Dehumidifiers: A Major Consumer of Residential Electricity

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ABSTRACT

An estimated 19% of U.S. homes have dehumidifiers, and they can account for a substantial portion of residential energy use. Annual electricity consumption by dehumidifiers can be 1,000 kWh or more, twice as much as an ENERGY STAR refrigerator uses. This study measured power, water removal rates and ambient humidity for 21 residential dehumidifiers in the Northeast and Mid-Atlantic regions over a three month period in 2011. Measuring water removal rates allowed for calculation of the energy factor (water removed per unit electricity), a metric rarely captured in field operation. The analysis shows efficiency, operating hours and electricity consumption. Key findings include that field efficiencies of many units are quite low and the humidity controls on some dehumidifiers do not function properly.

Dehumidifier Use and Efficiency

A recent report estimates that 19% of U.S. households have at least one dehumidifier (Appliance Magazine 2008, 7). Dehumidifier capacity is rated by the volume of water that can be removed from the air, usually measured in pints per day. Most residential units have rated capacities between 25 and 75 pints/day with some more than 100 pints/day. Most dehumidifiers sold in recent years allow the user to adjust the relative humidity (RH) setpoint (often selected in terms of % RH, sometimes other options such as low/medium/high) and the fan speed.

Efficiency Ratings

Efficiency of dehumidifiers is rated in terms of energy factor (EF), the volume of water removed from the air per unit of energy consumed, measured in liters per kilowatt-hour (L/kWh).

A Federal standard regulates the minimum EF of dehumidifiers manufactured in the U.S., with a scale of EF requirements based on unit capacity, and ENERGY STAR provides a specification for high efficiency dehumidifiers. The current ENERGY STAR specification for dehumidifiers (V2.1) has been in effect since 2006, and EPA estimated that 82% of dehumidifiers sold in 2009 met the current ENERGY STAR requirements (EPA 2011a). In October 2012, both a revised Federal standard and revised ENERGY STAR specification (V3.0) will go into effect. Table 1 shows these current and future standards.

Table 1: Efficiency Standards for Dehumidifiers, Energy Factor (L/kWh)

Current				Effective October 2012			
Federal standard		**ENERGY STAR V2.1**		**Federal standard**		**ENERGY STAR V3.0**	
≤ 25 pints/day	1.0	≤ 25 pints/day	1.2	≤ 35 pints/day	1.35	< 75 pints/day	1.85
> 25 to ≤ 35	1.2	> 25 to ≤ 35	1.4				
> 35 to ≤ 54	1.3	> 35 to ≤ 45	1.5	> 35 to ≤ 45	1.5		
		> 45 to ≤ 54	1.6	> 45 to ≤ 54	1.6		
> 54 to < 75	1.5	> 54 to < 75	1.8	> 54 to < 75	1.7		
≥ 75	2.25	≥ 75	2.5	≥ 75	2.5	≥ 75 to ≤ 185	2.8

Source: NARA 2010 & EPA 2011b

Research Methodology

Study Sample & Metering Period

The Cadmus Group metered 21 dehumidifiers operating in 19 homes in Massachusetts, New York, Maryland and Virginia. Metering of each unit began between mid September and early October 2011 and continued for one to 12 weeks. In most cases, metering continued until the dehumidifier was turned off for the season, or for at least two months for the units that run year round. We interviewed participants about their usage patterns and asked them to run their dehumidifiers as they normally would throughout the metering period.

The timing of this study did not allow for measurement of peak operation expected during the spring and summer. Therefore annual projections based on this study are expected to be conservative estimates of dehumidifier operation.

Metering Approach

Power meters measured the wattage of the dehumidifier continuously and logged power in five-minute increments. Meters placed near the units measured the ambient temperature and RH. We gave data collection sheets and graduated measuring buckets to participants who manually emptied their units, and they kept a log of the time and volume of water each time they emptied it.

Research Findings

Model Information & Configurations

Table 2 shows the sample of dehumidifier models and configurations included in the study. Dehumidifiers ranged from new to 15 years old, with an average of four years old. The average rated capacity was 45 pints/day, with units ranging from 25 to 70 pints/day.

All of the models purchased in the last five years meet the current ENERGY STAR standard. The EF rating was not available for the three oldest models, but neither of the units older than five years for which we had EF ratings met the current ENERGY STAR level.

All of the dehumidifiers were used in basements, a mix of finished and unfinished. Two participants had two units each operating in the same basement. Six of the 21 units were set up

to drain directly, and the remaining 15 units needed to have the tub of collected water emptied manually.

Participants used an average RH setting of 50%, with a range of 35% to 65%. Reported fan speed settings were split evenly between low and high, with a few participants changing their setting during the metering period. A few of the oldest models didn't offer a choice of fan speed.

