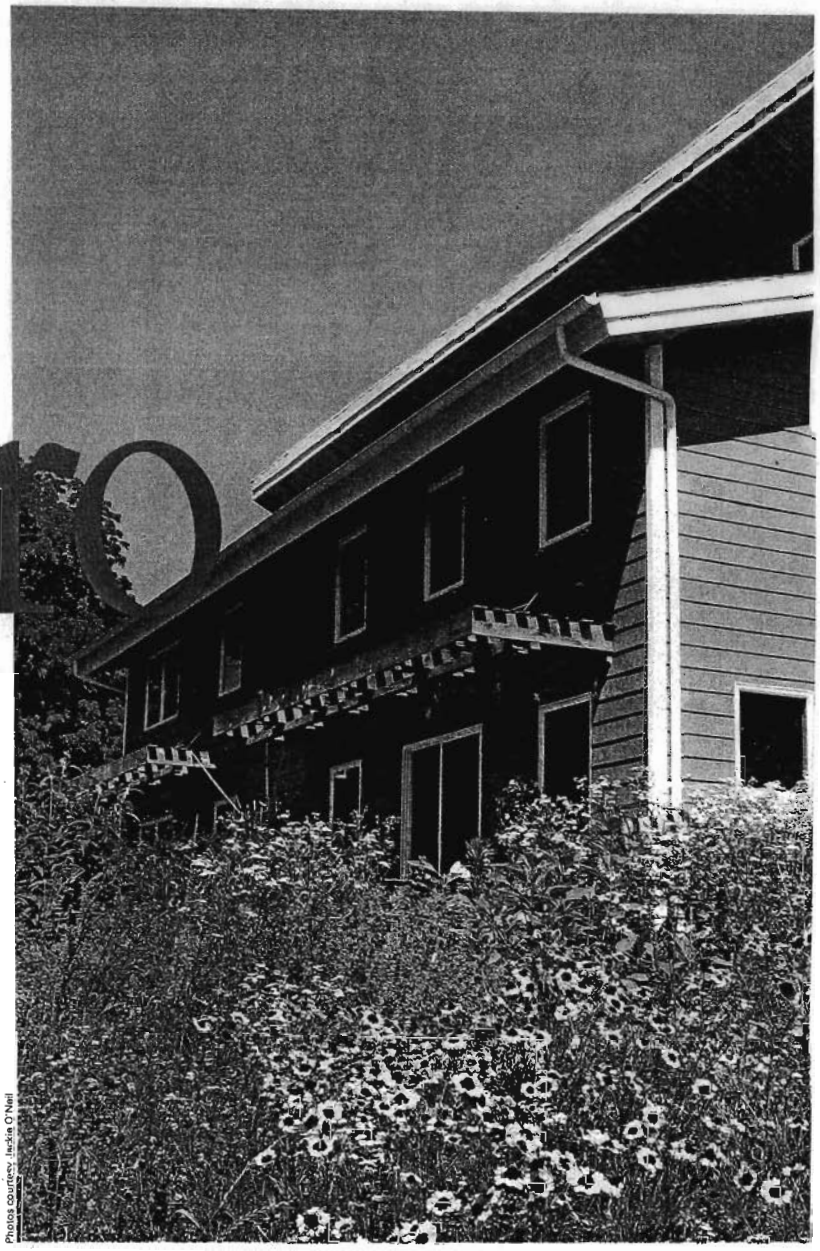
Two new homes in Pennsylvania produce as much energy as they use

Closing in on Net Zero

by Cathleen McCarthy



Photos courtesy Jackie O'Neil

TOP and BOTTOM: The simple exterior of the first gold-rated LEED home in the U.S. belies its carefully orchestrated design and systems.

Enter Jackie O'Neil's home on a muggy 90-degree afternoon and you're struck by the shock of cool air — not the artificial cool of air conditioning but the natural comfort of a perfectly designed home. O'Neil pays nothing for heating and cooling. In fact, solar panels and a geothermal system produce more energy than the house uses. O'Neil actually gets a refund on her utilities at the end of the year.

From outside, the place projects a contemporary simplicity. Newly planted wisteria and flowering shrubs have not yet had time to grow around the overhangs, softening the look of the fiber-cement siding and strategically placed Energy Star windows. Inside, nothing screams "sustainable." A modern kitchen and seating area open onto a pier fireplace with a stone surround, dramatic peaked ceilings and a spacious loft.

