Near Zero Maine Home II

Vassalboro, Maine

BUILDER PROFILE

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FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Near Zero Maine II
- Location: Vassalboro, Maine
- Layout: 2 bedrooms, 2 baths, 1 floor
- Conditioned Space: 1,200 ft^2
- Completion: October 2013
- Climate Zone: IECC 6A Cold Climate
- Category: Affordable

Modeled Performance Data:

- HERS Index without PV: 35
- HERS Index with PV: 11
- Projected total annual energy cost savings (compared to a similar house built to the 2006 IECC): without PV $1,533, with PV $2,587
- Projected annual utility costs: without PV $1,054, with PV $320
- Annual PV production revenue: $734
- Annual energy savings: without PV 15,218 kWh, with PV 19,536 kWh; 393 gallons of oil
- Annual PV production: projected 4,204 kWh, actual 5,400 kWh

"It can't be done." Those words were enough to motivate Tom Fullam of Vassalboro, Maine, to build his first high-performance house. The home achieved a HERS score of 38 and earned him a 2011 silver Energy Value Housing Award from the National Association of Home Builders Research Center. That soon led to a second, even higher performing house, which has earned distinction as the first home in Maine to meet the requirements of the U.S. Department of Energy's DOE Zero Energy Ready Home certification.

Fullam, a building science educator and construction consultant, had been running load calculations to determine sizes for heating systems and started wondering "what would it take to build a house so efficient you wouldn't need a boiler?" Saying house with no boiler is like saying fish with no fins in a state where 7 out of every 10 homes has an oil boiler - a higher share than any other state in the union - and where per capita petroleum consumption leads the region.

Fullam plugged in some aggressive insulation and glazing values and got a 1,500 ft^2 home in his central Maine climate (IECC zone 6), with a projected heating load of under 10,000 Btus. None of his local builder friends believed such a house was really possible. So Fullam decided to build one.

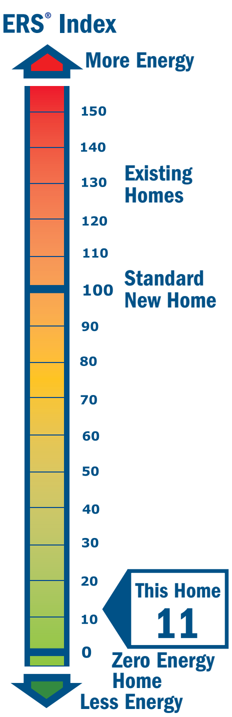
The first home, started in 2008, was a 1,250-ft^2, 3-bedroom, 2-bath, 1-story home with an enclosed porch and unheated basement that achieved a Home Energy Rating Score (HERS) of 38 *before* photovoltaic panels were installed on the roof (a home built to the IECC 2006 would typically score a HERS 100). That home had double-wall construction with a whopping 8.5 inches of dense packed cellulose and 3.5 inches of fiberglass batt in the wall cavity for an insulation value of R-40. Blown cellulose also covered the ceiling deck to a settled depth of 18 inches for an R value of R-60. (This far exceeded local practice of R-19 for walls and R-30 for ceilings.) Triple-pane windows provided an insulation value of R-6.

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 ReadyHome 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.

One minisplit heat pump provides all of the heating and cooling the 1,200-ft^2 home needs. A heat recovery ventilator (HRV) provides needed ventilation for the super-airtight home. The HRV and its ducts are installed above a second ceiling in the utility closet, keeping the HRV in conditioned space and leaving the primary ceiling air barrier intact. The HRV brings in fresh air, which is warmed by the heat exchanger, then further warmed as it enters the living space near the heat pump. Stale air is drawn from return vents in the bedrooms and baths, which help pull the conditioned air through the home.

WHAT MAKES A HOME DOE ZERO ENERGY READY HOME-CERTIFIED?

1. **BASELINE** certified 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.



(Most windows are R-2 to R-4.) A solar water heating system provided hot water for radiant floor heat and domestic hot water. Fullam has made some efficiency improvements to that house, which he currently uses as an office and classroom, including adding 2.9 kW of photovoltaic panels on the roof, which has brought the home's HERS rating down to about 15.

