Bindley Residence

A Net Zero Deep Energy Retrofit on Squam Lake NH

Before…


After…

Team

- **Home Owner**

  Jane Bindley
- **Design/Build**

  Ben Southworth

  www.garlandmill.com
- **Energy Consultant**

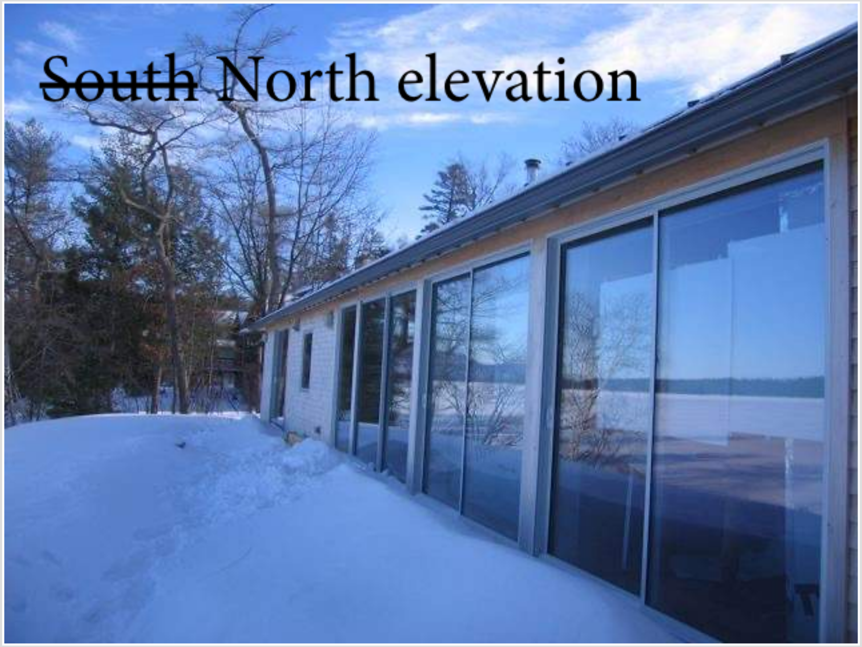
  Marc Rosenbaum, PE

  www.energysmiths.com
- **Engineer** - James Petersen, PE

  www.petersenengineering.com

The owner was inspired by a session on Zero Net Energy Homes at Building Energy and wanted her renovation to be ZNE. However, Squam Lake is on the north side…and a steep hillside with trees is on the south, with Route 3 beyond. So the envelope is extraordinary, to compensate.

This is a second home with intermittent occupancy. When occupied it can be occupied by large groups. The first year the house was kept at comfort temperature to get data.



