NET ZERO ENERGY READY HOME IN DILLINGHAM, ALASKA

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Despite increases in the energy efficiency of homes, the total energy used in the residential sector in the U.S. continues to rise. As shown in the residential statistics of the U.S. Department of Energy's report for the period of 1985–2004, the average energy usage per square foot decreased by about 10 percent, but at the same time, the average square footage of a household increased by almost 20 percent. If society acknowledges the importance of reducing energy consumption, a logical question to ask is: What good does it do to increase the energy efficiency of homes if it is outweighed by escalations in their size? This question is addressed by the project described in this article. The main purpose of this project is to demonstrate that by combining super-efficient construction technology with small house size, an extremely low energy home can be achieved.

For readers not interested in the small-house-size aspect, though, it should be mentioned that the basic technical concepts presented in this article can also be applied to larger structures. Readers are also encouraged to look at the summer 2011 issue of this newsletter, which describes several super energy-efficient homes built in the Fairbanks area by professional builders — these houses are not just super energy efficient, they are beautiful pieces of art. The house described in this article is much simpler (I am not a professional builder). It is shown in Figure 1. It was built by me, Kristin Donaldson (my wife) and many valuable helpers. The design is based on the UAF Bristol Bay Campus Environmental Science Lab's small experimental structure known as the "Passive Office."

Figure 1. A view of the house from north west. Yes, it does have a window on the north side — not a good idea for passive solar design, but we couldn't resist putting one there because of the beautiful mountain view towards the north. The majority of our window area is in the south wall. The house has outside dimensions of 24' x 24', 1½ stories (main floor plus a loft), two bedrooms, one bathroom, and is located in Dillingham (about 11,000 heating-degree-day climate).

The interior floor area of our house is about 600 square feet. It should be mentioned that the building envelope could accommodate a full second floor (as opposed to just a loft), and therefore, the house could have a higher square footage if that was a priority. It was our personal preference to sacrifice the square footage for the open feel (see Figure 2). The interior isn't completely finished yet, but we have been living in the house since January 1, 2012. Despite the fairly small

Figure 2. A view of the kitchen (still unfinished) from the loft. Besides being extremely efficient (note the window sill, which reveals the 28" thick wall), the house also features healthy and environment friendly materials, such as zero VOC paints, recycled glass counter tops and window sills, and bamboo cabinets and flooring.

size of the house, we are finding the home pleasant and comfortable thanks to the open concept and efficient use of space.

The house is largely based on the Passive House standard. Even though it doesn't meet the requirements for certification, this standard was used as a guiding principle. Our goal was to build a house that doesn't need a conventional heat source — a house that is so superefficient that the internal heat gains (byproduct heat from lighting and appliances, body heat and passive solar gain) are sufficient to provide the majority of the heat.

Our home was constructed using a double-frame technique, which allowed for a continuous wall/ceiling cavity between the interior and exterior frame (see Figure 3). After wrapping the interior frame in a continuous vapor barrier, the cavity was filled with blown-in cellulose insulation (a very environment-friendly type of insulation made from recycled newspaper). This achieved a super-tight structure and minimal thermal bridging. Some of the energy related features of the completed house are as follows (values are approximate):

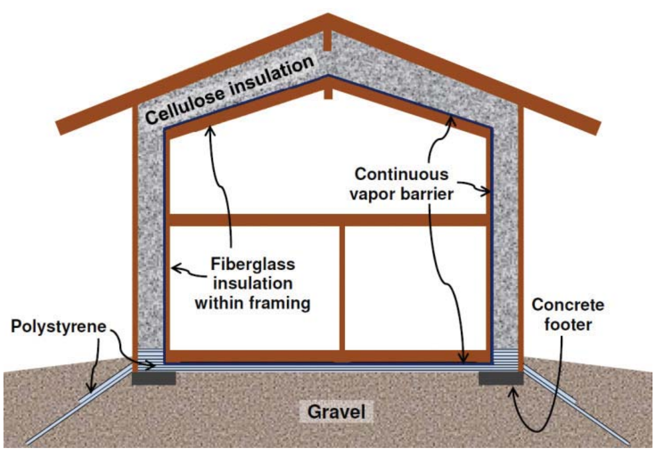

Figure 3. Conceptual drawing. The basic idea is simple – build a small box inside a bigger box, seal the small box in a plastic bag, fill the whole cavity between the boxes with insulation, and you will end up with a supertight and superinsulated structure. This concept has several advantages: The fact that the inside box is basically a stand-alone structure minimizes thermal bridging and creates a simple surface that can be easily wrapped in plastic, creating an almost perfect vapor barrier. Since the plastic is applied on the outside of the interior structure, wiring and plumbing can be run without puncturing the vapor barrier.

Figure 4. Preliminary blower door test before installing the drywall (the final test is yet to be done). The results are astonishing: 9 cfm at 50 Pa, which translates to about 0.10 ACH50. It is the tightest house in the U.S. that Energy Conservatory (the blower door manufacturer) is aware of!

