



NECCO INC

NEW ENGLAND CONSTRUCTION CO.



Energy Efficient Buildings



Incremental Passive House Retrofit of a House in Vermont -
Climate Zone 6

13th Annual North American Passive House Conference

Boston, MA
Sept. 21-22, 2018

www.eplusbuildings.com

PHIUS Climate Specific Criteria

PASSIVE STANDARDS IN VARYING CLIMATES

Seattle

State	WA
Location	Tacoma Intl AP
Zone	4C
Annual Heating Demand...	5.4
Annual Cooling Demand...	1
Peak Heating Load Btu/...	3.3
Peak Cooling Load Btu/...	3.4
Manual J Peak Heating ...	5.6
Manual J Peak Cooling ...	4.8

USA PHIUS+ 2015 Building Criteria

Heating Demand (Site):	1 - 12 kBTU/Ft ² -YR
Cooling Demand (Site):	1 - 21.4 kBTU/Ft ² -YR
Peak Heat Load :	0.8 - 5.4 BTU/Ft ² -Hr
Peak Cooling Load:	1.8 - 8.9 BTU/Ft ² -Hr
Total Energy Demand (Source):	Beds+1 / 6200 kWh/PERSON-YR (Temporary) Beds+1 / 4200 kWh/PERSON-YR (Future)
Air Tightness:	0.05 cfm/gross sqft shell @ 50 pa 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

51 Upper Pines – Warren VT

Case History

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



51 Upper 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.

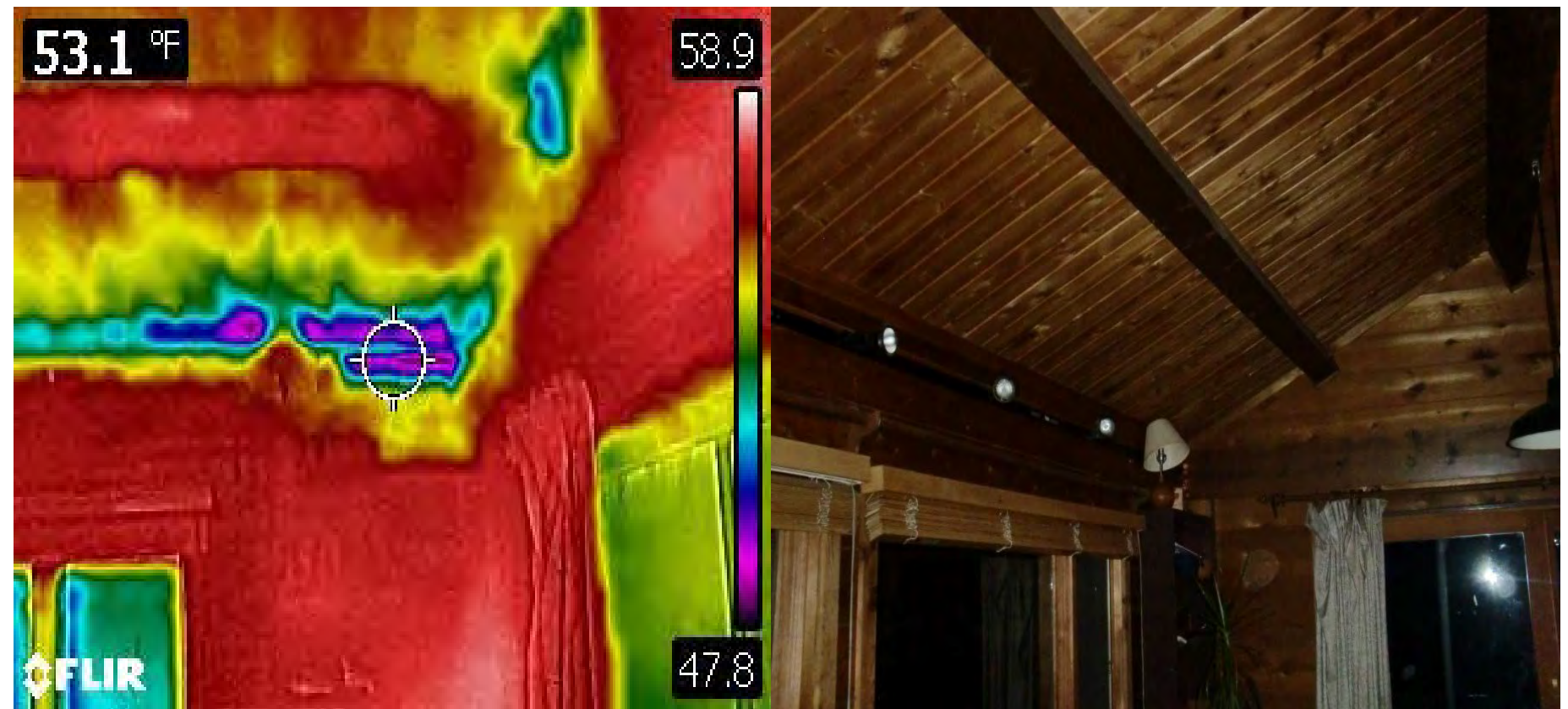
The 2 bathrooms have poor ventilation with potential to mold formation. One fan was pulling only 6-10 CFM, while a BR-fan should be pulling 50-80 CFM.



