Building AMERICA®
U.S. Department of Energy

Research Toward Zero Energy Homes

The Habitat for Humanity of Metro Denver Zero Energy Demonstration Home:

Proof that a well-designed home can produce as much energy as it consumes — and more!

The Metropolitan Denver affiliate of Habitat for Humanity (Habitat for Humanity of Metro Denver, or HFHMD) has improved the energy efficiency of its homes by working with researchers from the National Renewable Energy Laboratory (NREL). Together, they have created a series of energy-efficient demonstration homes.

In 2004, HFHMD partnered with NREL for a third time to design and build a demonstration home. This time, however, the partners set out to build a zero energy home. It would be designed to produce as much energy as it consumed over the course of a year. To meet this goal, the design would include attributes such as building envelope efficiency; passive and active solar features; and efficient equipment, appliances, and lighting. NREL's managing partners at the time, the Midwest Research Institute, Batelle, and Bechtel Corporation, sponsored the home.

The 1,280-sq.-ft., three-bedroom home was completed in September 2005. Once built, NREL researchers monitored the home's energy production and use, and found that the home actually produced 24% more energy than it consumed over the course of a year, on a source energy basis.[1]

[1] Source energy is the total energy used to deliver energy to a site, including power generation, transmission, and distribution losses. From a societal point of view, source energy better reflects the overall consequences of energy use.

Amy Glickson, NREL/PIX14166

The Habitat for Humanity of Metro Denver and NREL worked closely together to design and build this home, which surpassed zero energy requirements by producing 24% more energy than it consumed over a 12-month period. The design includes superinsulation, active and passive solar elements, ENERGY STAR® appliances, and a mechanical ventilation system.

Energy Features of the Zero Energy Home

Superinsulated Building Envelope

- Double-stud wall construction with raised heel roof trusses
- Fiberglass insulation: R-40 walls, R-60 ceiling, R-30 floor
- Air tight with continuous air and vapor barrier

Passive Solar Tempered

- Expanded southern window area with summer shading overhangs
- Reduced east and west window areas
- Low-e windows throughout (U = 0.23 to 0.30 Btu/sq. ft. hr °F)
- Orientation-specific glazing: high solar heat gain coefficient (0.58) on the south and low solar heat gain coefficient (0.27) on the west, north, and east

Solar Water Heating and Electricity

- 96 sq. ft. of water heating collectors with 200 gallon thermal storage tank
- Backup water heating from high efficiency tankless water heater
- 4-kW grid-tied photovoltaic system

Fresh Air Ventilation with Energy Recovery

- Energy recovery ventilation (ERV) system with ducting inside conditioned space

Distributed Hybrid Space Heating System

- Ductless direct-vent natural gas space heater in the living/dining room
- Small thermostatically controlled electric baseboard heaters in each bedroom

Other Features

- All mechanical equipment is within the conditioned space
- Light-colored roofing shingles and increased attic ventilation reduce attic overheating
- ENERGYSTAR® appliances
- 100% compact fluorescent lighting

With performance like that, it is no surprise that the house received local and national media attention and won an exemplary building award from the Colorado Renewable Energy Society. The house has also been lauded by U.S. Secretary of Energy Samuel Bodman and was included in the 2005 National Solar Tour.

Partners in Building Design

From the beginning of the design process, NREL building researchers and HFHMD staff and volunteers worked closely to find a balance between engineering ideals and practicality. The combined perspectives led to a design that balances ease of construction and low cost while still meeting the zero energy goal.

Credit: Paul Norton

This photo was taken after the solar hot water collectors were installed on the roof, but before the PV panels were added. Here it's apparent how the 3-ft. eaves shade the windows in the warmer months.

Components of a Super-Efficient Design

Insulation

This demonstration home was "superinsulated" with R-40 fiberglass batt insulation in the walls, R-60 insulation in the attic, and R-30 insulation in the floor. The roof required raised heel trusses to allow room for 2 feet of blown-in insulation in the attic. The house exterior actually has two walls — an outer 2-in. x 4-in. structural stud wall and, 3½ in. inside that, a second 2-in. x 4-in. stud wall. Fiberglass batts were placed within and between these walls. This superinsulated shell greatly reduces the demand for heat.

Space Heating

The space heating system combines a direct vent natural gas furnace in the living/dining area and small baseboard electric resistive heaters in the three bedrooms. Because each heating appliance has its own thermostat, each zone can be warmed as needed.

Credit: Paul Norton

These raised heel trusses at the intersection of the wall and roof frames allowed for 2 feet of insulation to be blown into the attic—just one of the home's superinsulation features.

Passive Solar Elements

A practice called "sun tempering" was used to get the most advantage from sun coming through the windows. Most windows were located on the long south side of the home, and fewer windows were placed on the north, east, and west sides. The roof was designed to have 3-ft. overhangs, which shade the window in the summer and allow sunlight to enter the windows in the winter. The windows themselves are double-glazed, low-emissivity models. This means they have been coated to reduce radiant heat transfer, which increases the windows' insulating value.

