Whole House Dehumidification for Occupant Comfort and Energy Savings

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INTRODUCTION

The relative humidity inside of a home or building, referred to as the indoor RH, should be maintained below certain levels for the comfort and health of the occupants as well as for the preservation of the building and its contents.

The indoor RH that is comfortable for humans varies from individual to individual and is dependent on temperature and air currents (from fans and furnace blower). For human comfort, during the cooling season, the indoor RH should not exceed 60%. Annoying insects such as earwigs and millipedes in a home can be reduced or eliminated by reducing the indoor RH with a dehumidifier.

High indoor RH is associated with numerous health issues for the occupants. These include allergies, asthma, arthritis, gout, infections and diseases from fungi and fungal toxins and many others. Based on health issues it is recommended that the indoor RH be maintained below 60%.

High indoor RH increases the probability that the home or building and its contents may be damaged. Corrosion, warping of wood, fungal (mold) growth and damage from insects will occur if the indoor RH is high enough. Damage to or malfunction of the building structure, electronics (TV, computers, etc.), medical devices (Eye Lasik, MRI scanner, etc.) furniture (some may be antiques), other wood items used in the construction of the home or building like floors and doors, musical instruments (piano, violin, guitars, etc.), wall coatings (paint and wall paper), paper items (books, periodicals, comics, stamps, art, etc.) may occur and occur more rapidly with increasing RH. For preservation of the building and its contents it is recommended that indoor RH be maintained below 60%.

Therefore, based on comfort and health of the occupants as well as the preservation of the home or building and its contents, the indoor RH should be maintained below 60%. Throughout this paper 60% will be used as the indoor RH by which comfort, health and preservation of the home and it contents will be judged.

Conventional air conditioning, the type of air conditioning installed in most every home, cools the air as well as removing moisture from the air and is the most frequently used equipment to reduce the indoor RH. Conventional air conditioning does not provide control of indoor RH and does not maintain the indoor RH at acceptable levels throughout the year because it operates based on indoor temperature (sensible cooling load) and not on indoor RH (latent load). In northern climates, there is a small sensible cooling load during the months of May & June, September & October and at nights during the summer months (July & August). In southern climates there is a small sensible cooling load from December through March. Therefore, these months will present the most challenging times in maintaining acceptable indoor RH level at these locations.

If a dehumidifier is used in conjunction with air conditioning and operated properly, the indoor RH can be maintained below 60% RH, while providing a significant reduction in energy usage (energy savings). The purpose of this paper is to present some operational strategies for air conditioning and dehumidification systems that provide acceptable indoor RH levels and significant energy savings.

METHODS

A residential home in Miami, FL was simulated on an hourly basis with TRNSYS, a widely used building simulation program. The home is referred to as a "High Efficiency House" and is designed for a hot, humid climate. This home is representative of a newly constructed air tight, energy efficient home as well as a condominium.

The home has a slab-on-grade foundation, which is the predominant foundation type in a hot humid climate. The home has 4 bedrooms, 8.0 foot high ceilings and 2000 ft^2 of conditioned floor area. The home is extremely energy efficient and air tight. R-values for the walls, ceiling and floor are 19.4, 38.5, and 13.0 (hr-ft^2-°F)/Btu respectively. The median infiltration rate, based on a variable infiltration model, is 0.17 ach. There is no supplemental mechanical ventilation.

Peak and average occupancy rate for the home is 3.0 and 2.4 people. The Internal Moisture Gain from human occupation is 10.3 pounds daily and is on a fixed schedule. An additional, variable amount of moisture that contributes to the Internal Moisture Gain is included in the model and is from re-evaporation off the air conditioning coil. Moisture capacitance of building materials and the contents of the home is included in the model.

The capacity of the air conditioner in the home is 1.7 tons with an Energy Efficiency Ratio, EER, of 13.3 (Btu/hr)/watt without the HVAC fan and a Seasonal Energy Efficiency Ratio, SEER, of 13 (Btu/hr)/watt. The same air conditioner is used in the conventional air conditioning system and in the air conditioning and dehumidification system. The small size of the air conditioner, 1.7 tons, is a result of the home being extremely energy efficient and air tight. The HVAC system fan uses 0.18 watts/cfm, delivers 680 cfm and operates only when cooling is required. The dehumidifier has an integral fan and operates only when the indoor RH exceeds the RH set point and has a rated capacity of 90 pints/day. Internal sensible heat gains include fixed schedule lighting and other equipment in the home (5,635 kWh annually), as well as an amount from the dehumidifier that depends on indoor conditions.

