BEST PRACTICE UPGRADES FOR NEW ENERGY EFFICIENT HOMES IN HOT AND HUMID CLIMATES

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ABSTRACT

The EPA's ENERGY STAR® Homes program is a national voluntary program that promotes the construction of new homes that are 30% more efficient than the Model Energy Code. Accordingly, with the Home Energy Rating System (HERS) scoring system, ENERGY STAR® Homes must achieve a score of at least an 86. This performance-based compliance requirement enables builders to be creative in the specific energy efficiency features that they build in their new homes. However, builders often want to know what the minimum energy efficiency features of an ENERGY STAR® Home would likely be - before they joined the program. To solve this problem, EPA developed the Builder Option Packages (BOPs). BOPs are currently used as marketing tools to communicate the typical energy efficiency features of ENERGY STAR® Homes. This paper will focus on the hot and humid portion of the U.S. and explain the technical methodology used to develop the BOPs as well as the energy use and HERS scores obtained for the various configurations analyzed.

INTRODUCTION

Energy efficiency is a term that is frequently used in the new housing industry. However, there is little understanding by both builders and consumers about what energy efficiency really means. For example, a feature being touted as energy efficient could in fact only meet the minimum efficiency level required by code. It could also be a feature that itself is very efficient but its impact on the home's energy use is nominal. In addition, the energy performance level of products and features is often greatly affected by its installation. Poor installation can result in poor energy performance.

There have been many efforts to clear up this confusion. For example, numerous best practice guides have been developed by building scientists and energy efficiency organizations. In addition, the Home Energy Rating System (HERS) was established to provide a consistent method that could be used nationally for evaluating the energy efficiency of a home. The key features of an energy efficient home should be low utility bills, improved comfort, and adequate indoor air quality.

Despite the efforts to promote energy efficient construction, the majority of builders in this country have not embraced the many tried and true technologies or construction practices that are known. EPA is trying to change this with its marketing based ENERGY STAR® Homes program. This national voluntary program is trying to make intelligent, cost effective, energy efficient designs easier to adopt by promoting the benefits of energy efficiency to both builders and consumers. By setting a minimum energy performance criteria, the program offers builders flexibility in design. At the same time, consumers are offered the assurance of truly buying an energy efficient home, because the energy performance of the house is verified by an independent 3rd party. In addition, the ENERGY STAR® Homes program makes it easier for homebuyers to make a smart purchasing decision by awarding certificates to qualified homes and promoting the ENERGY STAR® brand.

One component of the ENERGY STAR® Homes program is Builder Option Packages (BOPs). BOPs are prescriptive packages that offer builders one solution for building an energy efficient, ENERGY STAR® home. ICF Consulting developed the BOPs using the DOE-2.1E computer-modeling program. The energy efficient features of these packages were selected based on several criteria, including input from many builders across the country and cost effectiveness of the measures. The anticipated energy performance level of the BOPs was verified by Lawrence Berkeley National Laboratory using both the DOE-2 and RemRate modeling tools. As a result of the careful selection and rigorous testing of the energy efficiency features, the BOPs are considered to represent best practice upgrades.

This paper is divided into four sections. The first section briefly discusses the ENERGY STAR® Homes program. The second section explains the technical methodology used by the Homes program to develop the BOPs. The third section describes BOPs specifically developed for hot and humid climates using this methodology. And, the fourth section discusses lessons learned.

EPA's ENERGY STAR® HOMES PROGRAM

EPA's ENERGY STAR® Homes program is a national voluntary program that promotes the construction of new homes that are 30% more energy efficient than a comparable home built to the Model Energy Code (for the HVAC and DHW end-uses only). It encourages healthy homes by recommending the homes maintain ASHRAE's minimum ventilation rate of 0.35 ac/h by building the house tight and using an active ventilation system. Homes certified as ENERGY STAR® are also third party verified to ensure the builder is properly installing the energy efficiency features. A homebuyer doesn't need to be an energy efficiency expert to feel confident about their purchasing decision, they only need to look for the ENERGY STAR® logo and house certificate.

The ENERGY STAR® Homes program uses the Home Energy Rating System (HERS) (or equivalent) methodology for determining an energy score for the home. A home built to the Model Energy Code receives a score of 80. Each 5% of energy savings is equal to 1 HERS point hence an ENERGY STAR® home has a HERS score of 86 or higher. This performance-based compliance requirement enables builders to be creative in the specific energy efficiency features that they design and build in their new homes.

