SOCIO-PHYSICAL FACTORS AFFECTING ENERGY CONSUMPTION IN SINGLE FAMILY DWELLINGS: AN EMPIRICAL TEST OF A HUMAN ECOSYSTEMS MODEL

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ABSTRACT

SOCIO-PHYSICAL FACTORS AFFECTING ENERGY CONSUMPTION IN SINGLE FAMILY DWELLINGS: AN EMPIRICAL TEST OF A HUMAN ECOSYSTEMS MODEL

By

Bonnie Maas Morrison

Selected socio-physical determinants were hypothesized to affect both 1) belief in the reality of the energy problem, and 2) total direct energy consumption (BTU's) in single family detached dwellings. The research undertaken here tested the viability of a second-order input/output model of physical housing factors and family factors derived from a broad human ecosystems model based in systems theory. Multiple step-wise regression and recursive path analysis were used as the analytic mode.

Four hypotheses were generated which tested both the net and gross aspects of the belief variable and the energy consumption variable via hypothesized direction of relationships (positive and negative signs), as well as the rank ordering of magnitudes of relationships.

Although minor changes in hypothesized signs were observed and shifting of rank ordering occured, a substantial amount of the variance for the belief variable (R^2 = .427) and the energy consumption variable (R^2 = .485) was explained.

The findings indicated that belief in the reality of the energy problem is positively related to mean (husband-wife) educational attainment, agreement (husband-wife) on the availability of electrical energy and reported total costs of all energy forms used in the dwelling unit (June 1974-May 1974), suggesting that belief is a factor in awareness of and experience with energy consumption problems.

Energy consumption in single family dwellings was found to be related to components of life-style and behavior, as well as the physical housing factors. The number of persons in the household, the number of major appliances and the number of rooms in the dwelling unit contributed most to the variance explained. Belief in the reality of the energy problem does not effect a change in energy consumption patterns.

Therefore, this study indicates that in the short-run (energy crisis period, Winter 1973-74) energy consumption was determined by aspects of family life

style, which did not incorporate a new energy conservation ethic. Implications for future research, public policy and educational programming based on these findings are suggested.

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By

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Undertaking the development and writing of a doctoral dissertation can be made analogous to the systems perspective found within the following pages. This system can be viewed as an adaptive self-organizing system reacting to convergent inputs, controlled by feedback from many sources; the output of which is printed between these covers.

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CHAPTER I

INTRODUCTION

Energy Dependency

Humans are energy dependent. Two decades ago Cottrell hypothesized that, ". . . the energy available to man limits what he can do and influences what he will do" (1955, p. 2). Thus, it would appear that human potential, as well as the level of development and complexity reached by human culture is highly related to the amount, cost and forms of energy available. Odum suggests, for example that:

> Energy is measured by calories, btu's, kilowatt hours, and other intraconvertible units, but energy has a scale which is not indicated by these measures. The ability to do work for man depends on the energy quality and quantity, and this is measurable by the amount of energy of a lower grade required to develop the higher grade. The scale of energy goes from dilute sunlight up to plant matter to coal, from coal to oil to electricity and up to the high quality efforts of computers and human information processing. (Man/Environment Systems, 1974, p. 231).

This statement illustrates quite clearly the relatively complex set of energy forms upon which humans have become dependent.

Over human history on earth, the linkages between people and energy can be traced from primitive low-energy cultures to high-energy cultures of great diversity and complexity.[1] Historically, the basic dependency on energy has grown and changed through progressive stages. As Cottrell indicates, both the level and form of energy consumed today has taken society out of the realm of a "low-energy" human-labor intensive state and placed society in a "high-energy", techno-mechanical state. This assertion is particularly true for most developed nations of the world, especially the United States,[2] although the developing nations of the world also have aspirations toward greater use of converted energy forms.

How modern day humans view energy resources has been largely based on the primary assumption that an infinite supply existed. Cheap and apparently plentiful supplies of energy have tended to reinforce a value position that energy could be considered for all intents and

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[1]It is not the intent of this essay to cover in detail the historical developments of energy use by humans over time, except to suggest that cultural development towards complexity is paralleled by increased use of converted energy forms. See: Cottrell, Energy and Society, 1955 and Starr, Energy and Power, Scientific American, Vol. 225, No. 3, September 1971, pp. 37-49 for a comprehensive coverage of the historical development.