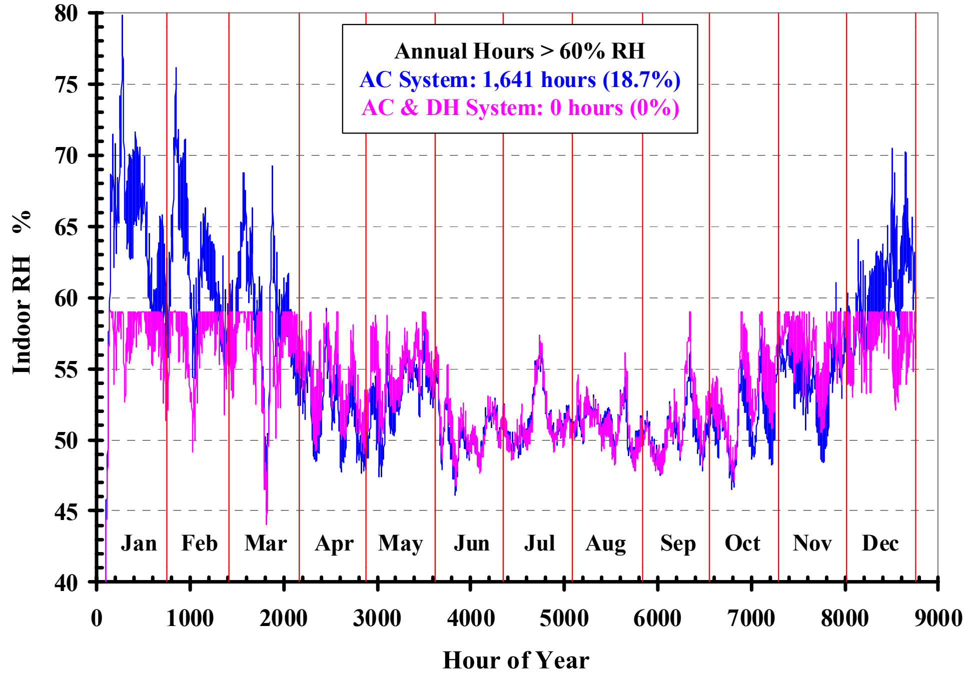
RESULTS

STRATEGY 1: Cooling Set Point

A number of factors affect the thermal comfort of the occupants of a home or building and include air temperature, air currents and humidity. Occupants experience equivalent comfort at higher temperatures when the indoor RH is lowered. ASHRAE incorporates this concept in the comfort zone in *ASHRAE Standard 55-2004*, Thermal Environmental Conditions for Human Occupancy. A published report indicates that schools served by a dehumidification system were maintained warmer than schools served by a conventional air conditioning system with equivalent occupant comfort.

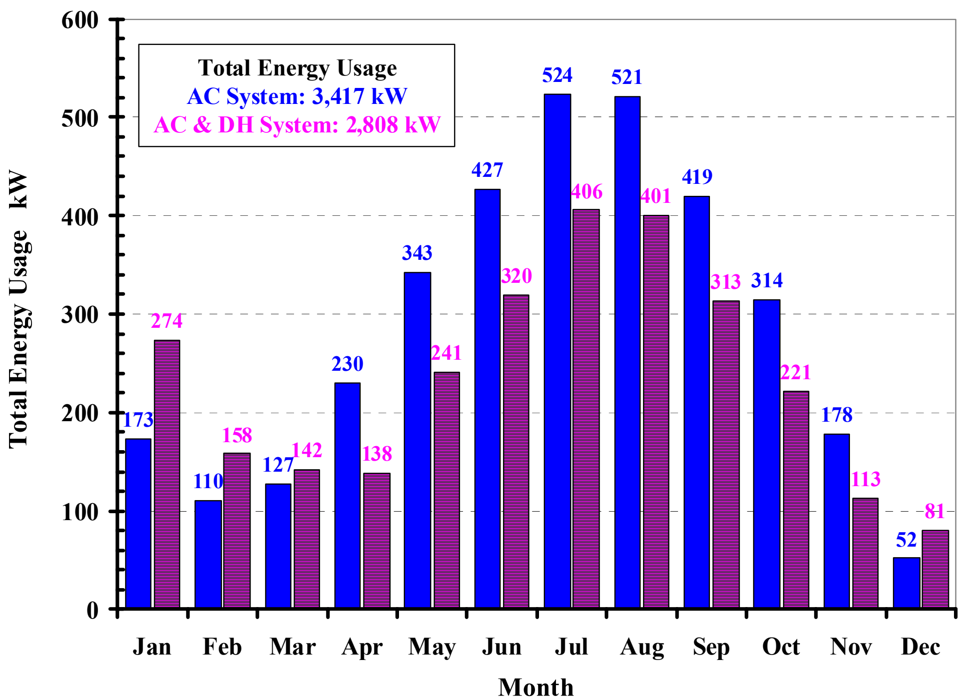
In this study, the performance of a conventional air conditioning system with a temperature setting (set point) of 75.0 °F was compared to an air conditioning and dehumidification system with set points of 78.0 °F and 59% RH. The difference in the cooling set point in this study is 3.0 °F. The 59% set point for the dehumidifier was chosen to keep the indoor RH below 60%.