Solar and Natural Gas Water Heating

NREL's building engineers specified a solar water heating system with a 96-sq.-ft., roof-mounted solar collector with a 200-gal. water storage tank. The water thermostat is set to maintain the temperature of the water at 115°F. If necessary, a backup natural gas tankless water heater helps maintain the temperature. The tankless system uses no heating energy when the solar water system is able to maintain the temperature.

Appliances and Lighting

The electrical load was reduced by using ENERGY STAR® appliances and using compact fluorescent lights throughout the home.

Solar Electric System

Once all energy loads were reduced during the design process, a photovoltaic (PV) system was sized to meet the remaining electrical needs and offset natural gas use. The 4-kilowatt solar PV system is grid-connected with no battery backup. The system feeds electricity into the utility grid when it produces more electricity than the home needs, and it consumes electricity from the grid when the home needs more electricity than the PV system produces. This means

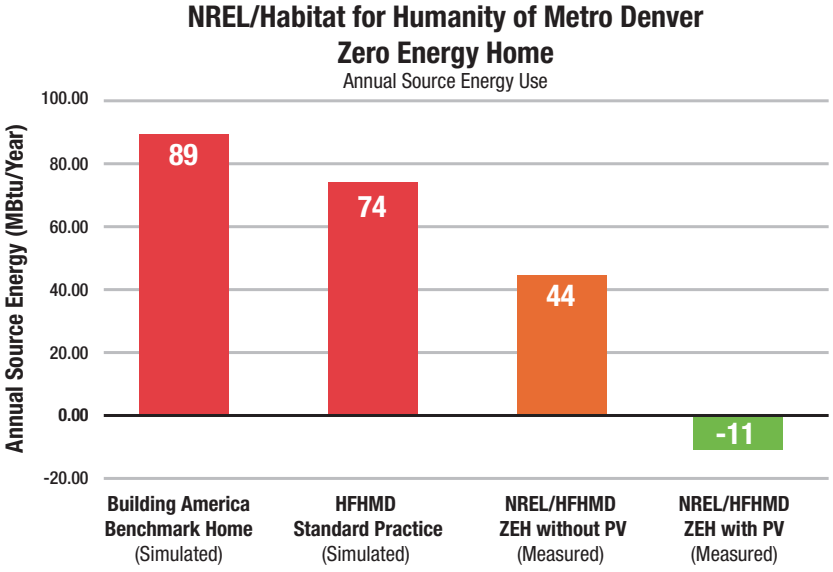
the electricity meter on the home sometimes runs backward — an arrangement called "net metering" that is available in most states.

Ventilation

Because the house leaks very little air, it requires a mechanical ventilation system to provide fresh air while minimizing energy losses. A balanced energy recovery ventilation system supplies fresh air to the living room and bedrooms and exhausts air from the kitchen and bathroom. The warmth of the exhaust air is used to heat the incoming fresh air.

Verifying Zero Energy Use

In January 2006, NREL researchers installed a monitoring system in the home to measure how much energy it produced and used. They found that, on a source energy basis, the home produced 24% more energy than it used during its first year. This, of course, surpasses the zero energy home goal of producing as much energy as it uses, and is a testament to Building America's integrated systems-engineering design approach and to the collaboration between NREL and HFHMD.



Credit: Paul Norton

The home's shell consists of two exterior walls, insulated both between the studs of each wall and in the space between each wall, providing superior heat retention.

12-Month Performance Summary of NREL/Habitat for Humanity of Metro Denver Zero Energy Home

Site Energy Summary	kWh (MBtu)
Total site electricity consumption	3,585 (12)
Total AC site PV electricity production	5,127 (17)
Net site electricity production	1,543 (5.3)
Total site natural gas consumption	1,665 (5.7)
Source Energy Summary*	**kWh (MBtu)**
Total source energy consumption	13,025 (44)
Total source energy offset	16,201 (55)
Net source energy offset	3,176 (11)
Percent of source energy consumption offset via onsite renewable production	124%

* The site-to-source energy conversions are U.S. national averages according to the *Building America Analysis Procedures for Existing Homes* (Hendron, et al. 2004): site-to-source multiplier for electricity = 3.16; site-to-source multiplier for natural gas = 1.02.

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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Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

A Win-Win Situation

Media exposure has triggered inquiries to HFHMD and NREL about this demonstration home. This attention provides visibility for project sponsors and equipment donors and may help generate more sponsors for Habitat for Humanity.

This home has proven it is possible to build efficient, affordable zero energy homes in cold climates with standard building techniques and materials, simple mechanical systems, and off-the-shelf equipment. Furthermore, the home is providing a well-built, comfortable place to live for a mother and her two sons. Lower and more stable energy bills mean more resources will be available to meet other family needs.

Additional Resources

- A Cold-Climate Case Study for Affordable Zero Energy Homes: www.nrel.gov/docs/fy06osti/39678.pdf
- Performance Results from a Cold Climate Case Study for Affordable Zero Energy Homes: www.nrel.gov/docs/fy08osti/42339.pdf
- The Building America Project: www.buildingamerica.gov
- Building Science Corporation's Cold Climate Design: www.buildingscience.com/documents/primers/plonearticlemultipage.2006-11-14.1183847686
- EPA's ENERGY STAR® Homes and appliances: www.energystar.gov

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