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.

Building to Meet ZERH w/Multiple Layers of Foam board: Lessons Learned

ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

Brian J. Wimmer

Rochester Area Habitat for Humanity®

Building to Meet ZERH w/Multiple Layers of Foamboard: Lessons Learned

1. Specifics of the ZERH home and what is required.
2. What worked well and what would we do differently?
3. Getting your "ducks in a row" (Architect, energy-rater, trades people)
4. Start at the beginning and build for success
5. Devilish details and following through on them
6. Testing and the numbers: what do they tell you?
7. What other techniques can be employed not specific to ZERH basics?

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ZERH: What is it?

"A DOE Zero Energy Ready Home is a high performance home which is so energy efficient, that a renewable energy system can offset all or most of its annual energy consumption."

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DOE ZERH Requirements

DOE Zero Energy Ready Homes must:

1. Comply with **ENERGY STAR for Homes** and the **Inspection Checklists** for
   - Thermal Enclosure
   - HVAC Quality Installation (Contractor and HERS Rater)
     - **Exceptions for QA-Credentialed HVAC Contractor**
   - Water Management
   - The target home/size adjustment factor used by ENERGY STAR

- ***Note: Revision 08 of EnergyStar V3 is now available and can be used by all partners effective immediately***

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DOE ZERH Requirements

2. Feature energy **efficient appliances and fixtures** that are ENERGY STAR qualified.
3. Use **high-performance windows** that meet ENERGY STAR v5.0 and v6.0 specifications (depending on climate zone). The required U and Solar Heat Gain Coefficient (SHGC) values are shown below, effective 8/22/2016.

ENERGY STAR Window Specs Required for DOE Zero Energy Ready Home Projects[1]	Hot Climates IECC CZ 1-2		Mixed Climates IECC CZ 3-4 except Marine		Cold Climates IECC CZ 5-8 and 4 Marine[2]	
	U-Value	SHGC	U-value	SHGC	U-Value	SHGC
	0.40	0.25	[CZ 3] 0.30 [CZ 4] 0.30	[CZ 3] 0.25 [CZ 4] 0.40	0.30 0.31 0.32	Any ≥0.35 ≥0.40

1. DOE Zero Energy Ready Home offers multiple compliance paths including area weighting and allowances for passive solar design. See the National Program Requirements, Exhibit 1 with footnotes, for details.

2. These U & SHGC values are based on the ENERGY STAR v5.0 Window Specifications. DOE ZERH will review the feasibility of adopting ENERGY STAR v6.0 Window Specifications, which entail lower U values, periodically. Any program update to require the v6.0 window specs will be announced with a minimum 1-year phase-in.

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DOE ZERH Requirements

4. **Meet 2012 International Energy Conservation Code levels for insulation.** In some states 2015 IECC insulation levels are required – see End Note #15 of the Rev.05 specs
5. Follow the latest proven research recommendations by installing **ducts in conditioned** space or using a high performance alternative as defined in the program specs.
6. ***Conserve water and energy** through an efficient hot water distribution system that provides rapid hot water to the homeowner.
7. *Provide comprehensive indoor air quality through full certification in EPA's **Indoor airPlus**Program

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DOE ZERH Requirements

8. Accomplish savings on the cost of future solar PV installations by following the PV-Ready **checklist** for climates with significant solar insolation. This checklist references EPA's **solar electric guide**. (Note that the solar-hot water provisions of the checklist are no longer mandatory and can be found below with encouraged items.)

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DOE ZERH Requirements -Solar

DOE Zero Energy Ready Home PV-Ready Checklist

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

DOE Zero Energy Ready Home National Program Requirements Mandatory Requirement 7 (Renewable Ready) shall be met by any home certified under the DOE Zero Energy Ready Home program, only where **all three conditions** of the following conditions are met. If any of these three conditions is not met, the home is exempt from requirements contained in the PV-Ready checklist.

1. Location, based on zip code has at least 5 kWh/m^2/day average daily solar radiation based on annual solar insolation using PVWatts online tool: http://gisatnrel.nrel.gov/PVWatts_Viewer/index.html **AND**;
2. Location does not have significant natural shading (e.g., trees, tall buildings on the south-facing roof, **AND**;
3. Home as designed has adequate free roof area within +/-45° of true south as noted in the table below.

Conditioned Floor Area of the House (sq. ft.)	Minimum Roof Area within +/- 45◦ of True South for PV-Ready Checklist to Apply (ft^2)
≤ 2000	110
≤ 4000	220
≤ 6000	330
> 6000	440

Note:
- If a solar photovoltaic system is included with the home, then compliance with the Consolidated RERH checklist is not required.

These requirements were adapted from the EPA's Renewable Energy Ready Home Solar Photovoltaic Specification Guide (RERHPV Guide). For further guidance on any of the above items, this checklist notes the section of the guide. This guide can be accessed on the DOE Zero Energy Home program website at http://www1.eere.energy.gov/buildings/residential/pdfs/rerh_pv_guide.pdf

Designate a proposed array location and square footage on architectural diagram: **PV** _____ sq.ft. *(RERHPV Guide 1.1)*	☐
Identify orientation (Azimuth) of proposed array location: **PV** _____ degrees. *(RERHPV Guide 1.2)*	☐
Identify Inclination of proposed array location: **PV**_____ degrees. *(RERHPV Guide 1.3)*	☐
Provide code-compliant documentation of the maximum allowable dead load and live load ratings of the existing roof; recommended: allowable dead load rating can support an additional 6 lbs/sq. ft. for future solar system. *(RERHPV Guide 2.1)*	☐
Provide architectural drawing of solar PV system components. *(RERHPV Guide 3.5)* **Alternative**: Provide home buyer with the following information: ➢ List of renewable-ready features ➢ Available free roof area within +/- 45° of true south ➢ Location of panel or blocking for future mounting of PV system components ➢ Location of Breaker or slot for future breaker in electrical service panel ➢ Copy of the PV-Ready Checklist ➢ A copy of the RERH Solar PV Specification Guide	☐
Install a 1" metal conduit for the DC wire run from the designated array location to the designated inverter location (cap and label both ends). *(RERHPV Guide 3.2)*	☐
Install a 1" metal conduit from designated inverter location to electrical service panel (cap and label both ends). *(RERHPV Guide 3.3)*	☐
Install and label a 4' x 4' plywood panel area for mounting an inverter and balance of system components. *(RERHPV Guide 3.1)* **Alternative:** Blocking is permitted to be used as an alternative to the 4' x 4' panel. The area designated for the future panel to mount PV components shall be clearly noted in the system documentation.	☐
Install a 70-amp dual pole circuit breaker in the electrical service panel for use by the PV system (label the service panel) *(RERHPV Guide 3.4)* **Alternative:** Provide a labeled slot for a double-pole breaker in the electrical service.	☐

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DOE ZERH Requirements

- energy.gov/eere/buildings/zero-energy-ready-home

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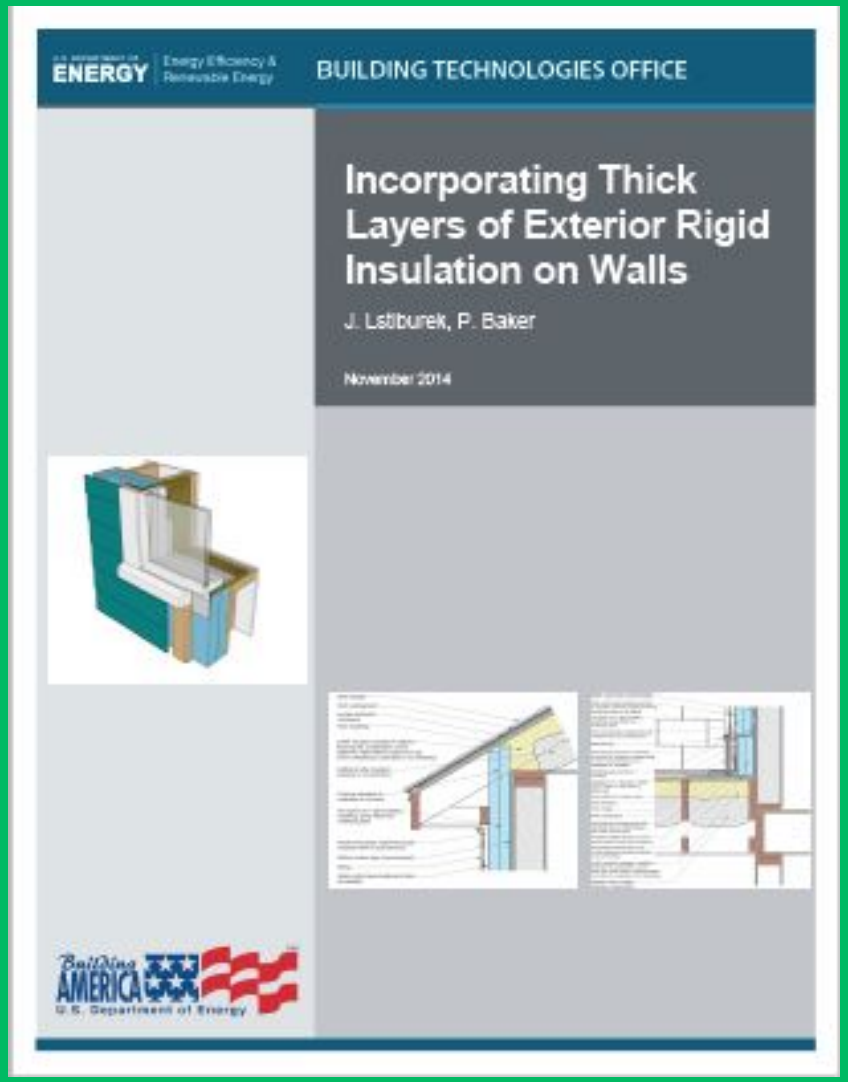
Rigid Foam: choosing a method



