Low-cost Construction for High-energy Savings

Rochester Area Habitat for Humanity®

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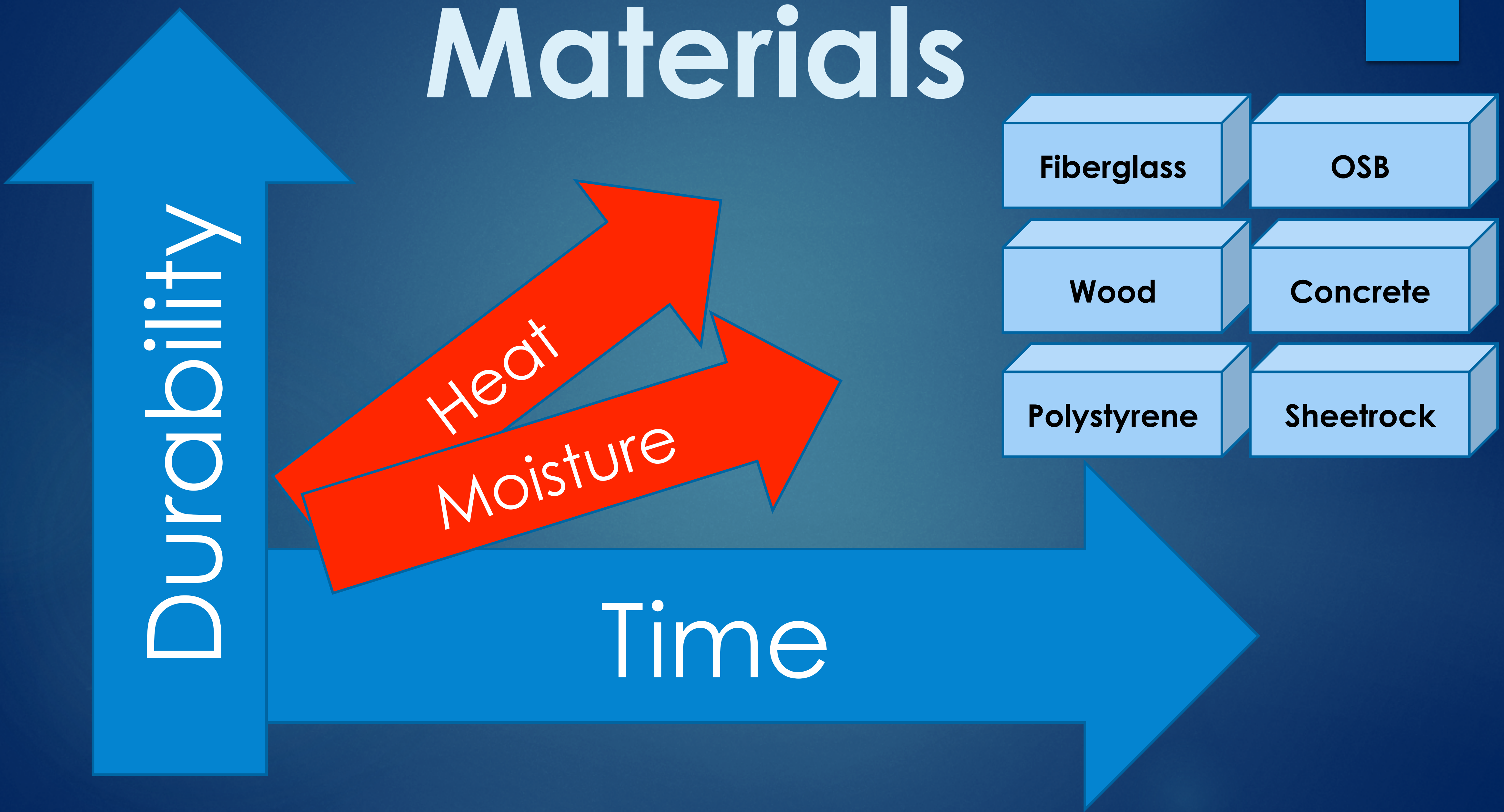
Objectives:

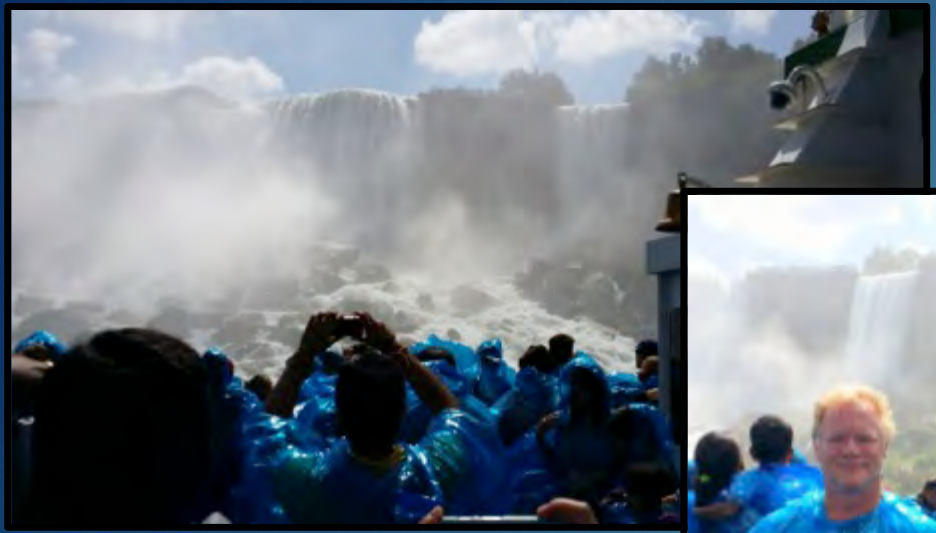
1. Control air & moisture in high-performance, low-cost construction
2. Basics at design stage of house
3. Material options (insulation, windows, mechanicals, etc.) for high-performing homes
4. Improve basics & modified techniques before high-tech solutions
5. ENERGY STAR for Homes process & checklists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

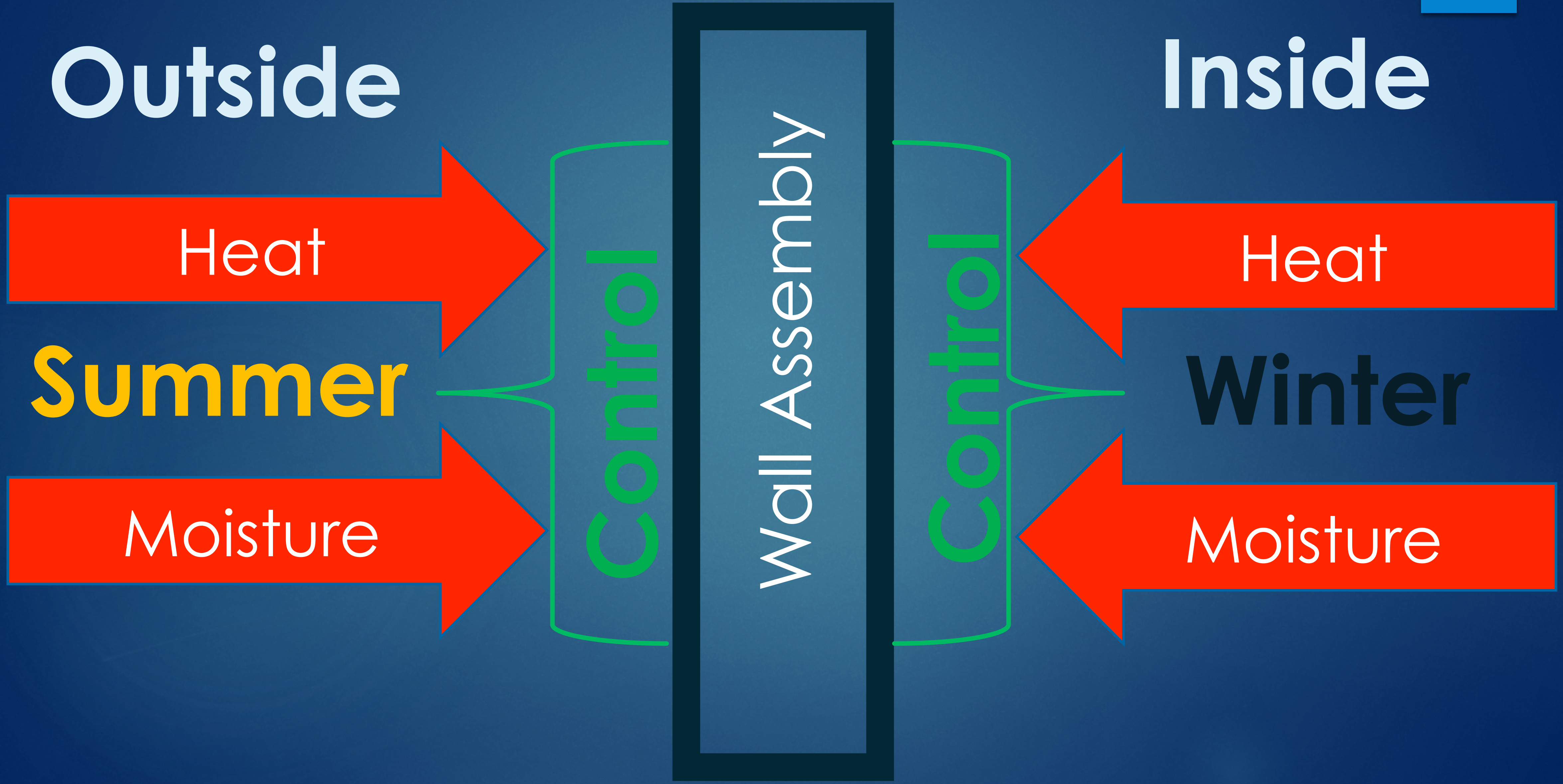
Are we building ships?

