To Achieve NET-ZERO You've Got to Live NET-ZERO

SOUTH MOUNTAIN CO.

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In 2009 and 2010, South Mountain Co. designed and built a cluster of eight high-performance affordable single-family homes in West Tisbury, Mass., on the island of Martha's Vineyard, for the Island Housing Trust. The homes at Eliakim's Way were designed so that it might be possible for the occupants to produce as much total energy as they use on an annual basis.

All eight houses received LEED Platinum designation and all have permanent affordability restrictions. One of the homes was constructed by Habitat for Humanity with technical assistance and guidance from South Mountain Co. during construction.

Half of the houses are three-bedroom units of 1,447 square feet (134 square meters) and half are two-bedroom units of 1,251 square feet (116 square meters), all with full basements. The main living area and upstairs bedrooms and bath are identical in the two house types; the third bedroom is a north extension of the two-bedroom plan. Designed and built to be net-zero-possible, they are all-electric homes, each with a 5.04-kilowatt (kW) SunPower photovoltaic (PV) array.

When the houses were occupied, on June 1, 2010, South Mountain announced the following challenge: Each household that was able to go the year (until May 31, 2011) at net-zero-energy use (or less!) would be awarded a year's membership in the local community-supported agriculture farm or a $400 gift certificate at a local fish market. After one year, two households used less energy than the PV array generated. Two other households were very close: within about 1,100 kilowatt-hours (kWh) of reaching net-zero.

Because this sample of low-energy housing is nearby and equipped with good metering, we were able to do comprehensive data collection and analysis and then issue a full report. In addition to the standard utility electric meter, each home has sub-metering on the mini-split heat pump, electric radiant panels, domestic water heating (DWH), PV inverter output and water to the domestic hot water tank. We read the meters monthly.

In short, our study confirms that however energy-efficient the house, performance ultimately comes down to household size and behavior — or, as energy consultant Andy Shapiro says, "There are no zero-energy houses, only zero-energy families." The data hold key lessons and raise questions that we can use to make our future projects even better.

Design Targets Ultra-Efficiency, Affordability

The houses at Eliakim's Way are super-insulated and have unobstructed southern orientation. Basements are within the thermal envelope, with R-20 walls and sub-slab insulation. Above-grade walls are R-31, roofs are R-50 (effective R values for the entire assembly). Windows are triple-glazed Thermotech casements with two low-emissivity layers and argon fill (south-facing windows have Energy Advantage low-e coating

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A yearlong study of eight high-performance homes confirms that performance ultimately comes down to household size and behavior.

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Lowest production is seen at houses 2, 3 and 8, and highest at houses 5 and 6. How much of this variation is equipment performance and how much is light shading or off-south orientation is unclear. Lowest production is in the one house that has installed a satellite dish on the open portion of the roof adjacent to the PV array. It's not clear how much, if at all, this dish shades the array.

with a solar heat gain coefficient of 0.62; all others are 0.48). Blower-door results range from 117 to 184 cubic feet per minute of air leakage at 50 pascals of pressure (CFM50) for the seven South Mountain homes and 236 CFM50 for the Habitat home. These results were achieved with no mechanical openings taped off and with the heat recovery ventilator running.

Heating and cooling are provided by a Daikin single-zone mini-split heat pump (RXS24 DVJU) with a wall cassette in the main living area. For supplemental heating, we used ceiling-mounted Enerjoy electric radiant ceiling panels. The houses are designed such that the single-point source of heat — the heat pump — should be able to provide all the required heating, as long as the doors to the bedrooms are left open to allow heating by natural convection. The radiant panels allow heating in the event of a doors-closed operation, or to provide supplemental heating in extreme cold conditions.

Ventilation is provided by a constantly operating Fantech 704 heat recovery ventilator. This unit draws about 30-35 watts, exhausts 25 CFM from each bathroom and supplies 15 CFM to each bedroom. (In the case of the two-bedroom units, 15 CFM is also supplied to the living area.)

Domestic hot water is supplied by a 50-gallon Marathon electric water heater. This polybutylene-lined tank is insulated with 2.5 inches of closed-cell foam.

The homes face close to due south and have essentially full solar access. Variation in PV production from house to house is small. The Massachusetts Clean Energy Center (MassCEC) PV production calculator for these arrays estimates an annual output of 6,247 kWh. The average output of the eight systems was 6,873 kWh, 9 percent higher than the estimate. We don't know how much of this is due to better-than-average solar insolation and how much is due to the premium SunPower product. Production exceeded the estimate for 10 of the 12 months and fell short for two months.

Not surprisingly, PV production reached a minimum in November and December and a maximum in July, although March was an excellent month. Every household achieved at least one month as a net exporter. All households were net importers in the four coldest, cloudiest months. As a neighborhood, the total annual net import was 13,680 kWh.

Occupant Choices Drive Energy Usage

The production of the PV array sets the total annual energy budget that a household can use if zero-net energy is the goal. As shown in

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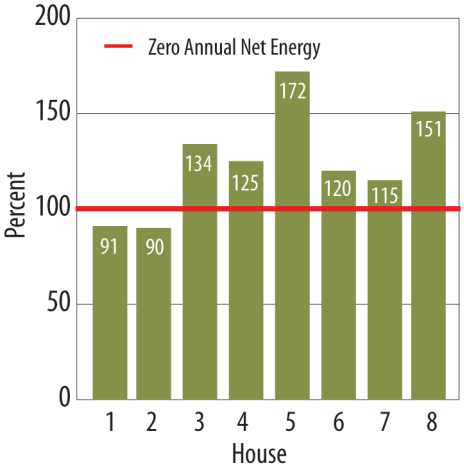
This article was adapted from a full report on Eliakim's Way by South Mountain Co. titled, "Zero-Net Possible? Yes!" To view the full report, visit southmountain.com.

