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Measured Performance of Heat Pump Clothes Dryers

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ABSTRACT

Within a 53 home monitored sample, long-term energy use of electric resistance clothes dryers was sub-metered. Average measured dryer energy use was 3% of total household energy or 814 kWh/year. Hourly dryer electrical demand profile showed large coincidence with utility summer afternoon peak and significant increases over weekends versus weekdays.

After collection of baseline data, electric resistance clothes dryers were replaced with a new condensing and unvented Heat Pump Clothes Dryer (HPCD) and matched ENERGY STAR® clothes washers in eight homes. Six homes had interior utility rooms; at two sites the sets were located outside the conditioned zone. Savings were achieved at all homes, with a median annual energy savings of 34% (312 kWh/year). The dryer was paired with a high-efficiency washing machine designed to remove more moisture than typical models. While the impact of the washing machine on the HPCD was not measured, a benchmark calculation suggests 35% of the HPCD savings may be attributable to the new washers improved moisture removal ability.

Although the unvented HPCD uses less electricity than a standard resistance dryer, it was found to release a significantly more heat than a conventional dryer during operation. The unvented units located inside the homes led to very high utility room temperatures and an increase in space cooling energy that may compromise identified savings. However, with a current retail cost of $948 there is only a small premium on the HPCD dryers, making them cost-effective when chosen at time of replacement.

Introduction

The U.S. Department of Energy Building America team— Partnership for Improved Residential Construction (BA-PIRC)—collaborated with the Florida Power & Light (FPL) utility to conduct a phased residential energy-efficiency retrofit program. This research sought to determine the impacts on annual energy reductions from the installation of advanced residential technologies. Earlier project work involving the application of two levels of retrofit - shallow, targeting simple, low-cost measures such as lighting and appliances; and deep, targeting major equipment replacement and envelope improvements. Average savings for the two levels of retrofit were found to be 8%–10% and 38%, respectively. The latter approaches the Building America program goals of reducing whole-house energy use of existing homes by 40% (Parker 2016). In addition, whole-house demand reduction among the deep retrofit homes averaged 39% during the FPL peak summer hour and 60% for peak winter hour.

Phase II of the Phased Deep Retrofit (PDR) project included single retrofit measures applied to shallow retrofitted homes that could be used to refine the deep retrofit package and identify technologies less well proven. This process was referred to as "Shallow-Plus" retrofits. Phase II involved the installation of eight energy-efficiency retrofit measures among subsamples of the larger study's 56 existing all-electric homes. This report describes measured end-use energy savings and an economic evaluation from evaluating heat pump clothes dryer (HPCD) retrofits in eight of the homes using the Whirlpool model WED99HED.

Background

The 56 central and south Florida homes in the PDR project were built between 1955 and 2006, average about 1,700 ft^2 in conditioned area, and have an average occupancy of 2.6 persons. Total house power as well as detailed energy end-use data were collected to evaluate energy reductions and the economics of installed retrofits. All of the studied homes were audited and instrumented during the second half of 2012, and shallow retrofits were conducted from March–June 2013. The energy reduction measures for the shallow retrofit included those for lighting (compact fluorescent and light-emitting diode lamps), domestic hot water (water heater tank wraps and low-flow showerheads), refrigeration (cleaning of coils), pool pumps (reduction of operating hours), and use of "smart plugs" for home entertainment centers.

When the PDR project began in 2012, detailed audit data were obtained from all homes, including house size and geometry, insulation levels, materials, finishes, and equipment. Blower door and duct leakage tests were completed on each home. Detailed photographs were also taken of each home's exterior, appliances and equipment, and thermostat. Monitoring of house power and the various end uses was accomplished with a 24-channel data logger, with an error of ±1%. This was supplemented by portable loggers to take temperature and relative humidity (RH) readings with errors of ±0.95°F and ±3.5% RH respectively. Data were collected on a 1-hour or 15-minute time step. A dedicated website[1] was set up to host monitored project energy data.

In a 45 home sub-sample of the PDR sites that did not receive a dryer retrofit during 2013, existing electric resistance clothes dryers were found to account for 3% or 741 kWh/yr of annual energy consumption. For a larger sample of 53 homes, including the higher-use "deep retrofit" sites, the average was 814 kWh/yr[2]. These estimates are lower, but match well with previous studies of measured electric residential dryer energy use. For instance, sub-metered clothes dryer consumption of 223 electric dryers in the Pacific Northwest (PNW) was 918 kWh/year (Pratt 1989). Similarly, measured clothes dryer energy use in a more recent Cadmus study in the PNW (Korn 2010) was ~950 kWh/year for standard units. In Florida, a utility metering study of 151 dryers in 1999 in single family homes showed average energy use of 885 kWh/year (Parker 2002). As documented in the Cadmus research, dryer energy use is strongly linked to clothes washer efficiency in terms of reducing residual washer moisture load. Thus, as clothes washers become more efficient, even standard resistance clothes dryers faced with lower residual moisture can be expected to show progressively lower overall energy use.

