Evaluating Indoor HPWHs in a Hot/Dry Climate

EEBA Excellence in Building – St. Louis, MO

September 23rd, 2014
Overview

1. Project Goals & Learning Objectives
2. Project Design (summer only)
3. Monitoring Methods
4. Results
   - Existing Electric Water Heater Performance
   - HPWH performance
   - Space Cooling Impacts
   - Projected Savings
   - Estimated Cost Effectiveness
5. Homeowner Feedback
6. Next Steps
Project Goals and Learning Objectives

1. What was the measured performance of the HPWHs in the two homes?
2. What is the level of customer satisfaction with the HPWH in terms of hot water capacity, cooling benefit, and noise concerns?
3. How significant are the observed space cooling impacts?
4. What are the economics of retrofitting a HPWH in this climate under different hot water loads and electric rates?
Project Overview

Research Supported By:
DOE’s Building America
Redding Electric Utility (REU)
Continued winter monitoring sponsored by PG&E & REU
Why Redding? (Summer ‘14 NWS Data)

Outdoor Temperature (degrees F)

- Dry Bulb Max (Avg June 1 to Sept 14 = 97.4F)
- Dry Bulb Min (Avg June 1 to Sept 14 = 64.6F)
- Dry Bulb Avg (Avg June 1 to Sept 14 = 81.3F)
# Monitoring Site Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>House floor area (ft(^2))</td>
<td>2,037</td>
<td>2,740</td>
</tr>
<tr>
<td>Year constructed</td>
<td>~1980</td>
<td>1987</td>
</tr>
<tr>
<td>Occupants and ages</td>
<td>Two adults</td>
<td>Six (2 adults, one child &lt; 10, three 10-20 year olds)</td>
</tr>
<tr>
<td>Existing electric storage water heater</td>
<td>50 gallon Bradford White</td>
<td>50 gallon Bradford White</td>
</tr>
<tr>
<td>HVAC system description</td>
<td>Two packaged heat pumps (age estimated at 20+ years)</td>
<td>2 split system heat pumps (both original equipment)</td>
</tr>
<tr>
<td></td>
<td>1. BDP 542D032HP</td>
<td>1. Bryant 663CJ036</td>
</tr>
<tr>
<td></td>
<td>2. n/a</td>
<td>2. no nameplate on unit</td>
</tr>
</tbody>
</table>
## Air Generate HPWH Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ATI66</th>
<th>ATI80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank volume</td>
<td>66 gallons</td>
<td>80 gallons</td>
</tr>
<tr>
<td>EF (hybrid mode)</td>
<td>2.35</td>
<td>2.2</td>
</tr>
<tr>
<td>First Hour Rating (hybrid mode)</td>
<td>70 gallons</td>
<td>80 gallons</td>
</tr>
<tr>
<td>Heat Pump Btu Rating</td>
<td>2.5 kW</td>
<td>2.5 kW</td>
</tr>
<tr>
<td>Backup Electric Element</td>
<td>4.0 kW</td>
<td>4.0 kW</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R410A</td>
<td>R410A</td>
</tr>
<tr>
<td>Tank Height</td>
<td>70.5”</td>
<td>75.5”</td>
</tr>
<tr>
<td>Weight</td>
<td>243 lbs</td>
<td>254 lbs</td>
</tr>
<tr>
<td>Duct Diameter</td>
<td>6”</td>
<td>6”</td>
</tr>
<tr>
<td>Decibel Rating</td>
<td>48 db</td>
<td>48 db</td>
</tr>
</tbody>
</table>
## Monitoring Setup

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
<th>Mfg/Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duct temperature/RH</td>
<td>HPWH inlet and outlet air</td>
<td>Vaisala HMD42</td>
</tr>
<tr>
<td>Wall mount temperature/RH</td>
<td>Indoor air temperature and RH</td>
<td>Vaisala HMW82</td>
</tr>
<tr>
<td>Outdoor air temperature/RH</td>
<td>Shielded outdoor sensor</td>
<td>RM Young model 41372</td>
</tr>
<tr>
<td>Power Monitors</td>
<td>HPWH and AC power</td>
<td>Wattnode/WNA-1-P-240-P</td>
</tr>
<tr>
<td>Flow meter</td>
<td>Flow to water heater (cold)</td>
<td>Onicon F-1300</td>
</tr>
<tr>
<td>Immersion thermocouple</td>
<td>Hot and cold side temps</td>
<td>Gordon 20CTOUH</td>
</tr>
</tbody>
</table>
Site 1: Exterior View, Water Heater Location
Site 1 HPWH Install
Site 2: WH Location & Proposed Ducting
Site 2: Laundry Room Install
Site 2: Ducting to Outside
Site 2: Exhaust Air Delivery to Kitchen
Site 2: Existing WH Pre-Monitoring
Daily Electric Storage WH Energy Use