Figure 1. Annual Energy Usage vs. Average PV Production at Each House



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The houses are super-insulated: Basements are within the thermal envelope, with R-20 walls and sub-slab insulation. Above-grade walls are R-31, roofs are R-50.

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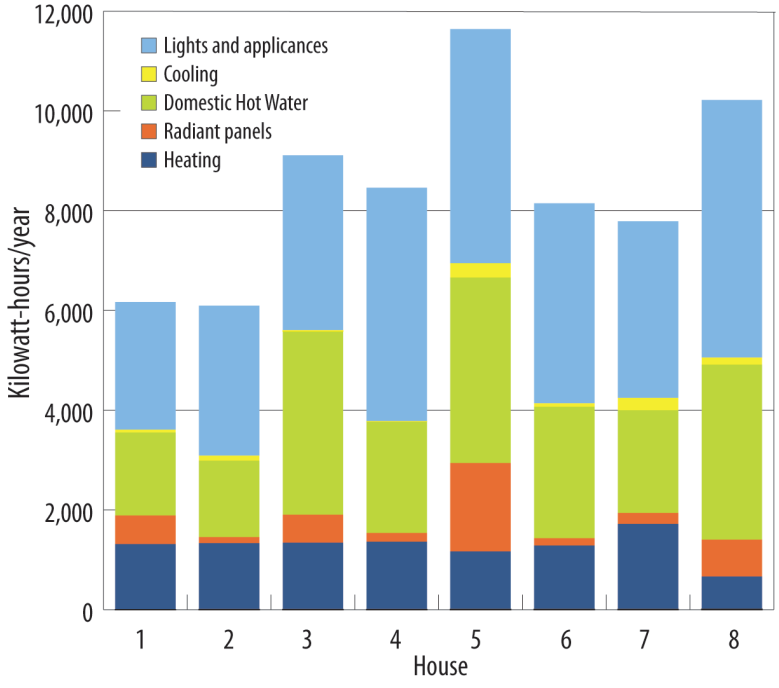
The single point source of heat — the heat pump — should be able to provide all the required heating, as long as the doors to the bedrooms are left open to allow heating by natural convection.

figure 1, two households achieved zero-annual net energy, and an additional two households had energy consumption that was within 20 percent of the PV production.

Figure 2 shows the breakdown of total annual energy use by end use. The meter that logs heat pump energy usage is covering usage for both heating and cooling. In the data analysis, I made the simplifying assumption that June, July, August and September usage was for cooling, and all other usage was for heating. The combined usage for lights and appliances is calculated for each household by subtracting the usage of the heat pump, the electric radiant panels and the domestic water heater from the total energy usage. Occupant choice matters hugely, as the key insights gathered from figure 2 highlight:

Figure 2. Annual Energy Usage at Each House by End Use



Energy used for cooling is small at this northern location, yet it varies by a factor of 26 to 1. It's clearly discretionary energy here — some folks use it, others hardly at all.

With the exception of one house, heat pump energy is relatively even. The electric radiant panel energy, however, varies by a factor of 14 to 1. Since the panels are much less efficient than the heat pump, it is in the occupants' financial interest to minimize panel energy. It may not be in their comfort interest to do so, though.

Heating energy varies by a factor of 2 to 1. If the highest and lowest usages are discarded (as in Olympic judging) the variation is much tighter — the next highest usage is 35 percent higher than the next lowest, and only 38 percent higher than the lowest. The highest usage is 52 percent higher than the next highest usage. Do folks at this house keep the house warmer than others do? In this house, the panel energy is more than twice the amount used by panels in the next highest house — yet the heat pump energy used is second to lowest. I don't think that the heat pump is faulty, but perhaps it is worth checking.

DHW energy varies by a factor of 2.4 to 1. The data reveal that this type of energy usage is much more linked to number of occupants than heating and cooling is.

In all but one household, DHW energy exceeds energy used for heating. That is what happens in low-energy-use houses using heat pumps and electric resistance for DWH. It is clear to me that the next available investment in energy savings in these homes would be either solar thermal or a heat pump water heater!

Plug and lighting loads vary by a factor of 2 to 1. Although it is reasonable to expect that these loads increase somewhat with number of occupants, the second-lowest users are a household of three.

Heating and cooling energy — which is most reflective of the efforts in design and construction — accounts for a small percentage of total energy usage. The two net-zero households have the highest percentage of total energy as heating energy, because their DHW and plug/lighting usages are smaller. Yet even in these cases the heating energy is less than one-third of the total.

Overall, we are pleased with these results. The homes at Eliakim's Way are a superb example of housing that is, as SMC president John Abrams says, "truly affordable forever." The real value of these homes will become apparent over time, as they require little or no expenditures for rising energy costs and will incur very low maintenance costs (due to long-lasting unpainted reclaimed cypress exterior trim, FSC cedar siding and fiberglass windows). We hope the lessons we have learned will help others in the pursuit of high-performance housing for the 21st century. **ST**