In the PDR monitoring, we found that dryer energy use was generally larger in homes with greater occupancy. Table 1 provides the average dryer energy consumption segmented by 1, 2, 3 and 4 person households for the non-deep sample (the subset of one six-person household is excluded). Table 2 shows the average monthly clothes dryer consumption with indications of little variation from the annual average.

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[1] www.infomonitors.com/pdr/

[2] As shown in Table 3, the eight homes that received deep retrofits tended to have greater dryer energy than the rest of the 45 homes in the sample. If all 53 homes are included, estimated annual dryer energy use was 814 kWh/yr.

Table 1. Average 2013 Dryer Energy Consumption by Occupancy

	Sample (n = 45)[a]	1-Person (n = 2)	2-Person (n = 30)	3-Person (n = 8)	4-Person (n = 4)
Avg. kWh/Day	2.0	1.1	1.7	3.2	2.4
Median kWh/Day	2.0	1.1	1.7	2.6	2.5
Avg. kWh/Year	741	405	609	1,169	887
Median kWh/Year	720	402	622	932	893

[a] The subset of one six person household is excluded.

Table 2. Average Daily Baseline Dryer Energy by Month for 45 Home Sample for 2013

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Energy (kWh/Day)	2.1	2.1	2.1	2.1	1.9	2.1	2.0	2.0	2.0	1.8	2.0	2.2

Figure 1 shows the average-day dryer demand profile for the homes for 2013, along with plots for select months. Each data point is the average hourly dryer power for all homes, taken from one minute measurements and then averaged for every day in the period resulting in the diversified appliance electrical demand. While individual electric resistance dryers can use on the order of 5 kW while operating (Bendt 2010), data points in Figure 1 represent an average demand for all measured dryers for the hour. In many cases, dryers are not operating in a given hour and the diversified demand includes averages both for those in use and those not in use. As seen in the figure, maximum dryer energy demand occurs around noon, with a broad demand between 8 AM and 8 PM. Little monthly variation is observed from the annual average mirroring the earlier finding of the large scale PNW study (Pratt 1989). Significant use occurs during utility summer afternoon and winter morning peaks and Figure 2 shows weekend dryer operation is nearly double use on weekdays.

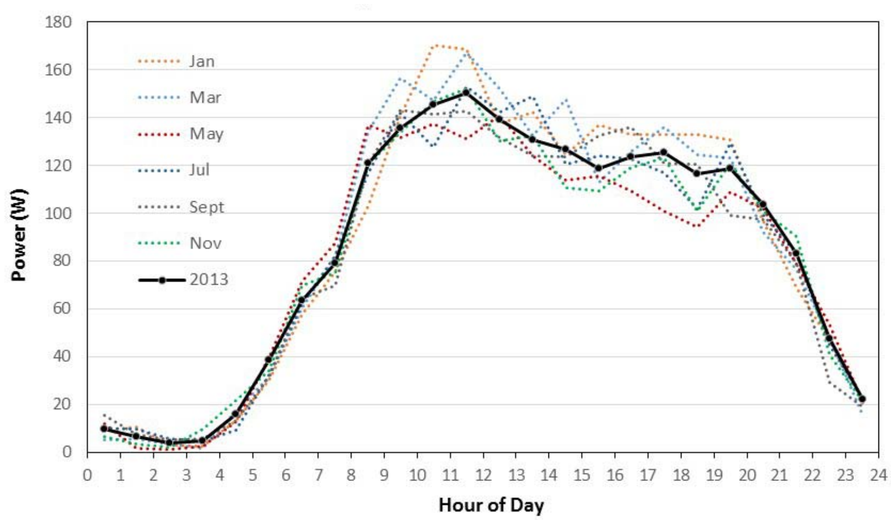

Figure 1. Average baseline clothes dryer daily load shape during 2013.

