Final Report

United Illuminating Heat Pump Water Heater Pilot: Impact and Customer Acceptance Study

Prepared for:
United Illuminating

June 4, 2010

Prepared by:
David Beavers, Matt Piantedosi, Sandra Brown
The Cadmus Group, Inc. / Energy Services

Russ Johnson
Johnson Research LLC

Table of Contents

1. Executive Summary

In 2009, United Illuminating (UI) hired The Cadmus Group, Inc. (Cadmus), with Johnson Research, LLC, to evaluate the performance of 11 heat pump water heaters (HPWH) installed under a pilot program. The primary objectives were to determine annual energy usage and savings and evaluate customer acceptance of the technology. Ten of the HPWHs were manufactured by A.E.R.S, a company located in Norcross, Georgia, recently obtained by leading water heater manufacturer A.O Smith. Two A.E.R.S. E-Tech models evaluated in this pilot, the R106H and R106K, are no longer manufactured. The smaller R060 model, also evaluated in the pilot, is still available.[1] In addition to the E-Tech units, a Geyser 6000-003, manufactured by North Road Technologies, was installed at one site.[2]

Each HPWH was metered for a period lasting 12 weeks or more. Cadmus worked with the installer, Hubbell Electric Heater Company of Stratford, Connecticut, to coordinate installation of metering equipment during or just after installation of the HPWHs. For the metering period's first six weeks, units were operated in HPWH mode. A follow up period, when units were operated as a standard, electric resistance water heater, allowed direct comparisons between the energy consumed in each mode to derive energy savings.

As shown in Table 1, below, hot water use at each site ranged from 10 to 134 gallons per day. Average use, across sites, was 61 gallons per day. Energy savings from operating the HPWH compared to a resistance hot water tank averaged just over 42% across the sites. However, as sites that used more hot water realized higher HPWH efficiencies, weighted average savings approached 51%. Table 1 demonstrates that low water use results in both low savings and low HPWH efficiency. This savings level is consistent with results from two HPWH evaluation studies conducted for Northeast Utilities in 2001 and 2002.

Annual electricity bill savings are projected to range from $38, for a site that uses relatively little hot water, to over $700 for the site with highest usage. Additional savings from cooling and dehumidification benefits were not substantiated in the study. However, participants in the study did mention that they perceived a dehumidification benefit when the HPWH was operating.

Clearly an opportunity exists for achieving energy savings from HPWHs in UI territory. Similar to previous studies, however, product reliability issues encountered make expansion to a full program problematic. Based on experience over a short timeframe with the E-Tech HPWHs, Cadmus does not recommend widespread adoption until the units can be proven reliable.

In regards to piloting or developing a program to promote installation of other HPWH makes and models, we recommend that the sites selected for a pilot be carefully chosen to match the

---

[1] Information on changes to the E—Tech product line is available at: http://www.etechbyaosmith.com/res_waterheating.html. Thirty previous E-Tech models were evaluated under the Northeast Utility's Hot Shot program in 1998–2000. See: A. Lowenstein, AIL Research; R. Johnson, Northeast Utilities. "Heat Pump Water Heater Field Test: 30 Crispaire Installations." April 4, 2001, Northeast Utilities, Connecticut Light & Power.

[2] Information on the Geyser HPWH can be found at http://www.northrdt.com/. The performance of 15 Nyle HPWHs, a predecessor to the Geyser model, were evaluated for Northeast Utilities in 2002. See: AIL, Research, *Nyle Heat-Pump Water Heater Evaluation*, January 24, 2002, Northeast Utilities, Connecticut Light & Power.

attributes of a particular model. For example, based on hot water usage results in this study and specifications for the new GE Hybrid model, households with two to four people are recommended for pilots with this model.

Table 1. Results Summary

Site	Number of Residents	Average Hot Water Use Per Day (gal)	Peak Hot Water Use (gal /hr)	Standard Resistance AVG COP	HPWH AVG COP	Savings (%)	Projected Annual Savings (kWh)	Projected Annual $ Savings
1	1	23	42	0.57	1.14	50%	670	$146
3	3	53	54	0.65	1.45	55%	1,737	$350
4	2	10	12	0.56	0.79	28%	186	$38
5[2]	5.5	78	44	0.96				
6[3]	5	134	78		1.50			
7	3	27	39	0.64	0.99	35%	603	$119
8	2	64	59	0.82	1.65	50%	1,881	$366
9	4	76	67		1.51			
10	1	29	43	0.68	1.02	33%	692	$137
11[3]	5	113	93		1.79			
Average	3.1	61	53	0.70	1.32	42%	961	$193
Weighted Average[4]				0.75	1.53	51%		

Notes:

1 Data for Site 2 was compromised by a faulty data logger.

2 Only resistance heating was used at this site.

3 Only HPWH operating mode was used at these sites.

4 Sites using more hot water have a larger impact on the weighted average than sites using less hot water.

2. Introduction

In January 2009, United Illuminating (UI) hired The Cadmus Group, Inc. (Cadmus), with Johnson Research LLC, to evaluate the performance and customer experience of 10 A.E.R.S. E-Tech HPWHs to be installed under a 2009 pilot program. Pilot program results will be used in assessing the opportunity for a larger-scale program to offer HPWHs as an option to all UI customers with electric resistance water heaters.

The study's primary objectives, as defined in the draft Measurement and Analysis plan, were:

- Determine annual energy usage and savings (including savings related to water heating, dehumidification, and air conditioning) associated with installation of HPWHs in uncontrolled applications; and
- Obtain information about customers' acceptance of the technology and perspectives on concerning factors such as savings, comfort, aesthetics, and noise.

UI selected Hubbell Electric Heater Company (Hubbell) of Stratford, Connecticut, to install the HPWHs. On January 8, 2009, a project kickoff meeting was held with representatives from Cadmus, Johnson Research, Hubbell, and UI to review and refine the proposed Measurement and Analysis Plan. The final plan is detailed on page 6 of this report. Cadmus worked with Hubbell to coordinate installation of the HPWH and meter placement.

In addition to the first 10 units selected for the study, UI requested a North Road Technologies model also be studied. This unit was installed at Site 11 in September 2009 and results are included in this report.

Heat Pump Water Heaters Installed

The HPWHs installed through this pilot were all "add-on" type, installed in conjunction with a standard resistance hot water heater. Table 2, below, provides details on the four models used in the pilot. Annual energy savings claims of 50% or higher have been made by manufacturers for each unit.[3]

Heating capacity ranged from 5,900 BTU/hr for the E-Tech R060 to 12,500 BTU/hr for the larger R106 models. The R106's also had a substantially higher reported recovery rate. The minimum ambient operating temperature for all units was 45° F. Rated dehumidification potential (which assumes a unit runtime of 24 hours per day) for E-Tech R106 models was equivalent to a midsize dehumidifier.

[3] For example, E-Tech claims 50 – 80% savings. See http://www.etechbyaosmith.com/res_waterheating.html

Table 2. HPWH Details

Make and Model	E-Tech R060	E-Tech R106H	E-Tech R106K	North Road Technologies Geyser 6000-003
Number Installed In Pilot	5	3	2	1
Claimed savings over resistance water heater	50 – 80%			50– 60%
Operating Modes	HPWH / Resistance / Off			HPWH/Off
*Heating Output (BTU/hr)	5,900	12,500		6,000
*Cooling Capacity (BTU/hr)	4,100	8,800		--
*Dehumidification Capacity (Pints/hr)	0.75	1.6		Up to 50 pints/ day
Refrigerant	R-134a	R-22		
Recovery Rate (gal/hr)	9.4 (135° F)	23 (125° F)		12.5 (120° F)
Sound Level At 5 Feet (db)	Less than 60	60	62	--
Minimum Operating Temperature (°F)	45			
Minimum Space (ft^3)	800			1,500
*At DOE water heater efficiency testing ambient conditions of 67.5 F, 50% RH and 58° F water temperature.				