However, builders often want to know what the minimum energy efficiency features of an ENERGY STAR® home would likely be - before they join the program. To solve this problem, EPA developed Builder Option Packages (BOPs). BOPs are a set of prescriptive measures and limitations that are designed to meet or exceed a HERS score of 86. The BOPs are designed to be applicable to a wide range of homes within a given climate region. BOPs are currently used as marketing tools to communicate the typical energy efficiency features of ENERGY STAR® Homes built in each of five climate regions of the U.S.

TECHNICAL METHODOLOGY FOR DEVELOPING BOPS

The goal of a BOP is to establish a set of parameters that will result in a minimum HERS score of 86 for a wide range of homes in a given climate region. These parameters are determined using the DOE-2.1E computer modeling software in a three step process of establishing the worst case scenario, determining the features required to reach a HERS 86, and then modeling the resulting package in other scenarios to ensure a minimum HERS 86 is consistently achieved.

The first step is to establish the worst case scenario. A worst case scenario is the house configuration that is the hardest to reach a HERS 86. Therefore, designing a BOP around the worst case scenario should ensure that all other possible house configurations would score higher than a HERS 86.

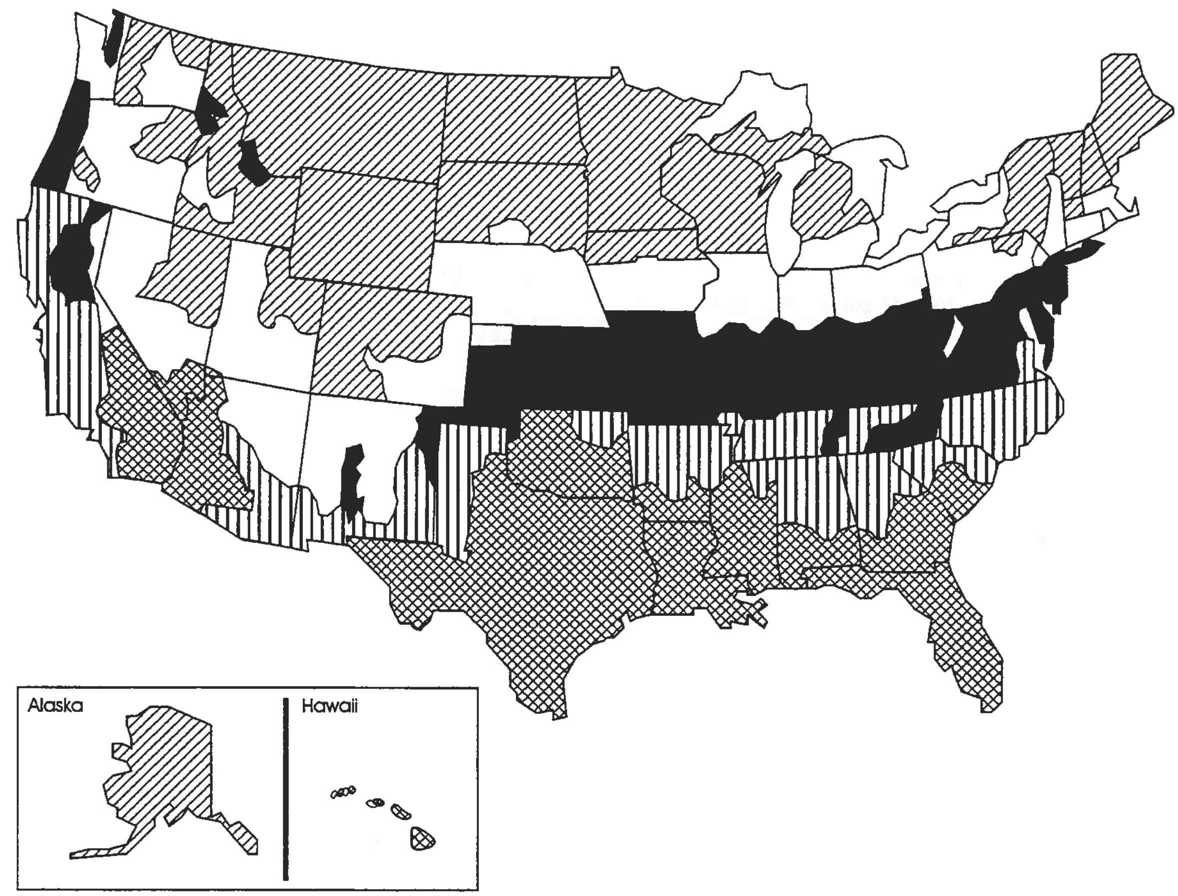
To establish the worst case scenario, the key energy drivers of a home need to be determined. Through literally thousands of DOE-2 runs, ICF identified several key features that had a significant impact on a home's energy use. These features are: the size of the home; the number of floors; the foundation type; the aspect ratio; the percent glazing and distribution of that glazing; and, the climate in which the home is located. By varying the combinations of house features, a worst case house configuration (i.e., results in the highest simulated energy use) could be established for a given climate region. A true worst case configuration would probably never be built in reality (e.g., all of the glass on the worst orientation of the home). Thus, a "likely" worst case configuration was established through conversations with many builders and building industry professionals. The features of a likely worst case configuration for a home are:

Aspect ratio of 2:1
House sizes up to 2000 square feet for single story and 4000 square feet for two stories
20% window to floor area (WFA)
Window distribution of 50% on the front, 25% on the back and 12.5% on the left and right

Using these limitations as a starting point, the remaining key energy features (i.e., size and foundation type) of a home are modeled to establish the worst case house configuration. The variations in house size are: single story home at 1000 and 2000 square feet; and, two story home at 2000 square foot per floor. Each of the house sizes is further modeled with foundation variations of basement, crawlspace, and slab on grade.

The BOPs are applicable to one of five broad climate region as defined by EIA (see Exhibit 1.) To ensure that the resulting worst case combination achieves a minimum HERS 86 in the entire climate region, it is modeled in three cities that represent the range of climate experienced in that region. The cities selected are the hottest, coldest, and driest cities for the particular climate region. Note that it was established that the most humid city always corresponded to the hottest city. By modeling the worst case house configuration in all three cities, the worst case scenario can be established.

U.S. Climate Zones



Climate Zones

- Zone 1 is less than 2,000 Cooling Degree Days and greater than 7,000 Heating Degree Days
- Zone 2 is less than 2,000 Cooling Degree Days and 5,500-7,000 Heating Degree Days
- Zone 3 is less than 2,000 Cooling Degree Days and 4,000-5,499 Heating Degree Days
- Zone 4 is less than 2,000 Cooling Degree Days and less than 4,000 Heating Degree Days
- Zone 5 is 2,000 Cooling Degree Days or more and less than 4,000 Heating Degree Days

U.S. Climate Zone Map from Energy Information Administration's Commercial Buildings Energy Consumption and Expenditures 1992, Appendix F. Graphic enhancements by Guaranteed Watt Savers Systems, Inc.

Exhibit 1. EIA U.S. Climate Zone Map.

The second step is to determine a set of energy efficiency upgrades for the worst case scenario (i.e., worst case house configuration in the worst case city of the climate region) that results in a HERS score of 86. The selection of upgrades is based on four basic criteria: the relative energy use of the end use equipment; the components contributing to the peak loads; the cost effectiveness of the upgrades; and the willingness by builders to incorporate the upgrade.

Once a HERS 86 has been achieved, the third step is to model the resulting package in the remaining cities to ensure scores of 86 or higher are also reached. Typically, scores higher than 86 are obtained.

BOPS FOR HOT AND HUMID CLIMATES

A similar process was used in developing BOPs for this paper. There are three differences however. First, the BOPs were developed for specific cities rather than broader climate regions. Second, the packages were developed for homes with up to 18% WFA instead of the 20% WFA typically used. Third, the worst case house configuration used in all of the cities was based on the analysis of one city (Houston, TX) as opposed to the worst case of the hottest, coldest and driest cities in a particular climate zone.

The first step in developing the hot and humid BOPs was to establish the worst case house configuration. Three house types and sizes were analyzed: a single story 1000 home, a single story 2000 square foot home, and a two story (2000 square foot per story) home. Each of these homes was modeled with a basement, crawl-space, and slab on grade to determine which configuration has the highest energy use and thus the lowest HERS score. Exhibit 2 shows the resulting HERS scores for the various configurations.

