Cold Climate Region
40+% Energy Savings

RDI Colrain Home

Colrain, MA

Developer/Owner:	Rural Development, Inc.
Location:	Colrain, Massachusetts
Building Type:	Single Family Detached
Building Size:	1,350 sq ft 3 bedrooms, 2 baths
Price:	$260,000
Status:	Completed May 2007
SWA Contact:	Robb Aldrich

Rural Development, Inc. (RDI) has been recognized nationally as a leader in developing and building sustainable, affordable housing; part of RDI's mission is to provide efficient, healthy, affordable homes to residents of Franklin County, MA. RDI partnered with SWA through the U.S. Department of Energy's Building America Program to achieve even greater levels of home performance. With this project, in partnership with local architects Austin Design, Inc., RDI took a significant step towards creating Zero Energy Homes.

During the design of the home, RDI worked closely with SWA and architects at Austin Design to incorporate efficiency and renewable energy systems effectively and affordably. On the site, the 1,350-ft^2 home is sited ideally to allow both active and passive solar collection. The envelope consists of framed, double-walls containing 12" of dense-packed cellulose (R-43); Heat Mirror™ windows with U-values of 0.20 Btu/ft^{2}hr°F; R-50 attic insulation; and R-20 foam insulation surrounding the radiant slab.

The roof of the home has a 3.2-kW photovoltaic array as well as three evacuated tube thermal collectors (approximately 60 ft^2). Energy from the solar thermal system is used to heat domestic hot water as well as a small portion of space heating (through the radiant floor). All lights and appliances in the home are ENERGY STAR™ and the home includes a very efficient, exhaust-only ventilation system. SWA has also been monitoring the energy performance of the home. Over the first year that the home was occupied, occupants consumed 3724 kWh (approximately half the regional average), and the PV system generated 3572 kWh – 96% of the total annual consumption. The solar thermal system provided 34% of the total space and water heating loads.

RDI's first prototype home approaching "zero energy."

Energy Efficient Features

- Low-e, krypton-filled windows with Heat Mirror (U-0.20, SHGC-0.34)
- 4" XPS insulation (R-20) under entire slab and along perimeter
- Loose blown cellulose insulation (R-50) in attic
- 12" double 2x4 wood framing with dense blown cellulose insulation (R-42) in walls
- Radiant floor heating system provided by solar thermal (59% solar fraction) and an auxiliary tankless, sealed combustion propane water heater
- Energy Star® Appliances
- 100% fluorescent lighting
- ASHRAE 62.2 compliant exhaust-only ventilation
- Solar thermal water heating system (82% solar fraction) with tankless gas auxiliary (0.82 EF)
- 3.22 kW PV system

Certifications

- Exceeds Energy Star® Homes Standards with HERS Index = 41
- Participated in LEED® for Homes (Silver certification)

http://www.ruraldevelopmentinc.org/

Steven Winter Associates, Inc.

