Photo: © Jim Westphalen

The Charlotte Vermont House

Verified Net Zero Home for a Cold Climate

General Specs

Building Type: Single Family Residence
Location: Charlotte, Vermont
Site: 44 Acres- Previously Developed
Bedrooms: 4 **Baths:** 2.5
Living Space: 2800SF
Cost (USD/SF): $196/SF
Completed: August 2007

High Performance Overview

Sustainable: Passive Solar + Super Insulated + Ground Source Heat Pump + 10 KW Wind Turbine + Lifestyle = Net Zero Home
Safe/Secure: Rural North East Community.
Functional: Maintains all the amenities of a conventional home.
Aesthetic: Modern Farmhouse Vernacular.
Historic: Existng structure was 100% reclaimed - New Footprint on reclaimed site.
Productive: Home office and Living Spaces -100% Daylighting.
Accessible: Open Floor Plan and Multi-Use Spaces = Flexibility.
Cost-Affective: Utilized Conventional Building Methods.

There were several goals in mind when we set out to design this 2800SF single family residence in Charlotte, Vermont. It was our intention to create a house that maintained all the amenities of a conventional home with as little environmental impact as possible, to eliminate all fossil fuel burning on site, to maintain a high level of design and detail and to use the most conventional means and methods possible so that it would be affordable and replicable. The challenge was to do all of this in a cold northern climate.

We knew that the only way to achieve net zero energy use was to create a house which had an ultra low energy budget utilizing all the natural renewable energy sources the site had to offer. The solution was to create an all electric house using the sun's energy passively, using the earth for mechanical heating and domestic hot water and the wind via a single net metered 10KW Wind Turbine. The house is a documented and verified net energy producer putting more energy back into the grid than it uses for all of its needs including cooking. In addition to being 5+ star ENERGY STAR rated (0 HERS Score) and Vermont Builds Greener certified, the house has also received the US Green Building Council's highest LEED rating of Platinum, the first and only one in Vermont. While the concept sounds straight forward it required a well thought out and carefully calculated design involving the collaboration of many different disciplines in the trade.

Photo: © Jim Westphalen

Integrated Design Approach

To create the most efficient solution possible a diverse collaborative team was assembled at the beginning of the conceptual design phase. As the client and architect I hired Jim Huntington, the builder, for his experience in design and energy efficient construction, energy consultant Andy Shapiro of Energy Balance, to do the modeling and design of the systems using Energy 10™ software, structural engineer John Higgins of Artisan Engineering to evaluate and minimize lumber sizes and headers, dowser Patrick McManaway to determine the water resource on the site and wind turbine installer Tom Halnon of Vermont Green Energy Systems to assess the feasibility and installation of a wind turbine. Through this holistic approach we were very effective in communicating and fine tuning the project, taking into account: construction methods, design aesthetics, affordability, minimization of construction waste, energy efficiency, site resources and mechanical design strategies. There were definitely trade-offs and compromises but this was a balanced process where the elements which were taken from one area ended up benefiting another. I believe that this integrated holistic approach was the key to the projects' success.

