive vapor control layer to retard the flow of water vapor into the wall assembly from either the inside or from the outside. This type of assembly is called **“vapor control layer” assembly**. The most common location for a vapor control layer is on the inside “warm in winter” side of the thermal insulation.
- ▶ The third is to control the temperature of the surfaces where condensation is likely to occur by raising the surface temperature with insulation. The most common method of achieving this is to use rigid insulation on the exterior of assemblies. This type of assembly is called **“control of condensing surface temperature” assembly**.

When rigid insulation is added to the exterior of the structural sheathing, the interior surface temperature of the structural sheathing is increased since the insulation keeps the sheathing warmer. By raising the temperature of the condensing surface of interest sufficiently, condensation from interior water vapor migrating into the wall assembly does not occur. **This allows assemblies to be constructed in cold climates without interior vapor control layers.** The building codes recognize this and provide guidance on the minimum thermal resistance values of rigid insulation required to control condensation, when Class I and II vapor retarders are replaced with Class III retarders in specific regions.”

“Table 5 is information taken from *Table R601.3.1 Class III Vapor Retarders of the 2009 IRC* and *Table R702.7.1 Class III Vapor Retarders of the 2012 IRC* and provides guidance for thermal resistance values to control condensation for Climate Zones 5, 6, 7, 8 and Marine 4.”

Climate Zone	Framing Rigid Insulation	Minimum R-Value
4C	2x4	2.5
	2x6	3.75
5	2x4	5
	2x6	7.5
6	2x4	7.5
	2x6	11.25
7/8	2x4	10
	2x6	15

**Table 5. Thermal resistance values to control condensation for climate zones 5, 6, 7, 8 and marine 4 from (2009 IRC and 2012 IRC).**



# Checklists



## ENERGY STAR Certified Homes, Version 3 (Rev. 07) Water Management System Builder Checklist<sup>1,2</sup>

Home Address:	City:	State:	Zip Code:				
				Must Correct	Builder Verified	Rater Verified	N/A
<b>I. Water-Managed Site and Foundation</b>							
1.1	Patio slabs, porch slabs, walkways, and driveways sloped $\geq 0.25\%$ per ft. away from home to edge of yardline or 10 ft., whichever is less.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2	Back-sill has been tapered and final grade sloped $\geq 0.5\%$ per ft. away from home to $\geq 10$ ft. See Footnote for alternatives. <sup>1,2</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.3	Capillary break beneath all slabs (e.g., slab-on-grade, basement slab) except crawlspace slabs using either $\geq 6$ mil polyethylene sheathing, lapped 6-12 in., or $\geq 1$ in. extruded polystyrene insulation with taped joints. <sup>1,2,3</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4	Capillary break at all crawlspace forms using $\geq 6$ mil polyethylene sheathing, lapped 6-12 in., & installed using one of the following methods: <sup>1,2,3</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4.1	Placed beneath a concrete slab. OR			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4.2	Lapped up each wall or pier and fastened with facing strips or equivalent. OR			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4.3	Secured to the ground at the perimeter using stakes.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.5	Exterior surface of below-grade walls of basements & unvented crawlspaces finished as follows: a) For poured concrete masonry: & installed concrete form, finish with damp-proofing coating. b) For wood framed walls: finish with polyethylene and adhesive or other equivalent waterproofer.