Team

• **Home Owner**  
  Jane Bindley (left)

• **Design/Build**  
  Ben Southworth (top right)  
  www.garlandmill.com

• **Energy Consultant** (bottom)  
  Marc Rosenbaum, PE  
  www.energysmiths.com

• **Engineer** - James Petersen, PE  
  www.petersenengineering.com
The Original 1970’s Ranch with Full Basement, Attached Garage
Vinyl Siding & Asphalt Roof
Original Sun Room
(Converted to Porch to Reduce Loads)
Awesome 70’s Kitchen Panorama
Everything Salvaged . . . Except Wall Paper
Jane hates fireplaces. Eliminating it not only gets rid of the fireplace but also a huge liability re energy, combustion air, and indoor air quality.
Original Triple-Pane Pellas
7’ 10” Flat Ceiling

Lake View - Northern Exposure
Original Oil Boiler –
Buderus Wood Preheat (not in use)
Jane and Ben
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

Marc Rosenbaum (left)  Ben Southworth  (right)
Annual Predicted Loads

- Annual Design Heat Load: 28.9 MBtus
- Design Peak Heat Load: 23,400 Btus/Hr
- Annual Heat Load: 8,500 kWh
- Annual DHW: 2,600 kWh
- Annual Plug Loads: 3,000 kWh
- COP: 3.0
- Annual Solar PV Production: 6,800 kWh
- R-values: Wall R-52, Roof R-72
  Basement Wall R-40, Basement Floor R-25
- Design ACH, CFM50: 1 ACH, 600 CFM50
Numbers that Matter

• HDD: 7,500/yr
• Design Temp: 85° F
• Floor Area: 3,400 ft² heated space (includes full conditioned basement)
• House Volume: 36,000 ft³
• Window Area: 568 ft²
• Shell Area: 6,243 ft³
• Blower Door Test: 330 CFM50
• GSHP COP: 3.2
# Actual Energy Use and Production

1-1-09 through 1-2-10

<table>
<thead>
<tr>
<th>LOAD</th>
<th>ACTUAL KWH</th>
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<tr>
<td>PV Generated</td>
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<tr>
<td>Heat Pump</td>
<td>2,334</td>
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<tr>
<td>DHW</td>
<td>536</td>
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<tr>
<td>All Other</td>
<td>2,428</td>
</tr>
<tr>
<td>Net</td>
<td>-1,732</td>
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</tbody>
</table>

Energy Producing!!
### Predicted vs. Actual Numbers

(from Marc Rosenbaum)

<table>
<thead>
<tr>
<th>LOAD</th>
<th>PREDICTED</th>
<th>ACTUAL</th>
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<tbody>
<tr>
<td>Woodstove</td>
<td>0</td>
<td>0.2 cords</td>
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<tr>
<td></td>
<td></td>
<td>(1,406 kWh)</td>
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<tr>
<td>Heat Pump</td>
<td>2,818 kWh</td>
<td>2,334 kWh</td>
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<tr>
<td>DHW</td>
<td>1,127</td>
<td>536</td>
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<tr>
<td>All Other</td>
<td>3,600</td>
<td>2,428</td>
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<tr>
<td>Total</td>
<td>7,545</td>
<td>6,704</td>
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<tr>
<td>PV</td>
<td>-7,500</td>
<td>-7,030</td>
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</table>
Design Heat Loss by Component

(Peak not Annual)
Meeting the Thousand Home Challenge

• This home’s customized threshold to meet or exceed is 8167 kWh/Yr (Threshold Allowance OPTION B)
• This household will officially meet the THC when the application is completed, & documentation of 1 year of household consumption verifies that energy use is less than 8167 kWh (net total site household energy)
• *This household meets the threshold without PV!*

NOTE: THC OPTION A (75% reduction from previous use) cannot be used because the energy value of the previous year’s wood use is not verifiable. OPTION B is not relative to previous use; inputs include weather, house size, number of occupancy and type of fuel used for heating. For information: www.ThousandHomeChallenge.org
Use (with & without PV) compared to Option B
THC Threshold (kWh/year)

<table>
<thead>
<tr>
<th>THC Threshold (kWh/year)</th>
<th>Actual Use (-PV)</th>
<th>Option B</th>
<th>PV Output</th>
<th>Net Site Annual</th>
</tr>
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<tbody>
<tr>
<td>-500</td>
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<td>1,500</td>
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<td>9,500</td>
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Sequence of Events