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

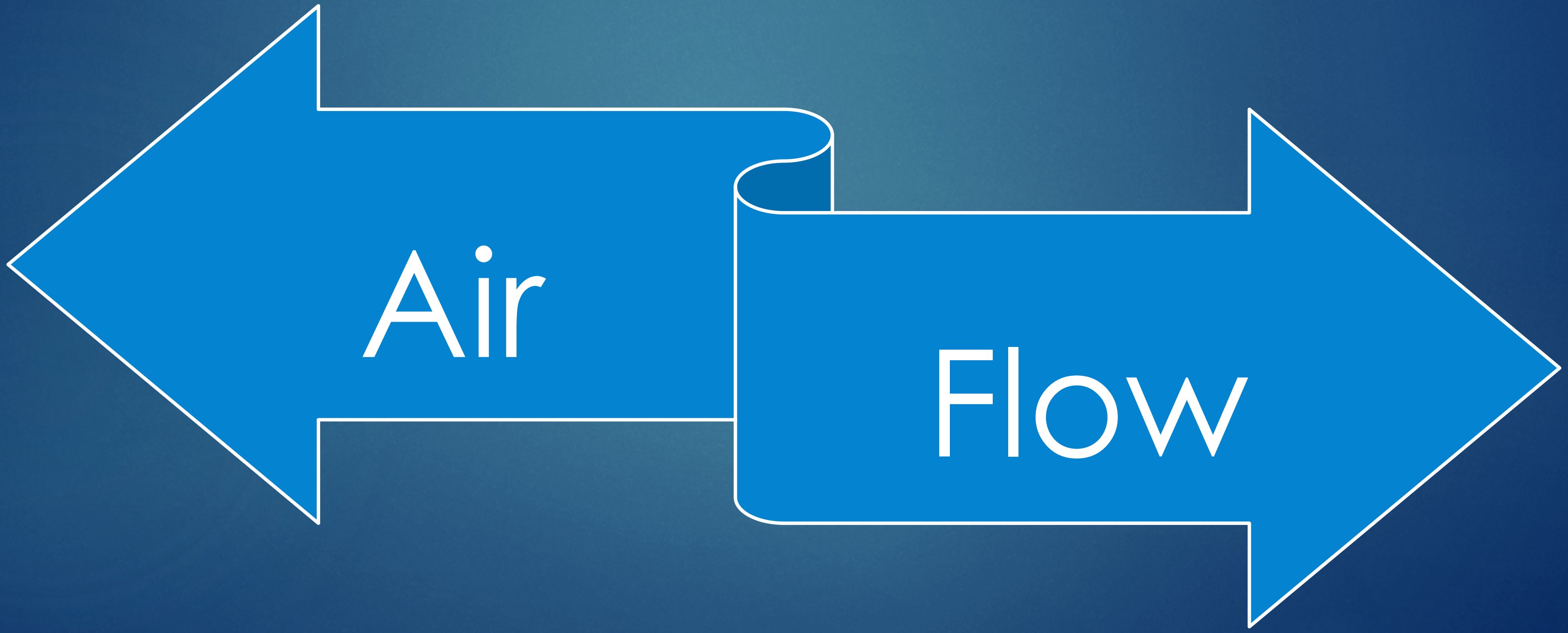
Control air & moisture in high-performance, low-cost construction