Looking around, you might never guess this was the first home in the country to receive a gold rating from the U.S. Green Building Council's LEED for Homes (Leadership in Energy and Environmental Design) program.

"When people walk into the house, I want them to say, 'Oh, wow.' So the cedar columns and granite countertops in the kitchen, the fireplace and the centerpiece loft — I was willing to invest in all that," says O'Neil, the developer as well as the homeowner. "I wanted to prove that a home could be sustainable, beautiful and affordable at the same time."

The Primary Goal

Five years ago, when O'Neil bought the building lot, a meadow an hour north of Philadelphia, she had made up her mind to create a prototype for the ultimate, affordable green home. She began by reading and attending seminars to

educate herself. "My first goal was energy [efficiency]," she says.

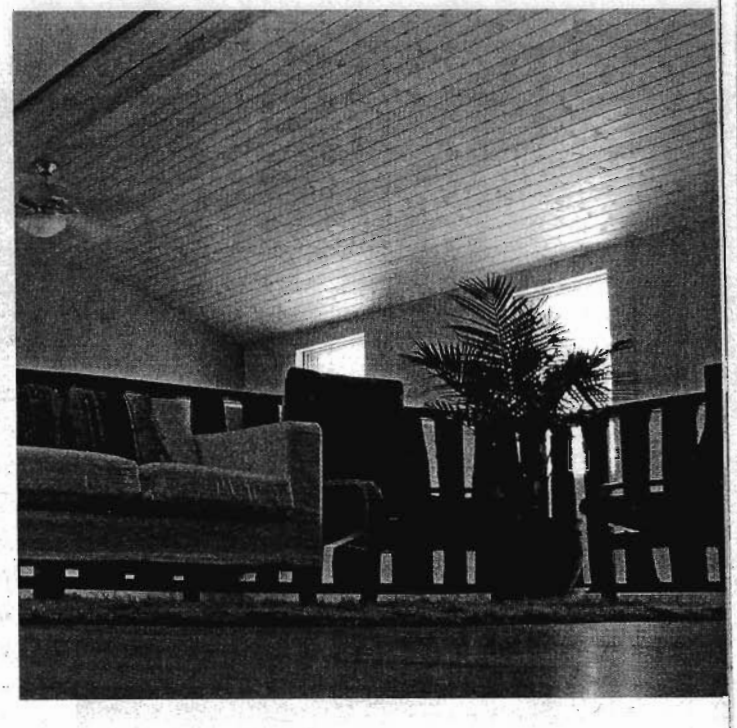
In 2004, she brought Philadelphia green developer Sandy Wiggins on board for the building project. Then she called Re:Vision Architecture, a Philadelphia firm that specializes in sustainable design. "I said, 'I want the greenest house you guys can [design] at this moment,'" O'Neil explains. "They said, 'We'll do it.'"

The 2,016-square-foot house cost about $167 per square foot to build, typical for a mid-market custom home in the Philadelphia area. By the time it was completed in April 2006 and an identical home constructed next door for O'Neil's twin sister, the builders had figured out how to quickly install components like the photovoltaic panels. The second house, which like the first was built with structural insulated panels (SIPs), was up in a day, reducing building costs by 8 percent.

