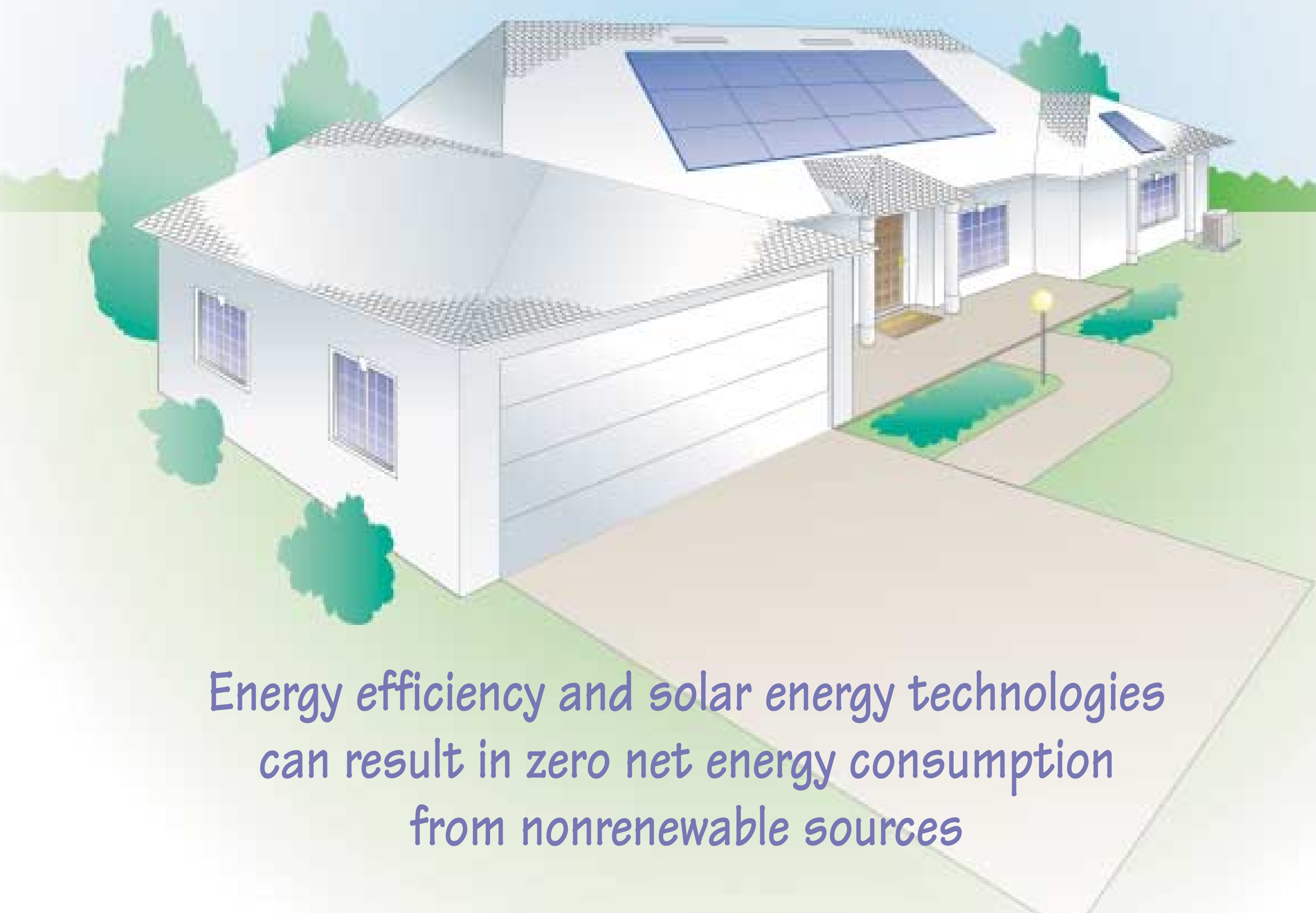
On The Path To ZERO Energy Homes



Energy efficiency and solar energy technologies can result in zero net energy consumption from nonrenewable sources

During times of peak demand, a Zero Energy Home generates more power than it uses, thereby reducing power demand on the utility provider. During times of power outage, the home generates its own power, allowing the homeowner essential energy security. In a Florida study, a prototype Zero Energy Home outperforms a conventional model by providing almost all of its own power needs throughout the year.