Figure 1. Indoor RH vs Hour of Year for Strategy 1



Hourly indoor RH values for Strategy 1 were predicted using the model and are shown in Figure 1. The dehumidifier operates primarily from December through March when the sensible cooling load is smallest; the conventional air conditioning system only operates 122 hours during these 4 months. The dehumidifier has a dramatic impact on the indoor RH during this time by maintaining the indoor RH below 60% at all times. In January, the indoor RH with conventional air conditioning exceeds 60% for 506 hours (68.0 % of the month) and 70% for 71 hours (9.5% of the month). On an annual basis the indoor RH with conventional air conditioning exceeds 60% for 1,641 hours (18.7 % of the year). Therefore, this conventional air conditioning system provides very poor control of the indoor RH. The air conditioning and dehumidification system maintains excellent control; the indoor RH is below 60% at all times throughout the year.

Figure 2. Total Energy Usage vs Month for Strategy 1



Monthly energy usage for these two systems is shown in Figure 2. Energy savings occur from April through November as a result of the 3.0 °F higher cooling set point for the air conditioning and dehumidification system.

Table 1 provides an annual comparison of the conventional air conditioning system and the air conditioning and dehumidification system for Strategy 1. The air conditioning and dehumidification system provides an annual energy savings of 18% as compared to the conventional air conditioning system. The air conditioning and dehumidification system maintains the indoor RH below 60% throughout the year while the conventional air conditioning system allows the indoor RH to exceed 60% for 1,641 hours (18.7% of the year).

Table 1
Annual Performance Summary for Strategy 1

Performance Paramater	Air Conditioning & Dehumidifier	Conventional Air Conditioning
Energy Usage, kWh	2,808	3,417
% Energy Savings	18	NA
Operation Time, hours	1279 (AC) 258 (DH)	1911
Time > 60% RH, hours	0	1,641
% Time > 60% RH	0	18.7

Therefore, significant energy savings and comfort improvements occur when using an air conditioning and dehumidification system at a slightly higher cooling set point.