Removed attached garage in southwest corner of a small sun challenged lot
Stripped and Recycled Vinyl Siding
Salvaged Windows
Recycled Asphalt Roof
Primer with Peel and Stick

PRIMARY AIR BARRIER
• Seal original outside wall and roof sheathing / plywood edges with peel-and-stick tape

BELT and SUSPENDERS
• Taped outside and closed cell spray foam inside
From Flat Ceiling to Cathedral Ceiling

- Removed and salvaged the 2x6 joists (from flat ceiling)
- Replaced it with a 7”x14” FSC hemlock structural ridge with 7”x7” posts
Structurally Insulated Panels (SIPS)

- 6-1/2 inch (R-35) urethane foam panels were added to the exterior envelope of the roof and walls.
R-73 Roof, R-52 Wall

• Original 2x6 walls were gutted and 2x6 flat ceiling was removed
• High density foam was sprayed into the wall and roof cavities
SIP Install – Air Sealing Detail

WE DID...

• Non structural SIPS 1/2” apart with no splines
• Wanted a visual air seal
• Spray foamed gaps with high expansion foam

DO DIFFERENTLY...

Have the CC spray foam contractor seal gaps with 2-part foam
We used a lot of cans of Big Stuff!
R-42 Basement Wall and Floor Detail

- Using salvaged studs, a new basement wall was framed 4-1/2” inside the foundation walls to create a 7” cavity.

- 7” of high density foam was sprayed against the concrete, sill plate and band joist, filling the new stud cavity.
**R-10 Floor with Warmboard Radiant Floor**

**NOTE:** Design addresses conduction at floor edge. Warmer corner = less risk of condensation. Thermal bridge minimized.
Cost of Superinsulation

• Resulting insulating values:
  Foundation Walls: R-42
  Walls: R-52
  Roof: R-73

• High density spray foam: $1/bd foot installed

• 6 ½” urethane foam panels: $12-$14 sq/ft installed

• Total insulation package: $110,000
Fog Test!

• The house was tested to verify the integrity of the air barrier as it was installed.

• Finally, the house was pressurized with the blower door. A theatrical fog machine visually located remaining leakage areas.
12-Fold Reduction in Air Leakage!

- Original house: 4,000 CFM50
- Finished house: 330 CFM50
- < .6 ACH50 required by Passive House – Yahoo!

Much of the remaining air leakage is in the sliding glass doors, which are difficult to make airtight. (Marc campaigned for less glazing area and fixed glass)
R-5 Windows and Doors

• Thermotech fiberglass windows
  – Hollow fiberglass frames filled with foam insulation
  – Triple glass with two low emissivity coatings, and low conductivity gas fill

• In addition, movable foam-filled insulation panels cover the large glass openings to reduce heat loss at night (+R-7)

• We are currently paying $66/sq ft for Thermotech glazing, uninstalled
Thermotech Installation Guide (Windows and Doors)

Prepare rough opening (See DWG 1). At the top of the window, cut and fold up exterior building paper revealing about 6” (150mm) of sheathing.

Ensure that the paper extends only 2” into the jambs to ensure uninterrupted installation of air barrier (low expansion foam between window and r.o. frame).

If the building paper extends past the interior plane of window it is difficult to seal paper to wood frame and then paper to window frame.

Water proof membrane laps building paper.
Create a sloped sill with a piece of clapboard. (See DWG 2)

The clapboard needs to be 3/8” shy of depth of window to insure installation of continuous air barrier.

Cover the clapboard with a self-adhering waterproof membrane.

It must overlap the clapboard by 6” (150mm) both up each jamb and down over the building paper.

Apply gussets in the bottom corners to ensure membrane is continuous. We used Vycorners
Before setting window in rough opening, caulk the side and top flange making sure not to caulk the bottom flange.

Set window in rough opening. Ensure visible drainage hole covers are on the outside and the bottom of window.

Shim window so that it is plumb, square, and level. (See DWG 3) There must be shims under bottom right and bottom left corners of all windows, as well as under all vertical mullions. Add other shims as necessary to support the window.
Join the flange to the rest of the building to maintain a continuous drainage plane. Cover the installation flanges with a self-adhering waterproof membrane.

