Pursuit of a Net Zero Energy Home, Part I

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your key to energy

It takes years, even decades, to permit, finance and build new power generation facilities. It only takes minutes to reduce the energy consumption inside the walls of any residence. A net zero energy building is one where the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building. Brakey Energy owns a large lakeside log cabin rental property in southern Maine near the last existing Shaker Village[1]. It is our goal to make it a net zero energy home by 2014 in order to better manage present and future energy costs. This report discusses steps we have taken toward this goal. We hope that it will give you some ideas for reducing the energy consumption in your home.

This tightly built log home with a passive solar orientation features large windows on the southern wall (shown at right). Forced hot air, fueled with propane, is supplemented by a large wood stove in the basement.

To immediately reduce residential energy consumption we:

- Replaced over 150 heat lamps (incandescent and fluorescents light bulbs) with LED's
- Installed LED lighting dimmers throughout the facilities
- Used power strip kill-switches to turn off energy vampires when not in use
- Replaced the standard hot water heater with a tank-less water heater
- Replaced the washer, dryer and refrigerator with new energy efficient models
- Eliminated overgrown trees to the south to increase the opportunity for daylight harvesting

"Blower-in-the-Door" tests on air leaks and drafts resulted in these actions:

- Plumb outside air directly to the wood burning stove to minimize heat losses and negative air pressure during the winter heating months
- Add to the roof, attic and basement insulation
- Modify dryer vent to retain hot, moist air in the cabin during colder months while venting the heat outside in the warmer months

Future plans include:

- Install 4 to 6 ton geothermal heating and cooling system
- Revamp entire HVAC ventilation system throughout cabin
- Gut out 1,700 square foot daylight basement to resolve energy deficiencies
- Installing a propane back-up generator
- Installing solar panels on the roof.

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1 Coincidently, we are conducting a second energy efficiency project in Shaker Heights, Ohio, the location of a former Shaker village from the late 1800s. Concerned that energy prices might double by 2015, our goal is to offset future energy increases in northeast Ohio by more than halving energy consumption while maintaining energy comforts. To learn more about the Shaker Heights projects you can go to the following two links: http://mgimmerman.kattare.com/wp-content/uploads/2009/10/Residential-LED-Lighting-January-3-2011.pdf and Reducing Gas Consumption with Home Insulation Sept 2006

Lighting

With the recent addition of a two-car garage and workshop, followed next spring with the conversion of a large unfinished daylight basement into a series of exercise, recreation and storage rooms (see the middle image below), there will be 6,000 square feet under roof. Standard rules indicate that general lighting and receptacles take three watts per square foot (18,000 watts). This home and garage had realistic peak electric lighting load of about 9,500 watts. Is it possible to shrink this lighting load to under 1,400 watts without sacrificing quality or performance? In the case of a power outage, with the aid of dimmers on the lights, could we lower lighting usage to less than 200 watts for the entire home with a back-up generator?

Incandescent light bulbs have changed little in 130 years and waste 95% of the energy delivered to them. Though fluorescent technology is a significant improvement over incandescent, fluorescents still waste close to 80% of the energy they draw, have poor power factor, and have contamination issues associated with mercury.

We are utilizing lighting solutions provided by light emitting diodes (LEDs) from Affineon, Array, CREE and Sylvania (see the top image at right). These latest LED products are over 90% efficient. Higher quality LED bulbs are dimmable and have power factor close to unity at one tenth the power requirements.

While LEDs have high initial costs, many of the superior LEDs last a minimum of 50,000 hours. Over 120[2] of the lighting fixtures on site have been converted to dimmable LED technology. The entire lighting load has been shrunk to under 1,200 watts with LEDs. The cabin's carbon footprint has been reduced by more than 360 metric tons over the 50,000 hour life time of these LEDs. (See the bottom image.) We will not have to install new bulbs for more than 20 years!

[2] Recent bulb fixture count of 153 includes outside lights plus garage and renovations to 1,400 square foot daylight basement.

Hot Water

The log home has its own endless supply of well water. With the addition of a whirlpool tub, second shower, and energy efficient washer and dryer, our next challenge was to economically provide an ample supply of hot water.

The solution was to replace the standard 50-gallon propane-fired water heater with a Rinnai tank-less water heater. It can generate 5 gallons per minute of 130° water. A tank-less water heater only operates when hot water is needed (about 5% of the time), and is 82% energy efficient when in operation. The Rinnai is 100% efficient when not in use, which is the remaining 95% of the time.