- **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

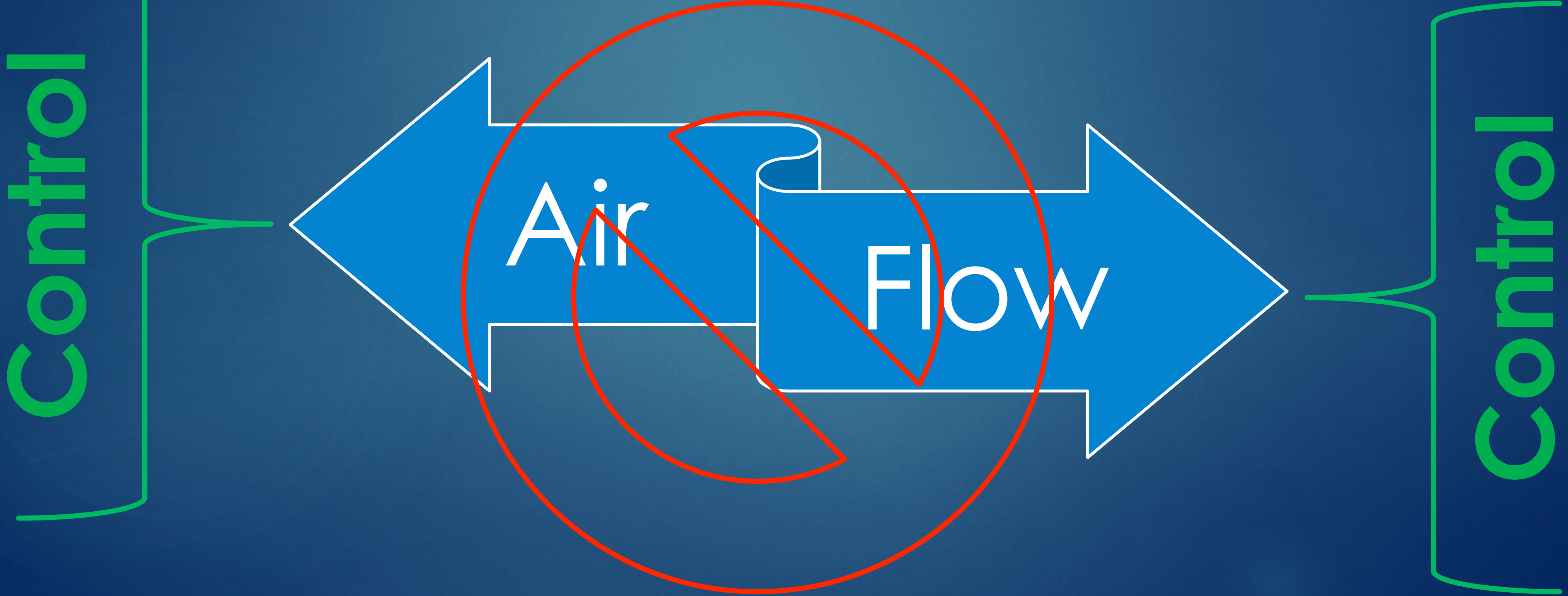
Control in the wall assembly



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



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



From 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

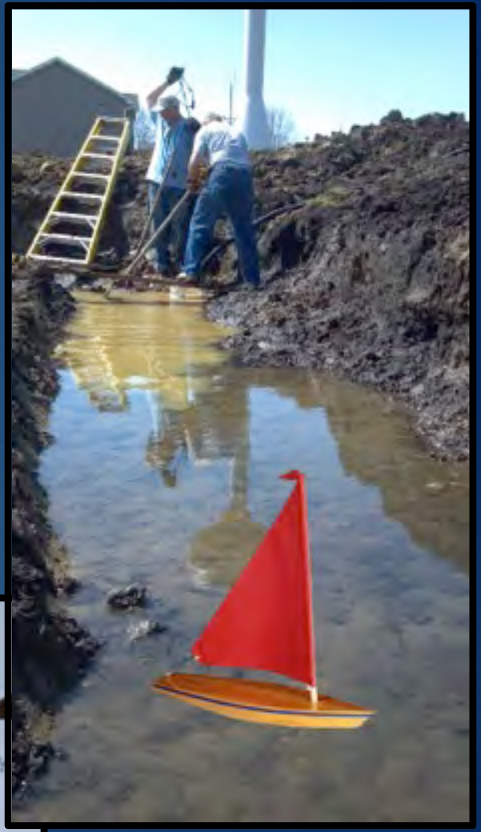
Foundation to wood connections

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

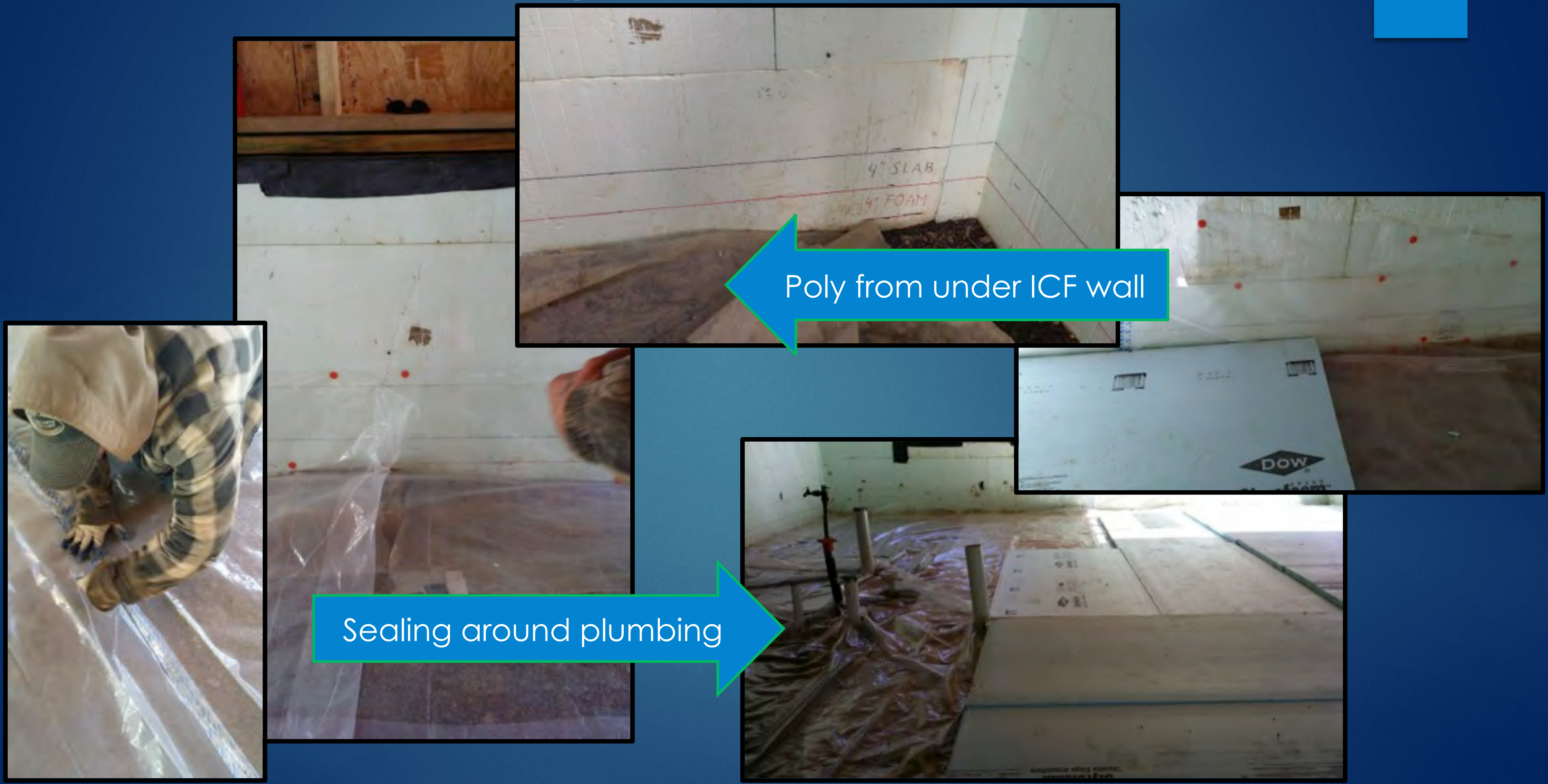
Follow up after sheetrock installation, attic & walls, etc.

