Building America Best Practices Series

Volume 12. Builders Challenge Guide to 40% Whole-House Energy Savings in the Cold and Very Cold Climates

Case Study: Rural Development, Inc.

Wisdom Way Solar Village | Greenfield, MA

The 20 duplexes built by Rural Development, Inc., in Greenfield, Massachusetts, with help from Building America's CARB team have HERS scores of 8 to 18.

BUILDER PROFILE

Builder: Rural Development, Inc.
www.ruraldevelopment.org

Where: Greenfield, MA

Founded: 1991

Employees: 6

Development:
Wisdom Way Solar Village

Size: 20 homes in 10 duplexes

Square Footage: 1,140-1,770 sq. ft.

Price Range: $110,000 (subsidized) to $240,000

Energy-Efficiency Commitment:
Better than 50% energy savings

Building America U.S. Department of Energy

Wisdom Way Solar Village is an appropriate moniker for the 20-unit community of energy-efficient duplexes in Greenfield, Massachusetts. The homes meet the requirements of the U.S. Department of Energy's Builders Challenge, achieving HERS scores of 8 to 18 by packing energy-efficiency features into the compact, heavily insulated homes and adding solar water heating and photovoltaics on top, to net home owners energy cost savings of at least $2,500 per year per home.

The homes are so well insulated, a small (10,000 to 16,000 BTU) gas-fired space heater is all that is needed to heat them. Most homeowners are spending less than $500 per year for natural gas. The space heaters cost builders about $5,000 less per unit than a typical central gas or electric furnace.

The homes were built by Rural Development Incorporated (RDI), a non-profit organization focused on energy-efficient, affordable housing in western Massachusetts. The Consortium for Advanced Residential Buildings (CARB), a U.S. Department of Energy Building America research team led by Steven Winter Associates, provided design assistance and analysis on the project.

CARB's preliminary analysis of utility bills showed most homeowners getting credits from the electric utility throughout the winter months thanks to the combination of energy-saving features and electricity-producing photovoltaic panels. "Homeowners are thrilled with their negative electric bills," said Robb Aldrich, an engineer with CARB. "If you can get the building shell this well insulated, you are going to see significant heating energy savings, almost regardless of what heating system you choose," Aldrich noted.

(top) The double-stud wall consists of two 2x4 16-inch-on-center framed walls set 5 inches apart.

(bottom) A vapor-permeable mesh is stapled to the inside surface of the inside wall forming a 12-inch-deep cavity to hold R-42 of dry-blown cellulose insulation.

With a better thermal envelope, builders can offer homeowners "protection" from high fuel bills.

Energy-Efficient Features

A unique feature of the homes is their double-walled construction. The exterior 2x4 16-inch-on-center framed wall is built first; it is sheathed on the exterior side with OSB, but no interior gypsum. Then the second 2x4 framed wall is built inside with a 5-inch gap between the two walls. A mesh liner is stapled to the inner wall's studs to form a 12-inch-deep cavity between the two walls. The cavity is filled with dense-pack dry-blown cellulose insulation at 3.4 pounds per cubic foot density for an R value of 42, with no thermal bridging. RDI employs its own carpentry staff and uses a basic rectangle-shaped house design to decrease complications with this nonstandard framing. CARB visited the site at least once a month during construction and provided training to the trades. Blower door tests by a third-party inspector found air leakage to be 200–350 cfm or 1 to 1.5 air changes per hour at 50 Pascals.

The vented attic incorporates ridge and soffit vents with baffles at every truss bay to minimize disturbance to the 14 inches of loose blown cellulose, which provides R-50 attic insulation. The homes have full, unconditioned basements. Although CARB would typically recommend insulating the basement walls, in this case RDI chose to insulate under the floor joists with R-40 of blown cellulose held in place with vapor-permeable mesh stapled to the I joists, after energy modeling showed that 3 inches of rigid insulation would have been needed to get the same performance, and at considerably higher cost because the local building department would have required that gypsum be installed to cover the foam due to flamability.

Because the homes are so well insulated and have compact designs (1,137 ft^2 to 1,773 ft^2), RDI was able to meet the design heat load of 12,000 Btu per hour with a space heater. RDI chose a sealed-combustion, natural gas-fired heater that was placed in the living room on the homes' first floor. The heater has a capacity of 10,200 Btu per hour on low fire and 16,000 Btu per hour on high fire with an annualized fuel utilization efficiency (AFUE) of 83%. In previous projects, RDI had used hydronic baseboard heating with a gas or oil boiler. By installing the space heater instead, RDI saved about $5,000 per home. Because the units are sealed combustion with piping directly to the outside to bring in combustion air and send out flue exhaust fumes, there is little danger of backdrafting.

There is no traditional duct system with this type of space heater. Instead, CARB suggested putting an exhaust fan in the living room ceiling above the space heater. In winter the fan "exhausts" warm air into each of the upstairs bedrooms through PVC "ducts" connecting the fan to duct registers located 1 foot above the floor on the inside wall of each room. CARB measured the air flow at each register and found the flow to be fairly evenly distributed at 20 to 30 CFM per outlet. CARB

also found temperatures were very consistent from room to room when occupants followed CARB's recommendations to leave the thermostat at one temperature with no day/night setbacks.

For north, east, and west-facing windows, RDI selected a triple-pane window with low-emissivity coatings on the second and fifth surfaces, a U-value of 0.18, and an SHGC of 0.23. To save costs and increase desired solar gain, on south-facing windows, RDI installed a double-pane window with a U-value of 0.26, an SHGC of 0.37, and a low-emissivity coating on the third (inside) surface.

