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# Executive Summary: Evaluation Of The Impact Of Vacant Home Space Conditioning Strategies On Summer Relative Humidity, Energy, And Peak Load

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# Executive Summary
# Evaluation of the Impact of Vacant Home Space Conditioning Strategies on Summer Relative Humidity, Energy, and Peak Load

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Florida Solar Energy Center (FSEC)

FSEC-CR-1487-04

The Vacant Home Space Conditioning Study was sponsored by Florida Power & Light (FPL) as part of its Conservation R&D Program and carried out by the Florida Solar Energy Center (FSEC). In the US, about one in four retiree "snowbirds" make Florida their destination to escape the northern cold. Snowbird residents number more than 900,000 in Florida during the winter. In some counties of FPL's territory these seasonal residents compose up to 15% of the population (Shih, 1981). This pattern of seasonal occupancy creates a need for space conditioning guidelines for vacant homes to avoid mold problems while minimizing both customer energy usage and electrical load during utility peak hours.

Three homes on Florida's east coast in Brevard County were equipped with monitoring equipment for this experiment. The first was a 45-year-old 1,100 ft2 single-story, painted concrete block home on a concrete slab with a low pitch tar and gravel roof. The second house was a 40-year-old 1,950 ft2 split-level home, with block and frame construction. The third home was a 900 ft2 single-wide mobile home manufactured in 1984. Nearly 10% of FPL's residential customers live in manufactured homes including a sizable seasonal resident population. All three test-homes had 2.5-ton central air conditioning (AC) systems with heat pump, gas, and electric strip heating, respectively.

Five space conditioning strategies for vacant homes were assessed during hot, humid summer conditions and/or warm, humid fall weather conditions. The aim was to control relative humidity (RH), minimize energy use, and limit peak electrical demand. The five approaches were: 1) no space conditioning as the baseline, 2) AC thermostat set at 85oF or 83oF, 3) morning AC operation at 74oF, 4) dehumidifier alone, and 5) space heating.

Project staff identified several RH targets for controlling RH. First, RH should stay below 70% essentially all of the time. Second, RH should stay below 65% most of the time. Third, the target for RH, when appliance control included a humidistat, was set at 62%.

Mold and mildew grow when RH is high, say over 70%, for extended periods of time. In order to control these indoor air quality health hazards, it is important to understand the concept of relative humidity. Relative humidity, expressed in percent, is the measure of how much moisture is in the air compared to the maximum amount of moisture the air could hold at that temperature. There are two ways to control RH; 1) raising room temperature by adding heat and 2) removing moisture from the air using an air conditioner or dehumidifier. This research study explored both strategies.

An important observation was that some homes require more aggressive action to control RH than others. Air infiltration was found to be an important factor in the struggle against high indoor RH. Air infiltration, usually measured in air changes per hour (ach), is the rate at which outside air enters the house. Homes that have higher infiltration rates require greater moisture removal rates to achieve RH control.

**Overview of Humidity Control Approaches**

The first control approach is to let the building "float" – no AC, dehumidifier, or heating system operation. "Floating" yielded indoors conditions that were 4.8, 6.1, and 4.2oF warmer than outdoors, respectively, in the three houses. Whereas outdoor RH averages about 77% from June through October, indoor RH averaged 62%, 69%, and 73% in the three houses (see Figures A and B; note that Figures A – H are found at the end of the executive summary). The elevation of indoor temperature caused by solar radiation striking the houses produced this reduction in RH below the outdoor RH. Since the objective was to keep RH below 65% most of the time, only House 1 experienced acceptable RH without mechanical intervention. This does not mean, however, that houses 2 and 3 would experience mold problems without mechanical intervention. It just means that the risk of mold is higher in these houses.

