Cultural Effect on Residential Cooling Energy Consumption

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Abstract

High-energy consumption is one of the major problems in the world today. Residential energy consumption represents a significant share of total energy consumption equaling about twenty percent of the total gross energy consumption in the United States. Residential energy cost is an important part of the household budget and could vary significantly across different population groups in many countries. Identical buildings often have different consumption patterns and different utility bills. This paper analyzes the cooling energy consumption in residential buildings across various cultural groups in Bryan/College Station, Texas. Three mainstream ethnic groups (Afro-Americans, Hispanic-Americans and White Americans) were considered for the analysis. A survey instrument was prepared and distributed among 66 randomly selected residents of Bryan/College Station, TX to collect data related to household structure. Monthly energy usage of the residents was obtained from the city utility departments. The data was analyzed using a General Linear Model. The results indicate that residential energy consumption is affected by ethnicity of a household.

Keywords: Residential, Cooling Energy Consumption, Ethnicity

Introduction

High energy consumption is one of the major problems in today's world, the United States being the largest consumer. Residential energy consumption has taken a front stage because it represents a significant share of total energy consumption equaling about 20% of the total gross energy consumption in the United States [1].

There are many factors that affect the variability of energy consumption in residential buildings. These factors include outside surface area of the building, the total area of door and window openings, the insulation system, the number of residents within the building, and the personal behavior of the occupants [2]. By analyzing these factors and their relationships to energy consumption, the best subset of explanatory variables can be

identified and a predictive model of energy usage in residential buildings can be developed.

Haas *et al.*[1] found that the energy savings achieved in practice due to energy conservation measures were lower than those calculated in engineering conservation studies. Their study further concluded that consumer behavior had a huge impact on energy demand for residential space heating in Austria. Identical buildings often have different consumption patterns and different utility bills. This leads one to think that consumer behavior plays an important role with respect to energy consumption in households.

In the United States, many studies have analyzed household fuel consumption by fuel type including electricity, natural gas, fuel oil, and liquefied petroleum gas (LPG). Energy consumption studies have concentrated on construction variables, such as building materials, craftsmanship, floor area, volume of buildings, window area and heating equipment, but there has been limited study on occupant behavior, number of occupants, type of activity, time of use, and desired level of environmental control. A study by Poyer, Henderson, and Teotia [3] is only one of the very few done on the effects of ethnicity on residential energy consumption.

The operations and activities of an occupant in a building can be viewed as caused by either physiological needs, or social and cultural norms, or by a combination of these factors that constitute human behavior. Residential energy cost is an important part of the household budget and could vary significantly across different population groups in many countries. There is a need to identify the energy consumption in residential sector with respect to various population groups.

The purpose of this paper was to analyze and identify cooling energy consumption in residential buildings across three different ethnic groups—Afro-Americans, Hispanic Americans, and White Americans— in Bryan-College Station, Texas.

Hypothesis

It was hypothesized that the cooling energy consumption is affected by difference in ethnicity of household members. The difference exists even in the presence of the following known predictors of residential cooling energy consumption: 1) Building area, 2) Cultural background of residents, and 3) Number of occupants.

Limitations

The scope of the study is limited by the following factors:

1. The data collected for the study was only for electrical energy used for residential cooling during May through September.
2. Other known factors that affect cooling energy such as construction material, insulation, and efficiency of the cooling equipment were not considered in the study.

Methodology

Study population
The study population consists of a sample of 66 randomly selected households living in single-family detached dwellings and owned by them in residential communities in Bryan-College Station, Texas. All the dwellings used electrical energy for cooling. The entities under study are individual households in these communities. The unit of analysis is the head of a household.

Data collection procedure
A structured questionnaire was prepared for collection of data. Face-to-face interview procedures were adopted to collect data related to cultural background of residents and household size. The households interviewed included 12 Afro-American households, 27 Hispanic American households, and 27 White American households.

