Building America worked with SMUD on this 1980s retrofit home to cut energy use by 104 points from a pre-retrofit California HERS score of 182 to a post retrofit score of 78. The home exceeded the energy performance of a new home built to the State of California's 2005 energy code (Title 24) by 22%.

Building America Comprehensive Energy Retrofit

Efficient Solutions for Existing Homes

Case Study: SMUD's Energy Efficient Remodel Demonstration Project

Fair Oaks, CA

"We have built a lot of new homes in the past, and because of the shift in the market, we are focusing on renovations and remodeling work today."

Jim Bayless, *President of Greenbuilt*

Building America and SMUD Use a Deep Retrofit as a "Lab House"

The Sacramento Municipal Utility District (SMUD) teamed with the U.S. Department of Energy's Building America to test approaches for achieving dramatic energy savings in retrofitted homes. Working with DOE's National Renewable Energy Laboratory (NREL), SMUD and Greenbuilt deep retrofitted a foreclosed 1980s home to reach computer-predicted 61% energy use savings compared to the pre-retrofit.

After the retrofit, SMUD leased the home from its owner for a year (September 2009- 2010) and operated it as a lab house where NREL scientists tested different equipment and energy usage scenarios. SMUD opened the house to builders, contractors, and the general public for tours and training.

"We are just beginning to analyze all the data," said Bethany Fisher, an NREL residential building engineer. "We are trying to figure out what works well in the Sacramento climate. It is a cooling climate, and we are hoping to use the results to develop some strategies for cutting cooling costs in similar climates."

"There is a huge opportunity here," said Jim Bayless, the president of Greenbuilt and owner of the home. He explains: "Of the 13 million homes in California, 8 million were built before energy-efficiency standards were adopted, and it is not difficult to reduce energy consumption by 40% to 50%."

Building America U.S. Department of Energy

Unless viewed from the backyard, as shown here, neighbors would not know that this remodeled 1980s house in Fair Oaks, CA, has a 2.3-kW photovoltaic system for generating electricity, and energy-efficient features that reduce energy use by 61% compared to the pre-retrofit.

"Retrofitting the existing housing stock to make it more efficient is a much larger opportunity for California than building increasingly efficient homes."

Jim Bayless, *President of Greenbuilt*

"Most people aren't aware that energy-consuming devices in the home—lights, thermostat, heavy duty appliances—can be integrated to benefit both consumers and the utility company. Home area networks bring together complementary technology and renewable energy to promote conservation."

Paul Nagel, *Vice President, Control4*

For more about SMUD research, contact Mike Keesee at MKeesee@smud.org or 916-732-5244

Some of the Energy-Efficient Features Studied

The all-electric, 1,748-square-foot, 3-bedroom, 2-bath home in Fair Oaks, California, required a major retrofit to make the home habitable, including a new roof; a new west wall because of weather damage; new windows; new heating, ventilation, and air conditioning (HVAC) equipment; new flooring; new kitchen appliances; and new counters.

"If you are going to do a gut rehab, you should add in the energy. People spend $20,000 on new cabinets, and the payback is zero for these," said Mike Keesee, a project manager within SMUD's Energy Research and Development Group. "What you have to do to reach higher energy efficiency is insignificant in the bigger scheme of things. If you are going to have to do a lot of work anyway, then do the energy-efficiency upgrades."

NREL used BEopt, a computer-assisted energy modeling tool, to evaluate and determine the least-cost measures to achieve energy savings compared to the pre-retrofit, with 61% savings predicted. (A listing of these measures is contained under the next page sidebar "Energy-Efficient Features.")

With the energy-efficient features installed and the retrofit complete, NREL began its year-long study to see if the predicted energy savings matched simulated use savings. "The idea of the lab house is to test how everything works together. You can test all the individual components, but how they work together is really important," said Fisher. To mimic the activities of two adults and one child, space heaters in each room radiated heat on programmed schedules. Lights turned on and off based on anticipated activities performed in specific rooms at specific times of the day.

