U.S. DOE ZERO ENERGY READY HOME 2015 WINNER Housing Innovation Awards

BPC Green Builders

Taft School Watertown, CT

BUILDER PROFILE

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FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Taft School
- Location: Watertown, CT
- Layout: 4 bedrooms, 2.5 baths, 2 floors, finished basement
- Conditioned Space: 3,891 ft^2
- Climate Zone: IECC 5A, cold
- Completion: February 2015
- Category: Custom

Modeled Performance Data:

- HERS Index: without PV 33, with PV -14
- Projected Annual Utility Costs: without PV $2,529, with PV $-1,017
- Projected Annual Energy Cost Savings (compared to a home built to the 2009 IECC): without PV $1,827, with PV $5,260
- Builder's Added Cost Over 2009 IECC: without PV without PV $30,000, with PV $90,000
- Annual Energy Savings: without PV 50.2 MMBtus, with PV 93.6 MMBtus

Students at the 125-year-old Taft School in Watertown, Connecticut, are learning something new about home building, thanks to BPC Green Builders and the U.S. Department of Energy's Zero Energy Ready Home program.

BPC Green Builders was hired to build a teacher's residence on the 220-acre campus of the Taft School, a private prep school founded by President William Howard Taft's brother Horace in 1890. The school was interested in more than just a design that would fit in visually on the historic campus. They wanted a high-efficiency structure that would showcase the latest advances in building science as a living laboratory for Taft's students.

BPC Green Builders worked with Trillium Architects to design the two-story 3,891-ft^2 colonial home to the highest levels of building energy efficiency. BPC Green Builders' co-founder Chris Trolle had worked on several homes that were certified to DOE's high-performance home programs and he recommended building the home to the DOE Zero Energy Ready Home program criteria.

The DOE Zero Energy Ready Home program requires homes to meet all of the requirements of ENERGY STAR Certified Homes Version 3.0 and the U.S. Environmental Protection Agency's Indoor airPLUS, 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 a solar electric system installed or have the conduit and electrical panel space in place for it.

The home is also certified as meeting the requirements of the Passive House Institute US, LEED for Homes Version 4 platinum level, and the Living Building Challenge.

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

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.

This home, built by BPC Green Builders for the Taft School in Wilton, Connecticut, was built to the DOE Zero Energy Ready Home criteria and has become an educational model for the Taft School's sustainability curricula. In 2015, students spent 3 days of class time at the house learning about the features and analyzing utility data. Future classes will be involved for the entire semester. Science teachers from the region have also toured the home.

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

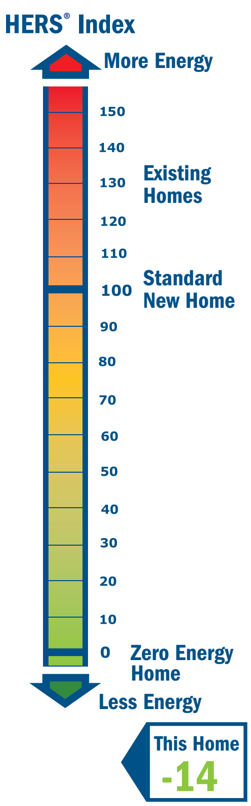
3 **DUCT SYSTEM**
located within the home's thermal boundary

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.

