This is to certify that the

dissertation entitled

Household and Environmental Characteristics
Related to Household Energy Consumption Change:
A Human Ecological Approach

presented by

Denise A. Guerin

has been accepted towards fulfillment
of the requirements for

PhD. degree in Family and Child Ecology

Donnie H. Morrison
Major professor

Date Aug. 1, 1988

HOUSEHOLD AND ENVIRONMENTAL CHARACTERISTICS RELATED TO HOUSEHOLD ENERGY CONSUMPTION CHANGE: A HUMAN ECOLOGICAL APPROACH

By

Denise A. Guerin

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Family and Child Ecology

1988

ABSTRACT

HOUSEHOLD AND ENVIRONMENTAL CHARACTERISTICS RELATED TO HOUSEHOLD ENERGY CONSUMPTION CHANGE: A HUMAN ECOLOGICAL APPROACH

By

Denise A. Guerin

This study focused on the family household as an organism and on its interaction with the three environments of the human ecosystem (natural, behavioral, and constructed) as these influence energy consumption and energy consumption change.

A secondary statistical analysis of data from the U. S. Department of Energy Residential Energy Consumption Surveys (RECS) was completed. The 1980 and 1982 RECS were used as the data base for this study. Longitudinal data, including household, environmental, and energy consumption measures, were available for over 800 households. The households used for this study were selected from a national sample of owner-occupied housing units surveyed in both years.

Interviewers collected the data from a probability sample. The records of household fuel consumption was collected from utility companies and fuel suppliers. The statistical analysis, done in the context of verification, used multiple regression and discriminant analysis and focused on explaining the relationships among theoretically important variables.

The following research questions were formulated. First, are there household and/or environmental characteristics that are predictors of household energy consumption change? Second, are there household and/or environmental characteristics that discriminate energy conserving and energy non-conserving households in relation to energy consumption change? Third, is there a fit between the Household Energy Consumption Change Model and reality as represented by this sample?

Results showed there was a significant ($p = <.05$) relationship between the dependent variable energy consumption change and the predictor variables heating degree days, addition of insulation, addition of a wood burning stove, year the housing unit was built, and weighted number of appliances. A significant ($p = <.05$) relationship was found between the criterion variable energy consumption change and the discriminating variables of age of the head of the household, cooling degree days, heating degree days, year the housing unit was built, and number of stories in the housing unit. The findings also indicated there was a significant ($p = <.05$) relationship between the theoretical Household Energy Consumption Change model and reality as represented by this sample.

DEDICATION

To Patrick, Amy, Nora, and Jay

For all that I have gained, you have lost.

As in the human ecosystem, over time, we will strive for equilibrium.

ACKNOWLEDGEMENTS

There are many persons who have guided, supported, and assisted in the completion of this degree. I would like to give special thanks and appreciation to the following:

To Dr. Eileen Earhart who, unknowingly, gave me the first indication that this degree would be possible.

To Dr. Joann Keith, Dr. Margaret Bubolz, Dr. Dennis Keefe, and Dr. Richard Ginther, whose assistance, critique, and boundless support are much appreciated.

To Dr. Bonnie Morrison, advisor, mentor, and friend, whose encouragement gave me confidence; whose assistance and critique allowed me to improve the quality of my work; and who has served as a role model as a professor, an advisor, and a woman.

To my friends and colleagues who supported, encouraged, and cared for the entire family over time.

To my parents, parents-in-law, and sisters-in-law, whose love, care, and assistance were instrumental to the completion of this degree.

To Anita and family for her knowledge and their caring that allowed us to frequently invade their family system.

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CHAPTER I. INTRODUCTION

The United States produced half of the world's oil supply until the mid-1950s. Then four events occurred that changed the picture. The first, in 1960, was an almost unnoticed event---the founding of the Organization of Petroleum Exporting Countries (OPEC). These countries, including Iraq, Iran, Saudi Arabia, Kuwait and Venezuela, held 90 per cent of the world's oil reserves (Byrne, et al, 1985, p.3). The second event was an increase in the consumption of oil by the United States, calling for more oil to be imported, and, therefore, creating a greater dependency on foreign countries for energy supplies. Through the 1960s, U.S. energy consumption and energy imports increased, thus providing OPEC with a rapid acceleration of power.

The third event occurred in 1973 when OPEC imposed an oil embargo and thereby challenged the power of the United States and other countries for the control of oil prices. This embargo was identified by the federal government as an energy crisis (Becker & Seligman, 1981). Oil prices increased rapidly, increasing from $2.00 a barrel in 1971 to over $17.00 a barrel in 1973, and then to over $35.00 a barrel in 1980 (Byrne, et al, 1985, p.3).

The fourth event, the 1979 Iranian Revolution, finally established the tenuous nature of oil imports. The Iranian Revolution served to curtail some oil exportation by other Arab nations who had become involved in the continuing Persian Gulf conflict. With decreased oil supplies and increased energy prices, the impact felt by the American household was a larger proportion of the income was spent on energy.

American households consumed a total of 14.1 quads (quadrillion BTUs or BTU x 1015, see Appendix A for definition of terms) of energy in 1982 (not including use of the family car). This represented nearly 20 percent of the total U.S. consumption of 70.5 quads (U.S. Bureau of the Census, 1985). The high proportion of family energy consumption coupled with the high energy cost resulted in a household energy crisis which can be seen as not only an increased burden of energy expenditures but an increased proportion of family resources used for energy costs.

Household energy researchers Byrne, Rich, Tannian, and Wang (cited in Byrne, et al, 1985, p.7) stated that identifying the factors which influence household energy demand is essential for understanding and ameliorating these household energy problems. In addition, these factors, once identified, may be used to explore the opportunities that exist for household energy conservation. In order to better understand the need to study household energy consumption and conservation, an overview of global energy events is necessary.

Note. Throughout this study, the word energy is used as a generic term meaning fuels, potential fuels, and fuel equivalents such as electricity and other sources of chemical, thermal, or mechanical energy. It does not, at any time, consider human energy.

Energy Overview

During the 1920s-30s, public utility commissions were established to regulate the prices of electricity and natural gas. This worked well in that energy shortages were unheard of, and real energy prices dropped steadily. During this time, however, the nation grew in population and complexity, impacting negatively on the availability of clean air, clean water, usable land, and cheap, abundant energy resources.

During the 1940s-1970s, several new institutions indirectly entered the energy decision system. These were federal, state, and local agencies that regulated air pollution, water pollution, and land use. For example, the Environmental Protection Agency (EPA) was created to develop environmental regulation and establish pollution standards. As these institutions pursued their own goals, they did not always consider the energy related consequences of their actions. Sometimes regulatory policy and energy supply production conflicted; for example, air pollution laws and expanding output of synthetic fuels conflicted with environmental standards in the Rocky Mountain states.

In the early 1970s, federal and state energy agencies were created as a result of OPEC's 1973 oil embargo. At this time, the U.S. experienced energy shortages, growing dissatisfaction with current energy technologies, and confusion caused by conflicting energy related regulations. The accomplishments of these agencies were often limited by conflicting goals within the various agencies. That is, they often were expected to solve several different problems, many of which had conflicting goals. For example, The Department of Energy (DOE) was expected to hold down energy prices while providing incentives for new technologies (often with higher costs). In addition, it was expected to both limit oil imports while subsidizing oil imports prices. Also, loss of credibility occurred when policies changed. For example, more than one industrial facility was requested by the DOE to shift from natural gas to oil to ease the 1976 natural gas shortage, and to shift back from oil to gas in 1978 to reduce the oil shortage and use the gas surplus (McClure, 1986).

This discordant approach to energy decision making and policy making did not allow proper response to some of the earlier events described or the later events. Perlman and Warren (1975) concluded that the lack of energy policy making at the institutional level allowed the forwarning of an energy crisis to be ignored until the OPEC oil embargo precipitated it.

The contributory event described by Perlman and Warren (1975), occurring in 1976-77, was weather related. It was brought about by the internal factors of record-breaking low winter temperatures over much of the nation; shortage of natural gas; and warm, dry weather in the West, resulting in drought which affected those regions dependent on hydroelectric power.

Federal response to these energy events was varied and inadequate. After the OPEC embargo in 1973, President Nixon responded by implementing emergency regulations: a national 55 mph speed limit, allocating petroleum supplies, banning the sale of gasoline on Sundays, and implementing daylight savings time year-round. This was a short term response and, even though President Nixon developed and presented a federal energy policy to Congress, it was not approved. Therefore, there was no preparation for the later energy crisis events. Households continued to be subjected to shortages of gasoline, increases in prices for energy resources, and appeals to engage in voluntary conservation of energy.

In 1980, the U.S. Congress responded to the energy crises of the 1970s by enacting the Energy Security Act. Among its various legislative initiatives, the Act created the U.S. Synthetic Fuels Corporation (SFC) and mandated, as a national goal, establishment of the capability for commercial production of synthetic fuels. The Act also had a broader purpose--enhancement of the long-term energy and economic security of the United States. Today, as the immediate energy situation has improved, the Reagan Administration no longer believes continued funding of the SFC serves any useful purpose, and was, in fact, instrumental in its demise through passage of the fiscal year 1986 continuing appropriations bill on December 20, 1985 (McClure, 1986). In addition, tax credits for energy conserving residential improvements, implemented by a legislative initiative, have been repealed.

There has been continued difficulty in developing a national energy policy that will reduce U.S. dependency on imported oil. Oil imports ranged from 14% in 1970 to 33% in 1985 and are estimated to rise to the 50%-70% level by 1990 (Hirsch, 1987). The difficulty in developing a national energy policy can be summarized in Chapter 1 of <u>Energy: The Next Twenty Years</u> (1979, p.i), a study sponsored by the Ford Foundation. The introduction stated,

> "....energy pricing and anti-inflation policies are at odds; energy and environmental objectives seem irreconcilable; there

is no ready strategic petroleum reserve; a national consensus that solar energy is a good thing has yet to result in significant resource commitments, while support for nuclear energy, yesterday's hope for tomorrow, is eroding; and coal is marking time. Meanwhile, the slow, steady increase in the number of barrels of oil imported, and intermittent rude shocks such as the Three Mile Island nuclear accident and the summer gasoline scramble, provide reminders that much needs to be done."

The realities presented to the consumer by the Ford Foundation study are ominous (1979, p. 47-48):

1. "Energy is not running out, but inexpensive energy is.

2. The world is critically dependent on oil from an unstable Middle East.

3. Conservation is an essential source of energy in large quantities, but because effective conservation involves many decisions by millions of individuals, there is no way to control it centrally.

4. There is a real danger that the world will be treated to a series of economic or energy shocks such as the Iranian revolution in 1979."

Eight years later, Robert Hirsch (1987, p.146) concurs with the Ford Foundation's study and further predicts the United States is likely to be headed for another crisis for several reasons:

1. "Saudi Arabia's announcement that it would no longer act as OPEC swing producer and therefore would increase its oil production causing a decrease in energy prices.
2. The resultant crippling of the United States' petroleum industry.
3. The continued existence and power of OPEC.
4. The unstable political situations of the Middle East.
5. The long time necessary to change the United States' and world energy system, and

6. The short term orientation of the United States' public, government and industry."

Household Energy Consumption

While the issues of energy consumption and conservation have been debated on a global scale, the issues at stake are the essentially human ones at the scale of the individual and the family. Genesis and resolution of energy consumption and conservation issues depend heavily on actions involving the household.

The household has been under pressure to conserve energy since the OPEC oil embargo in 1973. The oil embargo brought to households an awareness of an energy problem and a variety of myths regarding the cause of such a problem. However, the ultimate reality was an increase in energy costs. Even though there was a stabilization and even decrease of energy costs during 1985-86, the prices started to rise again in 1987. Since the costs of household energy now represented a larger proportion of the family budget, this price increase led many households to become interested in energy conservation in order to reduce their residential energy expenditures.

There are many factors impacting on households and their decisions regarding energy consumption/conservation. These include macro environmental issues, such as energy cost, availability, and national energy policies; and micro environmental issues, such as household income, physical aspects of the housing unit, and climate conditions. In addition, households use a variety of methods to conserve energy and reduce energy expenditures, such as household temperature reductions and changes in the structure of the housing unit.

Most household studies of energy consumption and conservation since the 1973 energy crisis have been from a socio-behavioral perspective investigating energy conserving behaviors and decision making of the household; or, from a techno-scientific perspective investigating the physical structure of the housing unit. Few studies have investigated energy consumption/conservation from an integrated perspective that incorporates the impact of socio-behavioral factors and techno-scientific factors with the overall confounding factor of natural environmental conditions. Few studies have investigated the impact that all three environments (the behavioral, the constructed, and the natural) have on household energy consumption over time (Keith, 1977).

Evidence still indicates there is a continuing need to study household energy consumption and conservation, especially due to the relationship of the various factors mentioned above, all of which impact on household energy consumption and conservation. From this discussion, it is evident that the situation is a very complex one and therefore requires an analysis from a systems perspective. The systems approach identifies components of the household and energy consumption as interrelated parts of a larger whole. A unique concept of the systems perspective is the ability to study several interactions or effects at the same time, indicating that a unit of study is not, in reality, completely isolated but interdependent with other parts of the system. Several environmental variables may be interacting at one time and therefore must be studied simultaneously. In any system, parts are closely and mutually interrelated and any change anywhere will, in some degree, affect the whole (Vickers, 1970). The systems approach, then, could be used to organize and examine the various factors of the system and their relationship to energy consumption and conservation.

Further, a useful application of the systems approach that would allow study of this multi-faceted problem is the human ecosystem framework. In the human ecosystem framework, interaction of the human organism and its environments can be examined. Specifically, the relationship of the household, as the organism (to borrow from ecology), and the natural environment, the human behavioral environment, and the human constructed environment in the context of energy consumption, could be examined.

For example, perhaps household members live in cold climate conditions (8000 degree days). The household members might elect to incorporate a variety of energy conservation measures, such as increasing wall or ceiling insulation, turning down the thermostat at night, closing draperies at night, or closing off a room to reduce the amount of heated space to conserve energy and/or money. These conservation methods can be categorized as related to, or measures of, the specific environments in a human ecosystem. Climate, in degree days, is a measure of the natural environment; thermostat turn down is a measurable action in the human behavioral environment; and heated square footage is a measure of the human constructed environment. Perhaps households implementing conservation measures are affecting the human behavioral or human constructed environments as they have been affected by the natural environment.

Energy conservation is generally seen as important, both in the short and long term, as a response to the energy concerns. Therefore, it is extremely important to understand what households, which directly consume 20% of the nation's energy, are doing to conserve. This study, then, will focus on the household as an organism and its interaction with the three environments of the human ecosystem (natural, behavioral, and constructed) as they influence energy consumption change.

This study uses the 1980 and 1982 United States Department of Energy's Residential Energy Consumption Surveys (RECS). Longitudinal data including household, environmental, and energy consumption measures, were available for over 800 households. These households, selected from a national sample, were surveyed in both years and owned their housing units.

Research Problem and Objectives

The research problem was to examine household energy consumption change by determining whether and to what extent energy conservation had occurred in households between 1980 and 1982. Further, to determine what factors in the natural, behavioral, and constructed environments contributed to household energy conservation. Next, to classify the sample households into three groups, conservers, non-conservers, and no changers then, illuminate the characteristics of the three groups in relation to energy consumption change. And, finally, test, in a preliminary fashion, the fit between the theoretical model and reality.

A secondary statistical analysis of data from the U. S. Department of Energy RECS was performed. The data were collected by interviewers from a probability sample of owner-occupied households as well an analysis of the records of fuel consumption from utility companies and fuel suppliers serving the households. The statistical analysis, done in the context of verification, focused on explaining the relationships between theoretically important variables.

The first research objective was to measure the actual household energy consumption of 1980 and 1982 in order to determine which households had significantly decreased or increased their energy consumption. The actual energy consumption from 1982 was subtracted from the actual energy consumption in 1980. This identified the energy conserving and non-conserving households.

The second research objective was to identify the household characteristics that had affected energy consumption change.

The third objective was to identify the characteristics of the natural, human behavioral and human constructed environments that were related to household energy consumption change.

The fourth objective was to test the relationship of the theoretical model with reality as represented by the sample.

Chapter II Literature Review will review research studies in order to provide a background for the relevancy of the study of household energy consumption and conservation and the importance of examining this issue in an human ecosystem framework.

CHAPTER II. LITERATURE REVIEW

Introduction

There are many factors relating and interacting in the study of the household and its energy consumption/conservation. It is appropriate to first view this problem from a systems perspective, i.e. viewing household and energy consumption/conservation as interrelated parts of a larger whole. Therefore, general systems theory will be reviewed briefly, followed by a discussion of the human ecosystem. This will provide a framework within which household energy consumption/conservation literature will then be discussed.

Systems Theory

Systems models have been used by numerous established disciplines such as the natural sciences, social sciences, and engineering to study the interaction of individual components within a complex whole. For example, the systems approach has been applied to pressing political and social problems such as air and water pollution, traffic congestion, and city planning by Wolfe (cited in Bertalanffy, 1967). It also has been applied to Ruesch's study of the cybernetic world and Boguslaw's study of human systems engineering (cited in Bertalanffy, 1967).

Systems models have been used with increasing frequency by social scientists, including family scholars such as Buckley (1967), Kantor and Lehr (1975), and Melson (1980). Although different approaches have been taken, these and other family scholars have used systems models to study the interaction of the individuals within the family system (Hill, 1972); the interaction of the family system with other systems (McCubbin & Patterson, 1983); and the interaction of the family system with its various environments (Morrison, 1974).

A system is a set of interdependent components in interaction with one another (Bertalanffy, 1968; Melson, 1980; Ackerman, 1984). Buckley defined systems theory as a unifying holistic model which focuses on the inter-relationships and feedback processes between components of a system (Buckley, 1967). Kantor and Lehr stated that a system is a set of different things or parts (such as electrical components, mechanics, or people) that meet two requirements: first, these parts are directly or indirectly related to one another in a network of reciprocal effects; and second, each component part is related to one or more of the other parts of the set in a reasonably stable way during any particular period of time (Kantor and Lehr, 1975). They further stated that the chief characteristic of social systems is an almost continuous interchange not only within the system, but across the boundaries between the environments (Kantor and Lehr, 1975, p.10).

As previously mentioned, a unique concept of the systems approach is the ability to study several interactions or effects simultaneously, indicating that a unit of study is interdependent with other parts of the system. Several environmental variables may be interacting simultaneously and therefore must be studied at the same time. In any system where parts or variables are closely and mutually interrelated, any change anywhere will, in some degree, affect the whole (Vickers, 1970).

Human Ecosystem Model

When using the systems approach to study the household, parts of the system include the individuals, the family, their environments, and their reciprocal interactions with the various environments and with one another. This approach is defined as the human ecosystem model and has been used to study the family as a household unit and its energy consumption/conservation. A brief discussion of the components of the human ecosystem model, the organism and environments, is necessary to suggest the possible interrelationships.

Organism.

Generally, the unit of analysis in the human ecosystem model is the human organism or family. In this study, however, the unit of analysis was identified as the household because the RECS study measured the variables in terms of the household. The household was further defined by the researcher as a single individual or a group of individuals living in the same housing unit. The household was defined by the Department of Energy as..."a family, an individual, or a group of up to nine unrelated persons occupying the same housing unit" (Energy Information Administration [EIA], 1984a). The focus here is, however, not upon the relationship of these individuals, but rather upon the individuals living within the same housing unit. Therefore household, not family or individuals, was the unit of analysis.

The household as the unit of study contains parts whose multi-effects are so interdependent that it is erroneous to look at only one part or effect at a time when studying the whole. All parts must be defined and considered. A basic tenet of the ecosystem model is that a change in any part of the system affects the system as a whole and its other sub-parts, creating the need for systems-adaptation rather than adaptation by a single part (Bubolz & Whiren, 1984).

Environment.

"Environment is the sum total of the physical, biological, social, economic, political, aesthetic, and structural surroundings for organisms," (Fundamentals of Environmental Education, 1976, p.vi). The human environment is composed of macro and micro environments. In the human ecosystem, the macro environment may be defined by a physical or social distance from the household and may include the regional or national governments, natural resource availability, global issues, and economic policies which indirectly affect the family. The micro environment in the human ecosystem directly affects the household members and is closer to the household physically, socially, and psychologically (Bronfrenbrenner, 1979; Bubolz, et al, 1979). It contains micro environment components such as the social and psychological interactions of the individuals within the household, local government, community or family issues, local energy costs, and local cultural mores.

Within the macro and micro environments, the human environment is also composed of three specific environments, the natural, the human behavioral, and the human constructed (Bubolz, et al, 1979). The natural environment is that formed by the organic world with space-time, physical, and biological components such as plant life, energy, and water. The human behavioral environment is that of human beings and their biophysical, psychological, and social behaviors such as values, emotions, and attitudes. The human constructed environment is defined as an environment altered or created by humans such as physical components of buildings, interiors, and clothing. The constructed environment also includes social constructions such as laws that impact on the components. These environments and their measures in relationship to this study will be defined more completely in Chapter IV Methodology.

The human ecosystems model is a complex framework, appropriate for a multi-variable research question. This makes it an ideal framework for the study of energy consumption/conservation as a system of several inter-relating environments and the household. The value of using an ecosystems model for the study of particular components, then, lies in the capacity to analyze a whole system and the relationships within that system simultaneously, as well as systems flexibility which occurs across time. This study will examine households to identify particular characteristics of the household and the natural, human behavioral, and/or human constructed environments which are related to energy consumption change, thus allowing both description and prediction of energy consumption/conservation in the American household.

Household Energy Consumption

Residential energy consumption is frequently measured by household use. Individuals within the households are making seemingly inconsequential daily decisions, which collectively shape the styles of life which, in turn, create the aggregate demand for energy (Morrison, et al, 1979). The household, an integral part of the ecosystem, is an appropriate unit of study for energy consumption.

Households consume, directly and indirectly, almost two-thirds of the nation's energy; one-third is used directly through the purchase of fuels and electricity, and another one-third is used indirectly through the energy embodied in the purchase of goods and services for personal use (Committee on Measure, 1977, p. 19).

While energy consumption per unit of GNP declined 26% in the U.S. during 1973-83, oil prices were on the rise. The American Council for an Energy-Efficient Economy felt that the plunge in world oil prices in early 1986 was in large part a consequence of energy efficiency improvements during the previous decade (Kempton & Neiman, 1987). There were opportunities for continued cost-effective efficiency improvements, particularly when oil prices were increasing.

Households have been and will continue to be influenced by energy related events. However, there is no clear indication of how these events might affect energy consumption in ways that redress the burden of rising energy costs and expand the range of energy choice (Byrne, et al, 1985). Numerous researchers have investigated the relationship between households and energy consumption. Literature that explores the effect of the natural environment, the behavioral environment, and the constructed environment on household energy consumption/conservation will be reviewed.

Natural Environment

The natural environment affects household energy consumption in several ways. Natural conditions and weather were investigated as determinants of energy consumption. Natural conditions of the macro and micro environments, such as geography, terrain, location, and urbanicity, affected energy consumption (Shurcliffe, 1980). Some of these factors affected the availability of materials and energy, as well as the cost of materials and energy. For example, location or terrain may increase delivery prices.