Site and Building Analyses

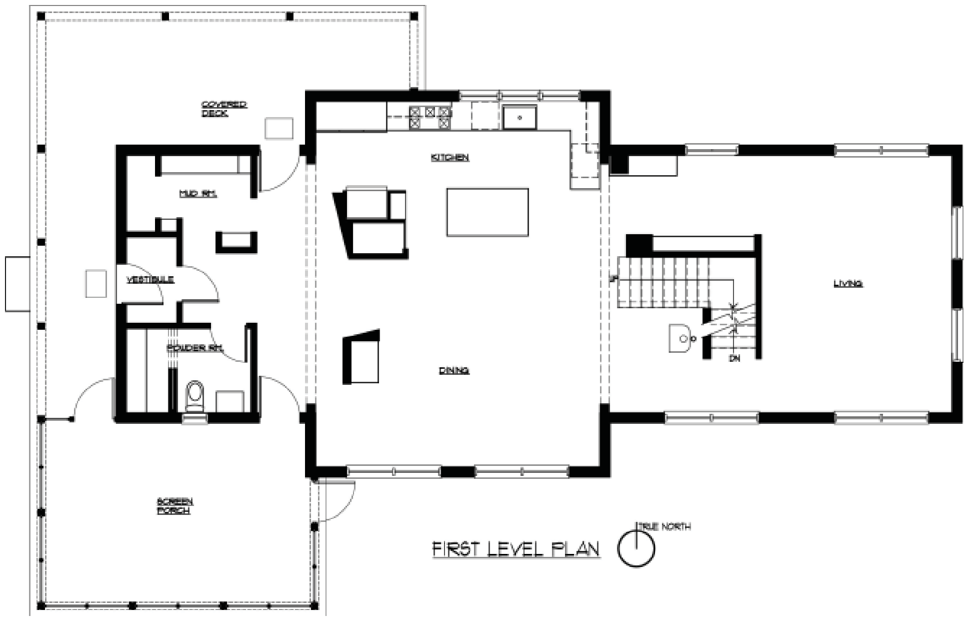
As the architect/client, my wife and I had a vision- we wanted to find a pre-developed site to renovate for maximum energy efficiency and begin a self-sufficient homestead. This 44 acre site was chosen for its solar access, pasture and agricultural potential and the fact that it had already been built upon with an existing 180' x 80' riding arena, with a residence within. Upon purchasing the property neighbors came forward who were interested in starting their own horse boarding business, and they moved the prefab metal structure piece by piece around the corner, to its new location, saving everything down to the roofing screws.

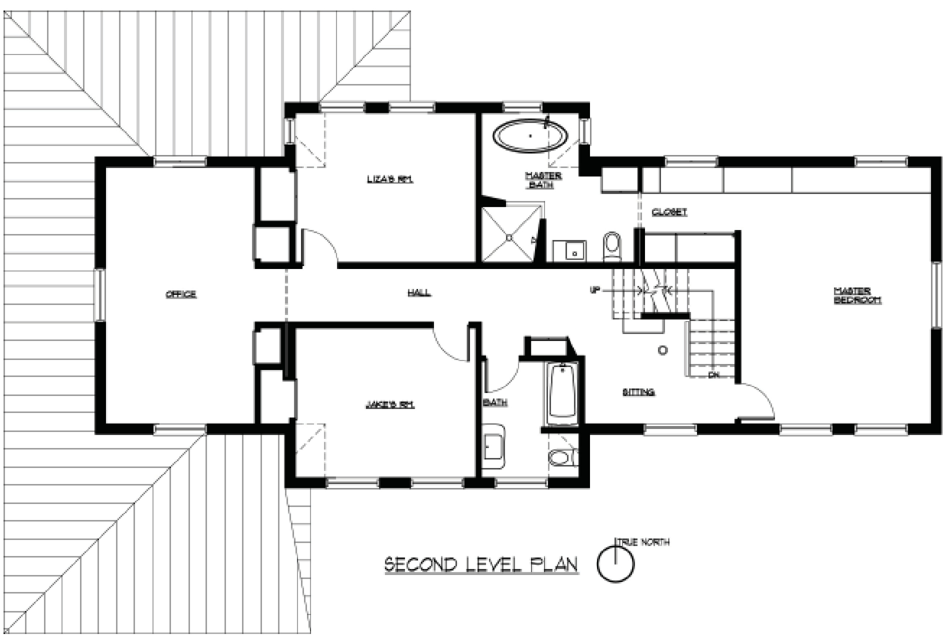
Our master site plan kept the house and the new parking area as well as any future outbuildings within the existing footprint of the arena. This allowed minimal impact to the remaining 43 acres and for full solar access. The topography of the site included a hillside to the east and a high knoll to the west creating a wind tunnel effect for the prevailing southern winds. After analysis, it was determined that the wind was substantial enough to make economical sense for a wind turbine. The Bergey 10KW wind turbine system cost $26,000 after a $12,500 rebate from Vermont and a $1,500 federal tax credit, reducing its overall cost by nearly 40%. With today's tax credit the final cost would have been $16,300. Photovoltaics would have cost around $45,000 after rebates to produce the same amount of energy, which through the Energy 10™ model, Shapiro had estimated at 7780 kWh to achieve the net zero energy goal. With a R.O.I. or payback analysis the numbers may not look great, but I used this as an opportunity to fix the price of my energy and pre-pay it for at least the next 20 years in today's dollars.