Table 2: Dehumidifiers in Study

Age (years)	Capacity (pints/day)	Rated EF (L/kWh)	RH Setpoint	Direct Drain or Manually Empty
0	25	1.2	Continuous	Empty
0	30	1.4	55%	Drain
0	45	1.5	55%	Empty
0	70	1.8	40%	Empty
2	40	1.62	60%	Empty
2	45	1.5	Unknown	Empty
2	45	1.5	40%	Empty
2	45	1.5	55%	Empty
2	50	1.6	50%	Drain
2	50	1.75	40%	Drain
2	65	1.8	60%	Empty
2	65	1.8	50%	Drain
3	Unknown	Unknown	35%	Empty
5	45	1.56	40%	Empty
5	45	1.56	65%	Drain
5	50	1.75	55%	Empty
6	30	1.3	63%	Empty
8	50	1.56	45%	Empty
10	25	Unknown	Medium	Empty
12	40	Unknown	Unknown	Empty
15	50	Unknown	Medium	Drain

Usage Patterns

About half of participants leave their units on year round, and the other half run them seasonally for a period between spring and fall. Most participants who use their dehumidifiers seasonally turned them off in October or November, and they reported that they turn them back on between April and July. The average reported operation was 8 months/year.

Most of the participants without direct drains waited until the tub was full to empty their dehumidifier. Some checked their units at least once a day, while others only checked and emptied their dehumidifiers occasionally, so the tub may be full for hours or days before being emptied.

Most participants left their units on throughout their metering period. A few people turned their units on and off manually, with reported reasons including saving energy and reducing noise when they are near the unit.

Power

Standby Power. Meter data showed that 10 units drew no power when not operating, while the other 11 drew standby power between 0.4 and 1.9 Watts. Units using standby power ranged from new to eight years old. One user observed that the fan operated continuously on his new unit after reaching the humidity setpoint, so he turned the unit off manually to reduce energy consumption.

In December 2010, the U.S. Department of Energy proposed to amend the test procedure and energy consumption equations for dehumidifiers to include the measurement of energy use in standby and off modes (NARA 2010, 75290).

Active Power. The average power when running, excluding standby power, was 459 Watts. Figure 1 shows the average active mode power and age of each unit. A linear regression shows a limited correlation between unit age and average power. While age may affect dehumidifier power, there are several other expected factors including unit efficiency, user settings and ambient conditions.

The maximum power metered for each unit ranged from 375 to 964 Watts, as shown in Figure 2. A linear regression shows a limited relationship between unit age and maximum power.

