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*

Bundle Design Studio

Birch House
Bellingham, WA

BUILDER PROFILE

Bundle Design Studio, Bellingham, WA
Dan Welch, dan@bundledesignstudio.com
360-296-2657, www.bundledesignstudio.com
Rater: Ecoe Company
Elizabeth Coe
ecoecompany.com@gmail.com

FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Birch House
- Location: Bellingham, WA
- Layout: 3 bdrm, 2 bath, 2 fl, 2,065 ft²
- Climate Zone: IECC 4C, marine
- Completion: July 2015
- Category: custom spec

Modeled Performance Data:

- HERS Index: without PV 36, with PV -9
- Projected Annual Energy Costs: without PV $763, with PV -$91
- Projected Annual Energy Cost Savings (vs home built to 2012 IECC): without PV $924, with PV $1,914
- Projected Annual Energy Savings: without PV 11,803 kWh, with PV 21,866 kWh
- Added Construction Cost: without PV $25,000, with PV $55,000

This living laboratory is a home performance triple-play: zero energy, zero water, and zero sewer. Solar panels produce more power than the highly efficient home uses in a year, while rain water provides all of the home's water supply and waste water is disposed on site.

"It was developed as our business card" said architect Dan Welch of the home he named the Birch Case Study House, which he now lives in with his wife in the Birchwood neighborhood of Bellingham, in northwest Washington state. Welch had designed or consulted on several high-performance homes since leaving a traditional commercial architecture firm to start Bundle Design Studio in 2014 but this is the first home he has actually built.

Welch and builder Chris Tretwold of Tretwold Construction built the home to the high energy performance standards of the U.S. Department of Energy Zero Energy Ready Home program. All DOE Zero Energy Ready homes must be certified to ENERGY STAR Certified Homes Version 3.0 and the U.S. Environmental Protection Agency's Indoor airPLUS program. Each home meets 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 installation of solar panels.

Welch designed the two-story home with a shed roof. The entire asymetrical roof faces south at a 7/12 pitch to maximize the roof space available for the 9.28-kW solar photovoltaic array. Together with the highly insulated building envelope and passive solar heating elements, the solar panels help the house achieve net zero energy bills over the course of the year. A web-based monitoring system tracks solar power production and energy usage.

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.

Bundle Design Studio built this 2,065-ft² home in Bellingham, Washington, to the performance criteria of the DOE Zero Energy Ready Home (ZERH) program. A green roof helps catch any water runoff that isn't collected in the two 5,000-gallon cisterns located behind the house. Wood shade panels can be rolled into place to reduce summertime solar heat gain from the second-story south-facing windows.

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

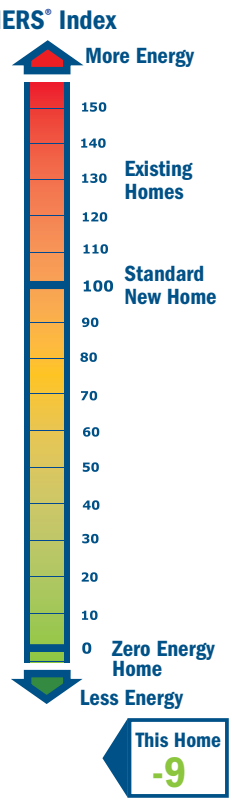
3 **DUCT SYSTEM**
located within the home's thermal boundary