51 Upper Pines – Warren VT

Initial Condition

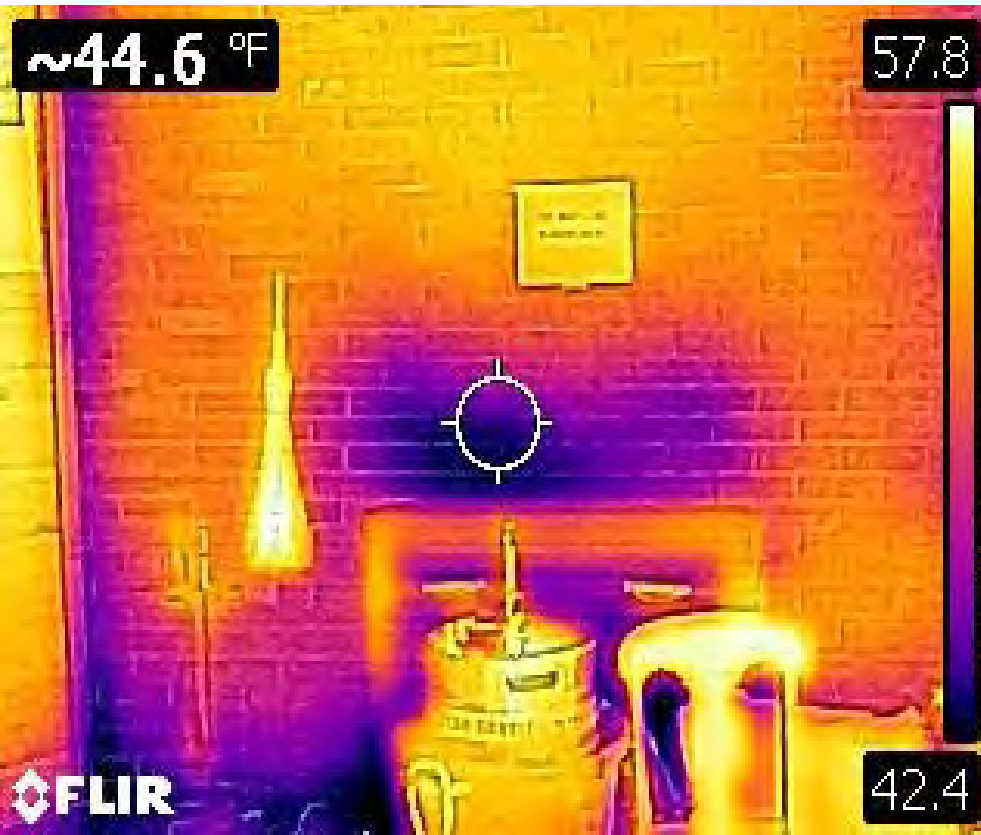
Thermal Bridges Everywhere



51 Upper Pines – Warren VT

Initial Condition

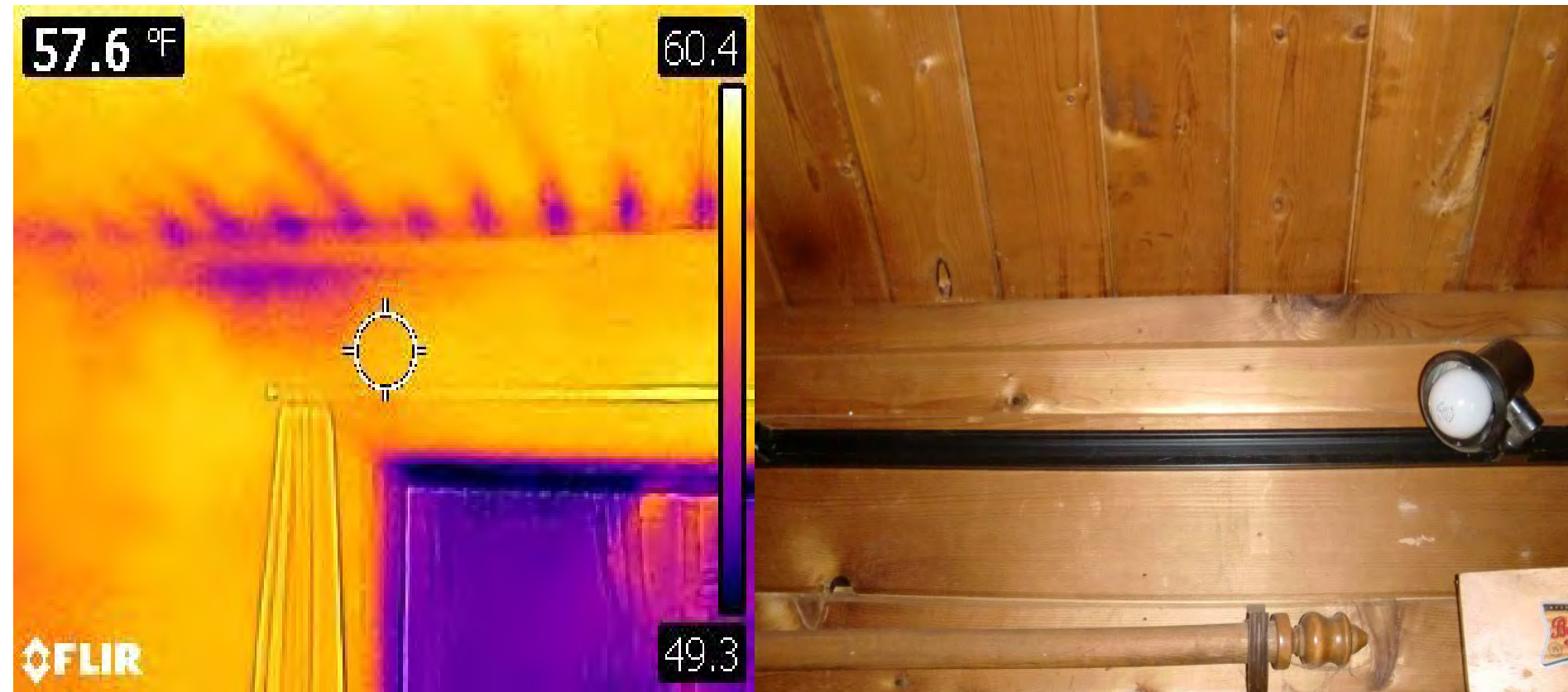
Thermal Bridges Everywhere



51 Upper Pines – Warren VT

Initial Condition

Air Leaks Everywhere



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

51 Upper 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

51 Upper Pines – Warren VT

1st Phase Implementation

Energy Balance with PHPP – Climate Input

EnerPHit planning: CLIMATE DATA

Building: **51 Pines - Warren VT**

Climate building: Montpelier AP VT

Region: **User Data**

