NECCO INC

NEW ENGLAND CONSTRUCTION CO.

Energy Efficient Buildings

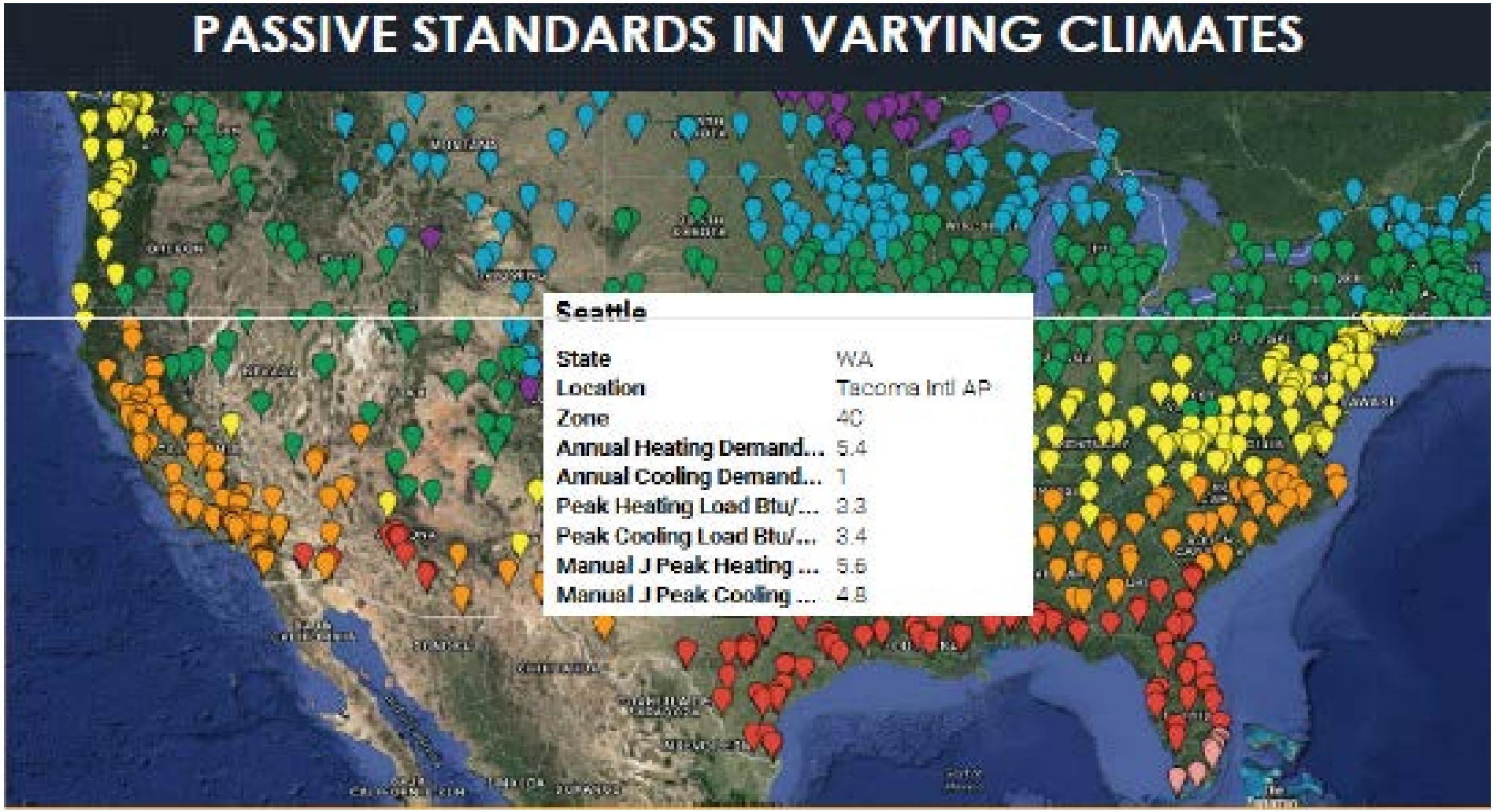
# Passive House Retrofit of a VT House

## BBbD-2018 Conference

Burlington VT
Feb. 7th, 2018

www.eplusbuildings.com

# PHIUS Climate Specific Criteria



# USA PHIUS+ 2015 Building Criteria

| | |
|---|---|
| Heating Demand (Site): | 1 - 12 kBTU/Ft2-YR |
| Cooling Demand (Site): | 1 - 21.4 kBTU/Ft2-YR |
| Peak Heat Load : | 0.8 - 5.4 BTU/Ft2-Hr |
| Peak Cooling Load: | 1.8 - 8.9 BTU/Ft2-Hr |
| Total Energy Demand (Source): | Beds+1 / 6200 kWh/PERSON-YR (Temporary)<br>Beds+1 / 4200 kWh/PERSON-YR (Future) |
| Air Tightness: | 0.05 cfm/gross sqft shell @ 50 pa<br>0.08 cfm/gross sqft shell @ 75 pa |

Climate Specific: Warren VT
Heating Demand: ***7.50 kBTU/ft2-yr***
Heating Load: **5.10 BTU/hr-ft2**

# PH New Construction Projects in Vermont


**Affordable Senior Housing**
**Elm Place - Milton VT**

**Habitat for Humanity**
**East Montpelier**

# PH New Multifamily Project in Vermont


## ELM PLACE - Best Overall Passive Building Winner

Multifamily project category Winner
Affordable project category Honorable Mention

2017 PHIUS Passive House Projects Competition

# 51Upper Pines – Warren VT Case History

Built in the early 70's.
Simple in construction
Slab on grade floor without insulation.
Inexpensive widows.
Full size sliding door on patio. Fiberglass insulation, Fireplace in great room and cathedral ceilings with no attic.
Fully shaded in the woods

# 51Upper Pines – Warren VT
# Energy Audit - Initial Condition

The 516 gallon of propane usage at 62-65 degrees in a 1440 sq ft home indicated the boiler was running often to keep up.