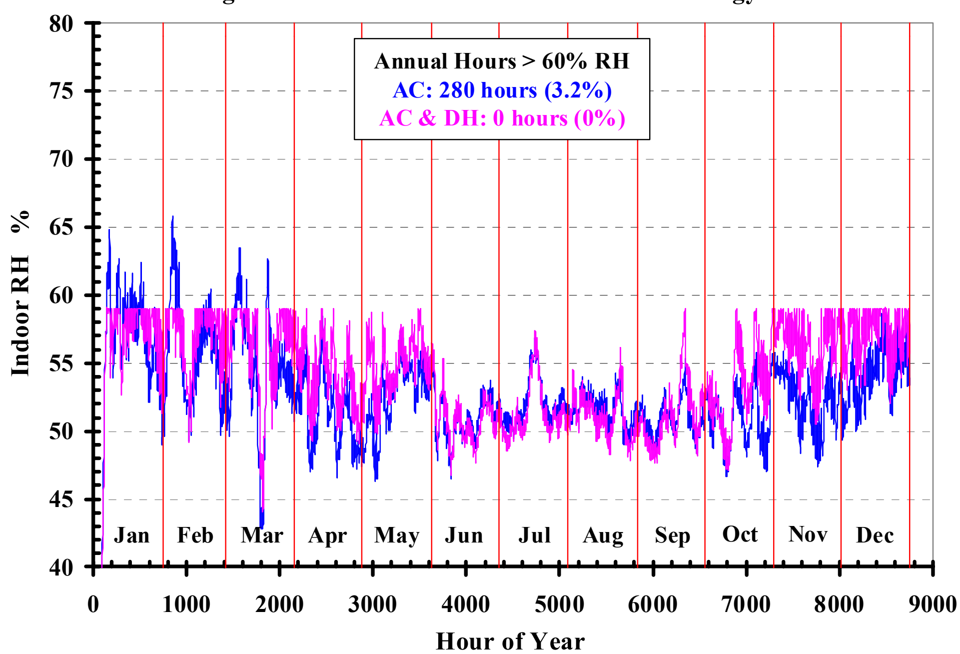
STRATEGY 2: Overcooling

One practice that is often employed to improve the comfort level in a home or building is to significantly lower the temperature setting (set point) for the conventional air conditioning system. This is referred to as overcooling. Overcooling improves comfort by reducing both the indoor temperature and the indoor RH. Overcooling is frequently employed even though it consumes a significant amount of energy and may result in moisture and mold problems if the cooling set point is lower than the dew point of the outdoor air.

In this study, the performance of a conventional air conditioning system operating at a set point of 72.0 °F (overcooling) was compared to an air conditioning and dehumidification system with set points of 78.0 °F and 59% (the same system from Strategy 1).

Hourly indoor RH values for Strategy 2 were predicted using the model and are shown in Figure 3.

Figure 3. Indoor RH vs Hour of Year for Strategy 2



The conventional air conditioning system operates 390 hours from December to March, more than three times as much as the conventional air conditioning in Strategy 1, yet in January, the indoor RH with conventional air conditioning exceeds 60% for 115 hours (15.5 % of the month). On an annual basis the indoor RH with conventional air conditioning exceeds 60% for 280 hours (3.2 % of the year). The air conditioning and dehumidifier system maintains the indoor RH below 60% at all times throughout the year.

Monthly energy usage for these two systems is shown in Figure 4. Energy savings occur every month of the year as a result of the 6.0 °F higher cooling set point for the conventional air conditioning system.

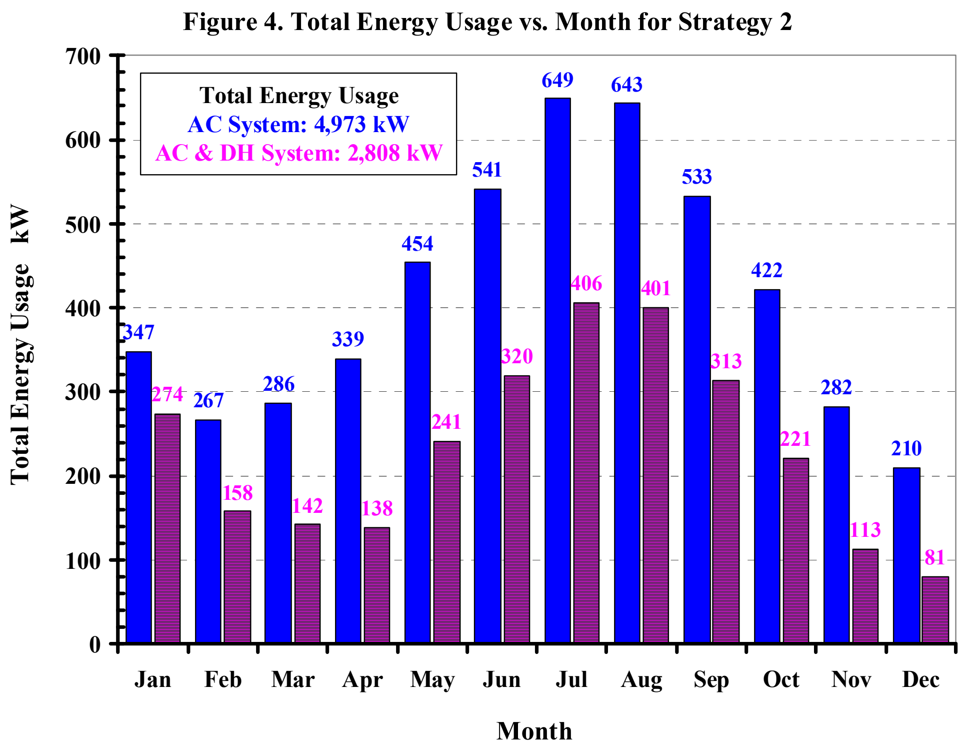


Table 2 provides an annual comparison of the conventional air conditioning system and the air conditioning and dehumidification system for Strategy 2. The air conditioning and dehumidification system provides an annual energy savings of 44% as compared to the conventional air conditioning system. The air conditioning and dehumidification system maintains the indoor RH below 60% throughout the year while the conventional air conditioning system allows the indoor RH to exceed 60% for 280 hours (3.2% of the year). This conventional air conditioning strategy provides for better indoor RH levels and comfort than that in Strategy 1, but it is still inadequate in January and February.