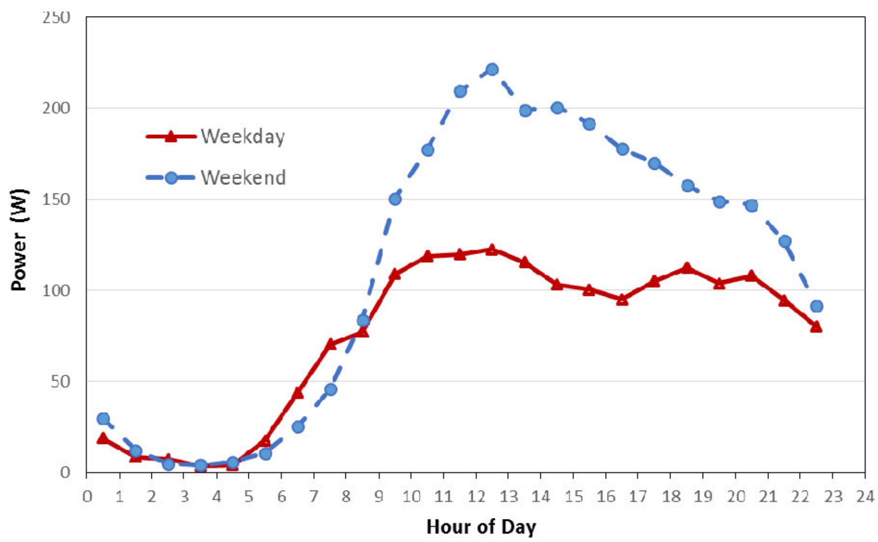

Figure 2. Weekday and weekend baseline clothes dryer daily load shapes during 2013.

Field Test of a More Efficient Electric Resistance Clothes Dryer

In 2014, eight project homes demonstrated energy savings from a highly efficient, washer and non-heat pump ENERGY STAR® clothes dryer. The Samsung DV457A1 clothes dryer modulates fan speed and drying time to provide energy savings. Energy savings were estimated in the laboratory at approximately 25-30% over standard dryers (Ecova 2013).

In this field experiment the matched clothes washer was a Samsung Model WF457 with a modified energy factor of 3.42.[3] Table 3 shows the measured dryer energy pre and post in the eight homes that received the higher-efficiency electric resistance dryer. Because clothes washer energy was not measured, its relative contribution to energy loads could not be examined. However, washer energy use is typically much smaller than that of the dryer; the energy use of the clothes dryer is the major energy-related impact of laundry cycles.

Table 3. Washer/Dryer Replacement Energy Savings (1 year pre and post)

Site	Average kWh/d		Δ kWh	Savings (%)
	Pre-Retrofit	Post-Retrofit		
8	3.8	3.2	0.6	17%
10	1.6	0.8	0.7	46%
19	10.1	6.3	3.8	37%
26	3.8	4.6	–0.8	–20%
30	2.5	2.0	0.5	19%
39[a]	0.7	1.1	–0.5	–70%
40	1.1	0.7	0.5	41%
51	0.7	0.8	–0.2	–24%
Average	3.4	2.6	0.7	22%

[a] Did partial line-dry before retrofit. Not included in averages.

[3] However, the owners of Site 26 objected to the front-load washer because of space constraints and selected instead an ENERGY STAR top-load washer (Samsung WA50F9A60).

In the eight home sample, the more efficient clothes dryer, supplemented by the matched washer, showed average savings of 22% (0.7 kWh/day) when evaluated over a 60-day period pre and post. Savings were highly variable, however; the home with largest use showed a 37% reduction, while some sites had negative savings. Explanation for such puzzling results were soon revealed. We received homeowner reports of dissatisfaction with the longer drying times of the most energy efficient "Eco-normal" cycle— likely a reason for the variability in savings. All but one of the sites often elected not to use the "Eco-normal" cycle because of drying cycle length and one homeowner was displeased with the unit's overall operation. Additional details of this evaluation are reported in the source report (Parker 2016).

Evaluation of Savings from Heat Pump Clothes Dryers

In order to explore the potential for greater dryer energy savings and improved customer satisfaction, the electric resistance clothes dryers were replaced with new Whirlpool HPCDs in 2015. This unvented condensing dryer model (WED99HED), with an Energy Efficiency (EF) of 3.71 lbs/kWh is designed to be approximately 40% more efficient than standard units and was one of the units awarded ENERGY STAR®'s 2014 Emerging Technology Award.[4] The dryers were matched with a Whirlpool 4.5 cubic foot clothes washer (WFW95HED), with an integrated Modified Energy Factor (MEF) of 2.75. Occupancy information for the study homes and their existing washer and dryer makes and models are provide in Table 4.

Table 4. Heat Pump Clothes Dryer Site Characteristics

Site #	City	# of Occupants	Existing Washer Make / Model	Existing Dryer Make / Model	Appliance Location
19	Melbourne	2(3)[5]	Samsung / WF457	Samsung / DV457	Interior
22	Cocoa Beach	2	Kenmore / 1020712990	Whirlpool / 4WED5790SQ	Interior
25	Melbourne	2	GE / S2100G2WW	Alliance Speed Queen / ADE30RGS171TW01	Interior
28	Merritt Island	2	Whirlpool Duet / WFW9470WR01	Whirlpool Duet / WED9750WR0	Exterior
52	Cocoa	2	GE / WHRE5550K2WW	Kenmore / 96284100	Interior
53	Melbourne	2	GE / WWSR3090T2WW	GE / DWXR473ET2WW	Interior
58	Rockledge	2	GE / WWSR3090T2WW	GE / GTDN500EM0WS	Interior
61	Cocoa Beach	2	LG / WM2016CW	Whirlpool / WED9200SQ	Exterior

The Whirlpool HPCD is a 7.3 cubic foot condensing clothes dryer and is unvented, similar to high-efficiency European models. It has both a heat pump section and a supplemental electric heating element. There are three primary modes of dryer operation—eco mode, which mainly uses the heat pump, but with longer drying times; balanced, which uses both heat pump and electric resistance element operation to achieve faster drying times; and speed mode, which uses both the heat pump and electric resistance elements to dry in the fastest possible time.