**Figure A:**

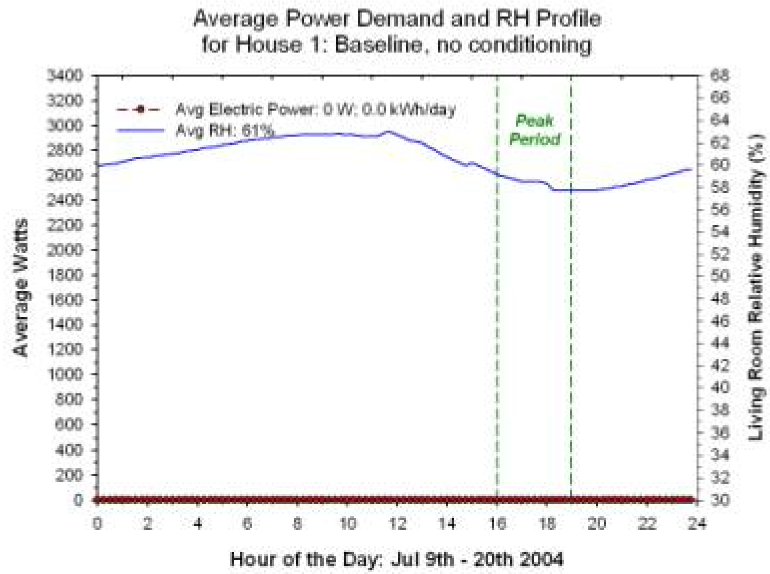
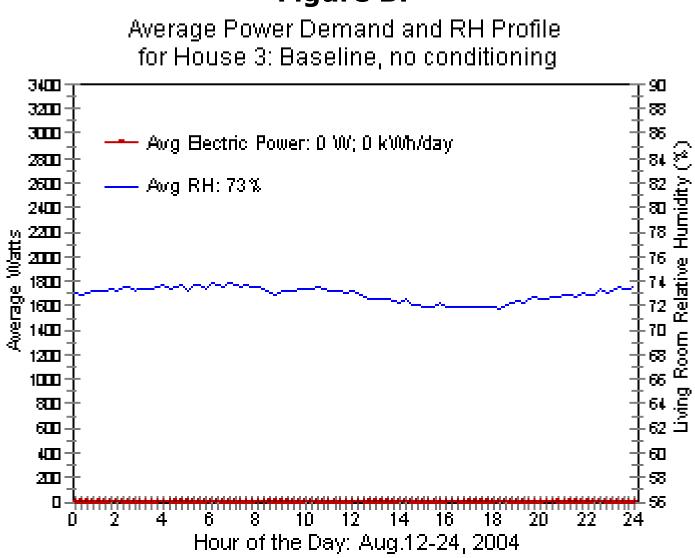



**Figure B:**




The second approach, AC at 85oF (fan AUTO), yielded generally poor results because the AC run time was too small to ensure adequate moisture removal. This approach works fairly well on hotter than average summer days, but on cooler and cloudier days, little or no AC run time lead to little or no moisture removal. Even setting the thermostat to 83oF did not ensure good performance, especially during the cooler months. During some test periods at some houses, neither AC at 85oF nor AC at 83oF caused the AC system to run at all. Furthermore, energy consumption tends to concentrate during the utility's peak demand period.

The third approach, AC set at 74oF from 3-5 AM (fan AUTO), yielded promising but mixed results. In House 1, this approach produced low RH (48%) in large part because of low natural infiltration (Figure C). In House 2, two-hour operation yielded marginal results with RH primarily in the range of 65-70%. Extending operation to four hours (3 - 5 AM and 10 AM - noon) yielded average 59% RH. In House 3, the results are inconclusive in part because the data collection for this home did not include the hottest summer months. The home reached the thermostat setpoint before the air conditioner had run the intended two hours each morning. In some homes, a thermostat setting lower than 74oF may be required. (Figure D).