RDI installed a 2.8- or 3.4-kW photovoltaic system on the roof of each home. In the first 6 months of occupancy (Nov. 2009 – April 2010) most of the homeowners reported negative electric bills. Water heating is provided by flat-plate solar thermal collectors with gas-fired tankless water heaters for backup.

Dollars and Sense

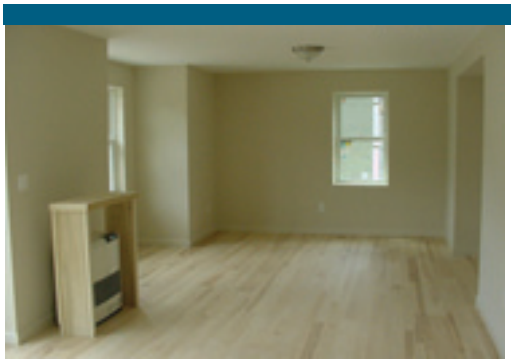
CARB collected natural gas billing data for four of the homes for November through April 2010 and found that natural gas bills totaled $242 to $354/home for the 6 months, or $40 to $59/month (for the space heater, a gas clothes dryer, a backup on-demand gas water heater, a cook stove with oven, and monthly service charges). This is about one-fourth the $1,930 average annual oil heating bill in New England based on 2005 data from the U.S. Energy Information Administration. The energy-efficient gas heater offers a stable alternative to heating with oil, which has seen erratic prices over the past two years, ranging from $2.50 to $4.50/gallon.

As shown in Table 1, CARB estimated that RDI spent about $11,800 more to add energy-efficiency features compared to a house built to the Building America benchmark. The largest expense was $9,750 to purchase and install the solar water heating system. RDI saved $5,000 per unit by replacing a gas or oil boiler and radiators with the ductless gas-fired space heater. CARB calculated the annual increased mortgage cost to cover these expenses at $1,050 per year, assuming a 30-year mortgage at 7%. The annual utility savings was calculated at $2,192, yielding a net gain to the homeowner each year of $1,142.

The photovoltaic panels are not included in the builder costs on Table 1. They would have cost $25,000 to purchase and install at market rate; however, RDI got state, federal, and local grants to cut the costs. If the solar electricity benefit were included in Table 1, the 3.4-kW systems would generate $635–$700 worth of electricity per year at $0.17/kWh and the 2.8-kW systems would generate about $525 to $575 annually.

Energy-Efficient Features

- Foundation: Full basement with R-40 dense-blown cellulose under first floor
- Walls: 12-inch double 2x4 wall with R-42 dense blown cellulose
- Attics: Vented attic with R-50+ loose blown cellulose
- Windows: East, north, and west: vinyl-framed, triple-pane, U = 0.18, SHGC = 0.23. South: double-pane, U = 0.26, SHGC = 0.37
- Doors: 0.20
- Infiltration: 200-350 cfm at 50 Pa, based on blower-door test
- Heating System: Small (10,200/16,000 Btu) space heater located in main living area; sealed-combustion gas-fired 83% AFUE (Monitor Products model GF1800)
- Cooling System: None
- Water Heater: Solar thermal system with tankless gas auxiliary
- ENERGY STAR Appliances: Refrigerators and dishwashers; 100% hard-wired fluorescent lights
- Ventilation: Continuous exhaust fan with variable-speed motor



The homes are so well insulated that a 10,200-Btu gas-fired space heater on the main floor, (shown in wood cabinet in top photo and alone in bottom photo), provides all the heat needed.

"This project shows that, with a highly efficient envelope, simple, low-cost space-heating systems can provide an affordable, efficient method for heating homes, even in a cold climate.

Robb Aldrich,
DOE's CARB Building America Team

For More Information

www.buildingamerica.gov
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
eere.energy.gov/informationcenter

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Table 1. Added Costs and Savings of Energy-Efficient Measures for Rural Development, Inc.

Total Energy Savings	56.5%
Total Added Builder Costs*	$11,844
Annual Mortgage Payment Increase**	$1,050
Annual Utility Savings	$2,192
Annual Net Cash Flow to the Homeowners	$1,142

*Costs are based on builder estimates, and manufacturers' data. These costs do not reflect rebates, incentives, and subsidies.

**The annual mortgage payment is an estimate calculated by CARB for comparison purposes and is based on a 30-year mortgage with a 7% interest rate.

The 20 two, three, and four-bedroom houses were offered at $110,000 (subsidized) to $240,000 (market rate) to buyers who qualified at different income levels. As of August 2010, all but the five homes still under construction had sold.

The Bottom Line

RDI has been building ever more energy-efficient homes for low- and moderate-income buyers since building its first ENERGY STAR homes in the year 2000. Anne Perkins, RDI's director of home ownership programs, noted that RDI has worked with Building America through its CARB team since 2006 when CARB's Robb Aldrich assisted RDI with development of a prototype solar home in Colrain, Massachusetts. That home achieved a HERS score of 21. The homes at Wisdom Way received HERS scores of 8 to 18.

"RDI could not have advanced to build near zero net energy homes without the design training and technical support it received from the CARB team led by Steven Winter Associates and DOE's Building America," said Perkins of the Wisdom Way project. "The technical information, the drawings, the modeling and monitoring made it possible."