Data on monthly electrical energy consumption was obtained from either Bryan Texas Utilities or City of College Station Utilities. A signed consent form authorizing the utility company to release the monthly energy consumption data of the participating households were obtained and mailed directly to either City of College Station Utilities or Bryan Texas Utilities depending on the participant's locality.

Variable and their operationalization
Energy (ENERGY): It is the total monthly electrical energy consumed by a household. The variable was measured in Kilo-Watt hours (KWh).

Building area (AREA): This is the total floor area of a dwelling. It was measured in square feet.

Cultural background of residents (*CULTURE*): This is the observed cultural background of the head of household supplemented by self-report. This is categorized into three groups: 1) Afro-Americans (*BLACK*), 2) Hispanic Americans (*HISPANIC*), and 3) White Americans (*WHITE*). This was used as a class variable.

Number of occupants (PEOPLE): This is the number of people who live permanently in a dwelling. It was measured in number of people.

Analysis and Interpretation

A general linear model was used to analyze the data. The following model was used for the analysis with *CULTURE* and *CCOMP* as class variables:

$$ENERGY = \beta_0 + \beta_1 AREA + \beta_2 CULTURE + \beta_3 OCCUPANT + e \qquad (1)$$

Results of the analysis are shown in Tables 1 and 2.

TABLE 1

General Linear Model Analysis of ENERGY using AREA, CULTURE, and PEOPLE

Variable	Intercept	Regression Coefficient	*T*	*p*>|*T*|	Critical Value of *T*
Intercept	4452.879		2.180	0.033	1.65
AREA		7.630	4.637	<0.0001	
CULTURE					
BLACK		-6966.599	-4.264	<0.0001	
HISPANIC		-30.15.120	-4264	0.016	
WHITE*		0			
PEOPLE		1716.647	3.873	<0.0001	
Model F = 30.090				Model R^2 = 0.66	
p>Model F = <0.0001				Adjusted R^2 = 0.64	

* This parameter is set to zero because it is redundant.

The *F*-value of the model used for multiple regression analysis was found to be statistically significant at less than the 0.0001 level. This provides evidence that a relationship exists between ENERGY and the independents variables used in the model. An important aspect of a statistical procedure that derives model from empirical data is to indicate how well the model predicts results. A widely used measure the predictive efficacy of a model is its coefficient of determination, or R^2 value. If there is a perfect relation between the dependent and independent variables, R^2 is 1. In case of no relationship between the dependent and independent variables, R^2 is 0. Predictive efficacy of this particular model was found to be moderately high with a model R^2 value of 0.66 and an adjusted R^2 value of 0.64.

The results indicated that all the independent variables included in the model were correlated to private outside space satisfaction at a very high level of significance. Cooling energy consumption was affected by the ethnicity of the members of household even in the presence other predictors such as building area and number of people.

TABLE 2

Pairwise Comparisons of ENERGY

Comparison	Mean Difference	*p*-value
BLACK vs. HISPANIC	-3951.479	0.0110
BLACK vs. WHITE	-6966.599	<0.0001
HISPANIC vs. WHITE	-3015.120	0.0160

Table 2 shows a pairwise comparison of cooling energy use by the three ethnic groups included in the study. The results indicated that the use of cooling energy by White

Americans (WHITE) is significantly higher than both Afro Americans (BLACK) and Hispanic Americans (HISPANIC). It was also indicated that the use of cooling energy by Hispanic Americans is significantly higher than Black Americans.

Discussions and Conclusions

The American Society for Heating, Refrigeration, and Air-Conditioning Engineers reports that ethnic origin makes no difference in cooling energy consumption [4]; but some other researchers suggest that thermal comfort may vary according to ethnicity [5,6]. The results of the study by Potkanowicz et al.[5] suggest that ethnicity is partly responsible for the disparity between the intrinsic systems of thermoregulation of different populations. This, in turn, may dictate different cooling needs for different people. However, for the present study, this difference may also be due to economic differences among the three ethnic groups. People with higher household incomes usually consume more energy [7]. Further research is required including household income as a variable and using a larger sample size so as to clearly elucidate the difference in cooling energy use due to ethnicity of people.

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