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 for Homes Version 3 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.
The home was built by Ted L. Clifton’s son, Ted W. Clifton, whose Bellingham, Washington, firm TC Legend Homes is gaining a reputation for highly efficient green construction. The couple selected a design for a three-bedroom, two-story 1,915 ft² home with an open floor plan. They asked Clifton to modify the plans slightly to let in more light and to save on construction costs. For example, they didn’t build a garage. The couple didn’t even own a car when construction started and, on their small urban lot, the only available spot for a garage would have been underneath the house, which would have required the considerable added expense of excavation.

Instead of a basement, they chose a slab foundation. The builder applied an acid stain to the concrete slab, which resulted in a beautiful, durable floor that saves on flooring costs and works well with their in-slab radiant floor heating. The concrete also acts as a thermal mass to absorb heat from the home’s many south-facing windows during the day, providing a source of passive solar heating.

The radiant heating system consists of PEX tubing in the first-floor slab, which circulates water that is heated by an air-to-water heat pump. The 3-ton heat pump has a capacity of 35,400 Btu/h with a heating efficiency HSPF (heating season performance factor) of 9.2 or a COP (coefficient of performance) of 3.0 to 5.5. Thanks to the home’s open design, well-insulated shell, and air-mixing ventilation system, this first-floor hydronic heating system is all that’s needed to keep even the second-floor bedrooms warm, with the exception of a small electric-resistance in-floor heating mat in the upstairs bathroom.

The air-to-water heat pump also preheats the home’s domestic hot water. The hot water system has three tanks: the first tank (a standard 50-gallon water heater with its element removed) is kept at a constant 105 degrees by the heat pump; it serves as a reservoir for the radiant floor and the rest of the system. When needed, a small circulating pump sends hot water from the first tank to the second tank. The second tank acts as a heat exchanger that preheats domestic water before it enters the third tank, a standard electric-resistance hot water heater.

The home’s building envelope is insulated and air tight to levels approaching Passive House standards. The slab-on-grade foundation is separated from the ground by four inches of extruded polystyrene (XPS) rigid foam, providing an R-20 insulation value. Two inches (R-10) of XPS rigid foam insulation covers the exterior of the foundation walls down to the footing.
The walls and roof of the home are composed of structural insulated panels (SIPs). For the walls, these panels consist of two pieces of OSB sandwiching a 5-5/8-inch layer of rigid expanded polystyrene (EPS) that, together with siding and drywall, provides a total wall insulation value of R-26. The walls are covered with a corrugated house wrap that provides a drainage plane and a slight air gap for ventilation. The home is sided with durable, rot-resistant fiber cement siding.

The EPS roof is built with thicker 10-1/4-inch SIP panels providing an R-41 insulation value. The SIPs are manufactured locally in a factory 30 miles south of Seattle and come to the site precisely cut for the home design, which enables quick assembly with much less construction waste than is typical of site-built framed walls.

Windows can be the weak spot in a home’s thermal envelope, but the builder selected high-performance triple-glazed windows sourced from a company in nearby British Columbia. The windows’ vinyl frames have extruded internal chambers that provide thermal breaks allowing them to outperform many more expensive wood- and fiberglass-framed products from an insulation standpoint. The windows have an insulating argon gas fill between the glass panes and the glass is covered with an invisible low-emissivity coating to minimize winter heat loss and summer heat gain. The windows have a rare combination of low U factors (U=0.15 to 0.20) meaning they are highly insulating, and a high solar heat gain coefficient (SHC=0.50) meaning they let in a lot of solar energy, which is important for a home designed to make use of passive solar heating.

Clifton recommended against a heat recovery ventilator (HRV) and instead incorporated a balanced ventilation system that he has used successfully in several homes in the Northwest climate. The system makes use of several exhaust fans: one in each bathroom, the laundry room, and the kitchen. The exhaust fan in the upstairs bathroom is motion-activated; it runs steadily at a low rate and ramps up when someone enters the room. When the powerful exhaust fan in the kitchen is switched on, it also activates a supply fan that brings fresh air into the home from outside, sending it through a HEPA filter and to all three bedrooms and the living room. “We keep the house at 69 degrees in the winter, and the air stays at a comfortable 55% relative humidity,” said Thomas.

An air-to-water heat pump heats water for the radiant floor heating embedded in the first-floor slab. The concrete slab was stained to provide the finished floor surface. The home’s south-facing windows allow in winter sunlight to warm the slab for passive solar heating.

HOME CERTIFICATIONS:

DOE Zero Energy Ready Home
ENERGY STAR Version 3 (Northwest version)
EPA Indoor airPLUS
Built Green – 5 Star

Every DOE Zero Energy Ready Home combines building science specified by ENERGY STAR for Homes and advanced technologies and practices from DOE’s Building America research program.
The home has no air conditioning and, in an August 2013 blog post, Thomas wondered, with all the south-facing windows, “would we find ourselves baking in our personal greenhouse in the summer?” But the homeowners have been pleasantly surprised to find they can stay cool, even without resorting to running the heat pump in reverse to chill the floors, thanks to a simple trick Clifton showed them. They leave the windows open to let in the cooler night air and turn on the exhaust fan in the kitchen (which also activates the powered HEPA ventilation system) for about 15 minutes first thing in the morning. When the outside temperature starts to rise at midday, they close the windows and lower the double-honeycomb cloth blinds; the indoor temperature stays low all day without any air conditioning. This technique is especially suited to the Northwest’s dry summers with cool evenings.

All of these energy-efficiency measures have added up to a house that performs remarkably well from an energy standpoint. Even without counting in the solar panels, the home earns a home energy rating system (HERS) score of 37 and would have projected utility bills of about $740 a year. For comparison, a home built to the 2006 IECC would typically have a HERS score of 100 and the average HERS score for typical older homes is 120. With the 6.4-kW photovoltaic power system installed on the roof, the home’s HERS scores drops to -1 and utility bills for the all-electric home drop to zero. The home has actually performed better than predicted, hitting zero on the net electricity meter three months ahead of schedule. By January 2013, after 15 months of living in the home, the home owners had a credit of $230 with the utility company. They chose to leave it in their account to cover winter months (November through March) when the bi-monthly electricity bills could get as high as $90. In contrast, from March through October, bimonthly bills ranged from -$12 to -$125.

With a custom design, high-end appliances and equipment, and so much performance, one would expect the price tag to be quite steep but the very average price is one reason the unique home has attracted so much attention.

The cost to build was only $124/ft² (or $114 if you count the rebates and incentives), whereas the average cost for new residential construction in Seattle is $200/ft². The $124/ft² included the costs for design, construction, materials, PV system, taxes, and permits (which totaled $237,000, including $32,696 for the PV system before rebates). The land cost $180,000. After subtracting a $9,000 federal tax credit for the PV system, and $9,000 for state solar production credits (paid out over 9 years), the total came to about $399,000. On top of that, the homeowners won’t be paying for utilities, which come to about $150 per month, or $1,800 per year, for the average Seattle household.

“All that we’ve lived in the house for a year, we’ve found it to be warm in the winter, cool in the summer (even without air conditioning), and comfortable overall. By keeping the design simple and minimizing expensive finishes, we were able to keep the cost of building down … we think our project demonstrates building green need not cost more than traditional construction. Now that we have settled in, we hope to play a role in inspiring others to build or retrofit existing Seattle homes to the net-zero-energy standard,” said Thomas.