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

Paul Torcellini, Builder

Eastford Farm House
Eastford, CT

BUILDER PROFILE

Paul Torcellini, Eastford, CT
Paul Torcellini, paul.torcellini@gmail.com
860-315-5475
Rater: Steven Winter Associates
Karla Butterfield
kbutterfield@swinter.com

FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Eastford Farm House
- Location: Eastford, CT
- Layout: 3 bdrm, 2 bath, 2 fl + bsmt, 3,597 ft²
- Climate Zone: IECC 5A, cold
- Completion: March 2016
- Category: Custom for buyer

Modeled Performance Data:

- HERS Index: without PV 35, with PV 2
- Projected Annual Energy Costs: without PV $2,303, with PV $80
- Projected Annual Energy Cost Savings (vs home built to 2009 IECC): without PV $3,246, with PV $5,469
- Projected Annual Energy Savings: without PV 17,404 kWh, with PV 29,758 kWh
- Added Construction Cost: without PV $0, with PV $25,380

What does a building scientist want in a house when he decides to build his own? "Of course it's going to be a zero-energy house," said Paul Torcellini, a principal engineer in the commercial buildings research department at the National Renewable Energy Laboratory (NREL) and professor of sustainability at Eastern Connecticut State University. To help make his dream home a reality, Torcellini followed the criteria of the U.S. Department of Energy's Zero Energy Ready Home program and in the process won a 2016 DOE Housing Innovation Award.

To be certified as a DOE Zero Energy Ready Home, the builder must certify the home to the ENERGY STAR Certified Homes Version 3.0 and the U.S. Environmental Protection Agency's Indoor airPLUS program and meet the hot water distribution requirements of the EPA's WaterSense program and the insulation requirements of the 2012 International Energy Conservation Code. In addition, the home must have solar electric panels installed or have the conduit and electrical panel space in place for future photovoltaic (PV) panel installation.

Torcellini's 3,600-ft² home in Eastford, Connecticut, has two floors plus a daylight basement, three bedrooms, two baths, a host of energy-efficiency features, and a 9.4-kW PV array on the roof that bring the home's Home Energy Rating System (HERS) score down to 2. The home is essentially a net zero energy home, producing as much power as it will use in a year and providing Torcellini with utility bills of less than $10/month (not including service charges). Even without the PV, the home would achieve a HERS score of 35, far better than the HERS 80 to 100 of a typical home.

To achieve these dramatic levels of energy efficiency, Torcellini first started with a good design that considers passive solar gain. The house was designed to mimic a 1920s bungalow in the arts and craft style. The style provides an efficient compact

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.

Paul Torcellini built this 3,597-ft² farm house in Eastford, Connecticut, to the high-performance specifications of the DOE Zero Energy Ready Home program. Standing-seam metal roofing, fiber-cement siding, and deep overhangs enhance the building's durability.

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

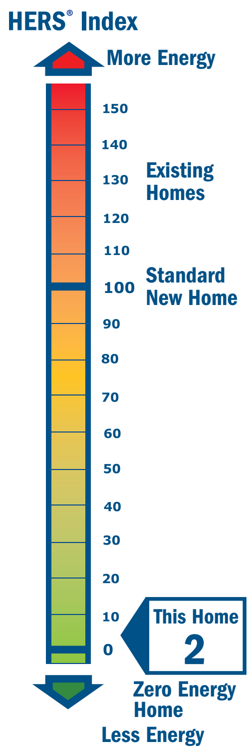
3 **DUCT SYSTEM** located within the home's thermal boundary

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.



design that minimizes envelope area. A south-facing sunroom is thermally isolated from the rest of the house but has doors that can be opened to the interior to provide nearly all the heat the home needs on a sunny winter day. The open floor plan is designed to naturally circulate air from the sunroom to provide uniform heating throughout the house. A porch on the north provides a venue for hot summer days as well as protection from the winter weather. Extra-long overhangs shed water away from the foundation. These overhangs also provide shading of the south windows to prevent summer-time overheating.