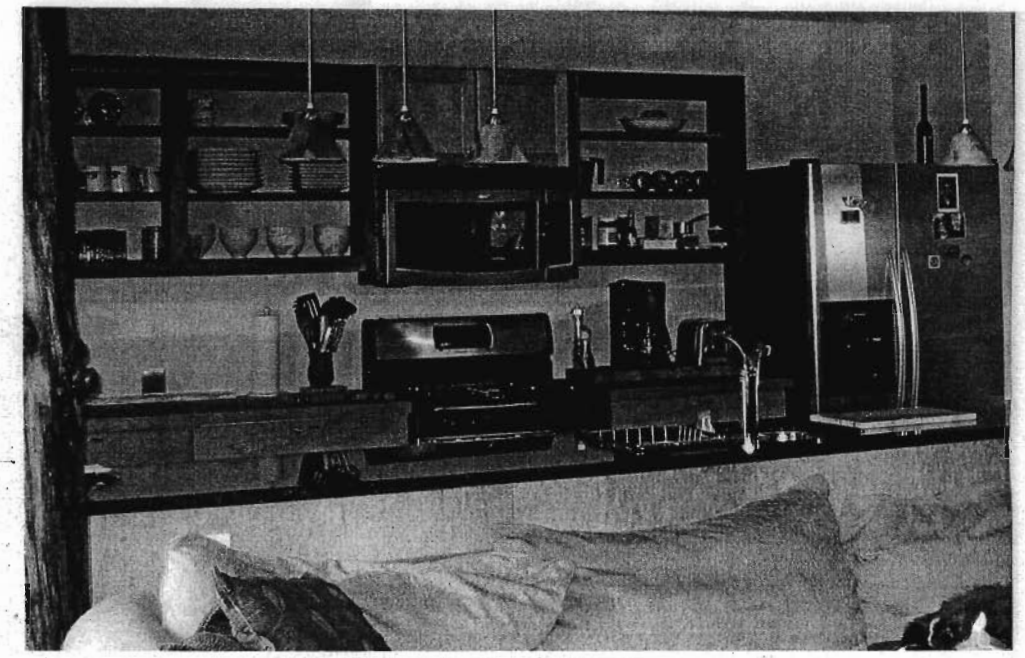
To come up with the perfect energy plan for the site and first house, Scott Kelly, the principal architect who worked on the project, convinced O'Neil to spring for sophisticated energy modeling analysis, something usually reserved for commercial projects because of the cost: a minimum of $10,000. "It's more expensive per square foot in a building this size, but it pays for itself," Kelly says. "Without it, we would have

Inside the Zero Energy House

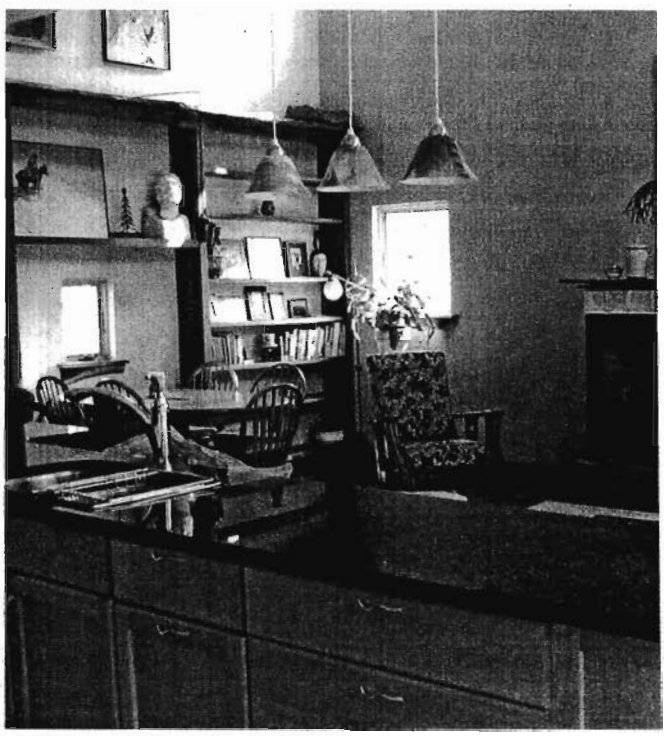
- At 1,884 interior square feet (2,016 total square feet), the house is smaller than the national average but its open design makes it feel spacious.
- Structural insulated panels (SIPs) maximize insulation, eliminate thermal bridging and use 18 percent less lumber than stick framing.
- Energy Star-rated windows (bought at Lowe's) are wooden, aluminum-clad, double-pane and open at the touch of a button, providing passive ventilation. Rain sensors allow the owner to leave windows open, knowing they will close automatically if necessary.
- A ground-source geothermal heat pump is controlled by an Energy Star-rated programmable thermostat, while a programmable humidistat regulates the mechanical ventilation system.
- When the geothermal pump is operating, a desuperheater collects waste heat to pre-heat water. When the pump is off, an on-demand water heater kicks in.
- About 95 percent of the lighting is compact fluorescent.
- Energy Star-rated appliances and fixtures, such as one-gallon per-flush toilets and shower-heads and faucets that reduce water flow to 1.5 gallons per minute, use 40 percent less water than average. Plus, less energy is required to heat water.
- A photovoltaic (solar) electric system provides more than 80 percent of the electricity.
- An energy recovery ventilator (ERV) supplies outdoor air and recovers energy in a fully integrated climate-control and ventilation system.
- About 85 percent of building materials came from within 150 miles of the home.
- Environmentally friendly products used in the home include site-harvested logs, zero-VOC paint, Bio-shield interior wood finish, formaldehyde-free insulation, salvaged doors and recycled-content drywall and siding.
- Energy testing included blower door duct blaster tests and energy monitoring.