"We played with different strategies," said Fisher. NREL tested the effects of shutting the blinds and using awnings and shades over glass doors and windows to influence heat gain within the home.

"Pre-cooling" is one of the key concepts DOE and SMUD wanted to test. "We think we can use pre-cooling to decrease energy use during our peak demand," said Keesee. In the summer, Sacramento can have temperature shifts in a day of up to 40 degrees, with cooler temperatures in the morning and the hottest temperatures between 4:00 and 7:00 p.m. Normally people run their air conditioners during this hottest time period. However, the SMUD and DOE idea is that a tightly sealed, well-insulated, mechanically vented home acts like a thermos. "The idea is to cool the house to 72 degrees before 4:00 p.m.," explains Keesee, "Then, at 4:00, you turn off your air conditioner, and you float through the 4:00 to 7:00 time before you need to turn your air conditioner back on to prevent discomfort." SMUD defines discomfort as temperatures above 80 degrees.

To test the pre-cooling idea, NREL placed a mini-weather station on the house to measure external conditions including sunlight, wind, temperature, and humidity. A programmable thermostat controlled the inside temperature for the pre-cooling study. Each room contained temperature sensors, and data from these sensors was collected and stored at 1-minute, 15-minute, and 1-hour intervals.

To help remotely monitor and continually update the energy activities in the home, NREL worked with Hood Branco Innovations to install a home automation Control4 system. "From an iPhone or from any internet-capable computer, the user can control and monitor the thermostat and lighting, and even open and close the garage door," said Bayless.

In addition to controlling lighting and the thermostat, the Control4 system controlled the power of the air handler and the air-source heat pump. Data loggers took power measurements of the total power consumed and time the equipment was operating. Combined with the detailed room temperature data, the power and time data will be used to analyze the effectiveness of the space conditioning system.

Innovations

"One really exciting product we used was AirGenerate's AirTap™," said Bayless. The AirTap is an air-source heat pump that attaches to the home's existing electric or gas water heater. The heat pump technology uses energy extracted from ambient air to heat water in the tank. It costs about $1,200 (according to the manufacturer).

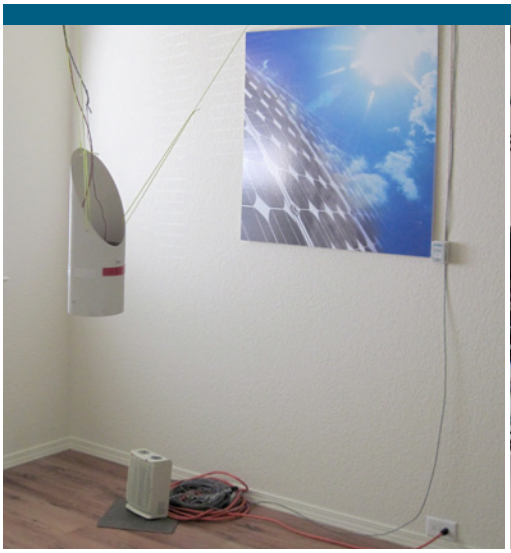
"The manufacturer claims, and NREL verified, that this product reduces the electric water heater consumption by 70%," said Bayless. "The average all-electric homes uses about $50 a month for heating water, so if you are saving $35 a month, with the equipments costs, it pays for itself in less than three years."

NREL also studied a solar pre-heat system for the 40-gallon water heater. An integrated collector system (ICS) mounted on the roof heated water and piped this through the attic to the water heater in the garage. Five submerged thermocouple probes measured heat within the hot water system, including water temperature entering the water main, entering and leaving the collector, and entering and leaving the hot water tank. These measurements along with power measurements will be analyzed to determine modeled versus actual performance.