Figure 1. HPWH (R060) and Tank Prior to Installation

Electric Water Heaters Installed

The majority of electric hot water tanks used in the pilot were produced by Hubbell-Electric Heater Company, with one Rheem and one Whirlpool model also included.

Table 3. Tank Details

Make and Model	Hubbell S80	Hubbell S120	Rheem 81V52DC	Whirlpool E2F8DHD045V
Number In Pilot	6	3	1	1
Size (gal)	80	119	50	80
Element Size (Watts @ 240V)	3,000	4,000	4,500	4,500
Used with HPWH Model (no. of units)	R060 (3), R106K (1), R106H(1) , Geyser (1)	R106H (2), R060 (1)	R060 (1)	R106K (1)

3. Measurement and Analysis Plan

Based on information needs identified for the pilot program, Cadmus proposed starting with consideration of two key issues:

- First, factors affecting energy consumption (such as hot water usage) and HPWH performance (ambient temperature and inlet water temperature) present a challenge to the study as they can vary seasonally. Further, the sampling period would not necessarily coincide with the season when additional dehumidification and cooling benefits could be captured.

  The HPWHs would be metered during a three-month period, which could include winter, spring, and summer. Each HWPH, depending on installation date, could run under varying seasonal conditions.

- Second, UI desired a cost-effective approach.

To meet these challenges, Cadmus proposed directly comparing unitary systems when operated in HPWH mode and when operated in resistance mode. That is, each unit would be run as a HPWH, then as a resistance water heater. Results, after accounting for differences hot water usage and environmental conditions, would be compared.

A data logger at each site would collect the following data, stored at five-minute intervals:

- Cold water inlet temperature
- Hot water outlet temperature
- Air temperature and humidity
- Water flow rate into the tank
- Electrical power to the HPWH
- Electrical power to the system (both resistance elements and HPWH)

This approach enabled the following information to be provided to UI:

(1) Annual energy savings obtainable in HPWH over resistance water heating;
(2) Average hourly load reduction in HPWH mode; and
(3) An estimate of secondary HPWH cooling and dehumidification benefits.

In addition to the metering-derived results, customer acceptance and satisfaction levels would be evaluated.

Representatives from Cadmus, Johnson Research, Hubbell, and UI reviewed and revised the proposed Measurement and Analysis Plan during a project kickoff meeting held on January 8, 2009. During the meeting, the project's overall approach was refined and adjusted, as follows:

- For the first six-week metering period, the systems would operate in HPWH mode with backup resistance heating. Off-Peak timers would be disabled.

- During the second metering period, the unitary systems would operate in resistance mode, providing a baseline from which to calculate energy savings.

- After reviewing the initial metering results, UI would instruct Cadmus whether to continue metering for an additional six-week period with off-peak timers enabled.
- HPWH condensate generation rates would not be measured. Dehumidification benefits would be based on HPWH run times and rated dehumidification levels.

Figure 2. Flow Meter and Temperature Sensor Assembly

4. Site Characteristics

UI selected 11 sites for participation in the pilot program. Volunteers associated with UI or the HPWH installation contractor, Hubbell, agreed to participate and have a HPWH installed.

Table 4, below, provides details on demographics for each site. The number of persons living in each household ranged from one to six. The sites included both oil and natural gas heating. All HPWHs units were installed in basements.

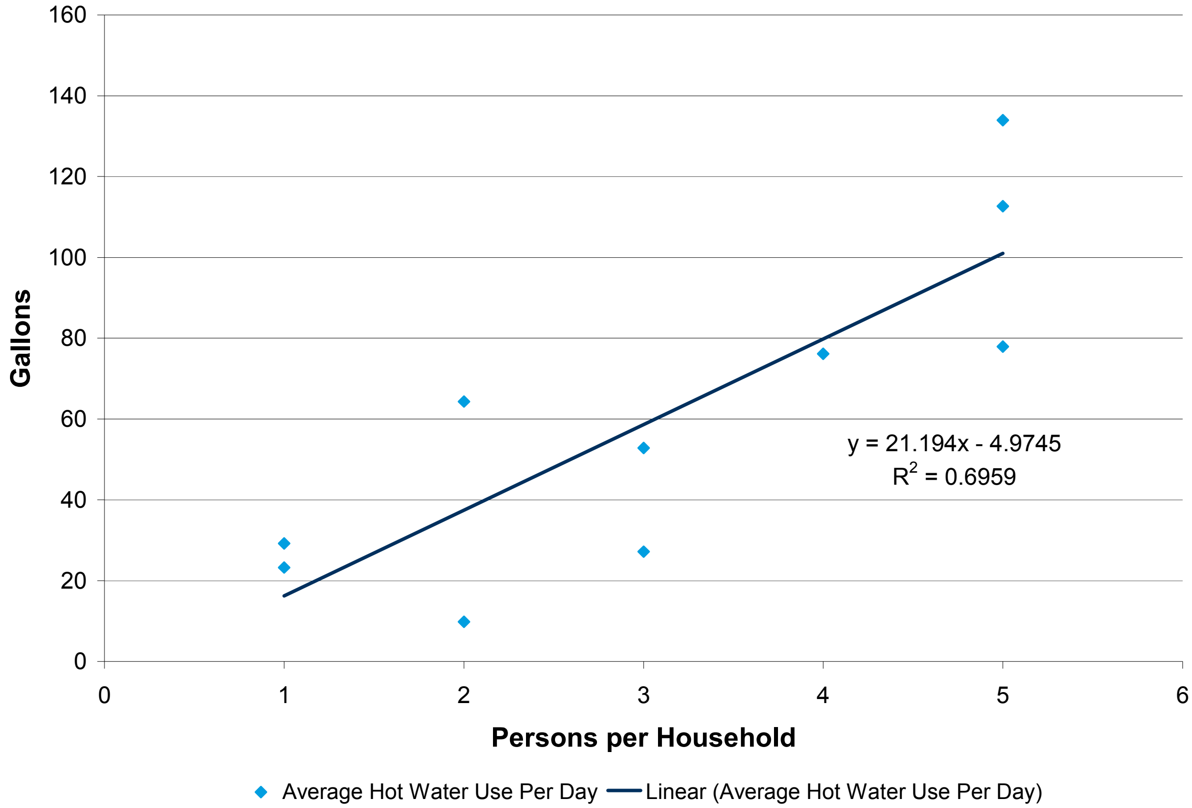
Table 4. Site Details

			Water Heater			Heat Pump Water Heater and Meter Install Date	
Site	Number of Residents	Heat Source	Capacity (Gallons)	Location	Dehumidifier?	Unit	Meter Install Date
1	1	Oil	50	Basement	No	R060	Mar 27, 09
2	2	Natural Gas	80	Basement	Yes	R106k	Jun 2, 09
3	3	Natural Gas	80	Basement	Yes, not in use	R106k	Mar 5, 09
4	2	Heat Pump/ Natural Gas	80	Basement	No	R060	Mar 27, 09
5	5.5	Oil	80	Basement	Yes	R106h	Mar 5, 09
6	5	Natural Gas	120	Basement	Yes, not in use	R160h	Mar 27, 09
7	3	Oil	80	Basement	Yes, not in use	R060	Mar 5, 09
8*	2	Natural Gas	120	Basement	Yes, not in use	R060	Feb 10, 09
9	4	Oil	120	Basement	No	R106h	Jun 2, 09
10	1	Natural Gas	120	Basement	Yes	R060	Feb 10, 09
11	5	Natural Gas	80	Basement	No	Geyser	June 2, 2009

*At Site 8 , the water heater served the master bedroom (with whirlpool tub) only. At Site 11, an electric tankless heater was installed on the hot water output to boost the temperature.