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.6	Class 1 vapor retarder not installed on interior side of air permeable insulation in all below-grade walls. <sup>4</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.7	Sump pump covers mechanically attached with full gasket seal or equivalent.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.8	Drain tile installed at the exterior side of footing of basement and crawlspace walls, with the top of the drain tile above the bottom of the concrete slab or crawlspace floor. Drain tile circumference with $\geq 2$ in. of 1/2 in. washed or clean gravel and with gravel layer fully wrapped with fabric cloth. Drain tile level or sloped to discharge to outside grade (street) or to a sump pump. <sup>5</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>II. Water-Managed Wall Assembly</b>							
2.1	Flashing at bottom of exterior walls with weep holes installed for masonry veneer and weep screed for stucco cladding systems or equivalent drainage system.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2	Fully sealed exterior drainage plane behind exterior cladding that laps over flashing in Item 2.1 and fully sealed at all penetrations. Additional bond-break drainage plane layer permitted behind all stone and non-structural masonry cladding wall assemblies. <sup>6,7</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.3	Windows and door openings fully flashed. <sup>8</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>III. Water-Managed Roof Assembly</b>							
3.1	Sloped exterior roof flashing at all roof-wall intersections, extending 2' in wall surface above roof deck and integrated shingle-style with drainage plane above, but not collar flashing at all roof penetrations. <sup>9</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2	For homes that don't have a slab-on-grade foundation and do have septic or seepage walls, gutters & downspouts provided that empty to below parking that discharges water on downspout grade $\geq 2$ ft. from foundation, or to underground catchment system not connected to the foundation drain system that discharges water $\geq 10$ ft. from foundation. See Footnote for alternatives & exceptions. <sup>10,11</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3	Self-sealing bituminous membranes or equivalent at all valleys & roof deck penetrations. <sup>12</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.4	In R-200+ ICC Climate Zones 5 & 6 higher, self-sealing bituminous membrane or equivalent over sheathing at eaves from the edge of the roof line to $\geq 2$ ft. up roof deck from the exterior edge of the exterior wall. <sup>13</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>IV. Water-Managed Building Materials</b>							
4.1	Water-wall paper not installed within 2.5 ft. of vents, fans, and chimneys.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.2	Cement board or equivalent moisture-resistant backing material installed on all walls behind tub and shower enclosures composed of tile or panel assemblies with caulked joints. Paper-faced backboard shall not be used.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.3	In Warm-Humid climates, Class 1 vapor retarder not installed on the interior side of air permeable insulation at above-grade walls, except at shower and tub walls. <sup>14</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4	Building materials with visible signs of water damage or mold not installed or allowed to remain. <sup>15</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.5	Framing members & insulation products having high moisture content not enclosed (e.g., with drywall). <sup>16</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Builder Signatures							
Builder Signature _____				Date _____			
Builder Signature _____				Date _____			
(Builder has completed Water Checklist in its entirety, except for items that are checked in the Rater Verified column, any?) Rater Signature: _____ Date: _____							