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 house is completely net-zero water with no connection to the City of Bellingham municipal water and sewer system. Water is collected, stored, and treated onsite. To reduce demand, the house is equipped with ultra-water-efficient appliances and plumbing fixtures and composting toilets. Water for all uses, potable and non-potable, comes from rain water catchment off the metal roof and solar panels. The rain water is stored in two 5,000-gallon tanks located on the north side of the house among the existing trees. Water that is used for indoor uses is drawn from these cisterns and filtered and treated with ultraviolet light prior to use. The house has a "green roof" of plants installed on a lower-level roof over the first-floor solarium. Downspouts from this green roof carry overflow downhill through woodchip-lined trenches to two native-plant rain gardens. Water from the showers, tubs, sinks, clothes washer, and dishwasher is treated in a small septic tank. An indoor planter was designed and constructed in the solarium to treat this grey water prior to the septic tank. Although the building department would not approve the use of grey water in this planter, the planter was constructed and planted, but is watered with approved potable water. In winter, the water from the septic tank is then distributed in two small infiltration beds. In summer the grey water from the septic tank is instead routed to irrigate 30 fruit trees that line the driveway. Beyond the food garden and the grey water irrigation at the orchard, no irrigation is used to maintain landscape plantings. Welch notes the decision to achieve net-zero water use was initially not prompted by a desire to save water but rather to highlight how much community energy is used to convey water to the house and back to the sewer treatment plant that is not accounted for in most zero energy projects.

Welch also plans for petal certification through the Living Building Challenge. The two-story home is designed with a solarium along the south-facing side that has nearly floor-to-ceiling windows and a thermal mass floor consisting of dirt, stone, and concrete pavers to absorb beneficial solar heat. A few operable windows face east and west for cross ventilation. To minimize heat loss, only two of the home's windows face north. The shed roof allowed for the construction of a loft above the second-floor bedrooms. Aside from the solarium and the loft, the first and second floors have identical floor plans, with the assumption that, as needs change over time, the house could be converted from a three-bedroom, two-bathroom home to two one-bedroom, one-bath units.

The home's 18 windows are all triple-pane glass and fiberglass framed, with an argon gas fill and high insulation values of U=0.16 to 0.18, while the home's two skylights are quadruple-paned glass. The home is equipped with ultra-efficient appliances and all of the lighting is LED.

In constructing the home, Welch wanted to create a "builder friendly" assembly that met all the high-performance requirements of DOE ZERH while using construction techniques that most builders are familiar with. Prior to permit and construction Bundle held a peer review session to evaluate the constructability of the project. The peer review included the builder, designers, structural engineers, contractors, plumbers, and solar installers. Although Welch was an experienced designer and Tretwold was an experienced builder, neither had worked on a high-performance building before. "We met constantly to review the construction documents, brain storm applications, oversee product installs, and check completed construction for deficiencies," said Welch.

They used 2x6 wood-framed walls, with only 2 inches of exterior mineral wool rigid insulation to reduce changes in window flashing details. The wall cavities were filled with R-23 mineral wool batts for a total wall assembly of about R-29. They used a liquid-applied sealant to seal seams in the plywood and flash around the windows then covered the entire sheathed walls with a roller-applied silyl-terminated-polymer product that provides a durable, seamless, elastomeric weatherproofing membrane over the exterior sheathing. Windows were sized and placed to keep rough openings within the framing layout. Over this, the builder installed 1x4 fir battens to provide a rain screen and air gap behind the exterior siding, which included metal panels and cedar planks.

All of the roof's insulation was installed above the 5/8-inch plywood roof decking. Seams in the plywood were sealed with seam filler, then three 3-inch layers (R-60) of polyiso rigid insulation were stacked on the decking and covered with 30-minute roofing felt, 2x4 battens (for ventilation), ½-inch OSB, and a continuous ice and water shield. The roof was then covered with standing seam roofing that was ENERGY STAR Cool Roof certified.

Welch used a common Northwest foundation type, a framed floor over a vented crawlspace, selected because the site is primarily clay and has sub-surface water issues that would be difficult to control with a slab-on-grade floor. The floor was constructed from salvaged 2x15-inch joists spaced 24 inches on center. The floor joists were filled with two layers of R-30 mineral wool batts for R-60 total. A ¾-inch plywood subfloor was installed that was glued in at all edges with construction adhesive and sealed on top of the floor with a putty knife-applied seam filler. A layer of ½-inch EPS rigid foam was laid over the plywood and glued to the wall studs to provide a thermal break around a 2-inch suspended concrete floor slab. Before pouring the floor slab, the builder laid down tubing

HOME CERTIFICATIONS

DOE Zero Energy Ready Home Program

ENERGY STAR Certified Homes Version 3.0

EPA Indoor airPLUS

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.