Weather conditions, such as air temperature, humidity, wind velocity, and insolation are additional natural environment variables that are related to household energy consumption. Hitman Associates, Inc.'s (1973) early computer simulation found that weather variables were related to energy consumption. These variables include the number of heating/cooling calendar days, local weather conditions, wind speed and direction, and cloud cover, all of which were significant natural environment variables for energy consumption.

Since the Hitman Associates' study, heating/cooling calendar days have been identified as degree days, one of the measures for temperature of a micro climate. This allows comparison of the temperatures of one area with another. Heating degree days are defined by the EIA (1984a) as the number of degrees per day the daily average temperature is below

65 degrees Fahrenheit. Normally, heating is not required in a building when the outdoor average daily temperature is above 65 degrees. Heating degree days are determined by subtracting the average daily temperature below 65 degrees from the base 65. For example, a day with an average temperature of 50 degrees has 15 heating degree days (65 - 50 = 15), while one with an average temperature of 65 or higher has none. The average daily temperature is the mean of the maximum and minimum temperature for a 24-hour period.

Cooling degree days are defined as the number of degrees per day the daily average temperature is above 65 degrees Fahenheit. Normally, cooling is not required in a building until the average daily temperature is above 65 degrees. Cooling degree-days are determined by subtracting the base 65 from the average daily temperature. For example, a day with an average temperature of 80 degrees has 15 cooling degree days (80 - 65 = 15).

It can be postulated that higher heating degree days increase household energy consumption due to lower natural environment air temperatures and that higher cooling degree days increase household energy consumption due to higher natural environment air temperatures. Heating degree days and cooling degree days were natural environment variables investigated in this study.

Human Behavioral Environment

The behavioral environment and its relationship to household energy consumption/conservation has been investigated in several ways. Researchers have studied energy choices such as behavioral and technical conservation, obstacles to energy conservation, and indicators of energy consumption.

One energy choice for household consumption that has been investigated is energy conservation. Of the various solutions to the energy crisis, many energy analysts concluded that conservation represents the best option, at least through the end of the 20th century. In the analysis of the energy crisis, Stobaugh and Yergin (1979) concluded that conservation is indispensable to any solution. Carlson, et al (1982, p.30) defined energy conservation: "In order to estimate how much energy is not used in any actual or hypothetical situation, it is necessary to estimate how much more energy would be used in some other hypothetical situation; the difference can be called "energy conservation." Energy conservation can be thought of as an incremental source of energy and can be measured by the extent to which certain energy-conserving actions or events reduce the use of fossil fuels.

Researchers have identified several advantages of conservation over traditional supply solutions including lower costs relative to traditional supply options (Sant, 1979); significant environmental benefits (Hayes, 1977; MacKenzie, 1983); and reduced international tensions (Lovins, 1977; Yergin & Hillenbrand, 1982). However, energy conservation is not always an easy process for the household to implement. There seem to be several obstacles identified by numerous researchers. Taschchian and Slama (cited in Byrne, et al, 1985, p.7) concluded that "the major problem the public encounters in attempting to conserve energy is the confusing and contradictory signals about energy shortages which are promulgated by current policy." For example, the Tax Reform Act of 1986 repealing the energy tax credits may send a signal to households that it is no longer a government priority to conserve energy. The authors also note the United States' lack of a consistent conservation policy and continued dependence on unstable imported oil as contradictory information and actions.

A second obstacle to household energy conservation may be the consumer's lack of information. A study completed by Kempton, Harris, Keith, and Wiehl (cited in Byrne, et al, 1985) indicated that most households do not know very much about how best to conserve energy. In a survey of 3000 Michigan households, it was found that because most families are unaware of conservation strategies which would save money and increase comfort at the same time, families have not invested in more efficient conservation measures. Additionally, Kempton, Gladhart, and Keefe (1981), discovered that families were misinformed about which energy uses in the household actually consume more energy and, therefore, the energy users did not know which activities to reduce or cut out in order to conserve.

Becker and Seligman (1981) concurred with these findings and propose that households could be most effectively informed about energy consumption reduction by means of various feedback devices, including reporting to consumers quickly the results of their efforts to conserve. This was concluded from a study examining the effects on residential energy consumption by providing homeowners with a signaling device that indicated a conservation opportunity and information feedback about their rate of energy use. The results showed a significant 15.7%

decrease in energy use for those households with a signaling device. Becker (1978) found improved energy conservation was a result of the joint effect of feedback and goal setting.

A third obstacle to energy conservation may be self-value. Psychological perspectives were investigated by Schulz (cited in Byrne, et al, 1985, p.7) who stated that "Americans use energy to increase their sense of feeling good about themselves." He further noted that in the conspicuous consumption of energy, individuals betray a psychological insecurity that makes significant energy conservation difficult to achieve for most Americans, that is, use of energy is to partially compensate for an inner sense of worthlessness.

Several studies supported other behavioral variables as consumption indicators. Carlson, et al (1982, p.51) stated: "Consumption expenditures are guided not only by constraints of time and money, but also by values, needs, and preferences and by the dominant attitudes, values, and institutional structure in the surrounding social context".

Perlman and Warren's (1977) classic study following the 1973 Arab oil embargo involved energy related behavioral changes. The study sample consisted of 1,440 families in the metropolitan areas of Hartford, CN; Mobile, AL; and Salem, OR. The study focused on relationships between attitudes and behavior, the issue of equity, and family tasks that were affected by actions of other systems. Data were gathered by interviews in November, 1974, and were followed by questionnaires mailed to the households one year later. The purposes of the study were to document the impact of the energy shortage on families, to analyze adjustments they made, and to assess the meaning of findings for public policies (Perlman and Warren, 1977, p.2). The researchers identified behavioral changes of families which occurred soon after the crisis, as well as changes which occurred two years later. They examined the effects of family adjustments on the family unit itself and the ripple effects of family adjustments on systems outside the family. They also examined reciprocal effects, that is, the effects of other systems on the family.

Perlman and Warren found immediate responses by government and business to the oil embargo had an important effect on families. In particular, lowered speed limits on highways, the inability to obtain gasoline, and high prices for energy resources affected families (Perlman and Warren, 1977, pp. 45-46). They also found that families reduced recreation and vacationing markedly during the energy crisis. Two-thirds of the respondents said they had reduced their driving for recreational purposes. The greatest adjustment came in the use of cars in lowered speeds and curtailed driving. Seventy-nine percent of the families reported curtailing the use of their cars.

One-half of the families in Perlman and Warren's study reported they had lowered the temperature of their dwellings during the winter of the crisis an average of 1.2 degrees Fahrenheit below their ideal during the day or evening when people were at home. Two-thirds of the families reduced their use of air conditioning by an average of 1.7 degrees Fahrenheit. In two of the cities, 14 percent of the families had cut back on electricity used and, in one city, 58 percent had cut back. Fifty percent of the families reduced their use of hot water. Twenty-two percent indicated they had decided not to make major purchases, due to the energy crisis (Perlman and Warren, 1977, pp. 81-87).

Perlman and Warren also reported that the adjustment to the problem was a process which occurred over time and that adjustments had ripple effects on economic and social systems outside the family. They suggested that in order to judge the impact on energy savings, it is necessary to know what proportion of energy resources each of the consumption changes affects. The prevalence of energy conservation by families does not correspond uniformly to the amounts of energy used. For example, more families had reduced their electrical consumption than had reduced their water heating, but the latter consumes double the amount of energy that is used for lighting and appliances (Perlman and Warren, 1977, pp. 105-109).

Overall, the households in the Perlman and Warren (1977, pp. 112-114) study reduced their energy consumption by 12 percent in the year following the oil embargo. The greatest savings were achieved in transportation, followed by home heating. The greatest saving in heating energy was due to the setback of thermostats. Installing insulation and storm windows accounted for a small part of the savings.

In the Perlman and Warren study, different income groups adjusted differently to the energy problem. The reductions in mobility, use of heating fuels, and electricity were not noticeably different among different income groups. However, the impact of adjustments differed. In terms of absolute reductions in energy use, families with incomes above $15,000 per year achieved the greatest reductions in energy use. These families saved almost three times as much energy as did families with incomes below $5,000 per year. In terms of percentage reductions, however, the low income group achieved the greatest reductions in energy use for transportation and heating. The authors pointed out that higher income households are able to achieve greater absolute reductions in energy since they own larger homes and more appliances and cars and therefore have more adjustment alternatives (Perlman and Warren, 1977, pp. 125-130).

Several studies have similarly identified characteristics of households that do or do not conserve energy. In a Lansing, Michigan community case study of energy consumption and conservation in the years 1974 and 1976, Morrison, et al (1978) determined that energy conservers were those households that had decreased energy consumption by 4 per cent or greater and non-conservers as those households that had increased their energy consumption more than 4 per cent. They found significant differences in a variety of demographic, physical housing and energy related attitudes, beliefs, and reported behaviors between the two energy consuming households, the conservers and non-conservers.

Variables used in Morrison's study, which distinguished between the two groups were: age (averaged ages of husband and wife), education (averaged education of husband and wife), income (total gross family income, 1976), number of persons in the households, added ceiling insulation, and added wall insulation in addition to several attitude, belief and lifestyle variables. The study found number of persons in the household, income, and education were positively related to energy conservation.

A household energy consumption study by Keith and Harris (1982) reported findings of a statewide sample of 2000 Michigan households surveyed in 1979 and again in 1980. Energy consumption data were obtained from the utility company records of the households surveyed. The findings are representative of Michigan households with more than one person residing in single family dwelling units which are owned or being purchased.

The findings by Keith and Harris indicated small reductions in the amount of energy used annually from 1979-1980. These reductions were not equal to the increase in the cost of energy, suggesting households are responding by long-term efforts and not responding to a crisis situation. There was no clearly identifiable group doing the conserving. However, life cycle and rurality were the most significant single predictors. The life cycle variable is consistent with energy consumption reduction as children leave home and the rurality variable may reflect fuel availability particularly the use of wood as fuel.

Conversely, in Smith's study (1976), respondents had reduced energy use as a result of higher prices for energy. The nationwide study conducted personal interviews in over 1,400 households. The reductions in energy use were primarily for lighting and heating. Additional variables which were found to influence reduced energy use were household income, age of head, education, and household size. Higher income groups made more adjustments than did lower income groups since they had more adjustment alternatives. Lower middle-age groups made more adjustments than other age groups while the elderly made the fewest adjustments. More adjustments were made by persons with higher levels of education than by persons with less education. Large households made more adjustments than did small households since the former often had more adjustment alternatives. Also, home owners made more adjustments than did renters since the former had more adjustment alternatives (Smith, 1976, pp. 29-34).

Morrison and Gladhart (1976, pp. 15-18) studied energy use and attitudes of 217 Michigan families and found that family and housing characteristics and attitude toward energy conservation influenced energy consumption. They found family income was the best predictor of energy consumption. High income families used more energy than did low income families. Large families and families in the child-rearing stage used more energy than did other family types. Families living in single-family homes used more energy than did those living in apartments. In families where adults felt that conservation was a social responsibility, energy conservation practices had been adopted.

Similarly, Hogan indicated that there are differences in energy consumption and conservation attitudes among different income groups. Case studies of families were conducted; families were identified as high, medium, and low energy users. Hogan found that as family income increased, energy consumption increased. High income families lived in larger homes and had more energy-using appliances than did low income families. Even though they used more energy than did low income families, the high income families believed in the energy crisis and planned to engage in some energy conservation behavior. Low income families lived in smaller housing units, often apartments, and used less energy than did high income families. However, energy costs represented a proportionally larger share of their budgets due, in part, to the conditions of their housing and the lack of insulation and storm windows. The low income families in Hogan's study indicated they did not believe in the energy crisis (Hogan, 1978, pp. 18-21).

Other researchers have identified additional indicators of energy consumption/conservation in the household. The number of people living in a household is an important determinant of energy consumption (Morrison, 1976; Gladhart, 1977). Family structure, i.e., social order within a household, affects energy consumption (Klausner, 1978). Stage of the family life cycle, i.e., age of children and their presence or absence, was of sufficient variation and magnitude to affect levels of energy consumption (Gladhart, et al, 1986).

Human Constructed Environment

In the micro environment, actual levels of energy consumption continue to defy simple formulations based on architecture (Socolow, 1978; Seligman, et al, 1978), suggesting that the unique qualities of individual consumers are as important as the inherent energy efficiency of a given building. However, Hitman Associates, Inc.'s (1973) early computer simulation found that several building variables were related to energy consumption. They found window and door size, orientation, number, and location; wall, roof, and floor construction; and building size and orientation significant as building definition variables. These variables have been supported by additional researchers (Mazria, 1985; Moore, 1987) as well as the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). These building variables are now considered standard indicators of a building's thermal performance.

Shurcliffe (1980), who has supported the use of additional building insulation to decrease household energy consumption, points out that not only is heat loss minimized with sufficient insulation, but thermal comfort of the occupants also is increased. Buildings that use construction methods which allow additional insulation to be used have been named superinsulated. Extensive analysis, backed up by accurate field measurements, have shown that superinsulated housing units, as well as components of housing, provided a cost effective energy consumption reduction (Schick, 1976; Dallaire, 1980; Rosenfeld, 1980). However, Holt (cited in Kempton and Neiman, 1987) found superinsulation may not be economically efficient based on potential short term owner occupancy. That is, superinsulation is cost effective on a long term occupancy basis but not for a transient home owner. However, it can still be postulated that weatherization or increased building insulation will reduce the household energy consumption.

In the macro environment, public policies and experimental programs designed to further energy conservation in the constructed environment have reflected a confusing theoretical patchwork of approaches (Stern & Gardner, 1981; Morrell, 1981). There have been a variety of government actions to stimulate energy conservation in the constructed environment including tax incentives, regulations, special loans and grants, and advisory services. These actions have taken place at all three levels of government, federal, state, and local and generally provide funds for technological assistance for building weatherization.

Local government regulations have included new and revised building codes to regulate the design of new or retrofitted buildings in the micro environment. In the macro environment, the state and federal governments have been developed energy conservation regulations for state or federally funded buildings. At the national level, ASHRAE has developed prescriptive standards for new buildings. Building Energy Performance Standards (BEPS) are under development and will assess building performance through computer simulation.

Other government actions for energy conservation have included the development of appliance standards for furnaces, water heaters, air conditioners, refrigerators, ranges, and clothes dryers. The Residential Conservation Service has provided energy audit and advisory agencies operated by the local utilities. Finally, weatherization assistance programs using federal funds help low income families to upgrade the thermal performance of their housing unit.

The Reagan administration, in January 1981, fostered a new governmental approach to energy conservation. Reagan supported a free market that encourages energy conservation rather than government controls and regulation. The Reagan administration also encouraged state and local governments to supplement energy conservation programs better aligned to their specific populations.

With the current technological advance in the human constructed environment, energy conservation methods are more efficient than they were ten years ago. "The solution, however, still lies in the building-by-building upgrading of thermal performance: increased insulation, reduced infiltration, better building maintenance, replacement of low efficiency equipment, reduced lighting, better control of commercial buildings, and recycling of waste energy" (Leverenz, 1982, p. 1.A.150).

Rationale

The literature clearly shows there are a multitude of factors influencing household energy consumption/conservation. It also has been shown that many variables work simultaneously to affect energy consumption/conservation. These factors include household characteristics, such as the number of individuals in the household and family income; natural environment characteristics, such as climate and temperature; human behavioral environment characteristics, such as conservation strategies and actions; and human constructed environment characteristics, such as building envelope design and weatherization. These are variables representing measures of both the organism and the environments in an ecosystem framework. It follows, then, that a human ecosystem model would be an appropriate theoretical framework through which to organize and examine these variables and their relationship to household energy consumption.

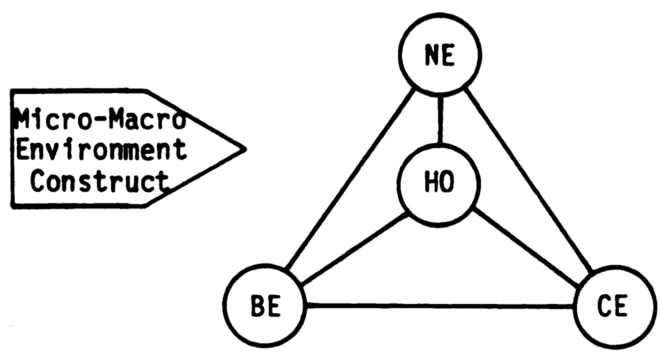
Chapter III Theoretical Framework and Hypotheses presents a theoretical ecosystems model for the study of energy consumption as well as the research questions and hypotheses.

CHAPTER III: THEORETICAL FRAMEWORK AND HYPOTHESES

Theoretical Framework

A theoretical model has been developed representing the human ecosystem that considers the relationship of the human to the natural environment, the behavioral environment, and the constructed environment. This model, The Human Ecosystem Energy Consumption Change Model, shows the three environments and the human organism as separate elements of the system with interaction or interface occurring through the connecting networks. The networks are uni-directional, that is, the organism can affect the environment or the environment can affect the organism. This is shown by the network line between each environment and the human. Additionally, two or three environments can interface along the network to allow interaction between more than one environment and the human. Further, the Model can be used to examine the relationship of a macro or micro environment construct as it interacts with or impacts on the elements of the ecosystem (See Figure 1). The Model is an adaptation of models developed by Morrison (1974), Doxiadis (in Morrison & Nattras, 1975), and Bubolz, et al (1979).

The Model serves as a framework to organize variables of study which focus on the inter-relationships between components of a system. By identifying a component of interest, the interaction and interface of system components, or the identification of component relationships to the construct, can be examined. After the construct of interest is determined, the variables of study for each element of the system can be identified.



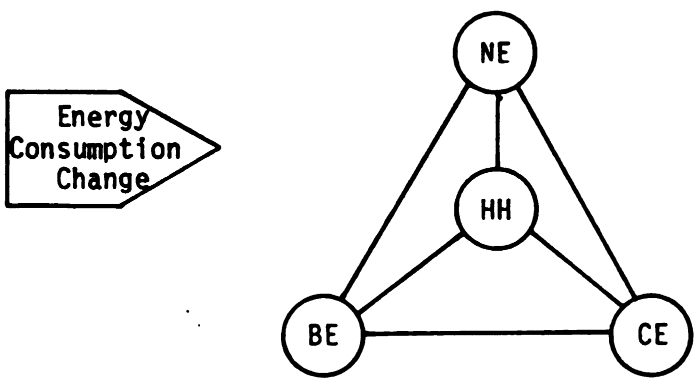
Key

HO = Human Organism
NE = Natural Environment
BE = Behavioral Environment
CE = Constructed Environment
— = Interaction Network

Figure 1: Human Ecosystem Model

The Human Ecosystem Model can be used to examine the inter-relationship of the construct energy consumption and specific human organism (household) and environmental characteristics. Researchers have used various human ecosystem models to explain factors affecting past energy consumption which may be determinants of future consumption (Keefe, 1978; Morrison, 1974). The Human Ecosystem Model can be developed into the Household Energy Consumption Change Model (see

Figure 2). For example, a characteristic of the household that could be examined in relation to energy consumption is income; a characteristic of the natural environment could be degree days; a characteristic of the behavioral environment could be conservation strategies; and a characteristic of the constructed environment could be number of heated square feet in the housing unit. Such a model would provide a theoretical ecosystems framework to organize variables of study which focus on the inter-relationships between components of a system.



Key

HH = Household
NE = Natural Environment
BE = Behavioral Environment
CE = Constructed Environment
— = Interaction Network

Figure 2: Household Energy Consumption Change Model

The Household Energy Consumption Change Model shows the household (HH) as the center of the energy consumption sub-system. The household receives energy from the macro environment, i.e. energy as a natural resource of the macro environment. The household interacts with all three environments of the system, the natural environment (NE), the behavioral environment (BE) and the constructed environment (CE), singly or concurrently, via the network.

Interaction occurs in the form of information transferred or processed through the network. In general, when the household receives input, it responds to this input by calling upon its resources in the environments for information. This interaction allows the organism to respond with a decision based on the environment/organism interface and aids the household in energy consumption decisions. This response may constitute an impact on other elements of the system.

This is not a linear model in the sense of sequential interface. In the real world many processes occur simultaneously. Indeed, the model allows for interaction between the household and one environment, two environments, or all three environments, concurrently, to provide the best information upon which to process energy consumption decisions. Therefore, an energy consumption decision could be based on the interaction with the behavioral environment only (economic value of reduced energy consumption), both the natural and constructed environments concurrently (very cold climate and high level of structural insulation), or all three environments (values, climate, and structure). A simple linear cause-effect model is not adequate for analysis of such interactions; rather, an integrated model is necessary for the study of concurrent or unequal, non-sequential relationships or impacts.

Definition of Components

In the Energy Consumption Change Model, the organism is defined as the humans in the household. Characteristics shaping the household are variables such as head of household age, income, and education, or number of household members.

The Model defines the natural environment as the entities and components of the physical world, i.e. climate, resources, plants, air, and water. In this study, climate is the major factor of the natural environment. Climate can be measured by variables such as heating degree days and cooling degree days.

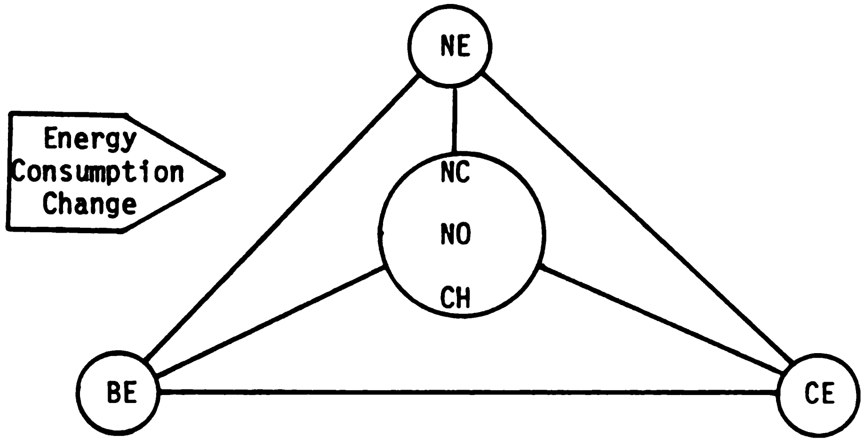
The behavioral environment is defined by the socio-behavioral, psychological, socio-political, and bio-physical factors of the household. This would include human activity and decision-making components such as interaction, attitudes, and values. The results of behaviors that are performed by the humans within this environment, such as turning down the thermostat or adding wall insulation, are variables of the behavioral environment.

The human constructed environment is defined as the housing unit or building envelope. This environment includes building materials, site integration, design, and energy system. These variables can be measured by known numerics such as R value, U value, square feet of window openings, or square feet of heated space.

The construct energy consumption is one component of the macro and micro environments. In this study, it is defined as the sum total of the household's energy consumption in the form of processed energy. In the macro environment energy consumption can be affected by such issues as natural resource availability, national energy policies, and global energy concerns. On a micro level, energy consumption can be affected by local energy supplies, availability of energy, energy costs, and conservation behaviors.