**Notes:**

1. The specifications in this Checklist are designed to help improve moisture control in new homes compared with homes built to minimum code. However, these measures alone cannot prevent all moisture problems. For example, leaks, pipes or overflowing drains or other can lead to moisture issues and negatively impact the performance of this Checklist's specified features.



## ENERGY STAR Certified Homes, Version 3 (Rev. 07) HVAC System Quality Installation Rater Checklist<sup>1</sup>

Home Address:	City:	State:	Zip Code:	Must Correct	Rater Verified	N/A
<b>1. Review of HVAC System Quality Installation Contractor Checklist<sup>1</sup></b>						
1.1 HVAC System Quality Installation Contractor Checklist completed in its entirety and collected for records, along with documentation on ventilation system (1.5), Sulfur Dioxide (2.16), and AHU Load/Leak (3.13).				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2 Review the following parameters related to system coding design, selection, and installation from the HVAC Contractor Checklist (Contractor Checklist Item # indicated in parentheses): <sup>2</sup>						
1.2.1	Outdoor design temperature (2.4) is equal to the PS and SPS ACCA Manual 2 design temperatures for contractor-designated design location. <sup>3</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.2	Home orientation (2.5) matches orientation of rated home.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.3	Number of occupants (2.6) equals number of occupants in rated home. <sup>4</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.4	Conditioned floor area (2.7) is within $\pm 10\%$ of conditioned floor area of rated home.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.5	Whistle area (2.8) is within $\pm 10\%$ of calculated whistle area of rated home.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.6	Predominant window SHGC (2.9) is within 0.1 of predominant value in rated home. <sup>5</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.7	Rated latent cooling capacity (3.6) exceeds design latent heat gain (2.12).			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.8	Rated sensible cooling capacity (3.9) exceeds design sensible heat gain (2.13).			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.9	Rated total cooling capacity (3.10) is 95-115% (or 95-125% for Heat Pumps in Climate Zones 4-6) of design total heat gain (2.14), or next nominal size. <sup>6</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.10	HVAC manufacturer and model numbers on installed equipment: Contractor Checklist (3.1, 3.2, 5.1), and AHU certificate or ODM catalog data all match. <sup>7</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.11	1.2.11 Unit reported liquid line (3.3) or suction line (5.5) pressure corresponding temperature (as determined using pressure/temperature chart) to refrigerant type matches required condense (7.1) or evaporator (7.5) saturation temperature (± 3 degrees). <sup>8</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2.12	Calculated subcooling (7.1 minus 6.4) value is within $\pm 5$ °F of the reported target temperature (7.2) or calculated superheat (6.8 minus 7.5) value is within $\pm 5$ °F of the reported target temperature (7.7). <sup>9</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.3	Rater-verified supply & return duct static pressure $\leq 110\%$ of contractor values (9.3, 9.4).			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4	Contractor prepared balancing report indicating the room name and design airflow for each supply and return register collected by Rater for records. In addition, total individual room airflows measured and documented on balancing report through one of the following actions: 1.4.1 Measured and documented by contractor (10.1.1). OR			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4.2	Measured by Rater using Section 84.2 of the Mortgage Industry National HERS Standard, documented by Rater. & verified by Rater to be within the greater of a 20% or 25 CFM of design airflow (10.1.2).			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.5 HVAC contractor holds credentials necessary to complete the HVAC System QI Contractor Checklist. <sup>10</sup>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>2. Duct Quality Installation - Applies to All Heating, Cooling, Ventilation, Exhaust and Pressure-Balancing Ducts<sup>11</sup></b>						
2.1	Construction and routing of ductwork completed without kinks or sharp bends. <sup>12</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2	No excessive soffit or trapped flexible ductwork. <sup>13</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.3	Flexible ducts in unconditioned space not installed in cavities smaller than soffit duct diameter. In conditioned space not installed in cavities smaller than twice duct diameter.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.4	Flexible ducts supported at intervals as recommended by mfg. but at a distance $\leq 5$ ft.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.5	Selling cavities not used as supply or return ducts unless they meet items 2.2, 2.3, 4.1, and 4.2 of this Checklist.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.6	HVAC ducts, cavities used as ducts, and combustion intake and exhaust may pass perpendicularly through exterior walls but shall not be on within exterior walls unless a 5-0 continuous insulation is provided on exterior side of the cavity, along with an inhibitor and exterior air barrier where required by the Thermal Enclosure System Rater Checklist.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.7	Quantity & location of supply and return duct terminals match contractor balancing report. <sup>14</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.8	Soffit/ceiling pressure-balanced using any combination of transfer grille, louver ducts, dedicated return ducts, and/or unvented doors to either: a) provide 1 sq. ft. of free area during per 1 CFM of supply air, as reported on the contractor provided balancing report; or b) achieve a Rater-measured pressure differential $\leq 3$ Pa with return to the main body of the house when all bedroom doors are closed and all air handlers are operating. <sup>15,16</sup>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3. Duct Installation - Applies to All Heating, Cooling, Supply Ventilation, and Pressure-Balancing Ducts<sup>17</sup></b>						
3.1	All unconditioned to-bulk ducts in unconditioned spaces are insulated.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2	Pressure-Pan: Supply ducts in unconditioned attic have insulation $\geq$ R-6. Perimeter Pan: Supply ducts in unconditioned attic have insulation $\geq$ R-6.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3	All other supply ducts and all return ducts in unconditioned spaces have insulation $\geq$ R-6.			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# Checklists



