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

DOE ZERO ENERGY READY HOME™

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

TC Legend Homes

Bellingham Power House
Bellingham, WA

BUILDER PROFILE

TC Legend Homes, Bellingham, WA
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Rater: Ecoe Company
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FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Bellingham Power House
- Location: Bellingham, WA
- Layout: 4 bedrooms, 3 baths, 2 floors
- Conditioned Space: 2,781 ft^2
- Climate Zone: IECC 4C, marine
- Completion: March 2015
- Category: Custom

Modeled Performance Data:

- HERS Index: without PV 34, with PV -12
- Projected Annual Utility Costs: without PV \$883, with PV \$-191
- Projected Annual Energy Cost Savings (compared to a home built to the 2012 IECC) without PV \$557, with PV \$1,586
- Builder's Added Cost Over 2012 IECC: without PV \$7-11/ft^2, with PV \$21-25/ft^2
- Annual Energy Savings: without PV 30 MMBtu, with PV -11 MMBtu

After years of building zero energy homes for other people, builder Ted Clifton finally decided it was time to build one for his own family. Clifton, founder of TC Legend Homes, built the 2,781-ft^2 2-story, 4-bedroom home in Bellingham, Washington, to the strict energy-efficiency requirements of the U.S. Department of Energy's Zero Energy Ready Home program criteria and added enough solar electric panels on the roof to power the house and two electric cars. With plans to use the home as a showcase for prospective clients, Clifton installed several features that he judged as not necessary but worth installing so that he could test and demonstrate them, including an HRV, a solar water heater, an earth tube, and an attached greenhouse. The Northwest Energy Efficiency Alliance is currently monitoring energy usage in the home through March 2016.

Clifton admits to feeling some jealousy when he would consider the benefits his clients were enjoying in the homes he had built—comfortable, healthy, indoor environments and zero energy bills—while he and his young family bumped along in their big, inefficient house in the suburbs with its \$300 a month utility bills. After dreaming about it long enough, Clifton and his wife took the plunge and purchased an urban infill lot in Bellingham, Washington. They completed construction on their home in March 2015.

The house is Clifton's fourth home certified to the DOE Zero Energy Ready Home criteria. His first, built in the Ballard area of Seattle in 2011, was a DOE Housing Innovation Award winner and Seattle's first true net-zero energy home (a home that produces as much electricity as it uses in a year).

All four homes are performing at net zero. Clifton plans to build all of his homes to the DOE Zero Energy Ready Home program criteria. The DOE program requires that homes are certified to ENERGY STAR Certified Homes Version 3.0 and the U.S. Environmental Protection Agency's Indoor airPLUS, and that

ZERO ENERGY READY HOME
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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.

TC Legend Homes built this 2,781-ft^2 2-story, 4-bedroom home in Bellingham, Washington, to the strict energy-efficiency requirements of the U.S. Department of Energy's Zero Energy Ready Home program criteria and added enough solar electric panels on the roof to power the house and two electric cars.

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

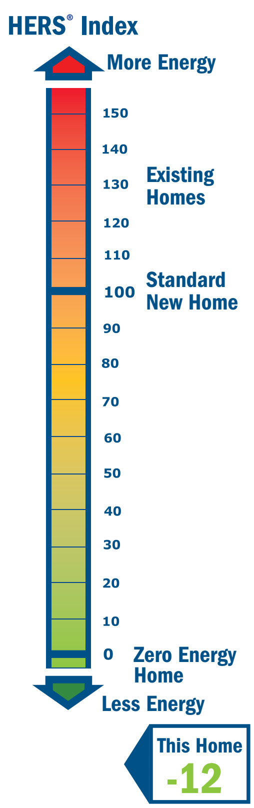
3 **DUCT SYSTEM** located within the home's thermal boundary

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.



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 homes are required to have solar electric panels installed or have the conduit and electrical panel space in place for them.