In the Household Energy Consumption Change Model, energy consumption can be viewed over time, that is, as changes in energy consumption from one time period to another. If there is change in energy consumption from one year to another, this change also can be measured with the goal of identifying the factors affecting that change, i.e. characteristics of the Natural Environment, the Behavioral Environment, the Constructed Environment, or Household.

The Model is flexible enough to allow the household organism to be classified in a variety of ways. Based on the change in energy consumption over time, the households can be categorized as conserving households, non-conserving households, or households where no change in energy consumption occurred (see Figure 3).



Key

CH = Conserving Households
NO = No Change Households
NC = Non Conserving Households
NE = Natural Environment
BE = Behavioral Environment
CE = Constructed Environment
— = Interaction Network

Figure 3: Household Energy Consumption Change Model

Purpose.

The purpose of this model is to provide a theoretical framework for examining household and environmental factors which impact on household energy consumption change. The data from the 1980 and 1982 Residential Energy Consumption Survey will be organized according to the Household Energy Consumption Change Model. Energy consumption change from 1980-1982 will be the construct of interest with its relationship to specific household and environmental characteristics examined.

<u>Research Questions and Hypotheses</u>

The literature related to household energy consumption leads to the following general research questions.

1. Are there household and/or environmental characteristics that are predictors of household energy consumption change?

2. Are there household and/or environmental characteristics that discriminate energy conserving and non-conserving households in relation to energy consumption change?

3. Is there a fit between the Household Energy Consumption Change Model and reality as represented by this sample?

Similarly, ecosystem and household energy consumption literature supports the formulation of the following null hypotheses:

1. There is no relationship between household energy consumption change and particular household and environmental characteristics.

2. There is no relationship between particular household and environmental characteristics and the household groups of conservers, non-conservers, and no changers.

3. There is no relationship between the Household Energy Consumption Change Model and reality as represented by this sample.

Chapter IV Methodology will discuss the methodology used to collect the data and the analysis methods used to examine these data. Additionally, the variables of interest will be discussed in relation to the Household Energy Consumption Change Model.

CHAPTER IV: METHODOLOGY

Description of the Study

This study was a secondary analysis of data compiled by the Department of Energy (DOE) from the 1980 and 1982 Residential Energy Consumption Surveys (RECS). The survey was designed to provide information concerning energy consumption within the residential sector. The information regarding energy conserving techniques and household data were collected through personal interviews with the head of the household. Data concerning actual energy consumption were obtained from records of the energy suppliers. The 1980 and 1982 surveys were, respectively, the fourth and fifth of a series of national surveys of households and their fuel suppliers conducted by the Energy Information Administration (EIA). Data were collected from a representative national sample of all housing units occupied as the primary residence in the 50 states and the District of Columbia.

The survey design, sampling procedure, and data collection for both surveys were very similar. Any differences of note are discussed in the individual sections below.

RECS was designed to provide timely information on how energy is used by households occupying all types of housing units, including single-family homes, apartments, and mobile homes. This study examined only the owner-occupied households. Owners were selected because evidence shows that energy conservation depends on both behavioral intentions and opportunities to perform the behaviors at issue (Fishbein & Ajzen, 1975; Williams, 1983). Renters do not have the freedom to make changes in their physical environment to the same degree that owners do; renters lack opportunity for some conservation measures. Table 1 shows the similarity of the RECS sample of owner households to the national population as well as the final household weight for the RECS sample.

Table 1
Owner Households

	RECS Percent of Total	National Percent of Total	Final Household Weight
Owner occupied	68%	64%	54,175,776
Renter occupied	30%	34%	25,612,637
Rent free	2%	2%	1,434,617
N	5979		81,223,030

The unit of analysis was the household, defined by the DOE as a family, an individual, or a group of up to nine unrelated persons occupying the same housing unit (EIA, 1984a). This study, then, examined the data of one subset of the 1980-1982 sample, the owner households that were also involved in the 1980 survey and occupied the same housing unit in both surveys. The N for this subset was 839 households.

Definitions of Constructs

Before proceeding further, it is timely to define the theoretical and operational constructs used in this study (see Table 2). Additional operational definitions of technical constructs are included in Appendix A.

Table 2
Definition of Constructs

Construct	Theoretical	Operational
Conservation Strategies for the Behavioral Environment	Use of conservation behavior to reduce energy consumption.	Energy saving actions employed by members of the household while in the housing unit occupied. (self-reported).
Conservation Strategies for the Constructed Environment	Use of conservation technology to reduce energy consumption.	Energy saving items added to the housing unit by the household occupants. (self-reported).

Table 2 (cont'd.)

Energy	A measure of the ability or power to do work, excluding human energy.	Mechanical energy produced through the consumption of refined or transformed fossil fuels, specifically electricity, natural gas, fuel oil, and liquid propane; not human.
Energy Consumption	Sum total of household's energy consumption in the form of processed energy, excluding transportation and human energy.	Amount of mechanical energy used by the household during the 365 day period, represented by the amount of fuel purchased (vendor reported).
Energy Consumption Change	Increase or decrease in energy used from 1980 to 1982.	Percent increase or decrease in household energy used from 1980 to 1982.
Family Household	Two or more persons who share resources, share responsibility for decisions, share values and goals, and have commitment to one another over time (AHEA, p.4).	Household with a family, individual, or a group of up to nine unrelated persons occupying the same housing unit (EIA, 1984a).

Sample Design

The universe for this sample design included all housing units occupied as the primary residence in the 50 states and the District of Columbia. The sample was selected by using a probability sampling design developed especially for the Residential Energy Consumption Survey. The sample design was used for the first time in the 1980 survey. The design required a sample with a minimum level of precision within each of the 10 Federal regions and 9 Census divisions. This requirement meant disproportionate sampling in each of the 17 intersections created by the overlap between the Federal regions and the Census divisions (Housing Characteristics 1982, 1984).

The 3,141 counties and independent cities in the 50 states and the District of Columbia were divided into 1,782 Primary Sampling Units (PSU's) on the basis of Standard Metropolitan Statistical Areas (SMSA's), county and independent city boundary lines, and population characteristics. The PSU's were grouped into 131 strata having roughly similar population totals within each of the 17 intersections. Each stratum contained PSU's similar in several characteristics, including, among others, the dominant space heating fuel and, in some strata, weather conditions. Some PSU's comprising all or part of large metropolitan areas were large enough in population to be a stratum by themselves; 31 of the PSU's were of this type and were called Self-Representing (SR) because the sample from each PSU represented only that PSU. In the other 100 strata, one PSU was selected from among two or more PSU's in the stratum. Each of the 100 PSU's selected from these strata was called Non-Self-Representing (NSR) because each PSU also represented the non-selected PSU's in its stratum.

A number of intermediate probability sampling stages preceded the final selection of RECS households. These stages included the selection of Minor Civil Divisions from which Census tracts were selected consisting of a segment of 25 or more housing units. Segments were formed from field counts in easily identified geographic units. Detailed field listings were created for each segment by a person who visited the area and identified each housing unit by street address or apartment number or other observable feature. A cluster of 25 housing units was selected from the sample segment. The ultimate cluster to be contacted for interviews (averaging about four housing units) was systematically selected from the cluster, and these housing units constituted the assignments given to the interviewers. The number of ultimate clusters totaled 1,515.

The 1982 survey was the first one in the RECS series to include a plan for rotation of sample units from an earlier RECS. The primary objective was to provide for longitudinal analysis of a sample of the same housing units over a two-year period. Therefore, a systematic random procedure was used to divide the 1,515 clusters in the basic sample into four subsamples, designated as A1, A2, B1, and B2. A1 and A2 constituted a rotation group in which procedures were designed to interview a sample of the same housing units that had been in the sample two years earlier (1980). B1 and B2 were new rotation groups, included in the RECS sample for the first time. Procedures for updating the sample for new construction and for other changes in the housing unit stock were incorporated in sampling operations so that each rotation group, as well as the total RECS sample, was a probability sample of the population covered by the survey.

Data Collection

The fieldwork for this study was conducted by Response Analysis Corporation of Princeton, New Jersey. For the 1980 survey, personal interviews were conducted at 4,475 of the 5,272 eligible (habitable) units, for a response rate of 84.9%. Subsequently, mail questionnaires were sent to 703 of the 797 households that had not participated in personal interviews. Completed questionnaires were returned by 249 of these households, or 35.4% of those mailed. Of the total eligible households, responses were received from 89.6% or 4,724 households.

In an effort to maximize the validity of the survey data, a multiwave, multicontact approach was employed. First a letter describing the survey and its importance was sent to all selected sample households. Interviewers then made contact with those who agreed to participate. At the end of this first wave, 4,037 interviews were completed, leaving 1,258 non-respondents.

A second effort was then made to contact non-respondents and refusals by a series of letters to these households. An additional 394 interviews were completed, leaving 842 non-respondents in this second effort. A third attempt was made with 44 interviews completed. Finally, an abbreviated version of the questionnaire, adapted for self-administration, was mailed (with a $2 incentive fee) to most of the remaining non-respondents. This effort resulted in 249 additional respondents. The total number of households surveyed in 1980 was 5,979 giving a final household weight for the population as 81,223,030 (EIA, 1982a).

The Interview

Interviews were begun in late September 1980 and continued through January 1981 for the 1980 survey and September 1982 through January 1983 for the 1982 survey. Over 90% of the personal interviews were completed in the months of October and November.

The average personal interview, including measurements of the housing unit, lasted 52 minutes. The interview with the householder, or his or her spouse, covered structural features of the house related to energy, such as insulation, doors, and windows; the heating and cooling systems, and the fuels used in these systems; use of wood; energy conservation improvements and the reasons for making the improvements; household appliances; household vehicles; receipt of government assistance for the cost of heating; and demographic data on household members. Questions relevant to the variables under investigation are included in Appendix B. The householder was asked to sign a waiver authorizing the housing unit's energy supplier to release energy consumption records to the DOE.

A total of 290 interviewers were used throughout the study to collect the data. While some of the interviewers (58%) had experience with previous RECS studies, others were conducting their first RECS, but had interviewing experience either with other survey research organizations, or with the U.S. Bureau of the Census. Interviewers received training through home study, a regional training meeting, or other training. All interviewers completed a practice interview and quiz.

Interviewers were paid an hourly wage for their time spent in interviewing, training, and traveling, as well as reimbursement for expenses. Each interviewer conducted an average of 15 interviews with a range from the lowest of 3 to the highest of 42. Twenty percent of the personal interviews were verified by telephone or mail to ensure that interviews were conducted as intended.

For additional information on sampling operations, survey estimates, minimizing nonresponse, see Housing Characteristics 1982, (EIA, 1984a).

Description of the Sample

Households were selected from the 1980 and 1982 RECS that were surveyed in both years, occupied the same housing unit, and owned the housing unit. Descriptive information is presented in the following tables. Total percentages may differ from 100.0 as a result of rounding. This descriptive information for the sample was obtained from the data files and the national data for the population was obtained from the 1980 data available in the Statistical Abstract of the United States: 1985 (U.S. Bureau of the Census, 1984). Frequencies and means were examined to compare the sample of the study to the population it represents.

The demographics of the sample age, education, income, job, marital status, number in household, race, sex, and square footage of housing unit were examined for the sample and the national population of households. T-tests were run to determine if the sample mean differed significantly from the population mean. There were no significant differences between the means of the variables age, education, marital status, number in the household, race, and square feet in the housing unit. There were significant differences between the means for the variables job of head of household, income, and sex of head of household. This supported the assumption that the sample was reasonably representative of the population. The frequencies and other descriptive data (mean and range) for the sample are presented in the following tables to provide an inclusive look at households of interest in the study. Some discussion of the variables follows each table.

Table 3
1980 Age of Head of Household

	Total Sample	National Data	Statistical Significance
Mean	49.91	46.7	NS
Range	18-94	15-94	
N	839	84,397,569*	
HH Weight	11,397,815	81,223,030**	

* 84,397,569 households was an U.S. Bureau of Census figure.
** 81,223,030 was the Household weight given to the data by the DOE.

Age.

Table 3 shows the age of the head of household for the sample, owner households, and the national population. The mean for the sample does not differ significantly from the national population mean, however, the sample can be described as slightly older than the population. The population data included a broader range of ages, as young as 15, whereas the sample showed 18 as the youngest head age.

It must be noted that Table 3 also includes the weight given to the cases in the sample. For example, the 839 households of the sample represent 11,397,815 households in the population and 81,223,030 are the number of households represented by the 1980 RECS sample (EIA, 1982). The implications for these household weights will be discussed further in Chapter VI.

Table 4
1980 Education of Head of Household

	Total Sample	National Data	Statistical Difference
Mean	12.08	12.00	NS
Mode	12	12	
N	839	84,397,569	

Education.

Table 4 shows extremely small differences in the means of the sample and population on the education variable, and no differences in mode. This is expected since over 90% of the U.S. population has a high school diploma (U.S. Bureau of Census, 1984). There is no significant difference between the means.

Table 5
1980 Household Income

	Total Sample	National Data	Statistical Difference
Category 1 $0-$13,999	31.2%	28%	NS
Category 2 $14,000-$49,999	64.2%	59%	NS
Category 3 > $50,000	4.5%	13%	SD
N	839	84,397,569	

Income.

Table 5 shows no significant difference between the income of the sample and the population in categories one and two. Category three (>$50,000) shows a significant difference between the sample mean and the population mean. Since the sample contained only owners of housing units, it was expected that the sample mean income would be skewed in an upward direction, that is, owners traditionally have higher incomes than do renters. However, the population had 13% of the households in the >$50,000, while the sample had only 4.5% of the households in this category. The income variable was collapsed, as will be discussed later in this chapter. This may explain some of the differences.

Table 6
1980 Job of Head of Household

	Total Sample	National Data	Statistical Difference
Part-time	28.4%	*	
Full time	65.4%	74%	SD
Not employed	6.2%	*	
N	839	84,397,569	

*Data not available

Job.

Table 6 shows 65.4% of the sample were employed full time while 74% of the population were full time employed. This was a significant difference between the means of the sample and the population and might be related to the previous variable, income. Since nearly 9% more heads of households are employed full time in the total population, compared to the sample., the income level of the population may also be significantly higher.

Table 7
1980 Marital Status of Head of Household

	Total Sample	National Data	Statistical Difference
Now Married	65%	63.1%	SD
Widowed	12%	13.1%	SD
Divorced/Sep.	12%	12.8%	SD
Never Married	11%	12.8%	SD
N	839	84,397,569	

Marital Status.

Table 7 shows the marital status of the head of the household. The sample and population do not differ significantly.

Table 8
1980 Number of Household Members

	Total Sample	National Data	Statistical Difference
Mean	2.96	2.76	NS
Mode	2	2	
N	839	80,800,000	

Number of Persons.

Table 8 identifies the number of persons in the household. The mean for the population was 2.76 persons per household, with a mode of 2 and the sample showed 2.96 persons per household, with a mode of 2. The sample and population do not differ significantly from one another.

Table 9
1980 Race of Head of Household

	Total Sample	National Data	Statistical Difference
White	85.0%	81.5%	NS
Black	10.0%	10.0%	NS
Hispanic	4.0%	5.0%	NS
Am. Ind./Ak. Nat.	.5%	.5%	NS
Asian, Pacific	1.0%	.8%	NS
Other	.2%	2.0%	SD
N	839	84,397,569	

Race.

Once again, the distribution of households on the race variable reflected the population. Table 9 shows 81.5% of the population is white and 85% of the sample is white. The other races represented a similar distribution between the sample and the population.

Table 10
1980 Sex of Head of Household

	Total Sample	National Data	Statistical Difference
Male	82.1%	71.8%	SD
Female	17.9%	28.2%	SD

Sex.

Table 10 shows the distribution of the sex of the head of the household. The population consisted of 71.8% male heads of households and 28.2% female. This differs significantly from the sample with 82.1% male and 17.9% female. This might be explained because the sample consisted of owners and no renters and males predominate as owners and head of households.

Table 11
1980 Square Feet of Housing Unit

	Total Sample	National Data	Statistical Difference
Mean	2023.52	1745	NS
Median	1880	1488	
N	839	84,397,569	

Square Feet.

Table 11 indicates the mean square feet of space in the sample housing units and the population housing units. Although the mean of the population was about 300 square feet smaller than the mean of the sample, this was not a significant difference. It could be speculated that the difference was due to owners in the sample and, traditionally, owner occupied housing units are larger that rental units.

Analysis Methods and Variables

The methods used in the statistical analysis of the data are described in this section. Additional discussion of these methods is presented in Chapter V Findings and Discussion. The computer programs designed for the analysis of social science data, Statistical Analysis System (SAS), was used for data analysis. Descriptive data analysis included one-way frequency distributions, means, standard deviations, and ranges. The statistical methods of data analyses included factor analysis, multiple regression, and discriminant analysis.

Factor analysis was used only for its data reduction capabilities, whereas, multiple regression and discriminant analysis made analytical contributions to the study. Multiple regression was used to first identify the predictors of energy consumption change. These predictor variables were measures of the household, the natural environment, the behavioral environment, and the constructed environment. Next, the households were assigned to three groups, conservers, non-conservers, and no changers, based on the percent of energy consumption change from 1980 to 1982. Discriminant analysis was used to classify the households into these groups based on the discriminating variables and then used to describe the differences between these groups. These analyses were conducted to examine as fully as possible, the household and environmental characteristics in relation to energy consumption change and the Energy Consumption Change Model.

Factor analysis was used for its data-reduction capability on the independent conservation strategy variables. The purpose was to see whether some underlying pattern of relationships existed so that these data could be rearranged or reduced to a smaller set of factors. These factors were used as newly created independent variables. The 16 conservation strategy variables were reduced to four factors, two of which were reliable and used as new variables for further analysis. These will be further discussed later in this chapter.

Multiple regression was performed to analyze the relationship between a dependent variable and a set of independent or predictor variables. The analysis was used as an inferential tool by which the independent variables from the sample data predict the dependent variable parameters for the population. For this study, the dependent variable was household energy consumption change from 1980 to 1982. Household and environment independent variables were selected that were thought to be theoretically related to energy consumption change. These variables are discussed below and represent the organism (household) and the three environments (natural, behavioral, and constructed) of the ecosystem which may impact on the household's energy consumption/conservation.

In the multiple regression analysis, the forward-selection stepwise technique was used for analyzing the relationships between energy consumption change and the household and environmental variables. With this method, the independent variables were entered into the regression equation one at a time. The order in which the independent variables were entered was determined by their degree of relationship with the dependent variable, that is, the amount of variance in the dependent variable explained by the independent variable in conjunction with independent variables already entered into the equation. The purpose of selecting multiple regression as one of the statistical analysis methods was to identify characteristics of the household and/or environment(s) that can be used to predict energy consumption change in the population represented by the sample. The implications of this prediction capability will be discussed in Chapter VI Summary.

Discriminant analysis was used to statistically distinguish between the three groups of interest, energy conserving households, energy non-conserving households, and no change households. For this study, the criterion variable, the variable upon which the groups were first assigned, was household energy consumption change from 1980 to 1982. This first placed the households into one of three groups based on their energy consumption pattern. Following Morrison, et al (1976), the household was assigned to the energy conserving group if it decreased energy consumption from 1980 - 1982 by 4% or more. The household was assigned to the non-conserving group if it increased energy consumption from 1980 - 1982 by 4% or more. Those households whose energy consumption change fell between a 4% increase and a 4% decrease were assigned to the no change group.

Discriminating variables were selected that measure characteristics of the household and environments, and upon which the groups were expected to vary. These variables are discussed below and represent the organism (household) and the three environments (natural, behavioral, and constructed) of the ecosystem and are related to household energy consumption/conservation. This forced the groups to be as statistically distinct as possible by forming one or more linear combinations of the discriminating variables. The purpose of selecting discriminant analysis as one of the statistical analysis methods was to establish a set of classification functions (characteristics of the household and/or environments) upon which new cases in the population represented by this sample, (with unknown memberships) could be classified. The classification will be used to describe characteristics of the household groups. The implications of this classification capability will be discussed in Chapter VI Summary.

Variables

The variables selected for study were from the 1980 and 1982 RECS data file. A listing of the survey questions from which these variables were drawn is included in Appendix B. All theoretically relevant variables were first selected from the data file for review and are listed in Appendix C as they were recoded for use in this study. These variables were examined for relevancy to the literature or theory and redundancy or duplication. The variables selected for use in the statistical analysis models are listed in Table 12 (Dependent) and Table 15 (Independent). These tables identify the variables, variable labels, and values for the dependent and independent variables. A discussion of the variables, the values, and method of recoding follows.

Dependent/Criterion Variable

Household energy consumption change from 1980 to 1982 was the dependent/criterion variable used in the multiple regression model and the discriminant analysis model. Actual household energy consumption was provided by utility companies and fuel suppliers for both 1980 and 1982 for all 858 households used in this study. For each year, the total energy consumption for each household was determined by adding together annual use, in thousands of British Thermal Units (BTU), for all fuel types used. The percent difference between the annual energy consumption for the two years was then found and identified as energy consumption change, i.e. increased or decreased energy consumption from 1980 to 1982. This percent change created the new variable (ENCH) and measured the percent change in energy consumption for each household.

To arrive at the variable of study, ENCH, several steps were taken to be certain all relevant data were included. First, to determine the quantity of energy consumed in 1980 and 1982 in thousands of BTU's per household, the annual energy used by fuel type was identified per household for 1980 and 1982 (see Table 12).

The quantity of energy used had been converted to BTU's in the data set. If a household used more than one type of fuel, the HOUSEHOLD USE IN THOUSANDS OF BTU's for all fuel types used were added together to determine the total for each household for each year and created new variables TOTAL HOUSEHOLD ENERGY USE IN 1980 (TEGUSE80) and TOTAL HOUSEHOLD ENERGY USE IN 1982 (TEGUSE82).

Next, the percent change in energy consumption, 1980-1982, was determined by subtracting TEGUSE80 from TEGUSE82 and dividing the response by TEGUSE80 to create the dependent variable of the study PERCENT ENERGY CONSUMPTION CHANGE 1980-1982 (ENCH). A positive number indicated an increase in consumption from 1980 to 1982. A negative number indicated a decrease in consumption from 1980-1982.

Table 12
Variables Used to Create ENCH

Var Label 1980	Var Label 1982	Variable
BTUEL	BTUEL	ELECTRICAL (EL) ANNUAL USE IN THOUSANDS OF BTU's
BTUNG	BTUNG	NATURAL GAS (UG) ANNUAL USE IN THOUSANDS OF BTU's
BTUFO	BTUFO	FUEL OIL (FO) ANNUAL USE IN THOUSANDS OF BTU's
BTULP	BTULP	LIQUID PROPANE (LPG) ANNUAL USE IN THOUSANDS OF BTU's
TEGUSE80	TEGUSE82	TOTAL HOUSEHOLD ENERGY USE IN THOUSANDS OF BTU's
ENCH	PERCENT ENERGY CONSUMPTION CHANGE 1980-1982	

Table 13 includes the descriptors for the newly created dependent variable ENCH for the sample. There were eight households that were outlyers, that is, two standard deviations beyond the mean. These households could have been deleted from the study, and perhaps should have been, but were included to keep the sample intact and to include these extremes in energy consumption. Deletion of these outlying households would have reduced one of the the sub-sets by 5%.