Double-hung windows were chosen because they fit the architectural style of the house. Because they can open from the top down, they also assist in ventilating the house. The floor plan allows for breezes to flow freely through the house for natural ventilation. The walk-out basement design allows for cool air to enter the lowest level and vent out the second floor, especially when wind is not prevalent. Taking advantage of this stack effect by opening the windows to cool the house at night, then closing them during the day has been shown to be an effective cooling mechanism. Even on a day when the outdoor temperature reached 94°F, the indoor temperature did not exceed 74°F. The roof's ventilated design and ENERGY STAR reflectance rating help to minimize solar gain and Torcellini noted that the solar panels themselves, which sit a few inches above the metal seamed roofing, provide some beneficial shading. He added that the 12-inch-thick walls and R-60-80 attic insulation resulted in a house that requires minimal heating and cooling. The design load for the house is 18,000 BTU/hour.

To build the very efficient structure, he chose double-wall construction for the exterior first- and second-floor walls. The double wall consists of two 2x4 24-inch on-center wood stud walls built side by side and set 5 inches apart. When sheathed, the walls form a 12-inch-deep wall cavity that is dense-packed with fiberglass insulation for an R-52 wall. The insulation between the walls stops thermal bridging or the transfer of heat through the studs and provides a continuous thermal blanket. The exterior surface of the OSB comes with a water-resistant coating. When the seams are taped with a proprietary sealing tape, the OSB acts as a sheathing, air barrier, moisture barrier, and drainage plane all in one; no house wrap is required. Vertical furring strips were installed over the sheathing to provide a drainage gap behind the fiber-cement lap siding.

The same coated OSB was used for the roof decking. It was topped with 1x2 furring strips installed vertically to provide a ventilation gap above the cathedral ceilings. The furring strips were topped with ¾-inch plywood decking that was

An air-to-water CO_2 heat pump provides hot water for radiant floor heat and domestic hot water with an efficiency of 4 COP. A ductless mini-split heat pump provides cooling at a very efficient 26 SEER, as well as supplemental heating at 12.5 HSPF.

completely covered with ice-and-water shield. The metal roofing was installed over this. Torcellini said he chose standing-seam metal roofing because it is long lasting, PV panels attach to it easily, and it provides a clean surface for rainwater collection systems. The attic was insulated along the roof line with R-60 to R-80 of blown fiberglass dense packed in the roof rafters. Vents were clustered on the roof to leave most of the south side free for solar panels.

The poured concrete walls of the daylight basement were insulated along the exterior down to the footing with R-10 rigid foam. The basement slab was poured over a 6-inch bed of gravel, topped with a plastic vapor barrier. About half the basement consisted of the uninsulated garage and an uninsulated root cellar to store vegetables from the home owners' garden.

The double-pane, double-hung windows had low-emissivity coatings and an argon gas fill between the panes to reduce heat transmission. Most of the glazing is on the south side of the home. For the south-facing windows, Torcellini specified higher U-factor, higher solar heat gain coefficient windows allowing more heat transfer for beneficial solar heat gain; for the other windows, he specified lower U-factor, lower SHGC windows that transmit less heat.

The tight home was tested per DOE Zero Energy Ready Home requirements and showed air leakage of only 0.75 air changes per hour at 50 Pascals. That's more than three times as tight as required by the newest energy code. (The 2015 International Energy Conservation Code requires 3 ACH 50 or less.)

To provide good ventilation for the home, a heat recovery ventilator (HRV) was installed. The HRV brings in fresh air from an outside air intake and exhausts stale air. The fresh air and stale air ducts pass through a heat exchanger in the HRV where heat is transferred from the warmer stream to the colder stream so the incoming air is warmed in the winter and cooled in the summer. The HRV operated continuously, pulling stale air from the hallways as well as the kitchen and bathrooms, which were equipped with a timered high-speed boost switch for spot ventilation.

