Appliance Standards Awareness Project
American Council for an Energy-Efficient Economy
Consumers Union
Natural Resources Defense Council
Northwest Energy Efficiency Alliance

October 17, 2012

Ms. Brenda Edwards
U.S. Department of Energy
Building Technologies Program
1000 Independence Avenue, SW
Mailstop EE-2J
Washington, DC 20585

RE: Docket Number EERE–2012– BT–STD–0027/ RIN 1904–AC81: Framework Document for Residential Dehumidifiers

Dear Ms. Edwards:

This letter constitutes the comments of the Appliance Standards Awareness Project (ASAP), American Council for an Energy-Efficient Economy (ACEEE), Consumers Union (CU), Natural Resources Defense Council (NRDC), and Northwest Energy Efficiency Alliance (NEEA) on the framework document for dehumidifiers. 77 Fed. Reg. 49739 (August 17, 2012). We appreciate the opportunity to provide input to the Department.

Dehumidifiers represent both a significant source of energy consumption and an opportunity to achieve significant national energy savings. However, the current test procedure for dehumidifiers neither adequately reflects energy consumption in the field nor ensures good performance over a range of operating conditions. Recent field studies and testing of dehumidifiers have found the following:

- The annual energy consumption of dehumidifiers in the Northeast and Mid-Atlantic is about 1,000 kWh, which represents about 9% of the electricity consumption of an average U.S. home.[1]
- The measured efficiency of dehumidifiers in some homes is more than three times lower than the rated value.[2]
- Ambient conditions (temperature and relative humidity) in the field are significantly lower than the current rating conditions, which means that the current test procedure will tend to significantly overestimate dehumidifier efficiency.[3]
- Some dehumidifiers maintain efficiency better than others over a range of operating conditions.[4]

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[1] Mattison, L. and D. Korn. 2012. Dehumidifiers: A Major Consumer of Residential Electricity. 2012 ACEEE Summer Study on Energy Efficiency in Buildings. The Cadmus Group, Inc. http://www.aceee.org/files/proceedings/2012/data/papers/0193-000291.pdf.
[2] *Ibid*.
[3] *Ibid*.

- Dehumidifiers with continuous fans consume roughly 40-120 W even when the compressor is off.[5]

As described in our comments below, we urge DOE to (1) amend the test procedures to better reflect field performance and to better ensure energy savings over a range of operating conditions; (2) ensure that the energy consumption associated with continuous fan operation is adequately reflected in dehumidifier ratings; (3) consider an equation-based approach to represent the minimum efficiency standard as a function of capacity; (4) include air-to-air heat exchangers as a technology option; and (5) work with ENERGY STAR to develop a label for dehumidifiers to educate consumers about appropriate relative humidity settings to achieve additional energy savings.

Rating Conditions

The current DOE test procedure for dehumidifiers references ANSI/AHAM DH-1-2008 for measurements of both capacity and energy factor (EF). DH-1-2008 specifies a single rating condition—80°F and 60% relative humidity (RH). We believe that this single rating condition is not representative of field conditions where dehumidifiers are used, and that ratings at 80°F and 60% relative humidity do not ensure good performance in the field.

Cadmus conducted a field study where they measured energy consumption and water removal for 21 dehumidifiers in homes in the Northeast and Mid-Atlantic regions.[6] The study found that for almost all of the units metered, the measured energy factor (EF) was significantly lower than the rated EF. For example, there were three units in the study that had rated EF values greater than 1.5 L/kWh, while the measured EF values were all less than 0.5 L/kWh. In these houses, these dehumidifiers used more than three times more energy than the rated values would have suggested to owners. Cadmus attributed the differences between the measured and rated EF values at least in part to differences between the rating conditions and field conditions. Specifically, the study found that ambient temperature and RH levels in the field were lower than the rating conditions.