Design and Evaluation

Heating a home in this cold cloudy northern climate was the biggest design challenge. Even though a lot of what we have done required "out of the box" thinking, the conceptual solution was in fact, "a box" – in effect a six sided Styrofoam cooler. The box was then altered for scale and aesthetics, proper fenestration and day lighting etc, but still maintained its simple massing. To achieve maximum energy efficiency an Energy 10 model was created to look at: passive solar and thermal mass, massing, envelope design, glazing, air tightness, mechanical systems, lighting and appliances. From the Energy 10™ model a spreadsheet with multiple options were developed to inform the choices for the design of the building and systems. While this process can only be described in a linear manner on paper, to synergize all of the factors described above plans and elevations were worked simultaneously.

To achieve Net Zero energy use requires a very tight energy budget which was made possible by using the natural resources of the site – the sun the earth and the wind. Using the passive energy of the sun was the first approach as the suns energy is free when you orient your house properly. The final footprint of the house is long and narrow, about 20' x 60', oriented east west for maximum solar gain. The first and second floor footprints are stacked for efficiency and the interior plans are open for flexibility. The open plan maximizes thermal mass and day lighting. The house is conventionally wood framed although In order to maximize insulation values and minimize resource use, 2x6 studs were placed 2' on center and walls were laid out in 2' increments. A 4" thick ground and polished concrete slab on the first level acts as the finished floor and as the thermal mass absorbing the southern sunlight through the triple pane, low-e, argon filled fiberglass windows which were chosen with respect to orientation. On the south side windows have a Solar Heat Gain Coefficient (SHGC) of 0.61, a Visual Transmittance (VT) of 0.63 and a U-Value of 0.17. The remaining windows have a SHGC of 0.37, a VT of 0.57 and a U-Value of 0.15. We tapped the earth's energy with an 3 ton Econair GSHP which draws heat from the constant temperature of the earth to produce the hot water supply for the low temperature radiant heating system and domestic hot water tank. A GFX drain heat recovery unit is also in place to maximize energy efficiency by recapturing wastewater heat before it exits the building. It was not until we brought our loads down as far as possible that we introduced renewable energy generation. This was





the best way to maximize its ability to produce more than we needed economically and without trying to overcome a huge load with sheer brut force.

Meticulous attention was given to air sealing the homes envelope. Corner, door and window breaks are filled with foam, taped and then covered with Tyvek house wrap. Similar attention to these details was carried out in the 2x10 roof assembly (R56). With this super efficient shell a Heat Recovery Ventilator was in order to ensure proper ventilation during the winter months. Otherwise the narrow footprint allows cross ventilation to cool the home when necessary.

One of the trade offs in our integrated approach was in the discussion about the sheathing. I knew that with lateral bracing we could save the material and omit plywood sheathing. The contractor felt very strongly that even though it may be a savings in material, the labor to detail the bracing properly would increase significantly, and secondly he felt the end product would not stand up as well, and eventually lead to slight movement in the interior. He did concede to using 2 stud corners for insulation and as counter intuitive as it looked, with the engineers stamp, he agreed to eliminate unnecessary headers in place of more insulation. Closed cell polyurethane foam (R6.5 per inch) completely fills the cavity of the frame and one inch of polyisocyanurate (rigid foam board) was wrapped around the outside to cut off any potential thermal bridges. The entire wall assembly has an R-Value of 40, although more expensive the cost was minimal to the benefit.