Hot water use averaged just over 20 gallons per day per person (see Figure 3). Average usage across sites was 61 gallons per day. The maximum one-hour draw over the entire pilot program averaged 53 gallons across all sites, with a range of 12 to 93 gallons.

Figure 3. Average Daily Hot Water Use vs. Number in Household

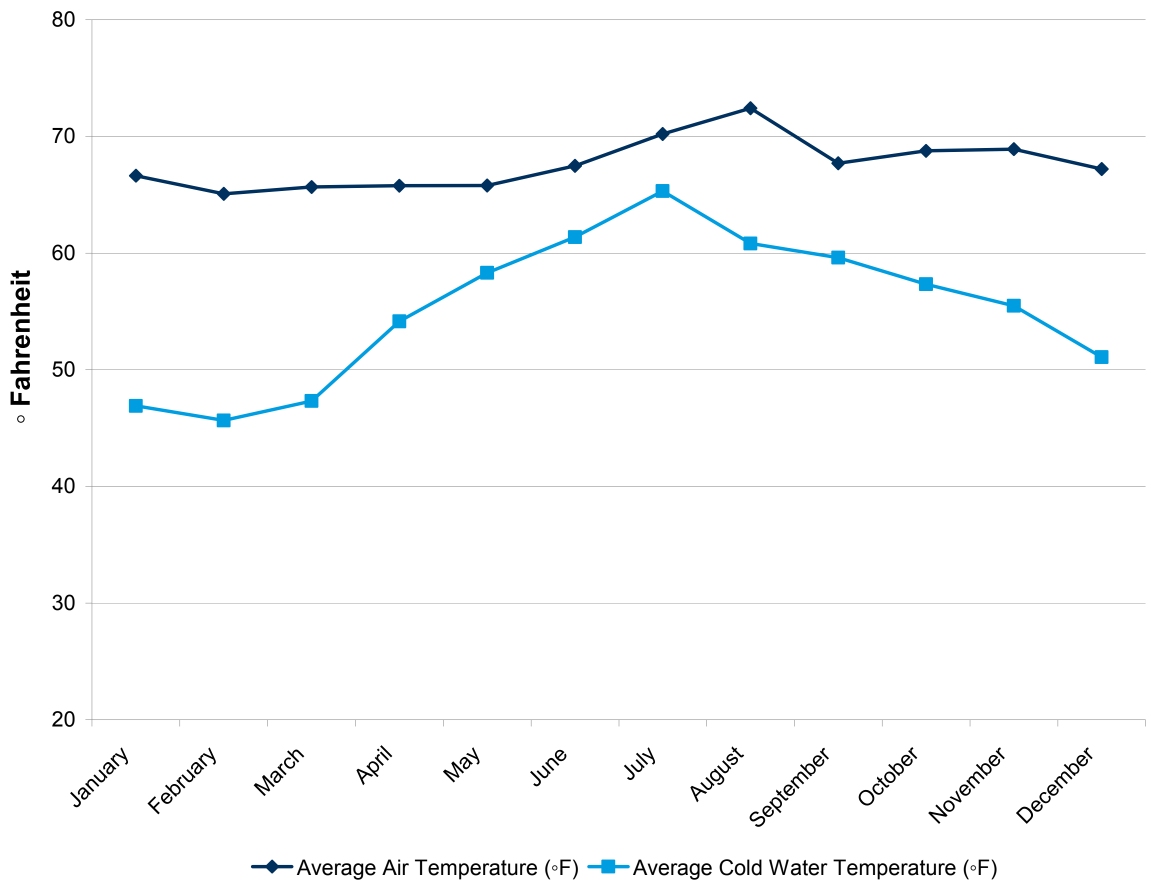


As shown in Figure 4, below, the average basement ambient air temperature for all sites, (measured near the HPWH located in the basement) rose from 65° F in February to 72° F in August. The highest average temperature for an individual site was 72.4° F for Site 6, while the lowest was 60.8° F at Site 7. As HPWHs were operated during the first six weeks of the pilot, they primarily operated in March, April and May. Average monthly ambient air temperatures across the sites averaged 65.7° F. This average is close to the Department of Energy's (DOE) water heating test condition of 67.5° F.

Cold water temperatures increased substantially from January to July, going from 45.65° F to 65.32° F in July. The average for all sites in March through May was 53.3° F. In comparison, the DOE water heating test procedure specified cold water at 58° F.

Relative humidity (RH) steadily increased as the weather warmed. In February, RH values at each site were around 28%. In spring, typical RH values increased to between 35% and 55%, and rose in the summer to between 65% and 80%. For comparison, the DOE test procedure calls for 50% RH during testing.

Figure 4. Average Ambient Air And Water Temperatures (All Sites)



5. Performance Results

Energy Savings

In terms of energy savings, HPWHs installed during the pilot program—including energy consumed by back-up resistance heating—used about 50% less electricity on average, when compared to resistance-only hot water heating. This savings level was similar to that found in previous HPWH studies in Connecticut. For example, the average COP_R[4] found in this pilot was 1.9.[5] The 2002 Northeast Utilities study of Nyle HPWHs returned an average COP_R of 1.8 or 1.9, depending on the sites included in the average. The 2001 Northeast Utilities study of 30 E-Tech WH-6BX-1 (similar to the R-060) HPWHs returned an average COP_R of 1.8.

Average projected kWh savings were close to 1,000 kWh per year (see Table 1, Page 2). This is roughly half of projected savings from the NU 2001 and 2002 reports, and results from the hot water use of pilot participants being lower than in previous pilots. Unfortunately, the high water users in this pilot (Sites 5, 6, and 9) did not run their units both in HPWH mode and in resistance mode, as requested, and could not be included in the average savings cited in Table 1. Sites that did follow the request averaged 43 gallons per day of hot water use. In comparison, average hot water use in the NU 2002 report was 75 gallons per day.