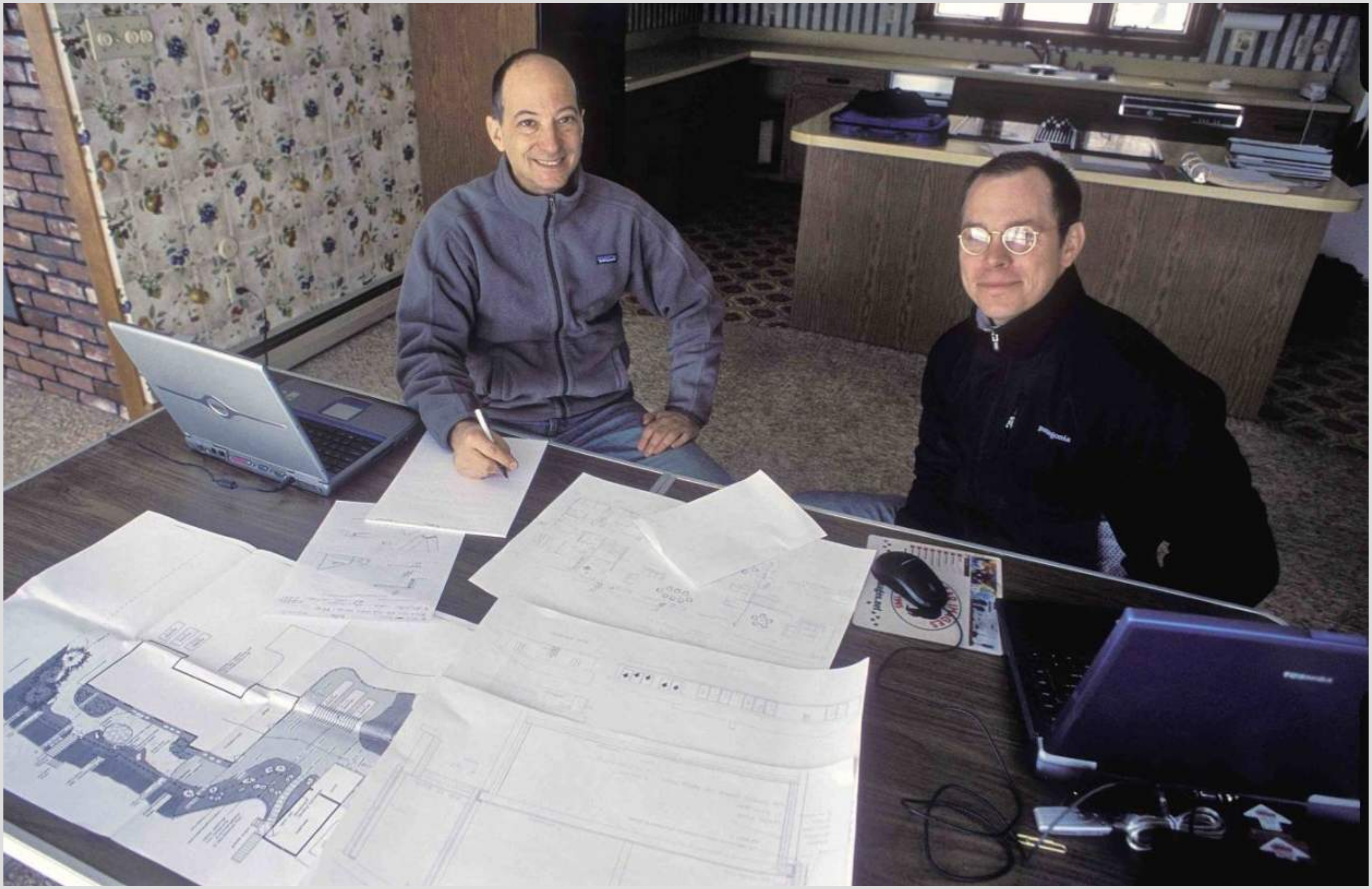
Sub-metering has enabled study of energy consumption by end use.

Winter view to the lake

Jane and Ben’s shared vision

- Shoot for carbon neutral
- Aim for net zero to reduce carbon emissions
- Provide lots of natural light and ventilation
- Preserve and help to improve lake’s water quality
- Gain universal access for house (and lake too, if possible)
- Use local, sustainably produced, and non-toxic products wherever possible
- Recycle and salvage as much as we can