Two methods

- Water control layer in front of rigid insulation
- Water control layer behind rigid insulation
- We chose behind rigid insulation.
- *Water control layer must be continuous and uninterrupted!*

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Rigid Foam Concept

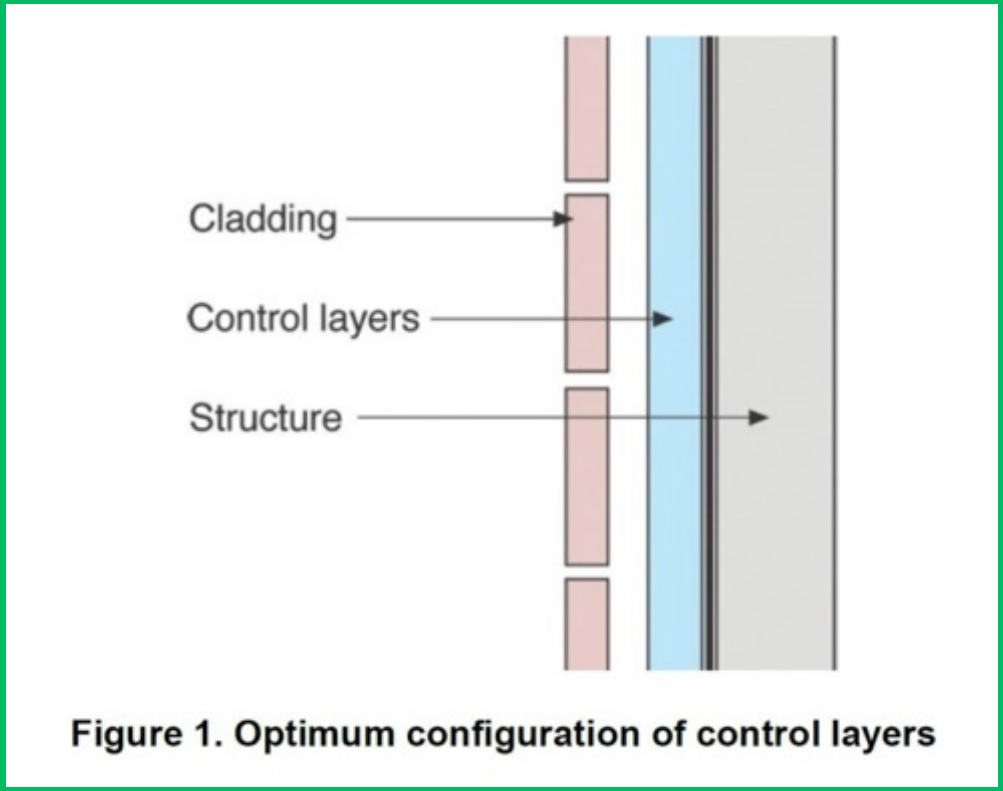

Figure 1. Optimum configuration of control layers

Thermal control layer outside the structure.

- Protecting the structure
- OSB sheathing never reaches dew point
- Dry to the inside – Class III vapor retarder

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What worked well? What didn't?

What worked well?

- Aligning upper and lower wall studs
- Long screws
- Drill press/pre-drilling and countersinking
- Battery impact drivers
- First layer of XPS
- Vinyl window/door jamb extensions
- Learning curve was reasonable/better than expected

What didn't work well?

- Long screws missing stud/poking through
- Extending bottom cord of roof truss to top cord
- Roof intersection with house wall
- Upper wall stud non-alignment with gable end
- Diverter flashing
- Window top drip cap
- Upgrade siding

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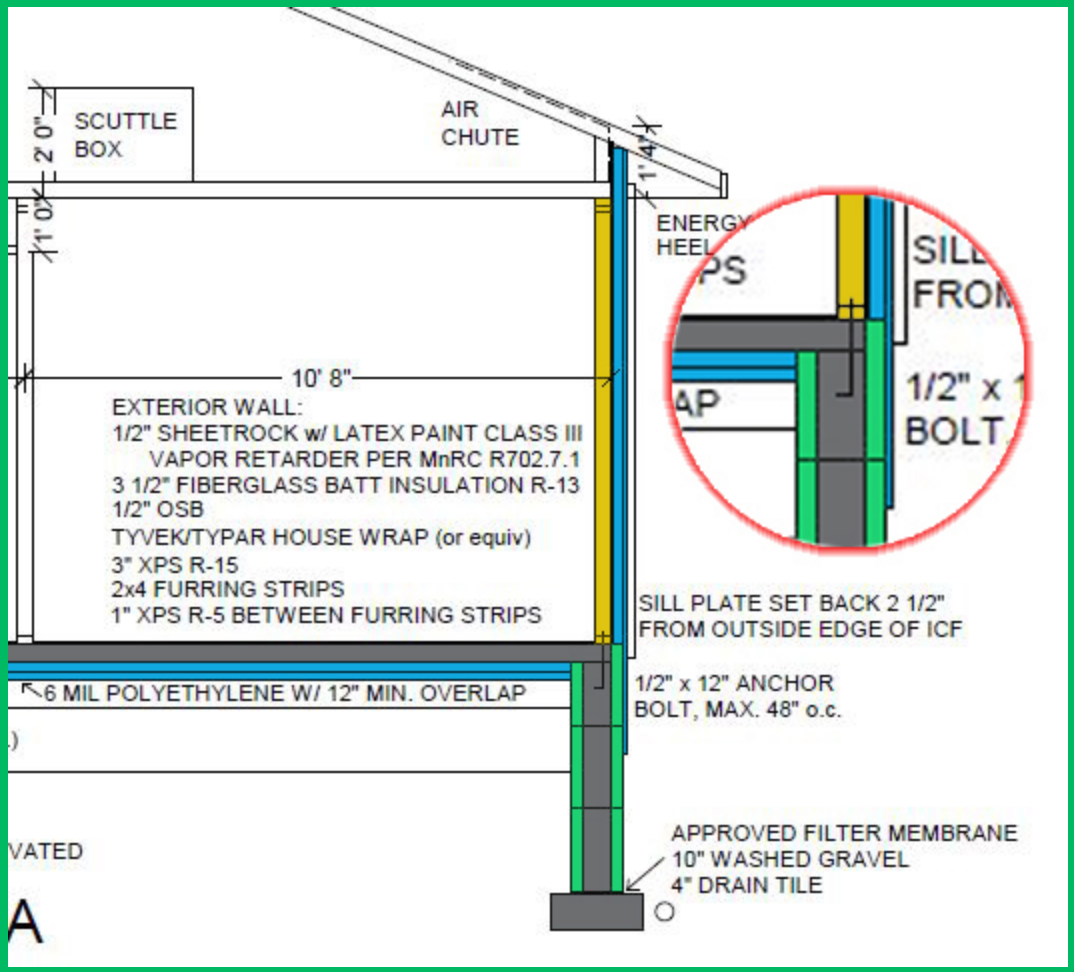
Starting with ICF foundation design



Foam board/ICF

- 3” foam board over framed wall (2” x 4”)
- 1” foam board over ICF foundation wall, extending down 2’