Cooling Off Under the Sun

Just imagine living in Florida and your fantasies might turn to swaying palms, fresh orange juice... and lots of air-conditioning. For most people, a summer spent in Florida's heat and humidity would be unbearable without it.

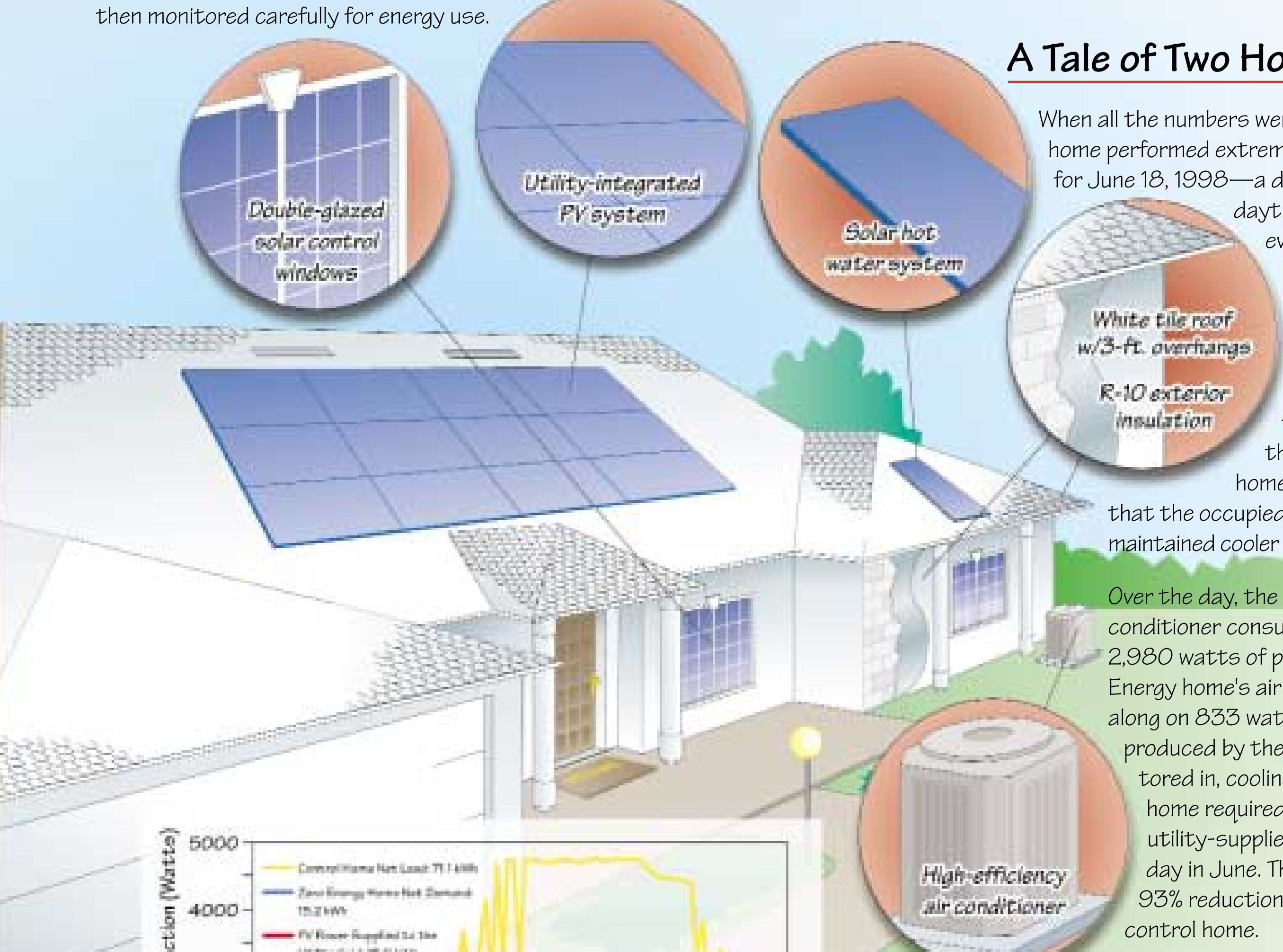
So air-conditioning is a necessity. But it's also a big energy drain, accounting for about 35% of all electricity used in a typical Florida house. As the largest single source of energy consumption in Florida, a home's air-conditioning load represents the biggest energy challenge.