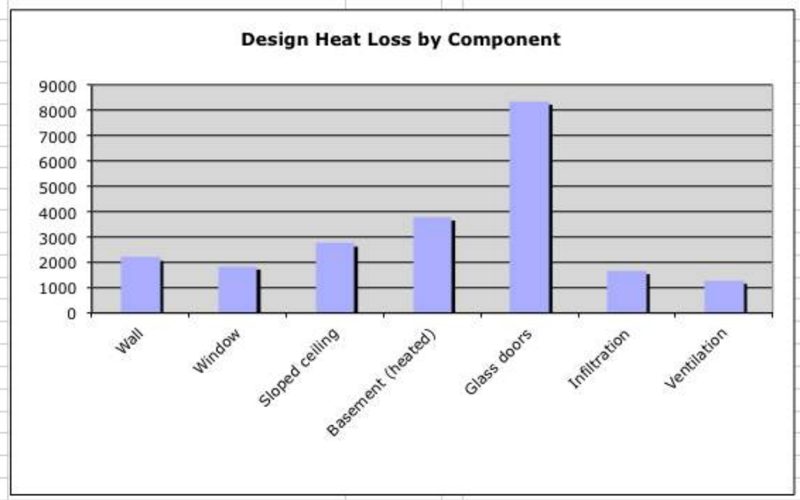
Marc making sure Ben delivers on vision



Apparently Patagonia was a sponsor…

Energy Model

	A	B	C	D	E	F	G	H	I	J
1	**Heat Loss Calculator**	This is a simple spreadsheet calculator to estimate annual energy use for heating for a house - not a substitute for hourly simulation								
2	**User inputs go into cells with yellow fill**									
3				Design Temperature Difference	80					
4				Max delta T to basement	47		Gross Heated Floor Area	3500		
5	R VALUES			Average delta T to basement	23		Heating Degree Days	7554		
6	Wall R Value	52.00		Flat Ceiling R Value	40.00		Frostwall (heated) R value			
7	Floor over unheated space R Value			Skylight R Value			Basement Wall R Value	42.00		
8	Window R Value	5.00		Opaque Door R Value	5.00		Underslab R Value	20.00		
9	Sloped Ceiling R Value	73.00		Glass Door R Value	5.00					
10	Floor over outdoors R Value									
11										
12	ELEMENT	AREA	AU	Heat loss BTU/hour						
13	Wall	1431	27.5	2201			Wall	2201		
14	Floor over outdoors	2214	0.0	0			Window	1856		
15	Window	116	23.2	1856			Sloped ceiling	2762		
16	Sloped Ceiling	2520	34.5	2762			Basement (heated)	3790		
17	Flat Ceiling	0	0.0	0			Glass doors	8376		
18	Skylight	0	0.0	0			Infiltration	1677		
19	Opaque Door	0	0.0	0			Ventilation	1296		
20	Glass Door	524	104.7	8376				21958		
21	Floor over basement	0	0.0	0						
22	Basement wall above grade	191								
23	Basement wall below grade	1227								
24										
25		PERIMETER								
26	Slab on grade (heated space)	0	0.0	0						
27	Basement Wall (heated space)	222	47.4	3790						
28	INFILTRATION Volume	ACH	Equiv. AU	CFM average air leakage	19					
29	33862	0.03	21.0	1677						
30	Ventilation	CFM								
31		60	16.2	1296						
32										
33	AU Conduction to outdoors only	237								
34	AU Conduction to basement only	0		Shell ft2	6243					
35	AU Total to outdoors	289		Blower door CFM50	330					
36	Design Heat Loss, BTU/Hr	23132		Electric use, kWh/month	300					
37	Design Heat Loss, kW	6.8		Electric use, kWh/year	3600					
38	Design Heat Loss/ft2, BTU/Hr/ft2	6.6		DHW use, BTU/year	3.8E+06					
39				DHW use. kWh/year	1127					
40	Gross annual heat load, BTU/year	5.16E+07		Total net thermal use, BTU/year	3.2E+07					
41	Net annual heat load, BTU/year	2.8E+07								
42	Boiler efficiency	80%								
43	Net annual heat load, gals. oil/year	255								
44	Net annual heat load, kWh	8298								
45	COP of heat pump	3		Total electric usage heat pump plus household	7494					
46	Net annual heat load, kWh, w/heat pump	2766		kW PV required for ZNEH	6.52					
47										
48										
49										
50										



Heat Loss Calcs | Take-offs | Air leakage | Basement-ground loss | Monthly heat loss | Solar heat gains | DHW

Inputs to the energy model

• Annual heating degree days 65F	7554
• Design temperature	-15˚F
• Floor area with conditioned basement	3400
• Shell area, ft2	6243
• Window/door area, ft2	568
• COP of ground source heat pump	3.0
• Predicted annual PV production, kWh	6800