In cooperation with homeowners, the more efficient clothes dryers and washers were installed in May and June 2015 with instructions provided on efficient operation. Seven of the

[4] www.startribune.com/energy-guzzling-clothes-dryers-finally-get-more-eco-friendly/292379401/, https://www.energystar.gov/about/awards/energy-star-emerging-technology-award/2014-emerging-technology-award-advanced-clothes-dryers

[5] Two-person occupancy for most of the pre-retrofit period; three-person occupancy for the last few months.

homes had conventional existing clothes washers and dryers that were then replaced by the efficient Whirlpool models. Site 19 had started in the PDR project with a standard washer and dryer, and participated in the Phase I retrofits, which included testing of the Samsung DV457 efficient resistance clothes dryer. Significantly, the occupants of Site 19 do a very large volume of laundry, with baseline dryer energy use (prior to project intervention) of about 9-10 kWh/day (~3,500 kWh/year). The Samsung efficient resistance dryer was shown to reduce consumption by 26% at this home. It was hoped that replacing the Samsung unit with the new Whirlpool HPCD dryer at this site would further reduce clothes drying energy.

Results and Discussion

Measured baseline data began at the onset of dryer energy monitoring, generally during the months of August – September 2014[6] through the install date for each washer/ HPCD pair, which occurred during the months of May – June 2015. The post-installation period data were from the installation date through early February 2016.[7] Although less than one full year, the 8-9 month baseline and study periods were deemed acceptable because, similar to what is seen in Figures 1 and 2, evaluation of clothes dryer data at each site revealed little time-of-year seasonality, although there was a strong time-of-day profile for clothes drying at each site. Each household also showed periodicity relative to the preferred time to do laundry—once every other day, each weekend or even every day. Figure 3 shows data for Site 25 from January 2014 to December 2015 with the daily clothes dryer demand plotted as well as the monthly summed clothes dryer energy. The timing and effect of the HPCD retrofit is clear in the data with measured clothes dryer electricity falling by more than half.

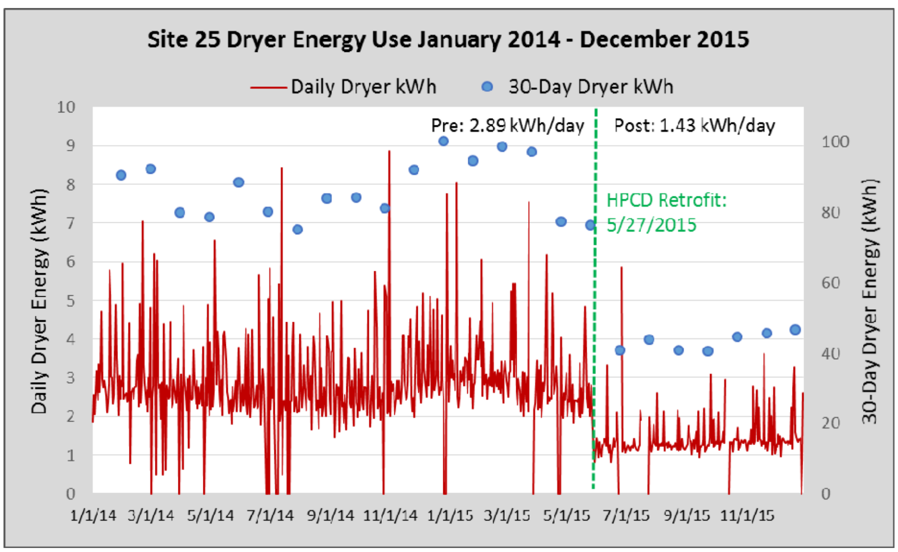

Figure 3. Time series data for clothes dryer energy at Site 25 from Jan. 2014 – Dec. 2015.

Table 5 shows the measured data in the pre- and post-installation periods for each site. However the savings level for clothes drying likely does not only reflect the efficiency of the

[6] Data collection for site 53 did not start until early December 2014.
[7] Homeowners at site 58 moved out 30 days after HPCD installation. While data continued to be collected with the new homeowners, analysis for this site is based on the one month the original owners spent with the HPCD.

clothes dryer, but also of the clothes washer in reducing the amount of moisture left in the clothes to be dried. An investigation into the washing machine's impact on the HPCD energy savings is presented in the next section.