**Figure C:**

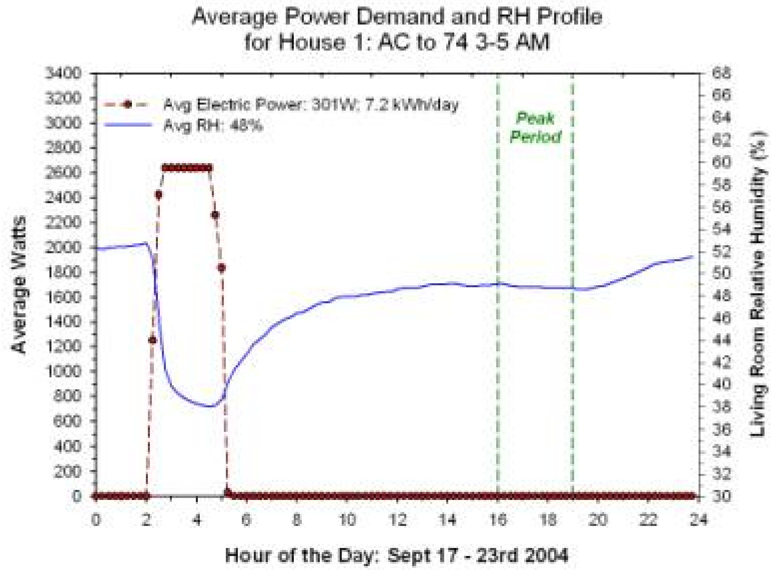
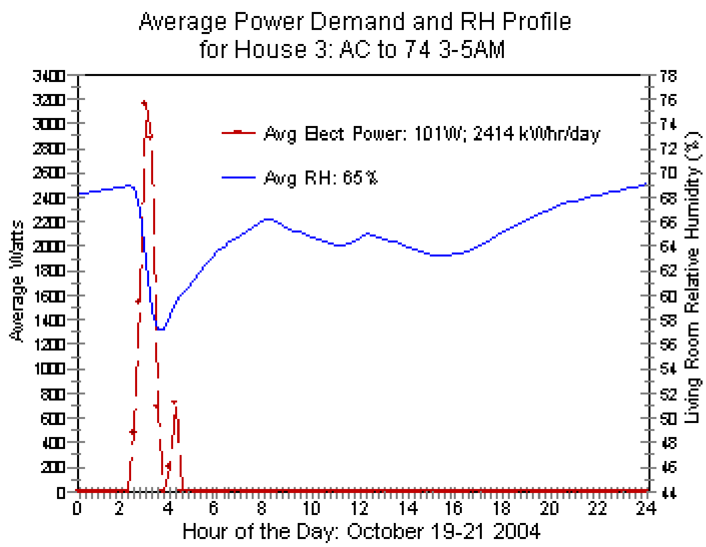



**Figure D:**




<u>The fourth approach</u>, a dehumidifier coupled with a floor fan to circulate the air, was effective in controlling RH in all the homes. Two control strategies were implemented. The first strategy involved setting the built-in humidistat to 62% (Figure E). This proved to be difficult because of erratic and undependable humidistat operation. The dehumidifier operation time required to control RH varied depending partly on the size of the house and more so on the infiltration rate. The second strategy, which involved operating the dehumidifier on a timer, provides reliable results with adequate operation time. Dehumidifier operation of 3 hours per day produced 56% RH in House 1 (small and tight; Figure F). 15-hour per day operation yielded 60% RH in House 2 (large and very leaky). 3-hour per day operation yielded 67% RH in House 3 (small and leaky). 4-5 hour operation time would be required in House 3 to meet our RH control objectives. It is interesting to note that a dehumidifier is a high efficiency space heater (coefficient of performance [COP] ~ 2.0) and that more than 50% of the RH reduction from dehumidifier operation resulted from indoor temperature increase. The timed operation can be set for off-peak hours, and operation using humidistat control would result in the least run time during the hottest (peak) hours of the day.