Table 2
Annual Performance Summary for Strategy 2

Performance Paramater	Air Conditioning & Dehumidifier	Conventional Air Conditioning
Energy Usage, kWh	2,808	4,973
% Energy Savings	44	NA
Operation Time, hours	1279 (AC) 258 (DH)	2757
Time > 60% RH, hours	0	280
% Time > 60% RH	0	3.2

Therefore, very significant energy savings as well as comfort improvements occur when using an air conditioning and dehumidification system rather than overcooling. In addition, the risk of damaging the home from mold problems associated with overcooling has been eliminated.

STRATEGY 3: Unoccupied in Summer Months

In the US, about one in four retiree "snowbirds" (about 900,000 people) reside in Florida to escape cold, northern climates during the winter. This seasonal occupancy creates a need for strategies for controlling the indoor RH to avoid mold problems while minimizing energy usage when the home is unoccupied. Previous studies have indicated that raising the set point of a conventional air conditioning system to 83.0 to 85.0 °F during the unoccupied period reduces energy usage but does not provide sufficient indoor RH control.

In this study, the performance of a conventional air conditioning system with a set point of 78.0 °F throughout the year was compared to an air conditioning and dehumidification system with set points of 78.0 °F when occupied (November through April), and 85.0 °F when unoccupied (May through October) and 59% RH year-round.

Hourly indoor RH values for Strategy 3 were predicted using the model and are shown in Figure 5. In January with conventional air conditioning, the indoor RH exceeds 60% for 596 hours (80.1%) and 70% for 309 hours (41.5%). Therefore, this conventional air conditioning system provides very poor control of the indoor RH.

Monthly energy usage for these two systems is shown in Figure 6.