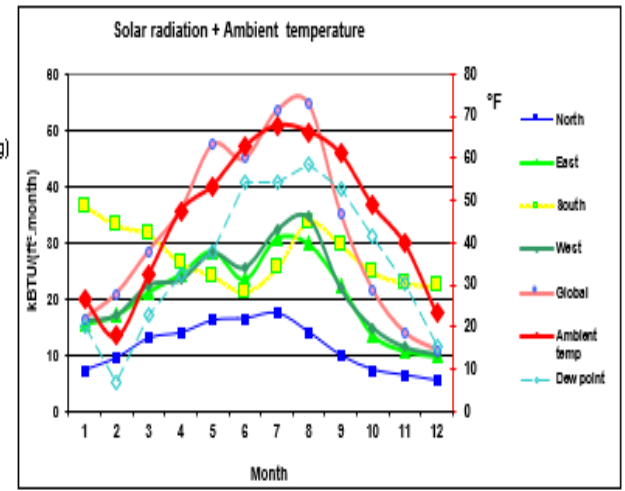
Climate data set: **MONTPELIER AP VT - Montpelier AP VT**

Weather station (altitude): **1125.3** ft

Building location (altitude): **896** ft

Transfer to annual method (Annual Heating)

H_T	222	d.y/yr	
Heating Degree Days, G_H	7468	F.d.y/yr	
Monthly data: MONTPELIER AP VT - Montpelier AP VT	North	66	kBTU/(ft ² yr)
Annual data:	East	118	kBTU/(ft ² yr)
Use annual climate data set: no	South	200	kBTU/(ft ² yr)
Results:	West	121	kBTU/(ft ² yr)
Annual heating demand	Horizontal	158	kBTU/(ft ² yr)
Heating load		6.39	kBTU/(ft ² yr)
Primary energy		4.29	BTU/h.ft ²
		54.46	kBTU/(ft ² yr)