As indicated in Exhibit 2, the worst case configuration is the single story, 2000 square foot home with a basement. While a basement construction may not be common in the south (i.e., in hot and humid climates), it was used none-the-less to maximize the applicability of the package.

Five cities were selected for developing BOPs. Miami, Houston, and Shreveport were selected based on their high seasonal levels of temperature and humidity. Little Rock and Greensboro were selected to provide comparison of how high humidity levels affect a home's energy performance and comfort when the outdoor temperatures are cooler. Exhibit 3 summarizes the weather data for these cities, with the cities listed from hottest to coldest.

The second step in developing the Hot and Humid BOPs was to model the worst case configuration in each of the five cities and determine the energy efficiency upgrades required to achieve a minimum 86 HERS score. Exhibit 4 presents a side-by-side comparison of the resulting BOPs for each of the five cities. Generally speaking, the Miami, Houston, and Shreveport packages have comparable features while the Little Rock and Greensboro packages require higher levels of insulation. As indicated in Exhibit 4, each of the five packages achieved a HERS score of 86.

LESSONS LEARNED

Because these packages were for humid cities, an analysis on the indoor relative humidity was performed for each BOP. Using a standard DOE-2 report, the number of hours per year that the indoor relative humidity fell within certain levels, or bins (i.e., 0% - 9% RH, 10% - 19% RH, etc.), was determined. While each BOP achieved a HERS score of 86, it was discovered that the indoor relative humidity levels were often outside of the 30% – 60% RH range. This range is defined by ASHRAE Standard 55 as the desired comfort zone. Exhibit 5 shows a comparison of the indoor relative humidity levels for the five BOPs. The dotted line box indicates the targeted relative humidity levels for maintaining a comfortable indoor environment. The percent of time spent outside of the comfort zone ranged from 18% for Miami to 48% for Greensboro.

In order to ensure the homes are comfortable, both humidification and dehumidification will be required. To estimate the amount of dehumidification energy required for maintaining the indoor relative humidity

	Slab on Grade	Basement	Crawlspace
Single story, 1000 sq.ft.	79.6	79.6	79.7
Single story, 2000 sq.ft.	78.6	77.9	79.0
Two story, 2000 sq.ft. per floor	78.8	79.0	79.1

Exhibit 2. HERS Scores for Various House Configurations in Houston, TX

	Miami, FL	Houston, TX	Shreveport, LA	Little Rock, AR	Greensboro, NC
Avg DB Temp (F)	75.8	68.1	64.7	61.2	57.0
Avg WB Temp (F)	69.1	62.4	58.6	55.0	51.3
Avg Daily Max (F)	81.9	78.3	75.3	71.9	66.9
Avg RH (%)					
4:00:00 AM	82.1	89.2	86.8	82.5	82.9
10:00:00 AM	67.4	68.9	67.5	64.8	65.8
4:00:00 PM	62.4	57.9	54.7	53.8	53.8
10:00:00 PM	75.9	82.3	78.7	76.1	74.3

Exhibit 3. Weather Data for Various Hot and Humid Cities.