Clifton installs solar on nearly all of the homes he builds. Many of his homes are not only net zero but what he refers to as positive-energy. The Bellingham Power house produces enough electricity to power the house, an attached apartment, a shop, and two electric cars, at an initial construction cost of only $150 per square foot. Clifton's first zero energy house was only $124/ft^2 (or $114/ft^2 if you count the rebates and incentives), whereas the average cost for new residential construction in Seattle is more than $200/ft^2 and that's for to-code construction, not zero energy construction. Clifton noted there are now other builders in Seattle who are building zero energy homes. "The difference is price; other builders' net zero homes cost $250-$300/ft^2. But, it doesn't have to take much more money to get to a super-efficient home," said Clifton. Clifton has built more 100% solar-powered homes than any other builder in the area and his company's mission is to make positive-energy and net-zero-energy homes that are affordable for the average home buyer.

Clifton's Bellingham Power House achieved a very low Home Energy Rating System (HERS) score of only 34 before the photovoltaics were added. (A typical home built to the 2006 IECC would score about 100.) To achieve the low score, Clifton starts with his standard construction practice—a concrete slab foundation, insulated concrete form (ICF) foundation walls, and structural insulated panel (SIP) above-grade walls and roof. One course of ICF blocks forms the 16-inch-high foundation wall, which provides R-28 of edge insulation for the floor slab. Before pouring the 4-inch slab, a 4-inch-thick (R-20) layer of rigid high-density expanded polystyrene (EPS) foam was laid over the crushed rock base, then covered with 6-mil poly vapor barrier. Then, radiant floor heating loops were laid out over the foam.

Clifton typically does traditional rebar-reinforced concrete slab floors. Because this was his own home, he decided to experiment with some new building materials. One was a micro-rebar product that uses tiny steel pieces 1 inch long and the thickness of pencil lead, instead of long steel rods. The micro-rebar is mixed in to the concrete. Because the microbars are going in every direction, they provide strength in many different directions at once, giving the concrete more

The home's ICF foundation walls and under-slab rigid foam wrap the concrete in a thermal blanket, keeping the radiant floor tubing warm, while the SIP walls and roof provide a sturdy, air-tight envelope for quiet, draft-free interiors. SIPs are produced and precision cut in a factory to the dimensions required for the job so they come to the site ready for fast assembly. Labor costs are reduced, there is almost no waste, and the building shell comes together quickly, a plus in the often damp Pacific Northwest.

plasticity. The strength of the mixture is based on how many pounds of steel are added. Clifton typically stains and seals the concrete then leaves it exposed as a durable, water-impervious, and economical finished flooring.

The walls consist of 8-inch, R-30 SIPs, and the roof is built from 12-inch R-46 SIPs. The SIPs consist of two OSB panels sandwiching a layer of adhered rigid foam. The home's exterior walls were covered with house wrap and clad with fiber cement siding. The SIPs provide cathedral ceilings throughout the home. A standing seam metal roof provides a fire-resistant covering. Because the SIPs are solid and the seams are connected with construction adhesive, the SIPs create a very airtight shell around the home. The Power House was third-party tested for airtightness and showed air leakage of only 0.64 air changes per hour at 50 Pascals, about four times as tight as the program requires.

The home was equipped with a high-efficiency, air-to-water heat pump, with a coefficient of performance (COP) of 4.4 that provides warm water for the radiant floor heating as well as hot water for domestic use. Although the heat pump is very efficient, it's almost more heating than is necessary because Clifton designed the home for passive heating. The home's south-facing windows allow winter sun to warm the thermal mass floors; the heat is absorbed during the day and released at night. The home's open, south-facing loft design helps to encourage a convective loop that brings heat up and into second-story rooms while the air-tight thermal-wrapped building envelope helps to prevent temperature fluctuations and extremes.

Clifton also installed a 31-ft^2 solar collector on the roof for solar water heating. He noted that it really wasn't needed, but he installed it so he could test its performance.

To provide ventilation for the airtight home, Clifton installed a heat recovery ventilator (HRV). This was the first HRV he had installed and he did so primarily so he could demonstrate and monitor its energy use. Typically, Clifton employs a ventilation strategy he learned from his father Ted Clifton, owner of Clifton View Homes on Whidbey Island and Zero-Energy Home Plans. The strategy employs one or more ENERGY STAR-rated exhaust fans that are installed on a shaded side of the house to direct air into the home. The air flow (cfm) of these fans is matched to the air flow of an exhaust fan set to pull air out of the home from a central location, typically the range hood fan. The fans are electronically controlled to operate together to bring air into the home periodically, and they can be set by timers to come on very early on hot summer days for night ventilation cooling.