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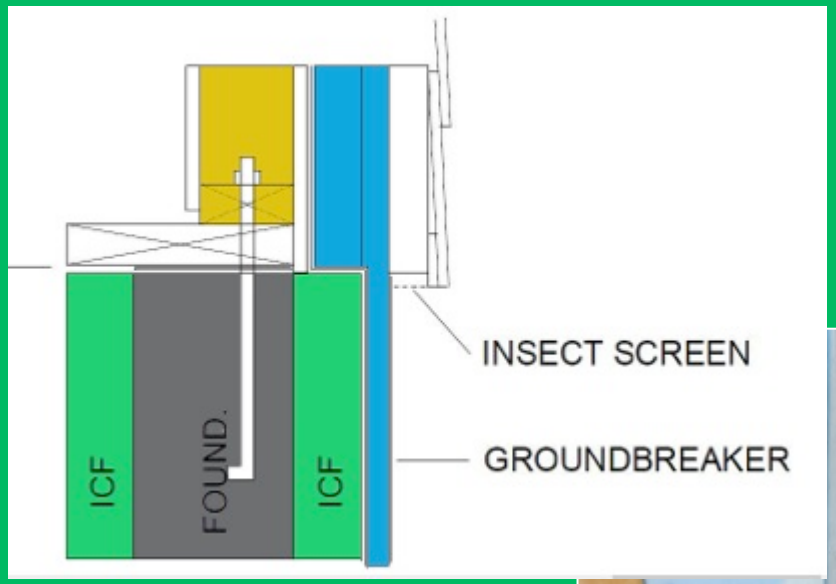
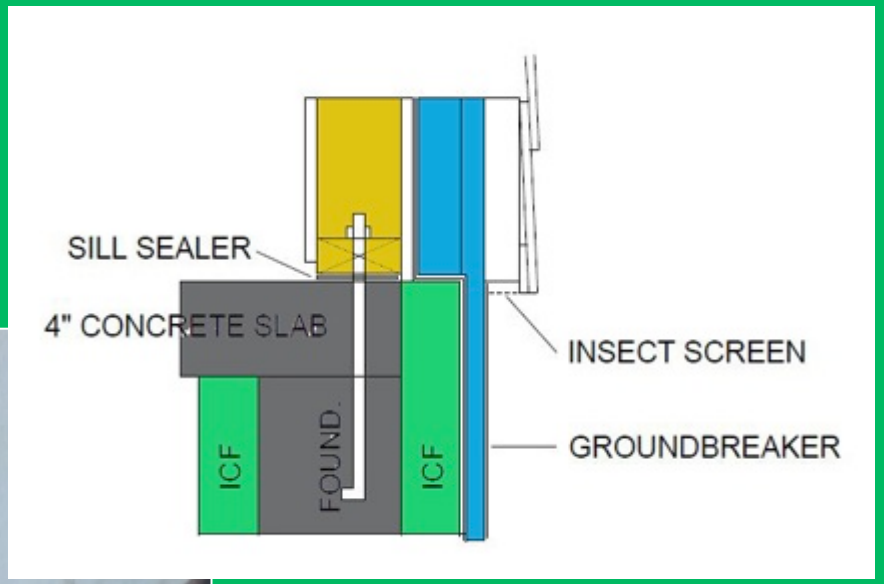
Foam board detail at foundation





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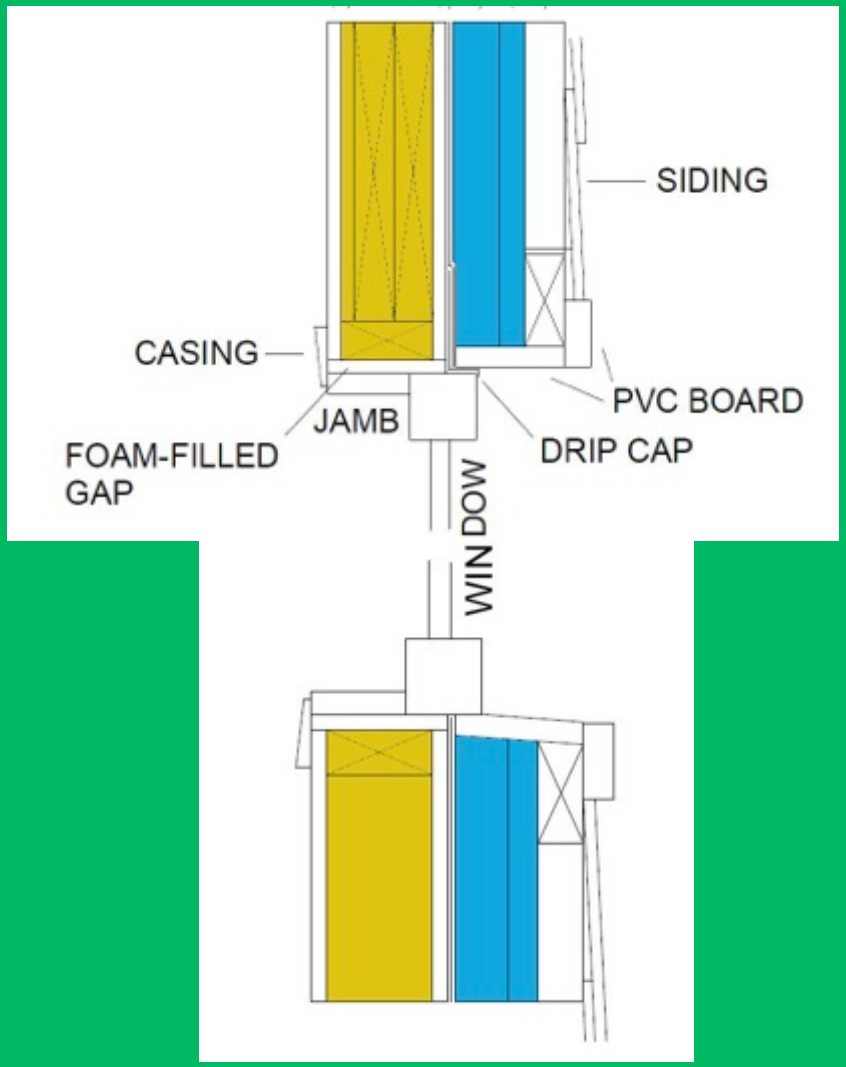
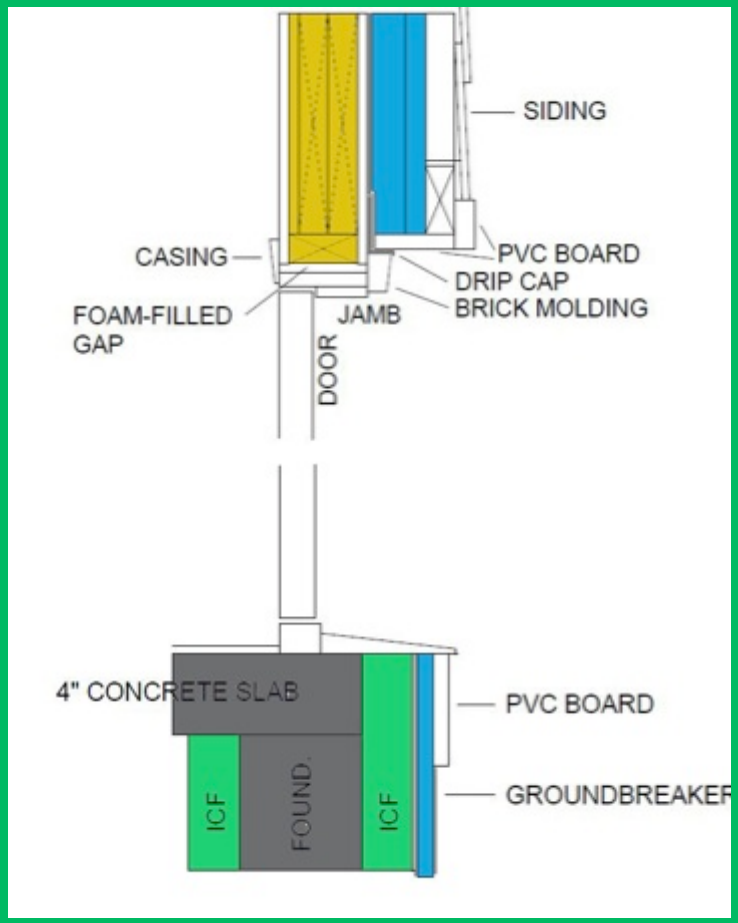
Foam board detail doors & windows





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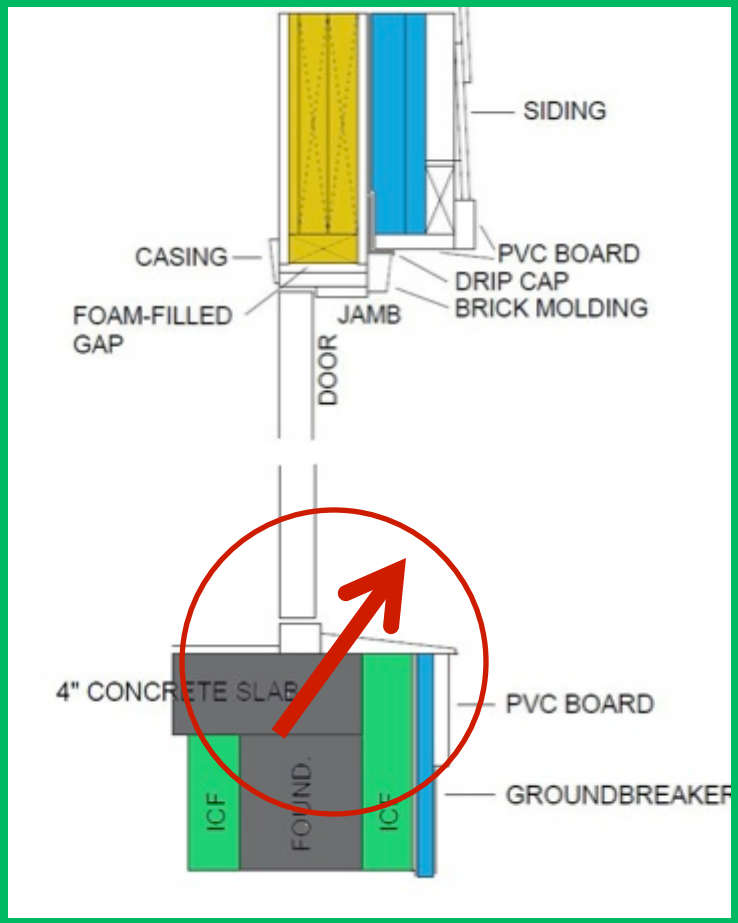
Foam board detail doors & windows



