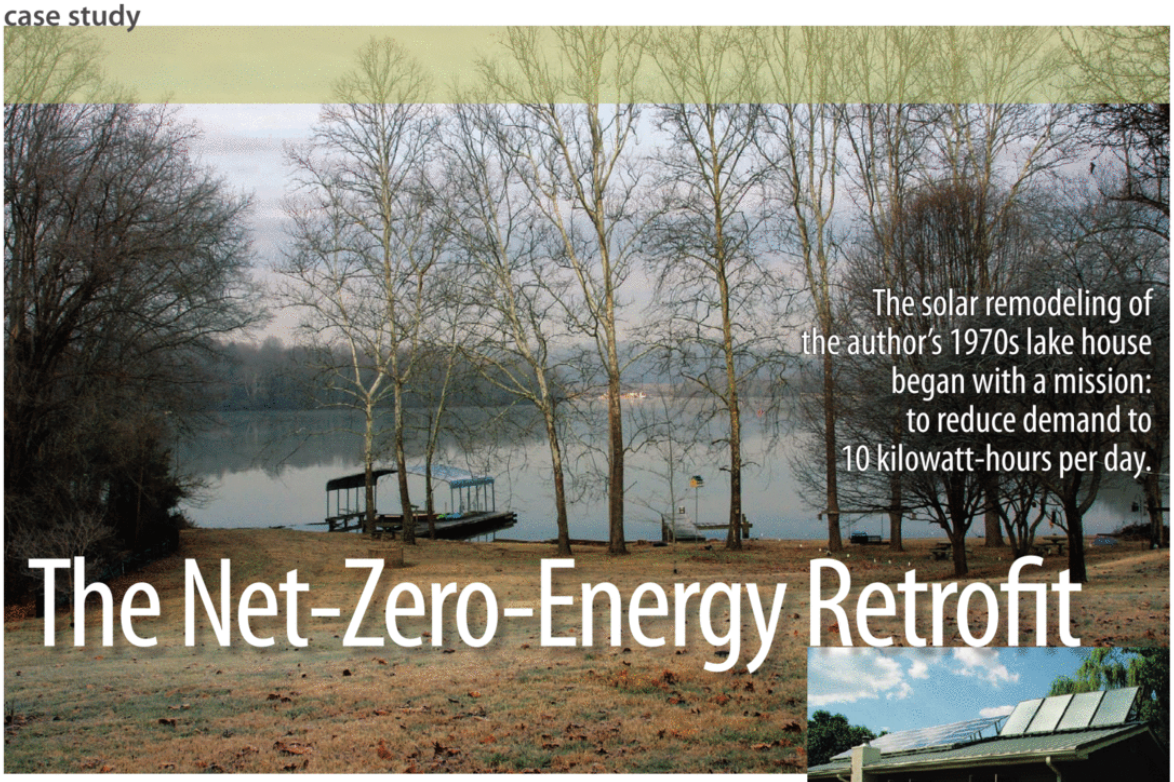
case study



The solar remodeling of the author's 1970s lake house began with a mission: to reduce demand to 10 kilowatt-hours per day.

The Net-Zero-Energy Retrofit

After increasing insulation and adding a fan in the attic, the Bolts are able to stay comfortable through Tennessee summers without air conditioning through old-fashioned natural ventilation.

By DAVID BOLT

Over lunch five years ago, the volunteer coordinator for Habitat for Humanity in Lenoir City, Tenn., mentioned five near-net-zero-energy houses her group was building with the Oak Ridge National Laboratory, the Tennessee Valley Authority and vendors. I'd been searching for ways to live more sustainably, and the prospect of building homes that generate as much energy as their occupants use jolted my thinking entirely. More than a year and much research later, in mid-2005, I launched a business to help people move toward net-zero-energy houses (ZEHs). It only made sense that the company's first customer should be me.

My family owns a lake house in Harriman, Tenn., that we used primarily on summer weekends. It seemed like a good place to get some experience in ZEH retrofitting. My mission: to reduce energy demand at the house to 10 kilowatt-hours (kWh) per day.

I set a budget of $100,000 to renovate the 30-plus-year-old, 2,400-square-foot house for net-zero reliance on grid energy, while making it suitable for full-time living with my wife and two children. The budget was roughly broken into one-third for solar electricity-generating and solar water-heating systems, one-third for energy-efficiency upgrades and one-third for general remodeling. We started the remodel during fall 2005 and paid the last utility bill in April 2006. Easy, right — draft a few checks and wait six months?