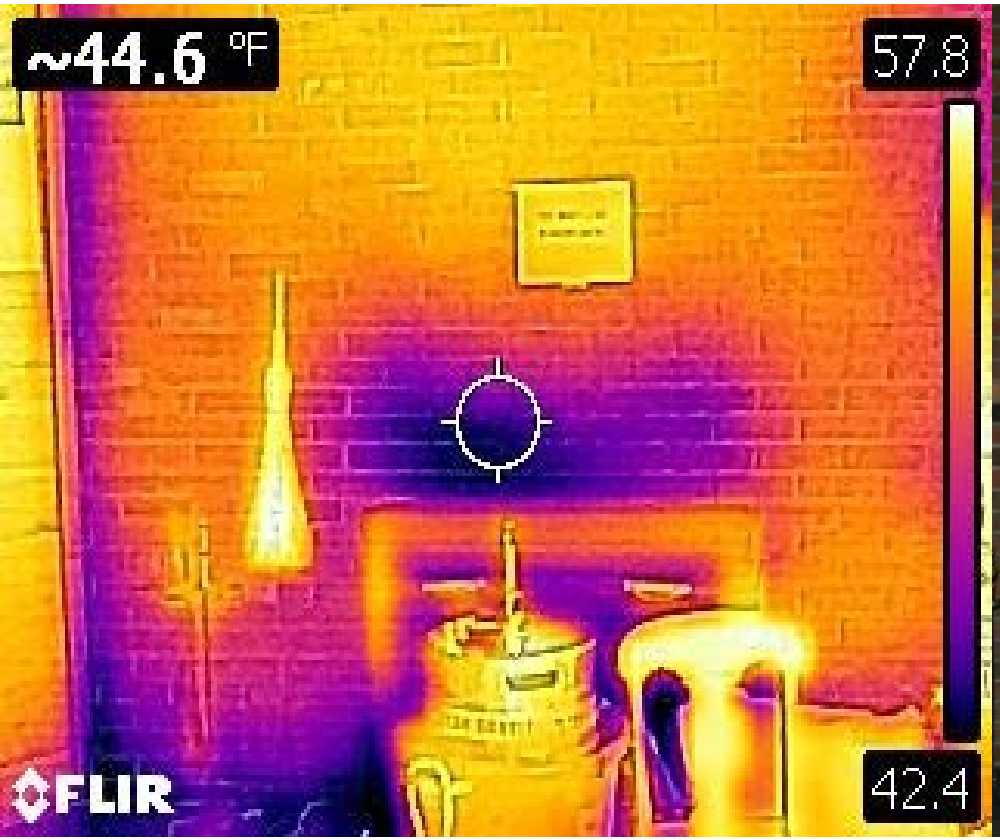
The 2 bathrooms have poor ventilation with potential to mold formation. One fan was pulling only 6-10 CFM, while a BR-fan should be pulling 50-80 CFM.

# 51Upper Pines – Warren VT
# Initial Condition

Thermal Bridges Everywhere

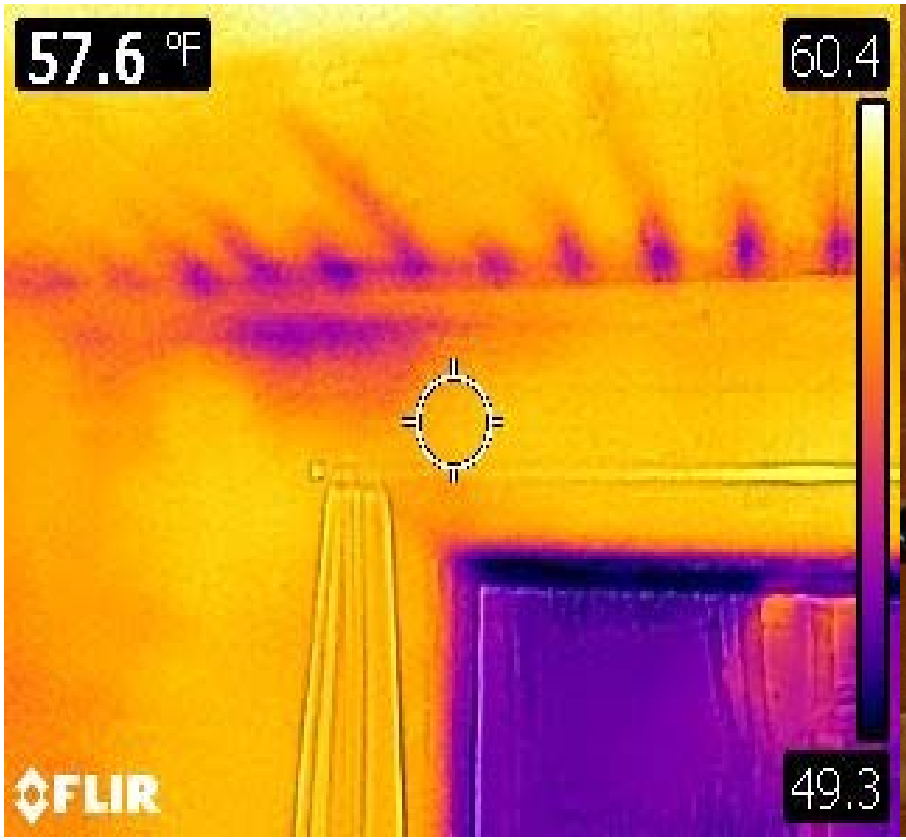

# 51Upper Pines – Warren VT
# Initial Condition

Thermal Bridges Everywhere




# 51Upper Pines – Warren VT
# Initial Condition

Air Leaks Everywhere




**Initial BDT came to 1740 CFM**
**A lot of infiltration for a 1440 ft2 house**

# 51Upper Pines – Warren VT
# PH Renovation Proposal

- 1st Phase – Roof repair, insulation and new metal roof – Fall 2015

- 2nd Phase – Floor removal, slab and frost wall insulation, new floor – Summer 2016

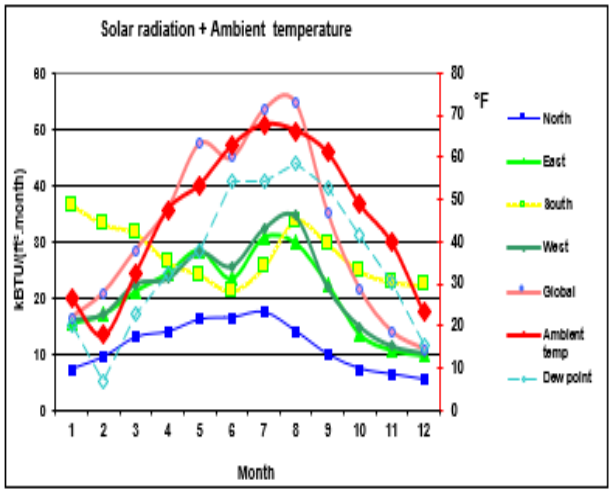
- 3rd Phase – Air sealing, walls insulation, new windows and ventilation system – Spring 2017