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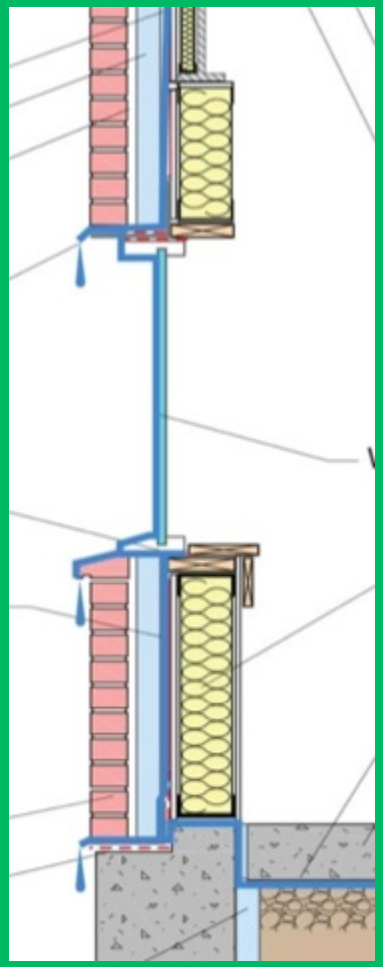
Foundation to framing

Continuous Water Control Layer

- Plans vs. real construction methods
- *Water control layer must be continuous and uninterrupted!*
- “Don’t lift your pen from paper.”



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Foundation to framing

- Continuous Water Control Layer
- Bug Screen/air flow
- Bringing 1” foam board down over ICF foundation

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Building the layers of rigid foam

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House wrap over top of walls

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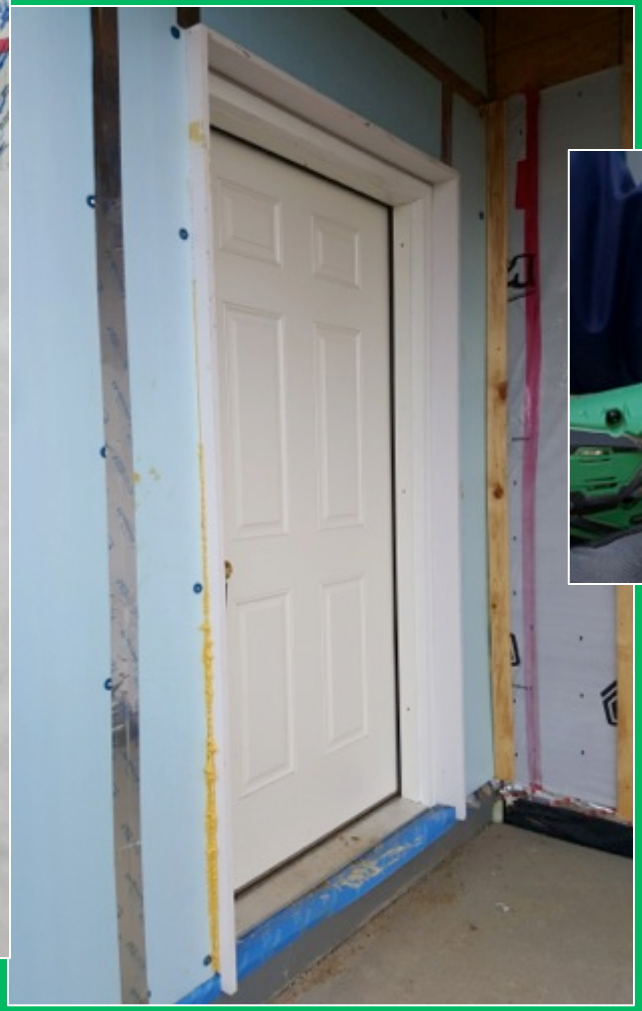
Window/door bucks and furring strips



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Window/door bucks and furring strips

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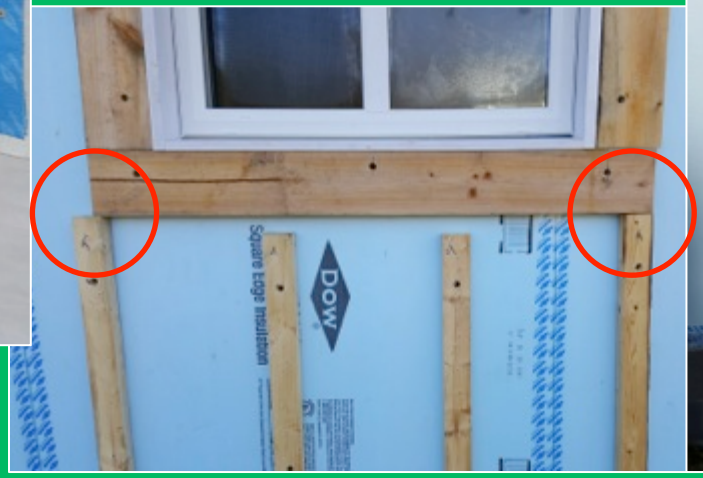
Maintaining Air Flow



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Evolution of Technique

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Garage/House, Penetrations, Soffit

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Windows: air/water control layers

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Fasteners

Pre-drilling & Countersinking

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Preparing for Siding

Foam board on house wall before roof truss

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Preparing for Siding

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Exterior

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Front Door/Stoop Details

Extended sills

Support and finishing

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Roof to Wall Detail

Thick layers,

Diverter flashing

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Roof to Wall Detail

Double water control layer

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Penetrations/Jamb Extension

Adding furring strips for penetratio

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HRV/Rim Cavity

HRV/Rim joists

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Interior

Central returns

Finished

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Ceiling Sealing

Electrical boxes

Top wall plates

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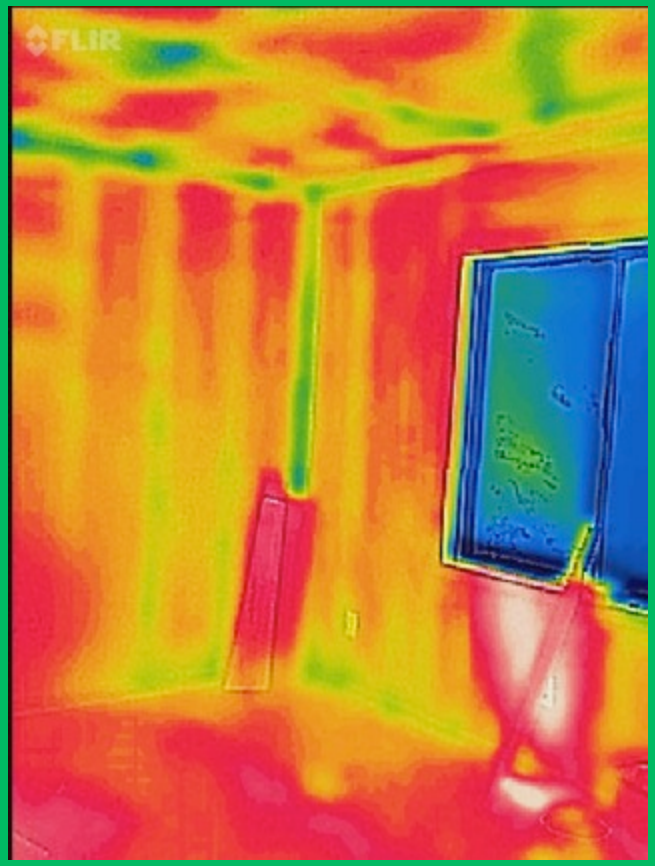
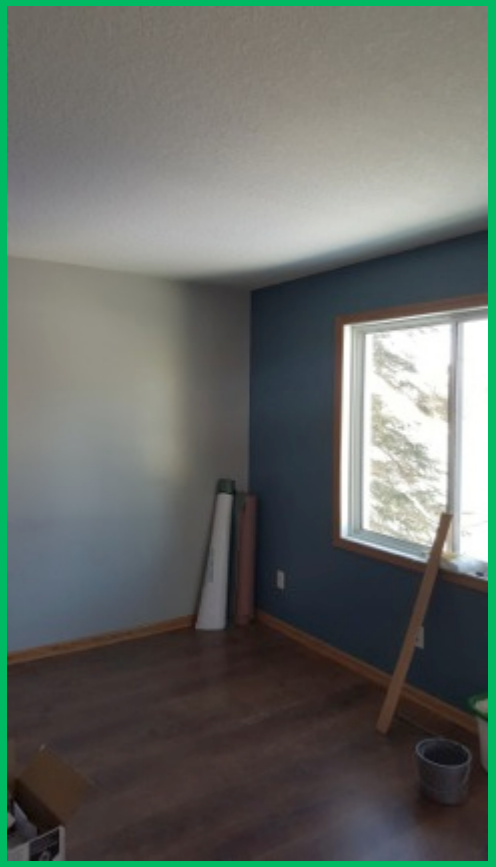
Thermal Imaging





