Pursuit of a Net Zero Energy Home II

Michael Brakey

Brakey Energy
your key to energy

In 2007, winter heating loads exceeded 12 tons at this lakeside, 5,000 square foot, log cabin home in New Gloucester, Maine. The heating and ventilation system were undersized, antiquated and needed to be replaced. Upon acquiring this investment property in the spring of 2008, we needed to go in one of two directions:

1. Do we immediately install a state-of-the-art 12-ton HVAC system?

   An immediate upgrade to a 12-ton propane furnace, coupled with 6 tons of whole house air conditioning and a properly designed and installed ventilation system throughout the cabin could cost $60,000 or more. Thereafter, we would be strapped with expensive propane fuel costs exceeding $10,000 annually. There would also be all the added electrical costs associated with summer air conditioning. This kind of desired comfort for our guests would significantly increase the cabin's carbon foot print.

   If we went with a 12-ton geothermal HVAC system though our initial installation costs would be higher at around $80,000, our operating HVAC energy costs would fall well under $5,000 annually. It would be too expensive to pursue a net zero energy home due to the large energy footprint. Solar panel costs would be too high.

2. Do we delay the HVAC installation until we explore all energy savings opportunities to reduce the energy footprint and possibly pursue a net zero energy home?

   Bring in Blower-In-The-Door energy consultant to review all energy savings opportunities. We would budget $20,000 to $40,000 to shrink our energy footprint by a minimum of 50%. While providing our guests exceptional comfort, we would significantly decrease the cabin's carbon foot print. We could continue our pursuit of a net zero energy home.

In our March 1, 2011 article[1] titled, "The Pursuit of a Net Zero Energy Log Cabin Home – Part I", we reviewed dramatic strides taken over the first three years in reducing energy consumption by more than 50% on this vacation retreat[2].

Now into the fourth year of our seven-year project, we turned our attention to the next critical task, namely using the powerful properties of well water to help us provide our guests with a state-of-the-art HVAC system.

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[1] See link: http://www.brakeyenergy.com/wp-content/uploads/2009/10/Pursuit-of-a-Net-Zero-Energy-Log Cabin Home-Part-I-March-1-2011.pdf

[2] The lakeside cabin comfortably sleeps 11 to 17 guests.

Antiquated Propane Heating & Delivery System

The prior owners disclosed to us that they burned five to six cords of firewood each winter in the basement woodstove to supplement the heat provided by the 6.6 ton, forced air Lennox Pulse G14 series propane furnace. Keeping the basement door open at all times, the woodstove operated to deliver additional hot air to the first and second floors, with the added benefit of keeping the first story floors warm to the touch of bare feet. To take the chill out of one of the second floor bedrooms and bathroom, electric radiant heating had been installed. There were also over 150 light bulbs (heat lamps) that could contribute close to 10 kWh of waste heat. We estimated winter heating loads could easily exceed 12 tons (144,000 Btus per hour or equivalent of 42 kWh per hour).

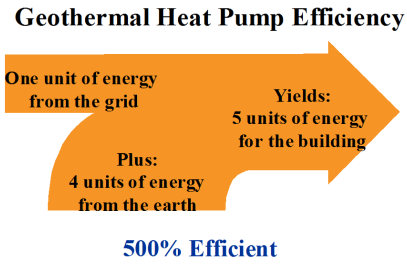
Prioritizing Renewable Energy Resources

Renewable energy sources include, solar, wind, geothermal and even wood (a biomass fuel). While good wood stoves are great short-term back-up heating systems in times of power outages, their intensive labor requirements often times prove impractical for long-term and continuous winter heating operations.

Unlike solar and wind that are only available when the sun is shining (average 5 hours per day in Portland, Maine) or the wind is blowing at the right speed and direction, a properly designed geothermal system offers heating (or cooling) whenever called upon, 24 hours per day, 365 days per year!

Sizing Geothermal vs. Solar Systems for 500 kWh a Day

Electricity is the dominant feature controlling the operating cost of a geothermal system. As shown in the sketch to the right, for certain geothermal arrangements, each unit of energy drawn from the local electric utility to run the well pump, the geothermal transfer equipment and the distribution system's pumps, circulators, and fans, yields up to 5 units of useful energy (500% efficiency)!



The geothermal heat pump efficiency of our system is estimated at 460%. Our six-ton geothermal system draws up to 4.6 kWh per hour of electricity from Central Maine Power to provide the cabin 21 kWh per hour of equivalent[3] radiant heat. Under worst case conditions of an entire day of -20^{0}F, our geothermal system provides 500 kWh of equivalent radiant heat while only drawing 110 kWh off the electric grid. If I wanted a solar panel system to deliver the same 500 kWh per day to match the 6-ton geothermal system, I would need 100 kW of

[3] One kWh equals 3,413 Btu's of energy.

solar panels. Remember that Portland, Maine sees on average 5 hours of sunlight per day. I have to divide 500 kWh by 5 hours of sunlight.

Installation Costs of Geothermal vs. Solar for 500 kWh Peak Winter Loading

The turnkey cost of geothermal systems typically run from $4,000 to $7,000 per ton of heating and cooling. Our turnkey installation costs ran towards the higher side[4] since we did not use the domestic well on the property nor the antiquated and undersized ductwork already in place. Our turnkey cost was $6,666 per ton ($1,900 per kWh of heating/cooling).