- R-values: wall R-52 Roof R-73 basement wall R-40, basement floor R-25; windows and doors R-5.5
- Design ACH, CFM50: 0.6 ACH, 330 CFM50

Envelope strategies

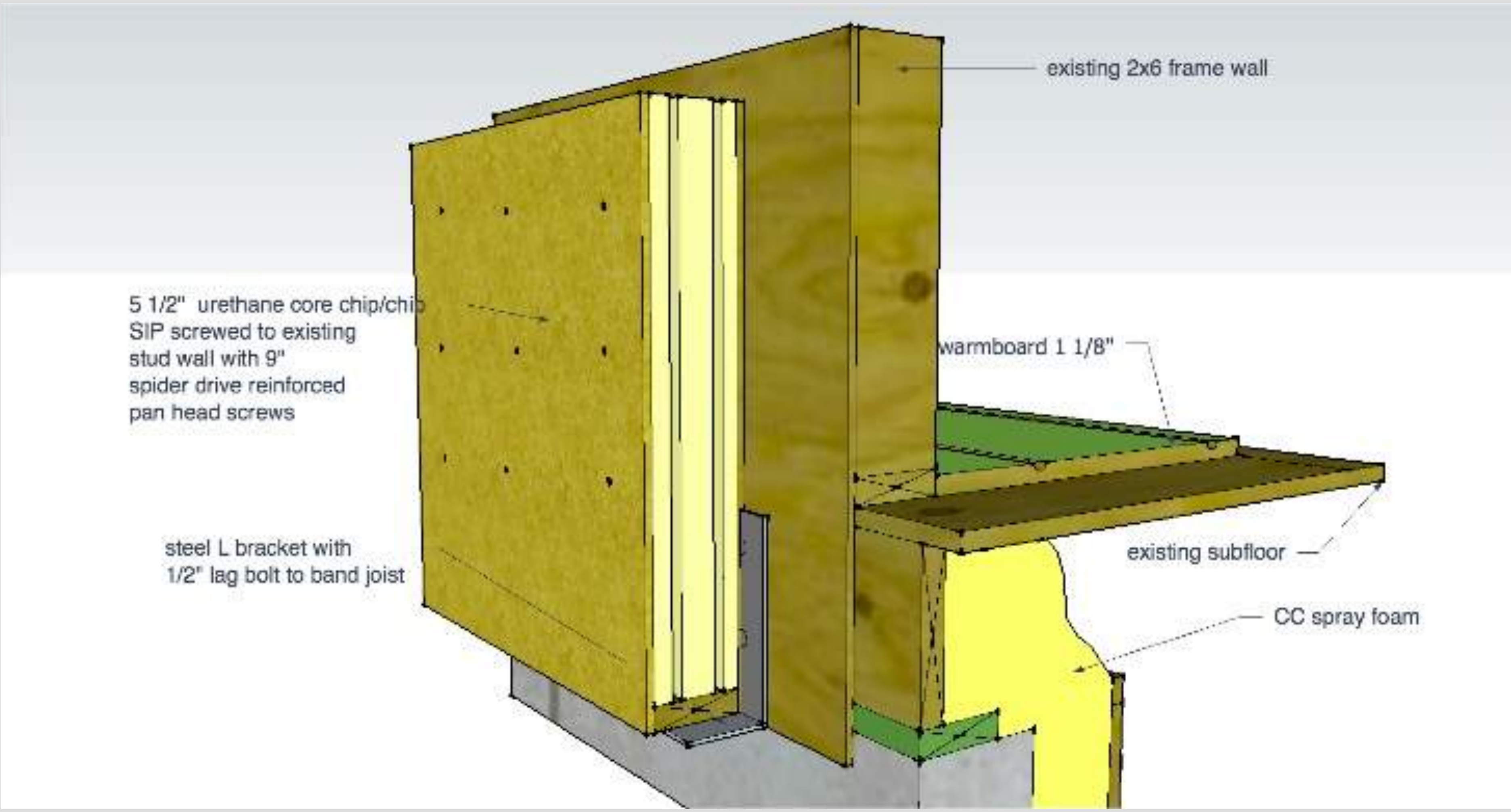
- Existing sheathing air barrier sealed with peel-and-stick tape
- Eaves cut off for AB continuity
- Urethane foam stress skin panels on roof and walls - forms new overhang for the roof – 5-1/2 inch foam core
- Four inches of rigid foam over the existing slab, then Warmboard
- Basement (mostly finished) studded out, seven inches of closed cell spray foam
- Walls and roof framing have additional closed cell spray foam
- Thermotech windows and doors, triple glazed with two low-e layers
- Blower door results – 4,000 CFM50 reduced to 330 CFM50