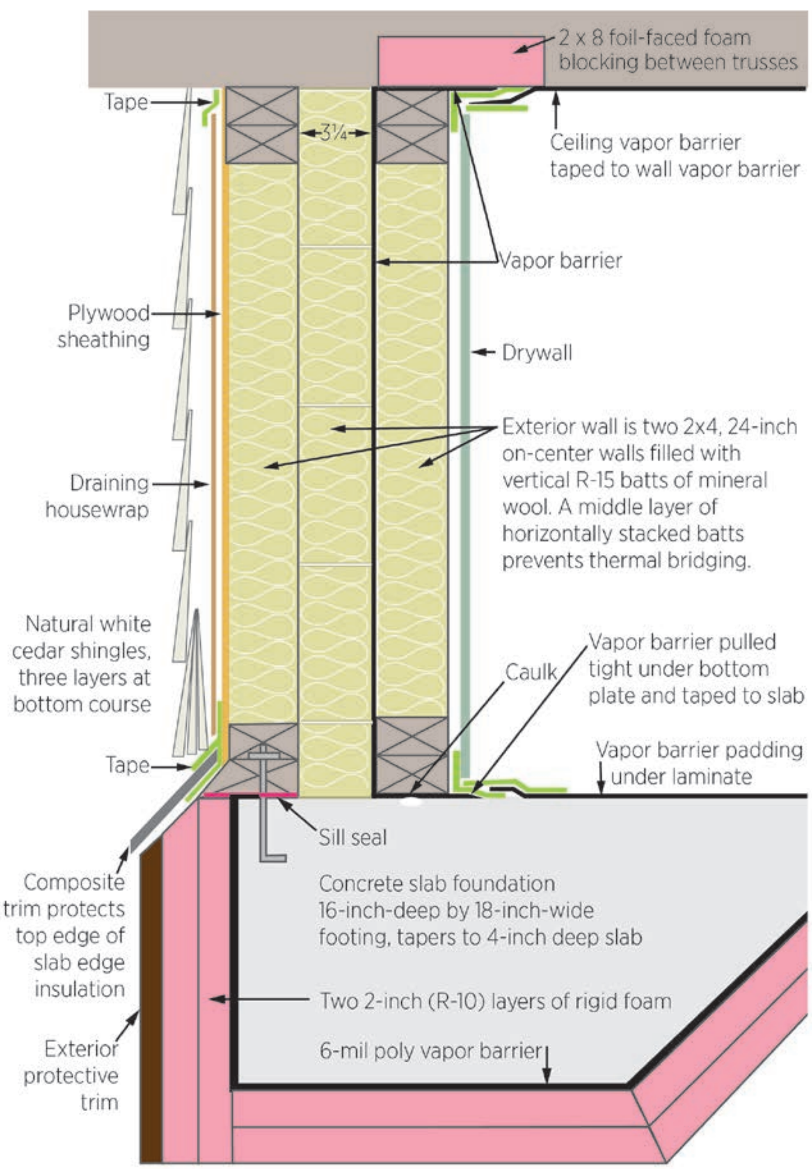
Despite this remarkable performance, Fullam felt that he could do better. And more importantly from his perspective, he wanted to show that he could bring the cost down to something comparable to code-minimum construction. "Maine has the oldest housing stock, oldest population, and highest heating oil dependency in the nation," said Fullam. "My goal is to reach the $170-180,000, turnkey market for older people on a fixed income. They want a house that is two bedrooms and two baths, with a garage. I want it to be high-efficiency, high-quality construction, fully handicapped accessible, and low cost.

The second home's performance was evaluated by a home energy rater (a DOE Zero Energy Ready Home requirement). The home achieved a HERS score of 35 without photovoltaic panels, or 11 when the PV is considered. Fullam noted that the HERS 11 score was based on projected not actual PV production. The home's 3.9-kW photovoltaic system produced a surplus of 1,100 kWh the first year, meaning the home is, in fact, operating as a true net zero energy home. Fullam installed the PV panels on the roof of the detached garage before construction of the home was started, "so my electricity bills were almost zero while I was building the house," said Fullam.

A blower door test for whole house air leakage was conducted on both homes. A typical older home in Maine might have air leakage of 12 to 30 or more air changes per hour at 50 Pascals of pressure (ACH 50). ENERGY STAR for Homes (Ver. 3) and DOE's Zero Energy Ready Home program requires air leakage rates of ≤4.0 and ≤2.0 ACH 50, respectively, in IECC climate zones 5 through 7. Fullam's first home tested at 1.25 ACH 50. Fullam's second home tested at 0.49 ACH 50, below even the super-airtight 0.6 ACH 50 requirement of the Passive Haus program. Fullam attributes the incredibly low air leakage rates to the floor-to-ceiling air barrier layer he incorporated in the double-wall shell used in both homes. Following guidance published by Building America research partner Building Science Corporation for cold climates, Fullam installed a polyethylene fiber vapor barrier on the outside face of the inner wall using tape not staples so there were no air holes. This vapor barrier was connected to the ceiling and floor vapor barriers with a very tenacious air sealing tape so that it

The exterior wall's center layer of mineral wool batt extends between the inner and outer wall framing to stop thermal bridging at the windows. The vapor barrier (a translucent mesh fabric) covers the outer face of the inner wall and is wrapped around the framing and taped to the inside face of the inner wall with a rugged air-sealing tape. A plywood and drywall box is constructed to line the window opening after the triple-pane windows are installed. This drywall and plywood box is less expensive than solid wood, has less cracks in the corners from expansion and contraction, and fits into a pre-formed pocket in the window frame to form an airtight seal around the window.

also served as a continuous air barrier for the entire building envelope (see figure and sidebar for construction sequence). All wiring went through the inner wall and plumbing went through the slab to prevent holes in the air /vapor barrier. (Note vapor barriers are not recommended in the mixed or hot climates.)