## ENERGY STAR Certified Homes, Version 3 (Rev. 07) HVAC System Quality Installation Contractor Checklist<sup>1</sup>

Home Address:	City:	State:	Zip Code:
System Description: Cooling system for temporary installation? <input type="checkbox"/> Yes <input type="checkbox"/> No			
<b>1. Whole-Building Mechanical Ventilation Design<sup>1</sup></b>			
1.1 Ventilation system installed that has been designed to meet ASHRAE 62.2-2010 requirements including, but not limited to, requirements in Items 1.2-1.5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2 Ventilation system does not utilize an intake duct to the return side of the HVAC system unless the system is designed to operate intermittently and automatically based on a timer and to restrict outdoor air intake when not in use (e.g., reduced demand)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.3 Distribution is attached with ventilation system type, location, design rate and frequency and duration of each ventilation cycle	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4 If present, continuously-operating vent. & exhaust fans designed to operate during all occupiable hours	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.5 If present, intermittently-operating whole-house ventilation system designed to automatically operate at least once per day and at least 10% of every 24 hours	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>2. Heating &amp; Cooling System Design<sup>2,3</sup></b> <small>Performance used in the design calculations should reflect needs to fulfill, specifically, ENERGY STAR requirements. Some provisions, including loadings, operational flexibility, moisture and, disconnection, extreme performance and equivalent length restrictions may, in addition to the minimum, also require a minimum of 100% or better than, and other performance restrictions, apply for heating, cooling or cooling.</small>			
2.1 Heat Loss / Gain Method: <input type="checkbox"/> Manual J v5 <input type="checkbox"/> 2005 ASHRAE <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2 Load Design Method: <input type="checkbox"/> Manual S <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.3 Equipment Selection Method: <input type="checkbox"/> Manual S <input type="checkbox"/> DOE Rec. <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.4 Outdoor Design Temperature: <sup>4</sup> Location: _____ TM _____ °F _____ °C _____ °F	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.5 Orientation of Ruled Home (e.g., North, South)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.6 Number of Occupants Served by System: <sup>5</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.7 Conditioned Floor Area in Ruled Home: <sup>6</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.8 Window Area in Ruled Home: <sup>7</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.9 Residential Window SHGC in Ruled Home: <sup>8</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.10 Infiltration Rate in Ruled Home: <sup>9</sup> Summer: _____ Winter: _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.11 Mechanical Ventilation Rate in Ruled Home: <sup>10</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.12 Design Latent Heat Gain: <sup>11</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.13 Design Sensible Heat Gain: <sup>11</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.14 Design Total Heat Gain: <sup>11</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.15 Design Total Heat Loss: <sup>11</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.16 Outdoor Airflow: <sup>12</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.17 Design Duct Static Pressure: <sup>13</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.18 Full Load Calculations Report Attached: <sup>14</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3. Selected Cooling Equipment, If Cooling Equipment to be Installed</b>			
3.1 Condenser Manufacturer & Model:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2 Evaporator / Fan Coil Manufacturer & Model:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3 AHR: Efficiency: <sup>15</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.4 Unit Efficiency: SEER _____ GSEER _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.5 Minimum Service Type: <input type="checkbox"/> TRV <input type="checkbox"/> Fixed orifice <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.6 Refrigerant Type: <input type="checkbox"/> R-410a <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.7 Fan Speed Type: <sup>16</sup> <input type="checkbox"/> Fixed <input type="checkbox"/> Variable (VCM / VCM) <input type="checkbox"/> Other:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.8 Listed Sys. Latent Capacity at Design Cond. <sup>17</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.9 Listed Sys. Sensible Capacity at Design Cond. <sup>17</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.10 Listed Sys. Total Capacity at Design Cond. <sup>17</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.11 If Listed Sys. Latent Capacity (Value 3.8) < Design Latent Heat Gain (Value 2.12), ENERGY STAR certified equipment is installed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.12 Listed Sys. Total Capacity (Value 3.10) is 95-115% of Design Total Heat Gain (Value 2.14) or per nominal size: <sup>18</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.13 AHR: Certified Attached: <sup>19</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>4. Selected Heat Pump Equipment, If Heat Pump to be Installed</b>			
4.1 AHR: Listed Efficiency: _____ HSPF in Ground-Source _____ COP	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.2 Performance at 17°F: Capacity _____ BTU/h Efficiency _____ COP <sup>20</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.3 Performance at 47°F: Capacity _____ BTU/h Efficiency _____ COP <sup>20</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