# 51Upper Pines – Warren VT
# 1st Phase Implementation

## Energy Balance with PHPP – Climate Input

**EnerPHit planning:** CLIMATE DATA

| | | | | | |
|---|---|---|---|---|---|
| Building: | 51Pines - Warren VT | | | | |
| | | Transfer to annual method (Annual Heating) | | | |
| Climate building | Montpelier AP VT | $H_T$ | 222 | day/yr | |
| | | Heating Degree Days, $G_t$ | 7468 | °F.day/yr | |
| Monthly data: | MONTPELIER AP VT - Montpelier AP VT | North | 66 | kBTU/(ft²yr) | |
| Annual data: | | East | 118 | kBTU/(ft²yr) | |
| Use annual climate data set | no | South | 200 | kBTU/(ft²yr) | |
| Region: User Data | Results: | West | 121 | kBTU/(ft²yr) | |
| Climate data set: MONTPELIER AP VT - Montpelier AP VT | Annual heating demand | 6.39 | kBTU/(ft²yr) | Horizontal | 158 kBTU/(ft²yr) |
| Weather station (altitude): 1125.3 ft | Heating load | 4.29 | BTU/h.ft² | | |
| Building location (altitude): 896 ft | Primary energy | 54.46 | kBTU/(ft²yr) | | |




| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Heating load | | Cooling load | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 | Weather 1 | Weather 2 | Weather 1 | Weather 2 |
| Parameters for PHPP calculated ground temperatures: | ONTPELIER AP VT - Montpelier AP | Latitude °: | 44.2 | Longitude °: | -72.6 | Altitude ft | 1125 | Daily temperature swing Summer (°F) | | 21.4 | Radiation data: | kBTU/(ft²month) | Radiation: BTU/hr.ft² | | Radiation: BTU/hr.ft² | |
| Phase shift months | Ambient temp | 26.8 | 17.8 | 32.4 | 47.5 | 53.5 | 62.6 | 67.7 | 66.2 | 61.0 | 48.8 | 39.8 | 23.2 | 0.2 | 28.1 | 76.1 | 76.1 |
| 0.60 | North | 7.3 | 9.5 | 13.0 | 13.9 | 16.2 | 16.5 | 17.4 | 13.9 | 9.8 | 7.3 | 6.3 | 5.4 | 12.7 | 5.7 | 22.8 | 22.8 |
| Damping | East | 15.5 | 17.1 | 21.2 | 24.4 | 28.5 | 23.5 | 30.7 | 29.8 | 22.5 | 13.6 | 10.8 | 9.8 | 23.1 | 9.2 | 42.2 | 42.2 |
| -0.31 | South | 36.5 | 33.0 | 31.4 | 26.3 | 24.1 | 21.2 | 25.4 | 33.6 | 29.5 | 24.7 | 22.8 | 22.2 | 58.6 | 13.9 | 37.4 | 37.4 |
| Depth ft | West | 16.2 | 17.1 | 22.5 | 23.5 | 28.2 | 25.7 | 32.3 | 34.6 | 21.9 | 14.9 | 11.4 | 10.1 | 29.2 | 8.6 | 46.6 | 46.6 |
| 3.27 | Global | 16.5 | 20.9 | 28.5 | 35.8 | 47.5 | 45.0 | 53.6 | 54.8 | 35.2 | 21.6 | 13.9 | 10.8 | 31.4 | 9.8 | 78.0 | 78.0 |
| Average Temp Shift °F | Dew point | 19.9 | 6.8 | 22.8 | 32.5 | 37.9 | 54.3 | 54.3 | 58.5 | 52.5 | 41.4 | 30.6 | 15.3 | | | 63.9 | 63.9 |
| 1.8 | Sky temp | 0.1 | -16.1 | 6.3 | 20.3 | 26.6 | 45.7 | 44.8 | 47.7 | 42.8 | 30.6 | 16.7 | -4.0 | | | 59.7 | 63.9 |
| | Ground temp | 39.4 | 35.4 | 34.8 | 37.8 | 43.5 | 50.4 | 56.8 | 60.8 | 61.4 | 58.5 | 52.7 | 45.8 | 34.7 | 34.7 | 61.5 | 61.5 |
| | Comment: | | PHIUS | | | | | | | | | | | | | | |

Climate Specific: Warren VT

Heating Demand: **7.50 kBTU/ft2-yr**

Heating Load: **5.10 BTU/hr-ft2**

# ENERGY BALANCE

## Finding the right R-value

### Assemblies' R-Value Calculation

| Assembly no. | Building assembly description | Interior insulation? |
|---|---|---|
| 2 | Roof | |

Surface Film Resistance [hr.ft².F/BTU]

interior Rsi : 0.57

exterior Rse : 0.23

| | Area section 1 | R per inch | Area section 2 (optional) | R per inch | Area section 3 (optional) | R per inch | Thickness [in] |
|---|---|---|---|---|---|---|---|
| 1. | T&G board | 1.280 | | | | | 1.500 |
| 2. | Glass-Fiber Batts | 3.330 | sleepers 24" OC | 1.280 | | | 1.500 |
| 3. | Plywood | 1.470 | | | | | 0.500 |
| 4. | Polyiso unfaced | 6.200 | | | | | 12.000 |
| 5. | OSB | 1.390 | | | | | 0.625 |
| 6. | | | | | | | |
| 7. | | | | | | | |
| 8. | | | | | | | |

| Percentage of sec. 1 | Percentage of sec. 2 | Percentage of sec. 3 | Total |
|---|---|---|---|
| 75% | 25.0% | | 16.13 in |