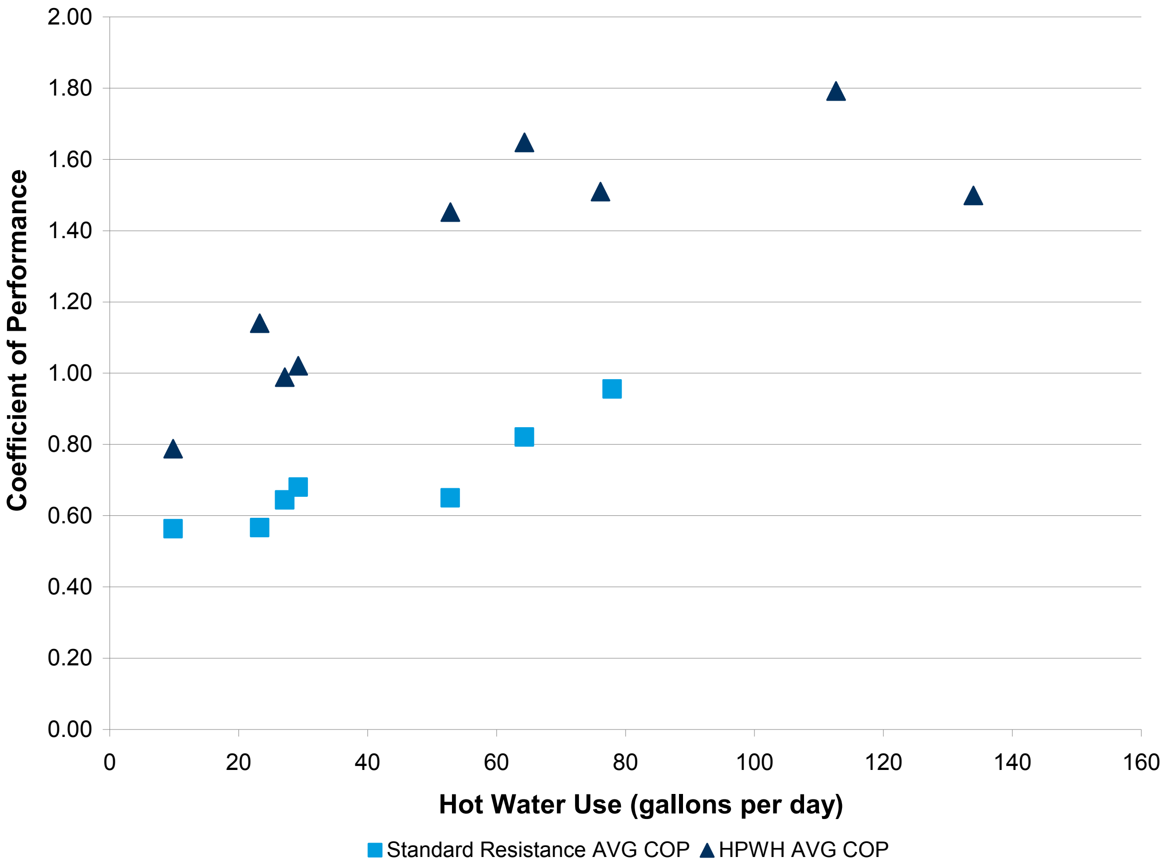
Efficiency, in terms of energy factor (COP), of the HPWHs varied with the amount of hot water used (see Figure 5). The COP of the sites with the lowest hot water use was below 1.0, while sites with 50 gallons per day or more of hot water use had a COP of 1.4 or higher. This trend can be explained by the higher proportion of total energy consumption used in standby, when no water is withdrawn, for lower water use sites, and a lower efficiency of the HPWH relative to resistance heating during standby periods. During HPWH operation, it was observed the temperature sensor in the cold water line increased during standby periods to a point about 20° F higher than ambient air temperatures. This was likely due to the HPWH cycling water through the unit to maintain tank temperature settings. This effect would increase heat loss during standby conditions relative to standby periods during resistance-only heating.

---

4 See Appendix A for definitions of terms used in this report.

5 The weighted average in this pilot, which gives more weight to sites that use more hot water, was 1.9.

Figure 5. HPWH & Standard Electric COP vs. Hot Water Consumption



Savings by Model

The Geyser 6000-003 returned a substantially higher COP than the E-Tech R106 or R060 models installed in the pilot program. The COP for the Geyser, which had the second highest average daily hot water use at 113 gallons, was 1.79 compared the average COP for R106 models was 1.5, while the average COP for R060 models was 1.1 (see Table 5).

The difference in COP for the R060 and the R106 could be attributed to lower daily hot water draws at the R060 sites rather than a lower efficiency, compared to the R106 models. For example, Site 8, with a R060, used 64 gallons per day, and had a COP of 1.65. Both water use and COP are comparable to the average for R106 sites.

Table 5. Results By HPWH Model

Make and Model	Number	Average Hot Water (gal/day)	Average COP	% Savings Over Std. Electric
R060	5	31	1.12	39%
R106 (H & K)[1]	4	85	1.49	55%
Geyser	1	113	1.79	

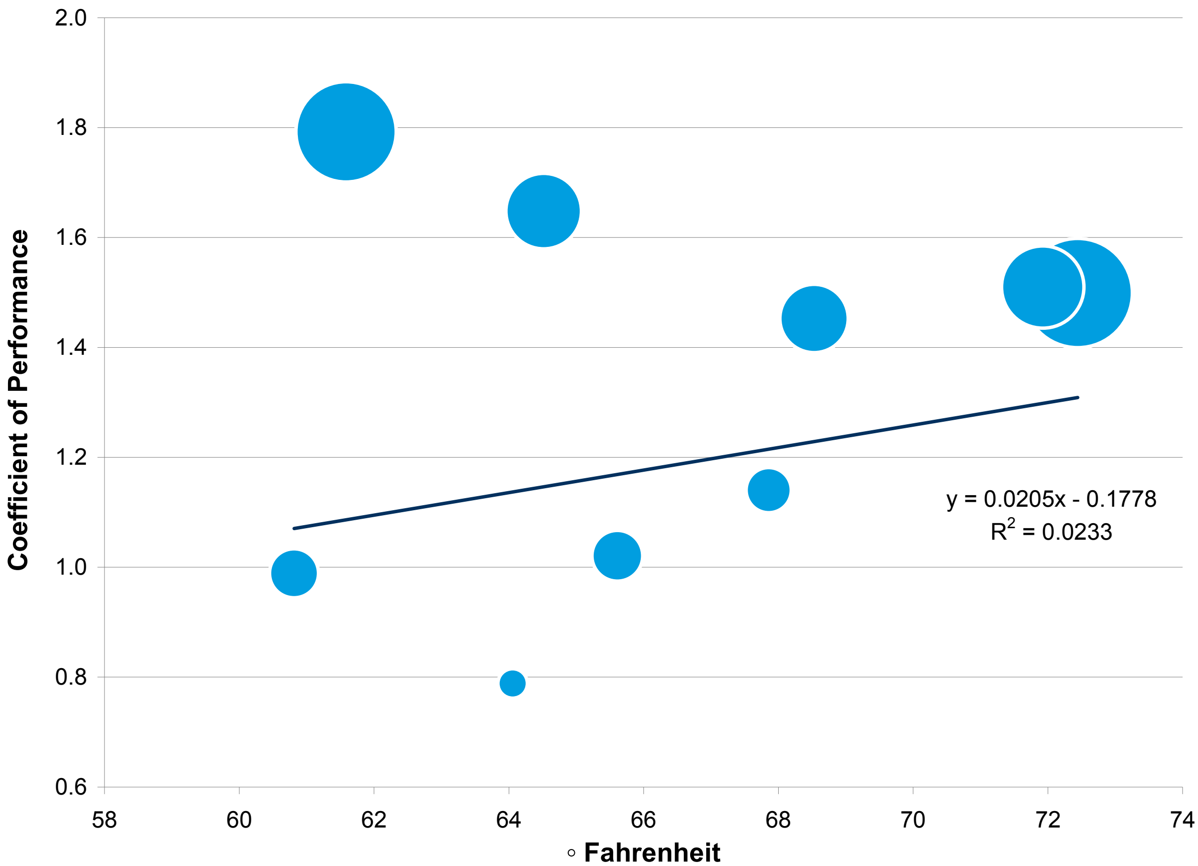
[1]Note: Data for Site 2 was compromised due to a faulty data logger.

Ambient Air Temperature and HPWH Efficiency

The NU 2002 HPWH evaluation found the HPWHs were slightly more efficient at higher ambient air temperatures, while the NU 2001 evaluation found the best site parameter correlating with HPWH efficiency was the ambient air temperature. In both cases, the correlation coefficient of the regressions performed on the data showed relatively weak correlations (i.e., less than 0.6).

Figure 6 shows the COP for each site's HPWH in this pilot, as plotted against the average ambient air temperature at each site. Results from this pilot study did not show a trend toward higher efficiency in HPWHs with increasing ambient air temperatures. The correlation coefficient was especially weak at 0.023. To gauge possible bias on the correlation from the amount of hot water used at each site, the relative water usage was displayed as the area of each plotted point. Figure 6 shows that sites with the highest hot water usage had higher efficiencies, but there is no apparent impact from ambient temperature.