Table 5. Summary Heat Pump Clothes Dryer Retrofits

			Pre- (2014-2015)		Post- (2015-2016)		Savings		
Interior	Site #	Install Date	Daily kWh	Annual kWh	Daily kWh	Annual kWh	Annual kWh	%	People
Y	58	May 14	1.4	513	1.2	453	60	11.7%	2
Y	52	May 26	1.4	527	0.8	308	223	41.6%	2
Y	25	May 27	2.9	1,073	1.4	518	573	51.7%	2
N	61	May 28	1.3	483	1.0	359	197	25.6%	2
N	28	June 1	2.4	890	1.9	679	335	23.8%	2
Y	53	June 1	2.4	878	0.7	245	500	72.1%	2
Y	19[a]	June 3	7.1	2,577	6.1	2,222	591	13.8%	3
Y	22	June 5	1.7	606	0.8	297	289	51.0%	2
Average			2.6	944	1.7	635	346	36.4%	2.3
Median			2.0	742	1.1	406	312	33.6%	2

[a] 2013—November 17, 2013, standard dryer used 8.30 kWh/day. Occupancy increased from 2 to 3 people toward the end of the pre-retrofit and the 3-person occupancy was maintained for the post-retrofit period, thus savings results are conservative.

Median energy savings in the pilot demonstration were estimated at 312 kWh/year or 34% of median baseline consumption and average savings of 346 kWh/year or 36%. Savings results at two sites are noteworthy. The savings for Site 19 would be 27% if based on the baseline unit, rather than more efficient Samsung DV457 unit in operation in 2014, and the owners at Site 58 refused to use the eco mode and instead chose the speed mode, which resulted in lower savings.

The HPCD impact on utility peak demand was also investigated. Figure 4 plots the average daily profile for seven of the eight HPCD sites pre-retrofit (2013) compared to post-retrofit (May/June 2015 – Feb 2016).[8] While this plot consists of annual data, as previously mentioned the seasonal variation is limited, thus this plot provides good indication for the large potential demand reduction coincident with utility summer peak—which typically falls between the hours of 4:00 and 5:00 pm. For the homes in this study, the HPCD generated a demand reduction in dryer energy of 0.09 kW or 48% between these hours.

[8] Site 61 was not instrumented until mid-2014 and is therefore excluded from the 2013 vs. 2015-16 evaluation.

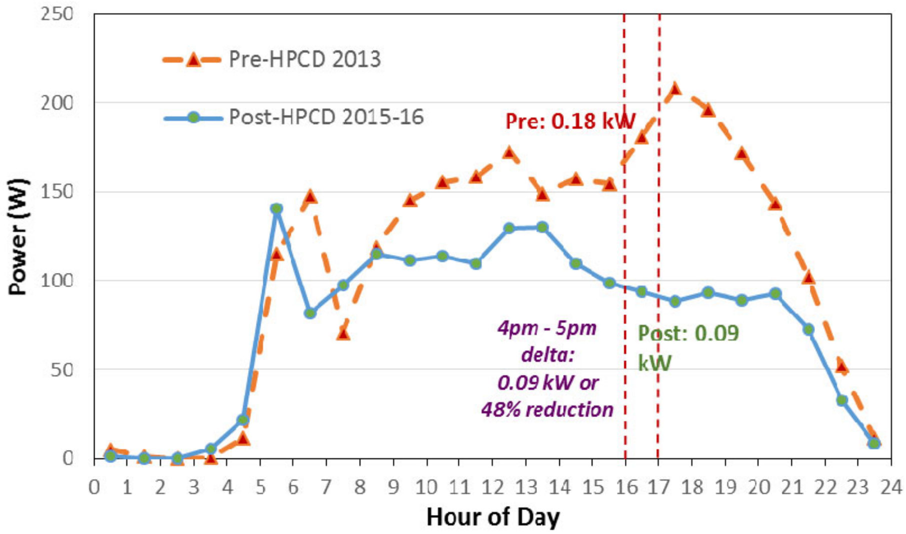

Figure 4. Comparative analysis between pre- and post-HPCD clothes drying demand. Post data also includes any effect of clothes washer replacement.

Low-Residual Moisture Washing Machine Impact on HPCD Energy Savings

The new heat pump clothes dryers were installed coincident with a high-efficiency, front-loading WFW95HED washing machine with an integrated MEF of 2.75. Washer energy measured for about 60 days pre and post suggests median annual washer energy use saving of 38% or 36 kWh/year, however with wide variation among sites including negative savings. In addition, this washer was designed to remove more moisture during its cycles than typical models. Thus, the matched HPCD dryer potentially has less work to dry a load and therefore some of the energy use reduction measured with the new HPCD may be attributed to starting loads with less moisture content.