Systems strategies

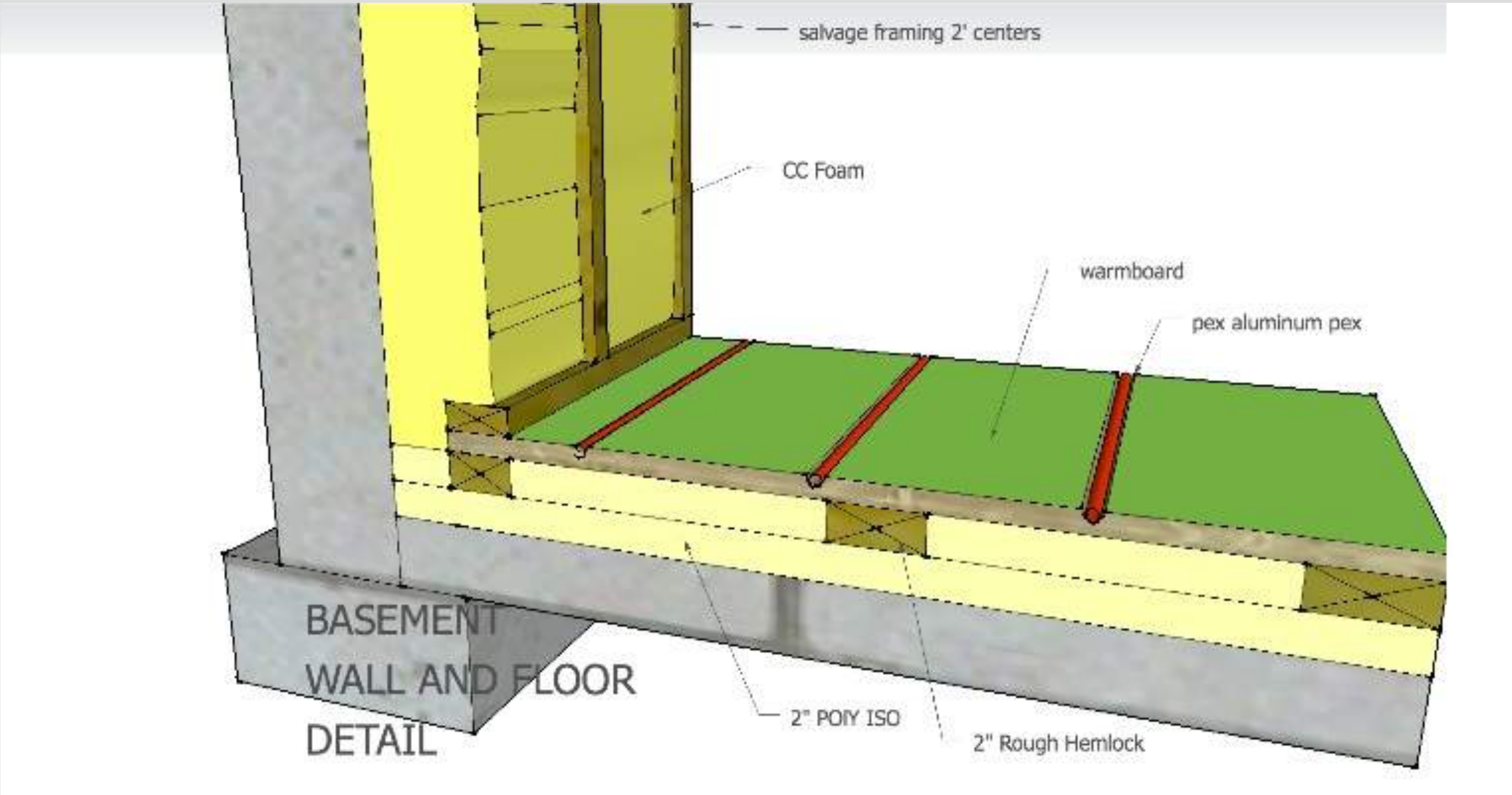
- Renewaire EV130 ERV
- WaterFurnace water-water ground source heat pump (GSHP), vertical closed loop ground connection, radiant floor heat
- 80 sf solar DHW system, designed so collectors heat the 80 gallon electric tank first then the 120 gallon preheat tank
- 7.5 kW solar electric system
- Meters on GSHP, DHW back-up, and PV output