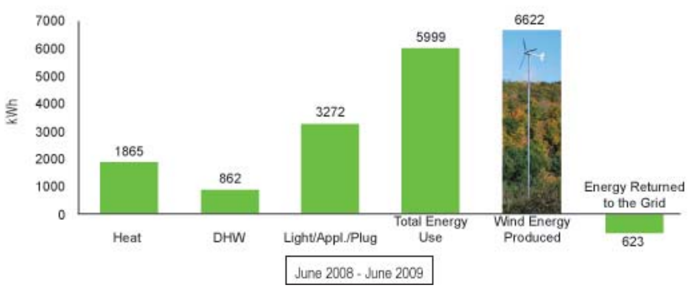
Conclusions

I believe the success of this project relied on the many synergies which occurred through planning as well as their serendipitous occurrence. One of the most important synergies was pairing the resources of the site with our needs, i.e. the sun the wind and the earth. Another was the choice to use electricity as the sole unit of energy, paired with the GSHP and wind turbine. It was serendipitous to find this particular site which met all of our criteria while at the same time having a neighbor who had a need and was able to take a 14,000SF structure with very minimal waste and energy use. An important lesson learned was to find the path of least resistance by using common sense and reducing the complications of multiple systems. Additionally, I learned how to take what may seem like a compromise and evolve successful relationships between the dynamic forces acting on a project.

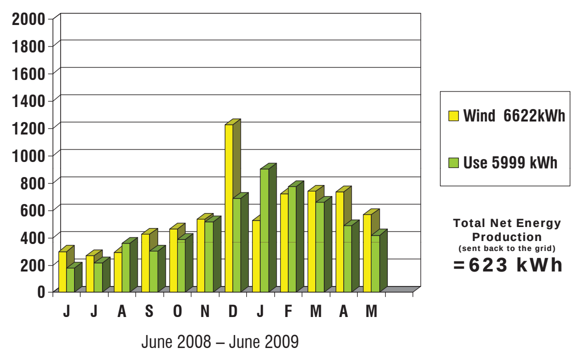
Comparing our actual use to the energy model was very enlightening. As you can see from the data, our use was 5999 kWh and the energy model predicted 7780 kWh. I believe this difference is related to occupant behavior and our conservative use of energy.

While the design of the house makes it possible to function at net zero energy use, it would not have been possible without homeowner awareness and behavior. We installed very simple monitoring devices including a separate kWh and Btu meter on the heating system, a kWh meter on the wind turbine, a wind logger to document the wind speed and other characteristics, and a meter which measures hot water use. All combined we were able to keep track of every unit of our energy consumption. These monitoring tools installed in our home made our family of four conscious of the direct correlation between our activities in the house, the exterior environment and our energy use. If our country is committed to reduce carbon emissions, decrease the use of fossil fuels and rely more on renewable sources than we not only need to build and renovate for more efficiency but we need to change our patterns of energy consumption. From the experience of living in this house with my family, I have learned that we absolutely can re-pattern ourselves to live within a framework of extreme energy efficient consciousness without feeling compromise.

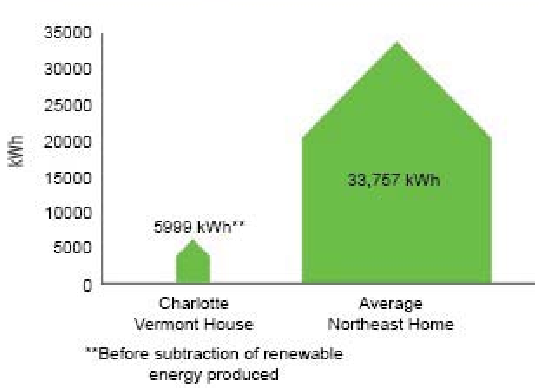
Energy Use by Load



Energy Production and Use



Annual Energy Use Comparison



Environmental Attributes

Certifications and Recognitions

Northeast Sustainable Energy Association Net Zero Energy Award 2009
AIA Vermont Design Award 2008
LEED Platinum Certified 2007
5+ ENERGY STAR Rated (0 HERS Score)
Vermont Builds Greener Certified 2007
Sustainable Building Industry Council 2009 High Performance Building award