	Miami, FL	Houston, TX	Shreveport, LA	Little Rock, AR	Greensboro, NC
Building Geometry					
Single Story Floor Area (sqft)	</= 2000	</= 2000	</= 2000	</= 2000	</= 2000
Multi Story Floor Area (sqft)	</= 4000	</= 4000	</= 4000	</= 4000	</= 4000
Total Window Area (% WFA)	</= 18%	</= 18%	</= 18%	</= 18%	</= 18%
South and West (% WFA)	</= 11.25%	</= 11.25%	</= 11.25%	</= 11.25%	</= 11.25%
Thermal Envelope					
Exterior Wall Insulation	>/= R-13	>/= R-13	>/= R-13	>/= R-15	>/= R-16
Attic Insulation	>/= R-30	>/= R-30	>/= R-30	>/= R-38	>/= R-38
Basement Wall Insulation	>/= R-6	>/= R-6	>/= R-6	>/= R-6	>/= R-11
Slab Insulation	none	none	none	>/= R-4	>/= R-4
Crawlspace Floor Insulation	>/= R-13	>/= R-13	>/= R-13	>/= R-19	>/= R-19
Infiltration	0.35	0.35	0.35	0.35	0.35
Window Performance					
U-Value	0.50	0.50	0.50	0.50	0.40
SHGC	0.57	0.53	0.59	0.50	0.50
Door	>/= R-5	>/= R-5	>/= R-5	>/= R-5	>/= R-5
Mechanical Equipment					
Thermostat	Manual	Manual	Manual	Manual	Manual
Water Heater	EF >/= 0.88	EF >/= 0.88	EF >/= 0.88	EF >/= 0.88	EF >/= 0.92
Wrap Insulation	None	None	>/= R-5	None	>/= R-5
Heating Equipment	>/= 7.2 HSPF	>/= 7.2 HSPF	>/= 7.2 HSPF	>/= 7.2 HSPF	>/= 7.2 HSPF
Cooling Equipment	>/= 12 SEER	>/= 12 SEER	>/= 12 SEER	>/= 12 SEER	>/= 12 SEER
Ventilation	Recommended	Recommended	Recommended	Recommended	Recommended
Duct Distribution	</= 6%	</= 6%	</= 6%	</= 6%	</= 6%
Duct Insulation	>/= R-8	>/= R-8	>/= R-8	>/= R-8	>/= R-8
HERS Score	86	86	86	86	86

Exhibit 4. Comparison of BOPs for Various Hot and Humid Cities.

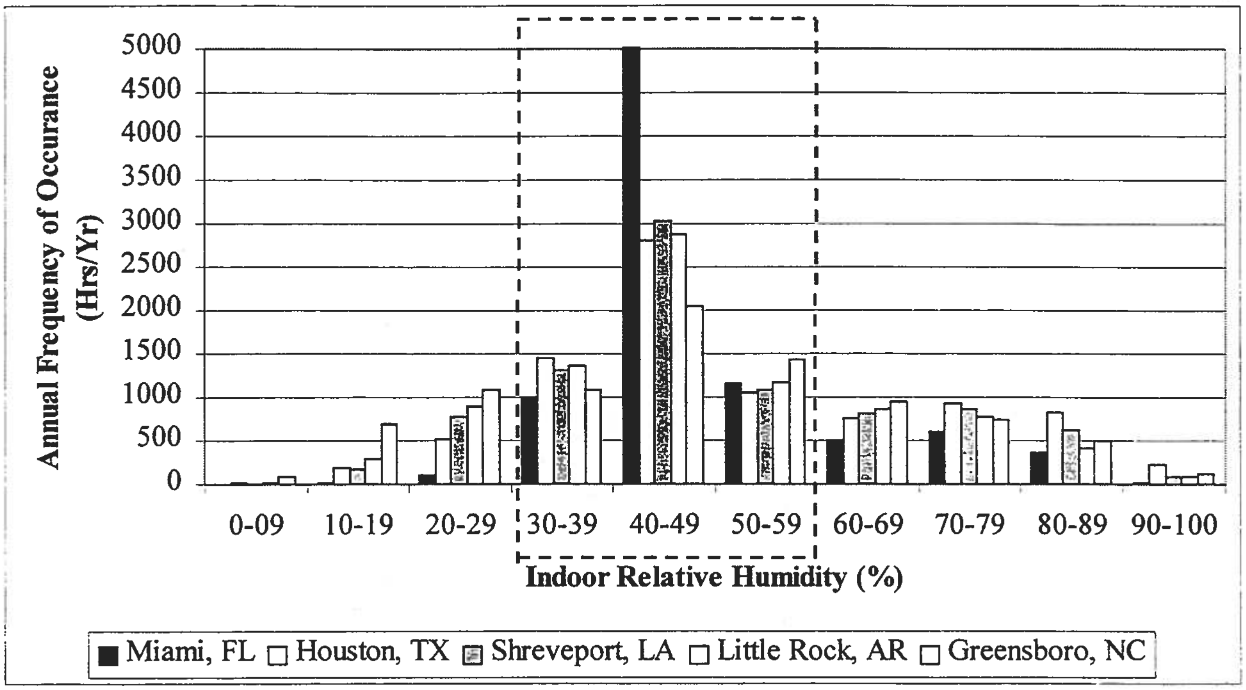


Exhibit 5. Comparison of Indoor Relative Humidity Levels for Five Hot and Humid Cities.