Figure 1: Average Active Power Vs. Unit Age

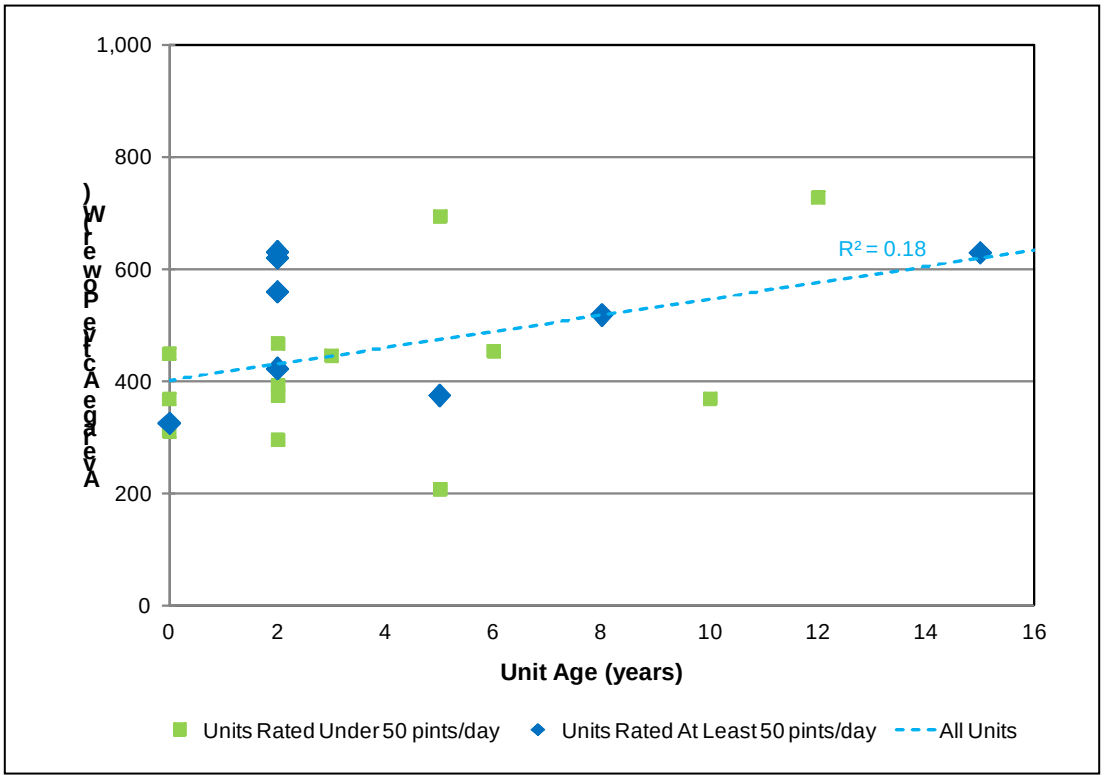
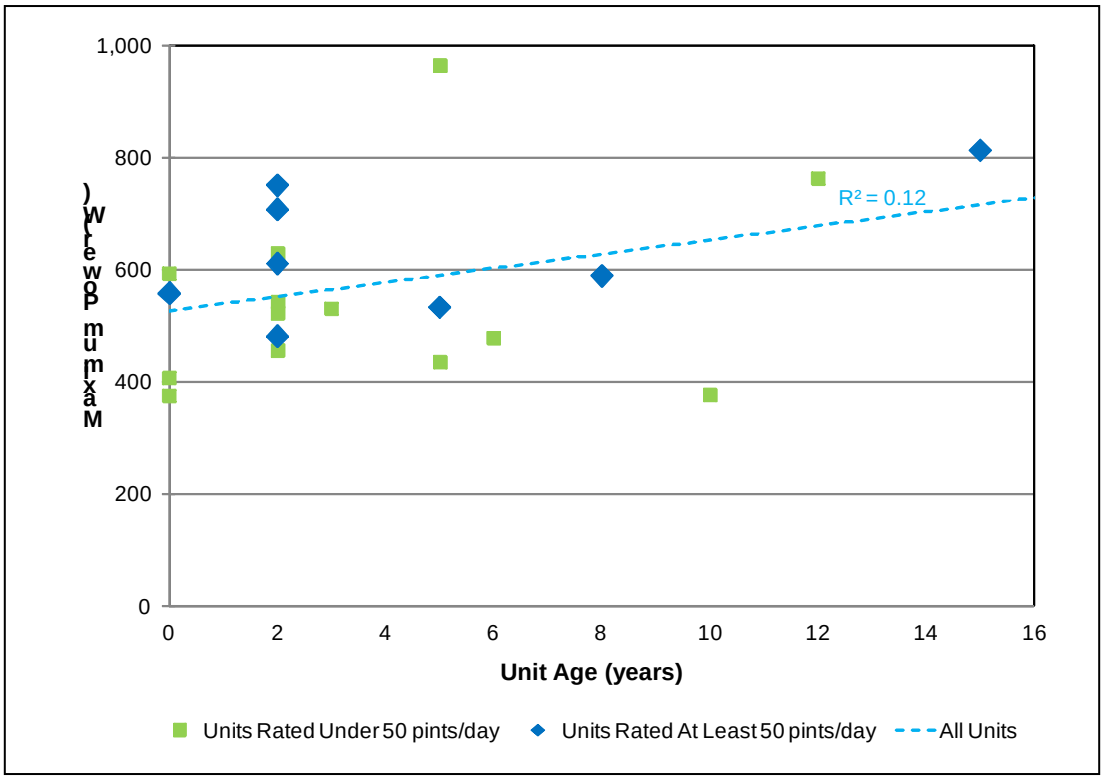


Figure 2: Maximum Power Vs. Unit Age



Water Removal

Participants who manually emptied their units logged the time and measured the water volume each time. The water removal averaged 4.9 pints/day for these units, with a wide range from 0.2 to 12 pints/day.

A limiting factor in water removal was the need to manually empty these units. While the rated capacity of manually emptied dehumidifiers in the study ranged from 25 to 70 pints/day, their tub volumes measured between 6 and 24 pints. Most tub volumes were less than half the rated unit capacity, meaning the units would need to be manually emptied more than twice per day to provide the rated water removal. Depending on unit size and ambient conditions, some units may not need to run at rated capacity to provide the desired results, but users should be aware of this potential limitation and the importance of tub volume when purchasing dehumidifiers. Other factors affecting the amount of water removed include ambient conditions and user settings.

Operating Hours

During the metering period, the average runtime (not including time drawing standby power) was 8.9 hours/day, for an average duty cycle of 37%. At that rate, annual runtime would be 2,160 hours, based on the 8 months/year average discussed above. The actual annual operating hours are expected to be higher because this study did not include metering during the time of year when dehumidifier operation is expected to be at its peak. This result indicates higher dehumidifier operating hours than the 1,620 estimated in a frequently cited 1998 Arthur D. Little report (Zogg, 34).