The real story is far more complex, of course. It involved working six months with an architect, a builder and subcontractors to achieve major structural changes and install the photovoltaic (PV)

David Bolt is an electrical engineer and a licensed solar and general contractor, as well as an active member of the building science industry. In 1996, Bolt cofounded MarketLinx, a software development company. In 2005, after the sale of MarketLinx, he founded Sustainable Future LLC to educate people about sustainable living and provide products to support this choice. Visit sustainablefuture.biz for details about Bolt's ZEH retrofit, or contact him at dwbolt@sustainablefuture.biz.

Facts: Net-Zero-Energy Home Retrofit, Harriman, Tenn.

- 2,400-square-foot house retrofitted to use 10 kilowatt-hours per day for a family of four
- $100,000 budget allocated
- Moved to wood stove heating and natural ventilation for cooling
- Replaced gas water heater with four AET 28 flat-plate solar collectors
- Installed a 3-kW photovoltaic system grid-tied with a Sunny Boy inverter
- Remodeling began in fall 2005; last utility bill received April 2006

CLICK: Find steps for moving toward net-zero-energy at your home: solartoday.org/retrofitzeh

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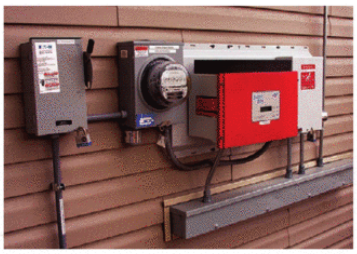
system. Then I, alone, moved full time to the lake in mid-2006 to play the "how can I live on 10 kWh per day" game for a year. At the end of the year, I had accumulated 1,700 kWh of surplus energy, and the sawdust had settled enough for my wife, son and daughter to join me at the lake. The real drama began when we received our first utility bill and discovered several hundred kilowatt-hours of the surplus had disappeared. And unfortunately, my family did not share my enthusiasm for playing "how can *we* live on 10 kWh per day." Much to my wife's displeasure, the sawdust began flying again, and this time, the whole family would live in a construction zone.

By last December, after much monitoring and adjustment of our energy systems, we were back to net-zero-energy and a surplus of 1,000 kWh. Happiest when I'm changing something, I've purchased a second house, dubbed ZEH2, to convert to net-zero.

Water heating takes about 20 percent of a typical energy budget, so Bolt elected to replace the gas water heater with a solar version. Through adjustments like changing the angle of the solar thermal collectors, he greatly improved system performance.



HUB

DATE BILLED 5/28/2008
NET BILL -255.34
PAY GROSS AFTER 6/12/2008
GROSS BILL

HARRIMAN UTILITY BOARD
P.O. Box 434
HARRIMAN, TN. 37748

DUE DATE DOES NOT APPLY TO PAST DUE BALANCE

RETURN THIS PORTION WITH PAYMENT

ACCOUNT NUMBER | ACCOUNT NAME | SERVICE ADDRESS | BILLING DATE 5/28/08

DESCRIPTION	MULT	METER NUMBER	DATE FROM	DATE TO	DAY	PRIOR READING	CURRENT READING	USAGE	AMOUNT
ELECTRIC	1	2101	04/16	05/17	31	8095	8507	308	35.22
SECURITY LIGHT	1		04/16	05/16	30				9.69
CO GENERATION	1	2101	04/16	05/17	31				61.80-
ELECTRIC	1	2095	04/16	05/17	31	1690	1586		238.45-
CREDIT BALANCE									

TOTAL DUE NOW $ -255.34

TOTAL DUE AFTER 6/12/2008 $

Bolt set a budget of $100,000 to renovate the 30-plus-year-old, 2,400-square-foot house for net-zero reliance on grid energy — allocating one-third for solar electricity-generating and water-heating systems, one-third for energy-efficiency upgrades and one-third for general remodeling.

Tour It

See David Bolt's Harriman, Tenn., net-zero-energy house and others on the ASES National Solar Tour in October: nationalsolartour.org

Becoming Aware of How We Use Energy

In theory, creating a net-zero-energy house is simple: Look at utility bills to see how much energy is being used and then install enough renewable energy to offset it. Excluding incentives, the upfront cost for renewable energy is about $10,000 for every 100 kWh per month that a house uses. That means most homeowners are looking at spending between $100,000 to $200,000 in order to convert to net-zero-energy — far too expensive for most. Instead, I set an energy budget of 10 kWh per day. I chose this amount because I had the roof space for a moderate size PV system (in this case, 3 kilowatts) and it fit into the budget. It was not at all clear my family could live on 10 kWh per day. In the 3,500-square-foot Knoxville, Tenn., house my family had been living in, we used about 40 kWh per day. That's slightly more than the average household's monthly electricity consumption, which, in 2006, was 920 kWh, according to the U.S. Department of Energy.

