Zero Net Energy Homes

By Marc Rosenbaum, P.E.

The concept of zero energy homes has really taken off. I don't really know how to do a zero energy home in New England, so I've been working on helping people do zero net energy homes (ZNEH). The difference is that a zero energy home makes all the energy it needs from site incident resources without importing any energy, whereas a ZNEH imports energy when site resources are insufficient and exports energy when the site incident resources exceed the home's usage. The result is that on an annual basis, the ZNEH exports at least as much as it imports.

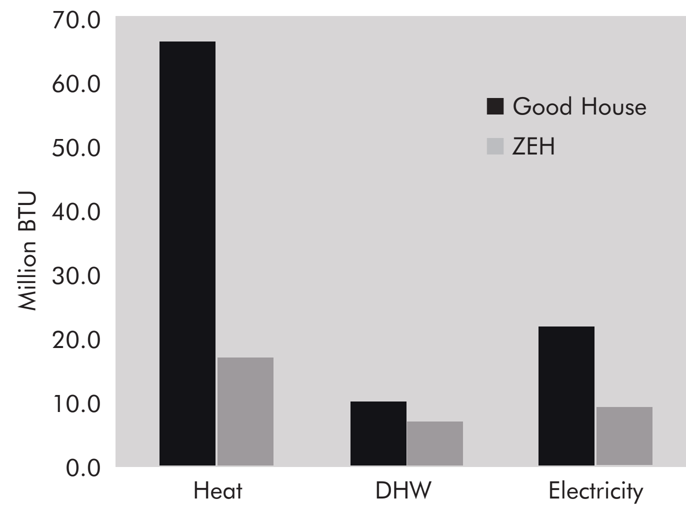
This 800-square-foot home in Portland, Oregon was designed to be a zero annual net energy home.

A Comparative Analysis

In order to get to a net zero performance in the Northeast, a home and its occupants must be unusually conservative of energy. I did some modeling of an 1800-square-foot home built and operated in two ways. The first scenario is a typical good house, not code minimum, inhabited by reasonably conservative occupants with domestic hot water usage (DHW) of only 40 gallons per day. The second is a superinsulated house that has heat recovery on the drainwater and with occupants who have chosen the most efficient version of each electrical device (lighting, clothes washer, dishwasher, computer, etc.) and are very conscious about turning things off when they are not in use. This house, and these people, are candidates for the ZNEH approach. In the ZNEH, annual heating energy is about 25 percent of the energy used by the good house, DHW energy is 30 percent less, and electrical usage is under half. None of these energy consumption levels are pie-in-the-sky figures; there is good data available that they are achievable even in northern New England climates.

This superinsulated house in Hanover, NH uses the equivalent of 55 gallons of fuel oil annually for heating and hot water.

Figure 1:
Comparative Annual Residential Energy Use



The characteristics assumed for the ZNEH include:

- R-40 walls, R-60 roof, R-5 windows (insulated fiberglass frame and sash, triple glazing with double low-e layers, high solar heat gain coefficient glass, 2/3 of the glass on the south), R-20 basement
- Airtight construction with an average air change of 0.1 per hour
- Heat recovery ventilation
- Drainwater heat recovery for the showers and sinks

Once the load is reduced to this level, it's possible to envision a renewable energy system that on an annual basis will contribute as much energy as the home and its occupants consume.

Getting to Zero

Renewable energy options for the Northeast include solar thermal and solar hot water and wind energy in coastal or certain interior locations (usually ridgetops). Less common, but possible, is micro-hydro. I am excluding in this discussion renewable biomass. I believe that biomass will play an increasingly important role in the energy picture in the Northeast, and some may say that site-harvested biomass can qualify as a source for a ZNEH. I might even agree, especially when small-scale biomass-powered cogeneration systems are available. For the purposes of this brief article, I'm going to focus on incident resources such as solar and wind.

The output of on-site conversion of solar and wind power can be either thermal or electrical. Often, a combination of solar thermal and solar electricity is harvested and directed to the most appropriate load. For example, DHW is a thermal load and mostly can be served by a solar thermal system. Heating can be served by a solar thermal system, but there is a disadvantage to this in that the time of greatest need is in the winter, when the system output is lowest. In the summer, when the solar thermal system is making far more energy than the home needs, that energy is not easily exportable to other users (an exception would be in a settlement pattern far more dense than the typical U.S. single family home.) Electricity is easily exportable, which supports the zero net energy concept well. This leads to using site-harvested electricity to drive a ground source heat pump (GSHP), which is an electrically powered device

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that heats and cools a home. This approach was first demonstrated by longtime NESEA member Steven Strong over 20 years ago. The GSHP can produce three or more units of output thermal energy for every unit of electrical energy (Coefficient of Performance, or COP, of 3), which reduces substantially the amount of renewable energy needed to heat the home. The heating distribution system for the house must be designed to work with low-temperature water (or air) because, as with solar thermal, GSHP efficiency is higher with lower temperatures.

If we go back to the loads calculated for the super-efficient home described above and convert it all to kWh/year, we get:

Heating	4900 kWh
DHW	1960 kWh
Electricity	2700 kWh

We can decide to use solar thermal to handle the DHW load—a single 40-square-foot collector would provide perhaps 70 percent of the annual load. A GSHP will supply the heating energy and the remainder of the energy for DHW. If the GSHP provides this energy at a COP of 3, then heating energy would be 1633 kWh/year (4900/3), and the remaining 30 percent of DHW would be 196 kWh/year ((1960 x 0.3)/3). Add these thermal loads to the electricity load for lighting and appliances and the total is 4529 kWh/year. This is about 2-1/2 kWh/sf/year total energy, a truly superior number. I believe it is achievable, partially because the Hanover House, a low energy, all-electric solar home I designed, averaged about 2-3/4 kWh/sf/year in its first three years in a climate more adverse than most of the Northeast.

Serving a load of 4529 kWh/year with a fixed array of solar electric panels would require an array of about 4 kW, which would occupy 250-400 square feet of roof area, depending on panel efficiency. The house would import energy from the electric grid during the winter months and export energy during the warmer months. This is not a bad thing, as most electric utilities have peak demand in the summer and can use the power right when the house is exporting it.

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Is this a sensible approach to building houses? Should all houses aim to be zero net energy homes? I don't know. I do think all houses should aim to reduce their loads to the levels discussed herein. Whether the societal benefit of tens of thousands of ZNEHs exceeds the benefit of houses with the same load levels but with somewhat more centralized energy generation is a question that has not been definitively answered. In the meantime, there are a growing number of pioneers who are aiming at designing and building ZNEHs, and we should all benefit from the knowledge gained in this process.

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