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

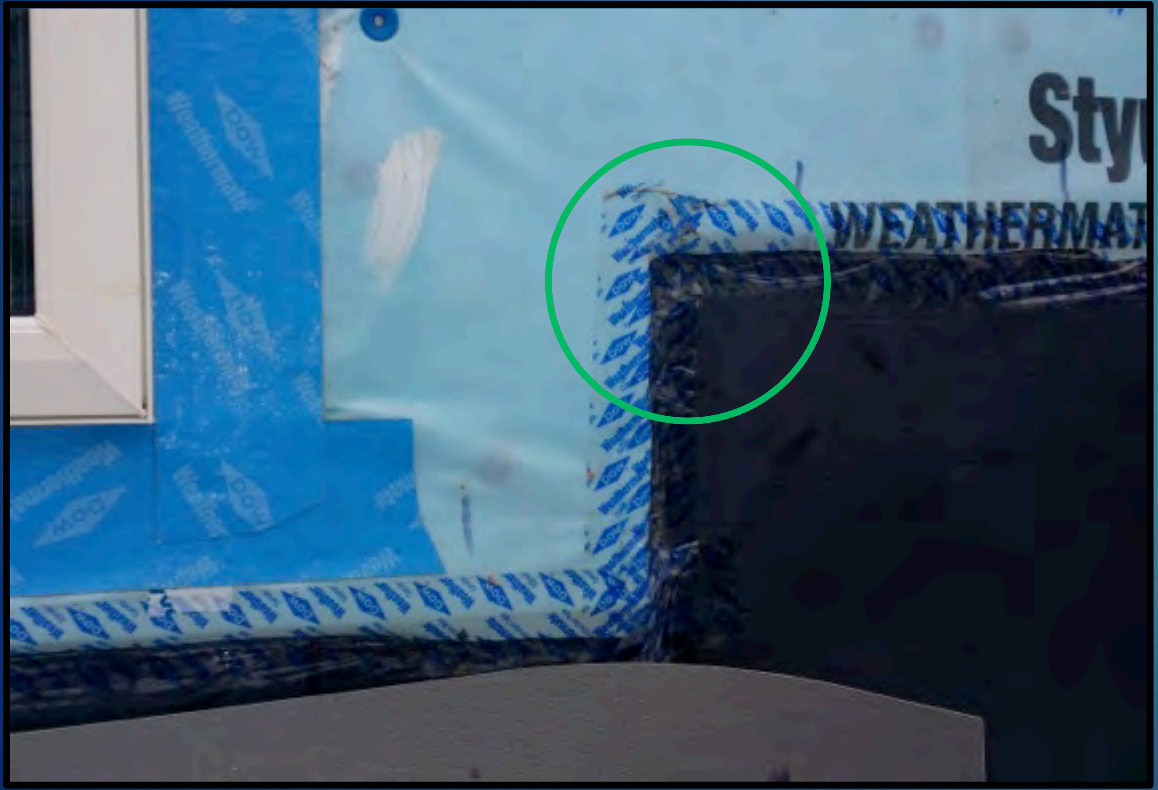


Connection between foundation wall & framing

Framing

Framing & Framing to Foundation

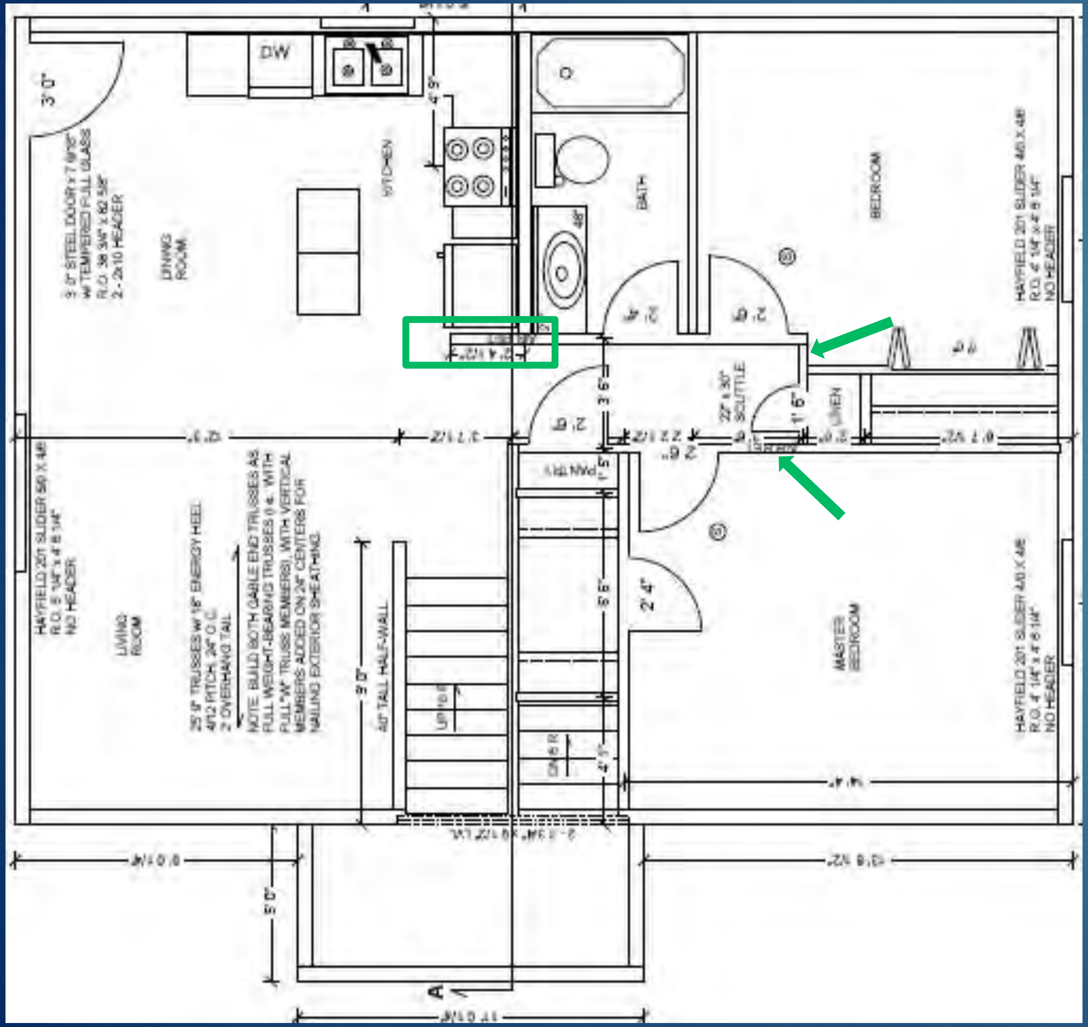
Connection between foundation wall & framing

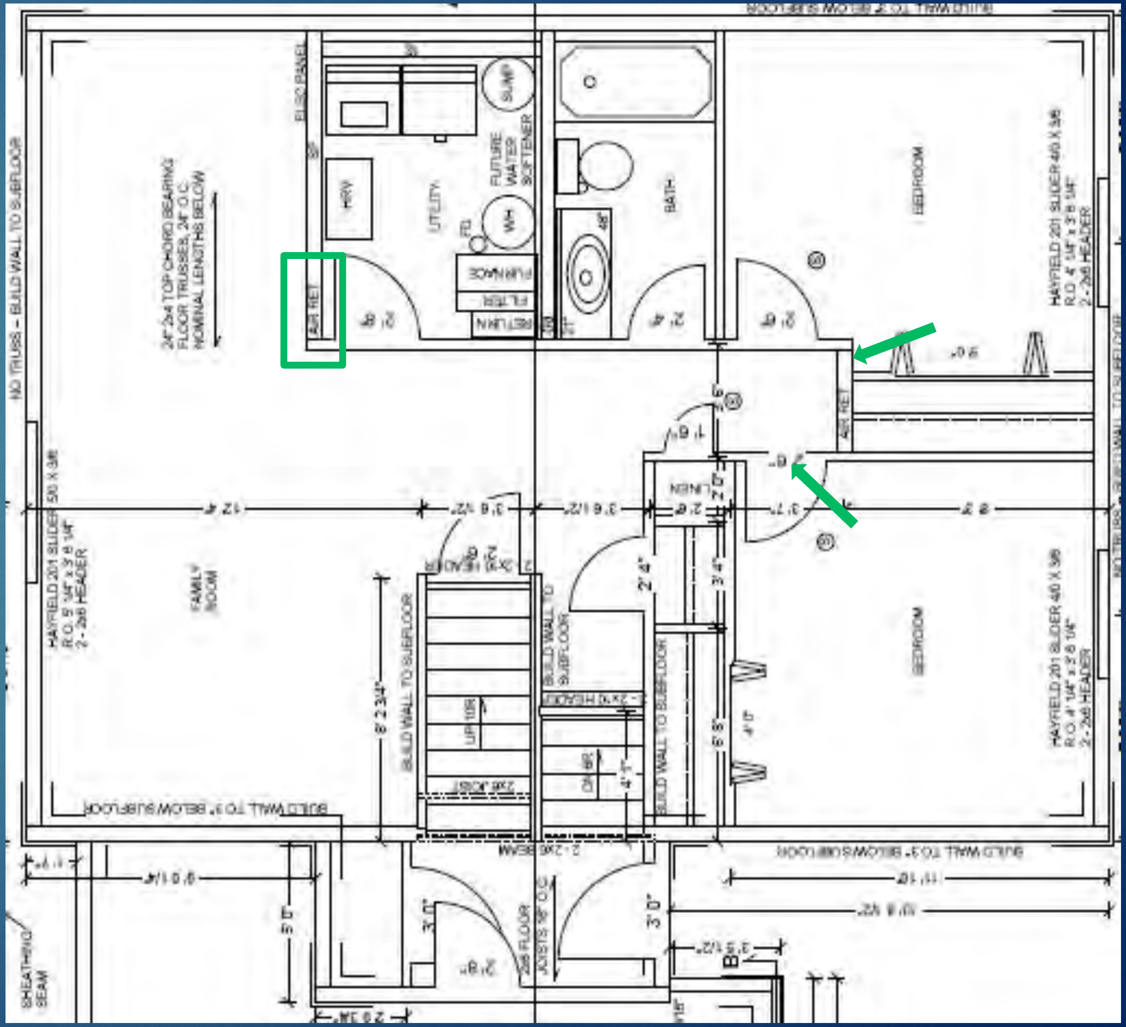


Basics at design stage of house

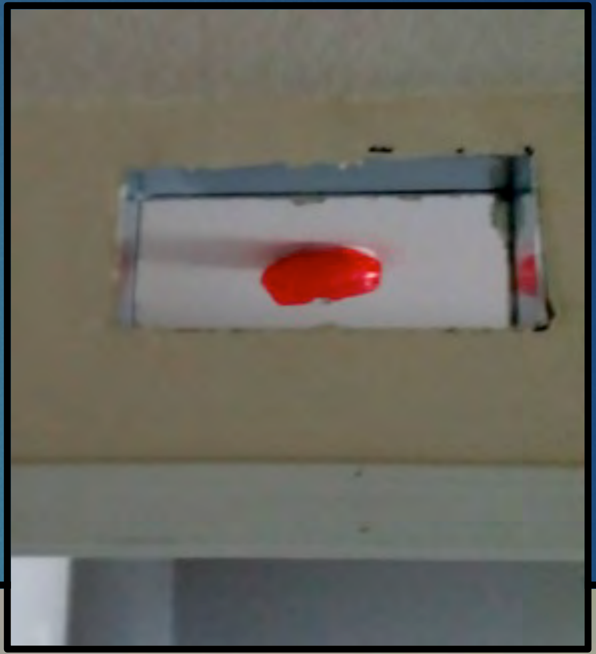
- Planning for minimal ductwork
  - Keeping ducts inside the thermal envelope
  - Pass-through instead of ducted returns when possible to minimize ducts
- Simplified design of home
- OVE framing
  - Line up floor trusses, wall studs, roof trusses (24: o.c.)
  - Reduce thermal transfer

Central Returns w/pass throughs





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[a]

CLIMATE ZONE	FENESTRATION U-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] 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[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13 + 5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20 + 5 or 13 + 10[h]	19/21	38[g]	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
  - NO un-ducted cavity returns
  - Seal ALL seams
  - Seal cabinet
  - Seal boots to subfloor/wall/ceiling
  - Credentialed through ACCA OR Advanced Energy

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

! **Opportunities for Quality Improvement**

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

Figure 1.3

Figure 1.4

Site Visit

Voids/gaps/compressions in fiberglass

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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