Table 13 also includes an examination of the total energy use, absolute change, and percent change for the sample. Percent change in energy consumption was used rather than absolute change in order to reflect a previous study of energy consumption change (Morrison, et al, 1976). Percent change was also used because of the distortion caused by the large numbers with high users. That is, mathematically, absolute change can be distorted by the size of the initial usage, therefore, percent change reflects more accurately the amount of change over the sample.

Table 13
Energy Consumption Data for the Sample

	Total Energy Used (BTU's) 1980	1982	Absolute Change (BTU's)	ENCH (% Energy Change)
Mean	21,022,624	20,816,890	4,133,019	-7.42%
SD	4,878,754	4,737,606	5,344,078	40.76
Range				
Low	10,025,863	10,036,958	98	-199.05%
High	30,152,346	30,192,898	20,024,383	66.47%

It was also important to view this sample's energy consumption in terms of total energy use for 1980 and 1982 to get a base line of use as compared to the absolute change. Additionally, a comparison of absolute change to percent change will give more description about which level of users were changing, i.e. low users or high users. Table 14 shows two correlations between types of energy use and change.

The results of the correlation of 1980 total energy used to absolute change was .13, significant at p = <.05. This is a slight indication that households who used more energy, changed more. That is, high users are changing slightly more than other users.

The results of the correlation of absolute change to percent change was -.28, significant at p = <.05. This is a moderate indication that households who increased their absolute change, decreased the percent change. That is, the larger the raw number of change is, the percent will be a smaller proportion of that raw number, hence decreased percent change. Therefore, the use of percent energy consumption change is more reflective of the amount and direction of change.

Table 14
Correlation of Energy Use and Change

	r
Correlation of 1980 Total Energy Used to Absolute Change	.1345*
Correlation of Absolute Change to Percent Energy Consumption Change	-.2781*
N 858	

*Significant at p = <.05

A second variable could have been used for the dependent variable, percent energy cost change from 1980-1982 (DIFFCOST). Energy cost was identified in previous studies as a predictor of energy consumption (Smith, 1976). A Pearson product moment correlation run between ENCH and DIFFCOST found a direct relationship with a very high correlation of .92, indicating the two variables measured the same element, energy change. However, ENCH was considered a more reliable variable since the data for the values were actual energy use as reported in fuel suppliers' records while DIFFCOST was an estimated dollar expenditure reported by the household.

In addition, the use of energy cost as a dependent variable in a regression model would not be a direct measure of change in energy consumption, only a direct measure of cost change, increase or decrease. When energy costs increased and energy consumption increased, the greater the annual cost of energy, therefore, the direct relationship between ENCH and DIFFCOST existed. For example, cost change could be due to inflation of the dollar, a rise in energy prices per unit of energy, or deregulation of a fuel type. Therefore, using DIFFCOST as a dependent variable could not help determine if energy consumption decreased because of the increase in energy cost. This is a relevant question and one that needs to be addressed, but cannot be addressed by this study due to the limitations of the data collected. Nor could DIFFCOST be used as a predictor or discriminating variable based on the high correlation with ENCH. It can be postulated that DIFFCOST is a predictor of ENCH, but empirical data were not available to examine this relationship.

Independent (Discriminating or Predictor) Variables

The independent variables were selected based on evidence in the literature of their measure of household (organism) and environmental characteristics related to household energy consumption. Table 15 lists the independent variables used in the regression and discriminant analysis models.

Since longitudinal data were used, it was possible to use both constant variables and change variables as independent variables. The constant variables selected were year built, number of stories, type of housing unit, age, education, income, number in household, and number of square feet,. The values for some constant variables, such as age, education, income, number in household, number of square feet, could have changed from 1980 to 1982. A T-test was run on the means for 1980 and 1982 for each of these variables. There were no significant differences between the means. It is important to note that these variables were not treated as change variables but that the values for these variables were all chosen from the 1980 data set as this was the value at the time of any household change that may impact on ENCH.

Change variables used were heating degree days, cooling degree days, and weighted number of appliances. The coding and values for these are discussed later. Finally, adding insulation, addition of a wood burning stove, and thermostat turn down were all variables included in the 1982 data set only and measure a behavior or activity change since 1980. Discussion on the coding of each variable is discussed later.

Table 15
Operationalized Independent Variables

Household Variables

Var Label	Variable	Values
HEADA80	AGE OF HEAD IN 1980	18=18 years 19=19 years . (Continuing) 95=95 years or older
HEADE80	ATTAINED EDUCATION OF HOUSEHOLD HEAD IN 1980	0=No Schooling 1=First grade 2=Second grade . (Continuing) 12=Twelfth grade 13=One yr of college 14=Two yr of college 15=Three yr of college 16=Four yr of college 17=Five+ yr of college
INCOME80	FAMILY INCOME IN 1979	1= 0-$13,999 2= $14,000-$49,000 3= >$50,000
NHSLD80	NUMBER OF HOUSEHOLD MEMBERS IN 1980	1=1 2=2 . (Continuing) 12=12 or more

Natural Environment Variables

Var Label	Variable	Values
CDD DIFF	DIFFERENCE IN TOTAL ANNUAL COOLING DEGREE DAYS BETWEEN 1980 AND 1982	Whole numbers from weather data.
HDD DIFF	DIFFERENCE IN TOTAL ANNUAL HEATING DEGREE DAYS BETWEEN 1980 AND 1982	Whole numbers from weather data.

Table 15 (Cont'd.)

Behavioral Environment Variables		
ADDINS82	ADDITION OF VARIOUS TYPES OF INSULATION SINCE 1980	Whole numbers from conservation scale. Range = 0 - 508
POTBEL82	ADDITION OF A WOOD BURNING STOVE AFTER 1980	0= No 1= Yes
TURNDO82	TURNDOWN OF THERMOSTAT WHEN NO ONE HOME OR AT NIGHT	Whole number from conservation scale. Range = 0 - 508
Constructed Environment Variables		
BUILT80	YEAR THE HOUSING UNIT WAS BUILT	1= < 1974 2= > 1975
HOMEA80	TOTAL SQ FT HEATED AND UNHEATED IN 1980	Whole number from interviewer measure of exterior, in square feet.
STORI80	NUMBER OF STORIES OR STYLE IN HOUSING UNIT IN 1980	1=One story 2=Two story 3=Three story 4=Split level 5=Other
TYPEHU80	TYPE OF HOUSING UNIT IN 1980	1=Mobile home/trailer 2=One-family house 3=Apartment building
APPLNC	WEIGHTED NUMBER OF APPLIANCES (weight based on energy consumption)	Whole number from appliance scale. Range =

Discussion of Household Variables

Previous research showed that certain demographic or household variables were related to energy consumption. The four variables of age, education, number in household, and income were selected for inclusion in the models. HEADA, HEADED, NHSLDMEM were all continuous level variables, coded in whole numbers. INCOME80 was an ordinal level variable that was coded in categories. It was recoded for statistical analysis purposes into three categories as shown in Table 15. These three categories were selected based on the range and frequency of households in each category. By recoding into three categories, the interval between each category became one, therefore, moving the variable to interval level.

Discussion of Natural Environment Variables

Most researchers acknowledge that the temperature of the natural environment is related to household energy consumption. Since a particularly cold winter in 1980 or a very hot summer in 1982 could increase the heating or cooling requirements for a household, the temperature of the natural environment was examined in this study. In order to accomplish this task, heating degree days (HDD) and cooling degree days (CDD) were used as independent variables in the models.

The value for HDD and CDD was found in a similar way to ENCH, with a whole number difference as the final value for each household, on each variable (the variables were not combined). A t-test determined there was no significant difference in HDD or CDD from 1980-1982. This analysis concurred with the RECS summary that "Both years were similar in weather and not much different from the normal....". (EIA, 1984b, p.15). CDD DIFF and HDD DIFF was a continuous level change variable, therefore, the percentage change between years was used in the models.

Discussion of Behavioral Environment Variables

ADDINS82 and TURNDO82 were independent variables created from a factor analysis of conservation strategies. Conservation strategies or behaviors were identified as relating to energy consumption (Bailey, 1979; Warren and Perlman, 1972; Smith, 1796; and Hogan, 1978). To measure the relationship of energy conservation behaviors to energy consumption change, a scale was constructed to measure Conservation Strategies. In the 1982 RECS survey, each household was asked to select, from a list, the energy conservation strategies it had performed since September 1980. In this study, each of the energy conservation strategies was assigned a weight representing its proportional energy consumption savings. This assignment was based on literature stating the percentage of energy consumption decrease annually for each strategy incorporated (Loftness, 1984; Byalin, 1980; Home Energy Guide, Sept. 1977). The weights were assigned as a factor of the conservation strategy with the lowest energy consumption reduction, plastic sheets added to windows. The weights gave no consideration for quality or quantity of each performed strategy since those data were not available. For example, there was no consideration given for the amount of insulation added to the attic, only to the practice of adding it.

If the household performed a conservation strategy, that strategy weight was added to the weights of any other strategies performed. The sum of these weights formed a continuum upon which the Conservation Strategy variable was measured. Therefore, each household received one score for conservation strategy that ranged from '0' for no strategies performed to 508 for numerous strategies performed. Table 16 lists the conservation behaviors and the weight assigned to each use of each practice. For example, if a household added two storm doors (12), attic insulation (22), and turned down the thermostat 2 degrees Fahrenheit when no one was home (4), the Conservation Strategy Score for that household was 38.

Table 16
Variables Contributing to Conservation Strategies

Var Label	Variable	Weight
ADDAT82	ATTIC INSULATED SINCE SEPT 80	22
ADDBA82	FLOOR INSULATION SINCE SEPT 80	11
ADDCL82	ADD CLOCK THERMOSTAT SINCE SEPT 80	18
ADDCO82	SHUTTERS ETC ADDED SINCE SEPT 80	2
ADDWA82	OUTER WALLS INSULATED SINCE SEPT 80	10
AUTOD82	AUTOMATIC FLUE DOOR SINCE SEPT 80	6
DOORO82	OTHER STORM DOORS SINCE SEPT 80	6
DOOR182	SLIDING STORM DOORS SINCE SEPT 80	8
HEATT82	DUCT INSULATION ADDED SINCE SEPT 80	3
PANES82	STORM WINDOWS SINCE SEPT 80	14
PIPES82	PIPE INSULATION ADDED SINCE SEPT 80	3
SEALE82	CAULKING ADDED SINCE SEPT 80	6
SHEET82	PLASTIC SHEETS ADDED SINCE SEPT 80	1
TEMPH82	WINTER TEMP DEGREES Fahrenheit. SOMEONE HOME Used as base for TEMPGONE AND TEMPNITE	
TEMPG82	WINTER TEMP DEGREES Fahrenheit. NO ONE HOME *If lower than TEMPHOME, add '2' for each degree lowered.	2*
TEMPN82	WINTER TEMP DEGREES Fahrenheit. SLLP HOURS *If lower than TEMPHOME, add '2' for each degree lowered.	2*
WSTRI82	WEATHER STRIPPING SINCE SEPT 80	4

Table 17 shows the results of the weighted scale for the three groups of households.

Table 17
Group Descriptors for Conservation Strategy Scale

	Conservers	Non-conservers	No changers
Mean	60.79	53.18	74.72
Range	0-392	0-414	0-508

In order to reduce the data, a confirmatory factor analysis was performed on the conservation strategy variables found by the researcher to be theoretically related (all insulation behaviors; all technical behaviors; all storm door/window additions; and thermostat behaviors). The weighted conservation strategy scores were used in the factor analysis to identify which of these variables were similar. This confirmatory analysis did not identify any reliable factors. Therefore, a Verimax (90 degrees) rotation was used to obtain the factors (see Table 18). Other rotations were also used to confirm the findings of the Verimax rotation. Four factors were found but the test of reliability showed only two factors had an alpha level of .40 or greater. Items on the conservation scale, their factor loadings, and alpha level are reported in Table 18. A discussion of the new variables created by these factors follows.

Table 18
Factors of Conservation Strategy Scale

FACTOR	VARIABLES	NEW VARIABLE	FACTOR LOADING	ALPHA
1	TEMPGONE	TURNDO82	.9534	a=.93
	TEMPNITE		.9528	
2	WSTRI82	ADDINS82	.6513	a=.44
	SEALE82		.5691	
	ADDWA82		.5380	
	SHEET82		.4863	
	ADDCL82		.4546	
	ADDAT82		.4136	
	AUTOD82		.2926	
3	PIPES82	INSULAT82	.7279	a=.23
	HEATT82		.6865	
	ADDBA82		.4542	
	ADDCO82		.3631	
4	PANES82	STORM82	.7369	a=.05
	DOORI82		.4744	
	DOORO82		.3996	

The independent variable POTBEL82 reflected the addition of a wood burning stove after 1980. This was a discrete variable at the nominal level. This was considered a behavioral variable due to the behavioral modification involved in the conversion or addition of wood burning as a fuel source.

The new variable TURNDO82 was a scaled variable consisting of a score given for each degree Farhenheit a household dials down the thermostat when no one was home and at night. This was a variable of the behavioral environment. The correlation between the two variables creating the factor was very high, indicating they were actually measuring the same behavior and were so combined on the scale. Since this factor had an alpha .93, it was used in the regression model.

Originally, the researcher assigned ADDCL82 to this factor due to the obvious relationship between the ease of thermostat turn down once an automatic set-back clock was attached to the thermostat. However, there was no relationship between the clock and turning down, indicating that this was a manual behavior.

The second new variable ADDINS82 was a scaled variable consisting of a score given for each insulation behavior completed by the household since 1980. The actions of adding weatherstripping, caulking, wall insulation, plastic sheets to the windows, attic insulation, automatic flue door, and thermostat clock were the conservation strategy variables included in this factor. The variables were theoretically similar, that is, all consisted of weatherproofing the building through increased resistance to heat loss (R value). The last two variables, thermostat clock and automatic flue door, did not have a high correlation with the entire factor, but were theoretically related to reduced heat loss and so remained loaded in the factor. Since this factor had an alpha .44, it was used in the regression model.

Additionally, all of these variables had other common features. Weatherstripping, caulking and adding plastic sheets to windows were all well advertised and relatively inexpensive. These behaviors also could be accomplished by the homeowner. Wall insulation and attic insulation were also well advertised methods of heat loss reduction and, although sometimes performed by the homeowner, identifiable professionals were available to perform these strategies. Finally, addition of a thermostat clock and automatic flue door, were, once again, well marketed energy consumption reduction methods and also had professionals available for hire.

The third factor, INSULAT82, was not reliable at the .40 or higher level and was not included in the regression model. However, it also contained variables all theoretically related to increased resistance to heat loss, such as adding insulation to pipes, heat ducts, basement, and windows. It was speculated that these behaviors were not as well marketed as other energy conserving improvements and were not as cost effective as the previous behaviors mentioned.

The fourth factor, STORM82, was not reliable at the .40 or higher level and was not included in the regression model. The variables, adding storm doors and windows were theoretically related to one another and also reflected reduction of heat loss. It was speculated that while these two behaviors were well marketed as energy conserving strategies, the cost of adding storm windows and doors prevented households from implementing these strategies.

Discussion of Constructed Environment Variables

The values for BUILT80, the year the housing unit was built, were originally coded at ordinal level. To theoretically reflect the energy consumption data, this variable was recoded into two categories, 1974 or earlier, and 1975 or later. This was a natural break in the data and reflected housing units built before the impact of the Arab oil embargo and after the impact had been felt. Table 19 shows 87% of the sample lived in housing units built before or during 1974 and 13% lived in housing units built during or after 1975.

Table 19
Year Housing Unit was Built

	Sample
≤1974	87.0%
≥1975	13.0%
N	839

HOMEA80 and STORI80 were continuous data. HOMEA80 used the values obtained in the 1980 survey. All cases that had changed the total square footage between 1980 and 1982 (19 cases) were dropped from the sample due to the error in measurement method previously discussed. STORI80 and TYPEHU80 values were also chosen from the 1980 data set to remain consistent with the selection for other non-change variables.

Weighted number of appliances (APPLNC) was considered as a variable in the Constructed Environment. Hogan's study (1978) indicated the number of energy using appliances was an intervening variable with family income as related to increased energy consumption. Therefore, a scaled variable was created to measure the contribution to energy consumption of number of appliances in the household.

Each of the following appliances or energy consuming components that were additional to the household's main space heating/cooling and water heating were assigned a weight representing their proportional energy consumption of estimated annual KWH. This was assigned based on literature reporting the average annual KWH of consumption (Loftness, 1984, p.408). The weights were assigned as a factor of the appliance with the lowest energy consumption, electric wringer washer. If the household used an appliance, that appliance weight was added to other appliance weights. If the household had more than one of the same appliance (for example, color television), the appliance weight was multiplied by the quantity of the type of appliances, then added to the other appliance weights. The sum of these weighted values measured the contribution of appliances to household energy consumption.

The difference between the means of these weighted values APPLNC80 and APPLNC82 was used as the Appliance Scale value for the statistical models. This controlled for added or deleted appliances over time. For example, several new appliances or components could have been added to the household since 1980, or some could have broken and/or not been replaced. This difference could have affected the total household energy consumption. Table 20 identifies the appliances and energy consuming components used in the household. The variable labels, variable, and the weight for each appliance or component are listed.

Table 20
Variables Contributing to APPLNC (1980 and 1982)

Var Label	Variable	Weight
DEHUM80	USE ELECTRIC DEHUMIDIFIER	5
EVAPC80	USE EVAPORATIVE COOLER	12
FREEZ80	NUMBER OF FREEZERS IN HOME	21
HAUTO80	USE AUTOMATIC CLOTHES WASHER	2
HELCL80	USE ELECTRIC CLOTHES DRYER	14
HELDI80	USE ELECTRIC DISHWASHER	5
HELRA80	USE ELECTRIC RANGE	16
HGASR80	USE GAS RANGE	16

Table 20 (Cont'd.)

HGSCL80	USE GAS CLOTHES DRYER	14
HODGA80	USE OUTDOOR GAS LIGHT	2
HUMID80	USE ELECTRIC HUMIDIFIER	2
HWRNG80	USE ELECTRIC WRINGER WASHER	1
NREFR80	NUMBER OF REFRIGERATORS IN USE	20
OVEN180	WHETHER OVEN1 IS MICROWAVE	3
OVEN280	WHETHER OVEN2 IS MICROWAVE	3
POOLH80	USE POOL HEATER	25
TVBLA80	NUMBER BLACK AND WHITE TVS	2
TVCOL80	NUMBER COLOR TVS	6

Extraneous Variables

Extraneous variables were examined to identify any descriptive relationship between the independent variables and the dependent variable. These variables were used to discuss and further explain the findings. This included a series of government assistance variables that were selected for examination. If a household received government assistance in any form (see Table 21) it was assigned one (1). If it received no assistance, it was assigned zero (0). The government assistance variable will be discussed in Chapter V Findings and Chapter VI Summary and Conclusions to identify implications for use. The variables are listed in Table 21.

Table 21
Extraneous Variables

Var Label	Variable
AUDIT82	ENERGY AUDIT PERFORMED IN PAST YEAR
	Government Assistance Variables
CASHA82	CASH HEATING AID RECEIVED FROM GOVT
FI^DO82	WINDOWS OR DOORS REPAIRED BY GOVT
FI^HE82	GOVT REPAIRED BROKEN FURNACE
FUELPA82	GOVT DIRECTLY PAID HEATING COMPANY
GADGE82	GOVT PROVIDED OTHER ENERGY DEVICES
GOVTA82	TOTAL HEATING COSTS PAID BY GOVT
HEATA82	GOVT HELPED PAY HOME HEATING COSTS
INSUL82	ATTIC OR BASEMENT INSULATED BY GOVT
NOLEA82	WINDOWS OR DOORS CAULKED BY GOVT
DOORW82	GOVT ADDED STORM DOORS OR WINDOWS
TUNEU82	FURNACE TUNEUP DONE BY GOVT
VOUCH82	HEATING VOUCHERS RECEIVED FROM GOVT

Relationship of Variables to the Theoretical Model

Referral to the theoretical model of this study, The Household Energy Consumption Change Model (Figure 4), shows the data organized into an ecosystem framework in an attempt to categorize and analyze the relationship between the organism and its environments in the context of energy consumption/conservation. Figure 4, below, identifies the measurable independent variables in the study as they are related to the components of the Household Energy Consumption Change Model. The dependent variable is the construct Energy Consumption Change.

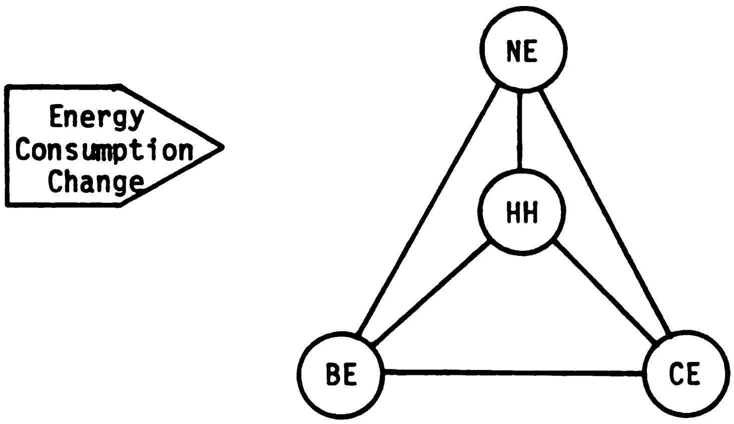


Figure 4
Household Energy Consumption Change Model

Key

HH = Household Variables
  Sex of Head
  Age of Head
  Employment Status of Head
  Education Level of Head
  Number of Household Members
  Family Income for 1979

NE = Natural Environment Variables
  Heating Degree Days
  Cooling Degree Days

BE = Behavioral Environment Variables
  Conservation Strategies Used
  Addition of Woodburning Stove

CE = Constructed Environment Variables
  Appliance Scale: weighted for energy consumption
  Type of Housing Unit
  Number of Stories of Housing Unit
  Total Square Footage
  Year the Housing Unit was Built

—— = Interaction Network

Discussion of the findings in Chapter V will further relate the theoretical model to the variables of the study.

Limitations of the Data

1. Data were collected for the primary housing unit only. Data were not collected for two types of housing units, vacant housing units and second home for the owner's use, due to the difficulty of collecting the data and the availability of funds.

2. The longitudinal data collected in the 1982 RECS indicated that the square footage measure system had a few flaws. There was a slight variation between the measure for 1980 as compared to 1982. In some cases this could be accounted for by remodeling or other changes in progress. This variation indicated measuring methods could be improved and limited the use of this variable in a longitudinal study.

