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

DOE ZERO ENERGY READY HOME™

U.S. DOE ZERO ENERGY READY HOME 2016 WINNER Housing Innovation Awards

PepperTree Homes and Zero Energy Home Plans

Mad River Glen House
Fayston, VT

BUILDER PROFILE

PepperTree Homes, Waitsfield, VT
Paul Fitzgerald, paul@peppertreehomes.com
802-793-0625, www.peppertreehomes.com

Zero Energy Home Plans, Coupeville, WA
Ted Clifton, ted@zero-energyplans.com
1-877-348-ZERO, www.zero-energyplans.com

Rater: Howard Vics and Phil Larocque
Phil Larocque
phil@philliplarocque.com

FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Mad River Glen House
- Location: Fayston, VT
- Layout: 4 bdrm, 5 bath, 1 fl + bsmt, 3,750 ft²
- Climate Zone: IECC 6A, cold
- Completion: November 2015
- Category: custom for buyer

Modeled Performance Data:

- HERS Index: without PV 41, with PV 18
- Projected Annual Energy Costs: without PV $1,569, with PV $757
- Projected Annual Energy Cost Savings (vs home built to 2009 IECC) with PV $4,039
- Projected Annual Energy Savings: with PV 30,856 kWh, 276 gal. propane
- Added Construction Cost: with PV $80,000

This home in Fayston, Vermont, winner of a 2016 Housing Innovation Award from the U.S. Department of Energy, was a team effort for the designer Ted Clifton of Zero Energy Home Plans, the builder Paul Fitzgerald of PepperTree Homes, and the home owners.

The home owners wanted a home near the Mad River Glen Ski Resort in northern Vermont where their ski-racing daughters practice. They also wanted the home to be energy-efficient in this heating-dominated climate where snow can linger until June. They found designer Ted Clifton through his Zero Energy Home Plans website. Clifton, who is currently consulting on more than 50 zero energy home design projects around the country, is also a builder in his own right, with over 45 years of experience building custom homes ranging from affordable and entry-level to luxury. He has partnered with the U.S. Department of Energy's Zero Energy Ready Home program since its inception as the DOE Builders Challenge and certifies all of his homes to the program's high performance criteria. Clifton has won several awards from building organizations, including five DOE Housing Innovation Awards and, notes the home owner, is known among SIP manufacturers as the "Grandfather of the net zero industry."

Clifton helped the home owner find a local Vermont builder also known for high-efficiency construction. Paul Fitzgerald of PepperTree Homes was selected because he had previous experience with structural insulated panels (SIPs) and was interested in learning how to build zero-energy homes. Fitzgerald has over 20 years of construction experience in north central Vermont and has won several awards for his unique custom homes that incorporate factory-produced modular components with site-built construction techniques. Clifton provided carefully detailed plans and the two collaborated via many long-distance phone calls as well as a site visit by Clifton when rough-ins were complete. Phil Laroque was

The U.S. Department of Energy invites home builders across the country to meet the extraordinary levels of excellence and quality specified in DOE's Zero Energy Ready Home program (formerly known as Challenge Home). Every DOE Zero Energy Ready Home starts with ENERGY STAR Certified Homes Version 3.0 for an energy-efficient home built on a solid foundation of building science research. Advanced technologies are designed in to give you superior construction, durability, and comfort; healthy indoor air; high-performance HVAC, lighting, and appliances; and solar-ready components for low or no utility bills in a quality home that will last for generations to come.

PepperTree Homes built this 3,750-ft² home in Fayston, Vermont, to the performance criteria of the DOE Zero Energy Ready Home (ZERH) program. The roof is constructed with structurally insulated panels (SIPs). The SIPs consist of two panels of OSB sandwiching a layer of rigid foam. They are premade in a factory to precise specifications and come to the site precision cut for quick assembly. The solid panels provide draft-free construction with considerable strength shear strength.

What makes a home a DOE ZERO ENERGY READY HOME?