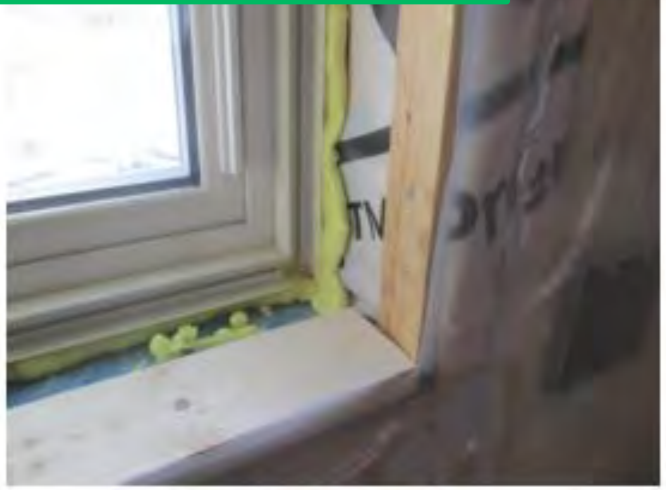


Figure 5.6

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 SF / 100 = 18.808

18.808 x 8 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

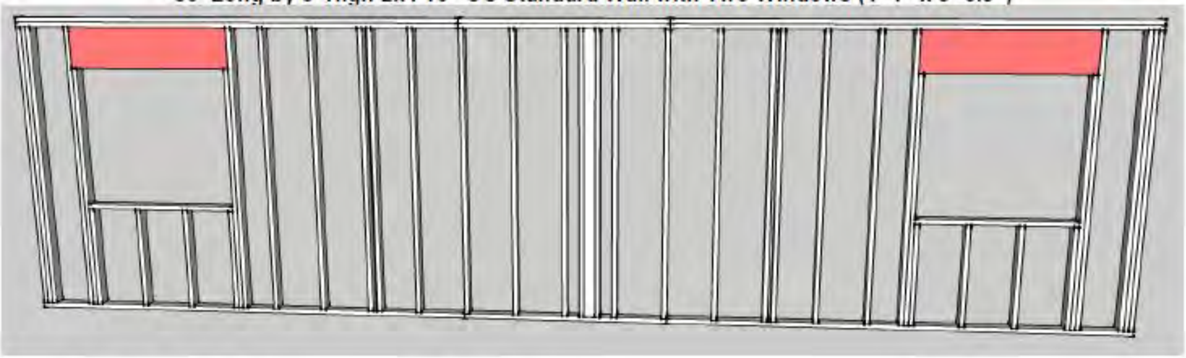
- Blower door: ≤ 4 ACH50
  - Air changers/hour @ induced pressure of -50 Pascals
  - Meant to simulate a "stiff wind" perhaps 15 -20 mph
- Ducts – total: ≤ 8 CFM / 100 SF finished
  - Total of all ductwork
- Ducts – outside: ≤ 4 CFM / 100 SF finished
  - Total leakage in ductwork in unconditioned space
- 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%.

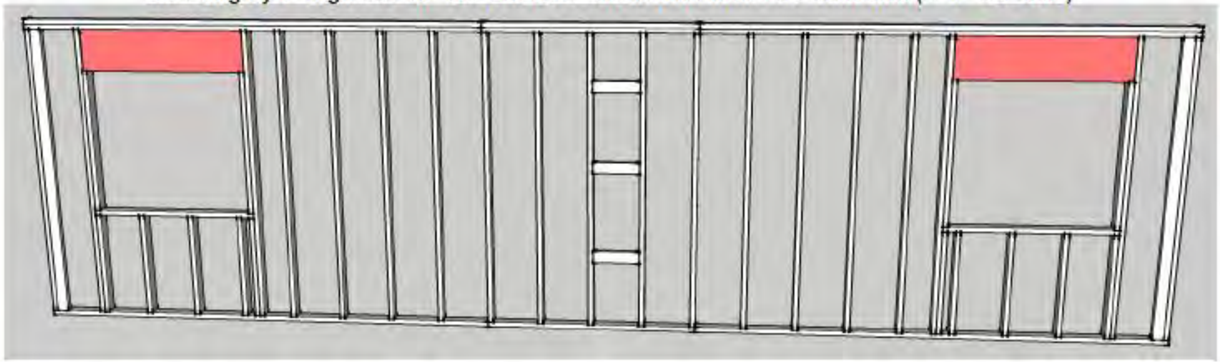
30' Long by 8' High 2x4 16" OC Standard Wall with Two Windows (4'-1" x 3'-8.5")



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
Total Wood Area		= 54.6 sqft
Total Wall Area		= 240 sqft
Framing Fraction	= 54.6 / 240	= 23%

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
Total Wood Area		= 44.1 sqft
Total Wall Area		= 240 sqft
Framing Fraction	= 44.1 / 240	= 18%

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

Home Innovation RESEARCH LABS TOOLBASE.ORG

"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 >

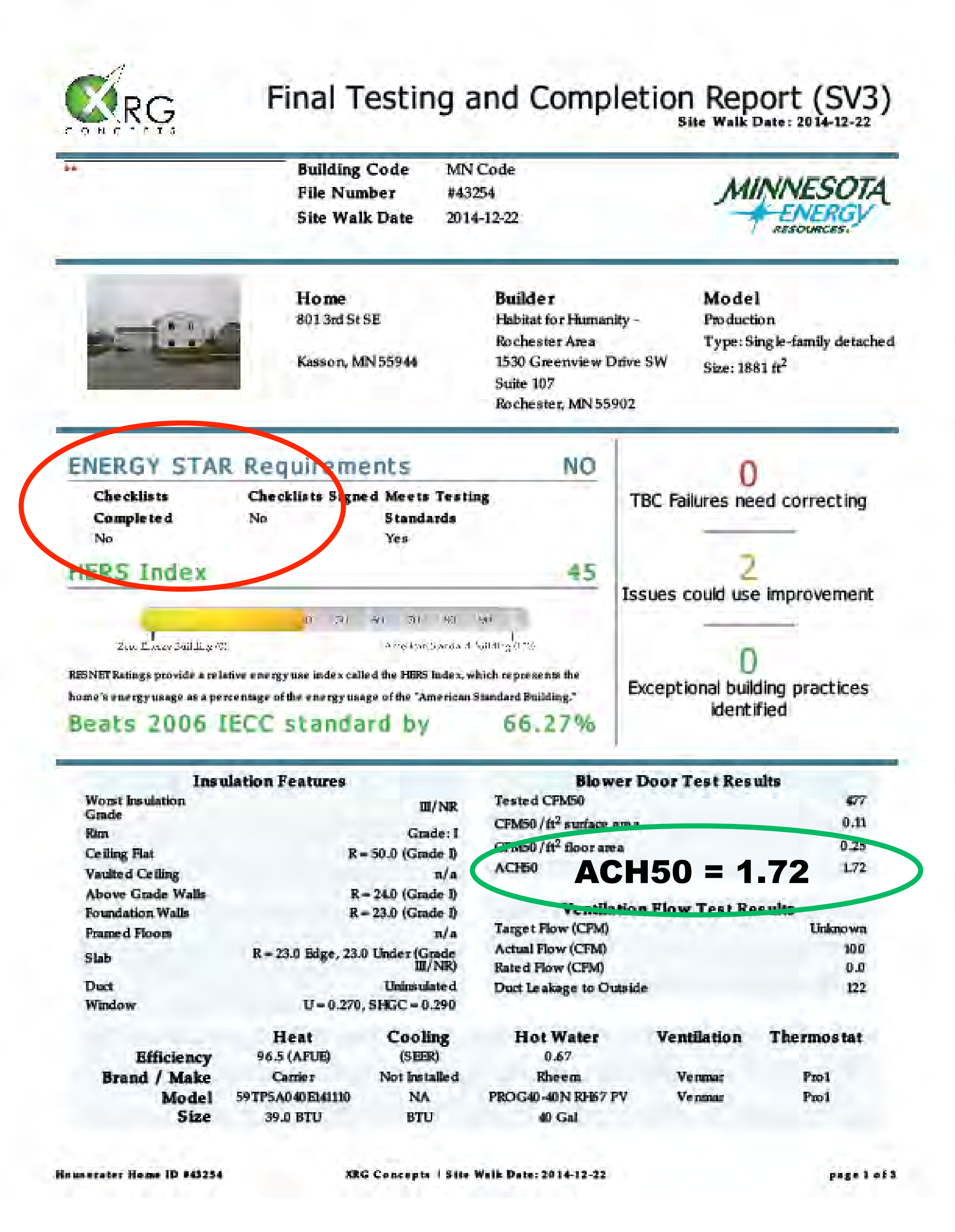
Framer-backs

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

MINNESOTA ENERGY RESOURCES

Home	Builder	Model
801 3rd St SE Kasson, MN 55944	Habitat for Humanity - Rochester Area 1530 Greenview Drive SW Suite 107 Rochester, MN 55902	Production Type: Single-family detached Size: 1881 ft^2