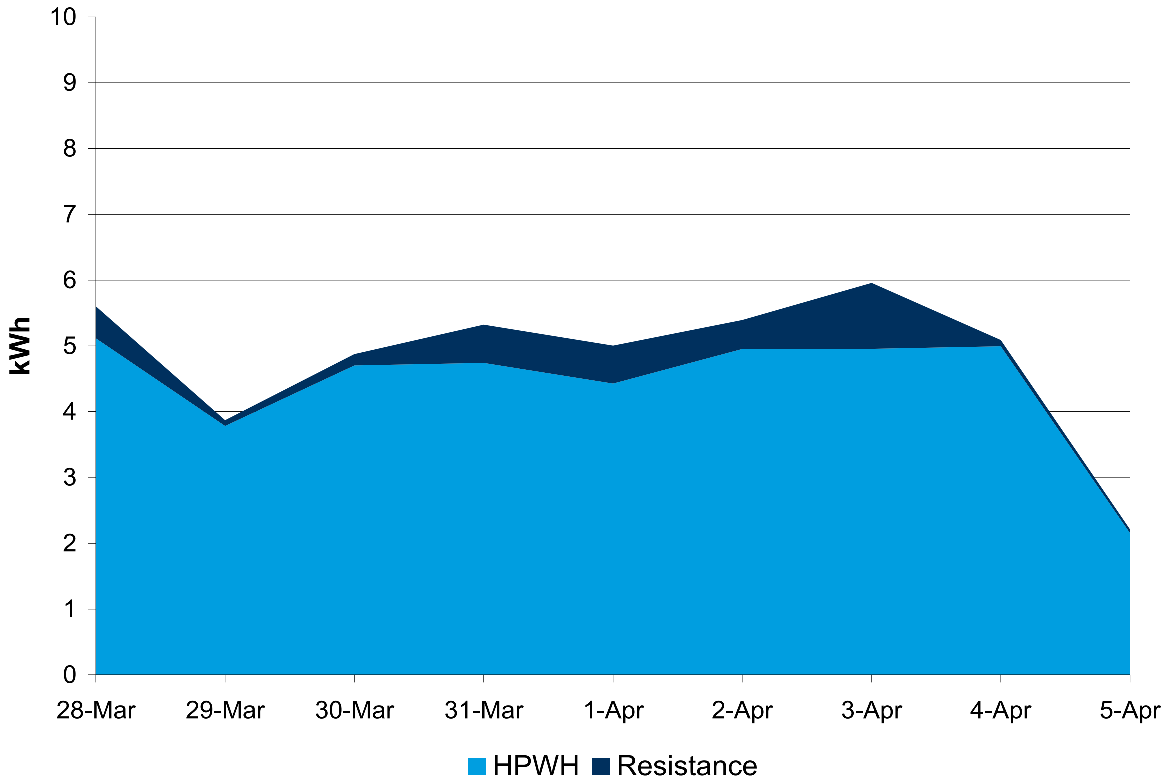
Figure 6. HPWH COP vs. Average Ambient Air Temperature For Each Site (Area Represents Relative Daily Hot Water Use)



Frequency of Back-Up Resistance Heating

The E-Tech models in this pilot allowed for back-up resistance heating from the water heaters' upper elements, when the HPWH alone was insufficient to maintain set water temperatures. On average, 8% of all energy used by the water heaters in HPWH mode was consumed by the upper element. The range was from 1% at the site using the least resistance heating to 12% at the site using the most resistance heating.

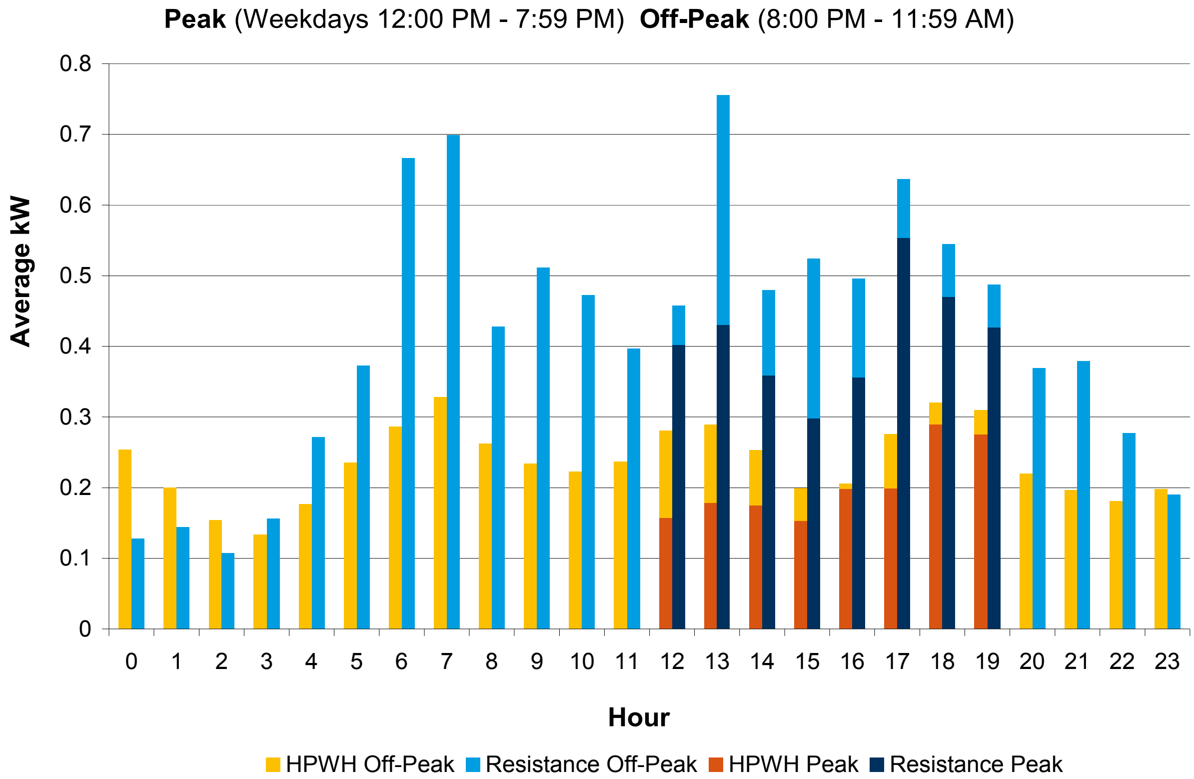
Figure 7. HPWH vs. Back-Up Resistance Heating



Demand Reduction

To demonstrate the impact on diversified electrical demand, demand for HPWH operation across all sites was averaged for UI defined peak and off-peak periods and compared to resistance heating periods. The peak period runs from noon to seven PM on weekdays. Figure 8 shows diversified demand for both HPWH and resistance water heating for both peak and off-peak periods.

Figure 8. Diversified Demand



<u>Off-Peak Hours</u>

- On average, demand was reduced at 7am - the peak hour in the morning by 371 Watts. A reduction of 53%.
- The largest reduction was at 1 pm during the weekend going from 755 Watts to 289 Watts.
- The weekend evening period also saw significant demand reduction on par with the morning reduction.

<u>Peak Hours</u>

- On average, demand was reduced during the evening peak hour of 5 pm from 553 Watts to 198 Watts.
- The demand during peak hours for both HPWH and resistance water heating was less than during the off-peak hours.

HPWH demand was on par with that found in earlier studies, but demand from the electric resistance heating was substantially less. Over half of the tanks had heating elements of only 3,000 Watts, which may partly be responsible for the lower demand from resistance heating. As opposed to higher capacity elements, these elements would tend to flatten the demand curve.