As discussed above, operation of some units was limited by the need for the user to frequently empty the relatively small tub. Because direct drain units were not limited by tub size, they operated longer hours, with average active runtime of 11 hours/day for direct drain units, compared to 8.1 hours/day for manually emptied units. During the peak operating season, this difference would likely be greater.

Electricity Consumption

The average metered electricity consumption was 4.2 kWh/day. As with operating hours, electricity consumption was higher for direct drain units (5.6 kWh/day) than for manually emptied units (3.7 kWh/day). It is assumed that the corresponding water removal was also higher, though this study did not include measurement of water removal from direct drain units.

Figure 3 compares the average daily electricity consumption and water removal for each of the 15 units that were manually emptied. This graph shows a weak correlation between water removal and electricity consumption. If the one outlying data point (a 12 year old unit consuming 14.3 kWh/day) were removed, however, the R-squared value for a linear regression would increase to 0.47. A number of other factors affect electricity consumption, including ambient conditions, user settings, and efficiency of the unit.

Figure 4 shows that electricity consumption was not related to rated unit capacity. As discussed above, no manually emptied unit reached its rated water removal capacity in this period, so the capacity would not be expected to be a major factor in operation, for those units at least.

Figure 3: Average Daily Electricity Use Vs. Water Removal

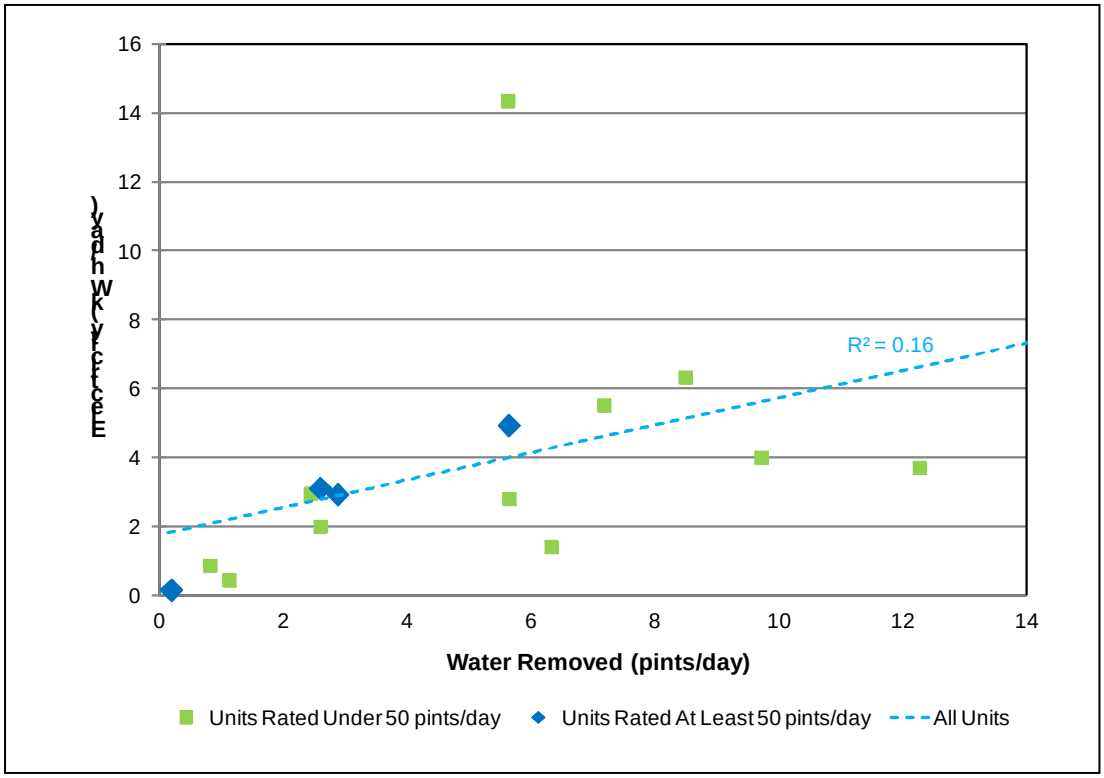
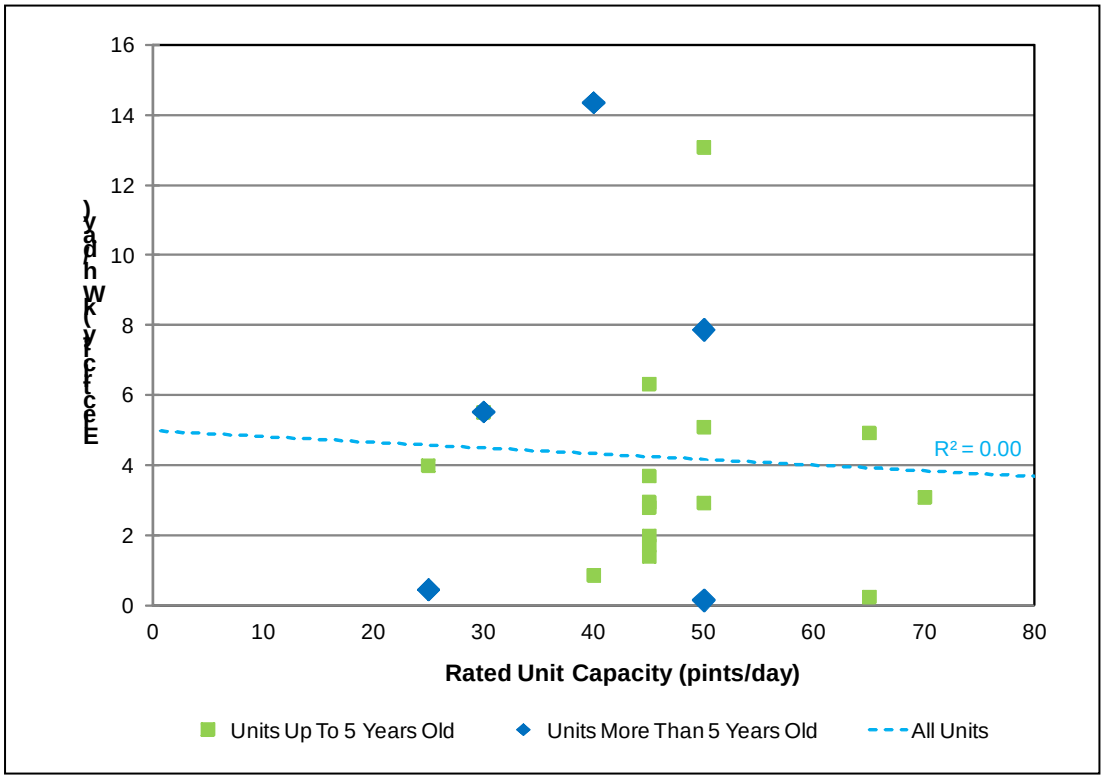