ENERGY STAR Requirements NO

Checklists Completed	Checklists Signed	Meets Testing Standards
No	No	Yes

HERS Index 45

Zero Energy Building (0) — American Standard Building (100)

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%

0 TBC Failures need correcting

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 Floors	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^2 surface area	0.11
CFM50 / ft^2 floor area	0.25
ACH50	1.72

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

	Heat	Cooling	Hot Water	Ventilation	Thermostat
Efficiency	96.5 (AFUE)	(SEER)	0.67		
Brand / Make	Carrier	Not Installed	Rheem	Venmar	Pro1
Model	59TP5A040E141110	NA	PROG40-40N RH67 PV	Venmar	Pro1
Size	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

MINNESOTA ENERGY RESOURCES

Home	Builder	Model
2011 Petersen Dr NW Stewartville, MN 55976	Habitat for Humanity - Rochester Area 1530 Greenview Drive SW Suite 107 Rochester, MN 55902	Custom Type: Single-family detached Size: 1758 ft^2

Meets ENERGYSTAR Requirements YES

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

HERS Index 57

Zero Energy Building (0) — American Standard Building (100)

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%

0 TBC Failures need correcting

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 Floors	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^2 surface area	0.20
CFM50 / ft^2 floor area	0.42
ACH50	3.03

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

	Heat	Cooling	Hot Water	Ventilation	Thermostat
Efficiency	95.0 (AFUE)	13.0 (SEER)			
Brand / Make	Trane	Trane	AO Smith	RenewAire	Honeywell
Model	TUH1B060A9361AA	4TTB3018D1000AA	GPVH 40 100	RenewAire	Honeywell
Size	57.0 BTU	18.0 BTU	40 Gal		
Serial Number	11234KNN7G		1114A025442		

Fuel Summary for Kasson House

Fuel Summary

Property
801 3rd St SE
Kasson, MN 55944

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

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

Builder
Habitat for Humanity - Roch

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

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
Total	1173

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

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
Total Winter Peak	0.5
Total Summer Peak	1.2

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.

Utility use in RAHH Homes

Prepared by Habitat for Humanity of Minnesota

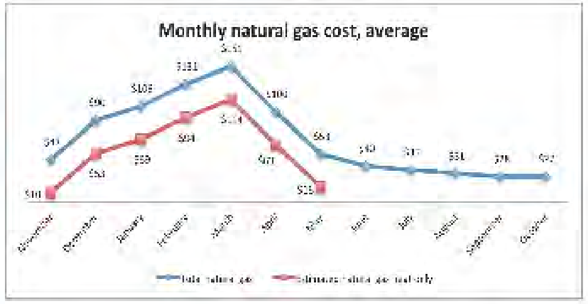
February 2, 2015

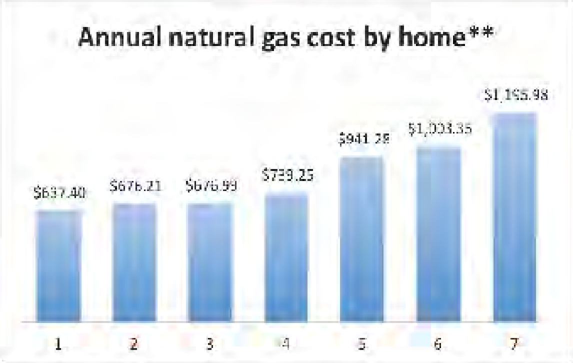
Utility Data Report

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





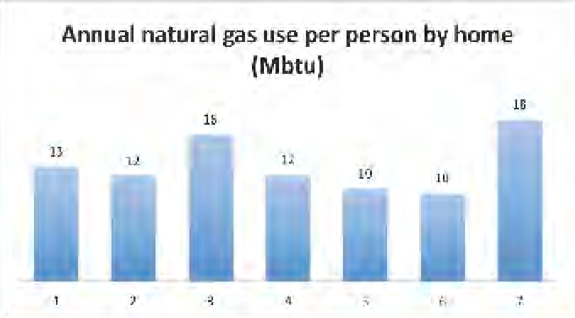
How to use this report

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.

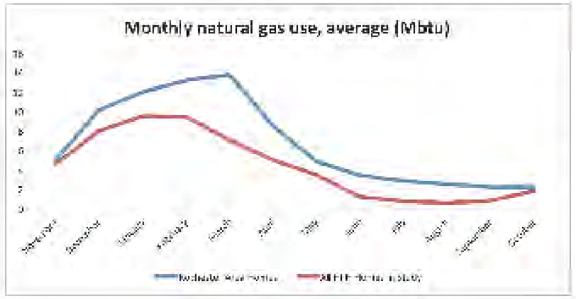
Digging deeper.... While all homes in your sample set are similar in size and climate location, further analysis can be done upon request to account for square footage or regional temperature differences.
For more information, contact Molly Berg, Sustainable Building Program Manager, Habitat for Humanity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



*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

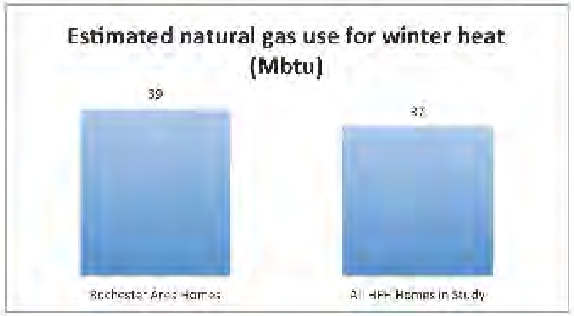


Utility use comparison

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

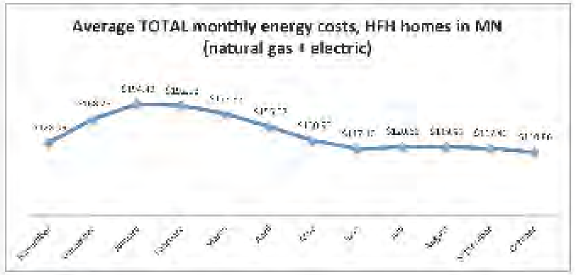


Results

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.

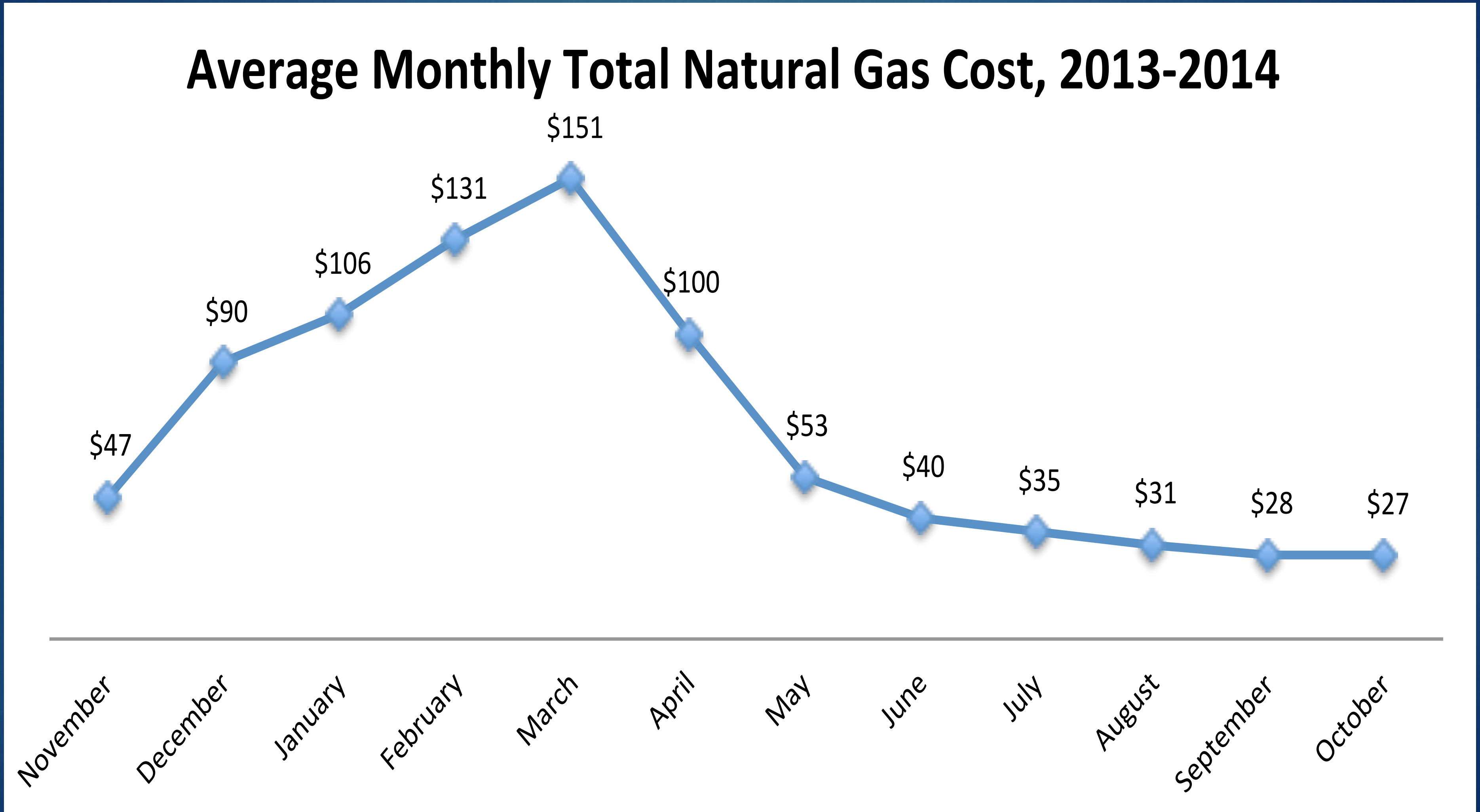
Most Rochester Area homes are supplied by Rochester Public Utilities, which charges a data fee not supported by this study. The final graph on the left represents the average TOTAL (electric & gas) monthly energy costs of HFH homes in Minnesota.