	Month	Month												Heating load		Cooling load	
		1	2	3	4	5	6	7	8	9	10	11	12	Weather 1	Weather 2	Weather 1	Weather 2
Parameters for PHPP calculated ground temperatures:	Days	31	28	31	30	31	30	31	31	30	31	30	31				
	MONTPELIER AP VT - Montpelier AP	Latitude : 44.2	Longitude : -72.6	Altitude ft: 1125	Daily temperature swing Summer (F)						21.4	Radiation data: kBTU/(ft ² month)		Radiation: BTU/hr.ft ²		Radiation: BTU/hr.ft ²	
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.ft².°F

R-Value: **82.6** hr.ft².°F/BTU

ENERGY BALANCE

COMPILING ENERGY LOSSES

Thermal Bridges' input

Each one positive or negative is accounted for

Thermal Bridge Report

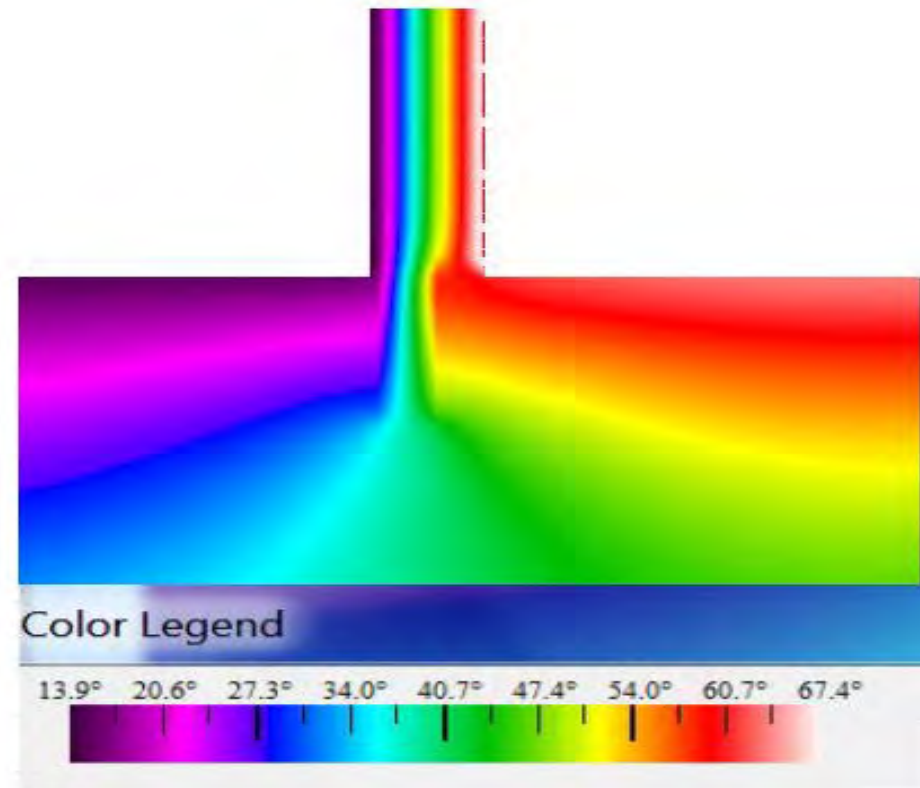
Project: 51 Pines - Waren VT - EnerPHit

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

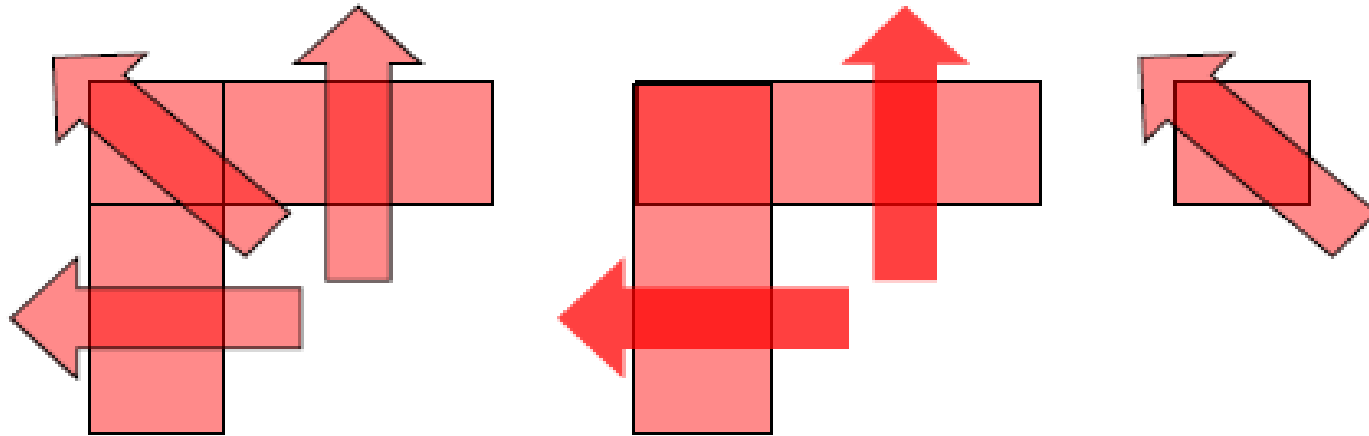
ψ_e for PHPP -0.769 Btu/hr*f*F



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



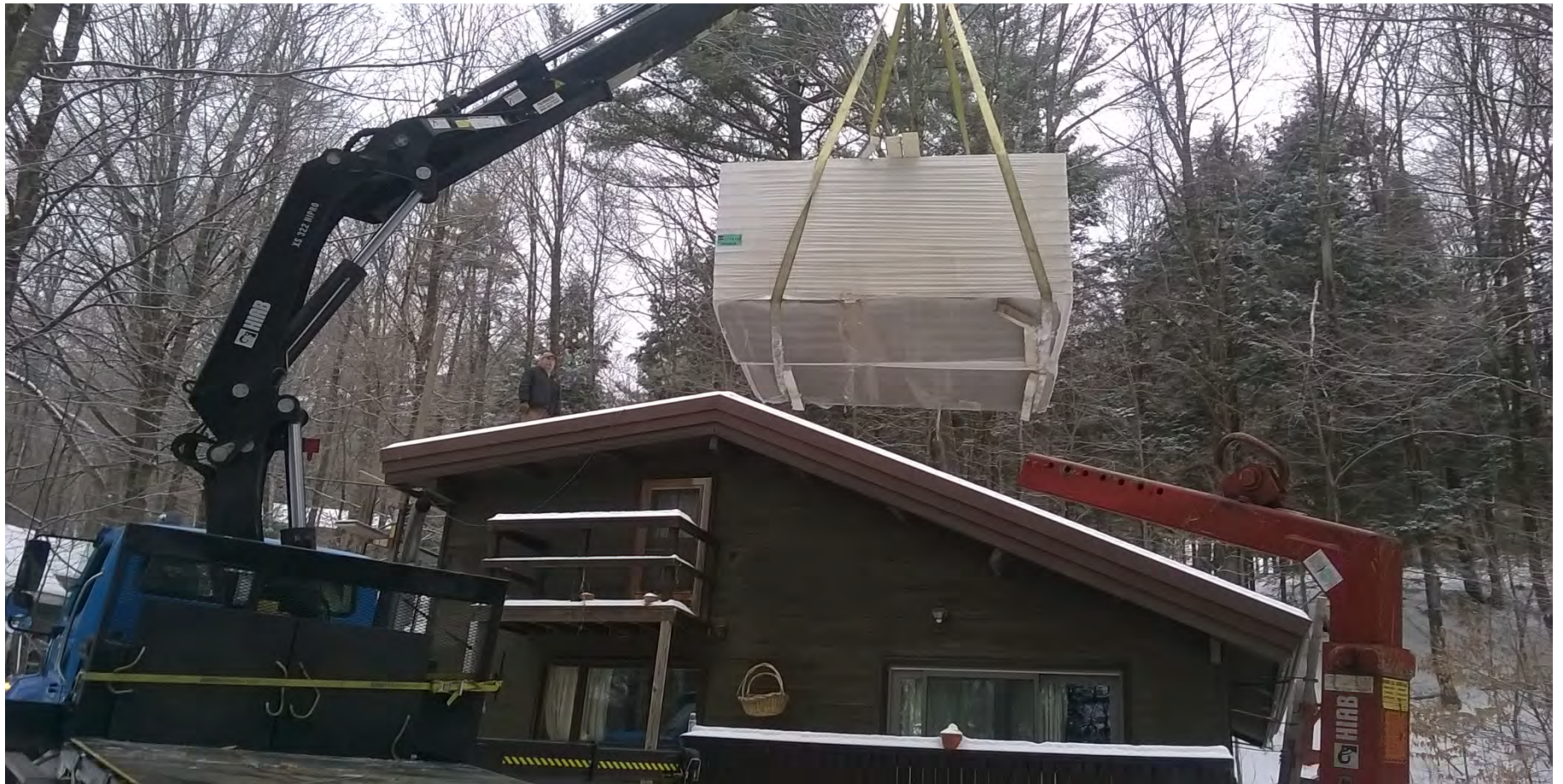
**The Passive House Retrofit has a heating demand of
only 7655 kBTU/yr for 1440 sqft floor home
and a Peak Heat Load of 5139 BTU/hr**