level at 60%, the following methodology was used. The number of hours spent at each percent of relative humidity was unknown (i.e., only the number of hours for a bin of relative humidity was known). Therefore, it was assumed that the all of the hours in the bin were for the average %RH of that bin (i.e., 95% RH was assumed for the 90% – 100% RH bin). The indoor air temperature was modeled at 78° F (as specified in the HERS *Guidelines for Uniformity*), hence the enthalpy difference between the average percentage RH for a given bin and the desired 60% RH could be determined using a psychrometric chart. The amount of annual energy consumed (Btu/yr) for dehumidification was estimated using the following equation:

$$\textit{Annual Dehumidification Energy Use} = (h_{hi} - h_{lo}) \times V \times (1/\rho) \times (Hrs) \times (1/COP)$$

Where:
h_{hi} = Indoor enthalpy at 78F, 95% RH
h_{lo} = Indoor enthalpy at 78F, 60% RH
V = Volume of the house
ρ = Density of air at 78° F
Hrs = The number of hours experience in that %RH bin for the year (e.g., 90% - 100% RH)
COP = The coefficient of performance for the dehumidification equipment

The dehumidification energy required to bring the indoor relative humidity level to 60% increased the original cooling energy by 12% for Miami and by 44% for Greensboro. This information is summarized in Exhibit 6. The original HERS scores of 86 did not take this dehumidification energy into account. Doing so decreases the HERS scores, as would be expected. Exhibit 7 compares the BOP HERS scores with and without the required dehumidification energy. The original HERS 86's now range from 84.1 to 85.3, however comfort is maintained in the home.

It is interesting to note that the largest impact of dehumidification occurs in the cooler city of Greensboro. This is due to relatively equal sensible and latent *annual* cooling loads. Additional energy consumption would be attributed to humidification when the indoor relative humidity is below 30%, but this paper does not examine that impact.

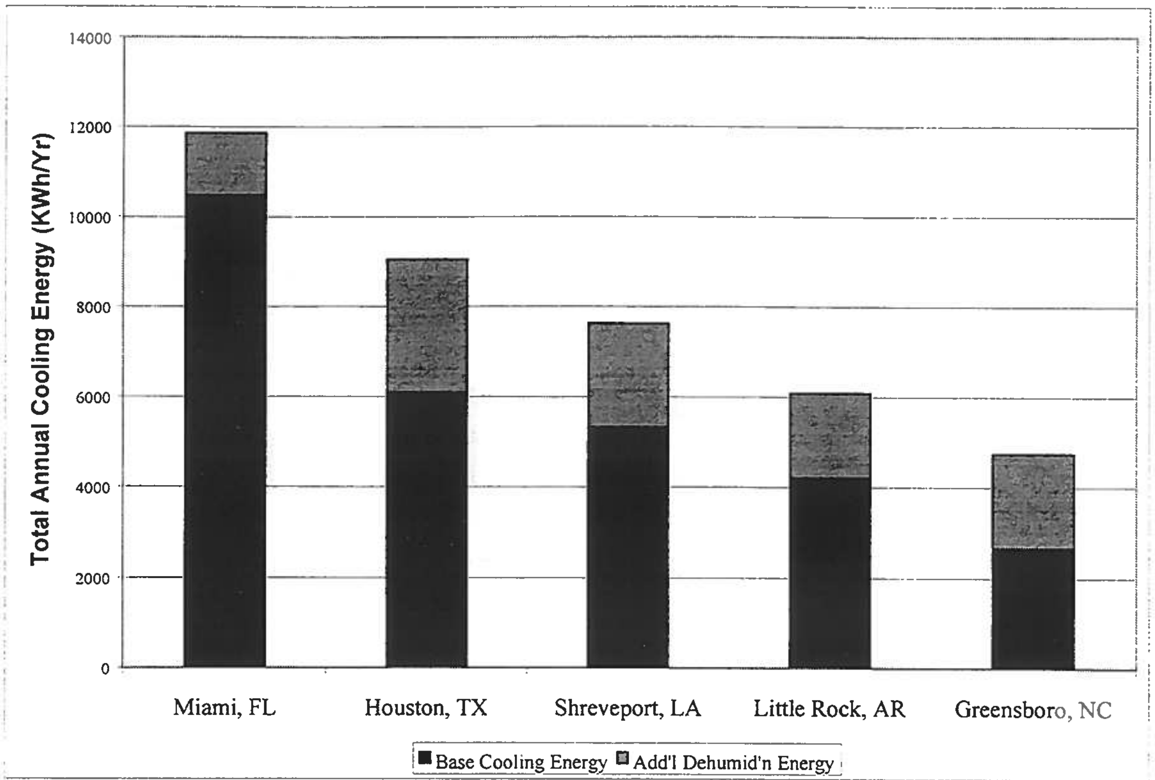


Exhibit 6. Comparison of Total Cooling Energy Requirements for Five Climate Locations.