Figure 4: Average Daily Electricity Use Vs. Rated Unit Capacity



Projecting the metered daily electricity consumption across the year based on the average 8 months/year of operation explained above, annual electricity consumption would be about 1,000 kWh. At the 2011 national average residential electric rate of $0.118/kWh, the average annual operating cost is $120 (EIA 2012a). For comparison, a new ENERGY STAR rated refrigerator uses about 500 kWh/year, or 1.4 kWh/day (EPA 2012c).

According to the U.S. Energy Information Administration, the average household used 11,496 kWh in 2010 (EIA, 2012b). At the average consumption of 1,000 kWh, one dehumidifier would account for approximately 9% of the electricity consumption in a home.

Energy Factor

To evaluate the efficiency of the dehumidifiers, we used the measured electricity consumption and water removal then calculated the actual EF for each unit that was manually emptied. The measured EF ranged from 0.2 to 2.1 L/kWh, with an average of 0.8 L/kWh. As shown in Figure 5, the measured EF was lower than the rated EF for all but two units. A 12 year old dehumidifier, the oldest of the manually emptied units, had the lowest measured EF at 0.19 L/kWh, but as shown in Figure 6, a minimal correlation was found between unit age and measured energy factor. As discussed above, EF ratings were not available for three of these units.

Figure 5: Comparison of Measured and Rated Energy Factors

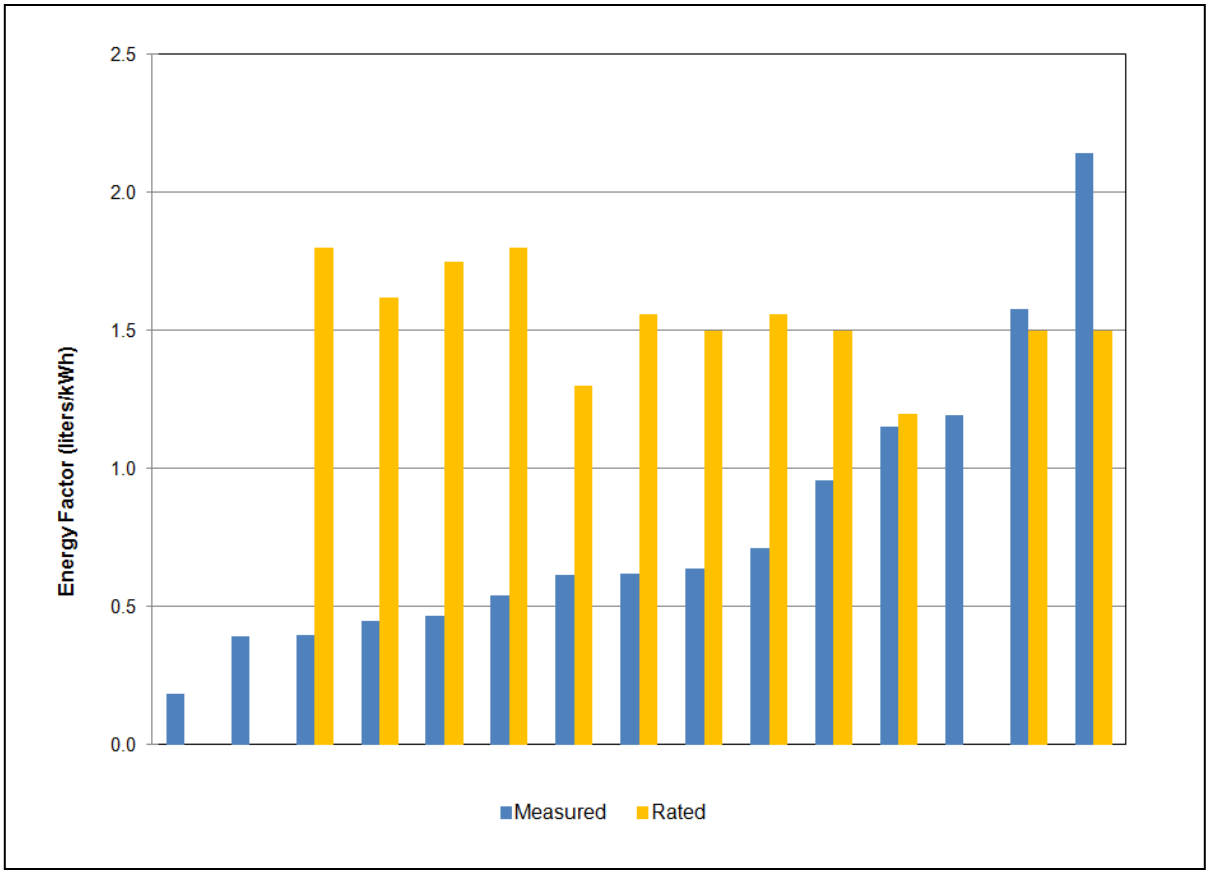
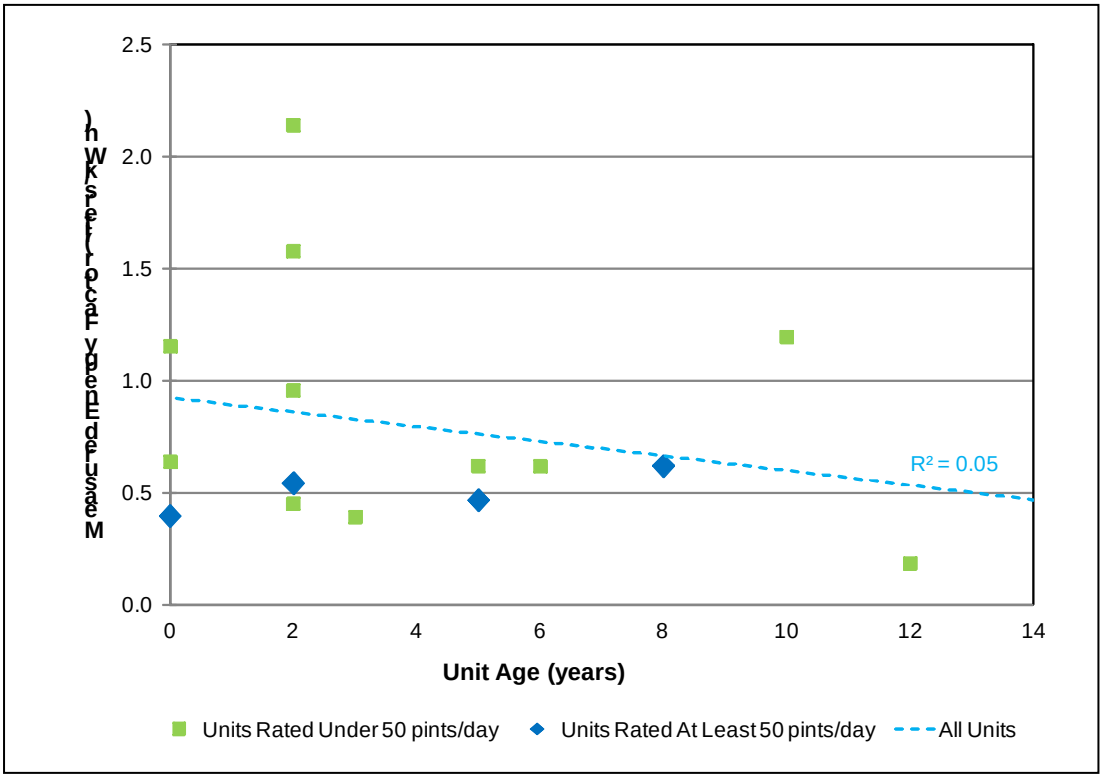