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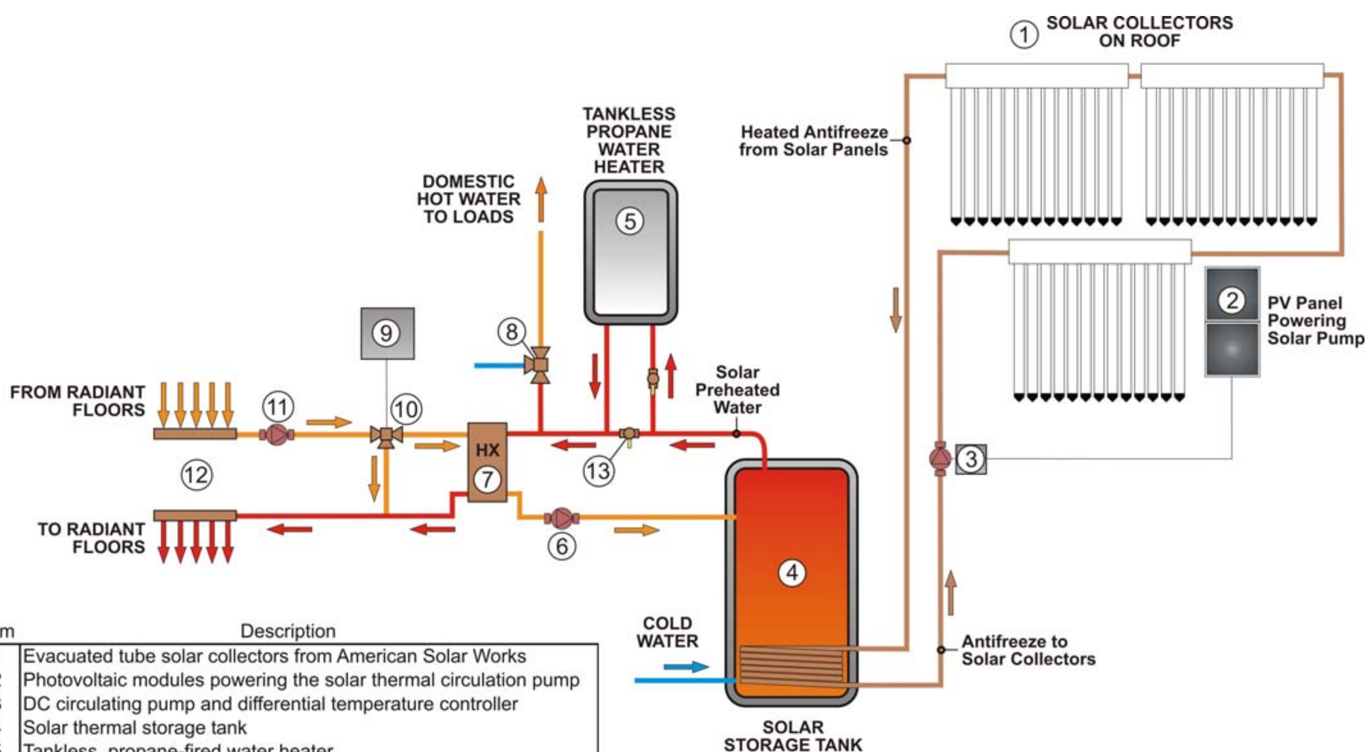
The long-term goal of the Building America program is to develop cost-effective systems for homes that can produce as much energy as they use—a zero energy home. As teams increase the savings targets towards zero energy homes, maintaining cost neutrality is a key component. The added cost of higher efficiency technologies can typically be offset by reducing unnecessary waste in other systems or through utility bill savings. The annual mortgage payment is calculated based on a 30 year mortgage with a 7% fixed interest rate. During construction of this home, RDI benefited from many utility and state incentives as well as donations from building system manufacturers. Each of the cost tables has two columns: one including all donations, grants, and subsidies; one including none. Incremental costs listed are costs above and beyond RDI's standard practice. For this home, the cost neutrality was positive only when including subsides.

Not Including PV

	Without Subsidies	With Subsidies
Incremental cost of energy improvements	$20,110	$4,700
Incremental cost plus 10% premium	$22,121	$5,170
Annual amortized improvement cost	$1,783	$417
Annual energy savings (over benchmark)	$1,626	
Net annual savings	($157)	$1,209

Including PV

	Without Subsidies	With Subsidies
Incremental cost of energy improvements	$46,573	$7,013
Incremental cost plus 10% premium	$51,230	$7,714
Annual amortized improvement cost	$4,128	$622
Annual energy savings (over benchmark)	$2,204	
Net annual savings	($1,924)	$1,583



Item	Description
1	Evacuated tube solar collectors from American Solar Works
2	Photovoltaic modules powering the solar thermal circulation pump
3	DC circulating pump and differential temperature controller
4	Solar thermal storage tank
5	Tankless, propane-fired water heater
6	Potable water circulating pump (for space heating)
7	Heat exchanger (domestic hot water / radiant floor water)
8	Anti-sclading valve
9	Radiant heating control
10	Radiant mixing valve
11	Radiant heating circulating pump
12	Radiant heating manifolds
13	Summer bypass valve (for solar-only operation)