## ENERGY STAR Certified Homes, Version 3 (Rev. 07) Thermal Enclosure System Rater Checklist

Home Address:	City:	State:	Zip Code:	Must be Correct	Should be Verified	Must be Verified	N/A
<b>1. High-Performance Penetration</b>							
1.1 Penetration Path: Penetration shall meet or exceed ENERGY STAR requirements <sup>1</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2 Penetration Path: Penetration shall meet or exceed 2005 IECC requirements <sup>2</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>2. Quality-Installed Insulation</b>							
2.1 Ceiling, wall, floor, and slab insulation levels shall comply with one of the following options:							
2.1.1 Meet or exceed 2005 IECC levels. <sup>3,4,5</sup> OR:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.1.2 Achieve ≥ 10% of the total UA resulting from the U-factors in 2005 IECC Table 402.1.3, including penetration and per guidance in Footnote 24. AND home shall achieve a 0% of the infiltration rate in Exhibit 1 of the National Program Requirements. <sup>6</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2 All ceiling, wall, floor, and slab insulation shall achieve RESNET-defined Grade 1 installation or, alternatively, Grade 1 or surfaces that contain a layer of continuous, air-impermeable insulation ≥ R-3 in Climate Zones 1 to 4, ≥ R-5 in Climate Zones 5 to 8.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3. Fully-Aligned Air Barriers<sup>7</sup></b>							
At each installed location noted below, a complete air barrier shall be provided that is fully aligned with the insulation as follows:							
• All interior or exterior surface of ceilings in Climate Zones 1-3, all interior surface of ceilings in Climate Zones 4-8. Also, include barrier at interior edge of attic eave in all climate zones using a solid baffle that extends to the full height of the insulation; include a baffle in every bay or sub-bay to be in every bay with a wall and that will also prevent lateral washing of insulation in adjacent bays							
• All exterior surface of walls in all climate zones, and also at exterior surface of walls for Climate Zones 4-8							
• All exterior surface of floors in all climate zones, including steps to ensure permanent contact and backing at exposed edge <sup>8</sup>							
<b>3.1 Walls<sup>9</sup></b>							
3.1.1 Walls behind showers and tubs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.2 Walls behind fireplaces	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.3 Attic knee walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.4 Drywall sheath walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.5 Wall adjoining porch roof	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.6 Garage walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.7 Drywall walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.8 Garage rim / base joint adjoining conditioned space	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.9 All other exterior walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3.2 Floors</b>							
3.2.1 Floor above garage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2.2 Conditioned floor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2.3 Floor above unconditioned basement or unconditioned crawlspace	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3.3 Ceilings<sup>10</sup></b>							
3.3.1 Capped ceiling / wall below unconditioned attic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3.2 All other ceilings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>4. Reduced Thermal Bridging</b>							
4.1 For insulated ceilings with attic space above (i.e., non-cathedralized), Grade 1 insulation extends to the inside face of the exterior wall below all base levels. G2: R-5 ≥ R-21, G2: R-6 ≥ R-10 <sup>11</sup>							
4.2 The studs in gable in G2 are higher, 100% of slab edge insulated to R-6 at the sheath specified by the 2005 IECC and aligned with thermal boundary of the wall <sup>12</sup>							
4.3 Insulation beneath attic platforms (e.g., HVAC platforms, walkways) ≥ R-21 in G2: R-6 ≥ R-10 in G2: R-6							
4.4 Reduced thermal bridging at above-grade walls separating conditioned from unconditioned space (rim / base joints exempted) using one of the following options: <sup>13</sup>							
4.4.1 Continuous rigid insulation, insulated siding, or combination of the two: ≥ R-3 in Climate Zones 1 to 4, ≥ R-5 in Climate Zones 5 to 8 <sup>14,15,16</sup> OR:							
4.4.2 Structural Insulated Panels (SIPs) <sup>17</sup> OR:							
4.4.3 Insulated Concrete Forms (ICFs) <sup>18</sup> OR:							
4.4.4 Double-wall framing <sup>19</sup> OR:							
4.4.5 Advanced framing, including all of the items below:							
4.4.5a All corners insulated ≥ R-6 to exterior <sup>20</sup> AND:							
4.4.5b All headers above windows & doors insulated ≥ R-3 for 2x4 framing or equivalent cavity width, and ≥ R-2 for all other assemblies (e.g., with 2x6 framing) <sup>21</sup> AND:							
4.4.5c Framing located at all openings & doors to one side of stud studs, stud size per of stud studs per window opening to support top header and sill <sup>22</sup> AND:							
4.4.5d All interior exterior wall intersections insulated to the same R-value as the rest of the exterior wall <sup>23</sup> AND:							
4.4.5e Minimum stud spacing of 16 in. o.c. for 2x4 framing in all Climate Zones and, in Climate Zones 5 through 8, 24 in. o.c. for 2x6 framing <sup>24</sup>							