What to do with a masonry chimney

Details


existing 2x6 frame wall
5 1/2" urethane core chip/chip
SIP screwed to existing
stud wall with 9"
spider drive reinforced
pan head screws
warmboard 1 1/8"
existing subfloor
steel L bracket with
1/2" lag bolt to band joist
CC spray foam

Details


salvage framing 2' centers
CC Foam
warmboard
pex aluminum pex
BASEMENT
WALL AND FLOOR
DETAIL
2" POlY ISO
2" Rough Hemlock


GRACE VYCOR PLUS

Flying in the SIPs


GRACE VYCOR®


Too darn much CCSF

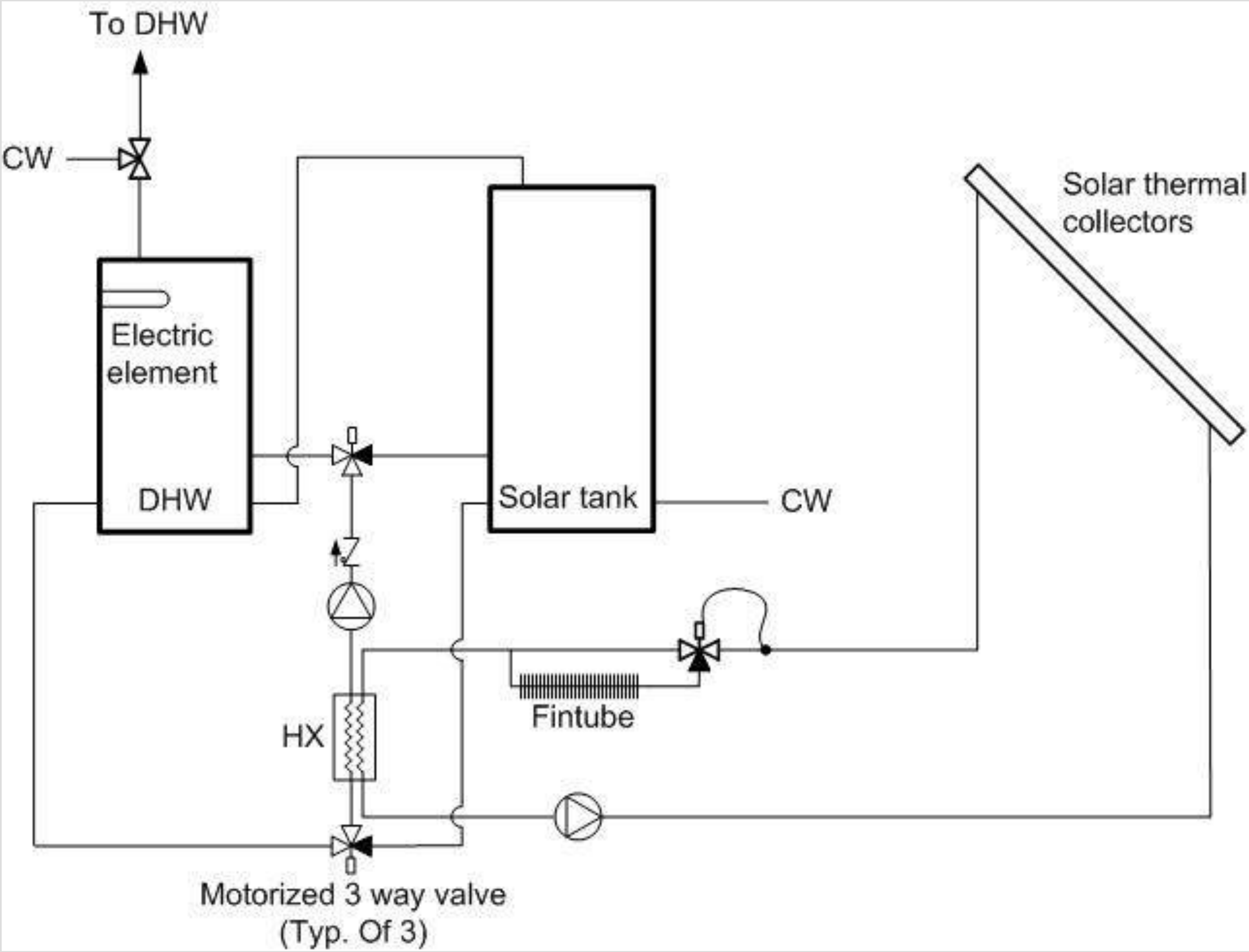
Fog test

Ground source heat pump

- WaterFurnace 2-1/2 ton water-to-water heat pump
- Vertical closed loop ground connection, with three 220 ft deep boreholes – Environol antifreeze
- Loops are over-sized by about 10% and the flow is not turbulent, which allows a smaller pump
- Hydronic radiant floor heat using Warmboard integrated subfloor and tubing tracks
- Heat pump heats an 80 gallon tank which is the source for the radiant floors – 95˚F water will heat the house, allowing the GSHP to operate at high efficiency

Solar hot water system

- Anticipated intermittent but high occupancy
- Two 40 ft2 flat plate collectors
- 120 gallon solar tank is preheat for the 80 gallon electric water heater
- System controls allows the solar system to heat the electric water heater first, then heat the preheat tank, so both tanks can be heated by the sun, and 200 gallons can be waiting for a weekend onslaught of guests
- There is also a heat dump of fintube to control overheating when the house is unoccupied
- The system has had some reliability issues including a freeze-up



Collectors heat primary tank first, then solar tank

Metering

Meters are on the PV inverter output, the heat pump system input, and the DHW back-up input, as well as the utility meter. There is also a water meter on the incoming water to the DHW system.

Actual first year energy results

• GSHP	2334 kWh
• DHW back-up	536 kWh
• All other loads	2428 kWh
• Total used	5298 kWh
• PV production	7030 kWh
• Net *exported*	*1732 kWh*

Many salvaged, FSC, and local materials

- Cedar shingles
- Hemlock timber frame
- Birch kitchen and maple built-ins
- Pine trim
- Salvaged antique pine and oak flooring
- and much more!

Observations on mechanicals and meters

- GSHP has been working very reliably and efficiently. Modest temperature lift between closed loops at about 40F and heat storage tank at 95F, coupled with attentive design to minimize pumping power, have yielded a system that appears to be operating above a COP of 3.

- Back-up heating of the DHW tank was using more energy than expected – this was tracked to incorrect wiring of the electric elements in the primary tank and an excessive setpoint. Once corrected, this energy dropped to close to zero. Several months later, it jumped up again – this was tracked to a freeze rupture in one of the collectors.