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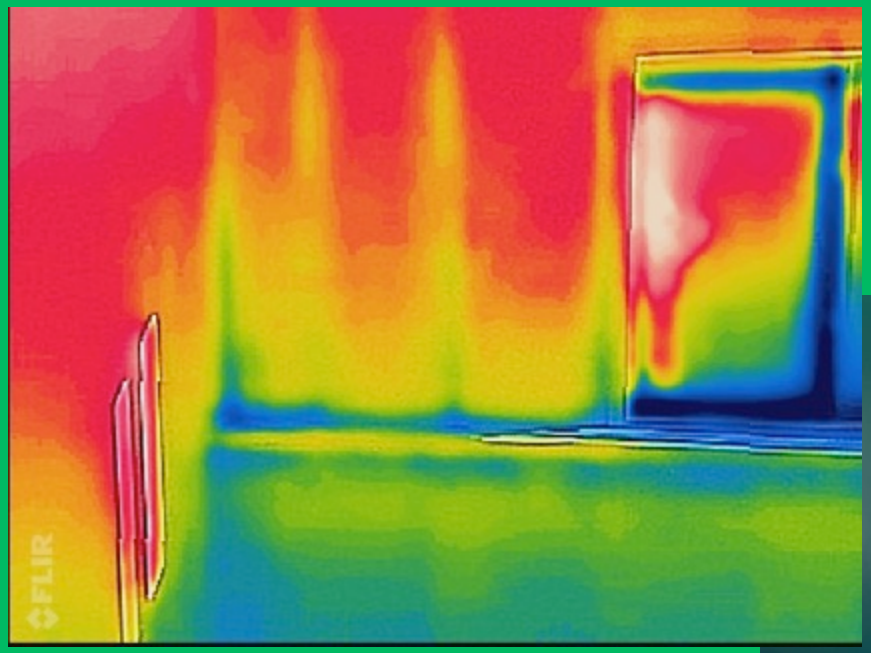
Thermal Imaging



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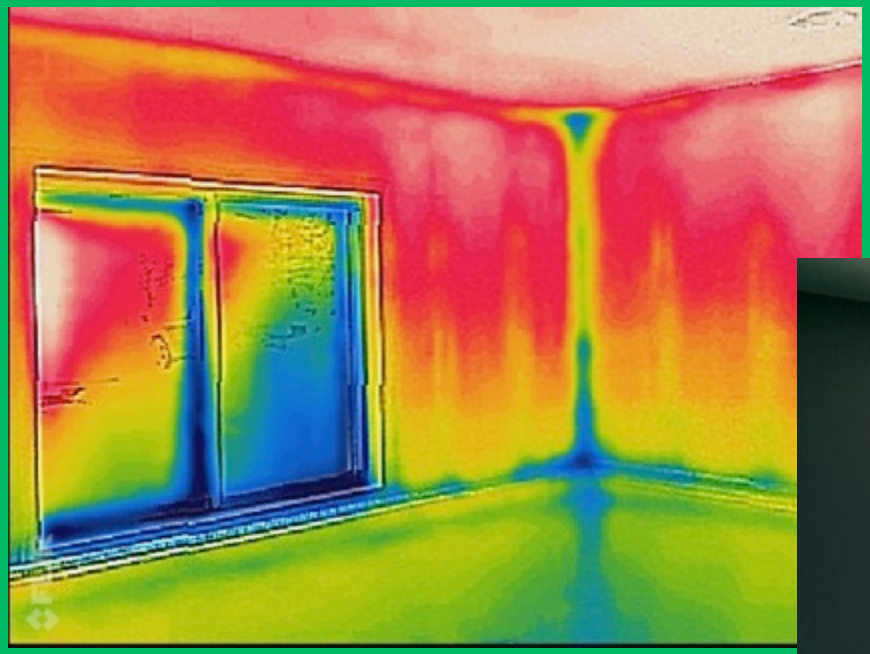

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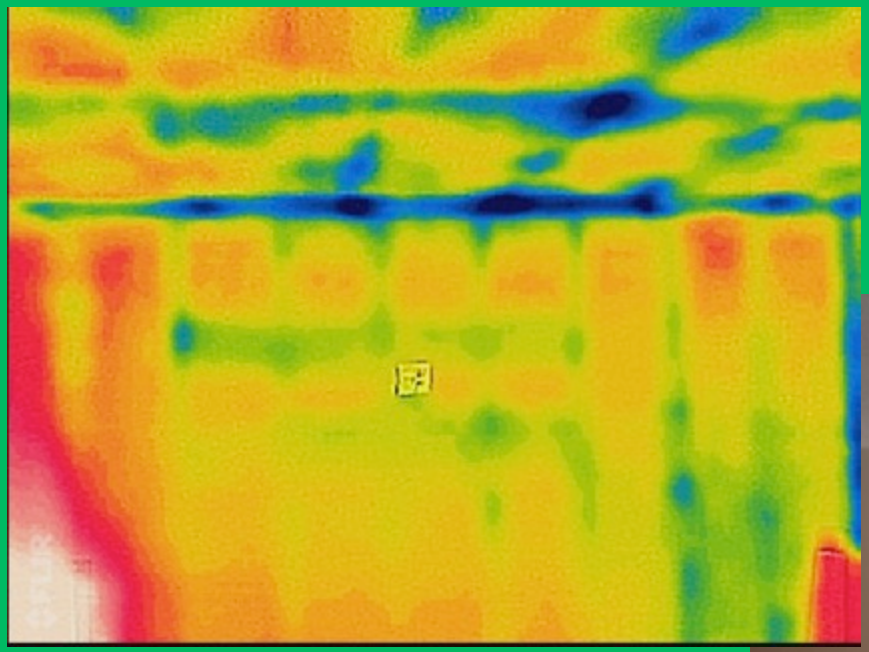