3. Much of the data regarding behaviors performed were acquired by self-report. For example, when indoor temperature was requested, the report may have given the typical temperature, not the measured or monitored temperature. Other self-report data included whether or not the household adopted energy conserving measures such as insulation, caulking, weatherstripping or practiced turning down the thermostat. These were not observed behaviors, but self-reported behaviors. There may be a difference in observation versus perception.

4. Some of the data were collected at a lower value level than ideal for flexible statistical analysis. For example, income was not collected at the interval level; therefore, analysis methods were limited.

Limitations of the Study

1. The study was limited to owner-occupied housing units; therefore, the findings can be generalized only to this type of housing unit.

2. Combination of fuel types to determine household energy consumption did not reflect the end use for each fuel type nor the efficiency of fuel type based on use, i.e. electricity was not the most efficient fuel type for space heating but was included in most household fuel consumption records.

3. The data set did not include some variables which could be of interest to this study and would have implications for further research. These will be discussed in Chapter VI Summary and Conclusions.

Assumptions

1. Multi-methodological research methods were appropriate for gathering data for this study. Sociodemographic measures of household characteristics were gathered by survey method. Physical properties measurements were taken by the interviewers. Self-report methods were used to gather data related to conservation behaviors and activities undertaken to conserve energy. Fuel use data was supplied by fuel suppliers.

2. For purposes of determining energy consumption, data gathered from utility, propane, and fuel oil companies, indicating actual energy purchase, were the most precise and reliable measures available.

3. It was possible to convert multiple measures of energy depending on type (electricity, fuel oil, natural gas, and liquid propane) to a standard measure, British Thermal Units, without significant loss in measurement reliability (see Appendix A for BTU conversion factors used by RECS).

4. The households were not aware they would be surveyed two years later, therefore the Hawthorne effect was not operational beyond the extent of awareness a survey pertaining to a specific topic would generate.

Chapter V Findings and Discussion will present the findings of the statistical models as well as discuss the findings in relation to the theoretical model, Energy Consumption Change Model.

CHAPTER V: FINDINGS AND DISCUSSION

This study was unique in four respects. It included 1) data from a national sample, 2) only owner occupied housing units, 3) a change variable for the dependent/criterion variable because of the availability of longitudinal data, and 4) a test of a theoretical human ecosystems model with independent variables that represented characteristics of the household (organism) and the natural, behavioral, and constructed environments. Based on this uniqueness, the data analysis of this study was exploratory in nature. Two statistical analysis methods, multiple regression and discriminant analysis were used to adequately explore and test the theoretical model.

Findings reported in this chapter are related to the research questions guiding this study. The findings are discussed as a reflection of the components of the ecosystem model. The findings and discussion are presented in three parts: results of the multiple regression analysis, results of the discriminant analysis, and results of the test of the theoretical model.

Multiple Regression

As stated in Chapter IV Methodology, the purpose of selecting multiple regression as one of the statistical analysis methods was to identify characteristics of the household and/or environment(s) that can be used to predict energy consumption change in the population represented by the sample. This prediction capability will then have implications for household energy conservation. In this study, multiple regression analysis was used to answer the following research question: Are there household and/or environmental characteristics that can predict household energy consumption change? The primary interest of this question was to explain the relative contribution of these characteristics to energy consumption change.

Multiple regression analysis examined the linear relationship between a set of independent variables and a dependent variable while considering the interrelationships among the independent variables. Additionally, multiple regression selected a set of independent or predictor variables that, when present, will predict the dependent variable value with some degree of accuracy. This accuracy can be determined by the strength of the relationship between the variables measured by correlation coefficients, which, essentially, measure the goodness of fit of the best single straight line or linear relationship.

The forward-selection stepwise technique was used to enter independent variables, entering each variable only if it met certain statistical criteria. The order of inclusion was determined by the respective contribution of each variable to the explained variance. The procedure involved scanning the variables and selecting the one that accounted for the greatest amount of the model variance as indicated by the R-square. If a variable was significant at the alpha level selected ($p=<0.05$), it was entered into the model, while at the same time, all other variables already entered into the model are held constant. The procedure was repeated with each predictor variable. The statistics obtained indicated how accurate the prediction equation or variables were and how much of the variation in energy consumption change was accounted for by the joint influences of the predictor variables.

Multiple Regression Model

Dependent variable.

The dependent variable for the multiple regression model was percent energy consumption change from 1980-1982 (ENCH). This was a continuous variable for the sample of owner households. The mean, standard deviation, and range for the sample are shown in Table 14, Chapter IV Methodology. The method for obtaining the values of this variable was discussed in Chapter IV Methodology.

An energy consumption decrease of -7.42% was the mean for this sample. However, the range showed notable outlyers at the extreme energy consumption decrease end of the continuum, thereby affecting the sample mean. These outlyers were included for theoretical reasons as explained in Chapter IV Methodology.

Independent variables.

The independent or predictor variables were identified from literature of previous research studies as well as by theoretical linkages made by the researcher. The RECS study contained over 650 variables, of which 169 were selected as relevant for investigation in this study. A complete listing of these variables is in Appendix C. These variables were placed in a master file separate from the RECS data tape to ease data handling and increase speed of analysis. From this initial selection, several steps were taken to arrive at the variables included in the statistical models.

First, these variables were checked for accuracy, that is, that the values in the data file reflected the range of possible responses. When errors of variable location on the RECS data file were found, Dr. Wendall Thompson or Dr. Robert Latta, statisticians, Energy Information Administration, Department of Energy, Washington, D.C., were contacted to verify the correct location and subsequent values.

Second, many variable labels differed from 1980 to 1982, for the same variable, so extensive recoding occurred to facilitate readability. The variables were recoded to represent the same variable and indicate the year from which the data were drawn, i.e. 1980 or 1982.

Third, variables were examined to identify key determinants of energy consumption and to eliminate colinearity among independent variables. For example, the variables for heated square feet in the housing unit when combined with unheated square feet had the expected high correlation with total square feet. Since measurement error occurred (as discussed under limitations) it was determined that total square feet was more reliable as well as reducing colinearity with other variables and therefore would be used in the model (HOMEA80).

Fourth, further study of the variables and their values eliminated those variables that were not usable in the statistical analysis methods desired. That is, limitations in the data collection were reflected in the limitations of using some of the variables in the statistical models. When possible, recoding of the variables occurred to facilitate their use in regression or discriminant analysis. Examples, such as income and government assistance, were discussed in Chapter IV Methodology.

Finally, other methods of recoding, scaling, reducing, or creating change variables were completed. The independent variables used in the statistical analysis models were previously listed in Table 15, and discussed in Chapter IV Methodology, they are also listed below in Table 22.

Table 22
Independent Variables Used in Statistical Models

Var Label	Variable
Household Variables	
HEADA80	AGE OF HEAD IN 1980
HEADE80	ATTAINED EDUCATION OF HOUSEHOLD HEAD IN 1980
INCOME80	FAMILY INCOME IN 1979
NHSLD80	NUMBER OF HOUSEHOLD MEMBERS IN 1980
Natural Environment Variables	
CDD DIFF	DIFFERENCE IN TOTAL ANNUAL COOLING DEGREE DAYS BETWEEN 1980 AND 1982
HDD DIFF	DIFFERENCE IN TOTAL ANNUAL HEATING DEGREE DAYS BETWEEN 1980 AND 1982
Behavioral Environment Variables	
ADDINS82	ADDITION OF VARIOUS TYPES OF INSULATION SINCE 1980
POTBEL82	ADDITION OF A WOOD BURNING STOVE AFTER 1980
TURNDO82	TURNDOWN OF THERMOSTAT WHEN NO ONE HOME OR AT NIGHT
Constructed Environment Variables	
BUILT80	YEAR THE HOUSING UNIT WAS BUILT
HOMEA80	TOTAL SQ FT HEATED AND UNHEATED IN 1980
STORI80	NUMBER OF STORIES OR STYLE IN HOUSING UNIT IN 1980
TYPEHU80	TYPE OF HOUSING UNIT IN 1980
APPLNC	WEIGHTED NUMBER OF APPLIANCES (weight based on energy consumption)

Multiple Regression Findings

The multiple regression model was found significant when consisting of five predictor variables: BUILT82, HDD DIFF, APPLNC, POTBEL82, and ADDINS82. The results of the analysis are presented in Table 23.

Table 23
Regression Model: ENCH as Dependent Variable

Step	Ind. Variable	Model R2	Prob>F	B Value
1	BUILT82	.04	.0001	-23.953
2	HDD DIFF	.07	.0001	- 0.002
3	APPLNC	.08	.0011	0.124
4	POTBEL82	.09	.0047	- 2.089
5	ADDINS82	.10	.0053	- 0.326
	MODEL	.10	.0001	

n = 839
p = <.05

The findings show that the model was significant at the .0001 level. The null hypothesis, there is no relationship between household energy consumption change and a set of household and environmental characteristics, was rejected. The five independent variables can be used as predictors of change in energy consumption although they explain only 10% of the variance in the dependent variable. It needs to be noted that the regression model tests only goodness of fit of the variables to a straight line, or linear relationship. It is probable that a relationship exists that is nonlinear; otherwise, the model may not have been significant. Each of the variables and their contribution to the model will be discussed.

Year the housing unit was built.

This variable explained 4% of the variance. The variable was coded to reflect the housing unit being built prior to and inclusive of 1974 and 1975 or later. The B value of -23.953 indicated the older housing unit (<1974) is a predictor of an increased energy consumption change and the newer housing unit (>1975) is a predictor of a decreased energy consumption change.

This finding is consistent with literature that shows adequate insulation of housing units before 1974 occurred infrequently (Shurcliff, 1980). Insulation increases the resistance to heat loss and therefore can reduce energy consumption. After the 1973 Arab oil embargo, emphasis was placed on adding insulation to existing housing units and increasing insulation in newly built housing units. This action is consistent with the findings.

Heating degree days difference.

Heating degree days difference added to the first variable explained 7% of the variance. The B value of -0.002 indicated very little change in heating degree days would result in a change in energy consumption. Since both the dependent and independent variables are change variables, the direction of change would be consistent between the two, regardless of the sign of the slope. That is, higher number of heating degree days would indicate increased energy consumption. This finding is consistent with previous studies that have shown a high number of heating degree days or decreased temperatures is a predictor of increased energy consumption.

Weighted number of appliances.

Weighted number of appliances added to the first two variables explained 8% of the variance. The B value of 0.124 indicated as the weighted number of energy consuming appliances increased, energy consumption increased. Therefore, weighted number of appliances is a predictor of energy consumption change. This agrees with Hogan's (1978) finding relating appliance stock to energy consumption.

Addition of a wood burning stove.

Addition of a wood burning stove combined with the first three variables explained 9% of the variance. The B value of -2.089 indicated that as use of wood burning stoves increased, energy consumption decreased. These households may be using wood as an auxiliary space heating fuel, not the main fuel which would explain a small decrease in energy consumption.

Addition of insulation.

The variable ADDINS82, when added to the first four variables, explained 10% of the variance. The B value of -0.326 indicated that as use of insulation strategies increased, energy consumption decreased. ADDINS82 is one of the factors derived by the factor analysis of the conservation strategies. As previously discussed, insulation housing unit components reduces heat loss and therefore decreases energy consumption. This finding is consistent with findings from other studies and from recognized experts such as the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). The significance of this variable in the model confirms added insulation is a predictor of energy consumption change.

Discriminant Analysis

The purpose of selecting discriminant analysis as the second statistical analysis method was to establish a set of characteristics of the household and/or environments upon which new cases in the population represented by this sample, with unknown memberships, can be classified. This classification capability will then have implications for household energy conservation. This method was also used to determine the ecosystem characteristics, i.e. the natural, behavioral, and constructed environments, that discriminate among the three groups, conservers, non-conservers, and no changers.

In this study, discriminant analysis was used to answer the following research question: Are there household and/or environmental characteristics that discriminate energy conserving, non-conserving, and no change households in relation to energy consumption change? The primary interest of this question was to explain the relative contribution of these characteristics to household groups based on energy consumption, with eventual application to energy conservation.

This method was used to statistically discriminate between the three groups of interest, conservers, non-conservers, and no changers.

Households were assigned to one of the three groups based on the criterion variable, percent change in energy consumption from 1980-1982 (see discussion in Chapter IV Methodology). Independent or discriminating variables were then statistically selected that reflect characteristics of group membership. This set of discriminating variables is known as a discriminant function. The objective of discriminant analysis is to weight and combine the discriminating variables so that the groups are forced to be as statistically distinct as possible. Discriminant analysis allows classification of the likely group membership of a case when the only information known is the case's values on the discriminating variables.

A second use of the classification was in testing the adequacy of the derived discriminant functions. By classifying the cases used to derive the functions and then comparing predicted group membership with actual group membership, the success in discrimination can be empirically measured by observing the proportion of correct classifications. The analysis aspects of this technique provided several tools for the interpretation of data. Among these are statistical tests for measuring the success with which the discriminating variables actually discriminate when combined into the discriminant functions. When there are more than two groups, it may be possible to obtain satisfactory discrimination with fewer than the maximum number of functions.

Discriminant Analysis Model

Criterion variable.

The criterion variable for the discriminant analysis model was percent energy consumption change from 1980-1982 (ENCH). In this model, ENCH was used to identify group membership of the households, i.e. conserving (> 4% decrease from 1980-1982), non-conserving (> 4% increase from 1980-1982), and no change (≤4% decrease or ≤4% increase from 1980-1982). The method for obtaining the values of this variable was discussed in Chapter IV Methodology. The mean, standard deviation, and range for the groups are shown in Table 24.

Table 24
Group Description with ENCH

	Conservers	Non-Conservers	No Changers
Mean	-73.14%	40.47%	-0.06%
SD	39.16	10.18	.44
Range			
Low	-46.83%	31.96%	-2.76%
High	-199.05%	66.47%	2.19%
N	173	154	512

It is interesting to note that there were three distinct numerical groupings that corresponded to the nominal groupings. Additionally, the mean percentages for each group were clustered surprisingly close to the mean of each group. The conserver group is the only group that may have had several outlyers that affected the mean. The inclusion of these outlyers was discussed in Chapter IV Methodology. It can also be noted that the use of a 4% energy consumption change was an appropriate selection. While the statistical analysis used three groups upon which to discriminate the variables, theoretically there are only two groups in the sample. The no change group could also be considered non-conservers since they did not conserve energy.

Independent Variables.

Since the requirements for variables used for multiple regression and discriminant analysis were the same, the independent or discriminating variables used in the statistical models were identical to the independent variables used for the predictor variables. The method and rationale for selecting these variables was discussed earlier in this chapter under Multiple Regression Model.

Discriminant Analysis Findings

The discriminant analysis model found one function significant consisting of five discriminating variables: BUILT82, HDD DIFF, CDD DIFF, HEADA80, and STORI80. The results of the analysis are presented in Table 25.

Table 25
Discriminant Analysis Model: ENCH as Criterion Variable

Function	Eigen Value	% Var	Cum %	Canon. Corr	Wilkes. Lambda	Chi2	DF	Sig
1	0.1193	82.1	82.1	0.33	0.8708	108.27	28	0.0001

n = 792
p = <.05

The findings show that the model was significant at the .0001 level. The null hypothesis, there is no relationship between household and environmental characteristics and the household groups, conservers, non-conservers, and no change, was rejected. The discriminating variables which contributed to the function can be used as characteristics upon which the groups can be distinguished.

The figures shown in Table 25, the eigenvalues and their associated canonical correlations, denote the relative ability of the significant function to separate the groups. The eigenvalue is a measure of the relative importance of the function. The sum of the eigenvalues is a measure of the total variance existing in the discriminating variables. Therefore, the variance explained by this model was 12%.

The canonical correlation is a measure of association between the function and the group variable, another measure of the function's ability to discriminate among the groups. As shown in Table 25, even though the model is significant, the eigenvalue shows a variance explained of 12% but at a highly significant level. Similarly, the canonical correlation shows moderate ability (.33) of the function to discriminate among groups.

Table 26
Discriminant Functions

	Standardized Canonical Discriminant Function Coefficients	Correlations Between Discriminating Variables and Function
Variable	Function 1	Function 1
BUILT82	0.6599	0.6702
HDD DIFF	0.5537	0.5741
CDD DIFF	-0.0098	-0.3960
HEADA80	-0.1002	-0.2362
STORI80	-0.1349	-0.2008

Table 26 shows the discriminating variables selected for the discriminating function. The standardized discriminant function coefficients represent the relative contribution of its associated variable to that function, when the sign is ignored. The sign merely denotes whether the variable is making a positive or negative contribution. The interpretation is analogous to beta weights in multiple regression. The correlation identifies the relationship of each variable to the function as a whole.

In this model, BUILT82 and HDD DIFF made the strongest contribution to the function, were moderately well correlated to the function, and showed a positive relationship. Additionally, CDD DIFF, HEADA80, and STORI80 made a moderate contribution to the function, were poorly correlated to the function, and showed a negative relationship. It must be noted, again, that the statistical model is looking for a linear relationship. The statistical model was significant and there were two variables that contributed substantially to the model.

Figure 5 shows a comparison of the group means on the discriminating function and indicates how far apart the groups were along that dimension. By averaging the scores for the cases within a particular group, the group mean on the respective function can be derived. For a single group, the means on all the functions are referred to as the group centroid, which is the most typical location of a case from that group in the discriminant function space. Conserving households and non-conserving households were nearly equi-distant from the no change group.

```
-1.0                          0                               1.0
  |-----------|-------------|-|------------|--------------|
          -0.53           -0.03         0.58
     Non-conservers    No change    Conservers
```

Figure 5

Means by Groups on Discriminant Functions

As a check of the adequacy of the discriminant functions, the original set of cases can be classified to see how many are correctly classified by the discriminating variables. Under the assumption of a multivariate normal distribution, the classification score can be converted into probabilities of group membership. The rule of assigning a case to the group with the highest score is then equivalent to assigning the case to the group for which it has the greatest probability of membership. Table 27 shows the results of the classification of the known cases based on the discriminating function. The overall correct classification for the groups was 36.87%. The discriminating function served best for non-conservers with 65.8% correctly classified; conservers were 49% correctly classified, and no change households were classified correctly only 24.3% of the time. This third group was the largest and had the smallest range.

Table 27
Classification Results

Assigned Group	No. of Cases N	Percentage of Predicted Group Membership		
Non-conservers	146	65.8%	14.4%	19.9%
Conservers	157	26.1%	49.0%	24.8%
No changers	489	43.1%	32.5%	24.3%

Percent of grouped cases correctly classified: 36.87%

Theoretically it may be concluded that a difference does exist between the three groups determined from the discriminating variables

indicating that there is a relationship between each group and the three environments. Further, the resulting discriminant function contained variables from the natural and constructed environments as well as from the household. However, with only 36.87% of the cases correctly classified based on the discriminating function, the empirical evidence supported a moderate
difference.

Discussion of the Discriminating Variables

It would be helpful to understand some of the differences between the groups. Table 28 includes some additional information, the descriptors of these variables, such as mean and standard deviation or frequency.

Table 28
Discriminating Variables

	Conservers	Non-conservers	No Changers
BUILT82			
<1974	72.8%	95.5%	89.3%
>1975	27.2%	4.5%	10.7%
HDD DIFF			
Mean	860.62	-1024.52	24.36
SD	2953.47	2929.45	2896.49
CDD DIFF			
Mean	-577.71	-84.93	-311.25
SD	1245.28	1143.94	1069.96
HEADA80			
Mean	48.2 yr.	51.7 yr.	49.9 yr.
SD	15.6	15.9	16.4
Range	22 - 88	22 - 89	18 - 94
STORI80			
1	64.7%	39.6%	60.0%
2	19.7%	30.5%	21.3%
3	.6%	6.5%	2.5%
4	1.2%	1.9%	3.1%
5	0.6%	0.0%	.4%
N/A	13.3%	21.4%	12.7%
N	173	154	512

BUILT82: The vast majority of all housing units were built during or before 1974. There is a significant difference, however, between conservers and non-conservers. Twenty-seven percent of the conservers housing units were built after 1974, that is, after the OPEC oil embargo and the raising of awareness for energy conservation. After 1974 considerable efforts were made towards improving housing construction technology to reduce energy heat loss.

HDD DIFF: Conserving households had more heating degree days in 1982 (somewhat colder weather) than in 1980, yet, consumed less energy. This occurrence can be explained by the increased use of conservation strategies, more energy efficient housing stock, or, perhaps, less comfort. (To find HDD DIFF, 1980 was subtracted from 1982, therefore a positive number indicates higher heating degree days in 1982, a negative number indicates fewer heating degree days in 1982). Non-conserving households had fewer heating degree days in 1982 (somewhat warmer weather) than in 1980, yet, consumed more energy. The no change households had very stable weather, and, perhaps, no motivation to conserve.

CDD DIFF: It was a slightly cooler summer in 1982 than in 1980, indicated by the negative difference in cooling degree days for all groups. There was a difference between conserving and non-conserving households, with the conservers having fewer cooling degree days than the non-conservers. This cooler summer weather could account for some of the energy consumption difference.

HEADA80: There is a small but significant difference between the mean ages of conservers and non-conservers. Perhaps the difference in energy consumption can be attributed to the slightly older mean for the non-conservers. But as the annual income may be greater for this group, concern for cost of energy may decrease.

STORI80: The number of stories in the housing unit is a variable upon which the groups differed. The majority of conserving households had one story houses, whereas, non-conservers were nearly equally divided between one and two story housing units. A two story house is more energy efficient because there is less envelope enclosing the square footage than in a one story house of the same square footage. Perhaps that helps to explain why the non-conserving households had less energy consumption change, they may already be energy efficient. Since space heating uses the majority of energy consumed by the household, number of stories, a constructed environment variable, may be a good discriminator. Or, the one story housing units of the conservers may be smaller square footage and therefore, be consuming less energy.

The no change household group was consistently between the other two groups' values on all variables. At times, the no change households were more similar to the conservers, such as on the variables STORI80 and CDD DIFF; on other variables, such as BUILTYR, the no change group was more similar to the non-conservers. However, this mixed picture probably lends support to the fact that they are distinctly different groups.

Test of the Household Energy Consumption Change Model

The third research question posed, is there a fit between the Household Energy Consumption Change Model and reality as represented by this sample? According to the theoretical model developed for this study, household and environmental characteristics do interact to affect household energy consumption. The regression model contained variables from each of the three environments and the discriminant analysis model contained variables from two environments as well as a household variable. Table 29 shows the significant variables in the models that served as predictors and discriminators of energy consumption change as they were related to the environments and the household (organism).

Table 29
Variables Found Significant for Theoretical Model

Household Variables	
HEADAGE	AGE OF HEAD IN 1980
Natural Environment Variables	
HDD DIFF	DIFFERENCE IN TOTAL ANNUAL HEATING DEGREE DAYS BETWEEN 1980 AND 1982
CDD DIFF	DIFFERENCE IN TOTAL ANNUAL COOLING DEGREE DAYS BETWEEN 1980 AND 1982
Behavioral Environment Variables	
POTBEL82	ADDITION OF A WOOD BURNING STOVE AFTER 1980
ADDINS82	ADDITION OF VARIOUS TYPES OF INSULATION SINCE 1980
Constructed Environment Variables	
STORIES	NUMBER OF STORIES OR STYLE IN HOUSING UNIT IN 1980
YRBUILT	YEAR THE HOUSING UNIT WAS BUILT
APPLNC	WEIGHTED NUMBER OF APPLIANCES (weight based on energy consumption)

Both statistical models were significant at the 0.05 level, therefore, the null hypothesis there is no relationship between the Household Energy Consumption Change Model and reality as represented by this sample, was rejected. A minimal amount of variance was explained by the variables in both models.