The Florida Solar Energy Center (FSEC) designed a project to answer this challenge. Two homes were built with the same floor plan on nearby lots. The difference was that one (the "control home") conformed to local residential building practices, and the other (the "Zero Energy home") was designed with energy efficiency in mind and solar technology systems on the roof. The homes were then monitored carefully for energy use.

The project's designers were looking to answer two important questions: Could a home in a climate such as central Florida's be engineered and built so efficiently that a relatively small PV system would serve the majority of its cooling needs—and even some of its daytime electrical needs? And, would that home be as comfortable and appealing as the conventional model built alongside it?

The answer to both questions turned out to be a resounding "yes!" And the test was especially rigorous, because it was conducted in the summer of 1998—one of the hottest summers on record in Florida.

This news is important for city planners, architects, builders, and homeowners not only in the Sunshine State, but elsewhere, too. The solar/energy efficiency combo worked so well in Florida that it can—and should—be tried in other parts of the country.

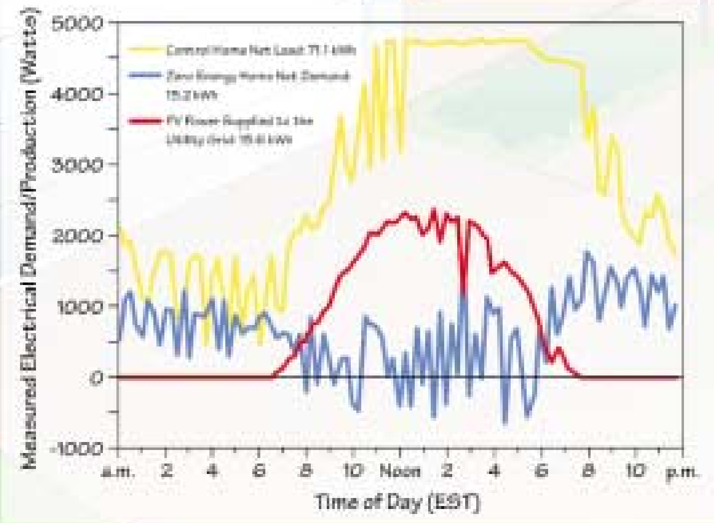


A Tale of Two Houses

When all the numbers were in, the Zero Energy home performed extremely well. The results for June 18, 1998—a day with the hottest daytime temperatures ever recorded in Lakeland, Florida—tell the story. During a 24-hour period, the Zero Energy home used 72% less power from air-conditioning than did the control home, despite the fact that the occupied Zero Energy home maintained cooler indoor temperatures.

Over the day, the control home's air conditioner consumed an average of 2,980 watts of power, while the Zero Energy home's air conditioner breezed along on 833 watts. When the power produced by the PV system is factored in, cooling the Zero Energy home required only 199 watts of utility-supplied power on that hot day in June. This is an astonishing 93% reduction compared to the control home.

The numbers are equally impressive for the rest of the year. So efficient was the Zero Energy home that its relatively small PV system (4 kW) provided 85% of the power required for all electrical loads. These results need to be taken seriously by anyone looking to save energy... and the environment.



Peak Day in June

This graph shows the difference between the energy demand of the control and Zero Energy homes on June 18, 1998. The local utility experienced its annual summer peak demand at 5:00 p.m. on this day. The spikes that dip below the zero line indicate the times when the Zero Energy home produced more power than it required and supplied the excess to the utility grid.

Conducting the Test

The two homes were built in Lakeland, Florida, in the spring of 1998. They were constructed by the same builder and had identical compass orientations and floor plans (of 2,425 square feet). The energy use of both homes was monitored for more than a year.

The objective was to test the feasibility of constructing a new single-family residence that was engineered to reduce the home's energy loads to an absolute minimum so that most of the cooling, water heating, and other daytime electrical needs could be met by the solar systems. The Zero Energy home included a number of features and engineering elements designed to minimize cooling loads, especially in late afternoon during the utility's peak period of electrical demand. As a research project, the goal was to see how much energy and peak demand could be saved without factoring in the cost of the efficiency and solar features. Now that the energy efficiency and solar energy production have been demonstrated, the next step is to determine the value of these features.

A Bird's-Eye View of Both Homes

The completed control and Zero Energy homes in the Windwood Hills development of Lakeland, Florida.