Available information about field conditions where dehumidifiers are used suggests that the differences between rated EF and measured EF that were found in the Cadmus study are not surprising. According to the 2009 Residential Energy Consumption Survey (RECS), 75% of the homes that have dehumidifiers have a basement, which suggests that most dehumidifiers are used in basements. In addition, according to RECS, more than 75% of homes that have dehumidifiers are in cold or cool climates.[7] Basements have large surface to volume ratios, and only the newest are expected to have foundation wall or floor insulation. Therefore, basements

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[4] Winkler, J., Christensen, D., and J. Tomerlin. 2011. Laboratory Test Report for Six ENERGY STAR Dehumidifiers. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy12osti/52791.pdf.

[5] Energy Center of Wisconsin. 2010. Dehumidification and Subslab Ventilation in Wisconsin Homes: A Field Study. http://www.ecw.org/resource_detail.php?resultid=436.

[6] Mattison, L. and D. Korn. 2012. Dehumidifiers: A Major Consumer of Residential Electricity. 2012 ACEEE Summer Study on Energy Efficiency in Buildings. The Cadmus Group, Inc. http://www.aceee.org/files/proceedings/2012/data/papers/0193-000291.pdf.

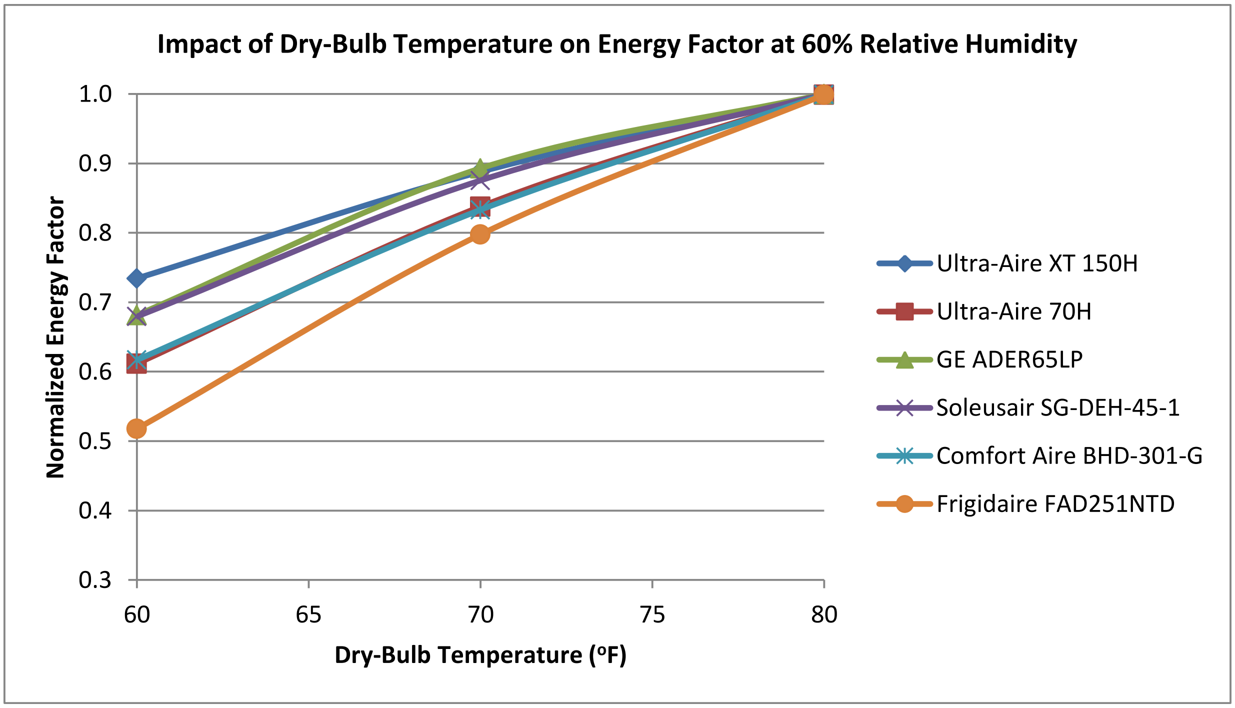
[7] According to RECS 2009, 30% of all dehumidifiers are in East North Central, 24% are in Mid Atlantic, 13% are in West North Central, and 10% are in New England.