With a traditional water heater, you are trying to maintain the desired water temperature around the clock even though hot water is only required intermittently. If you currently have an electric hot water heater, there can be dramatic savings in electric consumption by going to a tank-less water heater. If the water heater has a flame pilot, natural gas or propane is consumed to maintain the flame. Just keeping the pilot lit typically costs about $8 (natural gas) to $24 (propane) per month. Remember, a tank-less water heater only operates when hot water is needed. Our tank-less water heater might actually consume less energy than what was consumed by the flame pilot alone[3]! The other benefit is that you get all the hot water you want when you want it.

Wood stove (biomass heating)

No log cabin should be without a good wood stove for back-up heating and cooking. This stove generates up to 30,000 Btus/hour. It has been set up to draw combustion air directly from outside the cabin. This drastically reduces chimney hot air combustion losses and the infiltration of cold air into the cabin from negative air pressure.

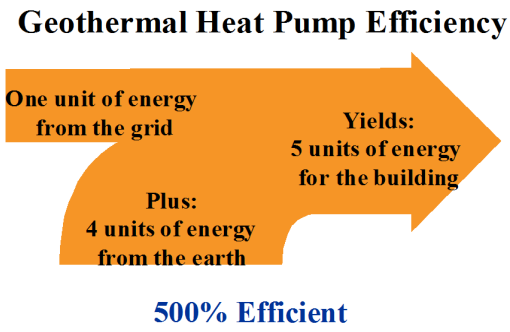
If you have a wood-burning stove or fireplace, introducing outside air prevents the pulling of warm air from the house and sending it up the chimney.

3 For more information on pilot lights, see: http://www.builditsolar.com/projects/conservation/pilotlights.htm

Geothermal Heating Opportunities

The cabin is presently heated with propane gas. In 2010, delivered propane cost as much as $3.77 per gallon. A single fill-up of the 375 gallon tank is over $1,400! Due to our concerns that the cost of oil and propane fuels might double over the next five years, it was time to examine geothermal heating and cooling.

Geothermal heating systems take advantage of the heat retained within the planet. They transfer the heat from ground water to provide heating, air conditioning and hot water within the home. Geothermal heat pump efficiency can be as high as five hundred percent. As shown in the figure to the left[4], for every unit of electric energy used by the pumps and heat exchangers, up to five units of usable energy can be introduced to the log cabin.



Since there is growing credibility that we are now twelve years into a 30-year global cooling cycle, we used worst case sizing conditions of Bangor, Maine for Portland, Maine of minus 20^0 F in our heating calculations. Fortunately, due to the excellent energy efficiency of the log home, our revised tests indicate that the winter heating requirements under these worst case conditions grew to 7 tons (84,000 Btu/hour)[5].

The table at right shows five forms of energy that can be used for heating and their associated current costs (*based on December 28, 2010 rates*).

Maine Statistics			Tons of Heating		Equivalent Btus of energy	Worst Case at	%
Input	=		7		84,000	-20^{0}F	
Energy Type	Unit of Measure	Equipement Efficiency	BTU/Unit	Cost per Unit****	Maximum Energy Units per hour	Cost per hour	% Difference
Electricity (100% eff)*	kWh	100%	3,413	$0.15	24.61	$3.74	311%
Propane (90%eff)	Gallon	90%	91,333	$3.77	1.02	$3.85	323%
#2 Fuel Oil (90% eff)	Gallon	90%	138,690	$2.81	0.67	$1.89	108%
Natural Gas (90%eff)**	1 Therm	90%	102,900	$1.35	0.91	$1.22	35%
Geothermal***	kWh	460%	3,413	$0.17	5.35	$0.91	0%

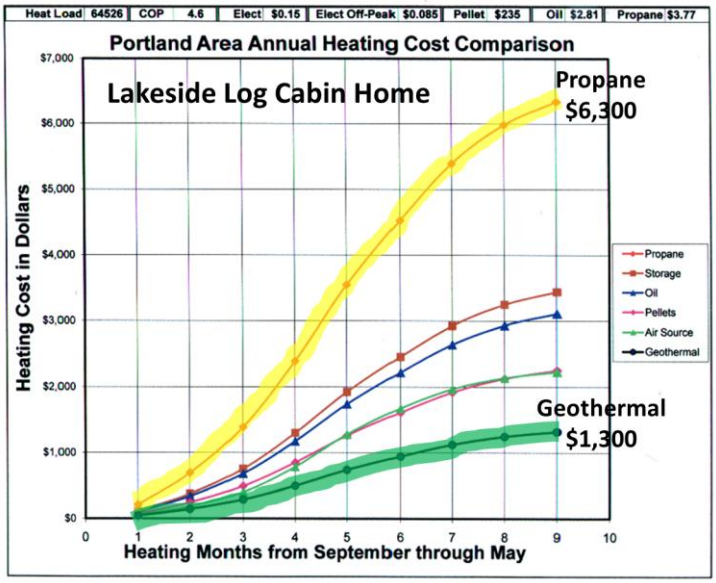
** Based on 800 kWh per month*
***Assumes 100 dekatherms per month on average (Meter fee $22.10/month and average delivery fee of $0.33/therm, 1 year contract at $0.8/therm)*
****Assumes Coefficient of Performance (COP) of 4.6*
***** Based on December 2010 prices*