**Figure E:**

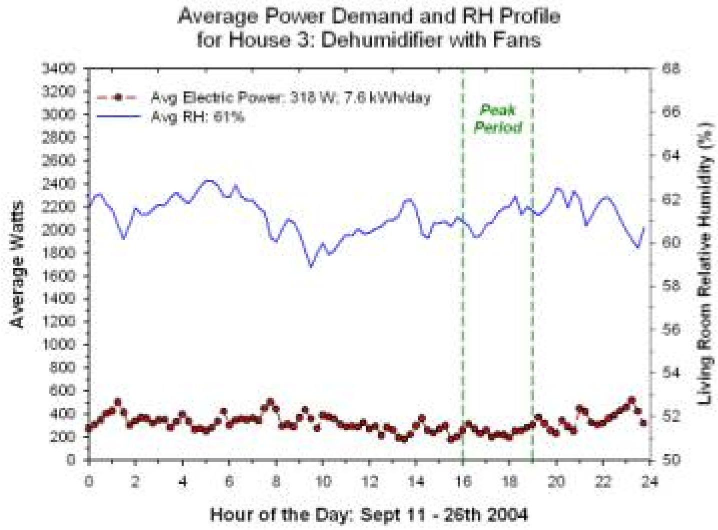
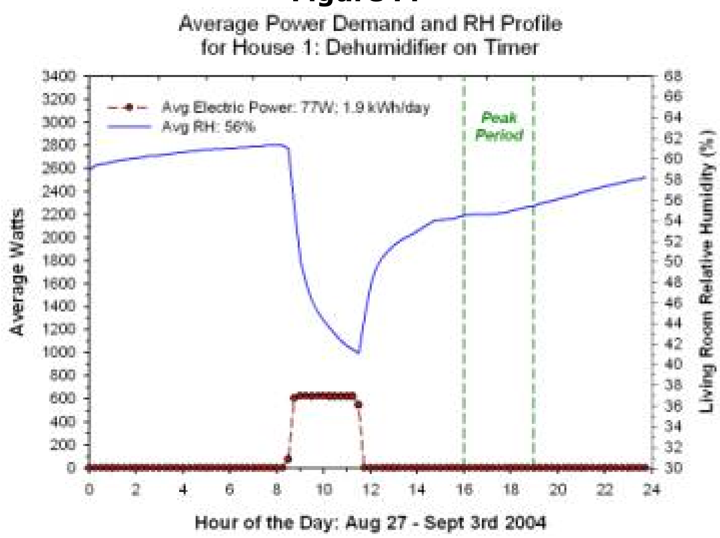



**Figure F:**




The fifth approach, which involved heating the house with the central space heating system, was also effective at reducing RH in all three homes. This result is not surprising. Typical Florida summer dew point temperatures are 74oF. Heating the indoor temperature to 88.5oF on this typical summer day increases the moisture capacity of the air and, as a result, reduces indoor RH to 62%. If the home is going to be vacant during the cooler months such as May and October when the dew point temperatures are lower, then maintaining this high indoor temperature will produce lower RH. In House 1, for example, indoor RH was 54% over a period from September 27-October 13 (Figure G; outdoor dew point temperature averaged 69oF during this period). In House 3, indoor RH was 59% over a period from September 30-October 14 (Figure H; outdoor dew point temperature averaged 69oF during this period). The difference in RH between Houses 1 and 3 results from House 1 being about 2 degrees F warmer than House 3.