tend toward steady-state conditions approaching the ground temperature at their site, but somewhat warmer.[8] The average ground temperature in the U.S. ranges from about 46^{o}F to 58^{o}F in most of the country, [9] and according to the Building Foundations Design Handbook, the temperature of unconditioned basements ranges between 55^{o}F and 70^{o}F most of the year in most climates.[10] This suggests that an ambient temperature of 80^{o}F is significantly higher than typical ambient temperatures in spaces where portable dehumidifiers are used.

Research has shown that adverse health effects, such as respiratory infections and allergies, are minimized by maintaining relative humidity between 40 and 60%.[11] Additional research has found that while people generally cannot sense fluctuations in relative humidity levels between 25% and 60%, most people can sense when the relative humidity rises above 60%.[12] This suggests that the current rating condition of 60% RH represents the upper bound of both recommended levels and levels which consumers are likely to select. The Cadmus study found that the average RH setting selected by study participants was 50%.[13] In addition, a field study of dehumidifier use in 40 Wisconsin homes conducted by the Energy Center of Wisconsin found that during the summer months, nearly half of the basements monitored maintained an average relative humidity of less than 50%.[14]

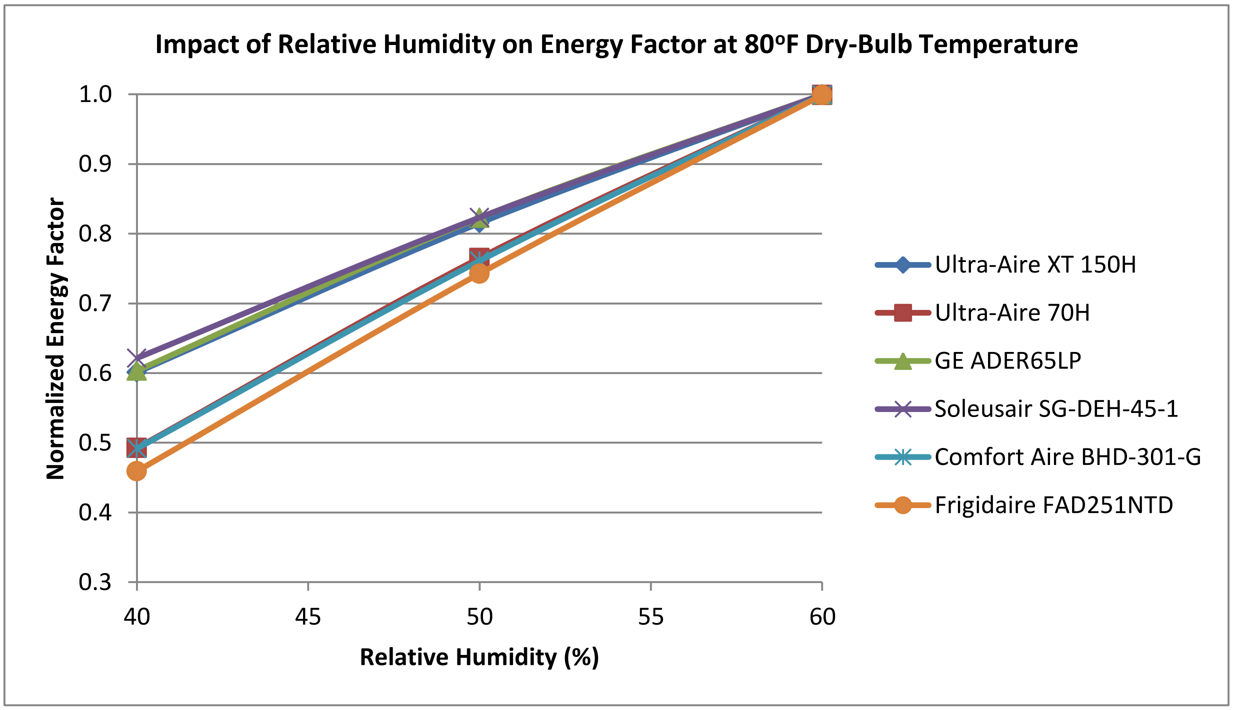
The National Renewable Energy Laboratory (NREL) conducted laboratory testing of six residential dehumidifiers—two whole-home units and four portable units—at a wide range of ambient temperatures and relative humidity levels.[15] Using the test results, NREL developed normalized performance curves to illustrate the impact of varying dry-bulb temperatures on EF at different relative humidity levels. The performance curves show that dehumidifier efficiency decreases significantly as both ambient temperature and relative humidity decrease. The graph below shows normalized energy factor (normalized to 80^{o}F and 60% RH) as a function of dry-bulb temperature at a constant relative humidity of 60%. The normalized EF values for the six units at a dry-bulb temperature of 60^{o}F range from 0.52 to 0.73, and there are significant differences in normalized EF at the lower ambient temperature both between the two whole-home units (the Ultra-Aire units) and among the four portable units.