Site

Previously Developed Site - Existing building reused locally
99% of all work completed in existing footprint.
Created linkages to community open space and trails
Restoration of land for pasture and agricultural use
Innovative Septic System – Presby Enviroseptic
Proper Grading for Stormwater

Enclosure

R40 Walls, R21 Basement Walls
R56 Roof
R26 Under Basement Slab
Triple Pane, Low-E, Argon filled Fiberglass Windows – Thermotec

Mechanical Systems

Bergey 10KW Wind Turbine, Net Metered
Ground Source heat Pump with Variable Speed Drive
Heat Recovery Ventilator
GFX Waste Hot Water Heat Recovery
Highest Rated Energy Star Appliances
Fluorescent Lighting
Dual Flush Toto Toilets
Low Flow Shower Heads

Materials

FSC Certified Decking
Cedar clapboard
Metal Siding and Roofing
Locally Crafted Concrete Counter Tops – Red Concrete
Local Sustainably Harvested Maple Flooring
Sustainably Harvested Hardwoods for Cabinetry
Butcher Block Counter locally harvested and crafted
Reclaimed Fir Columns
Cellulose Insulation
Denim Insulation
Closed Cell Spray Foam Insulation
4″ Ground and Polished Concrete Slab for Thermal Mass

Construction Techniques

Passive Solar Heating Design – Long & Narrow (60′ x20′)
Exterior Walls sheathed with Rigid Insulation to Mitigate Thermal Bridging
2′ on Center Studs – Maximizing Insulation & Minimizing Material Usage
All Sill Plates, Top Plates and Double Studs Caulked
All Dimensions on 2′ Module- Minimizing Material Waste
Building Envelope Tightly Sealed – NACH .08 for Heating
100% Daylighting
Design to Prevent Intrusion of Moisture

Software Used

AutoCad
Sketch-Up
Energy 10
Microsoft Excel

Meters

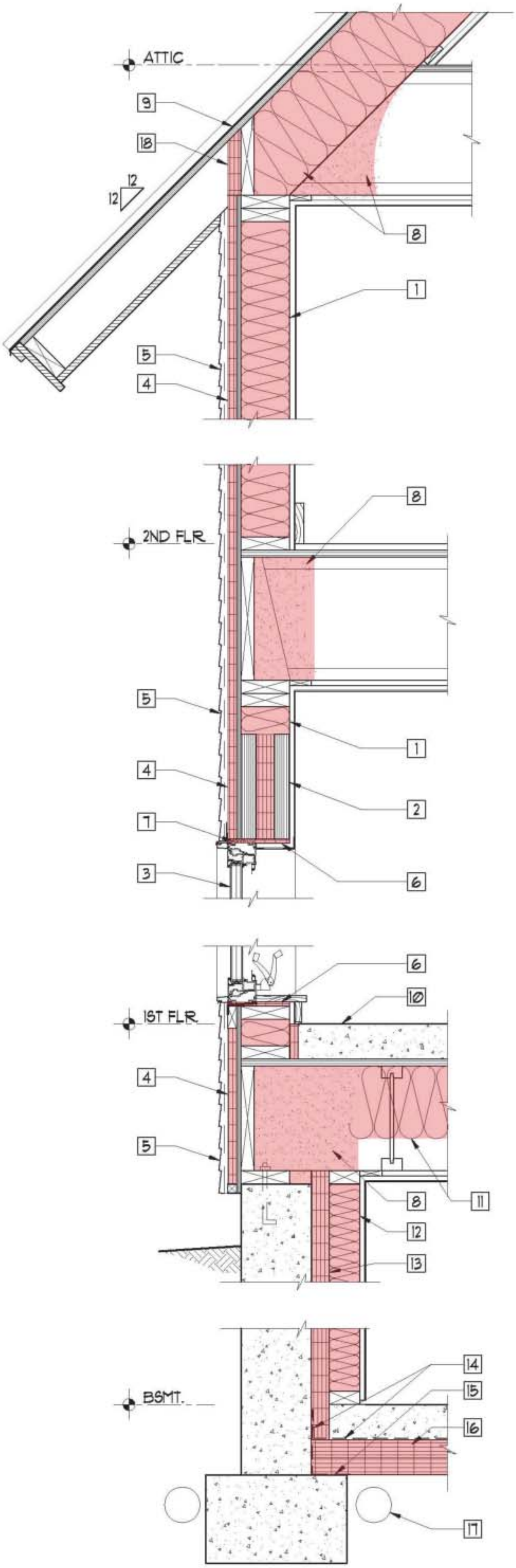
Wind Data Logger – NRG
kWh Meter on Wind Turbine
BTU Meter and kWh meter on the heat pump
Meter for hot water usage