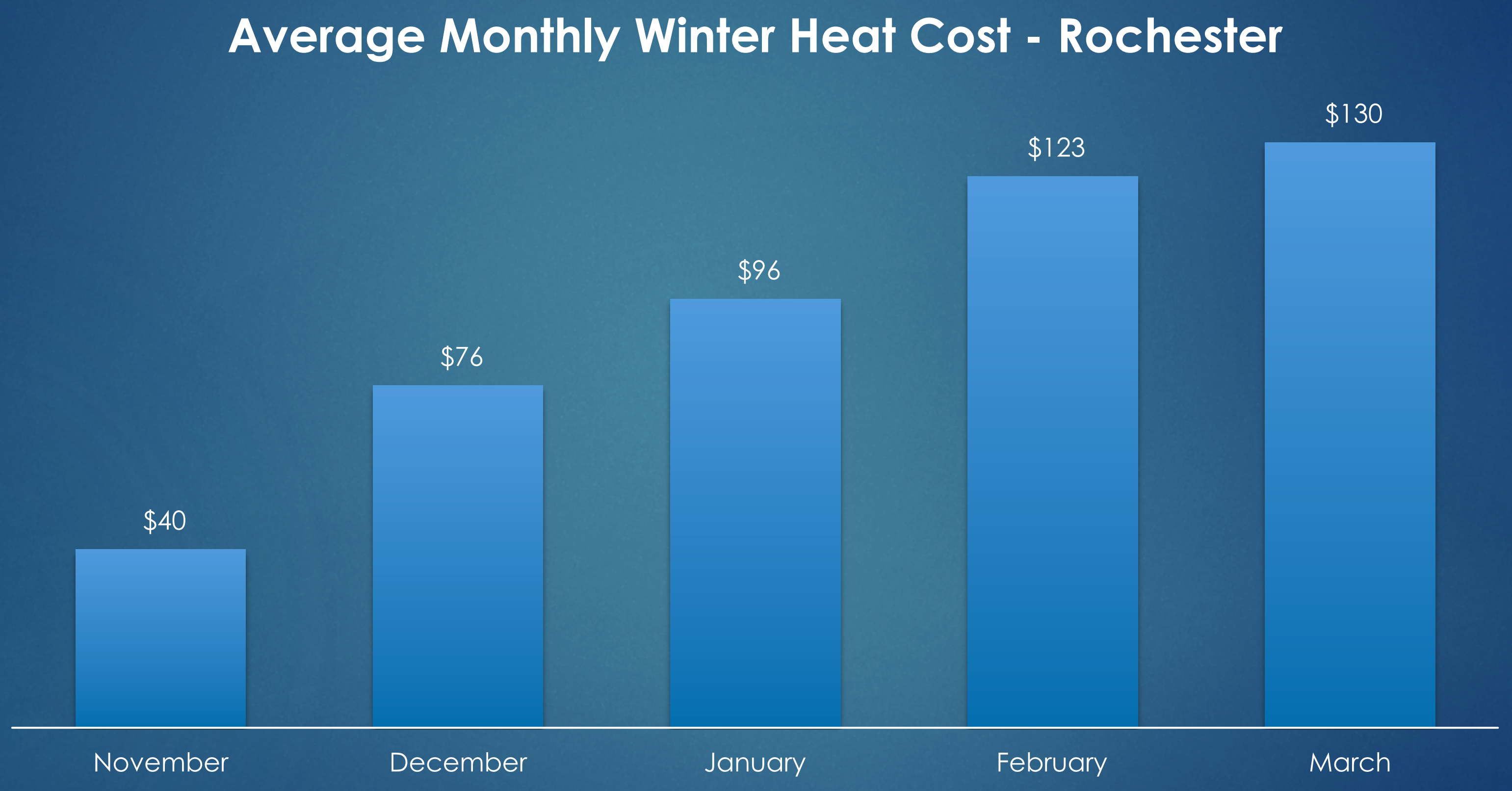
Methodology

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@hfhmn.org.

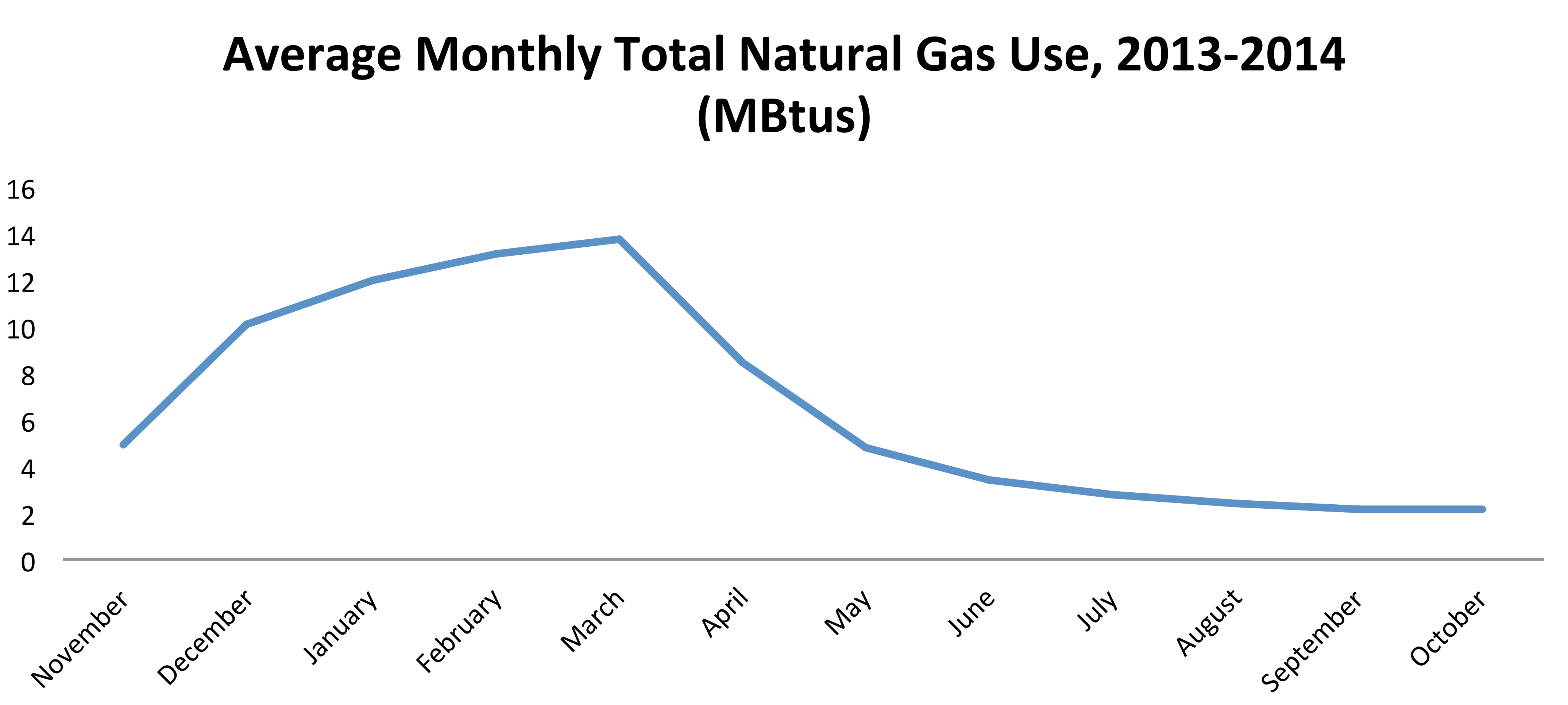
Utility Use Assessments



Utility Use Assessments



Utility Use Assessments



Is Energy Star 3 Worth the Cost?