[8] There is some heat gain from the living space, summer infiltration, and equipment in the basement (including the dehumidifier, water heater, and furnace or boiler).
[9] http://www.geosundesign.com/Deep_Earth_Temperature_Map.html.
[10] http://www.ornl.gov/sci/buildingsfoundations/handbook/section2-1.shtml.
[11] Arundel, A.V., Sterling, E.M., Biggin, J.H., and T.D. Sterling. 1986. Indirect Health Effects of Relative Humidity in Indoor Environments. Environmental Health Perspectives, 65: 351-361. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1474709/pdf/envhper00436-0331.pdf.
[12] Lstiburek, J. 2002. Relative Humidity. Building Science Corporation. Research Report – 0203. http://www.buildingscience.com/documents/reports/rr-0203-relative-humidity.
[13] Mattison, L. and D. Korn. 2012. Dehumidifiers: A Major Consumer of Residential Electricity. 2012 ACEEE Summer Study on Energy Efficiency in Buildings. The Cadmus Group, Inc. http://www.aceee.org/files/proceedings/2012/data/papers/0193-000291.pdf.
[14] http://www.homeenergy.org/show/article/id/777.
[15] Winkler, J., Christensen, D., and J. Tomerlin. 2011. Laboratory Test Report for Six ENERGY STAR Dehumidifiers. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy12osti/52791.pdf.



Source: Adapted from Winkler et. al.

The graph below also shows normalized energy factor for the six units, but in this case as a function of relative humidity at a constant ambient temperature of 80°F. The normalized EF values for the six units at 40% RH range from 0.46 to 0.62, and again there are significant differences in normalized EF, in this case at the lower RH level, both between the two whole-home units (the Ultra-Aire units) and among the four portable units.



Source: Adapted from Winkler et. al.

The NREL test results demonstrate that performance at the current rating conditions (80°F and 60% RH) is not a good predictor of performance at ambient conditions that are more representative of field conditions (lower temperature and relative humidity). While the EF of all units decreases at lower temperatures and lower RH levels, this decrease is larger for some units than for others. Since there is less moisture in the air as dry-bulb temperature decreases (at a constant relative humidity) and as RH decreases (at a constant dry-bulb temperature), dehumidifiers have to work harder to remove moisture at typical field conditions (lower ambient temperature and RH) compared to the rating conditions. Therefore, the current test procedure does not reflect performance at conditions where the unit has to work hard to remove moisture. In addition, the current test procedure does not capture dehumidifier performance under frost conditions (i.e. when the dry-bulb temperature drops below about 65°F), which are likely to occur for a dehumidifier operating in a basement.