Breaking Out the Savings

The traditional wide roof overhang of old-style Florida homes is seldom used these days, on the assumption that air-conditioning takes care of cooling needs. But why make the air conditioner work harder—and cost more to operate—than it should? The Zero Energy home's **3-foot roof overhang** (versus 1.5 feet for the control) produces twice as much shade, which is especially beneficial for controlling solar gain (heat buildup) on walls and windows.

Another innovative feature is the **reflective white-tile roof** on the Zero Energy home versus the locally popular gray/brown asphalt shingles on the control home. Both homes have R-30 fiberglass insulation in the attic. But records from that peak utility day of June 18, 1998, point up the differences. The attic temperature in the control house rose quickly in the afternoon to reach a maximum of 138°F, while the Zero Energy home's attic reached only 100°F—about the same as the outside air temperature.

Exterior insulation (R-10 value) thermally encases the Zero Energy home. This allows the masonry to be precooled during daytime hours when the sun is shining brightly and the PV system output is at maximum power. The precooled concrete walls help maintain indoor comfort into the late afternoon and evening.

Site Description	Power Use (kWh)	PV Array Output (AC kWh)	Net Power Use (kWh)	Monthly Cost of Power	PV Output % of Total Loads
Zero Energy Home	837	502	335	$27	60%
Control	1,839*	0	1,839*	$147	0%

*Air-conditioning only

Energy Bottom Line for June 1998

During the month of June, the occupied Zero Energy home consumed only 335 kilowatt-hours (kWh) of utility-grid power for all its electrical needs. This compares to 1,839 kWh used by the unoccupied control home for air-conditioning only! The monthly power cost in the Zero Energy home was only 18% of the control home's power cost.

The Zero Energy home's windows, accounting for almost one-fifth of the energy savings (for cooling), were selected carefully for both appearance and thermal effectiveness. The **advanced solar control windows** are spectrally selective, which means that they transmit much of the light in the visible portion of the solar spectrum, but limit transmission in the infrared and ultraviolet portions (which causes overheating and fading of interior materials).

Interior-mounted, oversized ducts—positioned within the air-conditioned space as opposed to the hot attic—are used in the Zero Energy home to great advantage. Tests at

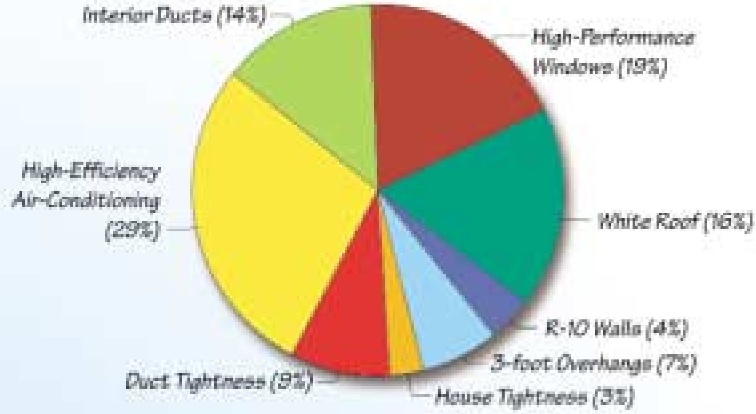
Control Home Features

- Gray/brown asphalt shingle roof with 1.5-foot overhangs
- R-30 attic insulation
- R-4 wall insulation on interior of concrete block walls
- Single-glazed windows with aluminum frames
- R-6 ducts located in attic
- Standard appliances (electric range, electric water heater, refrigerator, and electric dryer)
- Standard incandescent lighting (30 recessed-can lights)
- Standard-efficiency, 4-ton, SEER 10 (seasonal energy efficiency ratio) heat pump (a typical air conditioner in Florida).

FSEC had shown that heat transfer to the duct system can rob the air conditioner of as much as one-third of its cooling capacity during the hottest hours. Oversizing the ducts allows high air flow and low friction loss (previously shown to provide as much as a 12% improvement in cooling efficiency at essentially no extra cost).

High-efficiency appliances and lighting further minimize the Zero Energy home's electrical load. These appliances and lighting also release less heat into the home while operating, which decreases the cooling load that must be met by the air-conditioning system. The smaller appliance, lighting, and air-conditioning loads result in less PV capacity required to meet the home's total electrical load.