[2]The U.S., with six percent of the world's population, uses thirty-five percent of the world's energy (Cook, 1971, pp. 135-144).

purposes a free good upon which economic growth and social evolution could be demanded as a human right.

The apparent energy shortage (referred to as the "energy crisis," winter of 1973-1974), however, tended to turn the viewpoint to a more conservative one based on an assumption of the finiteness of certain energy resources (particularly petroleum based fossil fuels) and their increased value as a scarce economic good. The outcome of this new awareness is the need for humans to re-evaluate their relationships to and dependency on energy. This need provides the primary focus for this study.

Although the energy crisis was eventually relegated to the status of a problem, albeit a serious international one; a general mood of "normalcy" was created, especially with the end of the Arab oil embargo in March of 1974. The energy problem, however, still remains a serious unsolved environmental problem with both global and national economic, political, social, technical and ecological implications.

At issue is the question of the serious imbalance apparently occuring between the growing requirements of society and the capability of the <u>natural</u> environment to deliver what is required (B. Morrison, 1974). Conservationists have for decades warned of the disasters impending if human society continued to ignore natural ecological balances. More recently ecologists and environmentalists have decried the sad misuse and abuse of the natural environment and its resources as demands to satisfy human ends accelerate (D. Morrison, 1972).

Thus the issues first raised by the environmental movement (early 1970's) and subsequently reinforced by the "energy crisis" have served to stimulate research to uncover the basic roots of the disequilibrium occurring.

Questions arise as to why the energy problem occurred. What circumstances culminated in the situation defined as an energy crisis? How does the public view the energy problem; i.e., do they view it as real or contrived; as a long-term or short-term problem? Does belief in the reality of the energy problem affect energy consumption? Finally, is there an emergent "new" energy conservation ethic?

These questions are of primary concern to a society whose dependencies on energy make it particularly vulnerable to a multiplicity of complex energy-related problems if answers are not sought and found. Of course, this research endeavor will not search for empirical insights into all these questions. Some of the questions will, however, be discussed heuristically, others will become the focus of the empirical work undertaken.

In general terms then, the present study considers the energy problem in relation to:

1) The more distal global and national environment. This focus will be narrative in nature, lending background insights into the roots of the energy problem.

2) The more immediate family environment. This will be the empirical focus which encompasses the specific concerns that form the research problem and the hypotheses of this study.

The Context of the Problem

The Energy Problem: The Distal Global and National Environment

In broad perspective the crux of the energy problem at the global level is the growing dependency on and competition for high energy resources. Many observers of the energy problem have articulated in more specific terms the conditions surrounding the problem. These observations can be synthesized to a few essentials:

1) Human populations are growing exponentially at an increasing rate (Bogue, 1969). On a world-wide basis the annual rate of natural increase in population as of 1973 was 2.0 percent, for the United States that increase was 0.6 percent for the same period (Freedman and Berelson, 1974).[3] This population growth rate corresponds to a "doubling time of 33 years" (Meadows, et al., 1972).

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[3] "Thus even if the country's fertility persists at a replacement level, the U.S. will not reach zero growth for 50 or 60 years, at which time its population will be

2) Per capita energy consumption is growing exponentially for non-renewable fuel sources (Perry, 1972). Globally, the annual per capita increase in energy consumption is six percent, in the U.S. use of energy has grown to more than four percent per capita per year (Ford Foundation Report, 1974a, p. 1).

3) Expectations for more and better goods and services are limitless (D. Morrison, 1974). "Mankind collectively is in the midst of a 'revolution of rising expectations,' involving a universal commitment to the concept of economic growth as 'an irreversible and irrepressible need'" (Jaguaribe, 1966).

4) Low-cost energy resources are limited (Perry, 1972). ". . .the earth's deposits of fossil fuels (coal, petroleum, natural gas) are finite in amount and non-renewable during time periods of less than millions of years. . ." (Hubbert, 1969, p. 158).[4]

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40 percent larger." (Freedman, R. and Berelson, B., 1974. The Human Population, in Scientific American, Vol. 231, No. 3, p. 32).