The Whirlpool heat pump dryer, in turn, is more efficient than conventional electric resistance models with a laboratory tested EF of 3.71 lbs/kWh. Conventional electric resistance dryers have a laboratory tested EF of approximately 3.10 lbs/kWh. To investigate the potential impact of the washing machine's improved moisture removal on the HPCD energy savings, participants were asked to weigh their wet loads before being dried and again after the load was dried to satisfaction. Measurements were conducted on a target of at least ten loads for each evaluation period. The median pre- to post-retrofit reduction to field-measured residual moisture content (RMC) is estimated to be 9%, ranging from 5 to 20%, as summarized in Table 6.[9] (Site 22 is excluded from this evaluation given measurement quality issues.) This represents a reduction in moisture level of material coming out of the washer of about 23% in the post condition. Results confirm that the new washing machine with superior residual moisture removal characteristics is responsible for some of the HPCD energy savings.

[9] The field Residual Moisture Content, an approximation of RMC, is (Wet Weight – Dry Weight)/Dry Weight, where Dry Weight is the level of dryness chosen by the occupant. The standard RMC calculation using bone-dry weight, not collected for this project, would generally be expected to exceed the field RMC calculation.

Table 6. Pre and Post-Retrofit Field Residual Moisture Content (RMC)

Site #	Pre-Retrofit Washer	Median Field RMC		
		Pre	Post	Pre - Post
19	Front-load	54%	34%	20%
25	Top-load	35%	30%	5%
28	Top-load	41%	32%	9%
52	Top-load	45%	29%	16%
53	Top-load	44%	26%	18%
58	Top-load	37%	28%	9%
61	Front-load	36%	27%	9%
Minimum		35%	26%	5%
Maximum		54%	34%	20%
Median		41%	29%	9%

We used calculations given in Parker and Fairey (2010) for predicting dryer energy use according to the Building America benchmark procedures (Hendron 2010) which largely mirror the very detailed methods outlined by Hannas and Gillman (2014) to estimate the relative impact of the washer and dryer on the overall achieved savings. The calculation considers EPA EnergyGuide data, washer and dryer Energy Factors, and washer capacity, among other variables. We evaluated and compared the installed Whirlpool set (WFW95HED and WED99HED) to the installed Whirlpool washer paired with a minimum efficiency ENERGY STAR® dryer and to an installed Whirlpool HPCD paired with a minimum efficiency ENERGY STAR® washer. Minimum efficiency ENERGY STAR® appliances were selected as the comparison appliance as general, approximate representations of the study homes' baseline equipment efficiencies.

Together, the model predicted that the HPCD and high-efficiency set would in combination produce a savings of 37% and 307 kWh/year. This compares very well with the field measured median savings of the washer/dryer combination of 34% and 312 kWh/year. This analysis also predicted that the installed washer would produce about a 118 kWh/year of the savings (14%) and that the installed dryer would produce a 220 kWh/year (26%) of the savings. As such, we surmise that about 35% of the measured dryer energy savings in our study are coming from the improved washer water removal with the remaining 65% coming from the heat pump clothes dryer – provided a minimum efficiency ENERGY STAR baseline washing machine. This agrees with the study of Korn and Dimetrovsky (2010) which found most of clothes washer energy savings came from the ability of higher efficiency washers to remove end-of-load residual moisture.

Measure Economics

With predicted median annual savings of 312 kWh ($37 at 0.12/kWh), the Whirlpool HPCD is not a cost-effective measure at outright replacement, given its full cost of $948[10]. Additionally, some portion of the energy cost savings can likely be attributed to the low-residual moisture washing machine. However, based on the assumption that consumers will only purchase the HPCD if they are in the market for a new dryer, economic evaluation should only

[10] The manufacturer's suggested retail price is $1699, but a few retailers, including Home Depot, advertise the dryer at this price online. There are no incentives available for this dryer in Florida. Costs for the Samsung dryer are not presented since the dryer is no longer available.

consider the incremental cost for the HPCD. Supposing a standard dryer costs about $700, the incremental cost of $248 will be paid back in about 5 years with a 20% annual rate of return.

Arguably, the cost of the paired low-residual moisture washer should be considered, which makes economics appear less attractive. While market data suggests matched washer-dryer pairs are chosen 50-55% of the time (US Department of Energy 2015) and a low-residual moisture washer was paired with the HPCD in this project, such economics are difficult to project within this study. The energy savings during laundry washing must also be considered. As previously mentioned, washer energy measured for about 60 days pre and post suggests median annual washer energy use saving of 38% or 36 kWh/year. Economics of the paired set would also need to account for water heating energy cost savings which was beyond the scope of this study.

Homeowner Acceptability Issues

During operation of the unvented HPCD, the condensed moisture from clothes is passed down a drain and the waste heat from the heat pump and electric resistance elements is released into the space. Although the amount of sensible heat released into the space from the non-venting HPCD was expected to be modest given the increased efficiency of the unit, the actual experience was quite different. Although vented electric resistance clothes dryers use about 40% more electric power, greater than 95% of that heat is vented outside the home as shown in detailed testing done by Ecova (Figure 1 in Bendt 2010). For the ventless HPCD clothes dryer, however, all of the energy used becomes heat that is released to its surroundings.