Figure 6: Measured Energy Factor Vs. Unit Age

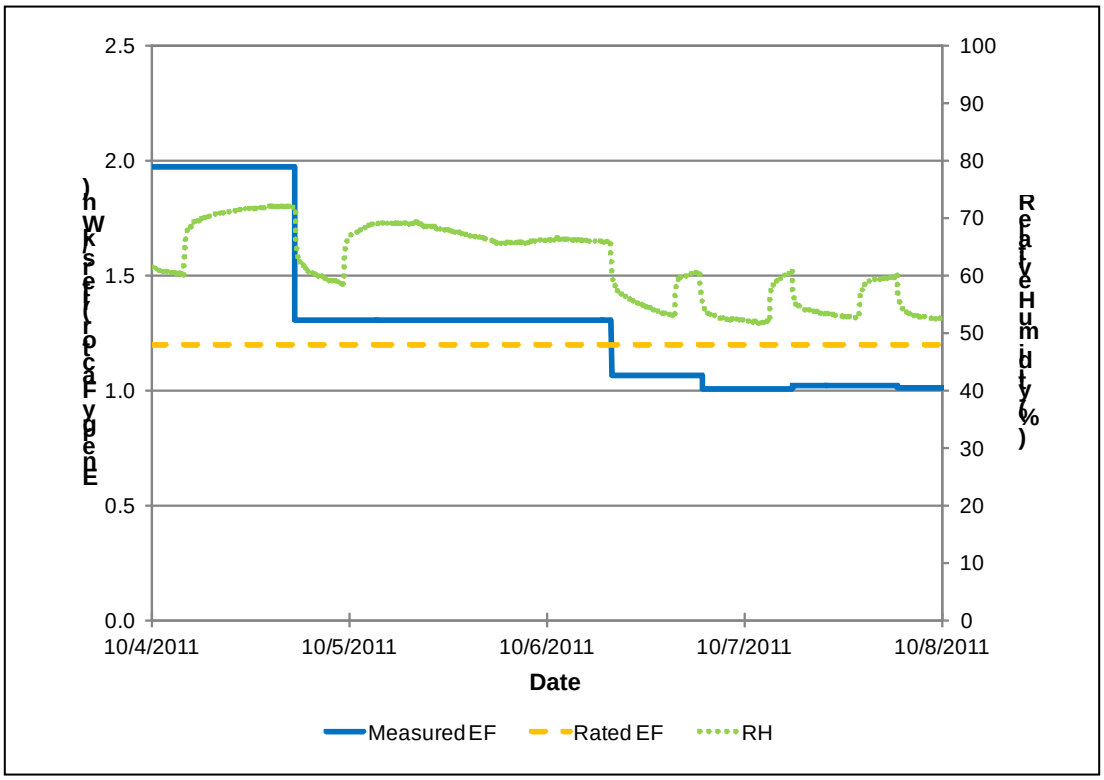


Impact of Ambient Conditions on Energy Factor. EF ratings are based on testing at dry-bulb temperature of 80°F and wet-bulb temperature of 69.6°F, which equates to about 60% RH at sea level (AHAM, 7). Meter data showed the actual temperature and RH were below these values for almost all units, as expected since most units were set to less than 60% RH.

When the study began, one of the units had just been installed in a basement where no dehumidifier had been used in recent years, so that meter showed RH levels as high as 72% early in the study. The average measured EF for that unit was 1.15, very close to its rating of 1.2 and one of the highest EF values in the study.

Figure 7 shows the EF and RH of this unit over a four-day period shortly after the dehumidifier was first turned on. The blue line shows that the EF starts out near 2, well above the rated efficiency, and decreased to 1 over a few days as the basement humidity in the dotted green line decreased below 60%. The meter measured RH continuously, while EF was calculated once or twice a day when the user emptied the tub.