Install a drip edge/cap over the window. (See DWG 4) It must extend at least 3” (75mm) upwards against the sheathing. It must also extend both out past and down over the outer face of the window by at least (6mm). Additionally, the drip edge must extend past each end of the window by 1/4” (6mm). Cover the vertical leg of the drip edge to the wall with a self-adhering waterproof membrane that completely overlaps the jamb membranes. Unfold the building paper down over the taped edge. A properly installed drip edge is required over the top of each window.

Join the window to the rest of the building to maintain a continuous air barrier. (see DWG 3) Caulk the interior edge of the sill to the self-adhering waterproof membrane below it. (See DWG 2) along the jambs and head insulate between the rough opening and the window. Careful installers do this by using low expansion urethane foam. Be sure to carefully follow all the directions and warnings from the foam supplier. Be careful not to distort the frame by over insulating.
Reducing Plug Loads

• The top outlet in each room is switchable so that inhabitants can switch off the plugs when they leave to reduce phantom loads.

• Jury is out on how well that works!

• Recently ventilated the cabinet where the fridge resides to reduce that plug load. Jury is out on this one as well.
Reducing Energy Use for Lighting

- Light Emitting Diode LED Bulbs are twice as efficient as CFLs
- Last 5 times as long
- Contains no mercury
- The LLF can (pictured) is the world’s most efficient.
- Cost $85 each
Solar Electric PV Panels

- 36 Sunpower *solar electric* panels produce power for the house
- 7.5 kilowatts (kW) array on the roof
- Photovoltaic panels cost ~ $8000 / KW installed (not including the 30% federal tax rebate or NH $.03/watt rebate)
7000 kWh Annual Production

• Shading and snow cover brought the production to around 7,000 kWh

• Original estimates from the PV installer were over 9,000 kWh per year

• When asked to revisit that estimate given poor solar conditions and potential for long term snow on the panels, estimate was revised to within 10% of actual output number
Closed Loop Ground Source Heat Pump

- Water Furnace heat pump
- Engineering by Marc and Jim Petersen
- Three 220 ft. deep vertical closed polyethylene piping loops provide connection to the ground
- Environol in the loops
- Heat pump concentrates the energy to heat an 80 gallon stone lined tank of water to 90°F
Warmboard Subfloor

- Grooves 12” on center that are sheathed in aluminum to help transfer heat
- The pex has a layer of aluminum in the tubing to aid heat transfer
- Cost: $6 ft$^2$ on the delivery truck
Renewaire ERV

Chosen because of low energy use during run time
Monitoring Critical to Performance
Simple Feedback

In addition to the house meter, there are meters on the HP, DHW back-up, and PV output.

Submetering helped to detect:
- DHW was miswired
- DHW thermostat was set at 135 F

PLUS, submetering helped to:
- Track down ~70W of phantom loads – a savings of 600 kWh/year

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1 This defeated the SDHW system design, which uses an external heat exchanger to have the collectors heat the primary tank FIRST, then switch to the solar preheat tank when the primary tank reaches 135F.
List of FSC and Local Materials

- Cedar shingles
- Hemlock timberframe
- Birch kitchen and built-in maple closets and built-ins
- Pine trim
- Wide board antique pine/oak flooring
- Local eastern white pine flooring and shiplap in boathouse
- Garage deck for porch floors
- Mahogany for shower, pergola and dock
- Local white cedar ceiling and pergola frame
- Heart of pine stairs
- Salvage maple handrails
- SPF framing lumber and interior partitions
Green Roof on Garage

• The garage’s green roof helps to reduce run-off from the driveway and Route 3 into the lake
• In cities, green roofs are also used to reduce the heat island effect caused by the storage of heat in thermal masses like concrete and asphalt
• While reducing the heat island effect isn’t a priority in Holderness, improving water quality in Squam Lake was very important to the project
Waterproofing

- A Hydrotech 160 mil waterproofing system was used as a barrier between the growing roof and the garage structure.
- 8” of Rooflite soil for an intensive roof system was added to the top of the waterproofing.
Low Bush Blueberries

Low-bush blueberries and other drought tolerant, native mixed shade vegetation were added to the roof.
Rainwater Irrigation Cistern

- Gutters capture and divert rainfall to a 1,200 gallon cistern to provide irrigation to flower and vegetable beds
- A ½ horsepower pump provides water to drip irrigation throughout the garden and landscaping beds
- A rain sensor overrides the pump when the grounds get sufficient water from rainfall
Implications for Other Projects

