Equinox House predicted and measured performance for energy supply and use closely match, say the authors, showing "that education and training of the home construction trades is essential to build a home that will perform as designed."

Equinox Meets Needs

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

A year after starting this column, Equinox House is demonstrating solar can meet residential living needs. Ty and his wife, who have been living in Equinox House since October, have found it to be a comfortable home. The house is a good example of an economical, energy efficient and comfortable dwelling. Other construction techniques and system designs also can achieve similar levels of performance. This column summarizes the primary impacts of our design analyses and choices.

Walls/Roof. We used a life-cycle cost analysis to determine the thickness of structural insulated panels (SIPs) for walls and roof. Our analysis found 200 mm to 400 mm (8 in. to 16 in.) insulation thickness for walls and roof would have similar economic performance. The lifetime used in the cost analysis is an important factor, which in our case was assumed to be 100 years. The shallow optimum indicates that our energy and insulation costs are similar over that insulation thickness range such that, one can pay for more energy (200 mm [8 in.] thick wall) or for more insulation (400 mm [16 in.] thick wall). A 400 mm (16 in.) thick wall is more robust from the viewpoint of less dependency on energy to maintain thermal comfort in the house. The simple wall/roof thickness analysis presented was based on independence of the wall and roof energy requirements from other house energy impacts, such as window energy gains or appliance loads. This assumption is good when other house components do not dominate energy.

Windows. Our window design analysis for Equinox House examined the performance and cost of windows with transmission and loss characteristics typical of good and superior windows. Our analysis found that windows do not decrease the life-cycle cost of a residence. Solar photovoltaic system (PV) panels are more cost efficient than windows. The cost impact of carefully selected windows is not large as long as the window-to-floor area ratio is less than 10%. Improperly designed windows are the primary cause

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of discomfort and poor energy performance in many buildings, as well as an additional capital and maintenance expense.

Infiltration. We chose to "superseal" Equinox House because SIPs construction allows low infiltration levels to be reached in a relatively easy manner. Careful attention to design details will save plumbing, electrical and HVAC installation costs, as well as minimize regions where utility penetrations impact house infiltration. We provided detailed cost and performance information for our sealing efforts with a goal of achieving the Passive House infiltration level (0.6 ach at 50 Pa). The rationale behind the Passive House infiltration level is that building loads can be reduced to a level where fresh air ventilation flow can maintain comfort conditions. There is nothing fundamental to this limit, and more or less infiltration, depending on climatic conditions, may or may not impact costs significantly. Our performance analyses indicated that the labor and materials to superseal a house with our construction would have a payback of five years. How long the effects of our efforts will last are unknown and need to be examined.

Foundation. Our February column discussed foundation energy analyses, which require computational models, as well as ground property information that typically is unknown. Ground properties have spatial and temporal variations. We performed three-dimensional transient analyses of our foundation with a range of ground property estimates and found that insulating our foundation wall without any insulation underneath our slab would be the most economical design. On average, our uninsulated slab stays within 1°C (1.8°F) to 2°C (3.6°F) of the 6 m (20 ft) tall ceiling. The superinsulated envelope of the house allows radiant communication among the walls, ceiling and floor to keep the interior relatively isothermal.

Our seasonal ground analysis also indicated that the winter heating detriment of an uninsulated slab in our region was counterbalanced by a reduced summer cooling load. On average, our floor heat transfer was 400 W. We also showed a significant beneficial seasonal storage effect due to typical thermostat setpoint variations from summer to winter.

From March through May, other factors impacting the comfort and conditioning of high performance homes were discussed. Our March column examined thermal mass, a topic that is often discussed in architectural circles without an understanding of what it is, and how to quantify it. We hope our discussion and data helps residential building designers have a better understanding that thermal mass is a combination of building envelope thermal resistance coupled with interior mass characteristics. Windows reduce thermal mass and, as described with data from a heavily windowed "passive solar" house constructed in the 1980s, thermal mass design should be based on engineering analyses. Physical mass does not necessarily make a building "massive." The thermal time constant of Equinox House, without adding any additional mass is four times greater than that of an older, conventional home and the 1980s "passive solar" home.

April's column featured appliances and their significant impact on energy performance in superinsulated residences.

The team during construction. Left to right are: Ben Newell, Alex Long, Mbikayi Nsumuna, and Ty Newell.

Climatic impacts on annual energy become less significant than energy impacts due to humans and their activities in high performance homes. The energy use and interaction of appliances and other human activities can be either favorable or detriments to overall house energy requirements.

The relatively new heat pump water heater technology, for example, provides significant cooling and dehumidification in addition to water heating. Continued advances in appliance technologies, such as ventless heat pump clothes dryers will reduce energy further. Overall, human behavior and habits will be the most important means for gaining high levels of performance.

Perhaps the most important aspect of high performance dwellings is the maintenance of a healthy indoor environment, as discussed in our May 2011 column. As energy requirements for high performance homes decrease, continued energy efficiency gains may not be cost effective and a focus on healthy environments may result in more substantial cost benefits. Modern refrigerators are analogous to this situation.

Three decades of refrigerator energy efficiency improvements have reduced refrigerator energy consumption to 300 to 400 kWh per year, with an annual operating cost of $30 to $40 per year. Rather than continuing to improve the energy efficiency of a refrigerator, it may be time to incentivize food quality and preservation efforts, resulting in less spoilage and food-borne illness. A refrigerator stores approximately $8,000 of refrigerated food for a family of four.[1] A refrigerator that reduces spoilage and waste by a small percentage may be more valuable than additional energy savings. Similarly, high performance homes that monitor and control indoor air quality may have more value than additional energy cost savings in terms of less illness and improved health and well-being.

At the beginning of the series, we discussed the predicted performance of Equinox House relative to similar homes of conventional construction in our neighborhood. Our results in-

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dicated that Equinox House would reduce energy requirements to less than half of that of our neighbors, with person-related energy loads becoming the dominant factor rather than climate. Our June and July 2011 ASHRAE Journal columns returned to the performance of the house and the solar photovoltaic system with actual performance data. The predicted performance and measured performance for energy supply and energy use are in reasonable agreement. Our experience as general contractors for Equinox House has shown us that education and training of the home construction trades is essential to build a home that will perform as designed.

The bottom line is the cost required to achieve high energy performance levels. The cost increase of a superinsulated, supersealed home can be less than the cost savings due to other factors. That is, many other home design and construction choices increase cost more. In our case, we estimated that the cost of our SIP construction for our exterior walls and roof cost $16,000 to $18,000 more than a conventional "stick built" home. This cost difference, when applied over an estimated building lifetime of 100 years is small relative to the energy savings over that same time period. Our "savings" associated with not installing natural gas, careful window design, elimination of thermal stratification (ceiling fans), and efficient utility runs is, at least, equivalent to the extra cost of a superinsulated house envelope. Overall, the additional cost for a superinsulated building envelope is much less than the cost associated with design choices based on fashion (e.g., granite countertops, stainless steel appliances, tiled bathrooms).

We appreciate the many comments, suggestions and ideas readers have communicated to us over the past year. We hope you will follow the performance of Equinox House as we continue posting data from the house on our website (http://newellinstruments.com/equinox). We would also like to express our appreciation to the ASHRAE editorial staff that made our writing experience a positive one. This is a time with many opportunities for our industries to profit while simultaneously improving the quality of life in an ever increasing sustainable manner.

References

1. Carlson, A., M. Lino, T. Fungwe. 2007. "The Low-Cost, Moderate-Cost, and Liberal Food Plans." USDA Center for Nutrition Policy and Promotion.

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