Geothermal heating technology, operated with minimal electricity, is the least

[4] Image from Dr. John Logan, Water Energy Distributors, Inc., Raymond, Maine.

[5] Since our January 1 analysis we have identified additional energy reduction opportunities in the 1,800 square foot daylight basement that will reduce our geothermal system requirements at least one or two additional tons. Based on these opportunities a 6 ton system will be installed in the spring of 2011.

expensive and is projected[6] to save us $5,000 per heating season (see chart to right) by taking our worst case energy costs from $3.85 per hour with propane down to 91¢ per hour with geothermal.



Geothermal heating is economically viable almost anywhere. Since the cabin has a forced air heating system in place a new geothermal installation might utilize much of the ventilation infrastructure in place.

We had the well on site tested[7] for geothermal heating and cooling capabilities. We learned the well is 303 feet deep, with 38 feet of casing. The pump is a Tait, ¾ hp, 3-wire submersible pump, set down on 280 feet of pipe. The well was pumped to determine the recovery rate measured at three distinct water levels. At the 100' water level, the well was recovering at a rate of 2.7 gallons per minute (gpm). At the 200' water level, the recovery rate was measured at 6.4 gpm. At the 235' level it was 6.7 gpm. Running these well characteristics through geothermal sizing software it was determined that at its current depth and yield, the well could support a three-ton heat pump using 20% bleed in addition to the domestic water demand. Since bleed water cannot be discharged directly, or indirectly, into the lake, if this well was to supplement up to three tons of overall geothermal demands, most likely, the water would be disposed of in a simple dry well installed off to the side.

The most likely option is to drill an 800 to 900 foot well[8] elsewhere on the property and draw all seven tons of heating and cooling from it. The present well might serve as a three ton backup for future needs. As we pursue a net zero energy home, we will have to eventually size solar panels for some additional electric power required to run a seven ton geothermal system. When we combine geothermal electrical needs with the balance of cabin's electrical requirements, our goal is to see if it is possible the keep annual electric consumption well under 12,000 kWh (1,000 kWh per month).

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[6] Chart created by Dr. John Logan, Water Energy Distributors, Inc., Raymond, Maine.

[7] The well was tested December 13, 2010, by Ike Goodwin, Goodwin Well & Water Inc., Northern Turner, Maine.

[8] The revised six ton Climate Master geothermal system to be installed by Mark Conley, Conley Enterprises, Raymond, Maine, will require a 660 feet (includes 10% safety margin) standing column well.

Passive Solar

Since the home was built in 1987, overgrown pine trees had drastically limited the passive solar collection capabilities of the large windows to the south and east of the cabin. These trees were cut down and processed into building materials. We can now capture more radiant energy through the large eastern and southern facing windows.

Solar Power

To ultimately achieve a net zero energy home, the solar generation has to be designed to exceed the average monthly electrical requirements. With the tree clearing, solar power has now become more feasible in the future. We are optimistic about ongoing advances in solar panel technology that will lead to continued price reductions. Once we establish overall annual electrical requirements, we can project the number of solar panels needed to match our cabin's needs.

Back-up Generator

Though this property's power lines are buried underground, they are exposed to the elements offsite. We want to pursue a small generator, fueled by propane, to use when power outages occur. A 350 gallon propane tank can run an 8.5 kW generator for 196 hours (about 8 days). The question is whether this would handle a geothermal system, water pump and other critical cabin appliances. Eventually, solar power panels could help supplement the overall electric load.

Next Steps

Dramatic strides toward reducing energy consumption have been made inside and outside this secluded lakeside retreat. In 2011 we hope to install geothermal heating (and cooling) and backup electric generation. By 2013, we will review advances in solar technology and select the system that makes the best sense for our circumstances. With on-site renewable energy provided by the sun and ground water, we hope to approach zero net energy consumption from the grid.

More images and information on renting this lake-front log home can be found at:
http://rentaldata.krainin.com/vacationrentals/cottages/brochure/URBRAK