The home is heated by a highly efficient CO_2 air-to-water heat pump that warms water for radiant floor heat with a coefficient of performance (COP) of 4. Thermostats in each room control the floor heat for zoned heating. A ductless mini-split heat pump provides cooling at an ultra-efficient 26 SEER and supplemental heating at 12.5 HSPF.

HOME CERTIFICATIONS

DOE Zero Energy Ready Home Program, 100% commitment

ENERGY STAR Certified Homes Version 3.0

EPA Indoor airPLUS

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.

The photovoltaic system includes two inverters that are tied to the grid but also wired to provide electricity to one outlet each should the grid go down.

The air-to-water heat pump also provides domestic hot water for an 80-gallon storage tank with an energy factor of 2.5. WaterSense fixtures cut water and energy usage. The hot water tank is located on the basement level directly below the bathrooms and laundry and PEX tubing speeds water to each faucet, minimizing the wait times for hot water. The home's gray water (from showers, sinks, etc.) and black water (from toilets) are separately plumbed to allow for future water recycling for irrigation. Currently, both discharge to the on-site septic system. The gutter system was designed to direct all downspouts to a single collection point for rainwater harvesting, in case a cistern is installed in the future.

The 9.4-kW PV system should meet all of the home's electricity needs over the course of a year and may supply enough surplus to power an electric car without incurring power charges. The garage was wired for an electric car charging station. Although the PV system is tied to the grid, the inverters are equipped to power one outlet each for emergency power. Also, when the home was wired, critical electric needs, including refrigerators and freezers, were set on a separate circuit that could be powered by the panels, even if intermittently. A storage system could be added when batteries become more cost effective.

The home meets all of the requirements of the EPA's Indoor airPLUS checklist, which encourages healthy indoor air. Torcellini sought out truly emission-free products and finishes and employed redundant water-management practices to reduce the likelihood of mold.

Contractors were carefully interviewed and selected based on their ability to meet the overall goals of the project. All contractors were provided a briefing on the zero energy goals of the project. Frequent quality checks by the builder and the HERS rater provided quality assurance to make sure that the details were followed.

Torcellini noted that the biggest challenge with zero energy homes isn't the construction itself but educating consumers that it doesn't have to be more expensive. The total construction cost for this house was less than $85/ft^2 as determined by Eversource, the local utility. The HERS rater was so impressed he put together a brochure promoting the house as an example of what is possible on a limited construction budget.

Photos courtesy of Paul Torcellini

KEY FEATURES

- **DOE Zero Energy Ready Home Path:** Performance.
- **Walls:** Double-stud walls, 12″ cavity dense-packed with fiberglass insulation (R-52); plywood sheathing taped at seams to act as drainage plane; fiber-cement lap siding.
- **Roof:** Taped plywood roof decking, furring strips, standing seam metal roof.
- **Attic:** Insulated along roof line with R-60 to R-80 fiberglass dense packed in roof rafters.
- **Foundation:** Daylight basement of poured concrete walls insulated on interior with R-10 rigid foam + fiberglass batts in stud cavities.
- **Windows:** Double-pane, double-hung, argon filled, low-e coating. South U=0.31, SHGC=0.48; all other sides: U=0.29, SHGC=0.24.
- **Air Sealing:** 0.75 ACH 50.
- **Ventilation:** HRV with timered high-speed boost for kitchen and bath spot exhaust.
- **HVAC:** Air-to-water CO_2 heat pump for radiant floor heat, 4 COP; ductless mini-split heat pump for cooling 26 SEER and supplemental heating 12.5 HSPF.
- **Hot Water:** Air-to-water heat pump with 80-gal storage tank 2.5 EF.
- **Lighting:** 100% LED.
- **Appliances:** ENERGY STAR refrigerator.
- **Solar:** 9.4-kW PV. Emergency circuits tied to inverters in case of grid disruption.
- **Water Conservation:** WaterSense fixtures, separate black water and gray water plumbing, future rainwater collection from metal roof, low-irrigation landscaping.
- **Energy Management System:** Radiant heat thermostats for each room.
- **Other:** No-VOC paints, glues, finishes; wired for electric car station.

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