- Superb energy performance (NZE +) is possible with a challenging site and cold climate
- Huge reduction in air tightness possible
- Demonstrates impact of a strong team, a motivated homeowner, and effective feedback
- Design / build process can be ideal to provide flexibility for project to evolve
- Project could have had similar performance at lower cost if that was a priority
Marc Rosenbaum…

“To achieve a net zero house one has a different options to tap. You could think of it as having a variety of dials to tweak to achieve the desired effect. In this project we confronted significant barriers – minimal passive solar gain, compromised solar aperture and roof pitch, northern view and large north facing glazing. To get to NZE we had to turn the dials we had control of all the way – thus very high insulation levels and tightness, and lots of renewables.”
OPTIONS to LOWER COST

• Insulation: 1) Substitute less expensive insulation sources (could have labor cost trade-offs); 2) Lower wall R-values if less glazing area or better orientation

• Windows: 1) Reduce window area; 2) More fixed glazing; 3) Addition of high performance storms in combination with movable window insulation in lieu of replacement

• Heating System: Point heat source instead of ground source heat pump with floor radiant
Storm Water System

• The cistern provides water to the green roof and helps the storm water collection system reduce runoff to the lake

• The storm water system returns as much water as possible to the ground through an infiltration trench before running to daylight
Bindley Carbon Neutral Renovation

Jane Bindley:

“In April of 2004, I heard Ross Gelbspan speak on Climate Change at an Appalachian Mountain Club event… His impassioned delivery and his documented evidence of the climate change already occurring and what was ahead left the audience stunned. …He set me on a course of learning and action.”
“Next, I audited Leith Sharp's Sustainability Class at Harvard Extension School. We learned by her example to see opportunities in every aspect of our lives to create sustainability. I began to think of a zero carbon home. Finding a like minded design/builder, Ben Southworth was one of life's major miracles.”
Ben Southworth:

“I own and operate a small design/build firm with my father, uncle, and cousin. We use a water powered sawmill built in 1856 to mill the timber we use in our homes. When the mill isn’t running, we use the water to power a generator to produce electricity. Clean, renewable power is important to us!”

“I have always wanted to design and build a home that produces as much energy as it uses. As greenhouse gases increase and peak oil has arrived, the necessity of building a home free from carbon based fuels has become more urgent. Convincing clients of the importance of an energy efficient home has always been easy, but when the hard decisions came to implement super-efficient strategies, folks prefer spending money on a big fireplace.”
Ben (continued):

“So it was with much excitement that I met Jane Bindley who wanted a home that emitted no carbon. What is more, Jane wanted us to renovate a 1970’s ranch on a beautiful lake in New Hampshire. Most people would demolish the building and build something far grander in its stead. Jane insisted that we keep the building out of the landfill. Very quickly I realized that this was the opportunity for me to achieve a long-held dream. The dream only got better.”
Ben (continued):

“I found that rather than having to ‘sneak’ in the efficient design, recycling, salvage and green materials, Jane was insisting on them. She even asked that we remove the fireplace!

The vinyl siding, asphalt roof, and carpets from the old building were all recycled. The framing lumber from the garage was reused in the renovation and the old windows, doors, bricks, cabinets and tubs found new homes in the area. At every turn we chose to use local or FSC lumber, recycled or salvage materials, low embodied energy products like clay plaster and low volatile organic compound binders and sealers.

These efforts resulted in a palpable improvement in indoor air quality, and augment the aura that Jane brings to the space.”
Ben continued:

“A special part of Jane’s home is the relationships that have come from it. All of the people involved in the taking apart and putting back together of Jane’s home took such pride in their work, knowing that the home would emit no carbon. Jane’s personal warmth and sincere respect and appreciation for the designers and craftsmen emanated through the job site and, I am convinced, is largely responsible for the peaceful feelings that visitors attribute to the home when they stop by.”
Jane Bindley lives in her newly renovated home in Holderness, New Hampshire. She enthusiastically awaits her electric bills which show the kWh she has banked each month. The home achieved net zero energy for 2008 to 2009 on Earth Day, April 22, 2009.

Visitors are always welcome!

Ben Southworth takes the lessons and relationships from Jane’s home to his next low energy home, which is already in production. The dream continues!
LEED Platinum Certified

• The Bindley Renovation achieved a LEED Platinum certification and is believed to be the first LEED Platinum renovation in New Hampshire.
For More Info

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- 603-631-0164

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- Janebindley@gmail.com