U-value supplement ____ BTU/hr.ft$^2$.°F

**R-Value:** 82.6 hr.ft$^2$.°F/BTU

# ENERGY BALANCE
# COMPILING ENERGY LOSSES

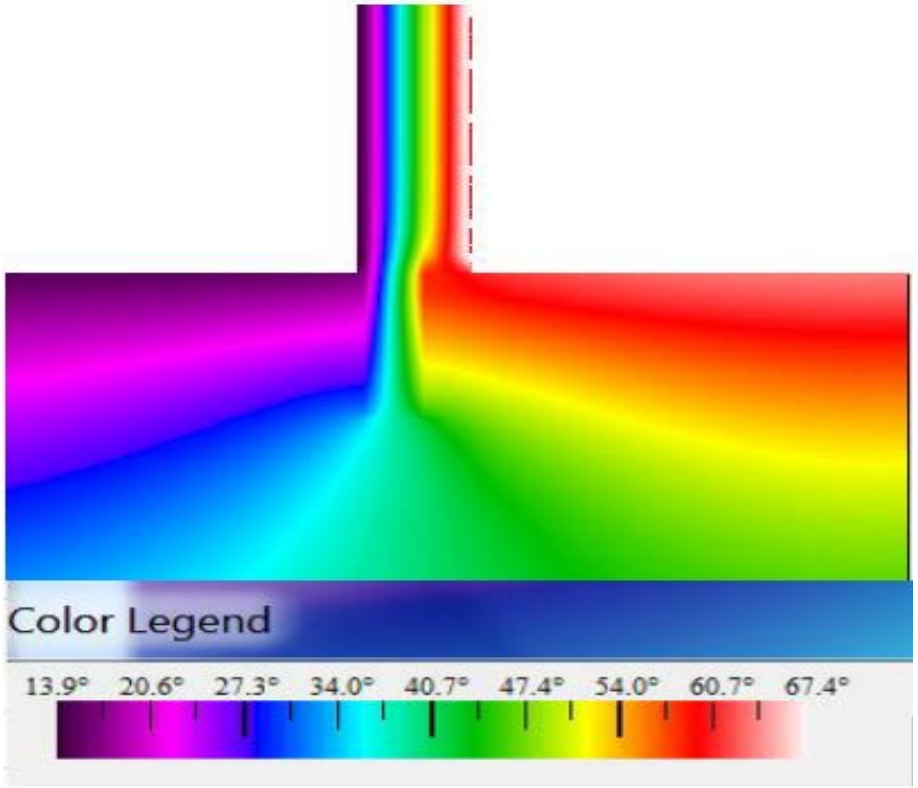
**Thermal Bridges' input**

**Each one positive or negative is accounted for**

## Thermal Bridge Report

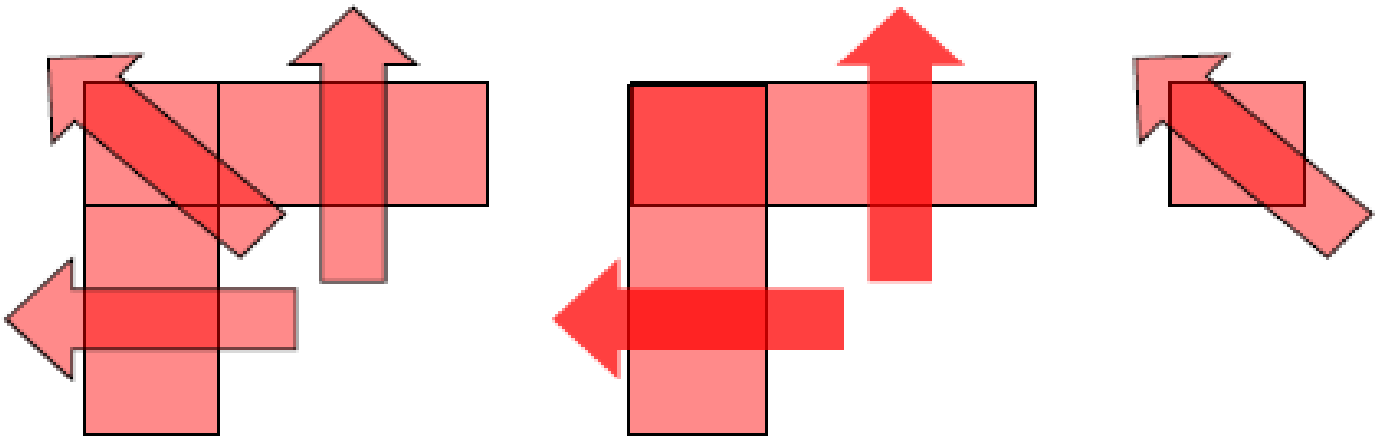
Project: 51 Pines - Waren VT - EnerPHit

| | | |
|---|---|---|
| U-value Floor U1 | 0.7999 | Btu/hr*ft2*F |
| U-value Wall U2 | 0.0177 | Btu/hr*ft2*F |
| Ufactor (2D) THERM | 0.0666 | Btu/hr*ft2*F |
| $\psi_e$ for PHPP | -0.769 | Btu/hr*f*F |



# ENERGY BALANCE
# COMPILING ENERGY LOSSES

**Thermal Bridge Pitfall**



$$L2D - (U1*A1 + U2*A2) = \psi*L$$

(from THERM)

**Evaluating the insulated wall as was being prescribed along with the uninsulated slab, the results are a large negative thermal bridge that can mislead the energy balance**

# ENERGY BALANCE OPTIMIZATION

**Mechanicals for supplemental heating/cooling & ventilation**

## Heating / Cooling

- Fujitsu 12000 BTU – Single Source located in the living room

## Ventilation

- Lunos e² – Two pairs located in the bedrooms and living room
- Lunos eGO – One unit in each bathroom

# 51 Upper Pines - / Warren VT
# Forecasted Heat Demand &Peak Heat Load

**The Passive House Retrofit has a heating demand of**
**only 7655 kBTU/yr for 1440 sqft floor home**
**and a Peak Heat Load of 5139 BTU/hr**

# First Phase of the Project
# The Roof Overhaul

# First of 7 lifts

# ISO sealed to insulation box


All Joints Carefully Taped

# First Phase of the Project
# The Roof Overhaul

12” PolyIso for R-83 Finished Roof

# First Phase of the Project
# Finished Roof

12” PolyIso for R-83 Finished Roof

# Execution of Second Phase Inside Slab Insulation

**Remove Old Floor and cover Slab with 5” of PolyIso**

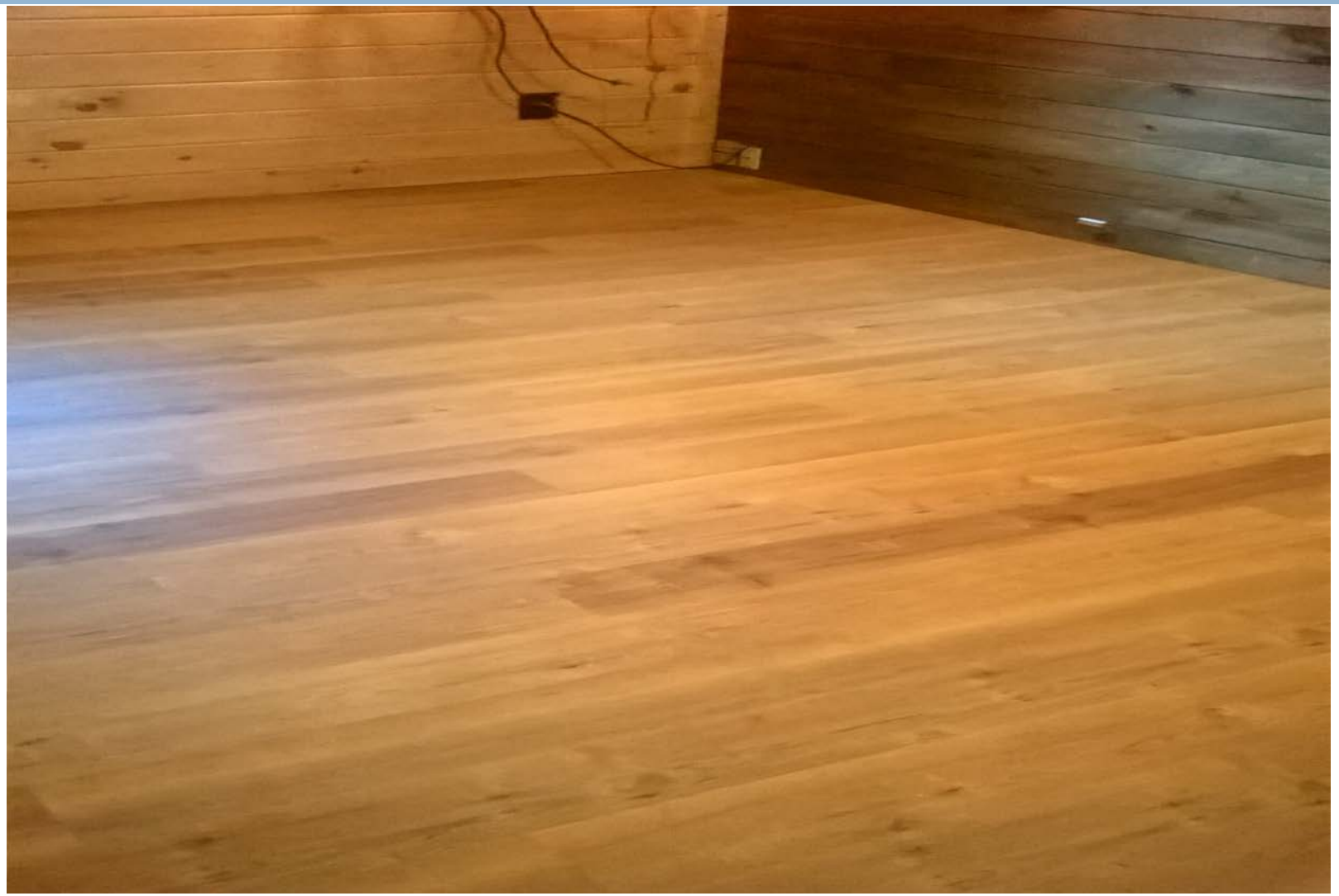
# Execution of Second Phase Inside Slab Insulation