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

					2009 IECC	ENERGY STAR Version 3						
#	CZ	Location	Found.	HVAC Equipment Type	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 Furance / 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 Furance / 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 Furance / 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 Furance / 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 Furance / 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 Furance / Elec. AC	$2,399	$1,852	$547	23%	$2,350	$46	$13	$33
13	7	Duluth, MN	Bsmt.	Gas Furance / 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

Construction Instruction: http://www.constructioninstruction.com/

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

Incorporating Thick Layers of Exterior Rigid Insulation on Walls

J. Lstiburek, P. Baker

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.**

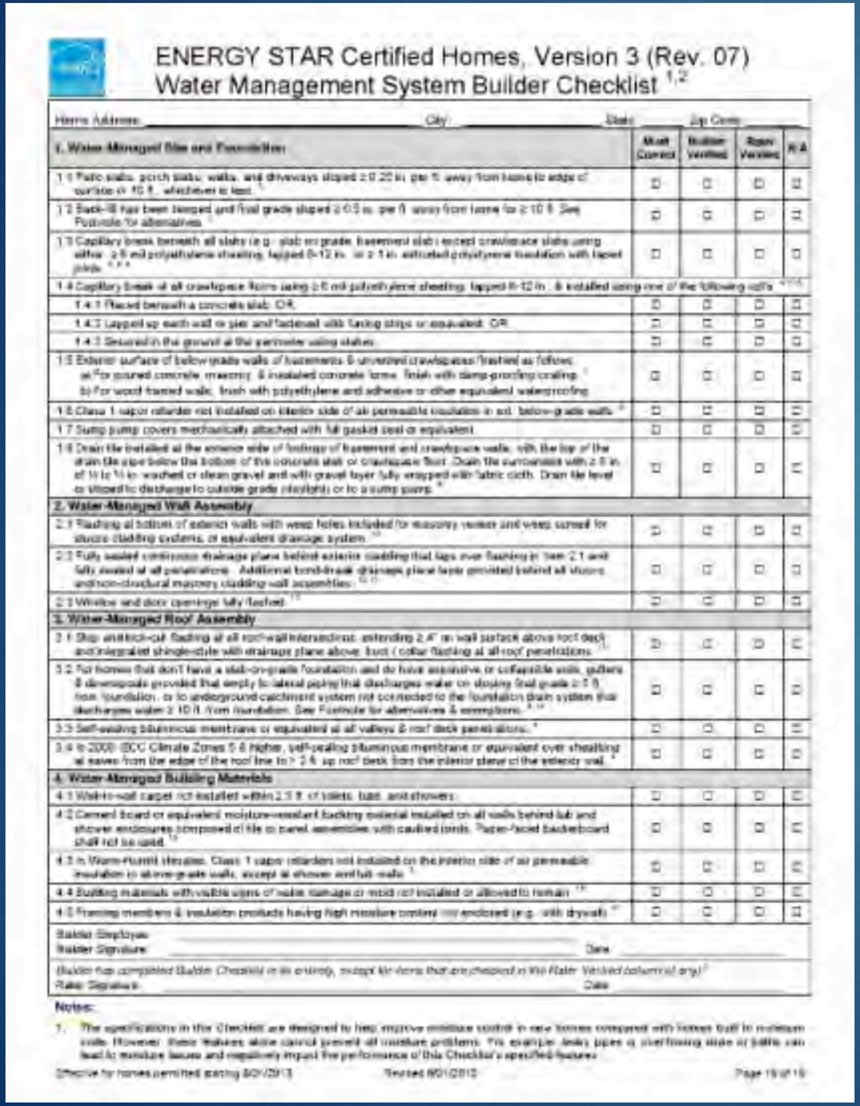
When rigid insulation is added to the exterior of the structural sheathing, the interior surface temperature of the structural sheathing is increased since the insulation keeps the sheathing warmer. By raising the temperature of the condensing surface of interest sufficiently, condensation from interior 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."

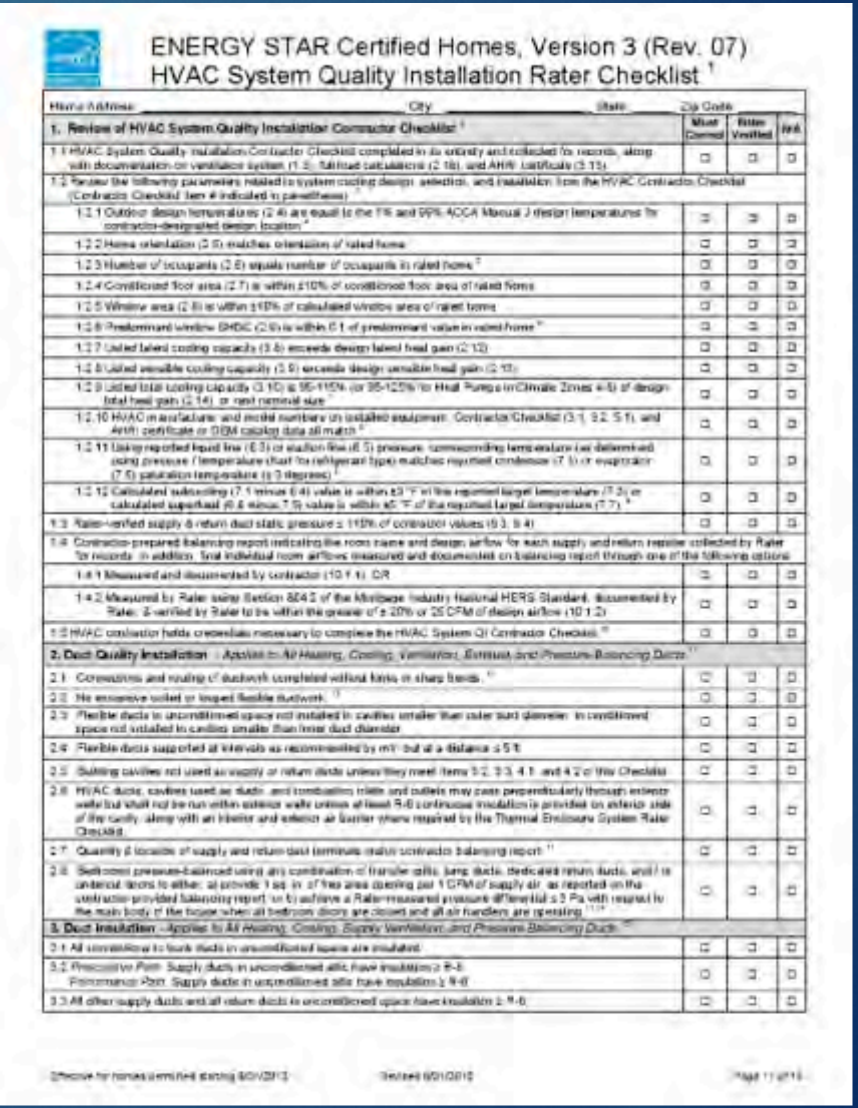
Climate Zone	Framing Rigid Insulation	Minimum R-Value
4C	2x4 2x6	2.5 3.75
5	2x4 2x6	5 7.5
6	2x4 2x6	7.5 11.25
7/8	2x4 2x6	10 15

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 [1,2]



ENERGY STAR Certified Homes, Version 3 (Rev. 07)
HVAC System Quality Installation Rater Checklist [1]

Checklists

ENERGY STAR Certified Homes, Version 3 (Rev. 07)
HVAC System Quality Installation Contractor Checklist[1]

1. Whole Building Mechanical Ventilation Design

2. Heating & Cooling System Design

3. Selected Cooling Equipment, If Cooling Equipment to be Installed

4. Selected Heat Pump Equipment, If Heat pump to be Installed

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

1. High-Performance Fenestration

2. Quality-Installed Insulation

3. Fully-Aligned Air Barriers

4. Reduced Thermal Bridging