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



Naked with air sealing at joints

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



West Wall Foam Complete

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



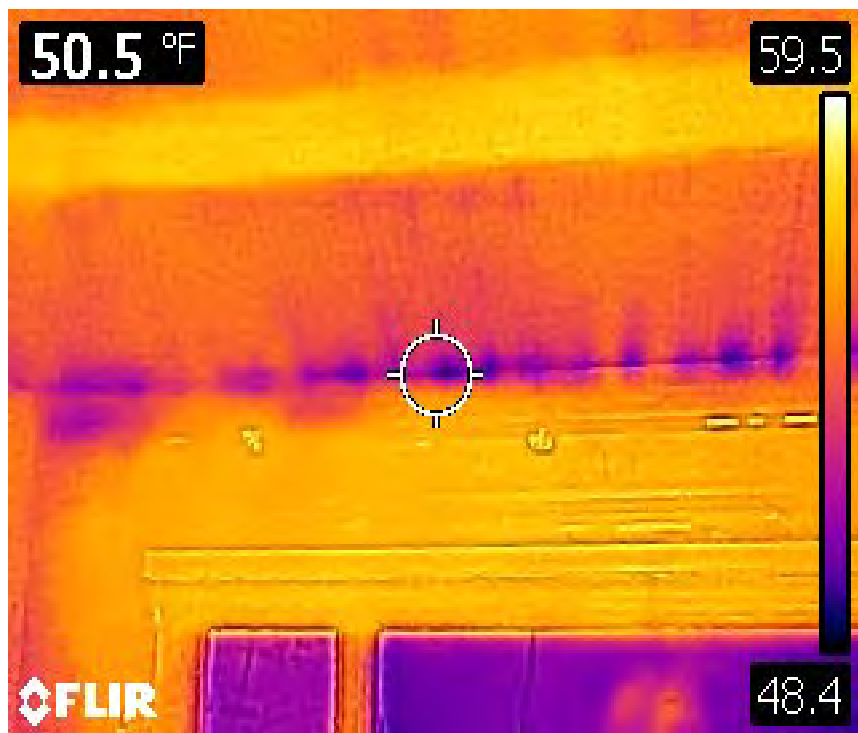
End Results Third Phase

Living Room East

Before

-

After



Mechanicals



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

