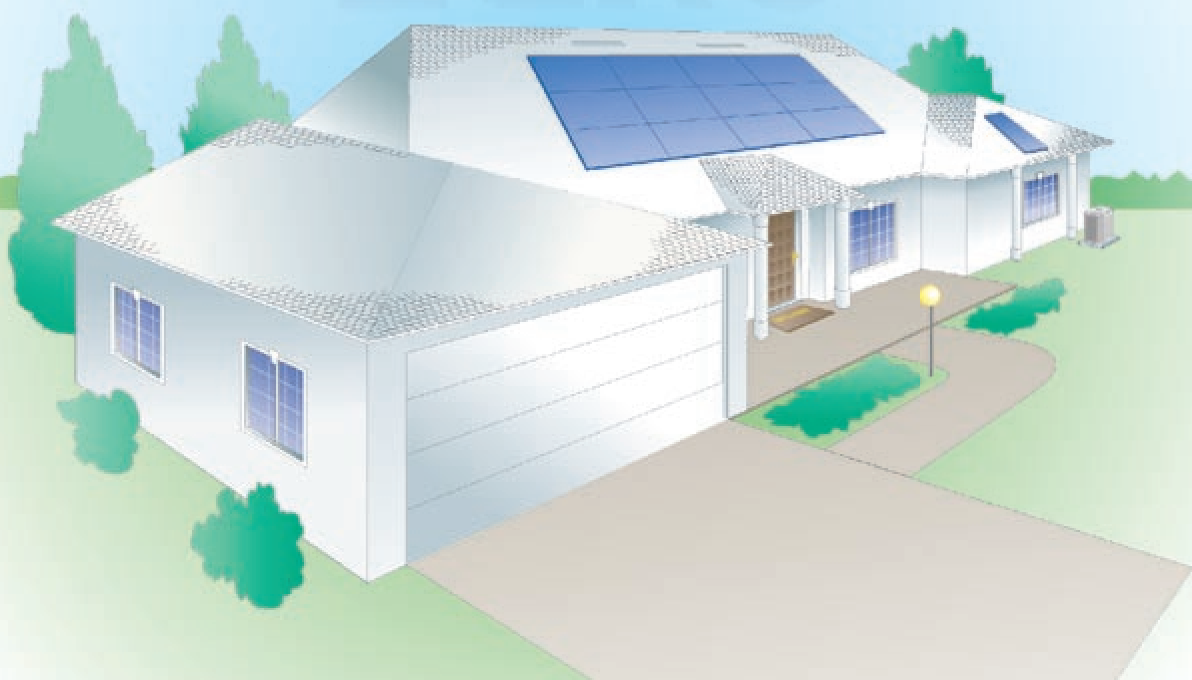
Building America Research Is Leading the Way to ZERO Energy Homes



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

During times of peak demand, a near zero energy home generates more power than it uses and reduces power demand on the utility provider. In a Florida study, a prototype near zero energy home outperforms a conventional model by providing most of its own power needs throughout the year.

Performance Features

Control Home

- 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 electric appliances (range, water heater, refrigerator, and 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).

Near Zero Energy Home

- 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.

Conducting the Test

A bird's-eye view of both homes

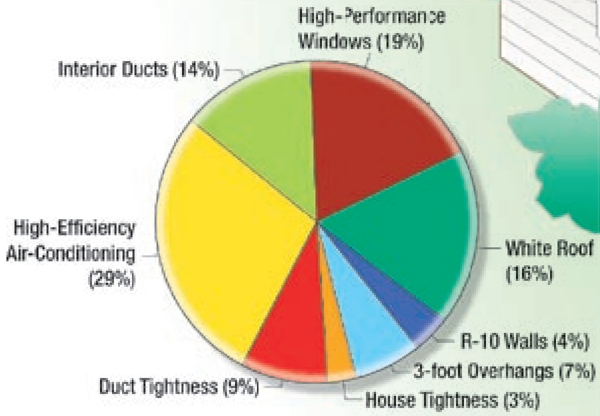
The completed control and near zero energy homes in the Windwood Hills development of Lakeland, Florida.

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 (2,425 square feet). The energy use of both homes was monitored from April 1998 to June 2002.