**Figure G:**

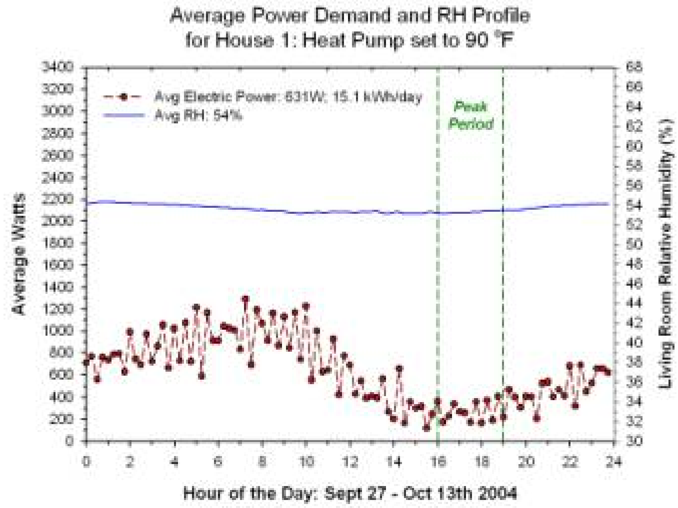
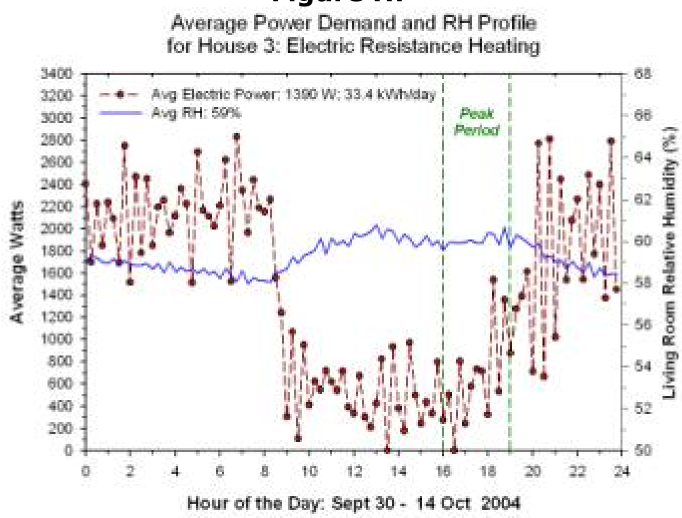



**Figure H:**




During periods with lower dew point temperature, the same RH can be achieved at a lower space temperature. If, for example, it is October and the outdoor dew point temperature is 68oF, the indoor temperature required to produce 62% RH would be 82oF. If possible, a friend or family member living nearby could manually set the thermostat to heat ON and fan AUTO with a setting of 88oF in June through September and 82oF for the other months (such as May, October, and November).

An analysis has been done to compare the relative energy cost of the three promising approaches (Table follows). In order to make the fairest comparison of approaches, the energy use is based on the optimum length of system operation to achieve the desired RH control. In House 1, for example, we estimated that only 1 hour per day of AC on at 74oF would be required, and in House 3, we estimated that the dehumidifier would need to run for 5 hours per day to achieve acceptable RH control. Keep in mind that House 2 is about twice the size of Houses 1 and 3.

**Monthly electricity cost (at $0.085 per kWh) required to achieve RH 65% or lower**

| | | | | |
|---|---|---|---|---|
| **HOUSE # ->** | **1** | **2** | **3** | **Average** |
| House size (square feet) | 1100 | 1950 | 900 | 1317 |
| Natural infiltration rate | low | high | high | |
| AC (ON at 74oF 3-5 AM) | $6.631 | $25.52 | $16.32 | $16.15 |
| Dehumidifier (on timer) | $5.36 | 29.33 | $8.933 | $14.54 |
| Space heating 4 (at 88 to 90oF) | $18.11 | $21.93 | $22.44 | $20.83 |

1 Assumes 1 hour per day AC operation.
2 Assumes 4 hours per day AC operation.
3 Assumes 5 hours per day dehumidifier operation.
4 Assumes heater is a heat pump and that the period of operation is June – October.

**Recommendations**

Two methods have been identified as "not effective".

Floating. This approach cannot reliably achieve RH below 65% most of the time.