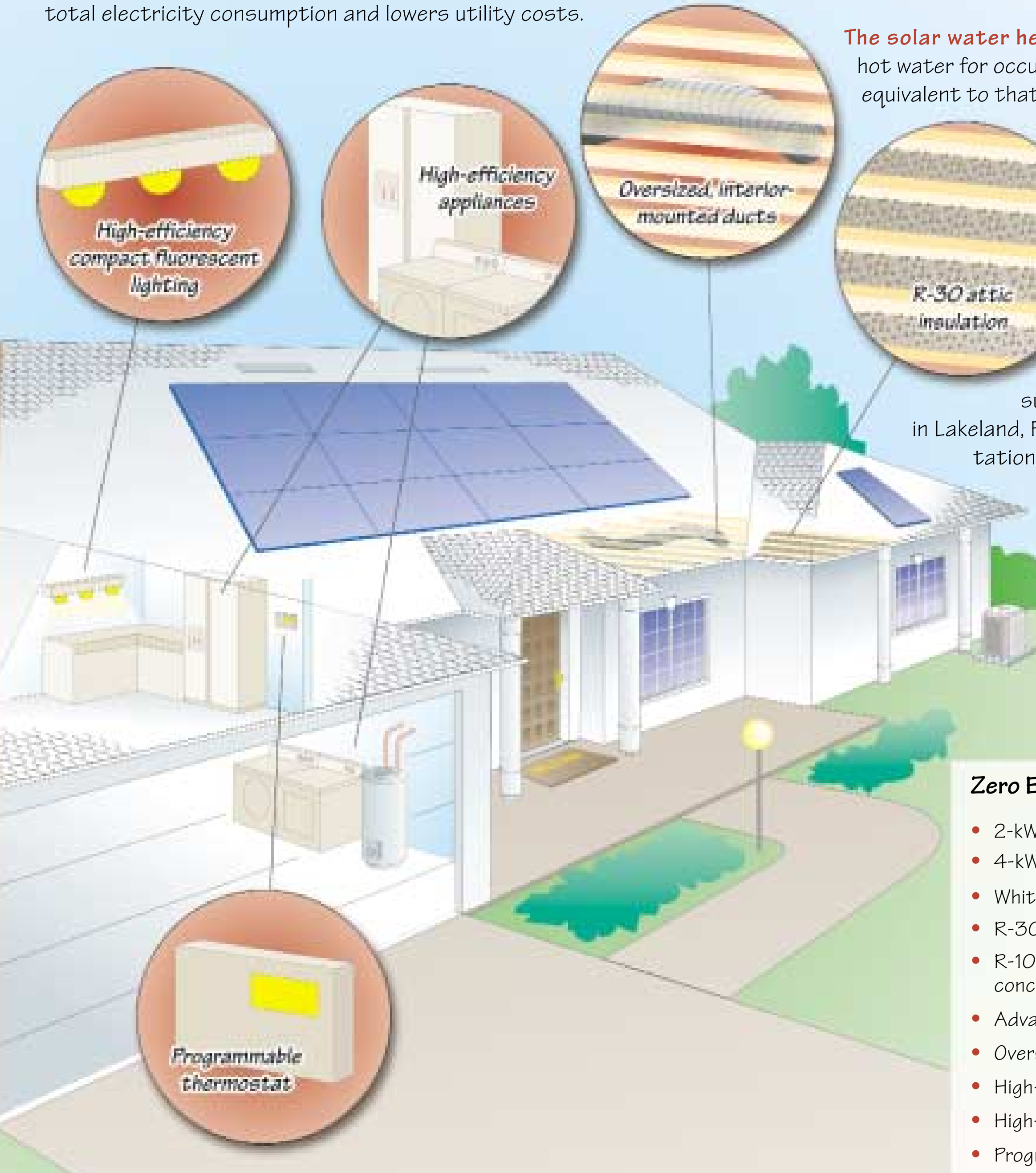
A programmable thermostat—set so that the indoor temperature is allowed to increase overnight and while the house is unoccupied—decreases the number of hours per day the air conditioner operates. Running the air conditioner less reduces the total electricity consumption and lowers utility costs.



The Energy Savings Picture (for Cooling): *The estimated percentage of energy savings attributed to each measure used in the Zero Energy home.*

The solar water heating system supplies most of the hot water for occupant needs. Its energy output is equivalent to that of a 2-kW PV system.