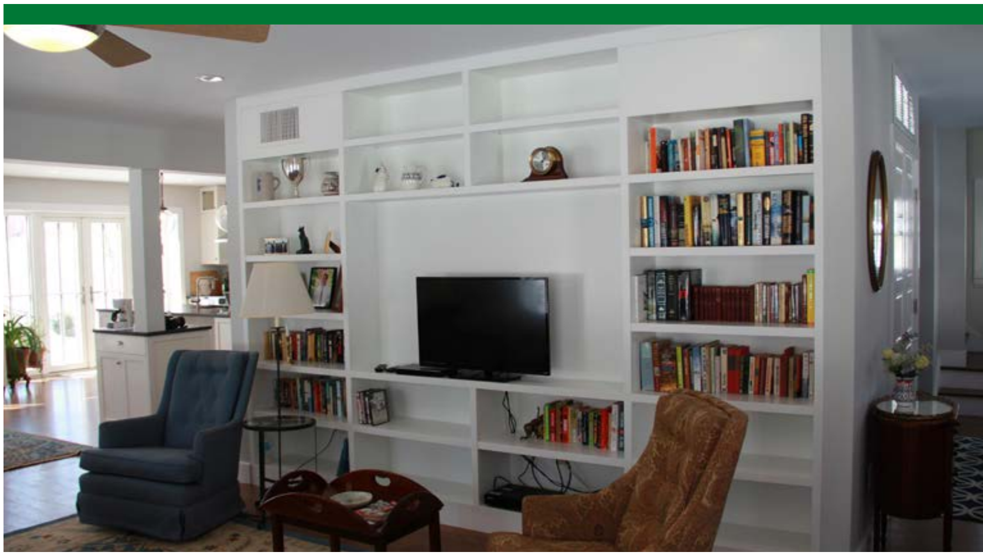


The high levels of energy efficiency worked into the home's design have yielded a house that achieves a Home Energy Rating System (HERS) score of 33 without solar photovoltaics or -14 when a 13.1-kW photovoltaic system is added. The REM/Rate analysis predicted household annual utility costs without PV of $2,529. According to Trolle, real utility data has showed dramatically lower costs of about $129/month or $1,500 annually, without operating the PV, with the heat recovery ventilator (HRV) running full-time, and with the heat pump operating at a coefficient of performance (COP) of 2.0 due to the extremely cold weather in early 2015. With the PV included, REM/Rate predicted annual energy bills of $-1,017. Trolle noted that, in its first 7 months, the home has actually produced four times as much power as it used, despite the record cold.

The home's envelope starts with a 10-inch poured concrete basement insulated on the inside with 3 inches (R-19.2) of closed-cell spray foam. A 2x4 wall is constructed to the inside of the spray foam and the wall cavity is filled with R-13.3 of blown cellulose for a total wall insulation value of R-32.5 for the finished basement walls. The basement slab floor is wrapped with R-20 (4 inches) of rigid foam at the slab perimeter and an additional 8 inches (R-35.6) of high-density EPS rigid foam extends under the entire slab.

Air sealing details are an important element of a high-performance home and must be correctly applied to meet the very tight Passive House standard. The air barrier begins below the basement with a 6-mil plastic sheeting that is placed over the sub-slab insulation and is taped and sealed to the foundation walls. Penetrations and joints in the plastic sheeting have been taped and sealed with mastic. The foundation wall serves as the air barrier up to the first-floor framing deck. EPDM gaskets installed atop the foundation walls continue the air sealing out to the exterior wall sheathing. A second EPDM gasket behind the wall sheathing ties the exterior wall sheathing to the basement.

The above-grade walls consist of a double wall of two 2x4 stud walls set 3.5 inches apart to form a 10.5-inch wall cavity. The exterior walls are sheathed with a coated OSB sheathing with 1 inch (R-6.6) of adhered polyiso rigid insulation. Then, 2 inches of closed-cell spray foam (R-6.4/in., R-16) is sprayed in to insulate and seal the wall cavity. Then, the remainder of the cavity is filled with 8.5 inches of dense-packed cellulose (R-3.8/in., R-32.3) for a total wall insulation value of R-54.9. All seams in the coated sheathing are taped to provide an exterior air barrier and a textured house wrap provides a 1-millimeter drainage gap behind



High-efficiency ducted heat pumps are installed in central locations on the first and second floors to provide heating and cooling through very short duct runs that are located within the home's conditioned space. A first-floor supply register is visible here above the book case. The second-floor ducts are located in a ceiling cavity between the drywall ceiling and a plywood attic floor.

the fiber cement siding. The studs are staggered so there is a continuous 7 inches minimum of cellulose everywhere. The spray foam in the wall assembly prevents moisture from inside air from condensing on the inside of the sheathing layer.

The vented attic has 24 inches of blown cellulose on the attic floor. This attic floor is a plywood layer that sits on top of the 9.5-inch engineered ceiling joists and is extensively air sealed. A drywall ceiling for the home's second floor was attached to the underside of the joists and together the drywall and plywood layers form a 9.5-inch sealed ceiling cavity to house wiring and HRV and heat pump ducts while minimizing penetrations to the vented attic. The roofing is an ENERGY STAR-certified silver birch-colored architectural asphalt shingle.

The windows are triple-paned with argon gas fill and two low-E coatings to minimize heat losses and gains. The majority of the house heating load is satisfied by internal and solar heat gains. The southern, eastern, and western walls of the house have 406 ft^2 of glazing with a 0.61 solar heat gain coefficient (SHGC) that admits beneficial solar heat during the heating season. The overall U value for the windows averages 0.137 but north-facing windows have a very low U value of 0.09 for increased insulation value. The most challenging aspect of window selection was getting triple-glazed windows that met the stringent historic district requirements; the builder was successful in finding windows that met the board's aesthetic approval.

