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

BUILDING TECHNOLOGIES OFFICE

U.S. DOE CHALLENGE HOME 2013 WINNER Housing Innovation Awards

DOE CHALLENGE HOME CASE STUDY

TC Legend Homes

Seattle, WA

BUILDER PROFILE

TC Legend Homes
Bellingham WA
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FEATURED HOME/DEVELOPMENT:

Project Data:

- Name: Thomas/Salmon Residence
- Location: Ballard, Seattle, WA
- Layout: 3 bedrooms, 2 baths, 2 floors, no basement
- Conditioned Space: 1,915 ft^2
- Completion: October 2011
- Climate Zone: IECC 4 Marine
- Category: Custom

Performance Data:

- HERS Index without solar PV: 37
- HERS Index with solar PV: -1
- Projected total annual energy cost savings: with solar $1,344, without solar $605 (compared to a similar house built to the 2006 IECC)
- Projected annual utility costs: with solar $74; without solar $739
- Annual PV production revenue: $1,333
- Annual energy savings: without solar 7,118 kWh; with solar 8,700 kWh

The owners of a U.S. Department of Energy Challenge Home in Seattle, Washington, are so excited about their high-performance net zero energy home they have become "energy evangelists," blogging about the design and construction process, organizing a series of community talks on sustainability, and hosting several local green home tours since construction started in 2011.

Homeowners Eric Thomas and Alexandra Salmon are not the only ones excited about this ENERGY STAR-certified, 5-Star Built Green home, which is one of Seattle's first true net-zero energy homes (a home that produces as much electricity from the sun as it uses over the course of a year). The home has garnered a lot of media attention from local TV and radio news shows and newspapers and national magazines and web sites as well.

Thomas and Salmon didn't set out to become local green celebrities. The newlyweds were just looking for a house to buy and couldn't find anything they liked in their price range. When they came across an empty lot for $180,000 in the Ballard neighborhood of Seattle, they decided to build.

A search for house plans turned up Zero Energy Plans LLC, a design firm started by pioneering zero energy home builder Ted L. Clifton who builds highly energy-efficient custom homes on and around nearby Whidbey Island in the Puget Sound. The couple was very attracted to the idea of building a home that produces at least as much energy as it consumes. Clifton encouraged them to also go for a DOE Challenge Home certification on the home. Clifton was one of a group of builders who provided suggestions to DOE for formulating the Challenge Home program. He has committed to meeting the Challenge Home criteria on all of his new homes.

U.S. DEPARTMENT OF ENERGY CHALLENGE HOME

DOE Challenge Home builders are in the top 1% of builders in the country meeting the extraordinary levels of excellence and quality specified by the U.S. Department of Energy. Every DOE Challenge Home starts with ENERGY STAR for Homes Version 3 for an energy-efficient home built on a solid foundation of building science research. Then, even more advanced technologies are designed in for a home that goes above and beyond current code to give you the superior quality construction, HVAC, appliances, indoor air quality, safety, durability, comfort, and solar-ready components along with ultra-low or no utility bills. This provides homeowners with a quality home that will last for generations to come.

SIP panels form the roof and walls for a high-performance shell without the thermal bridging and cold spots that can occur with other types of wall cavity insulation. SIPs provided the added benefits of sound proofing, structural strength, and air-tight construction. Night-ventilation cooling is all the air conditioning the highly insulated home needs in the summer.

CHALLENGE HOME CERTIFIED:

1 **BASELINE**
certified ENERGY STAR for Homes Version 3.0

2 **ENVELOPE**
meets or exceeds 2012 IECC levels

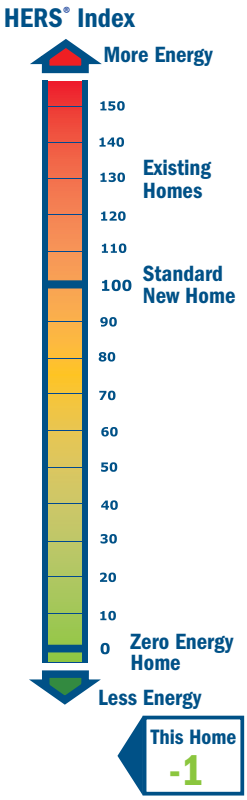
3 **DUCT SYSTEM**
located with the home's thermal boundary

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 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 ft^2 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, 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.

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.

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 for insulating properties allowing them to outperform many more expensive wood- and fiberglass-framed products. 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.

HOME CERTIFICATIONS:

- DOE Challenge Home
- ENERGY STAR Version 3 (Northwest version)
- EPA Indoor airPLUS
- Built Green – 5 Star

Every DOE Challenge 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 pretty steep but the very average price is one reason the unique home has attracted so much attention.

The cost to build was only $124/ft^2 (or $114 if you count the rebates and incentives), whereas the average cost for new residential construction in Seattle is $200/ft^2. The $124/ft^2 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.

"Now 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.

KEY FEATURES

- **Path:** performance
- **Walls:** 6.5" SIPs with 5-5/8" EPS foam for R-26; corrugated house wrap; fiber cement siding
- **Attic:** 10-1/4 SIPs (9-3/8" EPS foam core) for R-41
- **Foundation:** slab on grade with 4 inches (R-20) XPS rigid insulation under slab and 2 inches (R-10) XPS at perimeter of foundation walls
- **Windows:** triple-pane, argon-filled, vinyl-framed, with low-e coating on 3 sides; U=0.14 to 0.21 SHGC=0.50
- **Air Sealing:** 0.56 ACH 50
- **Ventilation:** timer-controlled fans balanced to bring in and exhaust air, HEPA MERV 19 filters
- **HVAC:** air-to-water heat pump (3-ton, 35,400 BTU/h capacity efficiency of COP 3.0-5.5, 9.2 HSPF) provides hot water for 1st floor radiant heat
- **Hot Water:** air-to-water heat pump preheats water for electric storage tank heater
- **Lighting:** 100% LED and CFL, 4 ENERGY STAR ceiling fans, solar tubes
- **Appliances:** ENERGY STAR dishwasher, clothes washer, refrigerator (all lowest energy use in their categories)
- **Solar:** 6.44 kW installed
- **Water Conservation:** low-flow plumbing fixtures; 100% xeriscaped with native drought-tolerant plants, drip irrigation from rain barrels for vegetable garden only
- **Other:** thermal mass concrete floors, passive solar design. No-VOC paints and finishes. Reclaimed flooring, tubs, and sink. Locally sourced SIPs
- **Electric Car Charging Station:** not installed but roughed in

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