ABOVE: An open loft floorplan creates a sense of spaciousness and helps improve energy efficiency.



RIGHT: O'Neil reduced costs in the kitchen by combining butcher-block countertops with a black granite island and open-shelf units instead of cabinets.



ABOVE and LEFT: Trees on the site that had to be cleared to meet town requirements were used to build unique beams, banisters, sills and furniture.

spent much more on insulation and windows."

O'Neil met with Thermal Energy System Specialists, an engineering consulting company in Manhattan that specializes in energy modeling and analysis. "Their calculations were very complicated but all we had to do was show them the amount of glazing [i.e. window glass] on each wall and the overhang, as well as other data like the wall space, the direction each wall faced and the R values of the walls, ceilings and floors, and they fed all that information into the computer," says O'Neil. Then she and Kelly considered the options and came up with the most cost-effective solutions.

"The classic error of most passive solar homes in the early years was that [builders] would over-glaze, and then [homeowners would] bake in the sun and have to compensate with full thermal curtains," O'Neil says. Energy modeling allowed her and Kelly to design insulation, windows and mechanical systems perfectly sized and situated for the house.

"Ninety percent of what was done was off-the-shelf, standard technology put together in a creative way," explains Kelly. To help keep costs low, the home does not have a basement (it sits on a slab). Instead, a simple utility room was constructed behind the kitchen.

A small pump located in the utility room is all that's visible of the home's geothermal system. When the system is running for heating and cooling purposes, the waste energy it produces is used to heat water. When the geo-thermal system isn't running, a tiny on-demand water heater kicks in.

A small wall-mounted converter in the utility room transforms DC current from the 5.25-kilowatt rooftop photovoltaic (solar energy) system into AC current, which feeds the home through an electrical circuit box. "As you can see, it's just an ordinary circuit box," says O'Neil. "It's just that it's fed by my own solar plant. And, if you look at it, I am my own power plant."

In fact, in its first six months of operation, the photovoltaic system provided 102 percent of the home's electricity — 2,911

Photos courtesy Jackie O'Neil

kilowatt-hours generated versus 2,845 kilowatt-hours consumed, which is slightly greater than net zero electricity use. Because O'Neil uses natural gas for a cooktop and fireplace, the structure is not considered a net zero energy home — but it comes very close.

Expensive Problems

One problem O'Neil encountered during construction was finding a mechanical system that was small enough to fit her requirements. The smallest geothermal system she and her team could find (and the one installed in the home) weighed three tons — twice the size needed and thousands of dollars more expensive than necessary. Just digging the extra 200 feet the system required to operate effectively cost O'Neil about $8,000. (Systems half that size have since become available.)

Another unexpected expense came from the local township, which demanded that the county road in front of the two properties be doubled in width. This required clearing a grove of old black walnut and cedar trees. Kelly argued, to no avail, that the trees kept the neighborhood cooler and helped control stormwater runoff. "Ripping up the trees destroyed a natural eco-system that had evolved over about 50 years," Kelly explains. "[Removing the trees] made the stormwater [runoff] so much worse." Leaving the trees intact would have saved about $50,000, he estimates.

Several oak trees had to go as well for the septic system. All the cleared trees and stones were used in the house, scoring major points toward the LEED rating and resulting in the home's most striking features: banisters, beams, sills and furniture of black walnut and cedar, floors and stairs of red and white oak, and stone fireplace surrounds and walkways.

An open loft floorplan keeps the interior compact but spacious, and helps to increase the home's energy efficiency. To maximize space, all the doors slide into wall pockets instead of swing out on hinges, allowing the use of reclaimed antique doors in odd shapes that would have been difficult to hang.

O'Neil shaved costs wherever she could in order to budget for a higher-tech energy system. In the bathrooms, for example, she used precut granite slabs from Lowe's overstock instead of paying hundreds extra for wall-to-wall custom cuts. In the kitchen, she saved by combining butcher-block countertops with a black granite island and open-shelf units in place of cabinets.

Integrated Design

Using a philosophy of integrated design, the team managed to get multiple benefits from every effort. Downstairs, for example, the poured concrete floor creates a heat sink in the summer and is equipped with a radiant floor heating system for the winter. Upstairs, air is heated and cooled by integrating the HVAC and geothermal systems, essentially blowing air over heated or cooled liquid.