All told, the combination of efficiency features reduces the cooling loads so that a **downsized air conditioner** suffices—and, here too, FSEC chose a high-efficiency appliance. The small size of this system (half that of the control home) is highly unusual for such a large home (2,425 square feet) in Lakeland, Florida, but it's performing to expectations. In addition, the unit's **cooling coil air flow** was field-verified at the Zero Energy house, which involves using a flow hood to adjust the fan speed of the variable-speed air handler. Installers who neglect this crucial step commonly cost the system a 10% drop in actual operating efficiency.



For illustration purposes, some features of the Zero Energy home have been relocated (versus actual).

Zero Energy home Features

- 2-kW solar water heater
- 4-kW utility-interactive PV system
- White-tile roof with 3-foot overhangs
- R-30 attic insulation
- R-10 exterior insulation over concrete block system
- Advanced solar control double-glazed windows
- Oversized, interior-mounted ducts
- High-efficiency refrigerator
- High-efficiency compact fluorescent lighting
- Programmable thermostat
- Downsized SEER 15.0, variable-speed, 2-ton air conditioner with field-verified cooling-coil air flow.

About the Solar Systems

The solar water heating system was a typical Florida direct circulation system with a 2-kW solar collector, an 80-gallon storage tank, and a PV-powered pump. This FSEC-approved system supplies most of the home's hot water need which, next to air-conditioning, is the second largest residential energy use in Florida. The solar water heater also eliminates any electrical requirements during hot summer afternoons — the utility's peak period of electrical demand.

The PV system was sized to provide power that would offset as much of the household load as possible. Based on the predicted load for a peak day, a 4-kW PV array (split into two subarrays) was specified. One subarray was located on the south-facing roof, which is generally the preferred placement for a PV system. The other was located on the west-facing roof, because this orientation provides more PV power during the hot afternoons, when the utility experiences its peak demand period. Reducing demand at this time of day is particularly valuable to the utility. The PV system is grid-interactive, producing DC power that is converted to AC and then fed directly into the local utility distribution system. The City of Lakeland Department of Electric and Water Utilities, which owns and operates the PV system, allowed unprecedented connection of a residential PV system to the utility grid in Florida.

Energy Efficiency Enhances Solar Technology

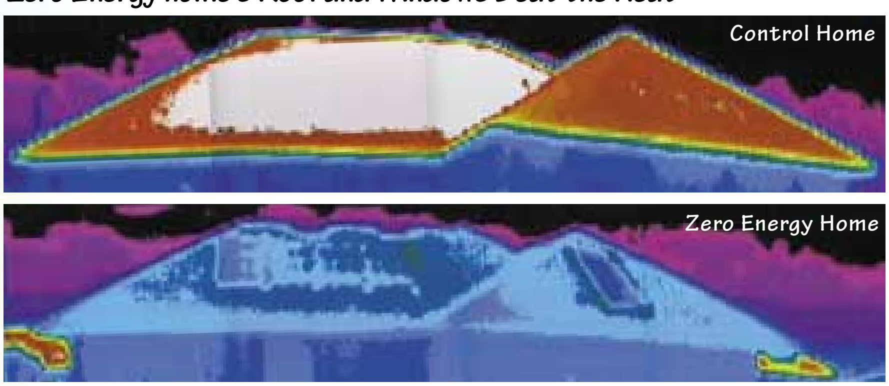
It's important to note that a solar technology system will not save energy. People invest in solar technology because it's an energy producer... one that releases no noxious gases into the air... one that can minimize or eliminate monthly utility bills. And, when solar technologies are combined with energy efficiency measures, solar technology's investment value is magnified.

Here's where energy efficiency factors in: as a home's energy efficiency increases, solar technology can offset more of the utility bill. This makes it a better investment, because the solar technology power stretches further. In the Florida case, building energy efficiency into the Zero Energy home—and sizing and locating the solar technology system correctly—resulted in the solar technology system offsetting about 85% of all grid-electricity needs on an annual basis.

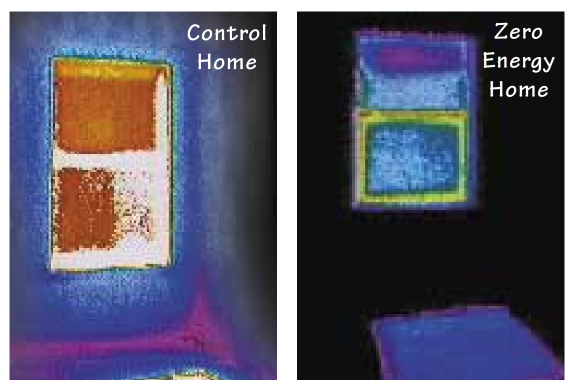
Of course, there are up-front costs incurred with purchasing the solar technology system and installing certain energy efficiency measures. But, in many cases, these costs can be recouped over time by the savings on the monthly energy bill.