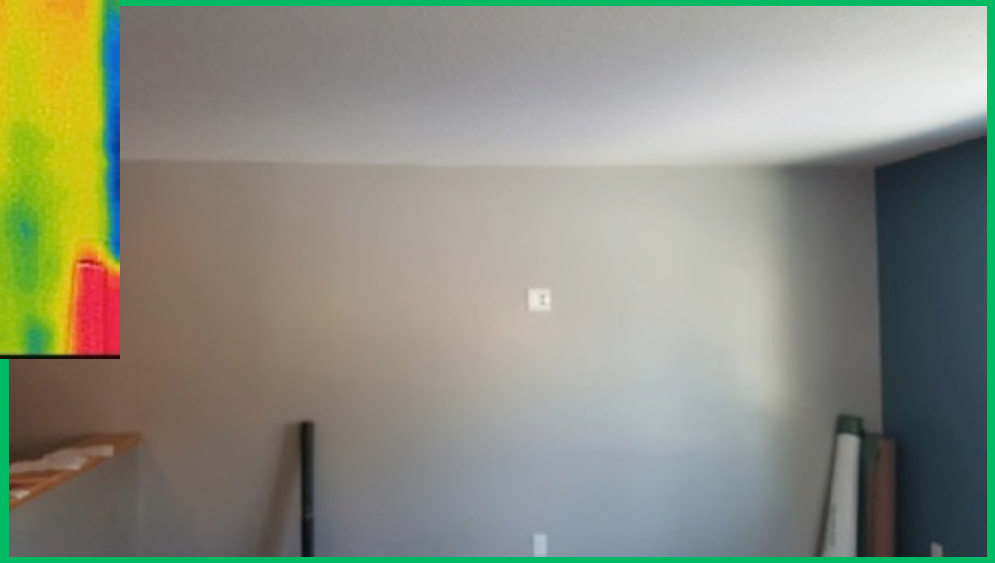

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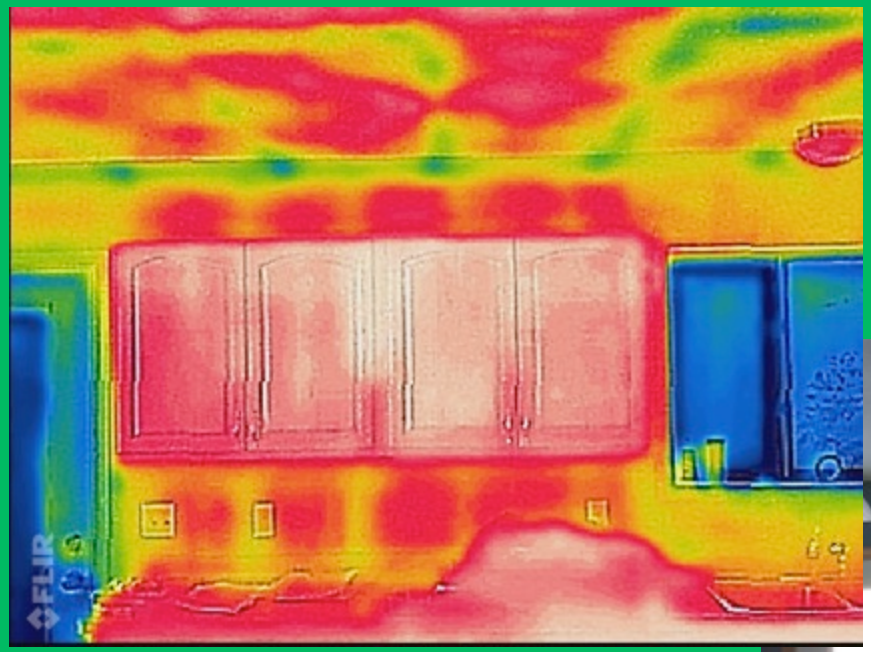

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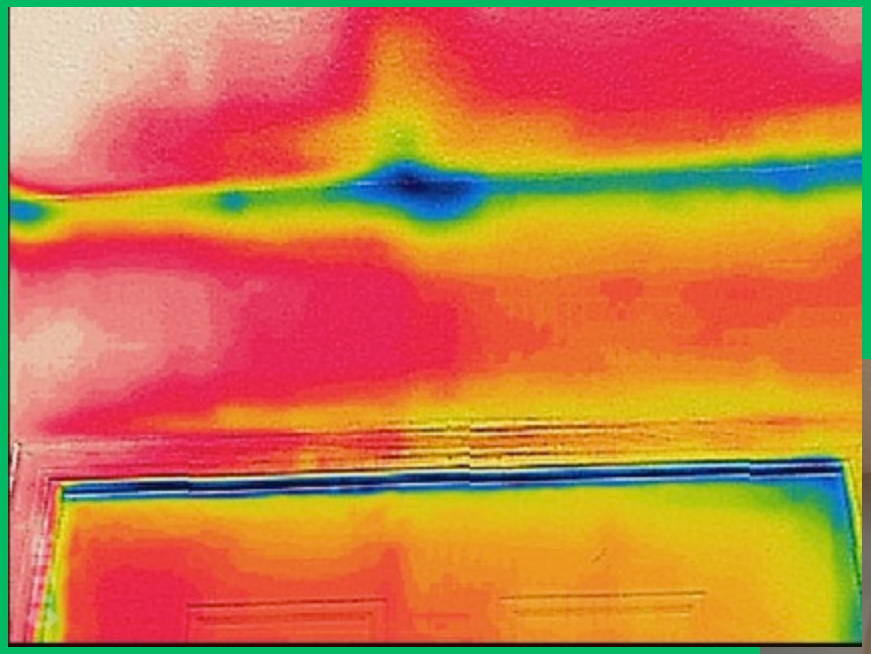

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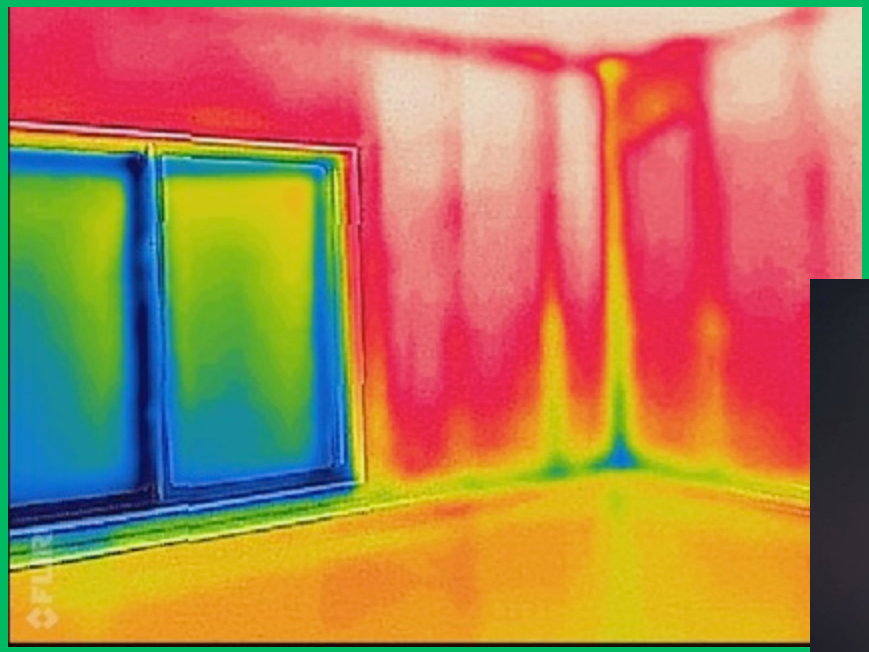
Thermal Imaging



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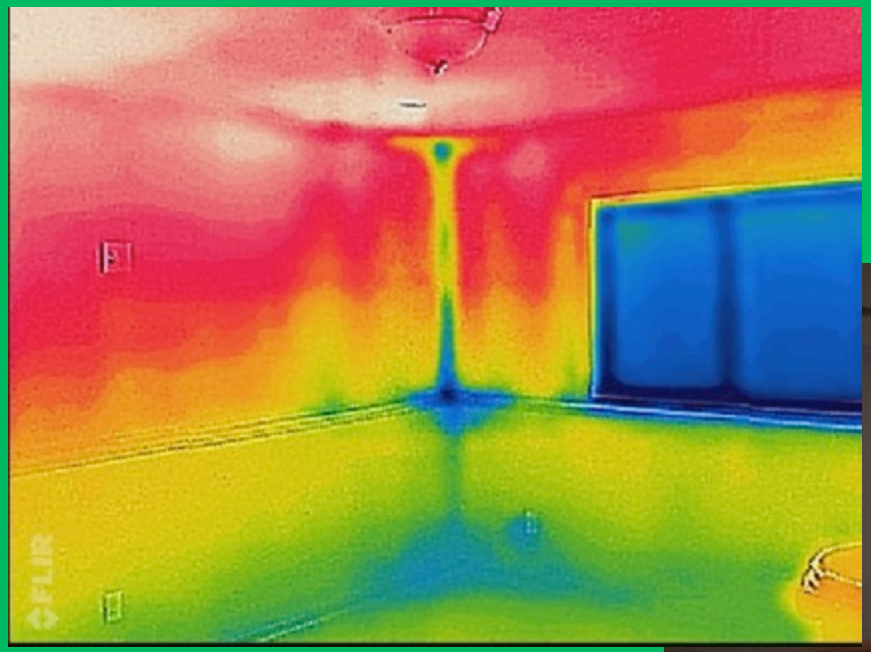
Thermal Imaging