So how did we drop from 40 kWh to 10 kWh per day? In some ways, we didn't. We use more than 10 kWh per day, but the meter never sees it. For example, every time we dry the clothes on the clothesline, we save more than 4 kWh. We use wood heating, a renewable energy source, and it never goes through the meter. So to say that we reduced our energy consumption by 30 kWh a day is not fair — but it is fair to say that we reduced our *electrical* demand by that much. It is fair to say ours is a net-zero-energy house, because we generate on-site the 10 kWh we use daily.

Getting to net-zero-energy is a process of becoming aware of energy usage in your home and asking —

1) Is this function needed? If no, then get rid of it.

2) If the function is needed, then is there a more energy-efficient way to provide it?

3) Is there a way to serve the needed function with renewable energy?

In deciding where to focus, I aimed for 50 percent of the home's energy supply to be used for heating and cooling, 30 percent for plug loads and 20 percent for heating water.

Returning to Low-Tech Heating and Cooling

The first 50 percent of our energy demand was knocked out when I opted to not turn on the heat pump. Instead, we use a wood stove for heating. That moved our heating load from grid electricity to renewable wood. Though chopping, splitting and carrying wood has been great exercise, I'm ready to try an alternative. For ZEH2, I plan to use solar heating with wood gasification for backup.

As for the challenge of staying comfortable in Tennessee's heat and humidity without air conditioning, we returned to old-fashioned natural ventilation. We opened windows after sundown and closed them in the morning. With all the efficiency improvements to the house, this strategy has controlled temperatures nicely. The first floor stayed in the 70s, even when the outside temperature was more than 100°F (38°C).

The humidity was a different story. The salt shaker stopped dispensing salt in July, and by August, mildew was a problem. So last September, we replaced the 4-ton SEER 10 heat pump with a 2-ton SEER 18. My plan is to close up the house once the humidity gets high and run the heat pump on humidity priority to less than 60 percent relative humidity. It remains to be seen whether we can stay net-zero-energy using the new unit.

Tackling Plug Loads

One of the biggest surprises for me was learning how much energy gets wasted on phantom loads. When we first installed a whole-house meter, it would read 500 watts at night when everything was turned off. At 0.5 kW times 24 hours, that's 12 kWh of energy daily. At that rate, I was 2 kWh per day over budget before even turning a switch.

Using a plug-in watt meter, I found that TVs, computers, cell phone chargers, the dehumidifier, microwaves and more items were using power even when they were turned off. After putting these devices on power strips, my nighttime demand is about 100 watts. That means that almost 25 percent of my budget is spent running things like the door bell and motion detection lights. In the ZEH2, I'm shooting for zero phantom loads.

Measuring plug loads also identified inefficient appliances. After I found that the refrigerator was using 130 kWh per month, we replaced it with one that uses 30 kWh per month. That was a big help in making my 10 kWh-per-day goal. Find detailed examples of other changes we made at sustainablefuture.biz/content/community/transformations/2006-04-DB/default.stm, or tinyurl.com/bqqmo7.

Heating Water with the Sun

Water heating takes about 20 percent of a typical energy budget, so I elected to replace the gas water heater with a solar version. It consists of four Alternate Energy Technologies 28 flat-plate collectors (4 by 7 feet each) and a 120-gallon hot water storage tank (aetsolar.com). By changing the angle of the solar thermal collectors from a flush-mounted summer bias to a 50 degree-tilt winter bias, I greatly improved system performance. Instead of running low on hot water in October while living by myself, I can serve all four family members without turning on the electric backup until December. I also went to larger solar collectors and larger tanks to further reduce any need for backup.

On the PV side, I have a 3-kW system grid-tied with a Sunny Boy inverter from SMA America (sma-america.com). I also have a 123-watt panel that I use as a charging station for battery-powered items. The original installation was flush mounted with six strings. I later reinstalled it with a 27-degree tilt and one string to improve efficiency and to increase panel ventilation, because PV panels operate better when cool. I'm considering making the tilt adjustable to increase winter generation.

Little did I know that my desire to live more sustainably would lead to an energy diet for my whole family and work with so many people committed to renewable energy. I'm looking forward to helping others with their energy goals — and setting more sawdust flying. ST