"We developed different hot water draw profiles to test the high and low limits of the water heating system," explained Fisher. "We also looked at draw profiles that mimicked significant water use in the mornings or in the evenings. You can imagine that the integrated solar collector would

Energy-Efficient Features

- **Blower door pre-retrofit test score:** 6,830 cfm 50 or 26 ACH @ 50 Pascals; post-retrofit blower door test score: 1,080 cfm or 4.1 ACH @ 50 Pascals
- Air Sealing to comply with ENERGY STAR Thermal Bypass Checklist
- **Attic:** Air sealed, insulated with R-42 blown-in insulation
- **Kneewalls:** R-6 foil-faced, 1-inch rigid foam over R-15 batts
- **Roof:** Asphalt shingles over a radiant-barrier roof sheathing
- **West Wall:** R-15 blown-in cellulose insulation (Other walls not modified –2x4, 16-inch on-center R-11)
- **Windows:** Vinyl-frame, dual-pane, low-emissivity, argon-filled, U-value = 0.29 to 0.28, SHGC = 0.19 to 0.22
- **Air Conditioner:** electric heat pump SEER 16/EER 13
- **Furnace:** Goodman 9.75-HSPF electric heat pump
- **Ducts:** R-6 insulated, tested to 4.5% leakage @ 25 Pa
- **Water Heating:** 97- energy factor (EF) electric storage tank with Air Tap heat-pump "booster" retrofit with 2.11 coefficient of performance (COP), and a 40-gallon, integrated solar water collector (50% solar fraction)
- **Control4 Home Area Network:** System remotely controls HVAC and lights
- **Programmable thermostat**
- **Lighting:** Hardwired ENERGY STAR compact florescent lights (CFLs), light-emitting diode (LED) fixtures in the master bathroom
- **Appliances:** ENERGY STAR refrigerator and dishwasher
- **Ventilation:** AirScape two-speed whole-house fan; ENERGY STAR ceiling fans; spot ventilation from ENERGY STAR bathroom low-sone fans with timer controls and ENERGY STAR range hood
- **Renewable Energy:** Photovoltaics 2.3 with AC PV.



(left) For a year, NREL monitored and tested the energy usage of a variety of innovative technologies and scenarios, while the home was open for tours to builders and contractors.

(right) AirGenerate's AirTap™ attaches to a water heater and uses heat pump technology to extract energy from ambient air to heat water in the tank, reducing the electric water heater consumption by 70%, with installed costs less than $1,200.

BUILDER PROFILE

Builder's Name: Greenbuilt

Contact: Jim Bayless
www.greenbuilt.com, 916-442-4225

Where: Folsom, California

Founded: 2003

Employees: 2, not including subcontractors

Size: 3 bedrooms, 2 baths, 1,748 sq. ft.

Year Built/ Remodeled: 1983 / 2009

For More Information

www.buildingamerica.gov

The EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

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be more effective if most of the water use occurred in the evening, so we wanted to test the difference in system efficiency between morning-dominated hot water draws and evening-dominated hot water draws."

Dollars and Sense

The total retrofit cost is $141,000. The energy-efficiency measures cost $42,000 including the contractor overhead (not including the awnings, photovoltaic system, or home area network).

Based on current energy prices and projected future utility rate increases, the remodeled home's annual electric bill is estimated to be $980, a savings of $2,151 per year or $179 per month. This is a 69% annual utility bill savings.

"It is incredible to see how much difference duct sealing and air sealing make. These things are not very exciting and not very visible…but it is amazing how cost effective they are to do. In a lot of houses they can save more money than all this other fancy, more expensive stuff," said Bayless.

Mike Keesee echoes this saying: "When looking at solar and other energy efficiency features, you definitely want to do efficiency first. The savings from efficiency are orders of magnitude higher than for the solar systems. We call this 'loading order' in California. This means that you want to do the cost-effective efficiency upgrades before you do the renewables."

Bottom Line

"As we speak, SMUD is launching a Home Performance program," said Keesee. "Our hope is to create an industry dedicated to doing these deep-energy retrofits going forward. We hope that this changes the way that people look at remodeling in general."