Cooling and Dehumidification

Average air temperatures and relative humidity data was collected at four sites in the pilot program, and is summarized in Table 6. Data was collected by two loggers located in the vicinity of the hot water heating system. The primary sensor was attached to the hot water system and placed in close proximity to the HPWH. A second sensor was placed at a distance of 20 feet or more from the system.

The average temperature at the remote sensors was slightly lower than at the HPWH. This is counterintuitive as the heat removed by the HPWH should cool the air the air nearby relative to the temperature farther away. A HPWH with performance similar to the units in this pilot, consuming 4 kWh per day and with an average COP of 1.45, would be expected to provide approximately 6,100 BTU of combined cooling and dehumidification per day.[6] This level of cooling is equivalent to a medium sized room air conditioner running at full capacity for two to three minutes every hour. Given this minimum level of cooling, other factors, such as heat lost from the hot water tank, nearby lighting, or normal variation in temperature could hide the cooling effect.

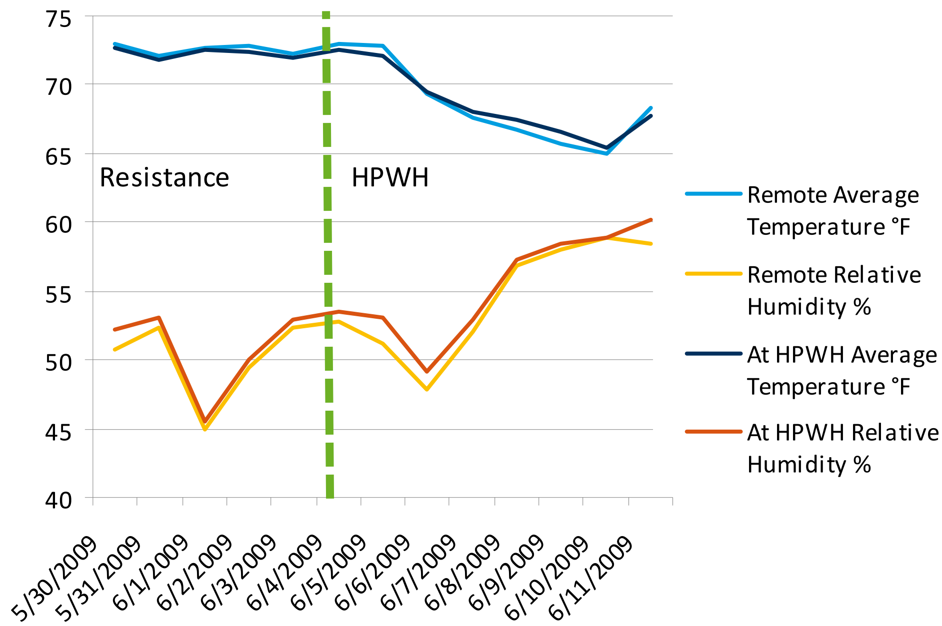
Relative humidity at the HPWH was slightly lower on average than at the remote location. This would suggest that the HPWH is reducing RH in the area near the unit. In addition, as shown in Figure 9, when looking at a transition from resistance water heating to HPWH operation for Site 3, it appears the HPWH dropped the RH by 2 to 3% over the period of 3 days. The site switched from resistance water heating to HPWH on June 5, 2009. However, the RH increased substantially thereafter for the next few days. On the whole, it appears the ability of a HPWH used in this pilot to help maintain relative humidity will vary from site to site and is difficult to document in terms of long term affect. Given the low average cooling capacity, as demonstrated above, dehumidification capacity would also be expected to be minimal.

Table 6. Average Air Temperature and RH

Site	Period	Air Temperature (° F)		RH (%)	
		At HPWH	Remote	At HPWH	Remote
2	Jun 3 – 6, 2009	64.2	63.8	66.1	69.1
3	Jun 5 – July 6, 2009	65.9	65.3	62.6	63.6
4	Apr 30 – May 29, 2009	62.4	65.6	52.8	45.5
10	Feb 24 – Mar 25, 2009	62.8	56.7	30.0	34.5
Average		63.8	62.9	52.9	53.2

[6] This assumes a simple energy balance: the amount of cooling is equal to the heat transferred to the water in the tank minus the energy used to run the HPWH. It is assumed that the energy used to run the HPWH ends up as heat transferred to the tank.

Figure 9. Site 3 Resistance To HPWH Impact



6. Additional Winter Metering

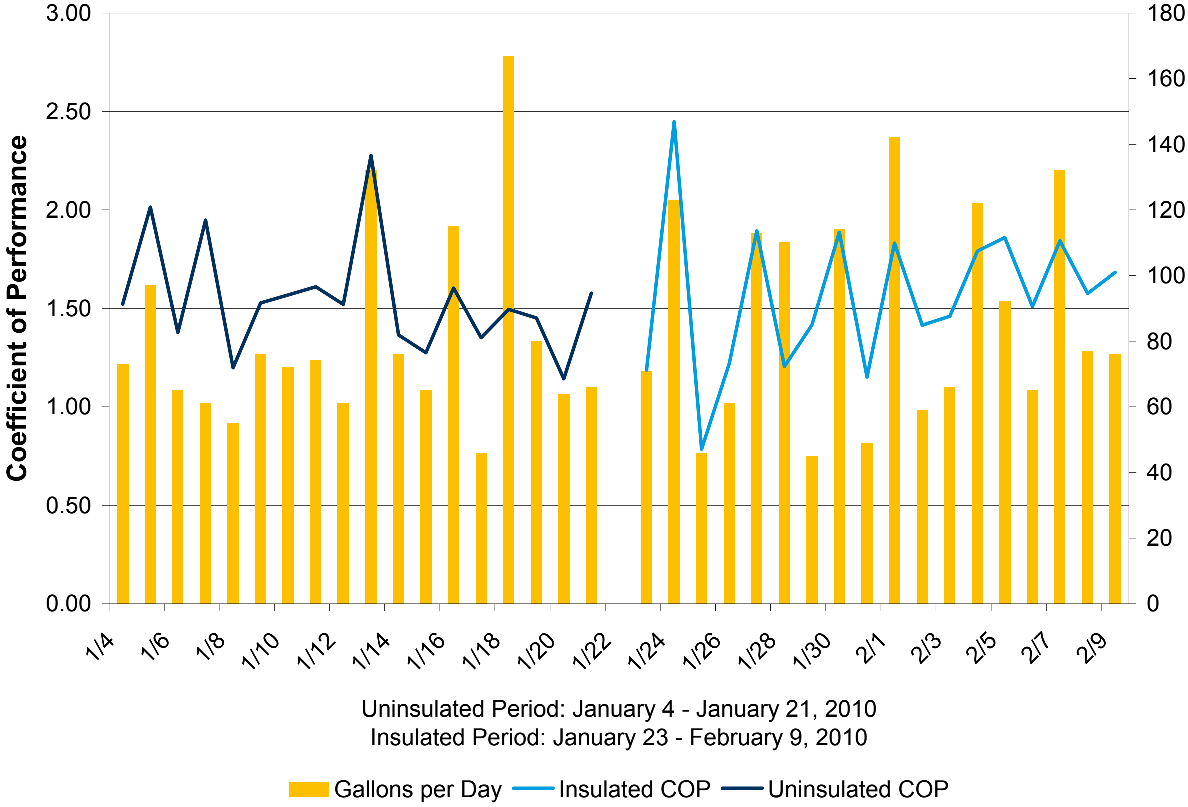
Per UI's request, additional metering through the winter of 2009 to April, 2010 was performed at three sites. The goal of the additional metering was to assess HPWH performance during the winter months and also assess the impact of adding insulation to the inlet and return lines going to each HPWH. The experience at each site included:

- Site 7 (R060): The homeowner switched from HWPH mode to resistance only mode shortly into the metering period. There were complaints in the family about a lack of hot water. The homeowner has subsequently decided to have the HPWH removed.
- Site 9 (R106): Performance data was collected at this site before and after insulation was added to the inlet and return lines. The insulation did not significantly improve the COP of the HPWH. See Table 7and Figure 10, below. Overall, this was one of the better performing sites with an average COP of 1.5 over a 10 month period including the winter months. During the summer and fall of 2009, the average COP was 1.6. The homeowner was generally pleased with the performance of the HPWH and indicated they planned to keep it.
- Site 11 (Geyser): Insulation was already installed to the inlet and return lines at the time the HPWH was installed. This unit had the best COP of all the HPWH in the pilot. This could be due in part to a lower tank temperature (115° F) relative to the other sites (typically 135° F). A backup electric tankless water heater was used to boost water temperature when needed.