1 **BASELINE** ENERGY STAR Certified Homes Version 3.0

2 **ENVELOPE** meets or exceeds 2012 IECC levels

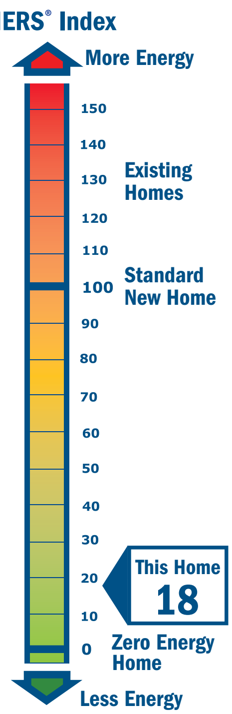
3 **DUCT SYSTEM** located within the home's thermal boundary

4 **WATER EFFICIENCY** meets or exceeds the EPA WaterSense Section 3.3 specs

5 **LIGHTING AND APPLIANCES** ENERGY STAR qualified

6 **INDOOR AIR QUALITY** meets or exceeds the EPA Indoor airPLUS Verification Checklist

7 **RENEWABLE READY** meets EPA Renewable Energy-Ready Home.



hired to manage the verification process and he brought along Howard Vic as his Home Energy Rating System (HERS) rater.

The DOE Zero Energy Ready Home program requires that homes be third-party verified as meeting all of the requirements of ENERGY STAR Certified Homes Version 3.0 and the U.S. Environmental Protection Agency's Indoor airPLUS program as well as the hot water distribution requirements of the EPA's WaterSense program and the insulation requirements of the 2012 International Energy Conservation Code. In addition, homes are required to have solar electric panels installed or have the conduit and electrical panel space in place for future photovoltaic panel installation.

The DOE Zero Energy Ready Home Program offers builders a performance path rather than just a prescriptive path to certification, providing great flexibility in design, and Clifton used innovative passive design elements to get far more performance out of the home's physical structure than builders typically achieve.

The site has a steep south-facing slope and the daylight-basement home with one above-grade floor was built into the hillside, which provides thermal protection for the downstairs. The home's shed roof slopes down toward the north. This opened up the south-facing wall to a height of 27 feet above grade, providing space for 555 ft² of south-facing glazing, consisting of vinyl-framed, triple-pane, triple-low-emissivity-coated windows with high solar heat gain coefficient (SHGC) glass, which allows for more beneficial solar heat transmittance.

A careful study of the area's weather revealed that the coldest part of the winter is relatively sunny, allowing nearly all of the January space heating needs to be provided by a combination of passive solar heating from the south-facing high-SHGC windows and radiant floor heat from the ground-mounted 120-tube active solar hot water system, which was large enough to also supply all of the home's domestic hot water needs. "We ran a calculation window by window, based on the exact orientation of each window versus the travel of the sun hour by hour throughout the day to determine the number of Btuh received on an average day for each month of the year," said Clifton. "We then reduced that amount by the SHGC of the glass to determine the net heat gain, and subtracted from that the net heat loss from each window per day based on the window's insulation value. (The windows had an average U-factor of 0.17.) Even in January, we were able to provide about 87% of the required total heat energy for the home with the

The back wall of the daylight basement is made of 13-inch-thick R-23 ICFs protected with a spray-on waterproof coating. Crews laid down a thick plastic vapor barrier, then stacked layers of type II expanded polystyrene (EPS) 6 inches deep for R-30 of insulation under the floor slab.

combination of active and passive solar energy." A thermal-mass trombe wall of concrete and stone extends from the basement floor up into the upper level, where it forms a half wall running parallel to the window wall but set back two-thirds of the way into the room along a staircase. This wall absorbs low winter solar radiation from the upstairs windows and transmits the heat into the basement.

In fact, Clifton noted, the HERS scores generated by REM/Rate far underestimate the home's actual performance, even though the calculated scores of 41 without PV, or 18 when including the 8.1-kW PV system are very good scores in comparison with the HERS 80 to 100 of typical new home construction.

Clifton explains the actual performance of the home's combined heating and hot water systems: "Regarding the HERS score of 18 with PV, the REM/Rate program assumed that the second back-up system (an on-demand propane-fired boiler) was the main heating system. It therefore rated the home on that basis." Clifton actually used passive solar heat and radiant floor heating with passive solar water heating as the primary heating system (as described above). Noted Clifton, "the main back-up to this system is the ductless heat pumps, of which there are three, each one managing a different area of the house. These 'high-heat' models will operate down to -15˚F. During the times when the passive and radiant floor solar heating systems are not adequate, the heat pump units will come on and supply the remainder of the needed heat. The phase-change materials in the 320-gallon solar hot water storage tank allow that tank to supply hot water as if it were storing about 3,000 gallons of 120˚ hot water. The tankless propane boiler is only there to provide back-up domestic hot water when the 3,000 gallons is not enough. There is enough thermal mass in the house that, even on the design degree day, the temperature will not drop more than 4˚F during the 12 night-time hours. The programmable thermostats are set to allow that 4˚ loss before they come back on in the morning. By operating the ductless heat pumps only during the day for heating (when the outside air is warmer), we can save up to 44% of the rated energy use of the heat pumps. REM/Rate hasn't a clue how to rate even one of these features, let alone all of them together," said Clifton.