Below is a published commercial solar electric systems loads table from one of many good solar installers. Each column lists a profile name, load size, square feet of panel area required, monthly average kWh generation and installed cost.

Question: Which of the solar panel profiles shown below might match the winter load requirements of our $40,000 geothermal installation?

COMMERCIAL SOLAR ELECTRIC SYSTEMS

clean, reliable, sustainable electricity

Dovetail Solar and Wind offers a full line of solar & wind energy systems that include professional turn-key installation.
Grants are available for many Ohio customers. All systems are eligible for 30% Federal tax credit and 5 year depreciation.

Sample Solar Electric (photovoltaic) Systems						
Solar PV System	**The Office**	**The Firm**	**The Shop**	**The Institution**	**The Building**	**The Plant**
Size (STC)	10.7 kW	26.9 kW	52.4 kW	67 kW	101.9 kW	249.9 kW
Area (Flush/10° tilt)	860ft.² / 1,440ft.²	2,150ft.² / 3,600ft.²	4,200ft.² / 7,050ft.²	5,360ft.² / 9,000ft.²	8,150ft.² / 13,650ft.²	20,000ft.² / 33,520ft.²
Estimated Monthly Energy Production						
Monthly Average ⓘ	990 kWh	2,470 kWh	4,820 kWh	6,160 kWh	9,370 kWh	23,000
Major System Components						
Modules	48 Sharp 224W	120 Sharp 224W	234 Sharp 224W	299 Sharp 224W	455 Sharp 224W	1,116 Sharp 224W
Inverter(s)	Fronius IG+11.4	Solectria PVI 13(2)	PVP 50K	Solectria PVI 60K	PVP 100K	PVP 260K
Typical Total Installed Cost						
Cost per Watt	$7.26	$6.82	$6.16	$6.00	$5.71	$5.33
Installed Cost ⓘ	**$78,100**	**$183,200**	**$323,100**	**$402,000**	**$582,000**	**$1,331,000**

Answer: Our 6-ton geothermal system draws 4.6 kWh per hour from the local utility. Does that mean "**The Office**" at 10.7 kW, with a price tag of $78,100, is double what we need? No. Remember that even though our geothermal system draws 4.6 kWh, it delivers 21 kWh of equivalent energy per hour.

[4] In this case our turn-key price included a Climate Master 6-ton heat pump, drilling a 660 foot well and the installation of an entirely new ventilation system throughout the cabin.

Does that mean "**The Firm**" at 26.9 kW and $183,200 exceeds our needs? No. Remember that our geothermal system draws 4.6 kWh per hour, delivers 21 kWh of equivalent energy per hour, each hour of the 24-hour day. Our geothermal system delivers the equivalent of 500 kWh per day. This solar package only averages 82 kWh per day.

Does this mean "**The Building**" at 101.9 kW and $582,000 is about what we need? In theory, yes; in reality, no. On average, Portland, Maine receives 5 hours of sunlight per day. Unfortunately, Portland receives less sunlight during the winter months and more sunlight during the summer months. In the column labeled "Monthly Average" for "**The Building**" Dovetail lists 9,370 kWh (312 kWh/day). On a snowy winter day in New Gloucester, we might get little if any electric generation when we need it most!

Central Maine Power allows customers to bank excess kWh generated during peak time periods and save it for sunless days and evenings. That would help us avoid storage batteries[5] and we could use a smaller solar system to build up kWh credits for winter heating months.

I suspect "**The Firm**" at 26.9 kW and $183,200 would meet our overall annual needs. The system would generate around 30,000 kWh annually.

Problem: If we had the $183,200 to proceed with "**The Firm**" installation, there are two additional drawbacks. The great room's large window faces the south for passive solar heating. The 2,000 square feet of metal roofing is orientated to the east and west limiting sunlight exposure. Even if half of the roof faced directly south, we only have enough room for "**The Office**" with a 10.7 kW system. Unfortunately, this option can only supply a little less than 12,000 kWh annually. Even if money was no object, we do not have enough ideal roofing for up to 3,600 square feet of solar panels.

Summary:

This example illustrates the startling and dramatic differences between two renewable energy technologies at this time in America. The 6-ton geothermal system addresses all our immediate heating and cooling needs. With the exception of a tank-less water heater fueled with propane, everything else on the property is

[5] Each cold, sunny day we would need to back up 410 of the 510 kWh of the daily generated electricity for the 19 off hours without full sun. These back-up batteries cost around $4K per 5 kWh of storage. We need $328,000 for 82 storage battery systems. We don't know where we would have room to store them either. It is a moot point if we have a cold, snowy day with no sunlight.

run with electricity. We will gather electrical data over the next two years to determine overall electric usage patterns.

We hope to see annual electric consumption under 12,000 kWh annually. If Central Maine Power rates average 18¢ per kWh over the next three years, electric costs will average $2,200 annually.

Over the same period of time, we expect solar technology to become dramatically more efficiency (resulting in smaller roof footprints). If solar panels advances continue to lower the installation cost per watt, we hope to install the equivalent of Dovetails "**The Office**" on half the roofing requirements in 2014. The payback period for the geothermal system is under six years. Unfortunately, even if the cost of the solar system dropped by $78,100 to under $40,000[6] the payback would still be over 23 years.

At that point in time, our seven-year energy experiment will be complete. We will have achieved our net zero energy home.

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

[6] This figure is before any federal or state business tax deductions (if still available). If Central Maine Power rates remained around 15 cents per kWh, the simple payback on $40,000 would be 23 years.