HOME CERTIFICATIONS

DOE Zero Energy Ready Home Program

ENERGY STAR Certified Homes, Version 3.0

EPA Indoor airPLUS

EPA WaterSense

WALL CONSTRUCTION SEQUENCE

1. Install outer wall.
2. Install ceiling joists and foam block.
3. Install vertical batts in outer wall.
4. Tack horizontal batts to outer wall studs.
5. Tape wall vapor barrier to ceiling joists and foam.
6. Attach top plate of inner wall to ceiling joists with vapor barrier laid over top plate and draped to floor.
7. Lay bottom plate over bottom end of vapor barrier. Pull barrier taut and tape to floor slab. Screw bottom plate to slab.
8. Construct inner wall of studs and 2nd top and bottom plates. Install between 1st top and bottom plates.
9. Tape top and bottom plate-barrier joints.
10. Attach ceiling vapor barrier with tape (no staples) to joint tape.
11. Install foam floor pad and tape to floor-wall joint tape.

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.

Fullam chose mineral wool to insulate the walls of the second home because of its higher R value and resistance to fire, moisture, and pests. The attic floor was covered with R-70 (26 inches settled to 20 in.) of blown cellulose. Fullam used advanced framing techniques like two-stud corners and insulated headers. He pre-drilled the inner wall studs with a hole at 24 in. from the bottom plate to run wiring.

After wiring was installed in exterior walls and before any interior partition walls were built, the entire ceiling and perimeter walls were sheet rocked. This provided a complete fire break and a second unbroken air barrier. "There is no waste when you do this," said Fullam. "The sheet rockers can come in with the largest sheets they can handle (4'x14') and there is little to cut around so it goes up fast."

Wiring for ceiling fixtures ran up through exterior walls to the attic. Fullam put the attic access on the outside wall on a gable end of the house then ran an 18-inch-wide gangplank on top of the insulation from the attic access door to the other end of the house. Any wiring that was routed through the attic went to junction boxes that were labeled by room name and fixed to a board that ran along the trusses within easy reach of the gangplank. "Electricians love it," said Fullam.

The home's only heat source, a ductless mini-split heat pump, is well suited to the home's low 6,600-BTU winter heating load. Solar thermal water heating panels provide 77% of the home's hot water needs. To reduce hot water consumption, Fullam installed low-flow plumbing fixtures and designed a compact plumbing layout where all hot water fixtures are within 10 feet of the tank and hot water is distributed through a central manifold with direct PEX tubing from the tank to each faucet.

Fullam estimated the second home cost about $4,800 more to build than a home built to the 2006 IECC, including purchase and installation of the PV and solar water heating systems. The HERS rater projected annual energy cost savings of $2,587, for a total projected annual utility bill of $320 when the PV production was included. However, as noted earlier, the PV has actually been performing better than projected and Fullam saw PV production revenue of $734 for the first year based on utility credits for the surplus power.

Fullam is recommending the DOE Zero Energy Ready Home program to all of the participants in his home building classes as well as to clients in his construction consulting business because he appreciates what these energy savings can mean for homeowners, especially those on fixed incomes.

Fullam also appreciates the low cost to certify for DOE's Zero Energy Ready Home program. He notes it only cost him about $800 for the HERS rater's inspection and documentation fees and there is no fee to DOE. But most of all, Fullam appreciates the third-party verification that is a mandatory part of DOE Zero Energy Ready Home because it proves to others "that it can be done."

Photos courtesy of Thomas Fullam.

KEY FEATURES

- **DOE Zero Energy Ready Home Path**: Performance
- **Walls**: Double wall construction 2 x 4, 24-in. on-center, 2-stud corners, insulated box headers, 3 layers (total of 10.5 inches, R-45) mineral wool unfaced batts, vapor barrier on outside of inner wall, drain wrap, untreated white cedar shingles
- **Roof:** Standing-seam white metal roof, SRI 81.6, 6/12 pitch
- **Attic:** 20 inches (R-70) cellulose installed on ceiling deck over vapor barrier
- **Foundation:** 18-in.x16-in. thickened edge slab foundation with 4-in. (R-20) rigid foam under full slab at slab edges
- **Windows:** Triple-pane, argon-filled PVC-framed, low-E, U=0.21, SHGC=0.40
- **Air Sealing:** 78 cfm 50 Pa, 0.49 ACH 50 Pa
- **Ventilation:** Heat recovery ventilator, 2.04 cfm/W
- **HVAC:** One mini-split air source heat pump, SEER 26, HSPF 10
- **Hot Water:** Solar thermal, 2 flat plate collectors w/electric back-up
- **Lighting:** 100% LED interior lighting
- **Appliances:** ENERGY STAR refrigerator, dishwasher, washer
- **Solar:** 3.9 kW PV
- **Water Conservation Features:** All fixtures EPA WaterSense
- **Energy Management System:** Smart Meter

On a recent consulting project, Fullam showed the homeowner how the energy-efficiency measures he suggested would only add $4,000 to the cost of building his new home, compared to one built to local code. *Except* that the home no longer needed a boiler and a chimney, which costs about $13,000 installed, so the super-efficient home was actually projected to cost $9,000 less than a home built to code. "When my client saw this, he said 'I'm building it your way,'" said Fullam.

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