The home's performance was tested when a pump failed on the solar hot water system toward the end of construction, before the ductless heat pumps were installed. It was -9˚F outside, but the house never dropped below 60˚F, even after more than a week without heat.

HOME CERTIFICATIONS

- DOE Zero Energy Ready Home Program
- ENERGY STAR Certified Homes Version 3.0
- EPA Indoor airPLUS
- NAHB National Green Building Standard

ENERGY STAR | Building America U.S. Department of Energy

Every DOE Zero Energy Ready Home combines a building science baseline specified by ENERGY STAR Certified Homes with advanced technologies and practices from DOE's Building America research program.

A deep overhang protects south-facing windows from too much heat gain in the summer.

To help keep construction costs down, Clifton developed spreadsheets allowing the home owner to weigh each option against other options to see which was the most cost-effective. For example, according to Clifton, the solar hot water heating system costs less than half of what a deep-bore ground source heat pump unit would cost, even including the ductless heat pump back-up system, and yet it only costs a fraction as much to operate, with virtually zero maintenance over time.

As with most of his homes, Clifton specified a slab foundation with a sealed, stained, exposed concrete floor slab that readily absorbs solar radiation for passive heating. The flooring for the upper floor is also stained concrete with a 3-inch slab for additional thermal mass. Insulated concrete form (ICF) foundation walls and six inches of rigid foam under the slab insulate the daylight basement. Clifton specified structural insulated panels (SIPs) for the walls. The 8-inch-thick graphite-enhanced SIPs have an R-value of R-35. The walls were covered with draining house wrap taped at the seams to form a continuous drainage plane behind the corrugated steel siding, which has a durable aluminium-zinc alloy coating. The roof was constructed of 12-inch graphite-enhanced SIPs providing an R-56 insulation value. The SIPs were covered with a synthetic underlayment under the commercial-grade steel standing-seam roof. Most of the ceilings were vaulted thanks to the SIPs construction; however, there were two small attic areas that provided conditioned space for the HRVs and the inside units of the ductless heat pumps. The two HRVs brought in fresh air and exhausted stale air, providing ventilation for the airtight home.

LED lighting, ENERGY STAR appliances, and low-flow faucets contribute to energy and water savings. The home was equipped with an energy management system with a cell-phone interface to provide remote monitoring of the heating system. The garage has an electric car charging station. These measures, along with the exceptional passive design and quality construction, have resulted in a home that should have annual energy costs of -$51 according to Clifton's calculations.

Clifton saw the home owner as an active member of the successful team. His enthusiasm to learn more about zero energy construction was a real plus. "I simply show people what is possible and let my customers make the responsible decisions," said Clifton. [The home owner] continually asked me what I would do if it were my own house, and while I kept giving him more conservative options, he always selected the most cutting-edge option, bringing this house to a level probably never seen before."

Photos courtesy of PepperTree Homes

KEY FEATURES

- **DOE Zero Energy Ready Home Path:** Performance.
- **Walls:** R-35, 8″ graphite-enhanced SIPs, draining house wrap, corrugated steel siding.
- **Roof:** R-56, 12″ graphite-enhanced SIPs, synthetic underlayment, steel standing-seam roof.
- **Attic:** Mostly vaulted ceilings, two small attic areas in conditioned space for HRV and air handler.
- **Foundation:** 13″ R-23 ICF foundation with spray-on coating and ribbed drainable membrane, backfill of washed drain rock; under slab 6" R-30, type II EPS.
- **Windows:** Vinyl-framed triple-pane, triple-low-e windows, U=0.13-0.17, SHGC=0.51.
- **Air Sealing:** 2.01 ACH 50.
- **Ventilation:** 2 HRVs, 95% efficient.
- **HVAC:** Radiant floor heat from solar hot water system, passive solar design.
- **Hot Water:** Solar hot water, propane-fired tankless back-up.
- **Lighting:** 100% LED.
- **Appliances:** ENERGY STAR refrigerator, dishwasher, clothes washer.
- **Solar:** Hot water system with 120˚phase change materials in 320-gal storage tank.
- **Water Conservation:** All low-flow faucets & fixtures.
- **Energy Management System:** Cell-phone interface w/heating system for remote monitoring of floor temperature, etc.
- **Other:** 83% of heating from passive solar gains, remainder from solar hot water radiant floor for annual energy cost of -$51; electric car charging station.

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