Daily Electric Storage Water Heater Usage (kWh/day)

Daily Hot Water Usage (gal/day)

Site 1 - Existing WH
Site 1 - HPWH (RH mode)
Site 2 - Existing WH

y = 0.137x + 0.7469
R² = 0.9871

y = 0.1347x - 0.1471
R² = 0.8735

y = 0.1179x + 0.0236
R² = 0.8752

Davis Energy Group
Cold Water Inlet Temperatures to WH

Site 1

Site 2

Cold Water Inlet Temperature During Flow (degrees F)

April | May | June | July | August | Sept

50 | 55 | 60 | 65 | 70 | 75 | 80
HPWH and Base Daily kWh vs. gpd

\[ y = 0.137x + 0.7469 \quad R^2 = 0.9871 \]
\[ y = 0.1179x + 0.0236 \quad R^2 = 0.8752 \]
\[ y = 0.0431x + 0.3942 \quad R^2 = 0.6094 \]
\[ y = 0.0405x - 0.0886 \quad R^2 = 0.6988 \]
Monitoring Summary - Aggregated Weekly

Average Hot Water Use (gpd)
Weekly Field Measured COP
Site 1 COP
Site 2 COP
Site 1 gpd
Site 2 gpd

RH operation
Household Daily Cooling kWh vs Tout

\[ y = 2.6299x - 190.72 \]
\[ R^2 = 0.5574 \]

\[ y = 2.7925x - 254.22 \]
\[ R^2 = 0.5441 \]
Monitored Indoor Temperature - 1st Floor

First Floor Indoor Temperature (deg F)

- Site 1
- Site 2
HPWH Delivered Exhaust Air Cooling

- HPWH Cooling (Btu/15 minutes)
- HPWH Entering Air (deg F, RH%)
- HPWH Entering Air T
- HPWH Entering Air RH
- HPWH Qsensible
- HPWH Qtotal

Graph showing HPWH Cooling (Btu/15 minutes) and HPWH Entering Air (deg F, RH%) over the day from 0:00 to 12:00.
### Extrapolated Annual Savings

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored gal/day</td>
<td>44.5</td>
<td>65.6</td>
</tr>
<tr>
<td>Estimated annual base kWh</td>
<td>2393</td>
<td>3923</td>
</tr>
<tr>
<td>Assumed Annual COP</td>
<td>2.35</td>
<td>2.20</td>
</tr>
<tr>
<td>Estimated annual HPWH kWh</td>
<td>927</td>
<td>1623</td>
</tr>
<tr>
<td>DHW Savings, kWh</td>
<td>1466</td>
<td>2300</td>
</tr>
<tr>
<td>Cooling Savings, kWh</td>
<td>135</td>
<td>120</td>
</tr>
<tr>
<td>Approx % of Annual Cooling Savings</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Total Annual Savings , kWh</td>
<td>1601</td>
<td>2421</td>
</tr>
</tbody>
</table>
## Estimated Savings and Payback

<table>
<thead>
<tr>
<th></th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual $ Savings, REU rate ($0.153/kWh)</strong></td>
<td>$245</td>
<td>$370</td>
</tr>
<tr>
<td><strong>Simple Payback, years</strong></td>
<td>7.3</td>
<td>4.9</td>
</tr>
<tr>
<td><strong>Annual $ Savings, SDG&amp;E rate ($0.18/kWh)</strong></td>
<td>$288</td>
<td>$436</td>
</tr>
<tr>
<td><strong>Simple Payback, years</strong></td>
<td>6.2</td>
<td>4.1</td>
</tr>
<tr>
<td><strong>Annual $ Savings, AZ/NV rate ($0.113/kWh)</strong></td>
<td>$179</td>
<td>$271</td>
</tr>
<tr>
<td><strong>Simple Payback, years</strong></td>
<td>10.0</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Feedback From Homeowners

What is the level of customer satisfaction in terms of hot water capacity, cooling benefit, and noise?

Site 1:

- Overall 3 of 5 satisfaction …” seems to be a nice unit, but problems with control panel…..” (mode switching issues)
- “The space that the unit is located gets very warm, and the cool air is great.”
- “The noise levels have not been an issue. It is understandable to hear the movement of cold air”

Site 2:

- “more hot water…. way better hot water delivery”
- “cool air to kitchen is great”
- no noise concerns
- Thinks bills are higher
- Overall “4 on a 5 point scale”; only downside is higher bills
How Does This Support ZER Homes?

- Indoor HPWHs in hot/dry climates allow for:
  - High efficiency water heating
  - Consistently better economics than solar thermal (prior NREL study)
  - Small space cooling kWh benefit, diminishing as ZER
  - More compact hot water distribution system saving energy and water
  - HPWH operation could be biased to match with PV output