Both the ANSI/AHAM test procedure and Consumer Reports' testing of dehumidifiers reflect the importance of adequate operation under frost conditions. DH-1-2008 recommends that dehumidifiers meet a "low temperature test" at 65°F, which includes recommended levels of performance related to unit operation and frost accumulation. Consumer Reports' ratings of dehumidifiers are based on a number of factors including "cool room performance," which measures dehumidifier efficiency at 50°F and 60% RH.[16]

For portable dehumidifiers, we encourage DOE to amend the test procedures to better reflect field conditions and to better ensure energy savings over a range of dry-bulb temperatures and RH settings that are typical for portable dehumidifier operation. We recommend that DOE include at least one rating point to capture performance at low temperatures (e.g. 60°F), which are likely to occur in basements and at which frost accumulation can affect operation. In addition, we encourage DOE to change the RH level for the test from 60% to a lower value. An RH level of 60% really represents the upper bound of recommended RH levels, and a lower RH level will likely better encourage good performance in the field since units have to work harder to remove moisture at lower RH levels. In addition, a lower relative humidity level would reflect the field data referenced above.

We also recommend that DOE develop separate rating conditions for whole-home dehumidifiers to reflect typical operating conditions of these units, which in many cases will be different than the operating conditions of portable units. Specifically, for whole-home units, the dry-bulb temperature of the entering air will always be close to the thermostat setting. For whole-home dehumidifiers, we would also recommend that the test be conducted at a lower relative humidity level than the current rating condition.

Continuous Fan Operation

Some dehumidifiers have fans that operate continuously even when the compressor turns off. Consumer Reports' dehumidifier ratings identify models that have a continuous fan. Of the models that are currently rated, three have continuous fans.[17] ENERGY STAR now requires that

[16] http://www.consumerreports.org/cro/best-dehumidifiers.htm.
[17] Amana D974E, Danby DDR6009REE, Danby DDR5009REE.

manufacturers report whether the fan continuously operates even while the compressor is off. As of October 17, there were 12 models on the ENERGY STAR Dehumidifiers Product List, six of which have continuous fans. [18] The field study conducted by the Energy Center of Wisconsin found that fan-only power consumption ranged from under 40 W to 120 W, which suggests that continuous fan operation could significantly increase dehumidifier annual energy consumption.[19] For example, an 80 W fan running in continuous fan mode for 1,000 hours annually would consume 80 kWh.

Continuous fan operation would circulate the air in the space being dehumidified, reducing gradients and perhaps affecting colder temperature and more humid areas (such as adjacent to walls). In addition to this 'averaging' function, fan-induced air movement 'tells' the dehumidifier when it needs to turn on. We believe that these goals could be met as well with intermittent fan operation, controlled by a timer (since most recent cycle) or 'learned' from recent use patterns.

DOE recently published a final rule amending the test procedures for dehumidifiers, which mostly addressed standby and off mode.[20] We request that DOE clarify how the energy consumption associated with continuous fan operation would be captured using the recently finalized test procedures. If the annual energy consumption of continuous fan operation is not adequately captured in the new test procedures, DOE should make any necessary modifications to ensure that the efficiency ratings of dehumidifiers with continuous fans reflect the significant additional annual energy consumption of continuous fan operation.

Product Classes

The current product classes for dehumidifiers, which were established by EPCA, are based on capacity. Dehumidifiers within each capacity bin are all subject to the same minimum EF requirement. The current product class structure effectively means that the standard is a stepwise function, as shown in the graph below.