Figure 5. Indoor RH vs Hour of Year for Strategy 3

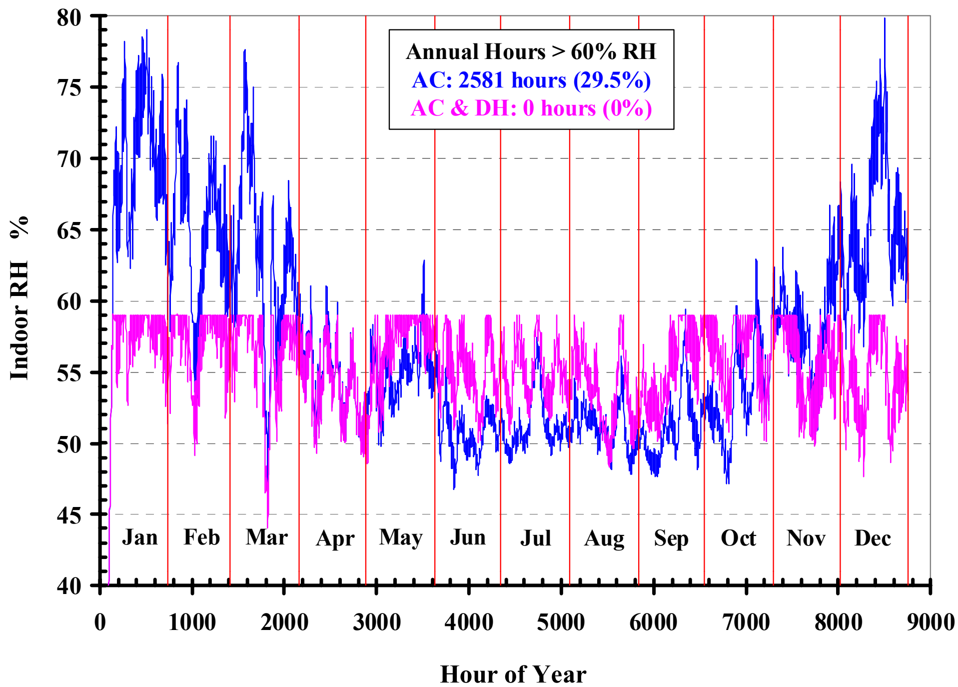
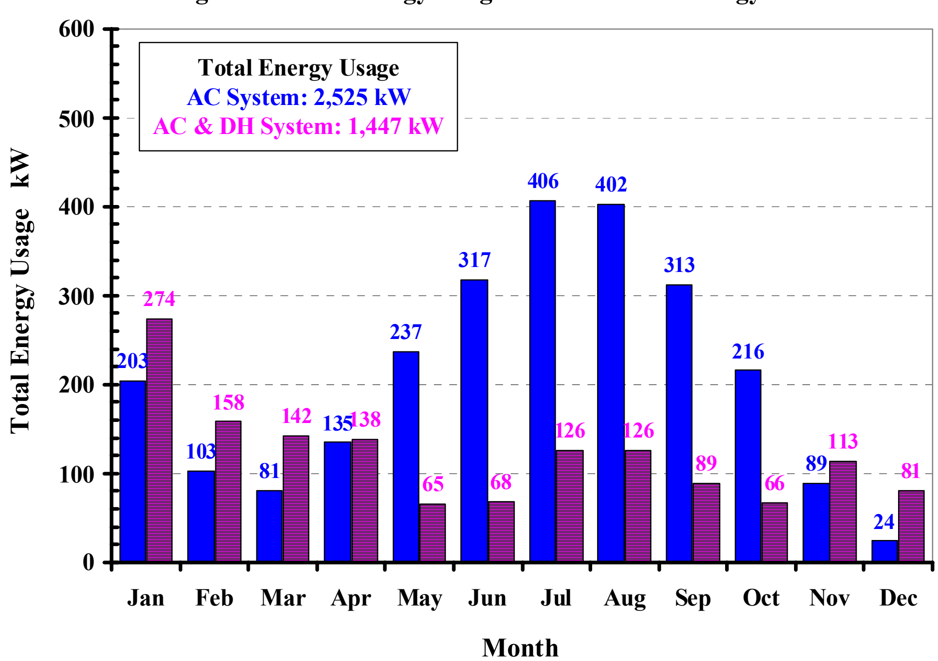


Figure 6. Total Energy Usage vs Month for Strategy 3



Energy savings for the air conditioning and dehumidification system occur during the unoccupied period from May through October.

Table 3 provides an annual comparison of the conventional air conditioning system and the air conditioning and dehumidification system for Strategy 3. The air conditioning and dehumidification system operates 201 and 252 hours, respectively, annually when the home is occupied and 213 and 102 hours, respectively, when unoccupied. The conventional air conditioning operates 1,076 hours when occupied and 169 hours when unoccupied. The air conditioning and dehumidification system provides an annual energy savings of 43% as compared to the conventional air conditioning system. The air conditioning and dehumidification system maintains the indoor RH below 60% throughout the year while the conventional air conditioning system allows the indoor RH to exceed 60% for 2,581 hours (29.5%).

Table 3
Annual Performance Summary for Strategy 3

Performance Paramater	Air Conditioning & Dehumidifier	Conventional Air Conditioning
Energy Usage, kWh	1,447	2,525
% Energy Savings	43	NA
Operation Time, hours	414 (AC) 354 (DH)	1245
Time > 60% RH, hours	0	2,581
% Time > 60% RH	0	29.5

Therefore, in seasonally occupied homes very significant energy savings and comfort improvements occur when using an air conditioning and dehumidification system rather than a conventional air conditioning system.

DISCUSSION

This study clearly indicates that there are operational strategies in which an air conditioning and dehumidification system can be used to provide significant energy savings as compared to a conventional air conditioning system, while significantly improving comfort and health of the occupants as well as preservation of the building and its contents.

Similar results would be found in other humid locations along the gulf coast and in the south such as Houston, TX and Jacksonville, FL since the cooling and dehumidification loads are similar. Increasing the air exchange rate from ventilation or looser construction increases the number of hours the indoor RH is greater than 60% with the conventional air conditioning system, making a dehumidifier even more beneficial. Simulations done in less humid Midwestern locations indicate an air conditioning and dehumidification system can provide better comfort with similar energy usage and in some cases an energy savings. Other energy and cost saving strategies for the air conditioning and dehumidification system could be employed when the home is unoccupied such as running the dehumidifier during off peak hours. The best time of day for the dehumidifier to run is based on the size and air tightness of the home.

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