Table 7. COP, Average and Peak Hot Water Use for Insulated and Uninsulated Pipe at Site 9

	Insulated	Un-insulated
Average Hot Water Use per Day (Gallons)	87	80
Peak Hot Water Use (Gallons/ hr)	55	42
Coefficient of Performance (HPWH)	1.57	1.54

Figure 10. Impact to Coefficient Performance Due to Pipe Insulation At Site 9



7. Billing Analysis

Annual savings, projected for sites that operated both in HPWH and resistance modes during the pilot period, varied significantly depending on the quantity of hot water consumed on average by at each site. Savings ranged from $38 at Site 4, which averaged 10 gallons per day, to $366 at Site 8, which averaged 64 gallons per day.

Table 8. Peak and Off-Peak Energy And Dollar Savings

Site	Percent Saved	kWh per Year			Operating Costs per Year		
		Off-Peak	Peak	Total	Off-Peak	Peak	Total
1	48%	393	277	670	$ 71	$ 75	$ 146
3	55%	1,351	386	1,737	$ 245	$ 105	$ 350
4	29%	142	44	186	$ 26	$ 12	$ 38
7	35%	499	104	603	$ 90	$ 28	$ 119
8	53%	1,599	283	1,881	$ 289	$ 77	$ 366
10	33%	561	130	692	$ 102	$ 35	$ 137
AVG	**42%**	**757**	**204**	**961**	**$ 137**	**$ 56**	**$ 193**

Three sites consuming more than 70 gallons per day did not operate in both HPWH and resistance modes during the pilot and were not included in projected savings calculations. If included, these two sites would have increased average savings projected in the pilot significantly. For Site 6, which used 134 gallons per day, annual savings would likely exceed $700 annually. Most pilot program participants subscribed to UI's Time of Day Residential Schedule (rate RT).[7] The billing analysis, constructed using the RT schedule, includes projected savings for off-peak and peak periods. The peak rate per kWh under the RT schedule is $0.10 greater compared with the off-peak rate, providing a substantial incentive to reduce energy consumption during peak periods. Rates used in the billing analysis are detailed in Table 9 below.

Table 9. UI Peak And Off-Peak Rates Used

Period	Summer (Jun – Sept)	Winter (Oct - May)
Peak*	$0.28	$0.27
Off-Peak	$0.18	$0.18

* Peak hours are 12 – 8 PM, Mon - Fri

The anticipated simple payback period is four years or less for sites consuming 50 or more gallons per day of hot water. To give an example, with an assumed cost premium of $1,200 for installation of a HPWH in an existing electric resistance system, and site characteristics equivalent to Site 3 in this pilot (averaging 53 gallons daily), the simple payback period would be 3.4 years. Federal tax incentives, if available, could substantially shorten the payback periods as well.

[7] Source: Correspondence with Megan Pomeroy, UI HPWH Pilot project manager (9/8/2009). Residential rates are detailed at http://www.uinet.com/uinet/connect/UINet/Top+Navigator/Customer+Care/Home-Residential/Time+of+Day+Rate+RT/To+learn+more+about+on-Peak+and+off-Peak+hours.

8. Customer Perspectives

After conclusion of the pilot program, occupants were asked to complete a brief survey covering their experiences with the HPWH. It should be noted the participant pool was limited to households related to UI in some way and which had volunteered for the pilot. Thus, participants' views may not be representative of the general population. Half of participants completed surveys as of the draft report date.[8]

In general, the main benefits perceived from installation of the HPWHs included dehumidification of basements and supply of hot water equivalent to or exceeding that provided by resistance water heaters. Participants were not able to identify savings on their electricity bills. This result was not surprising, given the study included both periods of operation of the system in HWPH mode and as resistance water heater alone, and each period lasted only six weeks.

Hot Water Satisfaction

Study participants were generally happy with the quantity and temperature of hot water during the operation of the HPWH. Two participants indicated the water was hotter and recovered more quickly after installation. However, as of December 2009, two sites complained they had insufficient hot water during the HPWH mode. Two factors helped explain this discrepancy. First, the hot water set temperature at the installation was 135° F. This temperature may have been higher than the setting before HPWH installation. Second, most HPWHs were installed in March or later, and ran into April in HPWH mode (see Table 4, above). The average cold water temperature in April was more than 10 degrees warmer than the average temperature in February (see Figure 4, above). Thus, most HPWHs were not operating in the period when the HPWH's capacity and backup resistance heating would be fully challenged.

Dehumidification

All survey respondents perceived a dehumidification benefit from HPWH operation. Three indicated they noticed a large difference. In one instance, the home owner unplugged their large, 100-pint per day dehumidifier, which they estimated operated 98% of the time during summer. They expressed satisfaction with the humidity control provided by the HPWH model R106, saying it was almost equivalent to that provided by the dehumidifier.

As discussed in the results section, large dehumidification benefits were not observed in the data. Dehumidification provided by a R106 should not equal that provided by a 100-pint/day dehumidifier operating 98% of the time (see Table 2 for rated dehumidification capacity of the HPWHs in this study). However, given the perceived dehumidification benefit, it appears home owners may switch off their dehumidifiers, believing the HWPH is providing equivalent or better humidity control.

---

[8] Additional winter metering continues at three sites, and surveys will be conducted after metering is completed.

Cooling Benefits

Survey respondents perceived a benefit from cooling related to HPWH operation. However, the impact was not perceived to be very large.

Noise

Survey respondents were aware of noise the HPWH produced, but they did not find it annoying. In one case, the home owner believed the unit became louder over time, but not to the point that it became a negative. Another participant thought the unit was quieter than the dehumidifier they usually ran. The HPWH installer told Cadmus staff he had heard complaints from participants about the units' noise. This may, however, be due to units malfunctioning and louder than normal operation. For example, Cadmus staff noted a loud and annoying sound from a R060 with a defective relay. Fortunately, this noise only lasted a few moments while the HPWH started. Decibel readings taken at the sites confirmed the manufacturers' ratings, and that the HPWHs, when operating correctly, produced noise equivalent to a dehumidifier.

Impact on Energy Bills

None of the participants could confirm an impact on their electrical bills. This partly could be due to the six-week HPWH operation period at each site during the pilot. To determine bill savings, a sustained operational period of a few months may be required.

Willingness to Lease a HPWH

Respondents said they would be willing to lease a HPWH, if a leasing option made financial sense.

Reliability and Performance

A number of reliability and performance issues were experienced with the HPWHs. At one site, for example, the R106 initially installed would not operate. A replacement unit had to be ordered and installed. The replacement unit developed a leak not long after installation, which, although it did not prevent the unit from operating, suggested a lack of quality in manufacturing.