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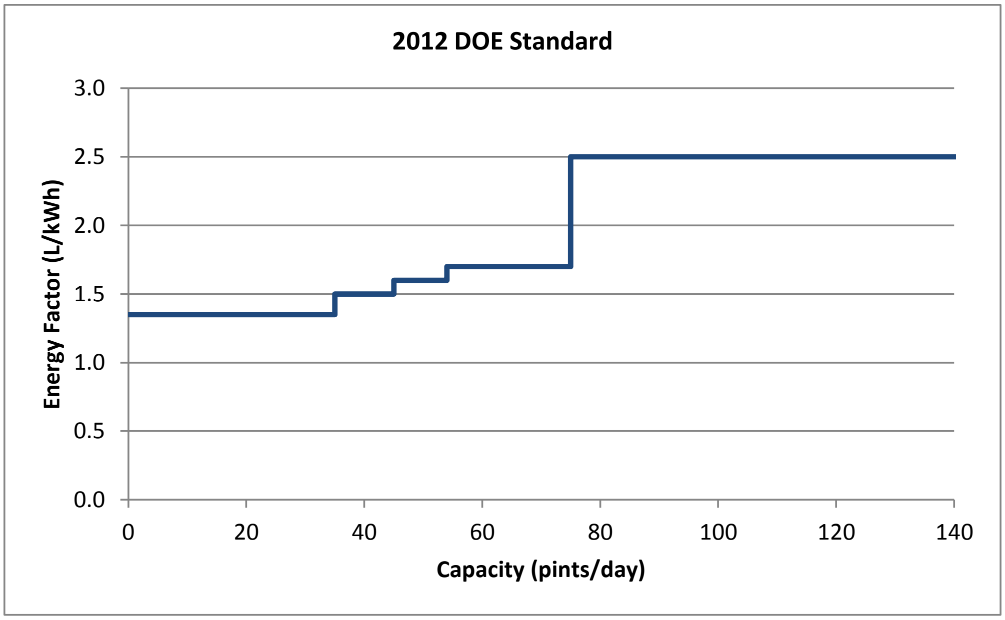
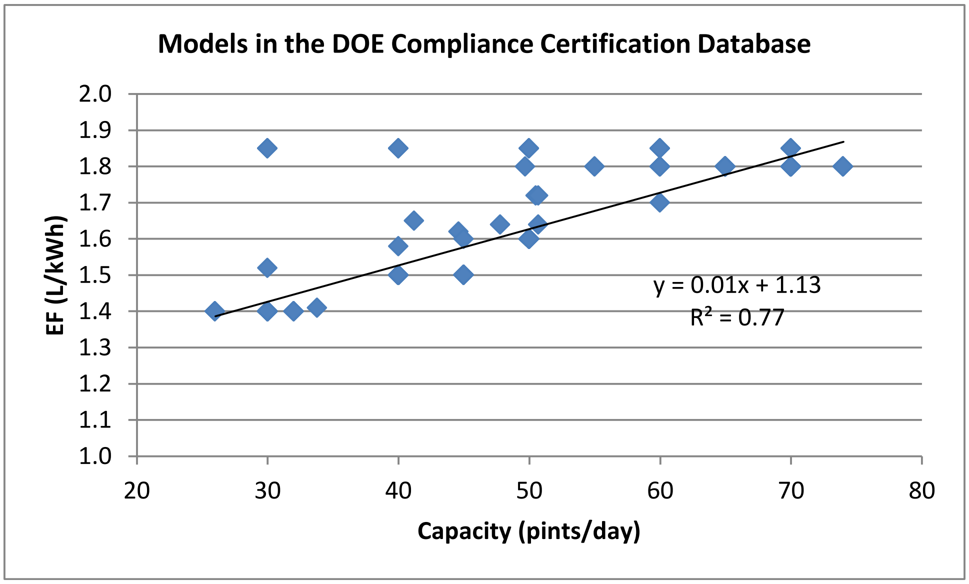
[18] http://downloads.energystar.gov/bi/qplist/dehumid_prod_list.pdf?7548-f20d.

[19] Energy Center of Wisconsin. 2010. Dehumidification and Subslab Ventilation in Wisconsin Homes: A Field Study. http://www.ecw.org/resource_detail.php?resultid=436.