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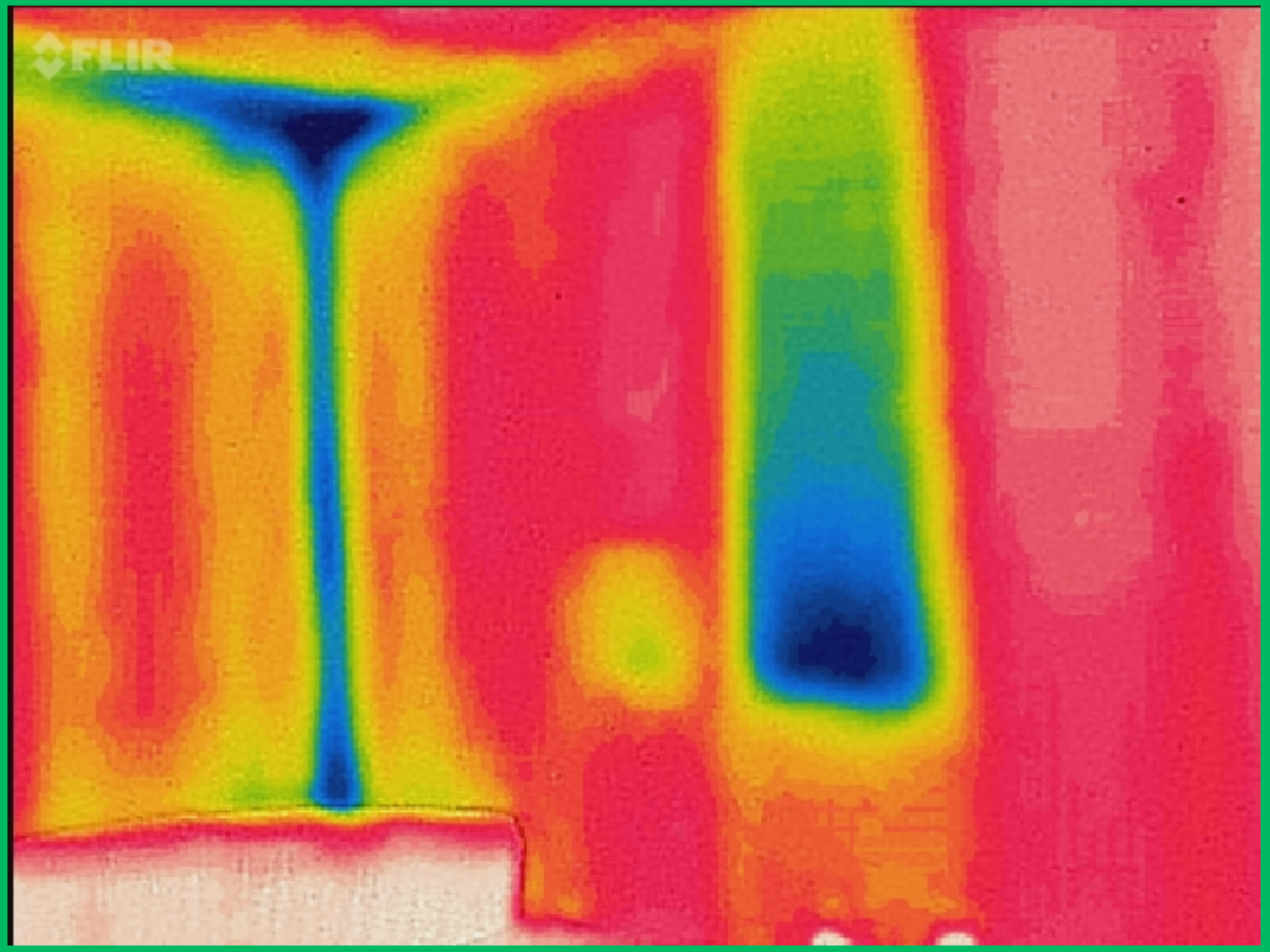
My House



Interior

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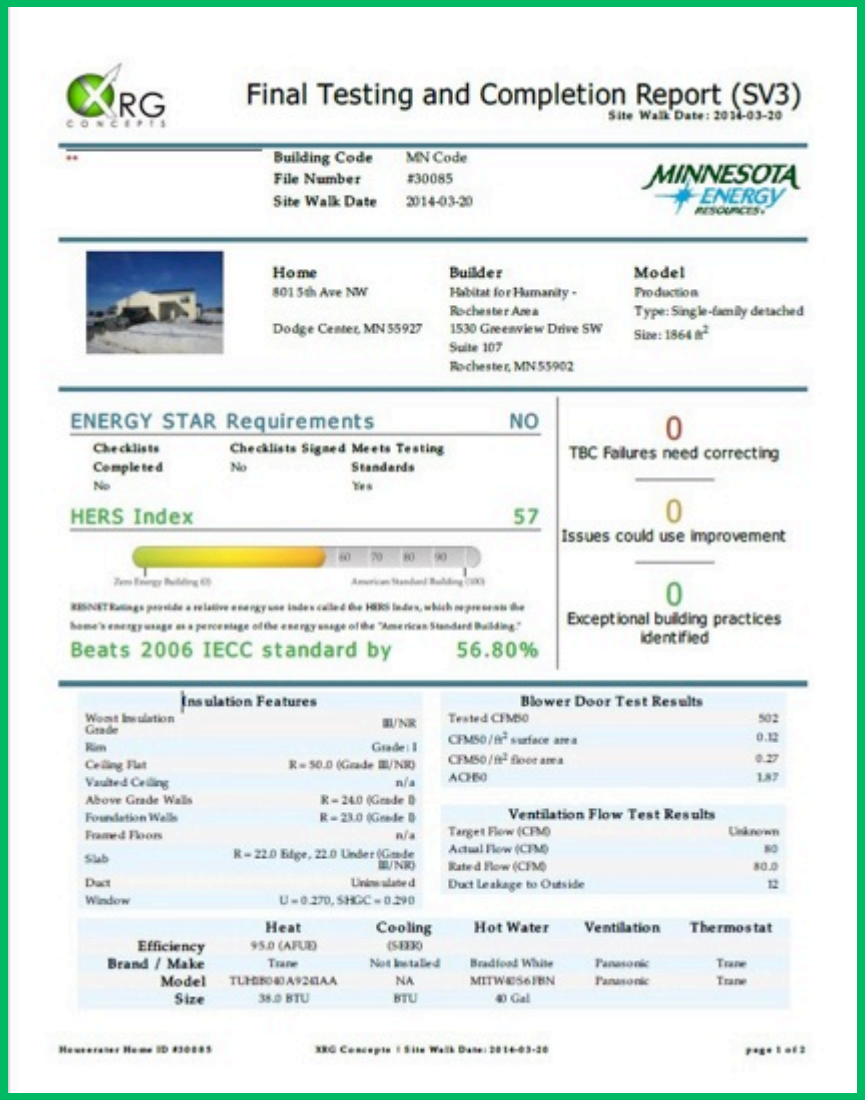
Results



XRG CONCEPTS

Final Testing and Completion Report (SV3)

Site Walk Date: 2014-03-20

Building Code	MN Code
File Number	#30085
Site Walk Date	2014-03-20

MINNESOTA ENERGY RESOURCES

Home
801 5th Ave NW
Dodge Center, MN 55927

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

Model
Production
Type: Single-family detached
Size: 1864 ft²

ENERGY STAR Requirements — NO

Checklists Completed	Checklists Signed	Meets Testing Standards
No	No	Yes

HERS Index — 57

60 70 80 90

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 56.80%

0
TBC Failures need correcting

0
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 III/NR)
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 = 22.0 Edge, 22.0 Under (Grade III/NR)
Duct	Uninsulated
Window	U = 0.270, SHGC = 0.290

Blower Door Test Results

Tested CFM50	502
CFM50 / ft² surface area	0.32
CFM50 / ft² floor area	0.27
ACH50	1.87

Ventilation Flow Test Results

Target Flow (CFM)	Unknown
Actual Flow (CFM)	80
Rated Flow (CFM)	80.0
Duct Leakage to Outside	12

	Heat	Cooling	Hot Water	Ventilation	Thermostat
Efficiency	95.0 (AFUE)	(SEER)			
Brand / Make	Trane	Not Installed	Bradford White	Panasonic	Trane
Model	TUH3B040A9241AA	NA	MITW40S6FBN	Panasonic	Trane
Size	38.0 BTU	BTU	40 Gal		

Fuel Summary

Property
801 5th Ave NW
Dodge Center, MN 55927

Weather: Rochester, MN
13-XRG-168-08
13-XRG-168-08 801 5th Ave NW
Dodge Center MN 55927 REM Fnl 040214.blg

Organization
XRG Concepts, LLC
507-358-6356
Brandon Vagt

Builder
Habitat for Humanity - Roch

HERS
Confirmed
3/20/2014
Rating No: 13-XRG-168-08
Rater ID: 8188958

Annual Energy Cost	$/yr
Natural gas	521
Electric	601

Annual End-Use Cost	$/yr
Heating	308
Cooling	0
Water Heating	228
Lights & Appliances	586
Photovoltaics	-0
Service Charge	142
Total	1264

Annual End-Use Consumption	
Heating (Therms)	349
Heating (kWh)	203
Water Heating (Therms)	271
Lights & Appliances (kWh)	7491
Total (Therms)	621
Total (kWh)	7693

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)	0.6
Lights & Appliances (Summer Peak)	1.4
Total Winter Peak	0.6
Total Summer Peak	1.4

Utility Rates	
Electricity	'14 Xcel Elec UnGrnd***
Natural Gas	MERC 2014 Current***

Results

Final Testing and Completion Report (SV3)

Site Walk Date: 2016-11-22

Building Code	MN Code
File Number	#58692
Site Walk Date	2016-11-22

Home
2290 Cedar Park Ct SE

Rochester, MN 55904

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

Model
Production
Type: Single-family detached
Size: 1985 ft²

ENERGY STAR Requirements — NO

Checklists Completed	Checklists Signed	Meets Testing Standards
No	No	Yes

HERS Index — 42

HERS/NET 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 68.11%

0
TBC Failures need correcting

3
Issues could use improvement

0
Exceptional building practices identified

Insulation Features

Worst Insulation Grade	III/NR
Rim	Grade: III
Ceiling Flat	R = 50.0 (Grade III/NR)
Vaulted Ceiling	n/a
Above Grade Walls	R = 26.0 (Grade III)
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	322
CFM50 / ft² surface area	0.07
CFM50 / ft² floor area	0.16
ACH50	1.09