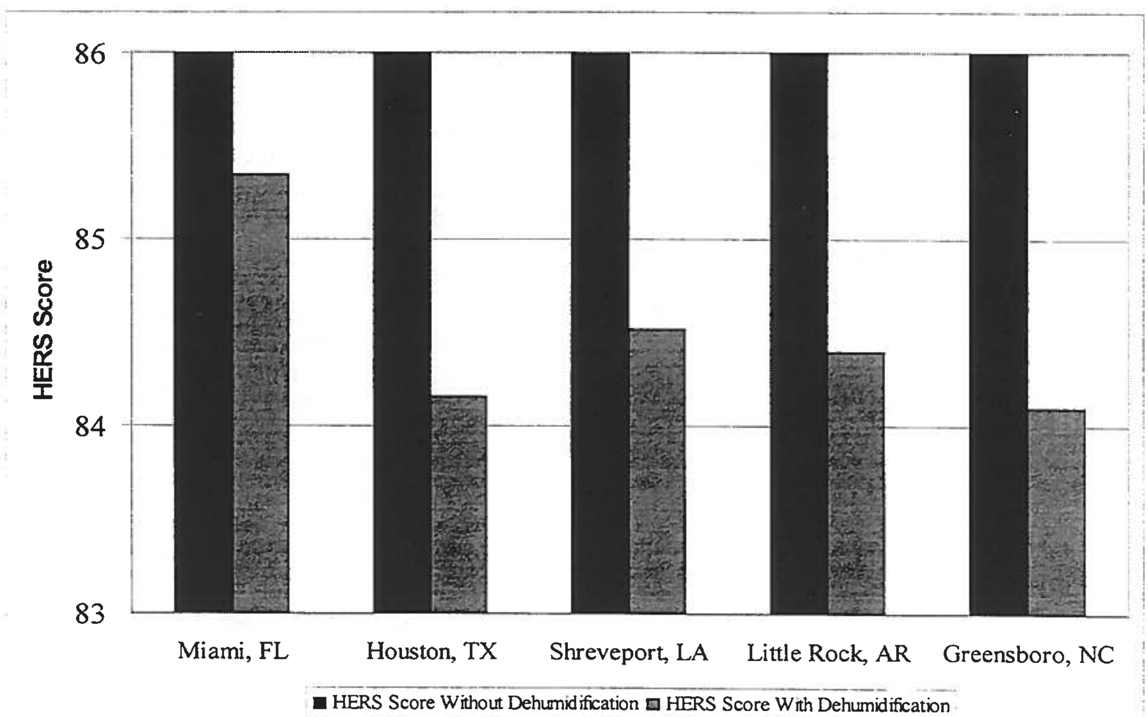


Exhibit 7. Comparison of HERS Scores With and Without Energy Use for Dehumidification.

SUMMARY

To build an energy efficient house in a hot and humid climate, builders can follow the prescriptive measures in an ENERGY STAR® BOP. However, to truly achieve best practices in energy efficient construction, the dehumidification needs must also be considered. There are a variety of means for reducing the indoor relative humidity level including: installing an HVAC system with a variable speed fan and humidistat control; tightening the house and installing an energy recovery ventilator; or simply placing a stand alone dehumidifier unit in the home. Each method has its own level of efficiency that will impact the overall energy use of the home. Thus, depending on the method of dehumidification selected, the HERS score may or may not be a good indication of the home's overall energy efficiency. Therefore, if the HERS methodology is used, designers of energy efficient homes in hot and humid climates need to consider the efficiency of the dehumidification method in addition to the traditional specifications of an energy efficient design. Further, the energy impacts of the dehumidification needs can be assessed by analyzing the annual sensible to latent cooling load ratio.