Building America Case Study

Testing Ductless Heat Pumps in High-Performance Affordable Housing

The Woods at Golden Given

Tacoma, Washington

PROJECT INFORMATION

Construction: New home

Type: Single-family, affordable

Partners:

Tacoma Public Utilities, *mytpu.org*

Habitat for Humanity of Tacoma/ Pierce County, WA, *tpc-habitat.org*

Building America Partnership for Improved Residential Construction, *ba-pirc.org*

Size: 1,133–1,391 ft² (monitored), 950–2500 ft² (all homes)

Date Completed: 2013–2015

Climate Zone: Marine

PRELIMINARY PERFORMANCE DATA

DHP testing of the first seven homes suggests DHP can offset 28%–66% of ER zonal space heating and maintain thermal comfort and humidity control.

DHP typically adds $5–$6/month to HFH 30-year fixed mortgage payments and saves approximately $20–$25/month in energy bills in the first year for electricity at $0.10/kWh.

Life-cycle cost analysis suggests that hybrid DHPs are more cost-effective than all ER heaters in high-performance homes and provide air conditioning.

Building America SM U.S. Department of Energy

The Washington State University (WSU) Energy Program—a member of the U.S. Department of Energy Building America Partnership for Improved Residential Construction (BA-PIRC)—works with builders in the cold and maritime climates of the Pacific Northwest to develop exceptionally efficient residential construction practices. Many of these practices have been adopted in utility, state, and federal energy-efficiency programs, codes, and standards.

The Woods is a 30-home, high-performance, energy-efficient, sustainable community that was built by Habitat for Humanity (HFH) in 2013. With support from Tacoma Public Utilities, WSU is researching the energy performance of these homes and the ductless heat pumps (DHPs) they employ. This project provides Building America an opportunity to:

- Field test heating, ventilating, and air-conditioning (HVAC) equipment, ventilation system airflows, building envelope tightness, lighting, appliance, and other input data that are required for preliminary Building Energy Optimization (BEopt™) modeling and ENERGY STAR® field verification.
- Evaluate cost data from HFH and other sources related to building-efficiency measures that focus on the DHP/hybrid heating system and heat recovery ventilation (HRV) system.
- Evaluate the thermal performance and cost benefit of DHP/hybrid heating systems in these homes from the perspective of homeowners.
- Compare the space heating energy consumption of a DHP/electric resistance (ER) hybrid heating system to that of a traditional zonal ER heating system. Conduct weekly "flip-flop tests" to compare space heating, temperature, and relative humidity in ER zonal heating mode to DHP/ER mode.

The Woods incorporates all the requirements for certification under ENERGY STAR Northwest Version 3.0. BEopt modeling indicates that these designs achieve the Building America program goal to reduce home energy use by 30%–50% (compared to 2009 energy codes for new homes).

Key Energy-Efficiency Measures

HVAC

- DHP with ER baseboards as backup
- Heating seasonal performance factor/seasonal energy-efficiency ratio = 12/25
- Ventilation: HRV
- HRV supplies fresh air to bedroom zones.
- Kitchen range fans and bathroom exhaust fans provide intermittent local exhaust ventilation.

ENVELOPE

- Wall R-value = 27 (R-21+1-in. XPS)
- Slab-on-grade R-value = 15
- Ceiling R-value = 49
- Windows U-value = 0.30
- Doors U-value = 0.19
- Air sealing, ACH50 = 3.2–4.7 (tested)

LIGHTING, APPLIANCES, AND WATER HEATING

- 100% compact fluorescent lamps and light-emitting diode bulbs
- ENERGY STAR® appliances
- DHP with ER backup
- Future test bed for other Building America research.

Image credit: All images were created by the BA-PIRC team.

The BA-PIRC team is conducting long-term monitoring to verify whole-house energy use, HVAC performance, and occupant behavior related to interior conditions that affect comfort. The study helps to demonstrate, evaluate, and optimize the use of DHP/ER systems in low-load "affordable housing" communities. Also, the team is educating occupants to encourage the use of the DHP as the primary heating source in lieu of the ER bedroom heater.

Future research will include community-scale energy-savings assessments of annual and peak load profiles and occupant behavioral impacts associated with DHP.

From left, top: R-15 slab; foam sheathing; "The Cottage," a 3-bedroom, 1,267-ft^2 home. From left, bottom: DHP outside unit, HRV unit in mechanical room, infrared-guided blower door testing and training by BA-PIRC partners.

Lessons Learned

- DHP/hybrid heating systems provide HFH homeowners with positive monthly cash flows from energy savings, which were large enough to offset the higher mortgage payments.
- Higher R-value walls were achieved with 2×6-in. advanced framing, R-21 high-density batt insulation, and 1-in. extruded polystyrene foam sheathing (XPS).
- Implementing "Built Tight-Ventilate Right" requires specific design details and performance testing. This testing is done with HFH crews and an ENERGY STAR verifier using infrared-guided air leakage testing and HRV flow measurement equipment for commissioning to meet ASHRAE Standard 62.2.

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

For more information, visit
buildingamerica.gov

The U.S. Department of Energy's Building America program is engineering the American home for energy performance, durability, quality, affordability, and comfort.

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