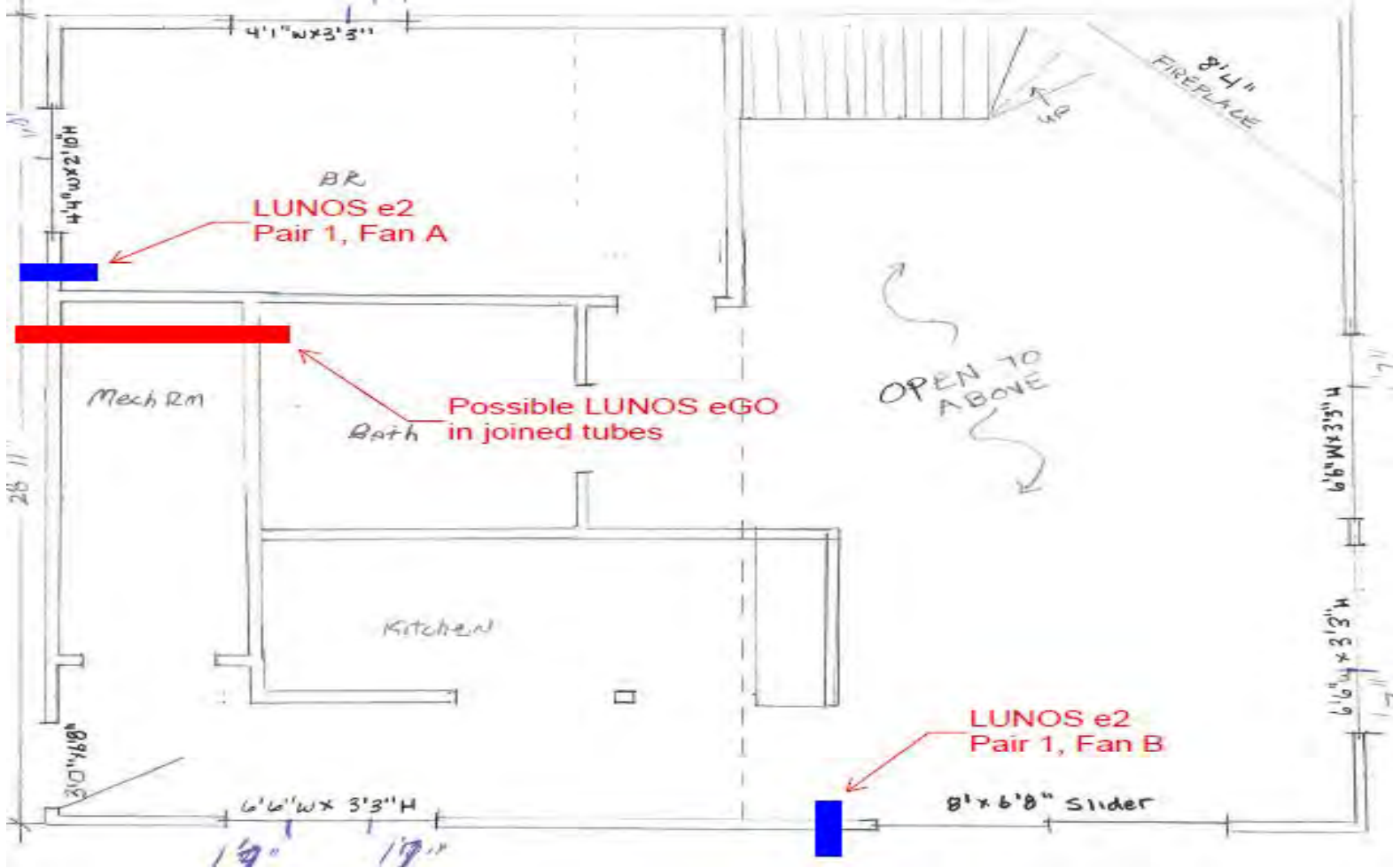


Lunos e²

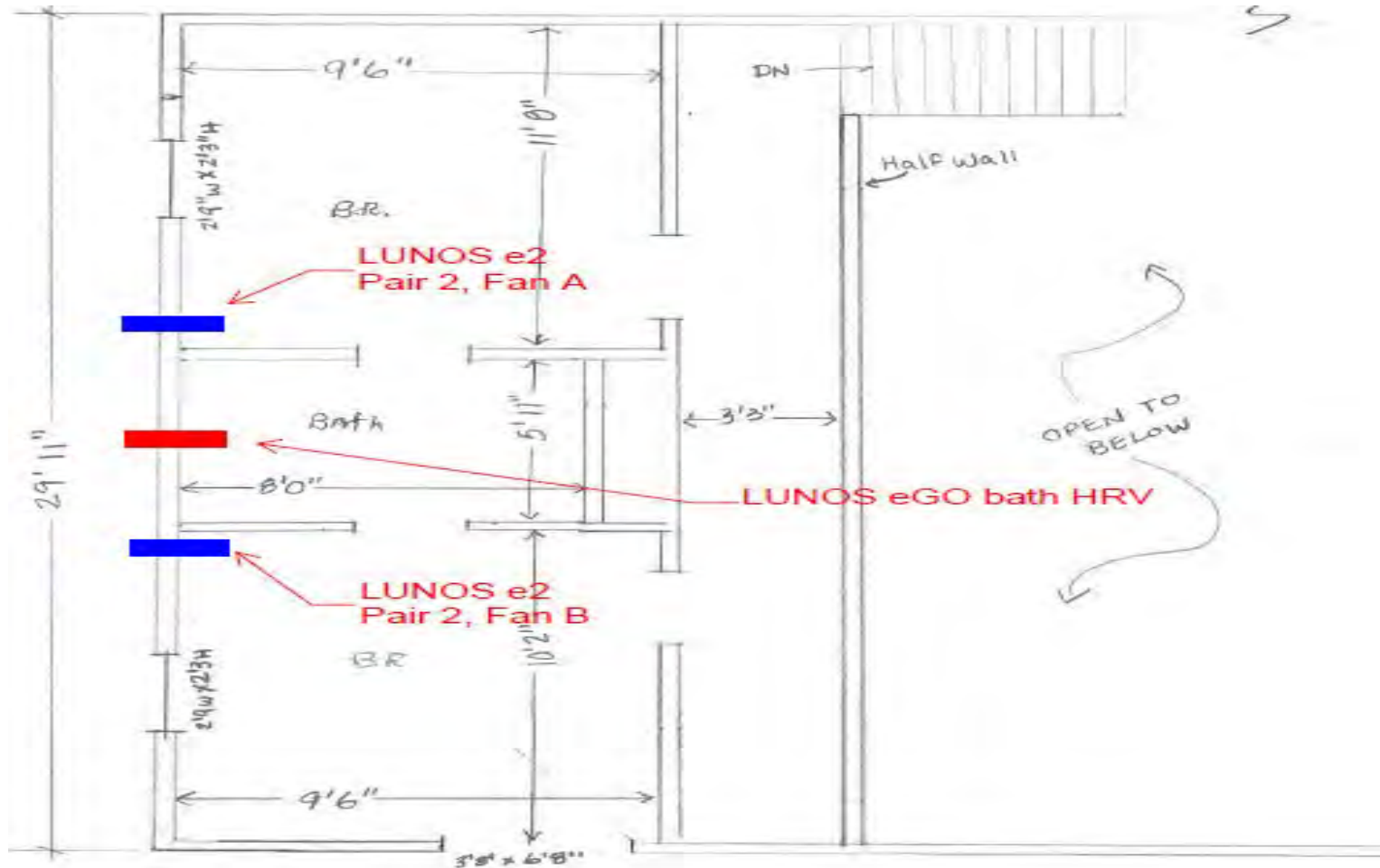


Lunos eGO

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/(ft²·yr)

870% of

7.50 kBTU/(ft²·yr)

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/(ft²·yr)

167% of

70.6 kBTU/(ft²·yr)

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