An HRV brings in fresh air.

for radiant floor heat. The concrete for the slab was reinforced with a product consisting of tiny pieces of twisted steel micro-rebar rather than standard rebar or wire mesh; the product is reported to distribute loads for less cracking. The floor assembly had a total insulation value of R-58 (when calculated with framing reduction).

For the home's air barrier, Welch used liquid-applied sealants to air seal the sheathing for floors, walls, and roofs. This approach paid off. Results from three blower door tests (conducted at dry-in, just prior to wall cavity insulation, and at completion of the project) showed final blower door results of 0.4 air changes per hour at 50 Pascals pressure difference, one-third lower than the maximum air leakage rate allowed by Passive House. Balanced ventilation was a necessity in such a tight home. Welch installed a heat recovery ventilator (HRV) with a MERV 13 filter that runs continuously to bring in fresh air while exhausting stale air.

Bundle worked with Washington State University to field test a unique heating system, an air-to-water CO_2 heat pump that was installed to supply hot water for both floor heat and domestic hot water uses. The Birch Case Study House was the first in North America to use the CO_2 heat pump as a "combi" system. In addition to working with WSU, Welch has partnered with the local non-profit Sustainable Connections on workshops, with the Northwest Energy Efficiency Alliance (NEEA) to do electrical, water, and humidity monitoring, with the Northwest Clean Air Agency (NWCAA) on a video, and with the Northwest Eco Building Guild on their Code Innovation Database. Welch's unique Birch Case Study House has also captured the attention of several local and national media outlets.

Welch knows that affordability is an important consideration and he will use lessons learned on this project to evaluate ways to be cost effective in future projects. Regardless of payback, Welch said "our business is steadily growing as the culture is quickly learning the importance of energy efficiency. However, it is when customers realize that energy-efficient design also provides the byproducts of comfort and quality that real change happens. EVERY builder and client we have worked with using high-performance building strategies has become an advocate. Most are astonished at the drastic difference they experience between living in a conventional house and their new well designed high-performance house. In practice this has resulted in zero call-backs on our high-performance projects."

Photos courtesy of Bundle Design Studio

KEY FEATURES

- **DOE Zero Energy Ready Home Path:** Performance.
- **Walls:** 2x6 24″ o.c., R-23 rockwool batt, ½″ plywood sheathing, fluid-applied air barrier and window flashing, 2″ R-8 rigid rockwool exterior insulation, 1x4 fir battens rainscreen, metal and cedar siding.
- **Roof:** R-60 total: ⅝″ plywood roof sheathing, fluid-applied membrane, three 3″ layers R-60 polyiso rigid foam, 30 min. roofing felt, 2x4 battens for venting, ½″ OSB, full ice & water shield, standing seam metal roof, ENERGY STAR Cool Roof certified.
- **Attic:** Cathedral ceilings.
- **Foundation:** Vented crawlspace. R-60 rockwool batt, ¾″ plywood subfloor, 2″ concrete slab w/micro-rebar, ½″ EPS under and at slab edge. Radiant heat tubes in slab.
- **Windows:** Fiberglass-framed, triple-pane, argon-filled, U=0.16, SHGC=0.47.
- **Air Sealing:** 0.4 ACH 50.
- **Ventilation:** HRV with MERV 13 filter.
- **HVAC:** Air-to-water CO_2 heat pump for hot water and radiant floor heat, EF=4.50.
- **Lighting:** 100% LED lighting
- **Appliances:** ENERGY STAR refrigerator, dishwasher, clothes washer; HP dryer, induction range.
- **Renewables:** 9.28 kW solar PV array.
- **Water Conservation:** Net-zero water: rainwater catchment + onsite waste treatment and infiltration, ultra low-flow fixtures, waterless composting toilets.
- **Energy Management System:** Web-based energy monitoring.
- **Other:** Extensive salvaged wood from local demolition, FSC certified countertops. Indoor solarium for edible plants + oxygen + greywater treatment + passive solar gain. Green roof.

PNNL-SA-123520, December 2016