AC at 85oF.This approach does not work in most homes because AC run time is not sufficient, especially on humid, cloudy days that typically represent the worst-case for indoor humidity control. Even setting the AC at 83oF did not result in reliable humidity control in all houses and during fall weather. Furthermore, this approach imposes maximum demand during the utility's peak period of 12 – 9 PM.

Three methods were found to be "effective". These methods show considerable promise, each showing the ability to control indoor RH with reasonable energy use and peak demand impacts. None of these methods stands out as being substantially better than the others within the limited sample of homes.

AC at 74oF from 3-5 AM. Using a programmable thermostat to operate the cooling system during the early morning hours appears to work well in a majority of homes and under a wide range of weather conditions. In homes with high infiltration rates, the AC operation time may need to be extended to four hours to keep RH below 65% most of the time. A lower thermostat setting of say 70 or 72oF may be necessary during the spring/fall months for manufactured homes. Energy use is modest for this strategy, and electrical load is kept off-peak, as long as the thermostat clock retains its memory. The effectiveness of this approach assumes that the AC system can produce cold supply air. Warmer than normal supply air can result from improper refrigerant charge, excessive system airflow rates, or large return duct leakage. It also assumes that system operation does not induce high infiltration rates due to duct leakage or closed interior doors. For those considering this approach, diagnosis and repair of duct leaks of the central air conditioning system would help to assure best results. Also, whenever using the cooling or heating system in a vacant home, fan control should be set to "auto" to save energy, to avoid drawing humid air into the house through duct leaks, and to prevent the filter from fouling up too quickly.

Dehumidifier. Dehumidifiers can be controlled by a humidistat or a timer.

- Humidistat control. Setting a dehumidifier at 62% and letting it cycle ON and OFF to maintain the desired RH is generally effective. The control performance of built-in humidistats was found to be imprecise, and there are questions about the reliability of available humidistats. If used with a more reliable humidistat, this approach can be quite effective. Energy use is moderate and favorable for utility peak impact, because the dehumidifier tends to operate more during off-peak periods.
- Timer control. Operating the dehumidifier at the lowest RH setting with a timer for a specific number of hours each day is effective and reliable in controlling RH at a reasonable energy cost. Dehumidifier run time must be determined based on the size and airtightness of the house, generally using a trial and error approach. If possible, avoid operating the dehumidifier between the hours of noon and 9 PM when the electric utility experiences its peak load. A timer with battery back-up is preferred to ensure the timer stays synchronized with the correct hour. If a dehumidifier is operated by means of a timer, a floor fan could be plugged into the same timer to help circulate air to the parts of the home furthest away from the dehumidifier.

Space heating. Heating the house to 88 or 90oF lowers indoor RH quite effectively for nearly all hours of the summer without removing moisture from the room air. Energy use is moderate for the period June through September, but increases substantially in late spring and late fall. In general, this approach should not be used during the months November through April, since heating energy use could become excessive. The space heating approach is nearly four times more energy efficient using a heat pump compared to strip heat. With either heat source, the peak hour demand to the utility is minimal since no space heating is required from 12 - 9 PM on hotter than average summer days.

- Humidistat control over the heating system can greatly minimize this higher energy use during cooler months. The premise of this approach is that during cooler months outdoor dew point temperatures decline. With lower dew point temperatures, the indoor temperature required to maintain 62% or lower RH also declines. In this approach, a humidistat is used to turn on the space heating system when indoor RH exceeds 62%. A humidistat is installed to operate the heating system. The thermostat is switched to OFF (or set to HEAT at say 60oF in north Florida to prevent house freeze-up). Either the thermostat or humidistat can now turn on the system to provide heating. Energy savings result during cooler months because the indoor temperature required to meet our RH objective is automatically reduced (by the humidistat) as the outdoor dew point temperature declines.

When operating either the air conditioning or heating system in a vacant home, be sure to set the thermostat fan selection to “auto” to save energy and avoid clogging the filter.  Before leaving any home vacant, open all the interior doors to allow unrestricted air circulation.