At this point, it is important to reflect on the exploratory nature of the theoretical model using data drawn from a national sample of owner occupied housing units. Additionally, the study was longitudinal, using a change variable as the dependent variable (ENCH) as well as change variables (HDD DIFF and CDD DIFF) for some of the predictor and discriminator variables. It can be speculated that the relationship between the dependent and independent variables, is, in fact strong, but not linear. Whenever such a nonlinear relationship exists, the variance will underestimate the true degree of relationship since regression measures only the goodness of fit of the best single straight line of the independent variables. It is possible to have outlyers or variables with extreme values that may pull the regression line into a curve, yet reflect a moderate to strong relationship (Blalock, 1972). Further exploration of the data using nonlinear statistical analysis, as identified in Chapter VI, would more fully test the Household Energy Consumption Change Model.

A final look at the fit of the variables in the Household Energy Consumption Change Model will show how empirical testing led to the identification of variables that reflect the components of the Model. In Figure 6, each variable found significant by one of the statistical models is placed with the household (organism) or in its appropriate environment.

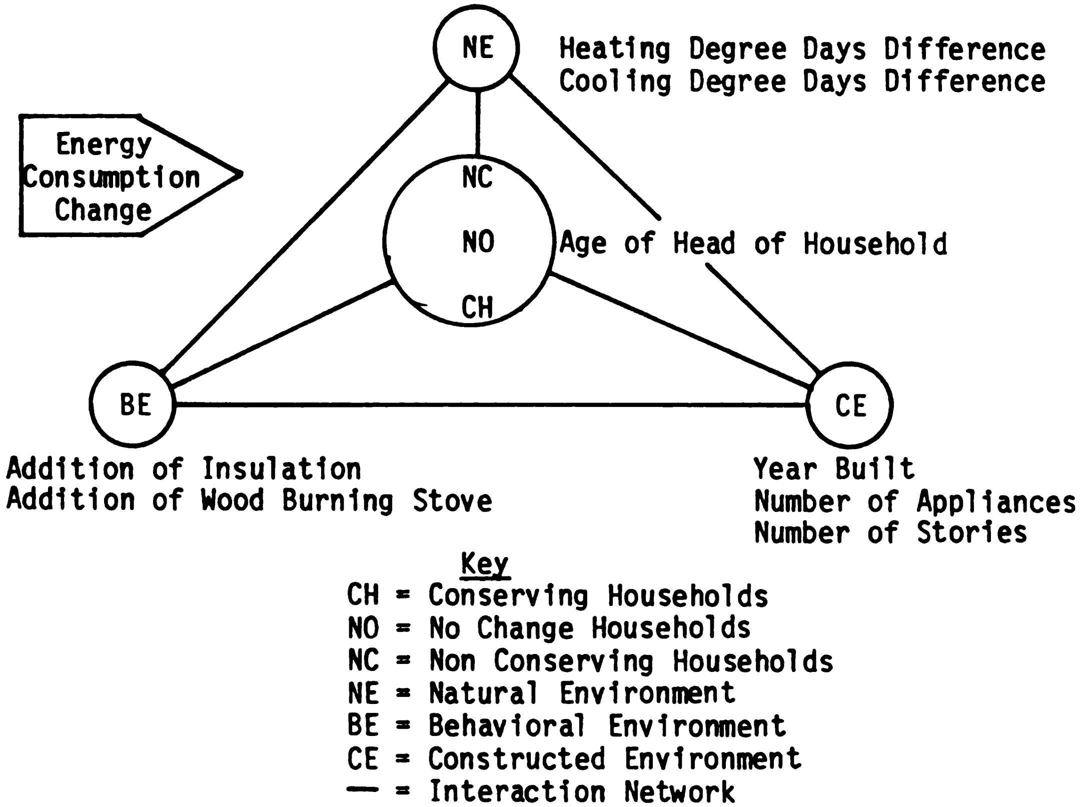


Figure 6: Household Energy Consumption Change Model

Variables Not Found Significant in the Statistical Models

Literature revealed several research studies of household energy consumption/conservation. The findings of the multiple regression and discriminant analysis did not reflect the findings of some previous studies such as Perlman and Warren (1977), Morrison and Gladhart (1976), Morrison, et al (1978), and Keith and Harris (1982). The variables found to be predictors or discriminators of energy consumption/conservation when possible, were used in the statistical models of this study. The findings of this study, however, did not confirm all of these variables. However, the previous studies were not representative of a national sample. Perlman and Warren used samples from three metropolitan areas; Morrison, et al used a single city, and Keith and Harris' study was statewide. Methods of coding the data contributed to some differences between the previous studies and the current one. Finally, use of change variables was not similar in all studies. It would be expected, then, that the results of this study may differ due to its unique components.

In addition to discussion of variables found statistically significant in the models, it is interesting to identify those independent variables selected for inclusion in the statistical models but not found significant in the models. A review and discussion of those variables is important and may help to explain their exclusion.

HEADE80, education of the head of the household, was not found statistically significant in this study as it had been in other studies. There were similarities in education between the means, including an equal mode. HOMEA80, the total square feet in a housing unit, and NHSLD80, the number of household members, also had similar means. T-tests showed there were no significant differences between groups.

INCOME80, the family income for 1979, was coded as an ordinal level variable in the RECS data. For this study, it was recoded into the three values identified in Table 15, Chapter IV Methodology. However, using only three values limited the variability of the households and group membership, possibly affecting the significance of the variable.

TYPEHU80, the type of housing unit, has previously been identified as a predictor of energy consumption. In this study, the housing unit type was on nominal level and identified only as mobile home, one-family house, and apartment. Considering that this study included only owner occupied housing units, this skewed the sample toward the one-family house, possibly affecting the significance of the variable.

INSULAT82 was a variable derived by the factor analysis of conservation variables. This factor included several variables all related to adding insulation to different components of the housing unit. All of these components, however, were those that were less accessible and less well known as energy conserving strategies. Additionally, most other studies did not have the extent of conservation strategies as did the RECS study. Perhaps that helps to explain the lack of inclusion of this energy conserving behavior in the model.

TURNDO82, was a variable derived by the factor analysis of conservation variables. This factor included two scaled conservation strategies, turning down the thermostat at night and turning it down when all household members were gone during the day. Empirical evidence of energy consumption decrease by thermostat set-back has been found in previous energy conservation studies. It was unusual that this variable was not found to be significant in this study. An explanation of this exclusion may be the lack of technical monitoring of this reported behavior. Thermostat set-back was self-reported by the head of the household. The head's estimate of degrees set-back, frequency of set-back, and reliability of set-back may not reflect reality. In other studies, this variable has been measured by a thermostat monitor, or automatic set-back clock. Perhaps that helps to explain the lack of inclusion of this energy conserving behavior in the model.

Further Discussion of Extraneous Variables

A description of the extraneous variables contained in the study may be of interest and aid in the understanding of the differences in the groups (see Table 30).

Table 30
Summary of Other Variables Examined

Variable	Conservers	Non-Conservers	No Changers
Received Government Assist for any Energy Component	5.9%	1.8%	2.6%
Had energy audit since 1980	4.6%	10.1%	4.0%
Conservation Strategies			
Factor 1: ADDINS82 (Addition of following insulation types and devices).			
ADDAT82 (attic)	16.2%	9.7%	10.7%
ADDWA82 (wall)	6.4%	2.5%	3.1%
ADDCL82 (clock)	4.6%	2.5%	3.5%
AUTOD82 (flue door)	.6%	0.0%	2.0%
SHEET82 (plastic sheets)	13.9%	15.5%	9.8%
SEALE82 (caulking)	30.0%	26.6%	32.7%
WSTRI82 (weatherstripping)	27.2%	17.5%	18.2%
Factor 2: INSULAT82 (Addition of following insulation types and devices).			
ADDBA82 (basement)	4.0%	3.9%	3.5%
HEATT82 (duct insulation)	4.0%	3.2%	2.9%
PIPES82 (pipe insulation)	4.1%	11.0%	4.5%
ADDCO82 (window insulation)	5.8%	6.5%	5.3%
Factor 3: STORM82 (Addition of storm windows or doors).			
DOORO/182 (storm door/s)	11.1%	7.1%	15.0%
PANES82 (storm windows)	16.2%	11.0%	12.7%

As shown in Table 21, Chapter IV Methodology, twelve variables were used to create the government assistance variable. It was interesting to note the conserving households exceeded the other two groups on obtaining some kind of government assistance. However, the total percentage for the sample was still a relatively small part of the whole (10.3%). While not statistically significant, this may have implications for energy policy formulation.

Another extraneous variable examined was use of a professional energy audit since 1980. The non-conserving household group had a surprisingly higher percentage of households that had a professional energy audit than the other two household groups. The conserving and no change households were very similar. One might assume the conserving group would have had the highest percentage of energy audits, with their conserving behavior the result of such an audit. In fact, the high percentage of non-conserving household may have been found, through an energy audit, to be conserving households already, and therefore could not reduce their energy consumption a great deal more. Perhaps, these households had already implemented as many conservation strategies as was cost effective. It would be informative to examine this variable further.

The third variable to be examined more closely was that of the conservation strategies and the related reasons given by the households for implementing the strategies. While the individual variables were reduced to four new variables through factor analysis, a summary of the frequency of implementation and reasons was useful for understanding more about this component of energy consumption. Table 30 shows the variables that contributed to three of the factors. This type of information was not available for the fourth factor TURNDO82. Additionally, the two major reasons given by the households for implementing these strategies are discussed.

The most frequently used strategies were the least expensive ones, caulking and weatherstripping. They also are two relatively easy improvements with adequate marketing and knowledge available regarding their installation. The next two most frequently installed strategies were addition of attic insulation (third for the conserving and no change households) and addition of plastic sheets over the windows (third for the non-conserving households). The next most frequently used conservation strategy included addition of storm windows and doors. While this was more expensive, it was also very cost effective.

In the 1982 RECS, households were shown a list of reasons for making conservation improvements and were asked to select from the list those that were most important in helping them decide to make the improvements. The list of reasons for making conservation improvements follows:

1. For comfort
2. To save heating and/or cooling costs
3. To take the cost as a credit on income tax return
4. To take advantage of government money or low-cost government loans for improvements
5. Did this because we were doing other home improvements at same time
6. Recommended by friend or relative
7. Recommended by professional energy advisor (energy auditor or expert)
8. Heard or read about benefits (on radio or tv, magazine or newspapers)
9. Replacement of broken or defective item
10. Other reason (specify)

In relation to these strategies, the most frequent reason for making an energy conservation improvement in the housing unit was to save money. While this reason was given for almost all conservation strategies, there was a high percentage of response for those improvements that were more costly such as storm doors and windows. The second most frequent reason was to increase comfort. The items most often installed for this reason were those most likely to control drafts or floor temperature, such as caulking, weatherstripping, window covering, and wall insulation. The other reasons seemed to play a minor role in promoting energy conservation improvements. These findings were reflective of the RECS findings of the total national sample (EIA, 1984a).

It was beyond the scope of this study to examine the conservation strategies further since the study did not focus on these strategies. Given the problems of measurement of the conservation strategies and the need to validate the scale, it would be helpful to do a further analysis of the strategies and reasons. For example, this information could contribute to policy making. Answers to questions about the percentage of the total sample who did any of these conservation improvements, which conservation strategies are most frequently done, and what are the reasons for each of the conservation strategies would be very helpful to energy policy formulation.

Chapter VI Summary and Conclusions will summarize the study and discuss implications for further study, governmental policy, and educational needs. Additionally, suggestions for further development of the theoretical model will be included.

CHAPTER VI: SUMMARY AND CONCLUSIONS

Summary

Energy conservation is generally seen as important both in the short and long term, as a response to energy concerns. Therefore, it is extremely important to understand what households, which directly consume 20% of the nation's energy, are doing to conserve and what affects household energy consumption. This study focused on the household as an organism and its interaction with the three environments of the human ecosystem (natural, behavioral, and constructed) as they influence energy consumption change.

The 1980 and 1982 United States Department of Energy's Residential Energy Consumption Surveys (RECS) were used as the data base for this study. Longitudinal data including household, environmental, and energy consumption measures were available for over 800 households. These households were selected from a national sample of owner occupied housing units that were surveyed in both years.

A secondary statistical analysis of data from the RECS data file was conducted. The data were collected by interviewers from a probability sample of owner-occupied households and included the records of their fuel consumption from utility companies and fuel suppliers. The statistical analysis, done in the context of verification, focused on explaining the relationships between theoretically important variables.

This need to understand household energy consumption/conservation, the ecosystems theoretical framework, and the research problem provided the rationale for three research objectives. The first research objective was to identify the energy conserving and energy non-conserving households by measuring their actual energy consumption during 1980 and 1982. In order to determine which households had significantly reduced or increased their energy consumption, the actual energy consumption from 1982 was subtracted from 1980. This identified the energy conserving and non-conserving households.

The second research objective was to identify the household characteristics that had affected energy consumption. The third objective was to identify the characteristics of the natural, human behavioral, and human constructed environments that were related to household energy consumption.

From the above, the following research questions were formulated. First, are there household and/or environmental characteristics that are determinants of household energy consumption change? Second, are there household and/or environmental characteristics that discriminate energy conserving and non-conserving households in relation to energy consumption change? Third, is there a fit between the Household Energy Consumption Pathways Model and reality as represented by this sample?

For this study, the unit of analysis was the household. The dependent variable was household energy consumption change from 1980 to 1982. Household and environment independent variables were selected that were theoretically related to energy consumption. These variables represented the organism (household) and the three environments (natural, behavioral, and constructed) of the ecosystem which may be related to the household's energy consumption.

Multiple regression was used in the statistical analysis of the data to identify characteristics of the household and/or environment(s) that can be used to predict energy consumption change in the population represented by the sample. Discriminant analysis was used to statistically distinguish between the three groups of interest, energy conserving household, energy non-conserving households, and no change households. The purpose was to establish a set of characteristics of the household and/or environments upon which new cases in the population represented by this sample, with unknown memberships, can be classified. Both prediction and classification capabilities provide potential for household energy conservation.

The findings of this study showed heating degree days, addition of insulation, addition of a wood burning stove, year the housing unit was built, and weighted number of appliances as significant ($p=<.05$) predictors of energy consumption change. It also showed age of the head of the household, cooling degree days, heating degree days, year the housing unit was built, and number of stories in the housing unit were significant ($p=<.05$) discriminators of energy consumption change. Finally, the findings indicated there was a significant relationship between the theoretical model and reality as represented by this sample.

Due to the nature of the probability sampling, the results of this study can be generalized to the population that it represents, owner occupied housing units included in the 48 contiguous states and Washington D.C. For example, using RECS household weight that the entire sample represented 81,223,030 households, the sample of this study represented 11,397,815 households.

Implications

From this study it becomes clear that energy consumption change and related conservation measures are part of a complex system that needs to be examined more holistically than it has been in past research. It is not enough to understand the impact of the micro or macro climate on the housing unit; it is not enough to examine the physical properties and mechanical systems of the housing unit; it also is not enough to examine the energy policies and programs, or lack thereof, at the local, state, and national levels for the management, regulation, and cost of energy systems. Finally, it is not enough to examine how households use energy, make decisions regarding energy conservation measures, or allocate resources within the household to meet various energy and non-energy related goals.

What has become more apparent from this study than from other studies of its kind, is that in order to more readily address energy consumption/conservation issues within households, a comprehensive model is needed and it needs to be tested. This, in part, was attempted within this study. However, due to limitations of the data base (Department of Energy's Residential Energy Consumption Surveys, 1980 and 1982), it was not possible to fully test and verify the energy consumption change model.

The study and its findings, however, contribute in several ways to the resolution of the energy problem. Implications of this research can be drawn for public policy, marketing, education, and future research. The results of this study can be used by: 1) local, state, or national government agencies for energy policy formulation; 2) individuals or agencies marketing energy conserving products or methods who now can understand the value of integrating conserving measures from several environments; 3) families who are interested in conserving energy in the residence by integrating conservation measures from several environments; 4) educators in the public sector to teach consumers the value of integrating energy conserving methods, i.e. identify ways to conserve in all environments, not just human-built or behavioral; and 5) educators of design professionals to teach them the value of integrating energy conserving methods, i.e. identify ways to conserve in all of the environments, not just the human-built or interior.

Implications for Public Policy

Carlson, et al in Energy Future, Human Values, and Lifestyles (1982) confirmed the need for energy studies of this nature to support formulation of public policy. They stated:

> "Energy consumption studies are needed for several reasons. First, data are needed to describe and monitor energy consumption. Second, data are needed to model and predict changes in patterns of energy use, both short-term and long-term. Third, data are needed to assess the effects of policy changes. Energy consumption patterns and predictors of energy conservation are basic to the formulation and implementation of effective policies."

The household sector is important in an analysis of U.S. energy consumption. Household energy consumption can be modified by a variety of energy conservation policies that could be adopted at the federal, state, and local levels. In this study, government assistance through funding of improvements and low income heat help did not play a significant role in energy consumption reduction. Free or low cost energy audits and conservation improvements related to tax credits seemed to be important to the long term affect on decreased energy consumption.

It has been shown that households respond to incentives for reduced energy cost and increased comfort. This can be supported in public policy by social and institutional frameworks that provide cost incentives for reduced energy cost and building code reform. Building code reform can affect the energy balance of the residence, including physical characteristics, such as size and interior layout; type and quality of construction; and amount, efficiency, and rates of energy using equipment.

Additionally, this study identified the segments of the population that are energy conservers and non-conservers. The household and environmental characteristics of these groups have been identified and, therefore, programs including tax incentives or education, could be formulated that will respond to these segments of the population.

Knowledge of this segmentation should prove valuable to industries or governmental agencies for use with energy conservation improvements. For example, it was shown that the free or low cost energy audit was underutilized. Public policies and programs designed for and promoted to specific market segments may be the most efficient method of reaching the appropriate households in the population. Further identification of the energy non-conservers needs to occur in order to more fully understand the incentives or programs that would be most beneficial.

Implications for Education

Consumer education: If energy conservation is to reach the public, consumers must be educated regarding conservation practices and behaviors. Kempton et al (1981) found that consumers were not aware of which conservation methods achieved the most energy reduction. This study began identification of the energy conserving and non-conserving households. Education packages designed for these groups could be made available.

Wilk and Wilhite (cited in Kempton & Neiman, 1987) analyzing informant statements, found that energy conservation measures are installed for many reasons apart from energy savings, such as improving a home's aesthetic and resale value, achieving independence, and increasing comfort. This is a component of energy conservation that could be included in consumer education packages.

Perlman and Warren found that the more easily implemented and less costly forms of energy conservation behavior were more likely to be adopted by households than were more difficult and expensive forms of behavior (Perlman and Warren, 1977, pp. 112-114). It can be assumed that many household have completed the most simple and least costly measures. There is, perhaps, a more sophisticated consumer who is able to accomplish different tasks. Therefore, information needs to be available at different levels of ability, ie. beginner, intermediate, and advanced. It also needs to be available at different levels of difficulty. The conservation methods should be prioritized so the homeowner knows what conservation method or behavior will yield cost effective results. There also needs to be an approximate cost for installing the conservation measure.

Consumer education also can play an important role in attitude and behavior. Borden, Fisher, and Doyle (1977) found that attitudes of consumers toward energy conservation are important factors affecting conservation behaviors; that is, if there are positive attitudes there can be positive behaviors. Perlman and Warren (1977) suggested that energy conservation strategies can be cognitive, altering people's attitudes and values; behavioral, altering incentives and influences exerted upon people; and structural, altering the social context in which people act. The latter approach stresses the exercise of social power (p. 170-171). Morrison and Gladhart reported that persons who felt that energy conservation is a social responsibility were more likely to have adopted energy conservation practices (Morrison and Gladhart, 1976, pp. 15-18). Bailey (1979) found attitude and behavior positively related to energy conservation, supporting the theory that a model incorporating attitude as well as socioeconomic variables has explanatory power greater than a model incorporating socioeconomic variables alone.

It seems, then, consumer education can be designed to appeal to a specific, identified group of conservers, or, as importantly, the group of energy non-conservers. Energy conservation packages should include conservation strategies and behaviors as well as technical improvements. This information should be available at a variety of levels of expertise as well as levels of interest from "how to do it" to how to hire an expert. The packets should include information about cost effectiveness and the use of feedback devices to reflect energy consumption decrease. Finally, the issue of energy conservation for increased comfort should not be ignored in consumer education.

Design education.

In 1977, Richard Stein, in looking into the future of building design, stated,

> "One fact that emerges clearly from investigations of buildings is that the hope for the future lies in the fundamental reversal of designers' present commitment to the sealed building, with its massive plant for manufacturing air and delivering it at predetermined temperatures and velocities along with its large lighting apparatus that substitutes as a universal switch for selectivity. Building practices [and therefore, education of building designers] will change out of necessity, if not out of logic and the aesthetics of appropriateness. Knowing the realities that have shaped our buildings in the past and the kinds of choices we can begin to make immediately may help us move toward a natural architecture, in peaceful coexistence with our natural universe." (Stein, 1977, p.293-294).

The response to Stein's call for natural architecture has been encouraging. Design education has moved toward this goal during the late 1970's and 1980's. Design educators are teaching passive solar design, daylighting, and energy conscious design as part of present curricula. More importantly, these concepts are being integrated into the existing course content as design criteria as well as included as specialty courses for practitioners and advanced students.

It is the role of design educators to complete the research necessary for conserving energy through rational design. It is their role to lead design practitioners into the 21st century by teaching the taxonomy for energy conscious design. The scarcity of energy resources need not adversely affect building designs, human lifestyles, and their interaction. Indeed, quality building design that considers the energy reality as a design criterion and not as a compromise is design that will improve the quality of life.

Implications for Further Research

Research variables.

There is a need to revise the values of certain variables so they can be considered interval or ratio level, as well as increase use of continuous rather than discrete variables. This would increase the flexibility of statistical analysis and could then answer some different research questions.

There are variables other than those included in this study that can affect or explain household energy consumption. An area for additional research would be to identify and measure other explanatory variables, such as the publicity and national attention given to the energy problem, specifically in view of the recent repeal of the energy tax credits. Additional measures of the interior and clothing are necessary for a truly integrated study. The use of interior materials, finishes, textiles, spatial layout, furniture design, and clothing behavior as modifiers of thermal comfort should be studied. Measures of daily activities that create or reduce energy demands should be examined.

Research questions.