**Interior floor plywood over ISO board**

# Execution of Second Phase Inside Slab Insulation

**Joints and perimeter air sealed**

# Execution of Second Phase Finished Floor



# Execution of Second Phase Outside Frost-Wall Insulation

**Dig Trench and cover Frost Wall with 6” of XPS**

# Execution of Second Phase Foundation Insulation Complete

# Foundation/floor insulated & Heat pump installed End Phase II

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Begin Phase III Sheathing Removed At South Wall

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

**Rear at chimney, actual insulation**

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Rear and West wall sill repair

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

East wall cantilevered beam fixed

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

stud with tape

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows


stud with tape

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

All joints sealed with tape

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

All joints/studs sealed with tape

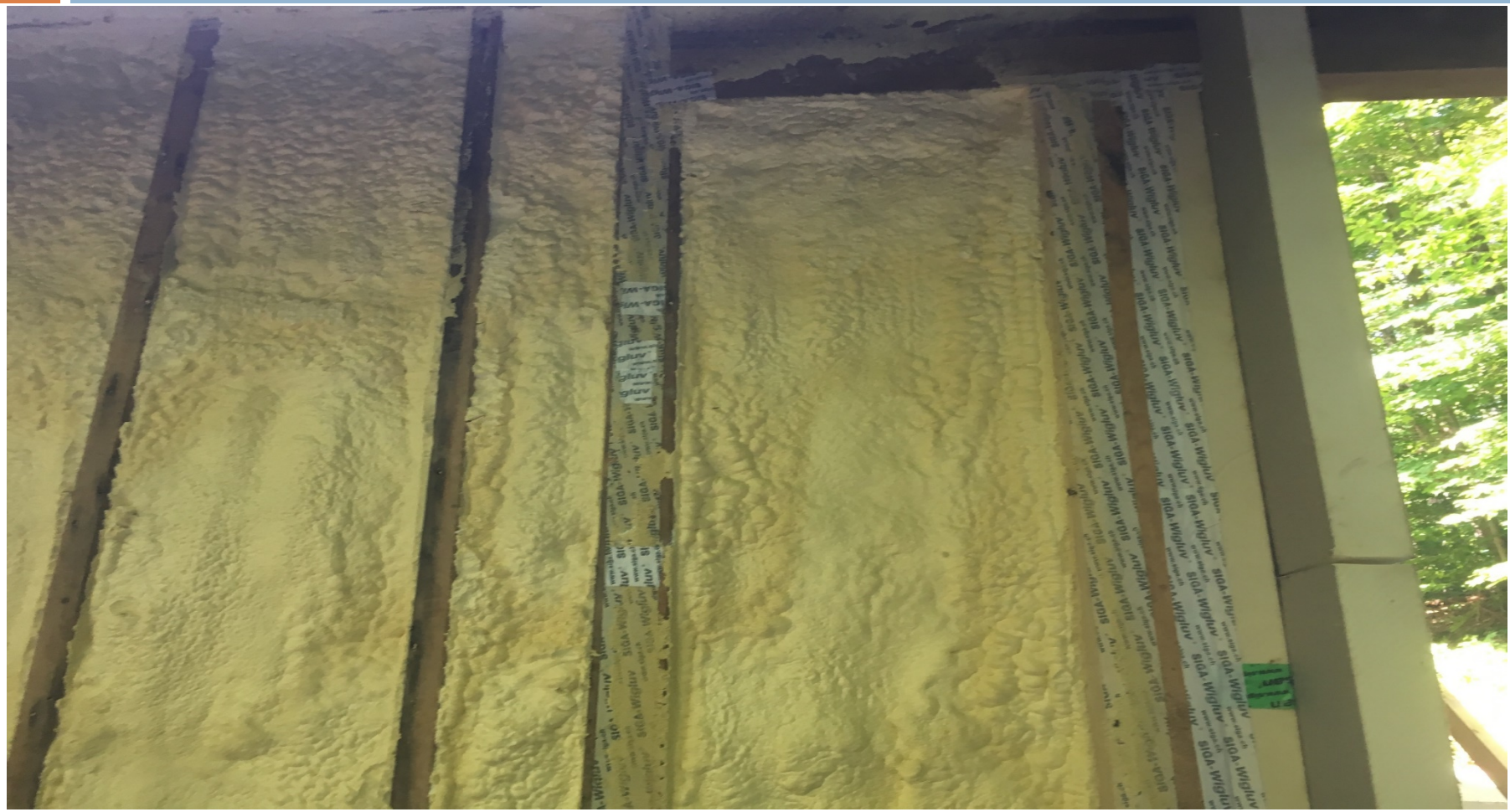
# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Insulation
Dam Rear
Wall Chimney
Cavity