Ventilation Flow Test Results

Target Flow (CFM)	Unknown
Actual Flow (CFM)	0
Rated Flow (CFM)	0.0
Duct Leakage to Outside	15

	Heat	Cooling	Hot Water	Ventilation	Thermostat
Efficiency	96.1 (AFUE)	(SEER)	0.66		
Brand / Make	Daikin	Not Installed	Bradford White	Venmar	Pro1
Model	DM96VEB4028NAB	N/A	RG1PV40S6N	Venmar	Pro1
Size	38.0 BTU	BTU	40 Gal		

Fuel Summary

Property
2290 Cedar Park Ct SE
Rochester, MN 55904

Weather: Rochester, MN
15-XRG-459-11
15-XRG-459-11 2290 Cedar Park Ct SE Rochester MN 55904 REM
FnL 112816 BV.blg

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

Builder
Habitat for Humanity - Roch

HERS
Confirmed
11/22/16
Rating No:15-XRG-459-11
Rater ID:B188958

Annual Energy Cost	$/yr
Natural gas	361
Electric	616

Annual End-Use Cost	$/yr
Heating	203
Cooling	0
Water Heating	172
Lights & Appliances	602
Photovoltaics	-0
Service Charge	323
Total	1300

Annual End-Use Consumption	
Heating (Therms)	255
Heating (kWh)	146
Water Heating (Therms)	232
Lights & Appliances (kWh)	5757
Total (Therms)	487
Total (kWh)	5903

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)	1.1
Total Winter Peak	0.5
Total Summer Peak	1.1

Utility Rates	
Electricity	RPU 2016 07/18/16**
Natural Gas	MERC 2016 3/23/16**

Results

Final Testing and Completion Report (SV3)

Site Walk Date: 2016-12-27

Building Code	MN Code
File Number	#66534
Site Walk Date	2016-12-27

Home
701 Blanch St

Mantorville, MN 55955

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

Model
Production
Type: Single-family detached
Size: 1982 ft²

ENERGY STAR Requirements — NO

Checklists Completed	Checklists Signed	Meets Testing Standards
No	No	Yes

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 70.10%

0
TBC Failures need correcting

4
Issues could use improvement

0
Exceptional building practices identified

Insulation Features

Worst Insulation Grade	III/NR
Rim	Grade: 1
Ceiling Flat	R = 50.0 (Grade III/NR)
Vaulted Ceiling	n/a
Above Grade Walls	R = 28.0 (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 = 0.220, SHGC = 0.270

Blower Door Test Results

Tested CFM50	330
CFM50 / ft² surface area	0.07
CFM50 / ft² floor area	0.36
ACH50	1.05

Ventilation Flow Test Results

Target Flow (CFM)	Unknown
Actual Flow (CFM)	0
Rated Flow (CFM)	0.0
Duct Leakage to Outside	235

	Heat	Cooling	Hot Water	Ventilation	Thermostat
Efficiency	96.1 (AFUE)	(SEER)	0.64		
Brand / Make	Daikin	Not Installed	Bradford White	Venmar	Pro1
Model	DM96VB1402BNAB	N/A	RG1PV40S6N	Venmar	Pro1
Size	38.0 BTU	BTU	40 Gal		

Fuel Summary

Property
701 Blanch St
Mantorville, MN 55955

Weather: Rochester, MN
16-XRG-437-09
16-XRG-437-09 701 Blanch St
Mantorville MN 55955 REM Fnl
122716 BV.blg

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

Builder
Habitat for Humanity - Roch

HERS
Confirmed
12/27/16
Rating No: 16-XRG-437-09
Rater ID: 8188958

Annual Energy Cost	$/yr
Natural gas	349
Electric	587

Annual End-Use Cost	$/yr
Heating	171
Cooling	0
Water Heating	190
Lights & Appliances	575
Photovoltaics	-0
Service Charge	154
Total	1090

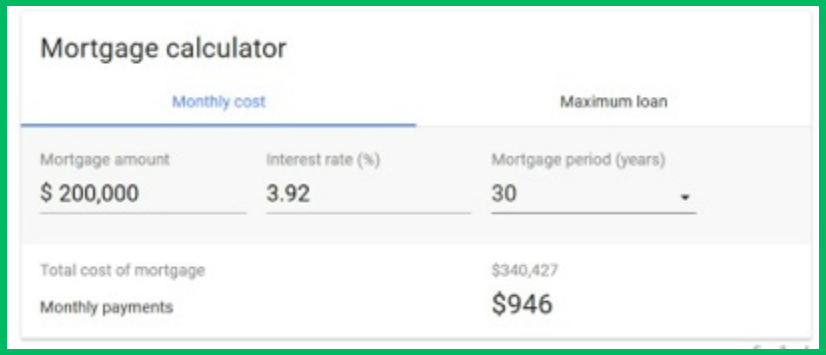
Annual End-Use Consumption	
Heating (Therms)	215
Heating (kWh)	146
Water Heating (Therms)	256
Lights & Appliances (kWh)	6773
Total (Therms)	471
Total (kWh)	6919

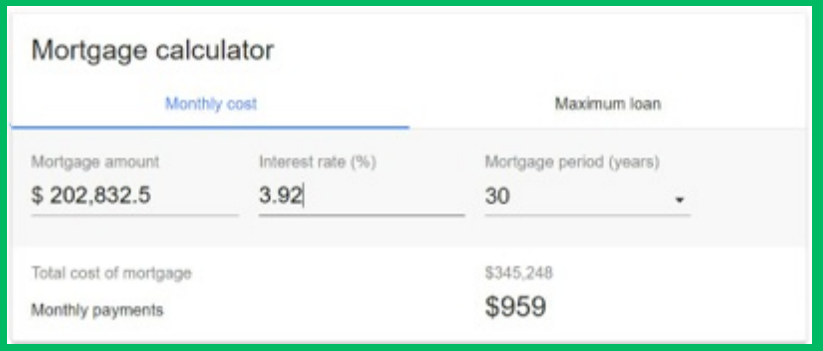
Annual Energy Demands	kW
Heating	0.1
Cooling	0.0
Water Heating (Winter Peak)	0.0
Water Heating (Summer Peak)	0.0
Lights & Appliances (Winter Peak)	0.5
Lights & Appliances (Summer Peak)	1.3
Total Winter Peak	0.6
Total Summer Peak	1.3

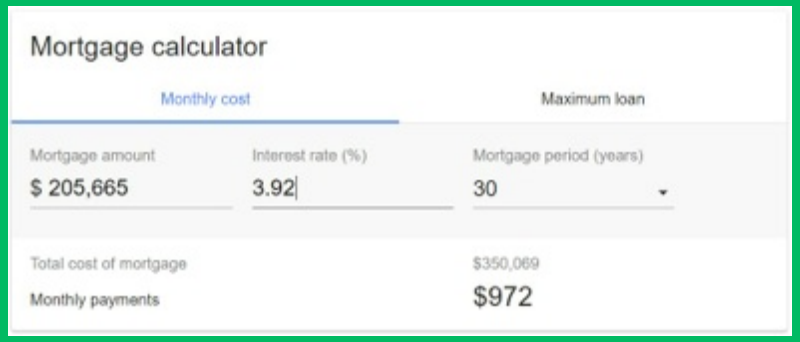
Utility Rates

Electricity	'16 Xcel Elec UnGrnd**
Natural Gas	MERC 2016 3/23/16**

Monthly Cost Increase







Qty	Item	Per each	Total
250	2" x 3"	$2.05	$512.50
1000	Screws	$0.50	$500
70	2" Foamboard	$26.00	$1,820.00
			$2,832.50
		Monthly at 0% interest	$7.87
	$200,00 Home	Monthly at 3.92% interest	$13.00
	$200,00 Home	Doubled for labor at 3.92% interest	$26.00

Rochester Area Habitat for Humanity®

Alternative?

$36.40

VS.

Per
4’ x 8’

$56.60

Rochester Area Habitat for Humanity®

Source:

Building Science Corporation

buildingscience.com

BA-1406: Final Measure Guideline: Incorporating Thick Layers of Exterior Rigid Insulation on Walls

Joseph Lstiburek, Peter Baker - APRIL 15, 2015

http://buildingscience.com/documents/bareports/ba-1406-final-measure-guideline-incorporating-thick-layers-exterior-rigid-insulation/view

https://energy.gov/eere/buildings/maps/zerh-navigational-button-graphic

Rochester Area Habitat for Humanity®