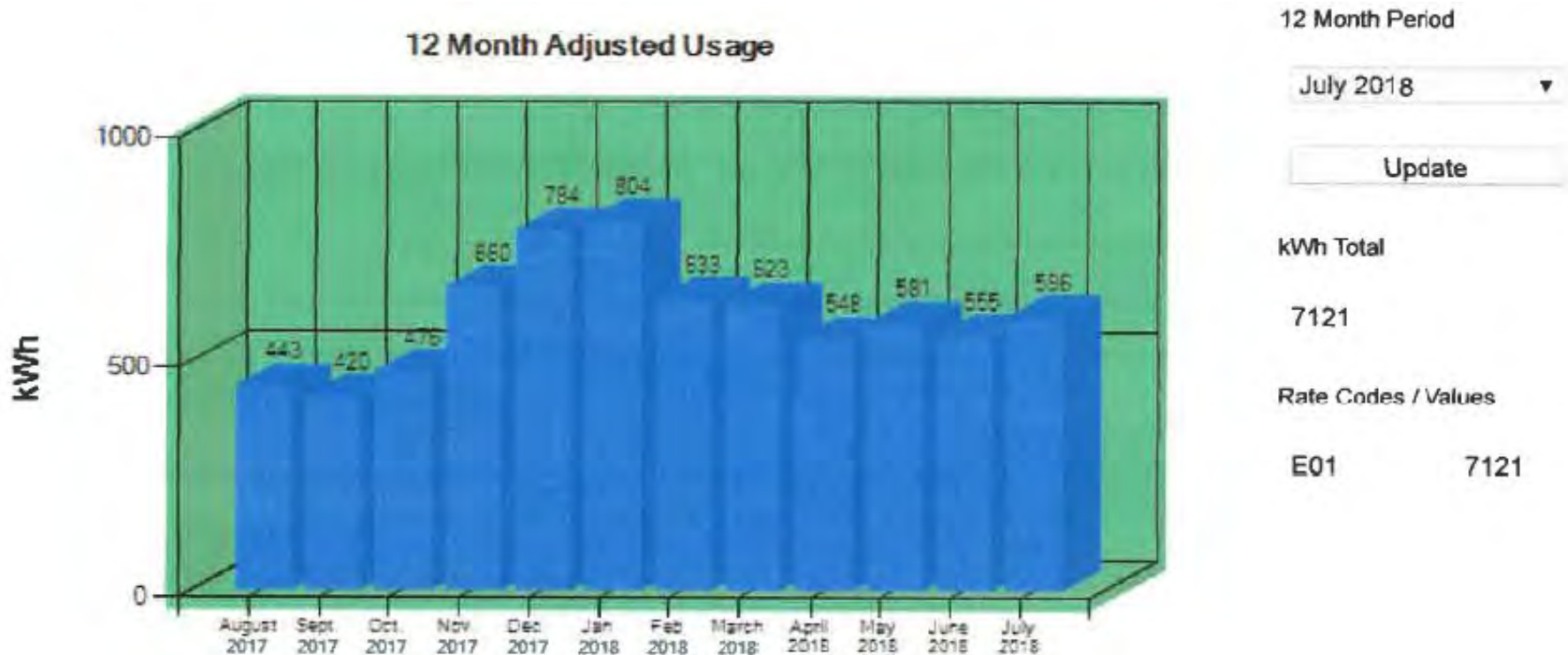
Heating, cooling, auxiliary electricity, dehumidification, DHW, lighting, electrical appliances

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



Because we care about you saving money and living healthy, and care about the environment, our legacy and our future, we make

energy efficient buildings.

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