HOME CERTIFICATIONS

- DOE Zero Energy Ready Home Program, 100% commitment
- ENERGY STAR Certified Homes Version 3.0
- EPA Indoor airPLUS
- Built Green 5-Star

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 home's concrete floors provide thermal mass for passive heating and cooling.

In this home, in addition to the HRV, Clifton also experimented with an earth tube ventilation system. The earth tube is a 4-inch-diameter pipe that passes through the ground to bring outside air into the home after being tempered by the roughly 55-degree ground temperatures. Clifton installed four loops of pipe around the foundation of the home at a depth of 2 feet and a length of 100 feet before he backfilled. One end opens outside of the home and one end opens inside the home. When the range hood fan operates, it passively draws outside air into the home through the tube. Because of the tempering effect of the earth, even if outside temperatures are 20 degrees, the air entering the home will come in at a temperature of about 50 to 55 degrees, said Clifton, who is monitoring the tube's performance. He added that the cost of the system is about $3,000 for piping, and exhaust fans, and a HEPA filter, which he said compared favorably to an $8,000 HRV, with equal efficiency.

Although the air-to-water heat pump could be set to provide refrigerant cooling, Clifton finds that the highly insulated building stays cool. Deep overhangs help to keep high summer sun out of the home's interiors and the thermal mass floors act as a heat sink pulling heat out of the air during the day.

Another unique feature of the home is the greenhouse located on the south side of the home by the kitchen. The greenhouse space serves as a mudroom. It is also a great buffer between the kitchen entrance and the outside. In the winter, opening the front door directly to the outside represents a big heat loss; it can exchange all the air in the room with the cold outside air in seconds. Having the greenhouse space stops much of that heat loss. Although it is not conditioned, the greenhouse is enclosed and south-facing so it does warm up. It is separated from the main house by a triple-pane slider door.

Clifton is installing a rainwater collection system for the home that will include two 500-gallon cisterns and one 2,000-gallon cistern, which should cover all of the irrigation needs for the huge vegetable garden he and his wife are planning. Clifton estimates the cost for the system at $3,000 for 3,000 gallons of storage.

The innovative Power House has already been the subject of several tours to high school classes, college classes, and local green aficionados. Clifton is happy that programs like the DOE Zero Energy Ready Home program are promoting the idea of zero energy construction. He is surprised at the number of people he meets who had not even dreamed that zero energy homes were possible. For Clifton, who has been building homes since he was 14, getting to build zero energy homes is more like a dream come true. "Ever since that first net zero home in Seattle in 2011, our team has been hooked. We don't want to build anything else," said Clifton.

Photos courtesy of TC Legend Homes

KEY FEATURES

- **DOE Zero Energy Ready Home Path:** Performance
- **Walls:** 8″ SIPs (R-30); house wrap; fiber cement siding.
- **Roof:** 12″ (R-46) SIPs; standing-seam steel roofing.
- **Attic:** 12" (R-46) SIPs.
- **Foundation:** ICF walls (R-28); rigid foam under slab (R-20).
- **Windows:** Triple-pane; argon-filled; vinyl-framed; low-e; U=0.16; SHGC=0.50.
- **Air Sealing:** 0.64 ACH 50.
- **Ventilation:** HRV; 4″ earth tube.
- **HVAC:** Air-to-water heat pump; COP 4.4; radiant floor heat.
- **Lighting:** 100% LED.
- **Appliances:** ENERGY STAR-rated refrigerator, clothes washer, and dishwasher.
- **Solar:** 9.9 kW PV.
- **Water Conservation:** EPA WaterSense-rated toilets; low-flow fixtures; rainwater collection for irrigation; native plants.
- **Other:** Energy management system; electric car-charging station; passive solar design; accessory apartment; low-VOC.

"Not a lot of technology has been applied to house building. The telephone in your pocket is a million times more technologically advanced than your house."

—Ted Clifton, owner, TC Legend Homes

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