[4]The United States produces thirteen percent of the world's coal, yet consumes forty-four percent. For petroleum, U.S. production is twenty-three percent of the world total but consumption is thirty-three percent. And for natural gas the U.S. produces fifty-eight percent of the world total, but consumes sixty-three percent. The difference between production and consumption (between five percent and thirty-one percent depending on the fuel source) is a strong indicator of U.S. dependency on "others" for the fuel supplied to support the present life style (Meadows, et al., 1972, pp. 56-59).

These four complex interacting factors, three which represent growth dimensions, the fourth a constraint to the continuation of growth, are considered the major components of the situation that culminated in the so-called "energy crisis," although, the Arab-Israeli War (Fall of 1973) and the ensuing Arab oil embargo triggered the event and elevated its intensity.

The Energy Problem: The Immediate Family Environment

The energy problem, although a problem of global and national proportion, has also had its affect on individuals and families. To be more specific a large proportion of American families have been the benefactors of the exponential growth in per capita energy consumption. As a nation we consume 35 percent of the world's energy in spite of the fact that we are 6 percent of the world's population (Cook, 1971, p. 135).

Montgomery suggests that, "each American today has the equivalent of 300 persons as 'energy servants'" (1973, p. 17). This calculation is based on work done by Rocks and Runyon in assessing the watts per capita expended in industrial production in comparison to the biological power of a person (1972, p. 8).

To become even more specific the annual growth of energy consumption in the United States is 4 percent per year, for residential energy consumption the annual growth rate is 4.8 percent (Ford Foundation Report, 1974a, pp. 3-4).

This growth rate indicates that the level of living enjoyed by many American families has been highly dependent on a cheap and plentiful supply of energy. Therefore, the shortages and increased costs of energy experienced during the energy crisis period have become a distinct threat to the very quality of life American families not only expect but also demand.

The increase in residential energy consumption[5] can be accounted for by several complex interacting factors. Those most discussed in the literature are given below:

1) A growth in U.S. population. Although the annual rate of natural population increase (0.6 percent) is less than for any other regions or nations of the world, (Freedman and Berelson, p. 39), during the 1960's the U.S. population increased 11 percent (Ford Foundation Report, 1974a, p. 2).

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[5]Residential energy consumption is used here as a general measure of family energy consumption. This is necessary as no standard measure is presently available for family energy consumption. Residential energy use is a measure for all dwelling unit types (single-family to multiple dwelling) and would include single individual households (18.4 percent of total U.S. population) as well as family households (81.6 percent of total U.S. population). Source: Dept. of Commerce, Bureau of Census, Current Population Reports, Series P-20, No. 200.

2) A tendency towards smaller households. During the 1960's household formation increased by 17 percent, indicating, in spite of the 11 percent population increase, a switch by the elderly and young adults to live in their own places (Reilly, 1973).

3) An increase in median family income. There has been a steady increase in median incomes for families. Table 1 indicates this for selected years.

TABLE 1.--Comparison of Median Family Incomes, Selected Years 1947 to 1973. (In current dollars).

Year	Median Family Income In Current Dollars
1947	$ 3,031
1950	3,319
1960	5,620
1965	7,974
1968	8,634
1970	9,867
1973	10,236

Sources: Department of Commerce, Bureau of the Census, Current Population Reports, Series P-60, No. 66, U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 80.

The percentage per capita increase in disposable income between 1950-1970 has allowed the purchase of greater numbers of energy consuming items, resulting in an increase of residential energy use by 50 percent during the 1960's (Reilly, 1973).

4) <u>Cheap and plentiful energy sources</u>. Until 1972, when the shift in both energy supplies and costs began to occur, U.S. families were benefiting from an incentive pricing structure for most energy sources that encouraged energy use. The plan was basically "the more energy used the less per unit the cost." This was true for fuel oil, natural gas and more recently for electricity (Tansil, 1973, p. 4).