Third-party testing of the home showed a very tight building envelope of only 0.6 air changes per hour at 50 Pascals pressure difference, meeting the Passive House requirement of 0.6 ACH 50. To provide clean air in such an airtight home, a heat recovery ventilator (HRV) was installed. The HRV provides balanced ventilation, bringing in and exhausting the same amounts of air. The two air streams cross in a heat exchanger that transfers heat from the warmer path to the cooler path to minimize heat losses in the winter and heat gains in the summer. The air passes through a high-filtration MERV 7 filter. The HRV model installed has a 93.3% heat transfer efficiency. The HRV has its own 3-inch ducts that supply fresh air to the bedrooms and living areas and draw stale air from the bathrooms, kitchen, laundry, and basement. The equipment is so quiet Trolle had to take the home owner to the unit to show that it was working.

HOME CERTIFICATIONS

- DOE Zero Energy Ready Home Program, 100% commitment
- ENERGY STAR Certified Homes Version 3.0
- EPA Indoor airPLUS
- EPA WaterSense
- Passive House Institute U.S.+
- LEED for Homes, platinum
- Living Building Challenge

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.

Four inches of rigid foam will wrap the slab perimeter while an additional 8 inches (R-35.6) of high-density EPS rigid foam will extend under the entire slab.

A split-system air-source heat pump was installed with an indoor air-handler unit on each floor. The heat pump has a cooling efficiency of 16.5 SEER and a heating efficiency of 9.3 HSPF, exceeding the minimum federal standard of 13 SEER and 7.7 HSPF. Each floor has less than 20 feet of duct work, sealed and insulated to R-8 and all within the conditioned area. Total duct leakage was tested at rough-in and was only ~45 cfm per zone. The heat pump is ducted to each of the rooms by the shortest routes possible. There is a central return and transfer ducts in the walls. "While we were working in the home last winter, we had record cold temperatures. We only had the first-floor air handler in and it kept the whole house comfortable," said Trolle.

Additional equipment in the home was selected for high efficiency. Domestic hot water is provided by an ENERGY STAR-labeled heat pump water heater with an energy factor of 2.73. An ENERGY STAR-rated refrigerator, dishwasher, clothes washer, and ceiling fans were installed. Light sources include 100% recessed and surface-mounted LED interior lights and 100% LED exterior lights.

All of the home's plumbing fixtures, except the kitchen faucet, meet the U.S. Environmental Protection Agency WaterSense criteria. A motion sensor-controlled circulator pump speeds hot water to second-floor bathrooms.

All finishes, sealants, and insulation are low- or no-VOC in keeping with the requirements of the EPA's Indoor airPLUS. The home has a detached garage and permanent walk-off door mats were installed to help minimize indoor air pollutants.

The 13.1-kW PV system was estimated to provide three times as much power as the home uses but, in its first 7 months, has actually been producing four times as much. The excess is sold back to the utility. According to Trolle, "the school owns 30 other homes that they pay utilities for. This house helps cover the utility bill for those homes."

Solar power production is one of the things that is tracked by the home's electronic monitoring equipment. The comprehensive electronic energy management system can control lighting and temperature and provide interactive web-based monitoring of energy use and production. The system can be run from the home with a built-in iPad mini. It can also be accessed from classrooms at the Taft School via the internet.

Photos courtesy of BPC Green Builders

KEY FEATURES

- **DOE Zero Energy Ready Home Path:** Performance.
- **Walls:** Double walls consisting of two 2x4 walls set; 3.5″ apart; 2″ closed-cell spray foam (R-16); 8.5″ dense-pack cellulose (R-32); insulated, coated, taped sheathing (R-6); R-55 total assembly.
- **Roof:** ENERGY STAR-rated architectural shingles.
- **Attic:** 24″ blown cellulose on attic floor over 9.5″ engineered joists (R-100).
- **Foundation:** 8″ solid concrete foundation wall; 3″ closed-cell on interior (R-19); 2x4 stud wall filled with blown cellulose (R-13); rigid foam at slab perimeter (R-20); rigid foam under slab (R-38).
- **Windows:** UPVC and aluminum-clad wood framing; argon-filled; triple-glazing; low-e; U=0.09 for north facing windows; U=0.11 for all other windows; SHGC=0.61 on south, east, and west facing windows for beneficial heat gain.
- **Air Sealing:** 0.6 ACH 50.
- **Ventilation:** HRV; MERV 8 filters.
- **HVAC:** Air-source heat pump.
- **Hot Water:** Heat pump hot water heater.
- **Lighting:** 100% LED interior and exterior lights.
- **Appliances:** ENERGY STAR-rated refrigerator, clothes washer, dishwasher, and ceiling fans.
- **Solar:** 13.1-kW PV.
- **Water Conservation:** All EPA WaterSense-rated fixtures (except kitchen faucet); motion-sensing recirculating pump.
- **Other:** Energy management system; detached garage; low-VOC.

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