[20] Docket Number EERE-2010-BT-TP-0039.



The graph below shows a plot of the models in the DOE Compliance Certification Database that meet the current standards (effective October 1, 2012) along with a linear trendline.[21] Based on currently available models, there appears to be a fairly linear relationship between capacity and EF, although we also note that the most-efficient model with a capacity of 30 pints/day has the same EF as the most-efficient model with a capacity of 70 pints/day. We encourage DOE to consider representing the minimum efficiency standard as an equation with EF as a function of capacity. An equation-based approach would be similar to the structure of the current standards for both refrigerators and water heaters, where maximum energy use and EF are functions of adjusted volume and rated storage volume, respectively.



[21] It appears that only portable dehumidifiers are currently being certified since there are no units in the database with capacities greater than 75 pints/day.

We note that the graph above shows that there is a group of models in the DOE Compliance Certification Database with capacities ranging from 30 to 70 pints/day that all have an EF of 1.85 L/kWh. In addition, as of October 17 there were 12 models on the ENERGY STAR Dehumidifiers Product List with capacities ranging from 30 to 70 pints/day, all of which also have a certified EF of 1.85 L/kWh.[22] These newly-introduced models suggest that the general relationship between EF and capacity observed in the graph above may not reflect the relationship from an engineering perspective. We encourage DOE to examine the technology options that manufacturers are using to achieve the efficiency levels of these newly-introduced models. If DOE does decide to adopt an equation-based approach, we urge the Department to ensure that the slope of the line reflects the relationship between EF and capacity from an engineering perspective.

We also note that if DOE does amend the test procedures to better reflect field performance, as we are recommending, the new EFs of current models would likely be very different from the current ratings, and the relative ranking of models might also change. Therefore, if DOE does amend the test procedures, we would encourage DOE to examine the relationship between capacity and efficiency based on the new test procedures.

Technology Options

In the framework document, DOE identified heat pipe technology as a potential technology option that was not considered in the previous rulemaking for dehumidifiers.[23] We encourage DOE to analyze heat pipe technology as an adder to the vapor compression cycle, which has the potential to significantly improve dehumidifier efficiency by pre-cooling the incoming air. We also encourage DOE to analyze additional technology options for pre-cooling the incoming air. Specifically, some of the most-efficient dehumidifiers on the market employ air-to-air heat exchangers (regenerative heat exchangers) to pre-cool the incoming air using the cool air coming off of the evaporator coil.[24]

In addition, multiple manufacturers have developed whole-home dehumidifiers that use a refrigeration system in conjunction with a desiccant wheel downstream of the evaporator coil.[25] The desiccant wheel removes additional moisture, and heat from the condenser coil dries the wheel and discharges the moisture outdoors.

Efficiency Levels

In the framework document, DOE identified the maximum available efficiency levels for the proposed representative product classes.[26] For the proposed product classes that cover units with capacities from 35-45 pints/day and 45-54 pints/day, there are models in the DOE Compliance Certification Database with efficiency levels of 1.85 L/kWh, which exceed the maximum

[22] http://downloads.energystar.gov/bi/qplist/dehumid_prod_list.pdf?2689-75a4.
[23] Framework document. p. 10.
[24] See, for example, http://www.ultra-aire.com/pdf/Ultra-Aire_XT105H_XT155H_XT205H_Manual.pdf and http://www.santa-fe-products.com/pdf/Santa_Fe_Cost_Comparison_Sheet.pdf.
[25] See, for example, http://www.munters.us/upload/Related%20product%20files/Product%20Guide-%20DryCool%20HD.pdf and http://www.novelaire.com/images/pdfs/ComfortPlus_300_Tech_Sheet.pdf.
[26] Framework document. p. 17.

available levels identified in the framework document as shown in the table below.[27] In addition, as of October 17 there were 12 models on the ENERGY STAR Dehumidifiers Product List with capacities ranging from 30 to 70 pints/day, all of which have a certified EF of 1.85 L/kWh.[28]