Photo: © Jim Westphalen




Photos: © Jim Westphalen

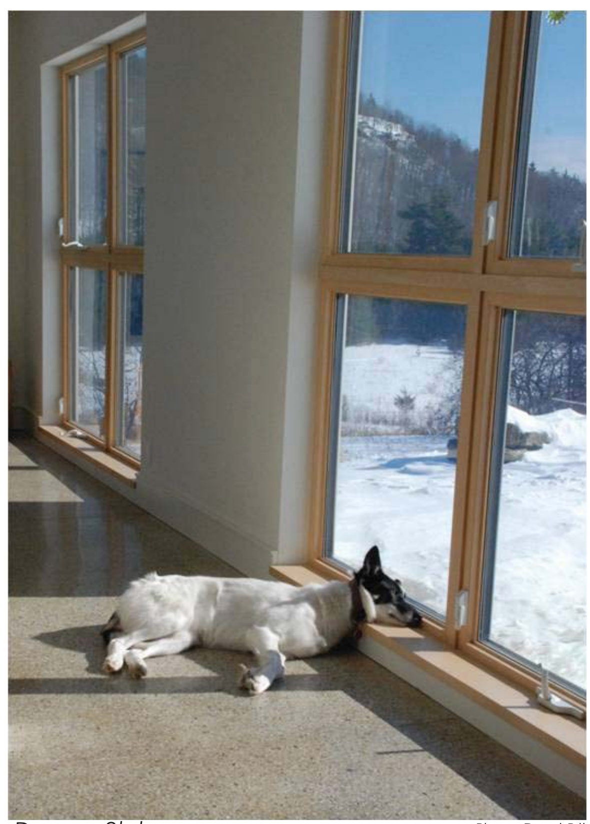
Photo: © Jim Westphalen



DETAILS - THERMAL ENVELOPE
1" = 1'-0"

KEYNOTES:

1. 2x6 FRAMING AT 24" O.C. WITH SPRAYED CLOSED CELL URETHANE FOAM INSULATION
2. INSULATED HEADER
3. THERMALLY-EFFICIENT FIBERGLASS WINDOWS
4. 1" POLYISOCYANURATE INSULATION WITH TAPED SEAMS
5. CEDAR CLAPBOARD WITH OPAQUE STAIN OVER 'CEDAR BREATHER' (RAINSCREEN)
6. ½" POLYISOCYANURATE INSULATION AROUND WINDOW FRAME
7. SHIM SPACE FILLED WITH LOW EXPANDING FOAM
8. SPRAYED CLOSED CELL FOAM INSULATION
9. STANDING SEAM METAL ROOF
10. 4" CONCRETE SLAB WITH RADIANT HEAT
11. RECYCLED DENIM INSULATION
12. 2x4 FRAMING AT 24" O.C. WITH BLOWN-IN CELLULOSE INSULATION
13. 2" EPS INSULATION, GLUED TO FOUNDATION WALL
14. VAPOR BARRIER, SEALED TO CAPILLARY BREAK
15. CAPILLARY BREAK
16. 2 LAYERS OF 2" EPS WITH STAGGERED JOINTS AND TAPED SEAMS
17. FOUNDATION DRAINAGE
18. 1½" POLYISOCYANURATE INSULATION, FIT BETWEEN RAFTERS WITH JOINTS SEALED



Dog on Slab

Photo: David Pill

pill·maharam architects
PMa
shelburne, vermont
802.735.1286
www.pillmaharam.com