**Photo 1:** Installation of the first structural insulation panel.

**Photo 2:** Installing the last SIP on the roof.

**Photo 3:** Completion of the building shell with windows, eaves, and house wrap. The photo was taken on the spring equinox (March 22). Note the overhang shadows at the top edge of the windows when exclusion of direct solar radiation begins.

# Modeling Zero Energy

**By Ty Newell,** Member ASHRAE; and **Ben Newell,** Associate Member ASHRAE

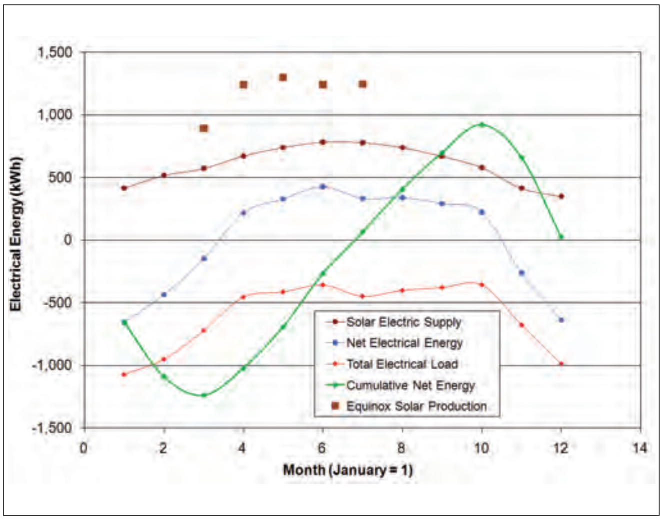
There are no big secrets for building a zero energy house. A zero energy building (ZEB), relative to the climate, should be well insulated, highly sealed and have appropriate windows. In future columns, we will discuss each of these items. In this column, we compare predicted Equinox House performance to actual energy data for similar sized homes to illustrate the performance differences between what we feel is a reasonable ZEB house design for our region (Urbana, Ill.) and typical, modern home construction as it exists in our area.

The basics of Equinox House performance are: R-value of 44 for the walls and roof and a well-sealed shell, achieving an infiltration rate of 0.37 ach at 0.20 in. w.c. (50 Pa), which is 170 cfm at 0.20 in. w.c. (80 L/s at 50 Pa) for Equinox House volume. Windows are triple pane, low emissivity, and appropriate overhangs have been installed over the southern glazing. High shell performance was achieved with 12 in. (305 mm) thick structural insulated panel (SIP) construction and additional foam and caulk sealing.

*Photo 1* shows the installation of the first SIP panel, and *Photo 2* shows the house shell near completion. The completed house shell in *Photo 3* shows the clerestory window overhang shadowing on March 22, the spring equinox. Within three weeks the shadow at the top edge of the clerestory windows will move completely over the windows to exclude direct sunlight from entering the house during the summer.

Equinox House is designed to be a "zero plus" house, meaning it provides house operation energy and transportation energy. The 8.2 kW solar photovoltaic (PV) electric system is designed to provide all house annual energy requirements of two people plus enough energy for driving an electric vehicle 8,000 miles (12 875 km) per year.

**This is the second in a series of columns. Find previous columns at www.ashrae.org/ashraejournal.**



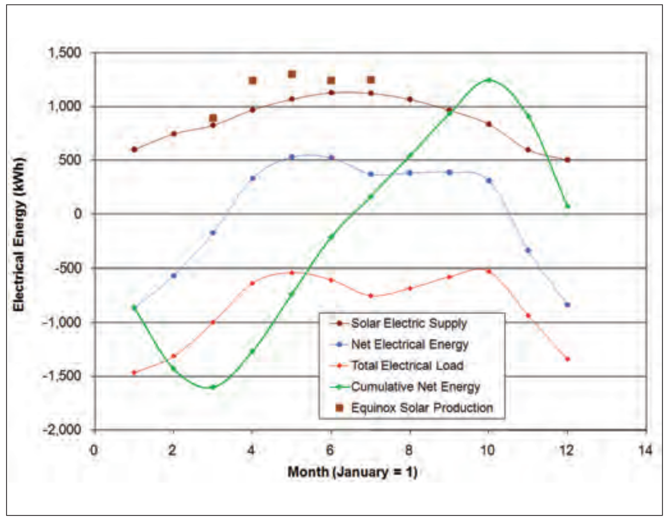




**Figure 1 (left):** Predicted Equinox House energy requirement, solar energy supply, net energy balance and cumulative energy balance for each month of the year with two occupants. Also plotted are actual solar energy system production data for March through July 2010. **Figure 2 (right):** Predicted Equinox House energy requirement, solar energy supply, and net energy balance for each month of the year with four occupants.