Utility room temperature data showed a very significant quantity of sensible heat was released—much more than the amount of heat released to the space from a conventional electric resistance vented clothes dryer. Figure 5 plots the dry bulb and dew point temperature measured inside the interior laundry room at Site 25 several weeks before and after the installation of the new unvented HPCD, installed May 27, 2015. This household provides a particularly telling illustration of the issue given their regular daily laundry. Pre-retrofit, the dry bulb temperature of the utility room during appliance operation rose from about 80°F to 83–84°F. However, post-HPCD dryer installation, the utility room dry bulb temperature frequently exceeded 95°F and nearly approached 100°F. Ambient moisture levels also varied somewhat, with slightly elevated room dew point temperatures coincidental with the room dry bulb temperature spikes associated with dryer operation.

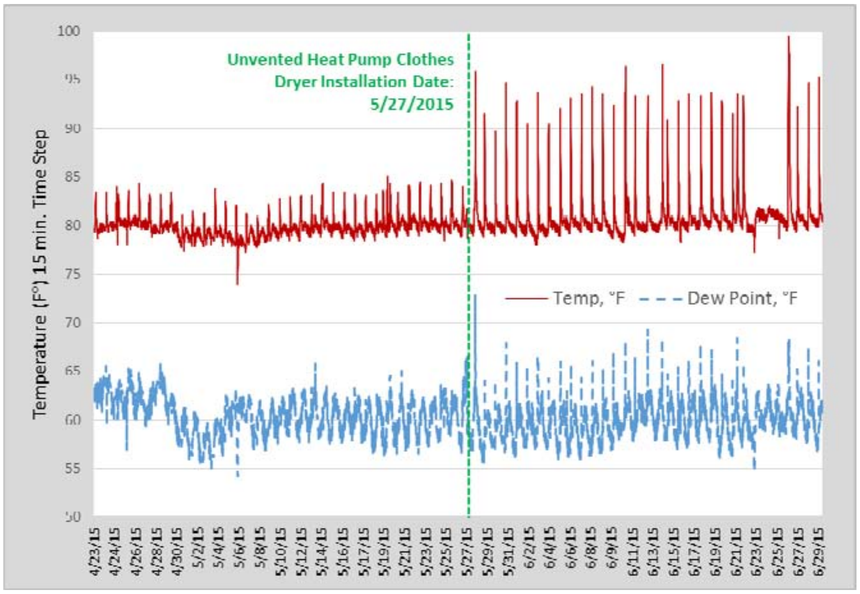

Figure 5. Site 25 laundry room dry bulb and dew point temperature pre- and post-unvented heat pump clothes dryer installation.

Notably, four other sites complained of both noise and excessive heat during system operation (19, 53, 58, and 61). Such issues, particularly excess heat release, could limit adoption of the technology in hot and humid Florida.[11] A HPCD vented to the outside is much more likely to be popular in Florida's climate, and researchers are looking for opportunities to test new vented models that have recently entered the market, such as the LG DLHX4072V.

Interactions of Condensing Clothes Dryers with Cooling

In recent years, it has been postulated that ventless clothes dryers, like the tested fully condensing Whirlpool model, might result in less heating and cooling given less induced air infiltration within the building envelope (eg, Bendt 2010).[12] Standard vented clothes dryers exhaust an air stream of approximately 125 - 150 cfm in operation and it seems certain that operation would alter building air infiltration. However, because of the complexity of how such unbalanced ventilation interacts with building air leakage and natural air infiltration, much of the anticipated increase to natural air infiltration may not occur.

More importantly, although the energy use of the ventless condensing clothes dryer is lower than the vented models for the same drying load, *all* of the energy used is converted to heat inside the dryer environment. If the dryer is in a garage or basement, this may not be an issue. However, if dryers are in interior utility rooms (as are many in Florida), the resulting increased internal gains potentially reduce space heating, but also may significantly increase cooling. This was explicitly observed in overheated laundry room temperatures in the study. This tendency to potentially increase space cooling has been predicted by a detailed simulation model (SEEM) developed in the Pacific Northwest (Dymond 2016). Essentially, ventless clothes

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[11] With shared data, Whirlpool is reportedly looking into several modifications to mitigate the excessive heat issue.
[12] Examples in popular media: http://www.greenbuildingadvisor.com/blogs/dept/guest-blogs/heat-pump-clothes-dryers Also: http://www.treehugger.com/sustainable-product-design/heat-pump-dryer-may-be-answer-energy-crisis-our-laundry-room.html

dryers look to have favorable space conditioning influences in heating dominated climates and disadvantageous ones in cooling intensive regions.[13]