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 near zero energy home included a number of features and engineering elements that were 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 in the near zero energy home compared to the standard or "control" home.

Energy Bottom Line for 2001–2002

From July 2001 to June 2002, the occupied near zero energy home consumed only 2,150 kilowatt-hours (kWh) of utility-grid power for all its electrical needs. This compares to 21,240 kWh used by the control home (unoccupied for 1.5 months). Energy efficiency along with solar generation reduced the energy use of the near zero energy home compared to a conventional identical home by 90%.



The energy savings picture (for cooling): The estimated percentage of energy savings attributed to each measure used in the near zero energy home.

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 near 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 near 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 June 18, 1998, a peak utility day, 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 near zero energy home's attic reached only 100°F, about the same as the outside air temperature.

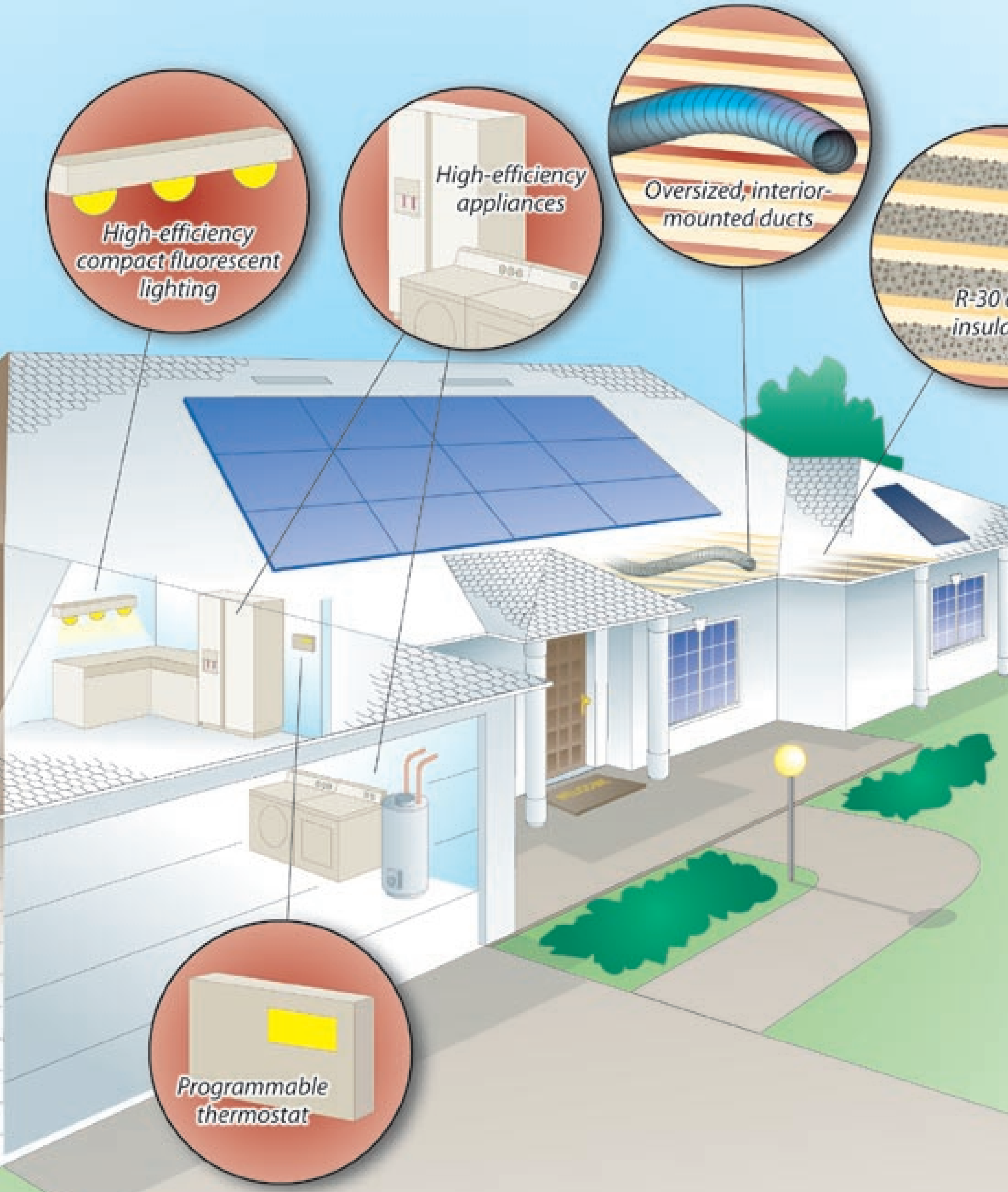
Exterior insulation (R-10 value) thermally encases the near zero energy home. This allows the masonry to be pre-cooled during daytime hours when the sun is shining brightly and the photovoltaic (PV) system output is at maximum power. The pre-cooled concrete walls help maintain indoor comfort into the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