Often, when it comes to heating or cooling the home, merely opening or closing a window will suffice. When the temperature outside is lower than inside, for example, the house can be cooled in minutes by pushing a button to open a window.

"Open those windows at the top of the stairs and it can make your hair move," says Kelly.

LEFT and BELOW: The poured concrete floor creates a heat sink in the summer and is equipped with a radiant floor heating system for the winter.

ABOVE: Reclaimed antique wood doors slide into wall pockets to maximize space.

"The shape of the home works like an airplane wing."

Seeing the house firsthand, it's hard not to dream of zero-energy production homes across the country. But Kelly says the production-home framework does not lend itself well to super-efficient design, since each home and each location is unique. "To make a good green home, you have to be not just environmentally responsible but environmentally responsive," he notes.

"Everything about that home is tailored [specifically] for that home. If you move trees 100 feet away, it doesn't work as well. You cannot design a green home and then just plunk it down from one site to the next."

Certain aspects of sustainable home building can be applied across the board, he says, but not orientation. In the case of the homes of O'Neil and her sister, both were designed with few windows on the north-facing side, while trees were planted near the east façades, which will render air conditioning unnecessary after about four years of growth. In the winter, those trees will lose their leaves, allowing the sun to warm the homes.

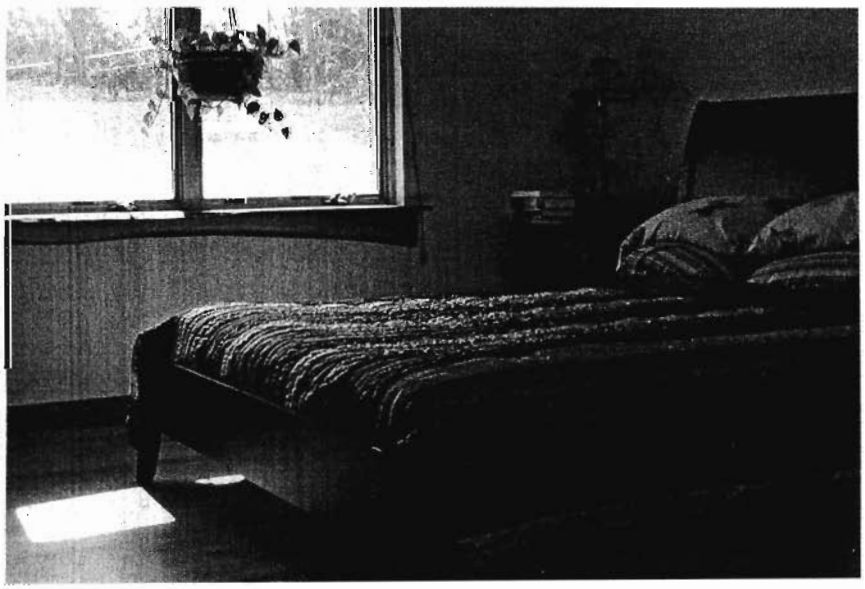
"The best nuclear power plant we've got is the sun," says Kelly. "That's why orientation is incredibly important. That is free energy coming through your windows everyday."

The twin zero-energy houses stand out among the conventional farmhouses around them. When O'Neil heard local residents calling the buildings "the weird houses," she had a sign made, explaining the significance behind their sustainable design, and posted it next to the road. She and her sister open their homes to the public whenever they can. So far, she has given the zero-energy tour to about 500 people, including school groups, sometimes accompanied by Kelly and Wiggins.

But it's the developers and buyers of the wealthiest housing developments around Philadelphia that O'Neil hopes to influence. "We have to stop building these insane neighborhoods of McMansions," she says. "They're energy pigs. You have to change people's desire for what they want. If you educate them, I think they'll make the right choice."

Cathleen McCarthy is a Philadelphia-based freelance writer whose work has appeared in The Washington Post, Country Living *and* New Old House.

BELOW: Recycled-content drywall, eco-friendly finishes and zero-VOC paints were used throughout the home.



Outside the Zero Energy House

- Landscaping was designed to control stormwater runoff through grading and the use of native plants and rocks.
- A gravel driveway and gravel walkways allow water to permeate and produce much less heat than asphalt or concrete.
- Native wildflowers were planted instead of a lawn, creating a natural air cooler and saving the need for mowing or frequent watering. A 90-gallon rainwater barrel provides water for landscaping.