The PDR project provided a unique opportunity to examine the above influences. Since heating and cooling energy as well as clothes dryer energy was measured, the project allowed the influence of dryer energy use on cooling energy in Florida's climate to be studied. Within the evaluation, we used well-developed weather normalized regression models to examine how dryer energy use might influence space cooling (the few winter days in Florida made it impossible to examine heating influences). Our evaluation indicates that any reduction of infiltration-related cooling loads is swamped by added internal sensible heat gains from interior located ventless dryers. The models consistently showed the electricity use of the vented electric resistance clothes dryers in the pre-retrofit period was not statistically associated with space cooling. This was expected since virtually all of the vented dryer consumption is released to the home exterior (Berndt, 2010). Also, the fact that a coefficient in the model for vented clothes dryer use was small and not statistically significant can also be interpreted to mean that the impact of the vented clothes dryer use on cooling loads arising from any added infiltration in summer is not large or is highly variable and not captured by the model.

Conversely, three of the four homes with the interior, fully-condensing, ventless clothes dryers showed a strong statistical increase in cooling energy even after controlling for weather and other internal appliance loads. The coefficients for the interior dryer electricity use were highly significant ($p > 0.000$ to 0.008) with the minimum coefficients at a 95% confidence level being 0.26 - 0.42 kWh increase in air conditioning for each kWh of dryer energy use. The fourth house did not show the ventless dryer retrofit increasing cooling energy in a statistically meaningful fashion. We also examined interior temperatures at each home by the thermostat (logged hourly) and found no evidence that the cooling system had been set lower in response to the dryer retrofit in any of the homes.

Our cursory evaluation suggests the NEEA SEEM model (Dymond 2016) is correct and interior ventless dryers can be expected to reduce heating loads, but at the cost of increases to cooling. The magnitude of the interactions depends on the climate. During Florida's long cooling season (often six months or more) interior, ventless clothes dryers can be expected to increase cooling in a fashion that will largely negate savings produced by the dryer itself. Of course, the impact during the few weeks of winter would likely trend the opposite direction and during the shoulder months in spring and fall, the dryers would likely not influence cooling.

Again, an exterior-located ventless dryer would not suffer from this cooling load penalty. Alternatively, vented heat pump clothes dryer technology may be more appropriate in cooling-dominated regions when being installed in conditioned space since added internal heat gain release is largely avoided. It is expected that in heating-dominated climates the characteristics of interior, ventless dryers would become a benefit, both due to the value of the added heat as well as the likely greater savings from reduced air infiltration.

[13] A common error is to assume that all the dryer ventilation increases infiltration by a like amount. Since unbalanced dryer exhaust ventilation of perhaps 150 cfm will strongly dominate natural air infiltration, the actual impact will depend on the building air infiltration in the particular hour when the dryer operates and will necessarily be less than the absolute flow rate. The SEEM model (Dymond, 2016) evaluates competing influences and indicates that while an interior non-vented condensing clothes dryer will significantly reduce heating in northern climates, the opposite is true in cooling dominated locations where increases can be expected to space cooling.

Conclusions

Measured clothes dryer energy in a detailed end use metering project in 53 Florida homes showed average consumption of 814 kWh/year along with rich information on load demand profile, seasonality of use and household usage patterns. Within the project two types of efficient clothes dryers were tested on sub-samples of homes.

A field test of an efficient electric resistance clothes dryer with longer drying cycles was measured to save 22% or an estimated 266 kWh/yr in eight sites in 2013, although with great variability in results and expressed dissatisfaction with the length of the drying cycle.

However, a field test of unvented condensing HPCD achieved energy savings among all eight homes. The estimated median energy savings were 34% (312 kWh/year or 0.92 kWh/day) for an average annual savings are 36% (346 kWh/year or 0.85 kWh/day). There were also sizeable energy demand reductions coincident with utility summer peak. ENERGY STAR® washing machines were installed along with the clothes dryer. The energy-efficient washing machines are likely removing more moisture from the laundry loads than the replaced washers, thus also contributing to these savings. The model installed in this study may be responsible for about 35% of the HPCD energy savings given its improved moisture removal capability.

With a current available cost of $948, there is only a modest premium at the time of purchase for the HPCD compared with standard resistance dryers. With replacement at the end of appliance life, and incremental cost, the HPCD choice appears quite economic, although depending on the cost of the standard model. However, these economics ignore HPCD energy savings that might be attributed to the paired low-residual moisture washing machines.

Although the HPCD use less electricity than a standard resistance dryer, the unvented model tested released a significant quantity of heat. It also added slightly greater moisture to the building interior during operation. The units that were located inside the home led to very high utility room temperatures and increases in cooling energy that may compromise identified dryer savings. Thus, these unvented clothes dryers appear only appropriate in Florida if they will be installed outside of the conditioned space, typically in the garage.

It seems likely that vented HPCD technology is the superior solution in Florida considering many dryers are located inside the conditioned space. However, the condensing unvented clothes dryers may be a very attractive option in heating-dominated climates, particularly given reductions to infiltration related air leakage (Dymond 2016).

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