What works in Florida can work just as well in other parts of the country. The appropriate energy efficiency measures and solar technology configurations will vary locally, but energy efficiency can improve the value of the solar technology resource anywhere.

Zero Energy home's Roof and Windows Beat the Heat



Thermographic images of the roofs in both homes. Note the lower roof and attic heat gain into the Zero Energy home, thus reducing the demand for cooling.



Comparison of the infrared appearance of west-facing windows of both homes in the afternoon. The Zero Energy home's windows accounted for almost one-fifth of the energy savings (for cooling).

What If?

The demand for electrical energy in Florida is increasing continually as a quarter-million people move to the state each year, building more than 100,000 new homes. Imagine the scenario if all those new homes were built like the Zero Energy home (rather than the control home). How big a difference would this make?

Figuring that each home would save about 18,000 kWh/year, the total savings for the 100,000 homes is 1.8 billion kWh. Based on Florida's 1998 average cost of residential electricity (8¢/kWh), this would save about $144 million a year in utility bills. Multiply these figures by all 50 states, and it's clear that the energy and air pollution savings in the United States would be astronomical. So dramatic, in fact, that it just doesn't make sense to build a new home without, at minimum, incorporating energy efficiency features.

Homeowners may want to check out an Internet Web site called the "Home Energy Saver" (at http://hes.lbl.gov). Here, you'll find estimates of how energy efficiency measures can shave dollars off an energy bill in your geographic area. By providing some information about your house, you'll get a custom report detailing which efficiency measures would save you the most.

Project Participants

Florida Solar Energy Center (FSEC)—Coordinated and implemented the project.

Sandia National Laboratories—paid for the PV system and FSEC's technical support resources.

Florida Energy Office/Department of Community Affairs—Funded the energy efficiency improvements for the building.

City of Lakeland Department of Electric and Water Utilities—PV system owner and operator.

Strawbridge Construction—Home builder.

Siemens/Hutton Communications—PV module supplier/system integrator.

Solar Source—Solar water heating system contractor.

The National Renewable Energy Laboratory produced this brochure as part of a series describing and promoting the use of solar energy technologies in a variety of applications.

Source Document: "Field Evaluation of Efficient Building Technology with Photovoltaic Power Production in New Florida Residential Housing," by Danny S. Parker et al. The entire document is available on-line at

http://www.fsec.ucf.edu/~bdac/pubs/CR1044/LAKELAND1.htm

See, "Priorities for Energy Efficiency in New Residential Construction in Florida," available on-line at http://www.fsec.ucf.edu/~bdac/pubs/PRIORITY/Priority.htm

Related Documents and Web Sites

DOE Solar Buildings Program,
http;//www.eren.doe.gov/solarbuildings

"A Consumer's Guide to Buying a Solar Electric System,"
http://www.nrel.gov/ncpv/pdfs/26591.pdf

DOE/NREL Photovoltaics in Buildings,
http://www.nrel.gov/buildings/PV

DOE/Sandia Photovoltaics Program,
http://www.sandia.gov/pv

Energy Savers: "Tips on Saving Energy & Money at Home,"
http://www.eren.doe.gov/consumerinfo/energy_savers

DOE Building America Program,
http://www.eren.doe.gov/buildings/building_america

NREL High-Performance Buildings Research,
http://www.nrel.gov/buildings/highperformance

U.S. EPA Energy Star Homes Program,
http://yosemite.epa.gov/appd/eshomes/ESHomes.nsf

For more information, contact:

Danny Parker
Florida Solar Energy Center
1679 Clearlake Rd. • Cocoa, FL 32922
407-638-1405 • 407-638-1439 (fax)
e-mail: dparker@fsec.ucf.edu

Mike Thomas
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0753
505-844-1548 • 505-844-6541 (fax)
e-mail: mgthoma@sandia.gov

Tim Merrigan
National Renewable Energy Laboratory
Solar Buildings Program
1617 Cole Blvd. • Golden, CO 80401
303-384-7349 • 303-384-7540 (fax)
e-mail: tim_merrigan@nrel.gov

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