The 1973 Arab oil embargo brought the energy problem to the awareness level of the American people. Longitudinal effects could be studied using the subjects identified in many of the research projects during the 1970's. Have the American people, nearly a generation later, integrated energy conservation ethics or methods into their lifestyle? Do they now do some activities as part of their normal behaviors that were once considered as sacrifices? In fact, has the American household adapted?

Statistical analysis.

The RECS data could be examined further. First, to more closely reflect previous energy studies, the sample could be analyzed on a regional or statewide basis. This would allow the findings to be compared to the previous studies. Second, the conservation strategies and reasons could be fully examined to explore these behavioral issues. Third, a statistical method used to empirically test the constructs of the model, path analysis, could be used on a limited basis, with the data. Finally, the 1984 RECS data base is now in the public domain and includes longitudinal data from the second half of the 1982 sample. This study could be replicated using this sample in order to validate the findings.

Expansion of the theoretical model.

There is a need to identify measurable variables for two areas of the constructed environment, interior factors and clothing factors, for a truly integrated ecosystem approach to energy consumption. This study could not accomplish this due to lack of measurable variables; therefore, the RECS would need to include some additional survey questions. The model would remain substantially the same (see Figure 7) with some additional information included for each of the components of the system.

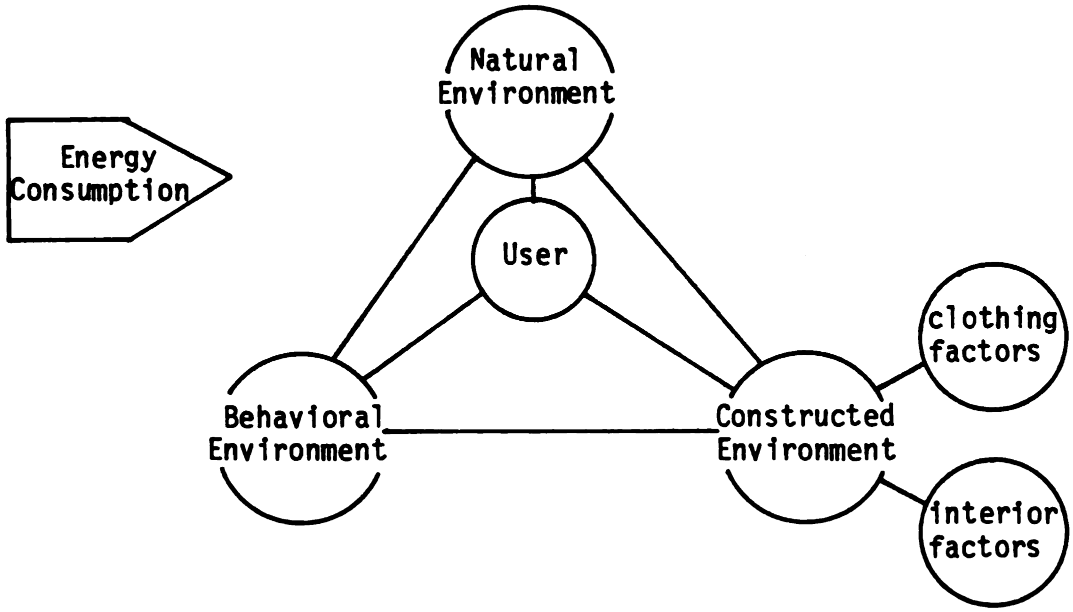


Figure 7
Energy Consumption Model

As previously described, the Energy Consumption Model is an ecosystem approach to study energy consumption/conservation. The final modification of this flexible model is to use it as a model from which the household examines energy consumption to become energy conscious. This is a system of information transfer. Information flows freely in both directions on all of the network lines, allowing the household to be stimulated by the environment or the environment impacted upon by the organism. The network allows exchange and interaction among all parts of the system. The components of the system are identified as follows:

The organism is identified as the user in the environments, the individual(s) or family. Information in the form of technical or behavioral stimuli travels from the environments to the user allowing the user to react to this stimuli and respond with an energy conscious behavior. For example, to increase thermal comfort, this transfer would enable the user to diagnose the conditions of each environment and adapt to maximize thermal comfort. Thermal comfort of the user is identified by the combination of physiological, psychological, and socio-economic variables.

The three environments natural environment, behavioral environment, and constructed environment, with its two specific components, interior and clothing factors, are all separate but interacting environments. Interaction between environments as well as between an environment and the user occurs by the pathway of information transfer at the point of interface.

The natural environment is identified as the physical world including plants, air, and water. This environment includes climate and the geography of the building site. Climate is measured by variables such as degree days, humidity, air movement, and insolation. Geography is measured by variables such as latitude, urban location, and altitude.

The behavioral environment is identified as the socio-psychological world that includes the activities, values, and cultural norms of the organism. Not only are conservation behaviors and non-conservation activities monitored as measurable variables, but the political impact of society is included here.

The constructed environment is identified as the building envelope. This environment includes building materials, site integration, orientation, design, landscaping, and energy system operation. These variables are measured by methods such as R value, U value, square footage, window openings, berms, and energy ratings.

The interior factors of the constructed environment are identified as the interior spaces and components of that space. These factors include movable insulation, wall/floor covering, color, lighting, furniture design and placement, and textile/materials,/textures. These variables are measured by R value, U value, footcandles, and reflectance.

The clothing factors of the constructed environment are identified as the selection of clothing available to the user. These factors include clothing function, fit, style, insulation, fiber construction, and vapor barrier. These variables are generally combined to be measured as CLO value. A second measure important to the analysis of the clothing environment is the metabolic rate of the organism. Clothing is generally considered the factor most easily modified for thermal comfort.

Empirical testing of this model could be accomplished by the assignment of a numerical score to each variable identified. The variables could be limited to those with known measures; then, each environment could be described numerically. Each environmental score would be tabulated and related to characteristics for energy conscious environmental systems design. This would allow the organism to adapt hourly, daily, or seasonally to the various interacting environments.

Modification of such a model could continue based on the results of empirical testing. The adaptability and flexibility of such a model would encourage its use by interdisciplinary teams of researchers who are examining energy consumption from a holistic viewpoint.

Conclusions

The Committee on Measurement of Energy Consumption supported the need for data and an ecosystems approach. They stated:

> "Data required for modeling energy use in the household sector are seriously inadequate, and substantial improvements are needed for explanatory data that relate the social and behavioral characteristics of households to their use of energy for space conditioning." (Energy Consumption Measurement, 1977, p.3).

Further, this committee specifically recommended studies of the relationship between energy consumption for space conditioning in buildings and the physical characteristics of the building, the activities of the occupants, and the use of equipment and appliances in the building. In other words, over ten years ago they saw the implications for studies that investigated the relationship of the household and its environments. While some researchers have been following this recommendation, additional study on a national, longitudinal level, using the human ecosystem framework, needs to continue.

The study of this complex energy consumption problem cannot be a single focus problem; rather, if energy conservation is to become a viable option for American households, it must be implemented from a variety of directions. The interface between environments and between the household and its environments must be examined empirically to provide a solution to the energy problem while improving the quality of life.

APPENDICES

APPENDIX A

DEFINITION OF TERMS

(Energy Information Administration, 1984a)

APPENDIX A

DEFINITION OF TERMS

Air conditioning: Cooling of air by a refrigeration unit. This does not include fans, blowers, or evaporative cooling systems or "swamp coolers" that are not connected to a refrigeration unit. Air conditioning units that are not currently in working condition or are not used, but are in place in the housing unit, are included in this survey.

Appliances used: Appliances possessed and used by the household during the year. Appliances possessed by the household but not used are not counted. Air conditioning units are an exception. Air conditioning is counted as present whether or not it is used.

Billing Period: The time between meter readings. It does not refer to the time the bill was sent or when the payment was to have been received. In some cases, the billing period is the same as the billing cycle that corresponds closely (within several days) to meter-reading dates. For fuel oil and LPG, the billing period is the number of days between fuel deliveries.

Btu (British Thermal Units): A Btu is the amount of energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit at or near 39.2 degrees Fahrenheit and 1 atmosphere of pressure. One Btu is about equal to the heat given off by a blue-tip match.
Btu conversion factors for this survey are:
Electricity: 3,412 Btu/kilowatt-hour
Natural Gas: 1,027 Btu/cubic foot
Fuel Oil No.1: 135,000 Btu/gallon
Kerosene: 135,000 Btu/gallon
Fuel Oil No.2: 138,690 Btu/gallon
LPG (propane): 21,540 Btu/pound
91,330 Btu/gallon
2,510 Btu/cubic foot
88,640 Btu/cubic meter
Wood: 20 million Btu/cord

Other conversion factors used include:
1 therm = 100,000 Btu
1 barrel = 42 gallons

Conservation Items Added: Energy-saving items added to the housing unit the household now occupies. Items added to a previous place of residence and changes made by previous occupants of the housing unit are not counted. Changes made by a landlord are counted.

Automatic or clock thermostat: a thermostat that can be set to turn the heating system off and on at certain preset times.

Flame-retention head burner for furnace (fuel oil): a device that controls the pattern of flame in the combustion chamber of a boiler or furnace.

Automatic flue door (vent damper): automatically closes the flue when the furnace goes off, preventing heat loss up the chimney.

Electrical or mechanical furnace ignition system (spark ignition): added to the furnace means that fuel will ignite from an electrically or mechanically produced spark rather than from a pilot light that burns continuously.

Insulation around heating and/or cooling ducts: extra insulation around the heating and/or cooling ducts to reduce the loss of hot or cold air as it travels to different parts of the residence.

Insulation around the hot water and/or cooling pipes: wrapping hot water and/or cooling pipes with insulation to reduce the heat or cold loss through the pipes.

Insulation around hot water heater: blanket insulation wrapped around the hot water heater to reduce heat loss. This is in addition to any insulation provided by the manufacturer.

Closeable shutters, insulating drapes, reflective film: counted if any one of these has been added to any door or window in the housing unit. Shutters that close to provide an insulating effect are counted as well as insulated roller shades or "window quilts" whose sidesride in a channel attached to the window frame. Decorative shutters that do not close are not counted.

Plastic sheets: may be used to cover a window or other opening in the housing unit in an attempt to reduce heat loss.

Caulking around any windows or doors to the outside: usually comes in a tube and is clay-like in that it can be molded into the space being treated. It is used to prevent drafts from coming into the house through cracks around the frames of windows or doors or cracks in other stationary parts of the house. Caulking could have been applied to the inside or outside of the home.

Weather stripping around any windows or doors to the outside: can be applied on the inside or outside of the home. Weather stripping comes in strips or rolls of metal, vinyl, or foam rubber. It is used to prevent drafts from coming into the house around movable parts of the door or window.

Consumed: Is the amount of electricity or natural gas used by the household during the 365-day period. For fuel oil, kerosene, and LPG, the quantity represents fuel purchased, not fuel consumed.

Cooling Degree-Days: Refers to the number of degrees per day the daily average temperature is above 65 degrees Fahrenheit. Normally, cooling is not required in a building when the outdoor average daily temperature is below 65 degrees. Cooling degree-days are determined by subtracting the base of 65 from the daily average temperature.

Estimated Bills: Are calculated by the fuel supplier when the meter is not read. The estimate may be based on one or more of the following factors: past usage, usage by similar households, and weather data.

Family Income: Is the total combined income in 1981 of all members of the family from all sources before taxes and deductions.

Head of Household: If the respondent was married and living with his or her spouse, the male was considered to be the head of the household. Otherwise, the respondent was the head of the household. (See also Householder.)

Heated square feet: that portion of the measured square feet that is heated during most of the season. Rooms that are shut off during the heating season to save on fuel use are not counted as heated square footage. Attached garages that are unheated and unheated areas in basements and attics are not counted as heated square feet.

Heating Degree-Days: The number of degrees per day the daily average temperature is below 65 degrees Fahrenheit. Normally, heating is not required in a building when the outdoor average daily temperature is above 65 degrees. Heating degree-days are determined by subtracting the average daily temperature below 65 degrees from the base 65. For example, a day with an average temperature of 50 degrees has 15 heating degree-days (65 - 50 = 15), while one with an average temperature of 65 or higher has none. The average daily temperature is the mean of the maximum and minimum temperature for a 24-hour period.

The heating degree-days for RECS households in the 48 states and the District of Columbia were assigned according to the NOAA division in which each household is located (See NOAA Division).

Household: Is a family, an individual, or a group of up to nine unrelated persons occupying the same housing unit.

Householder: The person (or one of the persons) in whose name the home is owned.

Insulation: Refers to any material that, when placed between the interior of the dwelling and the outdoor environment, reduces the rate of heat loss to the environment or heat gain from the environment.

Number of Rooms: Whole rooms are rooms such as living rooms, dining rooms, bedrooms, kitchens, lodger's rooms, finished basements or attic rooms, recreation rooms, and permanently enclosed sun porches that are used year-round. Rooms used for offices by a person living in the unit are included in this survey. Finished means that the ceiling and walls are covered with finishing materials. Bathrooms, halls, foyers or vestibules, balconies, closets, alcoves, pantries, strip or pullman kitchens, laundry or furnace rooms, unfinished attics or basements, open porches, and unfinished space used for storage are not included.

QUAD: A commonly used gross measure of U.S. energy demand and supply. Quadrillions of BTUs (BTU x 10[15]).

1 Quad = 180 million barrels of petroleum
42 million tons of bituminous coal
0.98 trillion cubic feet of natural gas
293 billion KWH of electricity

Quadrillion: Equals 1,000,000,000,000,000 or 1015

Square Feet: The floor area of the housing unit that is enclosed from the weather. Basements are included whether or not they contain finished space. Garages are included if they have a wall in common with the house. Attics that have finished space and attics that have some heated space are included.

Storm Doors and Windows: Storm doors made of double or insulating glass such as thermopane. Glass or plexiglass placed over a sliding glass door on either the exterior or interior is counted as a storm door. A plastic sheet covering the door is not counted as a storm door.

APPENDIX B

SURVEY QUESTIONS AND RESPONSES IN RELATION TO VARIABLES

1. In what year did your family move into this (house/apartment)?
   ___ Before 1940
   ___ 1940-1949
   ___ 1950-1959
   ___ 1960-1964
   ___ 1965-1969
   ___ 1970-1974
   ___ 1975-1979
   ___ 1980
   ___ 1981
   ___ 1982
   ___ 1983

3. In what year was this (house/building) built? Just your estimate.
   ___ Before 1940
   ___ 1940-1949
   ___ 1950-1959
   ___ 1960-1964
   ___ 1965-1969
   ___ 1970-1974
   ___ 1975-1976
   ___ 1977
   ___ 1978
   ___ 1979
   ___ 1980
   ___ 1981
   ___ 1982
   ___ 1983

6. What is the main fuel used for heating your home?

	Q.6 MAIN FUEL (Mark only one)	Q.7 (Mark all that apply)
Gas from underground pipes serving the neighborhood	___	___
LPG gas (bottled or tank gas)	___	___
Fuel oil	___	___
Kerosene or coal oil	___	___
Electricity	___	___
Coal or coke	___	___
Wood	___	___
Solar Collectors	___	___
Other (specify):__________ ____________________	___	___
Don't know	___	___
No heating fuel used	___	
No additional fuel		___

7. What other fuels, if any, are used to heat your home--including those that are used to provide heat just occasionally?

8. Does your main heating fuel--(fuel named in Q.6)--provide almost all of the heat for your home, about three-fourths, or closer to half of the heat for your home?
   ___ Almost all (more than 95%)
   ___ About three-fourths (67-94%)
   ___ Closer to half (66% or less)

9. What is the main heating equipment used with your main heating fuel?

	Q.9 Main Equipment (Mark only one)	Q.10 (Mark all that apply)
Hot water pipes running through a slab floor (radiant heating)	___	___
Steam or hot water system with radiators or convectors	___	___
Central warm-air furnace with ducts to individual rooms (do not count heat pump here)	___	___
Heat pump	___	___
Built-in electric units (permanently installed in wall, ceiling, or baseboard)	___	___
Floor, wall, or pipeless furnace	___	___
Room heater burning gas, oil, kerosene (not portable)	___	___
Heating stove burning wood, coal, coke	___	___
Fireplace(s)	___	___
Portable electric heater(s)	___	___
Portable kerosene heater(s)	___	___

Cooking stove, range, or oven
(used to heat home, as well as
for cooking) ____ ____
Other (specify)________________ ____ ____
Don't know ____ ____
No additional equipment ____

10. What other types of equipment, if any are used to heat your home--including those that are used to provide heat just occasionally?

21. At what temperature do you usually keep your house during the day in the wintertime when someone is at home?
___ Degrees fahrenheit
___ Heat turned off

22. At what temperature do you usually keep your home during the day in the wintertime when no one is at home?
___ Degrees fahrenheit
___ Heat turned off

23. At what temperature do you usually keep your home during sleeping hours in the wintertime?
___ Degrees fahrenheit
___ Heat turned off

32. Do you have air conditioning equipment, either a central system or individual window or wall units? (Mark all that apply)
___ Yes, central system
___ Yes, individual (window/wall) units
___ No

33. How many individual window or wall units do you have?
___ Number of units

41. How many (storm/insulated glass) doors were put in your home since September 1,1980?
a. Sliding glass doors
___ Number of doors
___ None

b. Other doors to the outside
___ Number of doors
___ None

43. Which of these were most important in your decision to install (storm/insulated glass door(s)?
1. For comfort
2. To save heating and/or cooling costs
3. To take the cost as a credit on income tax return
4. To take advantage of government money or low--cost government loans for improvements
5. Did this because we were doing other home improvements at the same time
6. Recommended by friend or relative
7. Recommended by professional energy advisor (energy auditor or expert)
8. Heard or read about benefits (on radio or tv, magazine or

newspaper)
9. Replacement of broken or defective item
10. Other reason (specify)________________________________

Circle numbers for reasons.

a. Sliding glass doors:	1	2	3	4	5	6	7	8	9	10
b. Other doors to the outside:	1	2	3	4	5	6	7	8	9	10

46. How many storm windows or windows with insulating glass were put in your home since September 1, 1980?
___ Number of windows
___ None

48. Which of these were most important in your decision to install (storm windows/windows with insulating glass)?
1. For comfort
2. To save heating and/or cooling costs
3. To take the cost as a credit on income tax return
4. To take advantage of government money or low--cost government loans for improvements
5. Did this because we were doing other home improvements at the same time
6. Recommended by friend or relative
7. Recommended by professional energy advisor (energy auditor or expert)
8. Heard or read about benefits (on radio or tv, magazine or newspapers)
9. Replacement of broken or defective item
10. Other reason (specify)________________________________

Circle numbers for all reasons that apply.
1 2 3 4 5 6 7 8 9 10

54. Please look at this list and tell me which items, if any, have been added or installed in your home since September 1,1980.

a. Roof or ceiling insulation
___ Yes
___ No
___ In process

b. Insulation in the outside walls
___ Yes
___ No
___ In process

c. Insulation in the basement or crawl space below floor of house
___ Yes
___ No
___ In process

56. Which of these were most important in your decision to add/install the insulation?
1. For comfort
2. To save heating and/or cooling costs
3. To take the cost as a credit on income tax return
4. To take advantage of government money or low--cost government

loans for improvements
5. Did this because we were doing other home improvements at the same time
6. Recommened by friend or relative
7. Recommened by professional energy advisor (energy auditor or expert)
8. Heard or read about benefits (on radio or tv, magazine or newspapers)
9. Replacement of broken or defective item
10. Other reason (specify)____

Circle numbers for all reasons that apply.
a. Roof or ceiling insulation: 1 2 3 4 5 6 7 8 9 10
b. Insulation in the outside walls: 1 2 3 4 5 6 7 8 9 10
c. Insulation in the basement or crawl space below floor of house: 1 2 3 4 5 6 7 8 9 10

57. Have any of these been added or installed in your home since September 1,1980?
a. A replacement or additional home heating system or furnace
___ Yes
___ No
___ In process
b. A replacement or additional hot water heater, boiler, or tank
___ Yes
___ No
___ In process
c. A replacement or additional central air conditioning system
___ Yes
___ No
___ In process

58. Was this a replacement or an additional system
a. Heating system or furnace
___ Replacement
___ Additional
b. Hot water heater, boiler, or tank
___ Replacement
___ Additional
c. Central air conditioning system
___ Replacement
___ Additional

59. Does it use the same fuel or different fuel than the one you had before?
a. Home heating system or furnace
___ Same fuel
___ Different fuel
b. Hot water heater, boiler, or tank
___ Same fuel
___ Different fuel
c. Central air conditioning system
___ Same fuel
___ Different fuel

60. In what month and year was the work completed?
 a. Home heating system or furnace
    Month:___________________
    Year: 198________________
    ___ In process
 b. Hot water heater, boiler, or tank
    Month:___________________
    Year: 198________________
    ___ In process
 c. Central air conditioning system
    Month:___________________
    Year: 198________________
    ___ In process

61. Which of these were most important in your decision to replace/add the new system?
  1. For comfort
  2. To save heating and/or cooling costs
  3. To take the cost as a credit on income tax return
  4. To take advantage of government money or low--cost government loans for improvements
  5. Did this because we were doing other home improvements at the same time
  6. Recommened by friend or relative
  7. Recommened by professional energy advisor (energy auditor or expert)
  8. Heard or read about benefits (on radio or tv, magazine or newspapers)
  9. Replacement of broken or defective item
  10. Other reason (specify)______________________________________

Circle numbers for all reasons that apply.

a. Home heating system or furnace:	1	2	3	4	5	6	7	8	9	10
b. Hot water heater, boiler, or tank:	1	2	3	4	5	6	7	8	9	10
c. Central air conditioning system:	1	2	3	4	5	6	7	8	9	10

64. Please look at this list and as I read each item tell me which, if any, have been added or installed in your home since September 1,1980.
 a. An automatic set-back or clock thermostat
    ___ Yes
    ___ No
    ___ In process
 b. Flame retention head burner for furnace (fuel oil)
    ___ Yes
    ___ No
    ___ In process
 c. Automatic flue door (vent damper)
    ___ Yes
    ___ No
    ___ In process
 d. Electrical or mechanical furnace ignition system (spark ignition)
    ___ Yes
    ___ no

___ In process

e. Insulation around heating and/or cooling ducts
___ Yes
___ No
___ In process

f. Insulation around the hot water and/or cooling pipes
___ Yes
___ No
___ In process

g. Insulation around the hot water heater
___ Yes
___ No
___ In process

h. Closeable shutters, insulating drapes, reflective film
___ Yes
___ No
___ In process

i. Plastic sheets (over windows or other openings)
___ Yes
___ No
___ In process

j. Caulking
___ Yes
___ No
___ In process

k. Weather stripping around any windows or doors to the outside
___ Yes
___ No
___ In process

l. Heat pump
___ Yes
___ No
___ In process

m. Wood-burning stove
___ Yes
___ No
___ In process

65. In what month and year was the work completed?

a. An automatic set-back or clock thermostat
Month:____________________
Year:198__________________
___ In process

b. Flame retention head burner for furnace (fuel oil)
Month:____________________
Year:198__________________
___ In process

c. Automatic flue door (vent damper)
Month:____________________
Year:198__________________
___ In process

d. Electrical or mechanical furnace ignition system (spark ignition)
Month:____________________
Year:198__________________

___ In process

e. Insulation around heating and/or cooling ducts
Month:________________
Year:198________________
___ In process

f. Insulation around the hot water and/or cooling pipes
Month:________________
Year:198________________
___ In process

g. Insulation around the hot water heater
Month:________________
Year:198________________
___ In process

h. closeable shutters, insulating drapes, reflective film
Month:________________
Year:198________________
___ In process

i. Plastic sheets (over windows or other openings)
Month:________________
Year:198________________
___ In process

j. Caulking
Month:________________
Year:198________________
___ In process

k. Weather stripping around any windows or doors to the outside
Month:________________
Year:198________________
___ In process

l. Heat pump
Month:________________
Year:198________________
___ In process

m. Wood-burning stove
Month:________________
Year:198________________
___ In process

66. Which of these were most important in your decision to add or install?

1. For comfort
2. To save heating and/or cooling costs
3. To take the cost as a credit on income tax return
4. To take advantage of government money or low--cost government loans for improvements
5. Did this because we were doing other home improvements at the same time
6. Recommened by friend or relative
7. Recommened by professional energy advisor (energy auditor or expert)
8. Heard or read about benefits (on radio or tv, magazine or newspapers)
9. Replacement of broken or defective item
10. Other reason (specify)________________________________

Circle numbers for all reasons that apply.

a. An automatic set-back or clock thermostat
1 2 3 4 5 6 7 8 9 10

b. Flame retention head burner for furnace (fuel oil)
1 2 3 4 5 6 7 8 9 10

c. Automatic flue door (vent damper)
1 2 3 4 5 6 7 8 9 10

d. Electrical or mechanical furnace ignition system (spark ignition)
1 2 3 4 5 6 7 8 9 10

e. Insulation around heating and/or cooling ducts
1 2 3 4 5 6 7 8 9 10

f. Insulation around the hot water and/or cooling pipes
1 2 3 4 5 6 7 8 9 10

g. Insulation around the hot water heater
1 2 3 4 5 6 7 8 9 10

h. Closeable shutters, insulating drapes, reflective film
1 2 3 4 5 6 7 8 9 10

i. Plastic sheets (over windows or other openings)
1 2 3 4 5 6 7 8 9 10

j. Caulking
1 2 3 4 5 6 7 8 9 10

k. Weather stripping around any windows or doors to the outside
1 2 3 4 5 6 7 8 9 10

l. Heat pump
1 2 3 4 5 6 7 8 9 10

m. Wood-burning stove
1 2 3 4 5 6 7 8 9 10

67. In the past 12 months, did a representative from your electric or gas company perform a detailed energy audit of your home?