Figure 7: Energy Factor Varying with Relative Humidity

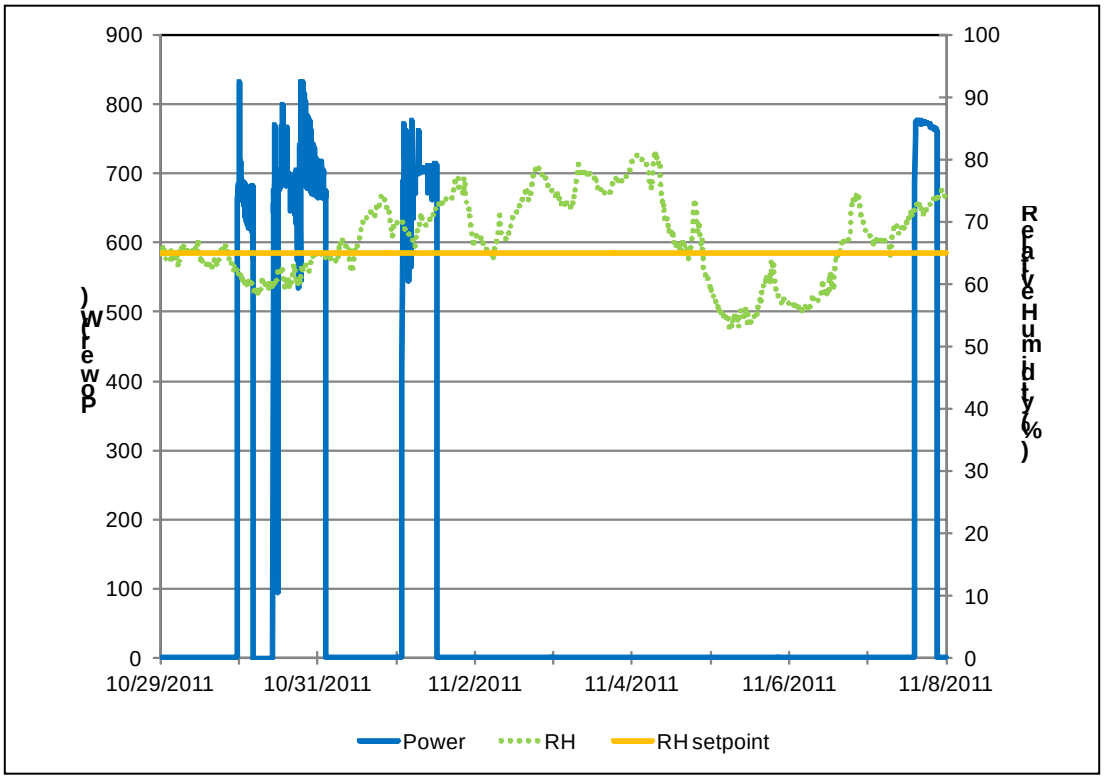


This indicates that dehumidifiers in actual operating conditions may perform at lower efficiency than they would at the test conditions used to rate dehumidifier efficiency. Additional metering could be performed in the summer to compare summer operating conditions to the test conditions and measure EF during peak operation.

Accuracy of Humidity Controls

To evaluate the accuracy of the dehumidifier controls, we graphed RH and power over time for each unit. Some units showed results tracking closely with the reported setpoint, while others showed potentially faulty controls. For example, Figure 8 shows operation of one unit over a 10 day period. The dehumidifier was set at 65% RH, indicated by the straight line, and the measured RH is shown in the dotted green line. As the blue power line shows, the dehumidifier did not operate during days when the RH was consistently above the setpoint. This unit has been set up to drain directly, so operation was not limited by tub capacity. At times this unit does operate, with an average of 2.4 hours/day of runtime during the metering period, but the data show a discrepancy between the RH measured during operation and the RH setpoint. This is an extreme case, as the participant described her basement as very wet, with puddles of standing water.

Figure 8: Dehumidifier Not Operating When RH Exceeds Setpoint



Conclusion

This study of 21 dehumidifiers operating in Northeast and Mid-Atlantic homes showed that dehumidifiers are energy intensive appliances that operate for several months a year in many homes. To build on this study, we plan to do additional metering in the future during the spring and summer months. Key findings to date include:

- Participants reported an average of 8 months/year of dehumidifier operation.
- The average metered runtime was 8.9 hours/day. At 8 months/year, the average unit would operate 2,160 hours annually.
- The average metered active power was 459 Watts.
- Eleven of the units drew standby power between 0.4 and 1.9 Watts.
- The average metered electricity consumption was 4.2 kWh/day, or 1,000 kWh/year based on 8 months/year of operation. This is equal to 9% of the electricity consumption in an average home.
- For the 15 manually emptied units, the average water removal was 4.9 pints/day and the average EF was 0.8 L/kWh.
- The humidity controls on some units did not function properly, as some units did not operate when a separate meter showed ambient RH exceeding the setpoint.
- The measured EF was lower than the rated EF for all but two units. This lower operating efficiency is believed to be in part because most units in this study were operating in spaces with lower temperature and RH than the standard test conditions.

- User operation is a key factor in effectiveness and energy consumption of dehumidifiers, including frequency of emptying tubs for units that don't drain directly.
- While it is beyond the scope of this study to quantify the ideal water removal in each home, water removal by some dehumidifiers in the study was limited by the need for tubs to be manually emptied when they reached capacity. Most tub volumes were less than half the rated unit capacity, meaning the units would need to be manually emptied more than twice per day, or set up to drain directly, to provide the rated water removal.

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