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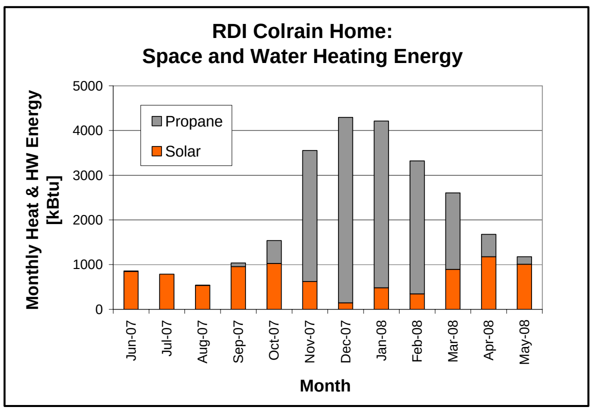
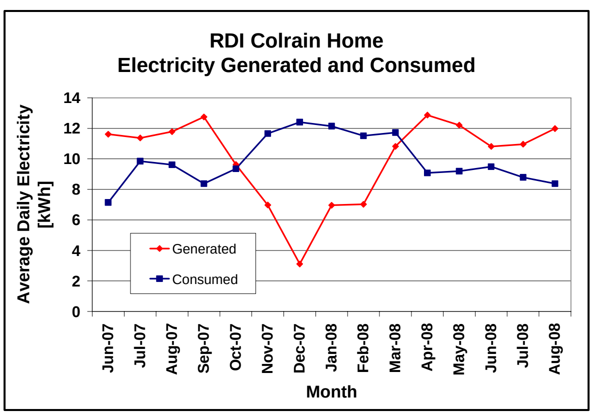
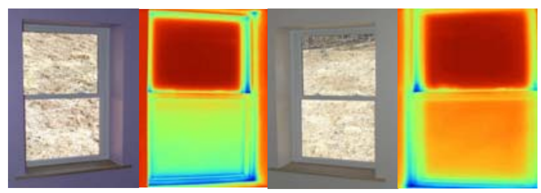
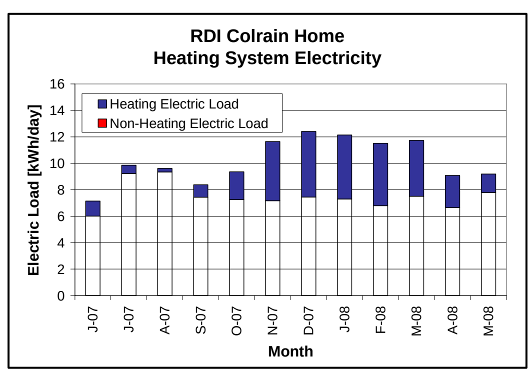




During short-term testing, CARB replaced two of the heat mirror window sashes. One was replaced with a clear, insulated window in a vinyl sash (left image below); the other was replaced with RDI's standard vinyl insulated low-e window sash (right image below). The windows were in place overnight, and NREL obtained IR images of the windows the next morning while outdoor temperatures were still cool. Images below show the two window assemblies; the top sash in each contains the heat mirror product. When these images were taken, the outdoor temperature was 52°F and indoor temperature was 69°F. Under these conditions, the infrared imaging shows interior surface temperature of the clear insulated window was 61°F. The insulated low-e window had an interior surface temperature of 64°F, and the surface temperature of the heat mirror window was 68°F. The images below show quite clearly the effect of the higher performance glazing.



The radiant system was designed to circulate fluid constantly whenever the outdoor temperature is below 55°F. There have been no complaints from home occupants, and CARB's monitoring shows that temperatures throughout the home do not vary substantially. The electricity use of this approach is significant, however. CARB was adamant that right-sized circulators be installed, but the plumbing/heating contractor used larger circulators recommended by the tankless water heater manufacturer. The electricity used by the heating system is displayed graphically below. Over the first year occupied, the electricity consumed by these two circulators (and peripherals) accounted for 26% of all the electricity consumed in the



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Snow on Solar Collectors

As mentioned previously, active solar space heating is challenging because the resource is least when the load is greatest. Snow covering collectors can compound this problem. While anecdotes of snow's effects on solar systems abound, CARB has not been able to find much reliable, quantitative information on the topic.

The winter of 2007-2008 was very snowy in northwestern Massachusetts, and the amount of solar energy collected (by both the PV and thermal systems) notably reduced during the snowiest months. The problem may be compounded for the solar thermal system at the prototype home because of the evacuated-tube collectors. These collectors have two features that may exacerbate the effects of snow:

- more contours which can retain snow (when compared to flat-plate collectors)
- vacuum insulation results in very low temperatures (so snow does not melt off collectors easily)

The images to the right show the roof of the home after a Fall snow of only a few inches. The flat, slick PV modules on the western end of the roof have shed the snow completely; the contoured, evacuated-tube collectors have not shed snow at all. Once a corner of a PV module is exposed to light, the collector will heat up somewhat – causing snow to melt and slide off the remainder of the module. Evacuated tubes, on the other hand, do not heat up significantly when exposed to sunlight.

Active Solar Space Heating

The perennial challenge with solar space heating is that the heat is needed when the available sunlight is least. At this point, CARB does not see active solar space heating as cost effective for most homes. If source energy savings of 50% and above are to be achieved in cold climates, however, it may be necessary to address gaps related to this technology. As space heating loads are reduced through excellent envelopes, smaller and simpler heating systems may become more common. It is possible that simple, relatively low-cost solar space heating can also contribute to these energy savings.

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