This program, largely coming into question since the energy crisis (Winter, 1973-1974), was, however, a major factor in energy consumption practices during the 1950's and 60's which resulted in the 50 percent increase in residential energy consumption in the 1960's mentioned before.

At the national level these four factors have contributed greatly to both increased energy consumption and to the energy problem. Obviously these are not the only factors. Transportation, industrial and commercial sectors of the economy also account for large proportions of energy consumption and growth in annual rate of energy use in the United States. Table 2 indicates the percent of national total and annual growth rate accounted for by each of these sectors.

It should be noted that for each sector, including the residential, the rate of energy consumption has grown, emphasizing the broad internal national factors giving rise

TABLE 2.--Total Fuel Energy Consumption and Annual Rate of Growth in the United States by End Use.

End Use	Percent of National Total	Annual Rate of Growth (%)
Residential	19.2	4.8
Commercial	14.4	5.4
Industrial	41.2	3.9
Transportation	25.5	4.1
National Total	100.0	4.3

Source: Stanford Research Institute, Patterns of Energy Consumption in the United States, prepared for the Office of Science and Technology, Executive Office of the President, 1972 (Modified for inclusion here).

to the energy problem. However, as this study focuses most specifically on the family and residential energy consumption, Table 3 is an indication of direct residential energy consumption, both as a percent of total national consumption and as a percent of total residential consumption, each given by end use.

Energy consumed directly by the residential sector is very nearly one-fifth of the national energy budget. Thus, it would appear important to study energy consumption in relation to the family and its dwelling place in order to shed light on the determinants of residential energy consumption.

TABLE 3.--Total Residential Energy Consumption in the United States by End Use.

Residential Energy* End Use	Percent of Total National 1968	Residential 1968
Space heating	11.0	57.0
Water heating	2.9	15.0
Cooking	1.1	6.0
Clothes drying	0.3	2.0
Refrigeration	1.1	6.0
Air conditioning	0.7	4.0
Other	2.1	10.0
Totals	19.2	100.0

Sources: 1) Stanford Research Institute, Patterns of Energy Consumption in the United States, prepared for the Office of Science and Technology, Executive Office of the President, 1972. 2) Agricultural Engineering Department, Michigan State University, Energy in Michigan Agriculture, March 1974, p. 7.

*This includes electrical energy as well.

The Study Problem, The Basic Objectives and the Assumptions

One of the difficulties in seeking a clear understanding of and, therefore, resolutions to the energy problem is the complexity of the problem itself. Strongly suggested in this recognition is the need for an integrated wholistic approach or conceptual framework which allows both a broad overview and particularistic insights into the pertinent factors contributing to the consumption of scarce energy resources. This would, of course, be the case of all sectors of the economy; however, this study is most concerned with residential energy consumption, particularly in single family detached dwellings and for these reasons:

1) Single family detached dwellings are the most prevalent form of housing in this nation for families at the present time. The 1970 census indicates that of the 67 million, year-around housing units available in standard metropolitan statistical areas, 69.4 percent were single family dwellings, 62.9 percent of which were owner-occupied (U.S. Bureau of the Census, 1970, pp. 846-847).

2) Single family dwellings are also considered the most energy consuming type of dwelling unit. A comparison of single family dwelling with multi-dwellings indicates that the total cost of providing energy for housing (natural gas and electricity) can be reduced as much as 50 percent depending on dwelling type. Table 4 provides the evidence using single family dwellings as the bench mark (100 percent) of the energy cost.

The problem of this research thus becomes an attempt to identify the major determinants of mechanical energy directly consumed in single family detached dwelling units using an integrated, multi-dimensional systems framework (hereafter termed human ecosystems conceptual framework or model).

TABLE 4.--Total Energy (gas and electricity) Costs and Percentages by Housing Types (Based on power consumption predictions).

Housing Type	Cost ($)	Percent (%)
Single-family conventional	484	100 (100.0)
Single-family cluster	483	100 (99.8)
Townhouse clustered	340	70 (70.2)
Walk-up apartment	278	57 (57.4)
High-rise apartment	248	50 (51.2)

Source: The Costs of Sprawl, Table 26, April 1974, p. 60 (Modified for inclusion here).

