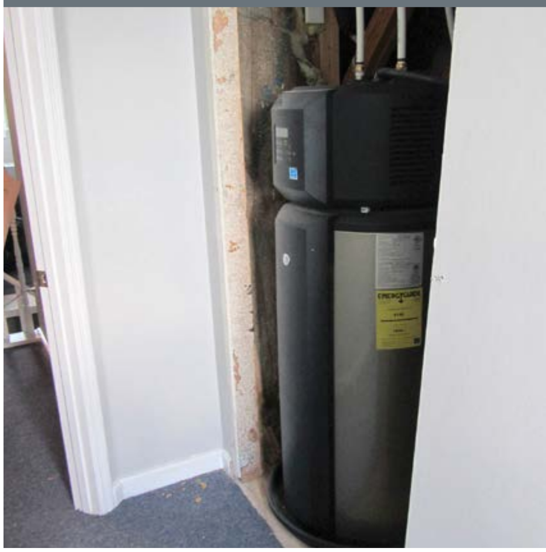
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES OFFICE



Building America Case Study
Technology Solutions for New and Existing Homes

# Performance of a Heat Pump Water Heater in the Hot-Humid Climate

Windermere, Florida

## PROJECT INFORMATION

**Project Name:** Systems Evaluation at the Cool Energy House

**Location:** Windermere, FL

**Partners:**

Southern Traditions Development
*http://southerntraditionsdev.com/*

Consortium for Advanced Residential Buildings
*www.carb-swa.com*

**Building Component:** Domestic hot water

**Application:** Retrofit, single family

**Year Tested:** 2012

**Applicable Climate Zone(s):** Hot-humid

## PERFORMANCE DATA

Cost of Energy Efficiency Measure (including labor): $2,100

Projected Energy Savings: 64% DHW heating

Projected Energy Cost Savings: $113/year

Other Benefits:
- Space Cooling
- Dehumidification

Building America U.S. Department of Energy

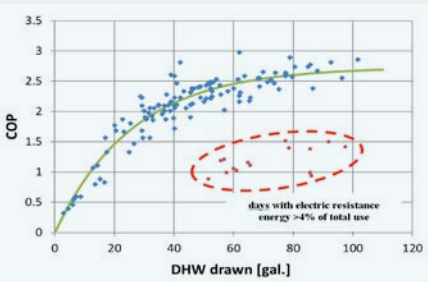
Over recent years, heat pump water heaters (HPWHs) have become more readily available and more widely adopted in the marketplace. A key feature of an HPWH unit is that it is a hybrid system. When conditions are favorable, the unit will operate in heat pump mode (using a vapor compression system that extracts heat from the surrounding air) to efficiently provide domestic hot water (DHW). Homeowners need not adjust their behavior to conform to the heat pump's capabilities. If a heat pump cannot meet a higher water draw demand, the heater will switch to electric resistance to provide a higher heating rate. This flexibility provides the energy savings of heat pump mode (when possible) while performing as an electric resistance water heater (ERWH) during periods of high DHW demand. Furthermore, an HPWH's operational byproduct is cooling and dehumidification, which can be particularly beneficial in hot-humid climates.

For a 6-month period, the Consortium for Advanced Residential Buildings, a U.S. Department of Energy Building America team, monitored the performance of a GE Geospring HPWH in Windermere, Florida. The study included hourly energy simulation analysis using the National Renewable Energy Laboratory's Building Energy Optimization-Energy Plus (BEopt) v1.3 software. The HPWH was estimated to save 64% annually ($113/year) on utility costs compared with a standard ERWH. Long-term field monitoring validated this predicted performance in an occupied setting.

The HPWH performance monitoring showed that the DHW draw profile was a primary factor affecting the system's operating efficiency. If a large amount of water was drawn over a short period of time, the unit reverted to electric resistance mode to support the high heating demand. Without having the family of six change their use patterns (typically ranging from ~15–85 gallons of daily hot water use), the HPWH achieved a total coefficient of performance (COP) of 2.2, with 23% of the unit's total energy use (not thermal energy fraction) associated with the electric resistance heating elements. HPWH performance will vary with many factors such as climate, unit location, cold water temperatures, and hot water use and patterns.

## DESCRIPTION

The heat pump water heater performance was analyzed in terms of energy efficiency (coefficient of performance) and operating costs. When operating in heat pump mode, the system performance is affected by water draw, tank losses, ambient conditions, set point temperatures, etc.




The daily coefficient of performance of the heat pump water heater was plotted against total domestic hot water draw for each day. Results show that the unit can achieve higher coefficient of performance values at larger volume draws if the heat pump's recovery rate is not exceeded. Larger, frequent volume draws will cause the heat pump water heater to switch to electric resistance (red data in graph). Over the monitoring period, the unit performed at an average coefficient of performance of 2.2 with a maximum daily coefficient of performance of 3.0.

| DHW Heating Method | Cost |
|---|---|
| Electric Tank | $177 |
| HPWH | $64 |
| Gas Tank | $138 |
| Gas Tankless | $81 |

Annual operating costs of various domestic hot water heating methods were analyzed in the National Renewable Energy Laboratory's BEoptE+ v1.3e. Modeling results predict that a heat pump water heater can save $113/year over an electric resistance water heater in domestic hot water costs. When space conditioning impacts are included, the savings increase to $120/year.

For more information, see the Building America report, *Systems Evaluation at the Cool Energy House,* at *www.buildingamerica.gov*

Image credit: All images were created by the CARB team.

### Summary of Monitoring Results

| | |
|---|---|
| Hot Water Set Point | 120°F |
| Average Water Inlet Temperature[2] | 82°F |
| Average Water Outlet Temperature[2] | 117°F |
| Total COP | 2.2 |
| % Electric Resistance[3] | 23% |
| Average Hot Water Use[1] | 48.8 gal |
| Average Ambient Air Temperature | 74°F |
| Average Ambient Relative Humidity | 55% |

1. Average of daily averages
2. Average estimated with 15 min. periods containing near-continuous flow
3. % electric resistance = % of total kWh consumed by resistance

HPWH operating metrics were calculated across the 6-month monitoring period to access long-term performance of the unit.

## Lessons Learned

- This HPWH performed 144% more efficiently than a traditional ERWH, saving approximately 64% ($113) on water heating annually.
- During the heat pump's operation, the air stream across the heat pump experienced an average decrease in temperature from 75°F to 60°F and in humidity ratio from 0.011 to 0.009 lbmw/lbmda.
- Water draw profiles (both frequency and volume) were the primary factors affecting this unit's operational performance. The inlet air conditions to the HPWH can also have a significant impact on performance, but because this HPWH was located in an unvented attic, conditions were fairly constant (ranging from 68°–83°F).
- There is an interesting inverse effect with HPWHs in the hot-humid climate zone. Although the cooling/dehumidification benefits and higher COPs of a HPWH would be more advantageous in a hot-humid climate, the incoming water temperature tends to be higher. The monitored incoming water temperature ranged from 75°–85°F over the monitoring period, meaning that less water heating is required. Lower loads equate with less energy savings, resulting in reduced HPWH cost effectiveness.

U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

**For more information, visit:**
*www.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.

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.

DOE/GO-102013-4050 • November 2013