The near zero energy home's windows, which account for almost one-fifth of the energy savings (for cooling), were selected for both appearance and thermal effectiveness. The advanced solar-control windows are spectrally selective. This 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 overheat and fade interior materials).

Interior-mounted, oversized ducts positioned within the air-conditioned space as opposed to the hot attic are used in the near zero energy home to great advantage. Tests at the Florida Solar Energy Center (FSEC) showed 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 near 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 mean less PV capacity is required to meet the home's total electrical load.

A programmable thermostat is set so that the indoor temperature is allowed to increase overnight and while the house is unoccupied. This decreases the number of hours per day



For illustration purposes, some features of the near zero energy home have been relocated (versus actual).

the air conditioner operates. Running the air conditioner less reduces the total electricity consumption and lowers utility costs.

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.

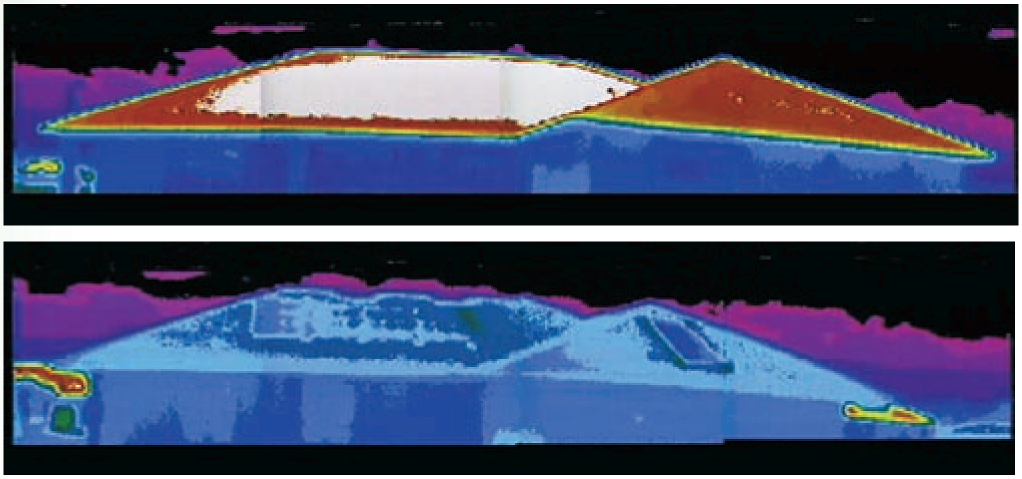
The combination of efficiency features reduces the cooling loads so that a downsized air conditioner suffices. Here too, FSEC chose a high-efficiency appliance. The small system (half the size of that in the control home) is highly unusual for such a large home in Lakeland, Florida, but it's performing to expectations. In addition, the unit's cooling coil air flow was field-verified at the near zero energy home, which involved 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 operating efficiency.

About the Solar Systems

The solar water heating system is 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, which is the largest residential energy use in Florida after air-conditioning. The solar water heater also eliminates any electrical requirements during hot summer afternoons—the utility's peak period of electrical demand.