The solar PV system is "grid-tied" allowing the house to feed in, or pull, electricity from the utility when needed. *Figure 1* shows the predicted energy requirements and solar production from a simulation model. This illustrates how net zero cumulative energy use over a year is achieved.

Our house simulation model, a monthly average spreadsheet that determines house latent and sensible energy requirements based on wall/roof insulation, windows, number of people, appliance use, and infiltration has been used to generate the total electrical load data for the figures. The model shows reasonable agreement with BESTTEST results (www.nrel.gov/buildings/energy_analysis.html). We will examine the details of these results in later columns.

Four occupants require 2,000 to 3,000 kWh more per year than two occupants due to additional hot water requirements and other human activity related energy requirements (e.g., ventilation, appliances). Predictions for this scenario are shown in *Figure 2*. The blue lines in *Figures 1* and *2* show the difference between the solar energy supply and the house electric energy requirements.

During the summer, excess solar energy is supplied (positive energy), which is designed to balance the energy deficit (negative energy balance) of the house in the winter. The green lines in *Figures 1* and *2* are cumulative energy amounts that add the solar energy produced (positive) with the house energy used (negative) starting with the first month (January). The cumulative energy swings from negative in winter, climbing to positive by fall, and then falling to zero by the end of the year.

## Building at a Glance

**Name:** Equinox House

**Location:** Urbana, Ill.

**Design/Construction:** Newell Instruments, Inc.

**Use:** Single Family Residence

**Owners/Occupants:** Ty and Debra Newell

**House Plan:** 2,100 ft$^2$ (195 m$^2$), four bedroom, 2.5 bath, single level, plus 600 ft$^2$ (56 m$^2$) attached garage

**Features:** Net zero energy, 12 in. (305 mm) structural insulation panel walls/roof, steel roof, cement board siding, 8.2 kW grid-connected solar PV, "equinox" clerestory overhang, 1,700 gallon (6435 L) rainwater collection cistern for toilets and garden, ADA compliant, 120 LED lights (7 W to 8 W each) for all house lighting

**Ground Breaking:** November 2009

**Estimated Occupancy:** October 2010

The 8.2 kW solar PV array for Equinox House will produce 10,000 to 11,000 kWh per year. The PV system was activated on Feb. 23, 2010, and the actual monthly solar electric energy totals from March through July 2010 are also shown in *Figures 1* and *2.*

The difference between the solar energy production and the predicted house energy requirements for two occupants (Ty and spouse, Debra) is for electric vehicle transportation. Approximately 2,000 kWh per year of solar generated electric energy is estimated to be available for transportation. Assuming four miles per kWh for modern electric vehicles, the additional energy should provide 8,000 miles (12 875 km) of electric vehicle transportation, more than sufficient to cover our annual short distance driving.

*Figure 3* illustrates the impact of house insulation, infiltration and conditioning system efficiency on house energy. This data was also derived from our energy simulation model.

Data labeled "Equinox" represents the Equinox House design with an average roof and wall insulation R-value of 44, and "Equinox R-22" is a house similar to Equinox dimensions with an average R-value of 22. Windows for both homes are the same with approximately 200 ft$^2$

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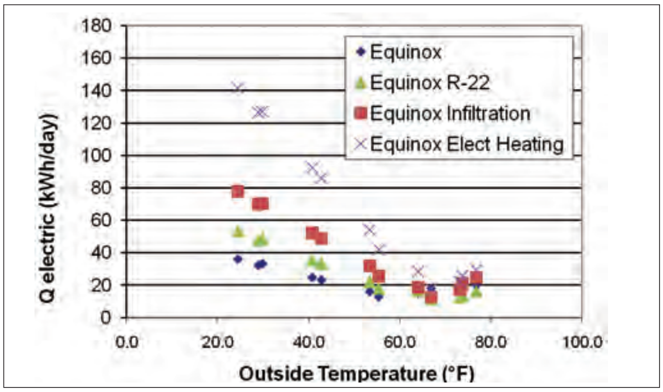


**Figure 3:** Daily house electric requirements for Equinox House design characteristics and three variations.

(18.58 $m^2$) of reasonably good windows and appropriate summer overhang protection (shade and uncover windows near the spring equinox and fall equinox, respectively).

The third data set, "Equinox Infiltration," represents a typical house with R-22 insulation and 100 cfm (47 L/s) of uncontrolled infiltration (taken from a blower door test performed on a home in the same subdivision measuring 2,000 cfm at 0.20 in. w.c. [944 L/s at 50 Pa], corresponding to a rate of 100 cfm [47 L/s] natural infiltration) compared to Equinox infiltration of 8 cfm [4 L/s]).