The HPWH installer believed the E-Tech units used in the pilot were of inferior quality to previous HPWHs installed under earlier programs in Connecticut. At several sites, major problems with the E-Tech units, such as faulty relays, developed and required troubleshooting and repair by the installer. See Appendix B for a log of reliability and performance issues.

9. Conclusion and Recommendations

Three studies based in Connecticut, including this pilot, conducted over the past 10 years using various makes and models of HPWHs, have shown average energy savings of 40% to 50% are possible over electric resistance hot water heating.[9] HPWHs represent a savings opportunity for households using electric hot water heaters.

We recommend that if UI is to develop this pilot into a larger program, 1) HPWHs not be offered to one-person households, and 2) two-person households should receive a HPWH only if high hot water use is anticipated.

Average demand reduction found in this pilot was about half that indentified in previous studies. HPWH demand was on par with that found in earlier studies, but demand from the electric resistance heating was substantially less. Over half of the tanks had heating elements of only 3,000 Watts, which may partly be responsible for the lower demand from resistance heating. As opposed to higher capacity elements, these elements would tend to flatten the demand curve.

Study participants were open to using a HPWH and did not express strong reservations outside of ensuring the units supplied an adequate amount of hot water, and that they actually saved energy. Noise was generally not an issue, unless units were malfunctioning. The dehumidification capabilities were valued by the participants, even though results of metering HPWH impacts on relative humidity and perceptions of their impact by participants did not necessarily correlate.

In all, an opportunity exists for achieving energy savings from HPWHs in UI territory. Similar to previous studies, however, product reliability issues encountered make expansion to a full program problematic. Based on experience over a short timeframe with the E-Tech HPWHs, Cadmus does not recommend widespread adoption until:

(1) The reliability of units can be demonstrated under conditions similar to those experienced in UI territory;

(2) Manufacturer representatives are locally available to help troubleshoot and repair problematic units; and

(3) Training from manufacturer representatives on installation and maintenance is available.

In regards to piloting or developing a program to promote installation of other HPWH makes and models, we recommend the following:

(1) Potential pilot sites should be screened for hot water usage and matched to an appropriately sized HPWH to ensure significant energy savings and that participants will have sufficient hot water. One person households should not receive a HPWH. Two-person households should get a HPWH only if they demonstrate higher than normal hot water usage (i.e. by frequently using a large, jetted bathtub).

[9] See AIL (2001) and AIL (2002) for previous results.

(2) When screening potential participants, it should be noted the cold water temperature in winter is less than 50 degrees. Actual recovery rates in winter will be significantly lower than in the summer. This indicates that larger tanks (i.e. 80-gallon) are recommended where high hot water use is expected.

(3) One recently developed HPWH is the GE Hybrid Water Heater. It has a 50-gallon tank and a recovery rating of 69 gallons per hour. Based on hot water usage results in this study and specifications for the GE model, households with two to four people are recommended for pilots with this model. Households with less people will likely use less water and see relatively minimal savings compared to a price currently around $1,800 with a premium over resistance water heaters on the market of over $1,000. Households with more than four people may occasionally run out of hot water in the winter months.

(4) Leasing rather than buying a HPWH may offer an added benefit of improved maintenance on HPWH. It is recommended any leasing option include annual maintenance and checkup to include cleaning or replacing filters and other required maintenance. It is unlikely homeowners will remember to perform maintenance.

(5) When selecting a HPWH for a pilot, consider whether manufacturers' representatives are available in the area to help with any troubleshooting or repairs.

(6) To maximize energy savings with a HPWH, homeowners will need to know how to balance comfort against energy savings. New units on the market have a number of operating modes, including those for optimal efficiency, temporary high-water use, and vacations. As most homeowners do not think of their water heaters as an appliance that needs to be adjusted to current use patterns, it is recommended pilot participants be trained in the HPWH's operation and be encouraged to call with questions.

Appendix A: Terms Used In This Report

For clarity, definitions and usage of terms used throughout this report are detailed below.

Coefficient of Performance (COP): The ratio of heat output in BTUs during the HPWH or resistance water heating periods to the energy input (kWh converted to BTU).

$$COP = \frac{8.33 \times V \times (T_{Hot} - T_{In})}{W_{Hours} \times 3.412}$$

Where: V = volume of water entering the tank (gallons)
T_{Hot} = hot water temperature (°F)
T_{In} = temperature of water entering the tank (°F)
W_{Hours} = Watt-hours of electricity used (Wh)

COP denotes results from field studies in this report. A higher COP indicates a more efficient unit. In this study COP typically refers to average results over a day or the entire metering period. Energy use by the HPWH or resistance water heater is affected by:

- *Recovery efficiency*: how efficiently heat from the energy source transfers to water.
- *Standby losses*: the percentage of heat loss from stored water compared to the water's heat content.
- *Cycling losses*: heat loss as water circulates through a water heater tank and/or inlet and outlet pipes.

Relative Coefficient of Performance (COP_R): the ratio of resistance water heating and HPWH COPs. This term follows the definition used in the 2001 HPWH evaluation except that a ratio of COPs is used rather than electricity.[10] COPs, rather than electricity used, are required to account for varying hot water use and temperature during the HPWH and standard water heater periods. The term is used here to allow direct comparison with results from previous studies. Relative savings can also be derived from COP_R:

$$\%Savings = \left(1 - \frac{1}{COP_R}\right) \times 100\%$$

Energy Factor (EF)**:** the ratio of heat output (BTU) to energy input (kWh converted to BTU). Federal appliance efficiency standards require water heaters be metered through a 24-hour period of simulated hot water use. The standard EF varies with a tank's rated volume, and ranges from 0.81 for a 120-gallon tank to 0.92 for a 40-gallon tank for electric resistance hot water heaters.[11]

[10] Ail Research, Inc. *Heat-Pump Water Heater Field Test: 30 Crispaire Installations*, Final Report. April 4, 2001.

[11] On January 17, 2001, the U.S. Department of Energy (DOE) prescribed the current energy conservation standards for residential water heaters manufactured on or after January 20, 2004. 66 FR 4474. DOE is currently revising these standards. See http://www.thefederalregister.com/d.p/2009-12-11-E9-28774

Appendix B: Reliability Log

2009 HPWH Pilot Program notes, comments and feedback.

1. **GENERAL.** R106k units have not had enough clearance to place on the top of the tank. They have been placed on the floor.
2. **SITE 5:** Installation of one R106h had issues which required troubleshooting by installer. Original unit was replaced with a backup.
3. **SITE 10:** R060 may be noisier than the larger units. The unit is reported to be loud.
4. **SITE 4:** Had a weird animal/metal sound coming from the unit. It sounded like it was trying to work but could not. Hone owner cycled it on and off and cleared the problem. (3/16/09)
5. **SITE 8**: Internal Relay and coil shorted out. Etech blamed it on a power surge, but nothing else in the house was damaged. (4/13-4/24)
6. **SITE 2:** Unit reported to be short cycling. Need to replace low ambient temperature sensor. (4/13-4/24)
7. **SITE 10:** condensate line was pushed back into the basement by an animal probably and caused water damage on the wall and GSI socket.
8. **SITE 11:** Unit was replaced before data loggers were installed. North Road Technologies had found a manufacturer defect during testing and had the unit switched out. (July)
9. **SITE 11:** ran out of hot water with the HPWH unit. They are looking into if it is a result of not having low flow shower heads.
10. **SITE 10:** compressor failed. Contacted ETech/A.O. Smith and the unit was replaced under warranty. There was a week delay in getting a response from the company.
11. **SITE 3 and SITE 7**: Units reported to have cycling issues, requiring continuous reset of the unit.
12. **SITE 8**: Relay chatters when unit starts (October)