___ Yes
___ No

68. This is a list of some possible reasons for requesting an energy audit. For each one, please tell me whether it was a very important reason for requesting an audit in your case, somewhat important, or not a reason at all.

a. High utility or fuel bills
___ Very important
___ Somewhat important
___ Not a reason

b. My home was uncomfortable
___ Very important
___ Somewhat important
___ Not a reason

c. We were planning other home improvements
___ Very important
___ Somewhat important
___ Not a reason

d. Friends or neighbors recommended it
___ Very important
___ Somewhat important
___ Not a reason

e. The audit was a bargain

___ Very important
___ Somewhat important
___ Not a reason

69. Were there other reasons, not on the exhibit, that were important to you?
___ Yes
___ No

70. What were they?____
____
____

71. Which of these was the main reason for not requesting an energy audit?
Mark one answer only.
___ Our utility does not offer energy audits
___ We have already installed as many energy conservation items as are reasonable
___ Don't need outside advice
___ The audit costs too much
___ Planning on moving soon
___ Just moved in
___ We rent this residence
___ The audit would not be worth the time and effort
___ Didn't know it was available
Other (specify):____

72. Do you have your own swimming pool?
___ Yes
___ No

73. Do you use a heater to heat the water?
___ Yes
___ No

74. What fuel is used for the heater?
___ Gas from underground pipes serving the neighborhood
___ LPG gas (bottled or tank gas)
___ Fuel oil
___ Kerosene or coal oil
___ Electricity
___ Coal or coke
___ Wood
___ Solar collectors
Other(specify)____
___ Don't know

75. Do you have a refrigerator in your home that you use regularly or occasionally?
___ Yes
___ No

76. Do you have one refrigerator or more than one that is presently in use? (How many altogether?)
___ One
___ Two
___ Three or more

77. Is it electric or gas?

Refrigerator #1
___ Electric
___ Gas

Refrigerator #2
___ Electric
___ Gas

78. Which of these best describes your refrigerator?
Mark one.

Refrigerator #1
___ Freezer section (or ice cube section) must be defrosted periodically
___ Freezer section defrosts automatically after frost builds up (catch pan must be emptied)
___ Full frost-free (frost does not build up)
___ No working freezer section

Refrigerator #2
___ Freezer section (or ice cube section) must be defrosted periodically
___ Freezer section defrosts automatically after frost builds up (catch pan must be emptied)
___ Full frost-free (frost does not build up)
___ No working freezer section

79. Do you have a home freezer -- one that is a separate appliance from the refrigerator -- that is presently in use?
___ Yes
___ No

80. Do you have one freezer or more than one that is presently in use? (How many altogether?)
___ One
___ Two
___ Three or more

81. Is it electric or gas?

Freezer #1
___ Electric
___ Gas

Freezer #2
___ Electric
___ Gas

82. Is it a frost-free freezer or must it be defrosted?

Freezer #1
___ Frost-free
___ Must defrost

Freezer #2
___ Frost-free
___ Must defrost

83. Thinking of all the different kinds of cooking done here, including cooking in the oven, on a range, and with small appliances, which fuel is used most?
___ Gas from underground pipes serving the neighborhood
___ LPG gas (bottled or tank gas)

___ Fuel oil
___ Kerosene or coal oil
___ Electricity
___ Coal or coke
___ Wood
___ Other (specify)____
___ No cooking done

84. Does your household use an oven of any type, including microwave or convection ovens, for cooking at least occasionally?
___ Yes
___ No

85. Do you have one oven or more than one oven that you presently use? (How many altogether?)
___ One
___ Two
___ Three or more

86. Is your oven electric or gas?

Oven #1	Oven #2
___ Electric	___ Electric
___ Gas	___ Gas

87. Is it a microwave oven?

Oven #1	Oven #2
___ Yes	___ Yes
___ No	___ No

88. Please look at this list and, as I read each item, tell me which of these you use here in your (house/apartment)?

Electric range (stove-top or burners)
___ Yes
___ No

Gas range (stove-top or burners)
___ Yes
___ No

Outdoor gas grill (using gas from underground pipes)
___ Yes
___ No

Outdoor gas grill (using LPG--bottled or tank gas)
___ Yes
___ No

Automatic clothes washer
___ Yes
___ No

Wringer washing machine (electric)
___ Yes
___ No

Electric dishwasher
___ Yes
___ No

Electric clothes dryer
___ Yes

___ No
Gas clothes dryer
___ Yes
___ No
Outdoor gas light
___ Yes
___ No
Electric dehumidifier
___ Yes
___ No
Electric humidifier
___ Yes
___ No
Evaporative cooler (swamp cooler)
___ Yes
___ No
"Whole house" cooling fan (in attic or entrance to attic)
___ Yes
___ No
Window or ceiling fan
___ Yes
___ No
Black and white television set
___ Yes
___ No
Color television set
___ Yes
___ No

108. Does another family share your home with you?
___ Yes
___ No

109. Which of the following best describes (householder): now married, widowed, divorced or separated, or never married?
___ Now married
___ Widowed
___ Divorced or separated
___ Never married

110. Which of the groups on this exhibit best describes (householder)?
___ White
___ Black or Negro
___ American Indian, Alaskan native
___ Asian, Pacific Islander
___ Other (specify):______________________________

111. Is (householder) of Spanish or Hispanic origin or descent?
___ Yes
___ No

112. What is the highest grade (or year) (householder) attended in school?
___ Never attended school ___ Seventh

___ First
___ Second
___ Third
___ Fourth
___ Fifth
___ Sixth
___ Eighth
___ Ninth
___ Tenth
___ Eleventh
___ Twelfth

College (Academic Years)
___ C1
___ C2
___ C3
___ C4
___ C5
___ C6 or more

113. Did (householder) finish that grade (or year)?
___ Yes
___ No

115. Now let's look at this list of income groups. Please tell me which group letter best describes the total combined income in 1981 of all members of your family living here, from all sources--wages, dividends, Social security, and so forth--before taxes and deductions. (Family includes all related persons living in this household.)
Circle letter for income group.

a. Less than $3,000	j. $11,000- $11,999	s. $27,500- $29,999
b. $3,000- $3,999	k. $12,000- $12,999	t. $30,000- $32,499
c. $4,000- $4,999	l. $13,000- $13,999	u. $32,000- $34,999
d. $5,000- $5,999	m. $14,000- $14,999	v. $35,000- $39,999
e. $6,000- $6,999	n. $15,000- $17,499	w. $40,000- $49,999
f. $7,000- $7,999	o. $17,500- $19,999	x. $50,000- $74,999
g. $8,000- $8,999	p. $20,000- $22,499	y. $75,000 or over
h. $9,000- $9,999	q. $22,500- $24,999	___ Don't know
i. 10,000- $10,999	r. $25,000- $27,499	___ Refused

116. Between October 1,1981 and September 30,1982 did your household receive any of the following services free or at reduced costs, from the federal, state , or local government?
a. Insulation in the attic, outside wall, or basement/crawl space below the floor of the house
___ Yes
___ No
b. Insulation around the hot water heater
___ Yes
___ No
c. Repair of broken windows or doors to keep out the cold or hot weather
___ Yes
___ No
d. Weather stripping or caulking around any windows or doors to the outside
___ Yes
___ No
e. Storm doors or windows added
___ Yes
___ No
f. Repair of broken furnace

___ Yes
___ No
g. Furnace tuneup and/or modifications
___ Yes
___ No
h. Other home energy-saving devices
(specify)____

117. The government has an energy assistance program that helps pay heating and cooling costs. This assistance can be received directly by the household or it can be paid directly to the electric or gas company, fuel dealer, or landlord.
Between October 1,1981 and September 30,1982 did your household receive assistance of this type for home cooling from the federal, state, or local government?
___ Yes
___ No

118. Between October 1, 1981 and September 30,1982 did your household receive assistance of this type for home heating from the federal, state, or local government?
___ Yes
___ No

119. Were heating assistance payments made in the form of checks, coupons, or vouchers sent to this household or were the payments sent directly to the utility company, fuel dealer, or landlord?
Check to household
___ Yes
___ No
Coupon/voucher to household
___ Yes
___ No
Assistance sent directly to electric or gas company, fuel dealer, or landlord
___ Yes
___ No

120. Altogether, how much government energy assistance to help pay heating costs has been provided directly to this household and/or provided on behalf of this household to a utility company, fuel dealer, or landlord between October 1,1981 and September 30,1982
$________.00

121. Do you or members of your household own your home or do you rent?
___ Own (buying)
___ Rent
___ Occupied without payment of rent

122. Is this (house/apartment) part of a condominium or cooperative?
___ Yes, condominium
___ Yes, cooperative
___ No

127. Do any of your household fuel bills include charges for fuel used for purposes other than for your own living quarters, such as farm buildings or machinery, the house or apartment of another household, a business or office, anything else?
___Yes
___No

129. About how much of your household's electricity bill is used for non-household uses such as farm buildings or machinery, the house or apartment of another household, a business or office, or anything else?
___ Very little (less than 5%)
___ 1/4 (5-33%)
___ 1/2 (34-66%)
___ 3/4 (67-95%)

130. About how much of your household's gas bill is used for non-household uses such as farm buildings or machinery, the house or apartment of another household, a business or office, or anything else?
___ Very little (less than 5%)
___ 1/4 (5-33%)
___ 1/2 (34-66%)
___ 3/4 (67-95%)

131. About how much of your household's LPG bill is used for non-household uses such as farm buildings or machinery, the house or apartment of another household, a business or office, or anything else?
___ Very little (less than 5%)
___ 1/4 (5-33%)
___ 1/2 (34-66%)
___ 3/4 (67-95%)

132. About how much of your household's fuel oil/kerosene bill is used for non-household uses such as farm buildings or machinery, the house or apartment of another household, a business or office, or anything else?
___ Very little (less than 5%)
___ 1/4 (5-33%)
___ 1/2 (34-66%)
___ 3/4 (67-95%)

153. Since September 1980, have any of the kind of things listed on this exhibit been done to your home--that is, anything that has either increased or decreased the total number of square feet of space, or that has changed the number of square feet of heated space?
___ Yes
___ No

154. Did the total number of square feet of space increase, decrease, or remain the same?
___ Increased
___ Decreased

___ Remained the same

155. Did the amount of heated space increase, decrease, or remain the same?
___ Increased
___ Decreased
___ Remained the same

156. Please give me a description of the work that was done.

157. In what month and year was the work completed?
Month:________
Year:198______

APPENDIX C

VARIABLES EXAMINED

APPENDIX C

VARIABLES EXAMINED

1980 and 1982 RECS Variables Recoded for Study

Var Label	Variable
ADDAT82	ATTIC INSULATED SINCE SEPT 80
ADDBA82	FLOOR INSULATION SINCE SEPT 80
ADDCL82	ADD CLOCK THERMOSTAT SINCE SEPT 80
ADDC082	SHUTTERS ETC ADDED SINCE SEPT 80
ADDIT82	NEWLY BUILT SPACE SINCE SEPT 80
ADDWA82	OUTER WALLS INSULATED SINCE SEPT 80
ADDINS82	FACTOR TWO FROM CONSERVATION SCALE
APPLNC	WEIGHTED NUMBER OF APPLICANCES
AUDIT82	ENERGY AUDIT PERFORMED IN PAST YEAR
AUTOD82	AUTOMATIC FLUE DOOR SINCE SEPT 80
BARGA82	REASONABLE PRICE REASON FOR AUDIT
BTUEL80	EL ANNUAL USE IN THOUSANDS OF BTUS
BTUEL82	EL ANNUAL USE IN THOUSANDS OF BTUS
BTUF080	FO ANNUAL USE IN THOUSANDS OF BTUS
BTUF082	FO ANNUAL USE IN THOUSANDS OF BTUS
BTULP80	LPG ANNUAL USE IN THOUSANDS OF BTUS
BTULP82	LPG ANNUAL USE IN THOUSANDS OF BTUS
BTUNG80	UG ANNUAL USE IN THOUSANDS OF BTUS

BTUNG82	UG ANNUAL USE IN THOUSANDS OF BTUS
BUILT82	YEAR HOUSING UNIT WAS BUILT
CASHA82	CASH HEATING AID RECEIVED FROM GOVT
CAUSE82	OTHER REASONS FOR REQUESTING AUDIT
CDD6580	COOLING DEGREE DAYS FOR 1980
CDD6582	COOLING DEGREE DAYS FOR 1982
CDD DIFF	COOLING DEGREE DAYS DIFFERENCE BETWEEN 1980 AND 1982
CEQUA82	SAME HOUSING UNIT IN BOTH SURVEYS
CONSRVR	CONSERVATION STRATEGY SCALE
DEHUM80	HAVE DEHUMIDIFIER
DIFF1	COST OF ENERGY FOR 1980
DIFF2	COST OF ENERGY FOR 1982
DIVISION	CENSUS DIVISION
DOLLAL80	ESTIMATED COST OF EL IN DOLLARS
DOLLAL82	ESTIMATED COST OF EL IN DOLLARS
DOLLAG80	ESTIMATED COST OF UG IN DOLLARS
DOLLAG82	ESTIMATED COST OF UG IN DOLLARS
DOLLAF80	ESTIMATED COST OF FO IN DOLLARS
DOLLAF82	ESTIMATED COST OF FO IN DOLLARS
DOLLAL80	ESTIMATED COST OF LPG IN DOLLARS
DOLLAL82	ESTIMATED COST OF LPG IN DOLLARS
DOOR182	SLIDING STORM DOORS SINCE SEPT 80
DOOR082	OTHER STORM DOORS SINCE SEPT 80
ENCH	ENERGY CONSUMPTION CHANGE 1980-1982
EVAPC820	HAVE EVAPORATIVE COOLER
FI‸D082	WINDOWS OR DOORS REPAIRED BY GOVT
FI‸HE82	GOVT REPAIRED BROKEN FURNACE

FNEWH82	FUEL USED BY NEW HEATING SYSTEM
FREEZ80	HAVE FREEZER
FUELP82	GOVT DIRECTLY PAID HEATING COMPANY
GADGE82	GOVT PROVIDED OTHER ENERGY DEVICES
GARAG82	GARAGE CONVERTED TO LIVING SPACE
GOVTA82	TOTAL HEATING COSTS PAID BY GOVT
HAUTO80	USE AUTOMATIC CLOTHES WASHER
HDD6580	HEATING DEGREE DAYS FOR 1980
HDD6580	HEATING DEGREE DAYS FOR 1982
HDD DIFF	HEATING DEGREE DAYS DIFFERENCE BETWEEN 1980 AND 1982
HEADA80	AGE OF HEAD OF HOUSEHOLD
HEADE80	EDUCATION OF HEAD OF HOUSEHOLD
HEADJ80	EMPLOYMENT OF HEAD OF HOUSEHOLD
HEADS80	SEX OF HEAD OF HOUSEHOLD
HEATA82	GOVT HELPED PAY HOME HEATING COSTS
HEATE80	TOTAL SQ FT HEATED AREA
HEATE82	TOTAL SQ FT HEATED AREA
HEATT82	DUCT INSULATION ADDED SINCE SEPT 80
HELCL80	HAVE ELECTRIC DRYER
HELDI80	HAVE ELECTRIC DISHWASHER
HELRA80	HAVE ELECTRIC RANGE
HGASR80	HAVE GAS RANGE
HGSCL80	HAVE GAS DRYER
HIGHB82	HIGH BILLS REASON FOR AUDIT
HODGA80	USE OUTDOOR GAS LIGHT
HOMEA80	TOTAL SQ FT HEATED AND UNHEATED
HOMEA82	TOTAL SQ FT HEATED AND UNHEATED

HUMID80	HAVE HUMIDIFIER
HWRNG80	HAVE WRINGER WASHER
INCOM80	TOTAL FAMILY INCOME 1979
INSULAT82	OTHER TYPES OF INSULATION ADDED
INSUL82	ATTIC OR BASEMENT INSULATED BY GOVT
KOWNRENT	DWELLING OWNED OR RENTED
LIHEAP82	ELIGIBILITY FOR LOW INCOME HEAT HELP
MARRI80	MARITAL STATUS OF HOUSEHOLDER
NEWHE82	NEW HEATING SYSTEM SINCE SEPT 80
NEWSP82	OTHER CONVERSIONS ALTER SPACE
NHSLD80	NUMBER OF HOUSEHOLD MEMBERS
NHSLD82	NUMBER OF HOUSEHOLD MEMBERS
NOAUD82	NO ENERGY AUDIT
NOLEA82	WINDOWS OR DOORS CAULKED BY GOVT
NOTCO82	HOME UNCOMFORTABLE REASON FOR AUDIT
NREFR80	NUMBER OF REFRIGERATORS
NUMOV80	NUMBER OF OVENS
ORIGIN	RACE OF HOUSEHOLDER
OVEN180	OVEN 1 IS A MICROWAVE
OVEN280	OVEN 2 IS A MICROWAVE
OVERH82	OTHER IMPROVEMENTS REASONS FOR CONSERVATION
PANES82	NUMBER OF STORM WINDOWS SINCE SEPT 80
PIPES82	PIPE INSULATION ADDED SINCE SEPT 80
POOLH80	HEATED SWIMMING POOL
POTBELL82	WOOD STOVE INSTALLED SINCE SEPT 80
PROFA80	HAVE A PROFESSIONAL AUDIT SINCE 80
REFER82	RECOMMENDATION REASON FOR AUDIT

REGIONC	CENSUS REGION
SDESCENT	HOUSEHOLDER OF SPANISH ORIGIN
SEALE82	CAULKING ADDED SINCE SEPT 80
SHEET82	PLASTIC SHEETS ADDED SINCE SEPT 80
SSYST82	ADD SOLAR SYSTEM SINCE 80
STORI80	NUMBER OF STORIES OR STYLE IN HU
STORM82	GOVT ADDED STORM DOORS OR WINDOWS
TEGCST80	TOTAL ENERGY COST FOR 1980
TEGCST82	TOTAL ENERGY COST FOR 1982
TEGUSE80	TOTAL ENERGY USE FOR 1980
TEGUSE82	TOTAL ENERGY USE FOR 1982
TEMPG82	WINTER TEMP DEGREES F NO ONE HOME
TEMPH82	WINTER TEMP DEGREES F SOMEONE HOME
TEMPN82	WINTER TEMP DEGREES F SLEEP HOURS
TUNEU82	FURNACE TUNEUP DONE BY GOVT
TURNDO82	FACTOR ONE FROM CONSERVATION SCALE
TVBLA80	NUMBER OF B AND W TELEVISIONS
TVCOL80	NUMBER OF COLOR TELEVISIONS
TYPEHT82	TYPE OF HEATING SYSTEM INSTALLED
TYPEHU80	TYPE OF HOUSING UNIT
TYPEH80	TYPE OF HEAT
UNHEAT80	TOTAL SQ FT UNHEATED AREA
UNHEAT82	TOTAL SQ FT UNHEATED AREA
USEPO82	PORCH CONVERTED TO YEAR-ROUND USE
USESO82	ADDITION OF SOLAR SYSTEM SINCE 80
VOUCH82	HEATING VOUCHERS RECEIVED FROM GOVT
WHYAT82	REASONS ATTIC INSULATION ADDED

WHYAU82	WHY AUDIT WAS REQUESTED
WHYBA82	REASONS BASEMENT INSULATION ADDED
WHYCA82	REASONS CAULKING ADDED
WHYCL82	REASONS CLOCK THERMOSTAT ADDED
WHYCO82	REASONS CLOSEABLE SHUTTERS ADDED
WHYDO182	REASONS DOOR1 INSTALLED
WHYDO082	REASONS DOORO INSTALLED
WHYDU82	REASONS DUCT INSULATION ADDED
WHYFLA82	REASONS FLAME RET HEAD BURNER ADDED
WHYFLU82	REASONS AUTOMATIC FLUE DOOR ADDED
WHYHE82	REASONS NEW HEATING SYSTEMS ADDED
WHYPA82	REASONS STORM WINDOWS INSTALLED
WHYPI82	REASONS PIPE INSULATION ADDED
WHYPU82	REASONS HEAT PUMP ADDED
WHYSH82	REASONS PLASTIC SHEETS ADDED
WHYSP82	REASONS SPARK IGNITION ADDED
WHYSTO82	REASONS WOOD BURNING STOVE ADDED
WHYSTR82	REASONS WEATHER STRIPPING ADDED
WHYWA82	REASONS WALL INSULATION ADDED
WSTRI82	WEATHER STRIPPING SINCE SEPT 80

APPENDIX D

REFERENCES

APPENDIX D

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