The last data set, "Equinox Elec Heating," is a house with typical infiltration and R-22 insulation, and winter heating from an electric resistance heating system rather than a high performance heat pump system. A heat pump system will be two times or more efficient than an electric resistance heating system. Overall, in *Figure 3* you can see how different house design and system parameters affect a home's energy use related to comfort conditioning.

A house with conventional "modern" construction in central Illinois requires 24,000 kWh of energy consumption per year. The Equinox House is predicted to require 7,200 kWh per year, or less than one-third of the energy requirement of a modern house. How much is this difference worth? On a simple economic basis, assuming energy costs 10 cents per kWh, a home with typical "modern" construction methods will have energy bills of $2,400 per year, or about $48,000 over 20 years. As a ZEB, Equinox will not have any utility cost. However, there are a few upfront "extra" costs that allow this to be the case.

Using 12 in. (305 mm) thick SIPs over conventional construction is estimated at $20,000, and the house energy portion of the solar PV system also had an installed cost of $20,000 (includes a 30% U.S. federal tax credit). The cost of these two important features together is less than the utility bills of a conventional home over 20 years. Amortized over 20 years, this extra upfront cost has a monthly payment similar to the utility bills that they replaced. Add in energy price inflation, and the case for building a ZEB is even more attractive. The remaining obstacle is finding a bank willing to write a larger mortgage to cover the features needed for ZEBs.

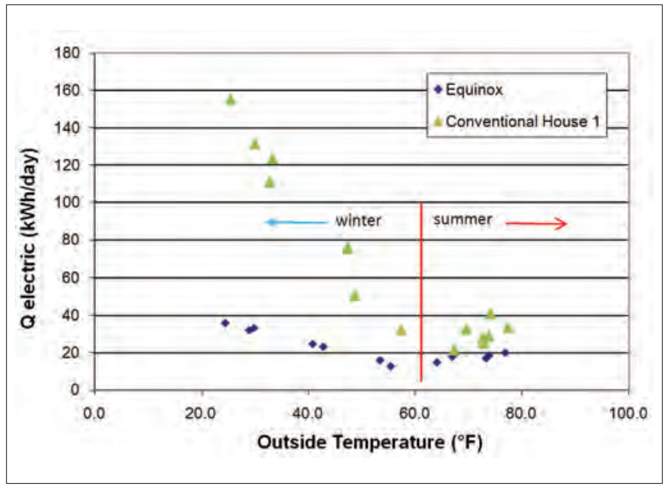


**Figure 4:** Comparison 1 of Equinox House with a recently constructed house.

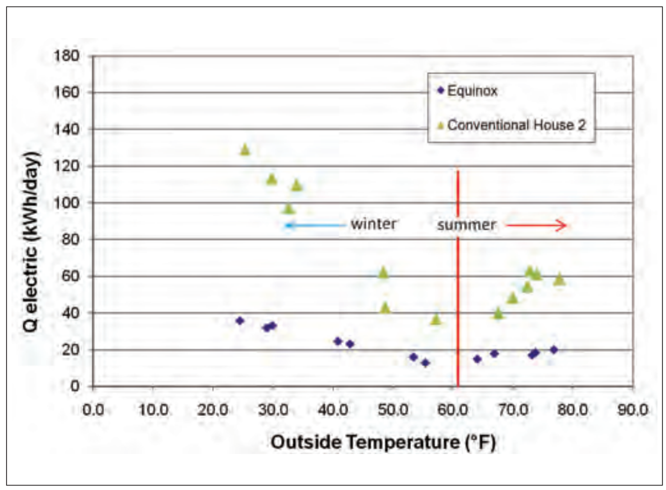


**Figure 5:** Comparison 2 of Equinox House with a recently constructed house.

Before ending this discussion, we compare the predicted performance of the Equinox House with the performance of two real homes in *Figures 4* and *5*. Similar to *Figure 3,* the average daily energy used relative to the outside ambient temperature for these two homes located in Urbana, Ill., are compared to the simulation model results for Equinox. Both homes are similar in size to the Equinox House (~2,000 $ft^2$ to 2,500 $ft^2$ [186 $m^2$ to 232 $m^2$] floor area), and were built within the last five years using conventional construction methods. Notice that both homes have energy performance levels that are similar to those predicted for a conventional, modern construction house shown in *Figure 3.*

So, will Equinox display a performance similar to the predicted? Stay tuned as we present more data and analyses.

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