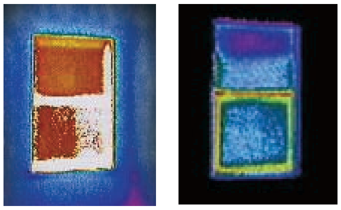
The PV system was sized to provide power that would offset as much of the household load as possible. Based on the predicted load for a peak day, a 4-kW PV array (split into two subarrays) was specified. One was located on the south-facing roof, which is generally the preferred placement for a PV system. 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. It produces DC power that is converted to AC and then fed directly into the local utility distribution system. The City of Lakeland's municipal utility, Lakeland Electric, owns the PV system and allowed unprecedented connection of a residential PV system to the utility grid.

Near zero energy home's roof and windows beat the heat



More Solar Heat Transmitted — *Heat Scale* — *Less Solar Heat Transmitted*

Thermographic images of the roofs in both homes. The lower roof and attic heat gain into the near zero energy home reduces the demand for cooling.



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

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 and that can minimize or eliminate monthly utility bills. And, when solar technologies are combined with energy efficiency measures, their 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 near zero energy home and sizing and locating the solar technology system correctly resulted in the solar technology system offsetting about 85% of all annual grid electricity needs.

Of course, purchasing the solar technology system and installing certain energy efficiency measures incurs up-front costs. 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 energy efficiency measures and solar technology configurations will vary locally, but energy efficiency can improve the value of the solar technology resource anywhere.

What If?

A quarter-million people move to Florida each year and build more than 100,000 new homes, so the demand for electrical energy increases proportionally. Imagine the scenario if all those new homes were built like the near zero energy home (rather than the control home). How big a difference would this make?

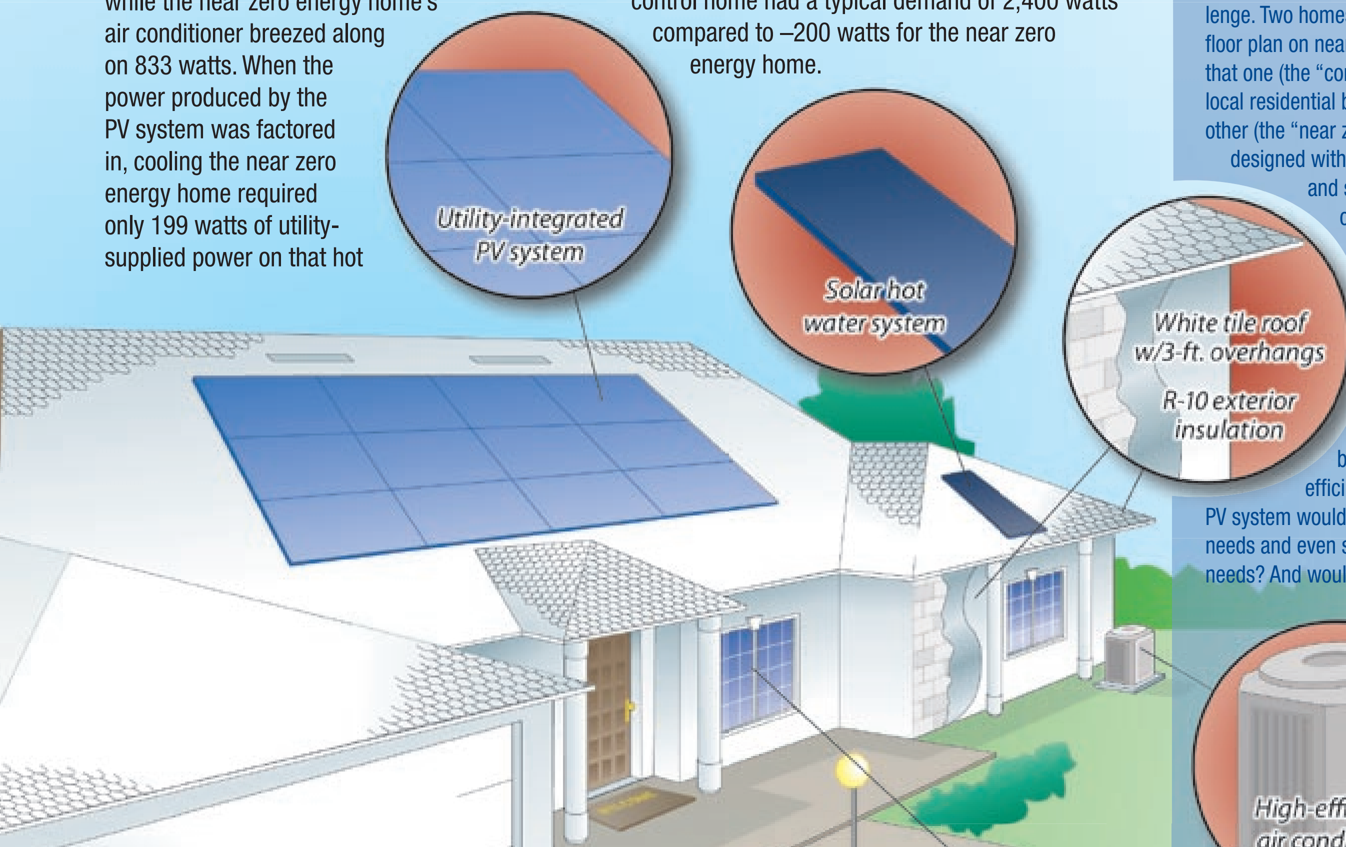
If each home would save about 18,000 kWh/year, the total savings for the 100,000 homes would be 1.8 billion kWh. Based on Florida's 2004 average cost of residential electricity ($0.09/kWh), this would save about $162 million per year in utility bills. Multiply these figures by all 50 states, and clearly 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 incorporating energy efficiency features.