Capacity Range (pints/day)	Maximum Available Efficiency Level Identified in DOE Framework Document (L/kWh)	Maximum Available Efficiency Level in DOE Compliance Certification Database (L/kWh)
35.01-45.00	1.62	1.85
45.01-54.00	1.80	1.85

As mentioned above, if DOE does amend the test procedures as we have recommended, the EF levels of current products would likely change significantly and the relative ranking of products might also change. Therefore, the models with the highest efficiency levels based on the current test procedure may not be the same as the models with the highest efficiency levels based on a test procedure that better reflected field performance.

Dehumidifier Energy Consumption

The framework document states that DOE is interested in data that can assist in characterizing dehumidifier annual energy consumption.[29] We are aware of two field studies that have measured dehumidifier energy use. The Cadmus study, mentioned above, found that average annual energy consumption was about 1,000 kWh.[30] The study noted that this estimate of annual energy use is likely to be conservative since metering took place during the fall, and therefore did not measure peak operation. The Cadmus study also estimated average annual operating hours to be 2,160, which is nearly double the number of active mode hours that DOE assumed for the purposes of calculating integrated energy factor (IEF) in the recent test procedure final rule (1,095 hours).[31] The field study conducted by the Energy Center of Wisconsin estimated average annual energy consumption to be 477 kWh. During summer months, the study found that dehumidifiers on average ran 56% of the time.[32]

Labeling

The relative humidity setting selected by consumers can have a significant impact on dehumidifier energy consumption in the field. As the RH setting decreases, the water removal rate (pints/day) increases, and the energy required to remove each pint of water increases. The Wisconsin field study found that all the homes in the upper quartile of energy use maintained basement RH levels of less than 50%, and several of these homes maintained RH levels of less

[27] It appears that these units may have been recently introduced to meet the new ENERGY STAR specification.
[28] http://downloads.energystar.gov/bi/qplist/dehumid_prod_list.pdf?2689-75a4.
[29] Framework document. p. 19.
[30] Mattison, L. and D. Korn. 2012. Dehumidifiers: A Major Consumer of Residential Electricity. 2012 ACEEE Summer Study on Energy Efficiency in Buildings. The Cadmus Group, Inc. http://www.aceee.org/files/proceedings/2012/data/papers/0193-000291.pdf.
[31] Docket Number EERE-2010-BT-TP-0039.
[32] http://www.homeenergy.org/show/article/id/777.

than 40%.[33] NREL conducted modeling to examine the impact of various dehumidification equipment and controls on a high-performance home in a hot-humid climate. The study found that a medium-capacity high-efficiency dehumidifier would increase source energy consumption by only 2.2% at an RH setting of 60%, while source energy consumption would increase by 16.7% if the RH setting were lowered to 50%.[34]

Currently, most consumers are probably unaware of the energy and energy bill impacts of their choice of RH setting. We encourage DOE to work with ENERGY STAR to develop a label for dehumidifiers as a way to educate consumers about the energy consumption impacts of low RH settings. A label could indicate the recommended range of RH settings as well as the potential consequences of selecting higher or lower settings.

In summary, we urge DOE to amend the test procedures to better reflect field performance and to better ensure energy savings over a range of operating conditions; ensure that the energy consumption associated with continuous fan operation is adequately reflected in dehumidifier ratings; consider an equation-based approach to represent the minimum efficiency standard as a function of capacity; include air-to-air heat exchangers as a technology option; and work with ENERGY STAR to develop a label for dehumidifiers to educate consumers about appropriate relative humidity settings to achieve additional energy savings.

Thank you very much for considering these comments.

Sincerely,

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[33] *Ibid*.
[34] Fang, X., Winkler, J., and D. Christensen. 2011. Using EnergyPlus to Perform Dehumidification Analysis on Building America Homes. National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy11osti/49899.pdf.

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