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

East Side air sealed

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows




Taped joints overlapped corners

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Rear wall SPF complete

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

East wall foam complete

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Rough opening prep

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Sill, membrane, window

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Air and water sealed

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

South Wall Partially Foamed

# Third Phase
# Insulation of Walls and Replacement of Windows

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Rear wall
1st Layer
3” ISO

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

West Wall ISO Complete

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows


First layer of 3” ISO board with window box

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

1st layer ISO sealed, second layer installed

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Typical 1st layer sealing

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

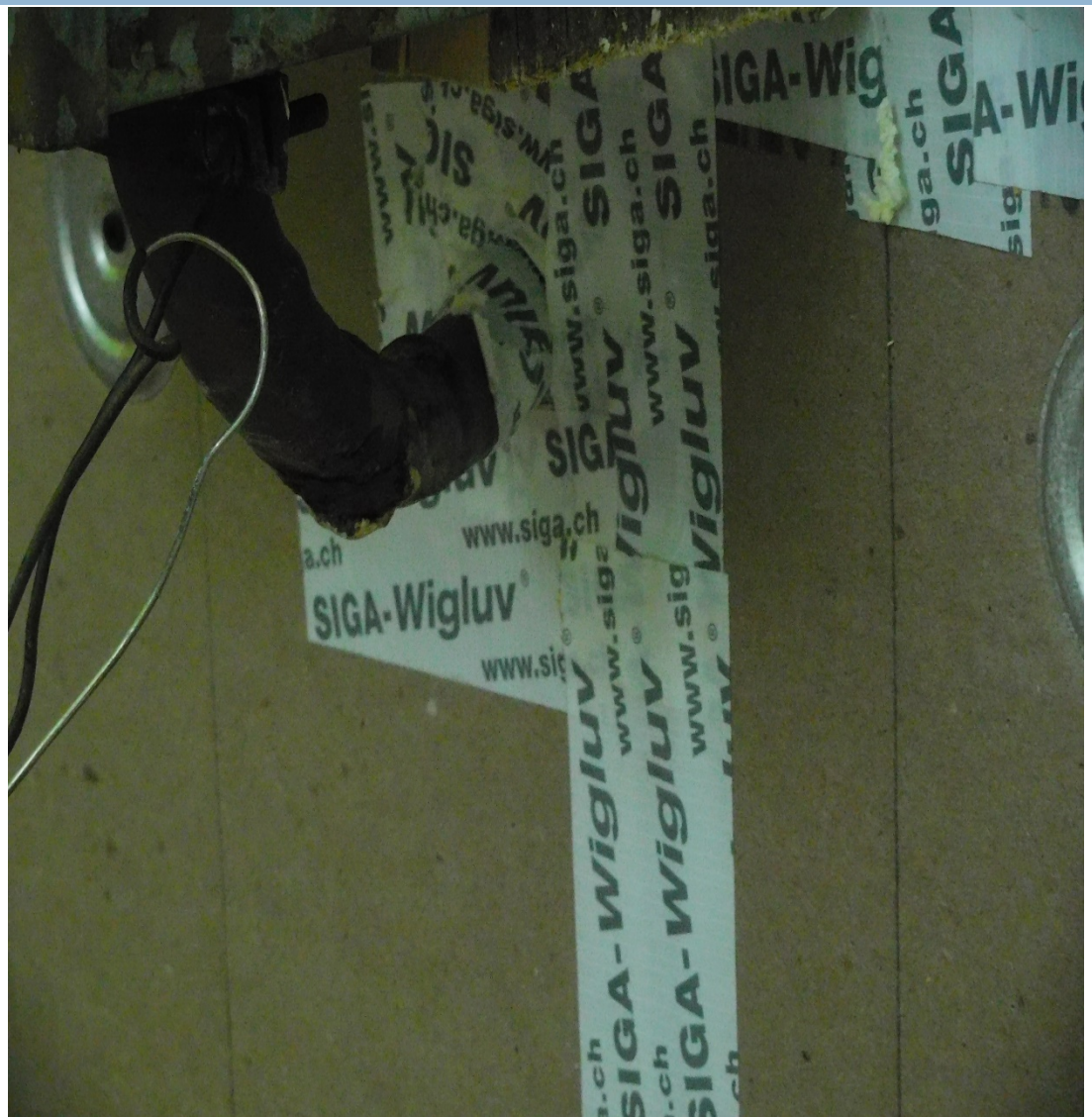
1st ISO taped to XPS found insulation

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Rear 2nd Layer ISO w/strapping