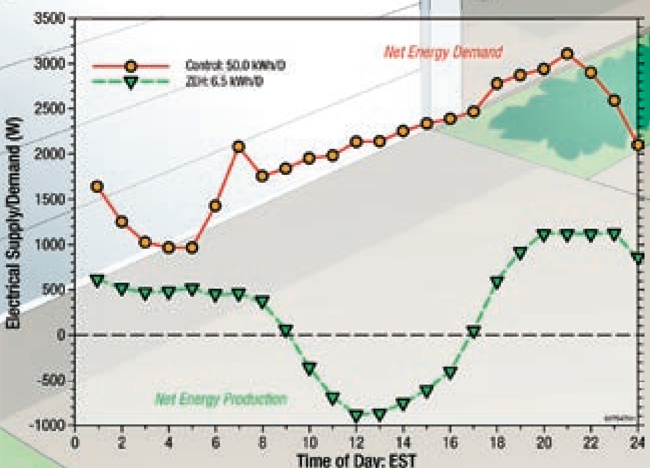
A Tale of Two Houses

When all the numbers were in, the near 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 near zero energy home used 72% less power from air-conditioning than did the control home, even though the occupied near 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 near zero energy home's air conditioner breezed along on 833 watts. When the power produced by the PV system was factored in, cooling the near 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 graph shows the difference between the average hourly energy demand of the control home and the near zero energy home from July 2001 to June 2002. The part of the curve that dips below the zero line indicates the times (~9:00 a.m. to ~5:00 p.m.) when the near zero energy home produced more power than it required and supplied the excess to the utility grid. During the Florida utility peak period from 4:00 p.m. to 5:00 p.m., the control home had a typical demand of 2,400 watts compared to –200 watts for the near zero energy home.





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 that accounts for about 35% of all electricity used in a typical Florida house. As the largest single source of energy consumption, a home's air-conditioning load represents the biggest energy challenge.

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 "near 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 most 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 begun during the summer of 1998–one of the hottest summers on record.

This news is important for city planners, architects, builders, and homeowners throughout the country. The solar/energy efficiency combination worked so well in Florida that it can and should be tried in other parts of the country.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

Research and Development of Buildings

Our nation's buildings consume more energy than any other sector of the U.S. economy, including transportation and industry. Fortunately, the opportunities to reduce building energy use—and the associated environmental impacts—are significant.

DOE's Building Technologies Program works to improve the energy efficiency of our nation's buildings through innovative new technologies and better building practices. The program focuses on two key areas:

- **Emerging Technologies**
  Research and development of the next generation of energy-efficient components, materials, and equipment

- **Technology Integration**
  Integration of new technologies with innovative building methods to optimize building performance and savings

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An electronic copy of this factsheet is available on the Building America Web site at **www.buildingamerica.gov**

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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 online at **www.fsec.ucf.edu/bldg/pubs/cr1044/index.htm**

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