- Walls: R-90 (28" thick)
- Ceiling: R-140
- Floor: R-35 plus R-20 outside along the perimeter
- Airtightness: 0.1 ACH50 (see Figure 4)
- Heat Recovery Ventilator (HRV)
- Triple-pane, argon-filled, double low-e, fiberglass-frame windows
- Passive solar design to a certain extent (not a great solar site)
- ENERGY STAR appliances
- Compact fluorescent lighting with step switching
- Heat pump water heater
- Low-flow plumbing fixtures
- Entirely electric (no oil, no propane, no wood)
- 2 kW electric heater for supplemental heat

The majority of needed heat is coming from internal heat gains (see Figure 5). A small amount of supplemental heat (which is needed in winter months) is supplied by an electric heater. The annual amount of the supplemental heat corresponds to about 35 gallons of heating oil (if we

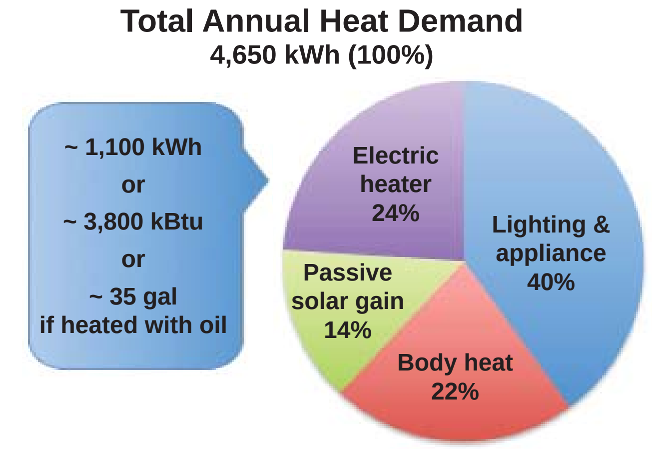

Figure 5. The proportions of supplied heat (as determined by a simulation for a typical year). As shown in the chart, the majority of the heat comes from internal heat gains (byproduct heat from lighting and appliances, body heat, and solar energy coming through the windows and glass door). The internal heat gains are not entirely sufficient to keep the house comfortably warm, and therefore, a small portion needs to be supplied from a heater, which currently is just a small electric heater. We are now investigating the possibility of using an air-source heat pump to further reduce the already small amount of electricity needed for heating.

were heating with oil). It is too small an amount to justify the capital cost of an oil heating system and associated issues, such as need for an oil tank, combustion safety concerns, etc. Also, an oil heating system wouldn't go well with the "net zero energy ready" theme of our house.

The total annual amount of electricity to operate our house (as determined by a simulation for a typical year) is about 3,800 kWh, which is an amount that could be reasonably produced from renewable sources (thus "net zero energy ready") and we are hoping to be able to purchase this amount of renewable electricity from our utility in the future (as a sustainable energy faculty at UAF Bristol Bay Campus, one of my many roles is to help research utility-scale renewable energy systems for our community). The 3,800 kWh/yr covers everything — heating, lighting and appliances, cooking, hot water, well pump, etc. The simulation results are in good agreement with real-life data. From January 1 to April 30, 2012, our house used 1,620 kWh total for the four months, while the simulation predicted 1,520 kWh for the same period. The small difference is largely due to the fact that January 2012 was unusually cold.

It is interesting to point out that our house uses less electricity than an average house in Dillingham. This, coupled with the fact that our house uses no heating fuel, results in a significantly lower energy bill (see Table 1). The more than $4,000 annual savings (based on current energy costs; likely more in the future) are achieved thanks to combining super-efficient construction technology with small house size.

Table 1. Annual energy cost of our house as compared to an average house in Dillingham.

	Electricity	Heating Fuel	Total
Average house in Dillingham	(5,930 kWh) $1,270	(700 gal of oil*) $3,990	**$5,260**
Our house	(3,760 kWh) $900	None	**$900**

* 700 gallons of oil per year is reported as average for rural Alaska; data for Dillingham not available.

The technique used for our house has its pros and cons. The pros include very low energy use, healthy indoor environment and safety (no combustion and no fuel storage). The main cons are the extra material and added labor (one basically has to frame two houses). Just the cost of insulation itself was about $20,000 — material is expensive in rural Alaska, but costs are partly offset by not having to install a conventional heating system (our electric heater was less than $400). A thorough economic analysis hasn't been done yet, but the payback period on the extra costs isn't going to be super short. However, a well-built home is likely going to last for a very long time, and given all extra benefits to society through a reduced consumption of fossil fuels, I think the extra initial investment is well worth it. With that, I am not suggesting that everybody should build houses exactly like ours. The actual design depends, of course, on the specific conditions at the specific place. What works well for us might not work well in a different climate and different conditions. The main message is that if there is a will, there is a way to build homes that support the sustainability of our communities, as demonstrated by several individuals and organizations across the state.