# Third Phase
# Air-Sealing/Insulation of Walls and Replacement of Windows

Air seal penetrations



# Third Phase
# Siding Finishing

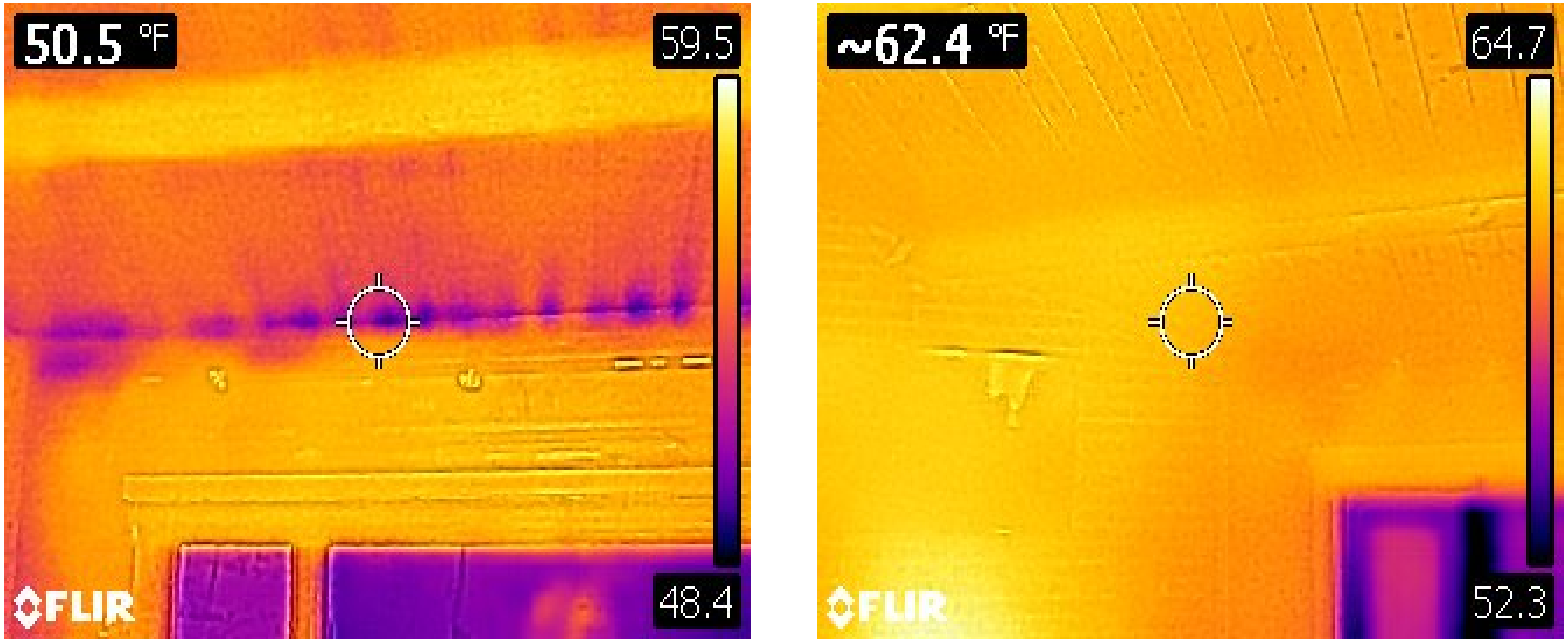
# Third Phase
# Siding Finishing

# End
# Third Phase

# End Results
# Third Phase

## Living Room East

**Before - After**



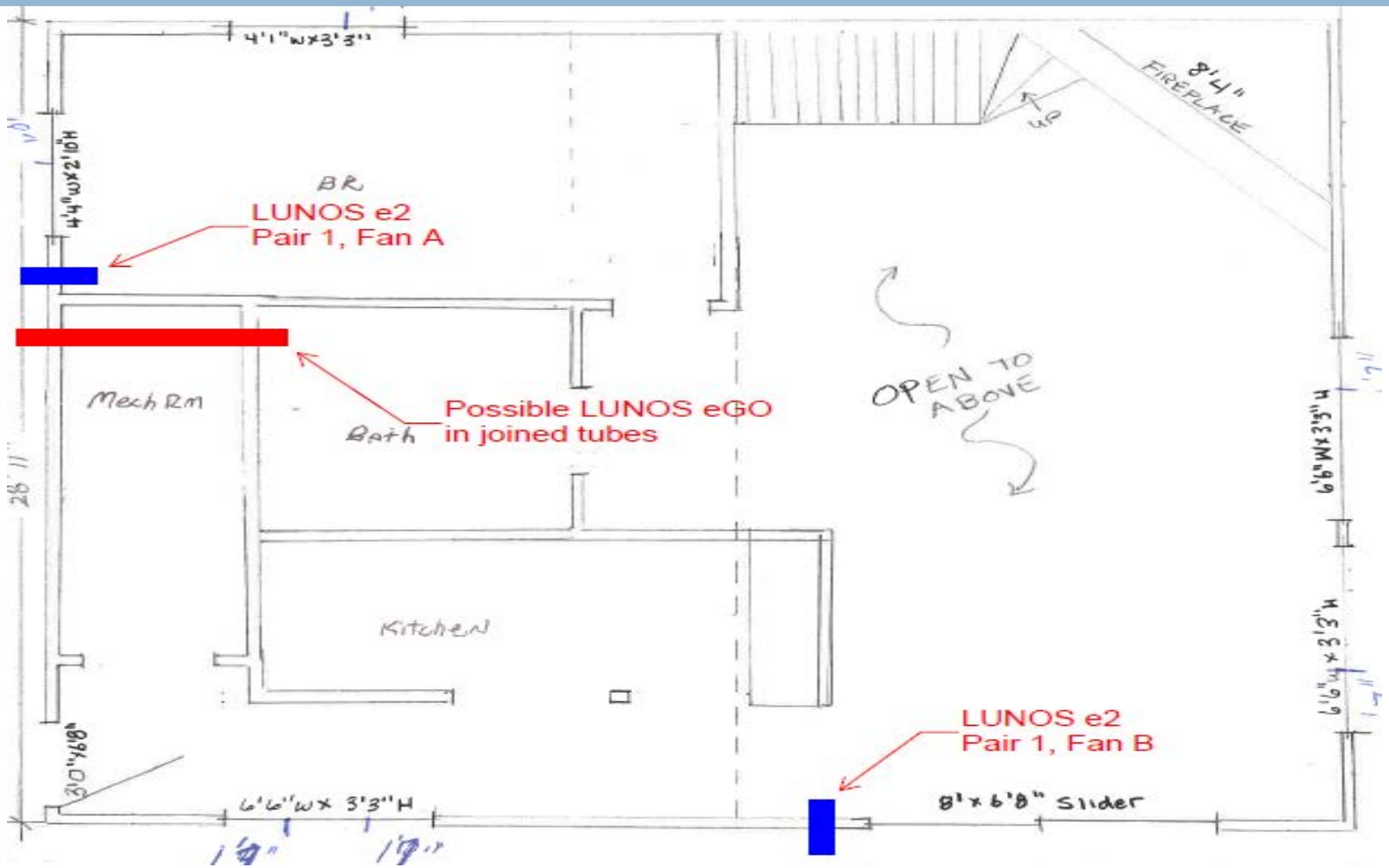
# Mechanicals

**Ductless Mini-Split Heat Pump Outdoor unit -- Indoor unit**

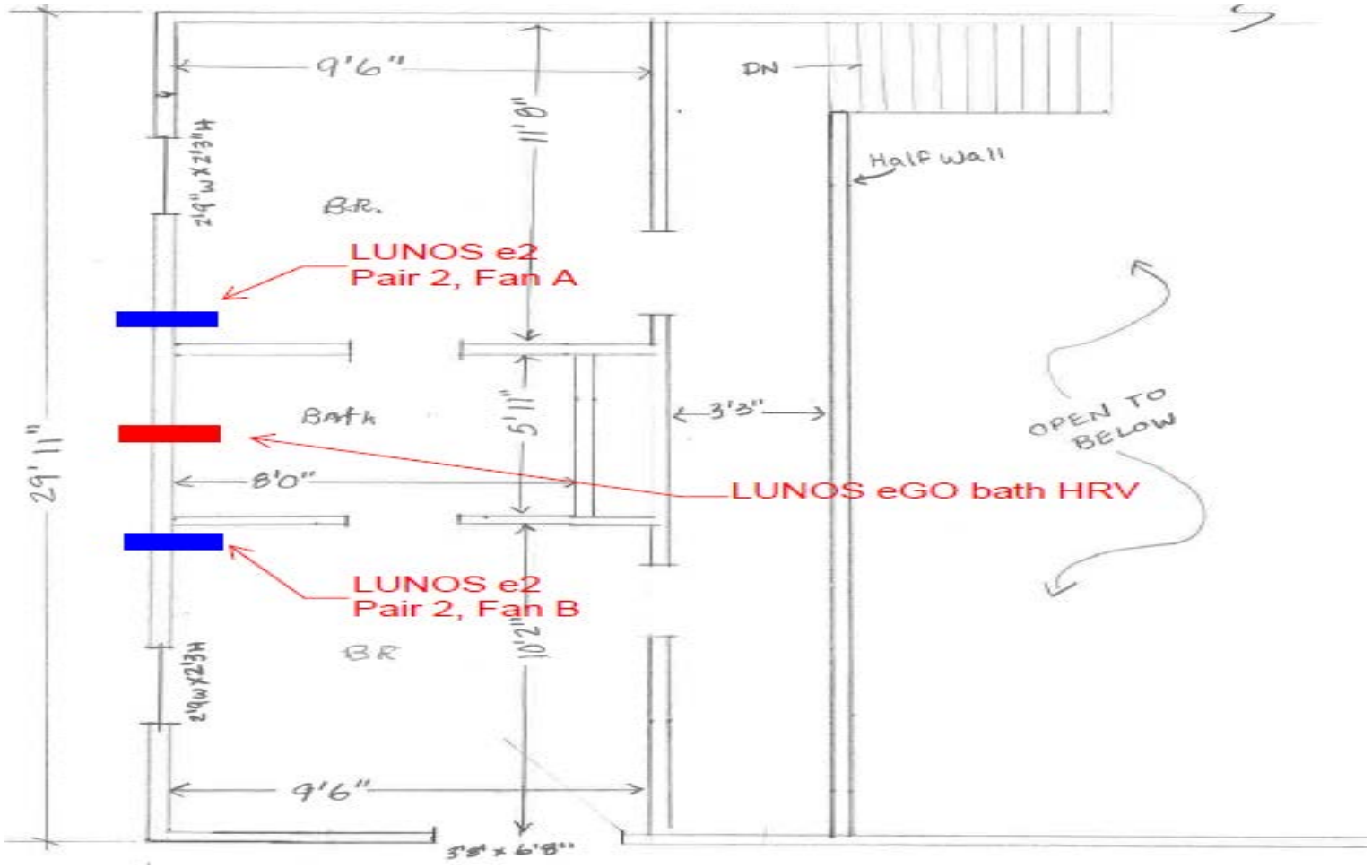
**Lunos e²**

**Lunos eGO**

# Ventilation ERV's Locations 1st Floor



# Ventilation ERV's Locations 2nd Floor



# Final Results
# Blower Door Test

The final Blower Door Test was

**48cfm@50Pa**

a reduction of **97%** air infiltration from the**1740 CFM** (0.48 cfm/sf of shell area @ 50Pa) in the initial condition

# Final Results
# Blower Door Test

**48cfm@50Pa**

Is equivalent to

**0.013 cfm/sf of shell area @ 50Pa (0.27 ACH50)**

# Passive House Planning Package – PHPP modeling comparison

## Estimated BEFORE Renovation

| | | | | | |
|---|---|---|---|---|---|
| Space heating | | Heating demand | 65.25 kBTU/(ft²yr) | 870% of | 7.50 kBTU/(ft²yr) |
| | | Heating load | 36.58 BTU/(hr.ft²) | 717% of | 5.10 |
| Primary energy | Heating, cooling, auxiliary electricity, | dehumidification, DHW, lighting, electrical appliances | 118.0 kBTU/(ft²yr) | 167% of | 70.6 kBTU/(ft²yr) |

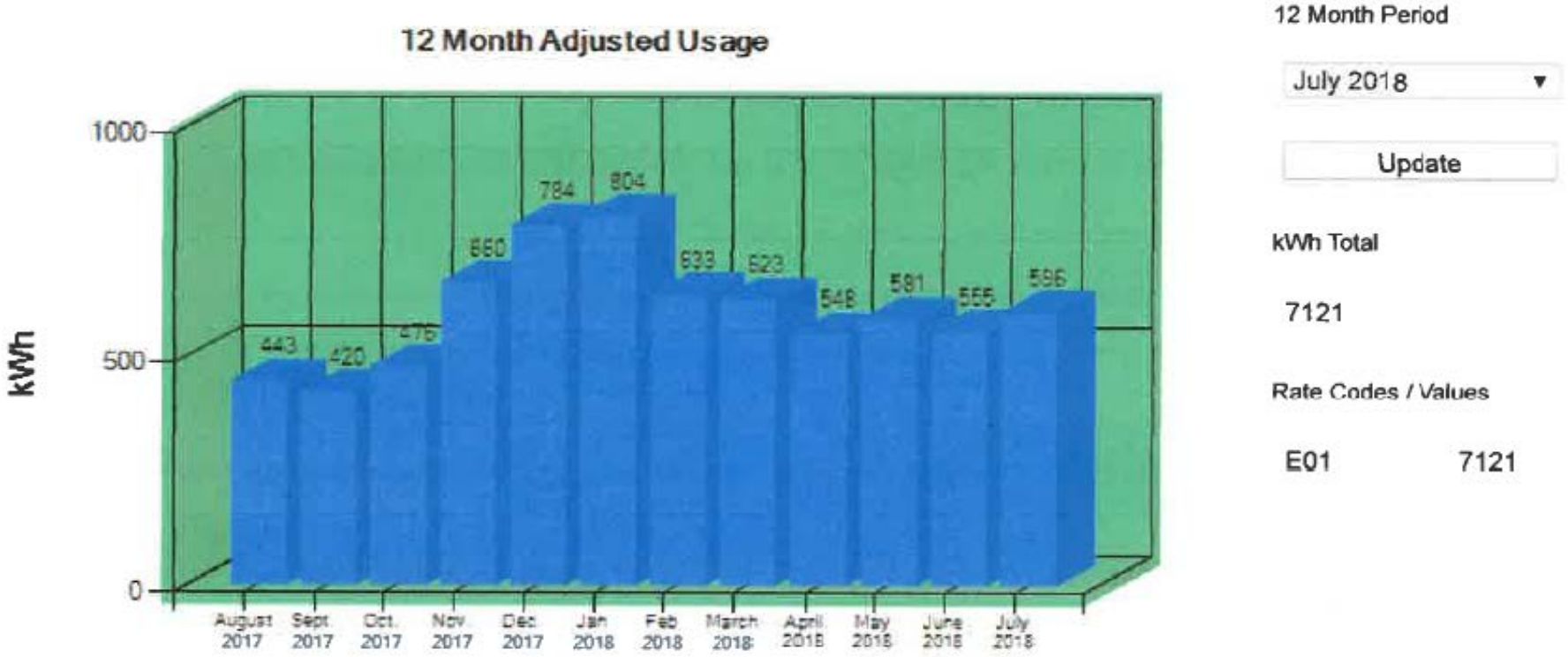
# Passive House Planning Package – PHPP modeling comparison

## Forecasted with Renovation

| | | | | | | |
|---|---|---|---|---|---|---|
| Space heating | | Heating demand | 6.39 | kBTU/(ft²yr) | 85% of | 7.50 kBTU/(ft²yr) |
| | | Heating load | 4.29 | BTU/(hr.ft²) | 84% of | 5.10 |
| Primary energy | Heating, cooling, auxiliary electricity, | dehumidification, DHW, lighting, electrical appliances | 54.5 | kBTU/(ft²yr) | 77% of | 70.6 kBTU/(ft²yr) |

**90% Reduction in Heating Demand**

# 51 Upper Pines - / Warren VT
# Actual Energy Usage




Actual kW usage metered for 12 months 8-2017 through 8-2018 = 7121 kW on site compared to 7750 kW allowed per PHIUS+ 2015 (6200 kW/person PE for 4 occupants)

# THE TAKE-AWAY

**If we want to make renewable energy sustainable we must start by eliminating the energy waste to the last kWatt possible**

# Thank you

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NEW ENGLAND CONSTRUCTION CO.

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