The general objective of this study therefore is: To test the viability of a hypothetical systems input/output model of energy consumed directly in single family detached dwellings, deduced from a human ecosystems conceptual model.

The specific objectives of the study thus become:

1) To determine the total amount of direct energy consumed in single family detached dwellings (measured in British Thermal Units--BTU's).

2) To determine the relative importance of a selected set of socio-physical factors on the total amount of direct energy consumed in single family detached dwellings.

3) To determine the relationships between the family's belief in the reality of the energy problem and the energy consumed in the single family detached dwelling.

Within these objectives then, certain basic assumptions have been accepted as reasonable. These are:

Assumption 1.--Survey research methods are appropriate to gain both subjective and objective measures from families and utility companies.

Assumption 2.--Determinants of residential energy consumption can be garnered from the combination of the subjective measures (belief and perceptual data from families), and objective measures (energy consumption data from utility companies and tax record data).

Assumption 3.--It is possible to convert multiple measures of energy depending on type (fuel oil, natural gas and electricity) to a standard measure, in this case the British Thermal Units (BTU's) without loss in measurement reliability.

Assumption 4.--Through the deductive method it is possible to narrow from a broad human ecosystems framework, the systems components which become the tested hypothesized relationships.

Operational Definitions

Energy is a measure of the ability or power to do work. In this study the only energy measured and used empirically (as the major dependent variable) is the mechanical energy produced through the consumption of refined or transformed fossil fuels. This study concentrates on electricity, natural gas and fuel oil. Human physical energy is not measured or used in this research; therefore any reference to energy (mechanical, residential, direct, and such) can be assumed to mean refined or transformed fossil fuels energy.

Direct residential energy.--is the energy measured at the place of residence, i.e., the actual meter readings in kilowatt hours of electricity, and cubic feet of natural gas consumed, along with the gallons of fuel oil delivered to the dwelling unit. This mix depends on the types of energy used within a particular residence. This study does not measure or use energy consumed in the mining, refining, production, transportation or transmission of the energy source prior to their use in the place of residence, i.e., no indirect energy consumed is measured or used in this study.

Total direct residential energy consumption.--is the summed amount of energy consumed, measured in British Thermal Units (hereafter BTU's)[6] in the place of residence depending on household mix. Each source of energy for each residence in this study was identified (a mixture of electricity and natural gas or electricity and fuel oil) using data supplied by utility and oil companies. These data were received from the companies in the standard units of energy measurement, i.e., cubic feet of natural gas,

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[6]A British Thermal Unit (BTU) is the amount of energy needed to increase the temperature of one pound of water one farenheit degree.

kilowatt hours of electricity, gallons of fuel oil. Each was then summed for a twelve month period (June 1973 to May 1974) and then converted to BTU's. Once the conversion to BTU's for each energy source was accomplished they were simply added together, depending on household mix, to gain the total amount of energy consumed per residential unit. The measurements conversion included in this study are as follows:

1 cubic foot of natural gas = 1,031 BTU's
1 kilowatt hour of electricity = 3,413 BTU's
1 gallon of fuel oil = 130,000 BTU's

Single family detached residential dwelling or unit.--is a housing unit which is physically separated from other dwelling units, suitable as a living space for one family. This type of dwelling unit usually has space around all sides (yard space) and has no common walls, facilities or utilities with other dwelling units. It is a physical, self-contained, basically self sufficient entity which may be owned or rented and may also be located in urban or rural areas.

The family.--is used in this study as the human unit of analysis and is defined as a household with two or more related persons, one over 18 years of age. Therefore, husband-wife; husband-wife-child(ren); single parent-child(ren) and bi-sex committed groupings were included. Single person households; two or more males; two or more female households were excluded from the survey.

For this study husband and wife scores on certain items where aggregated within the family as the human unit of analysis criteria. This was done only on the two items in the study where both husbands and wives gave responses: (1) the belief in the reality of the energy problem item where recoding was done so that:

1) if husband and wife agreed "yes" in the reality of the energy problem, their combined score was 4.

2) if the husband and wife disagreed about the reality of the energy problem, their score was 3.

3) if the husband and wife agreed "no" in the reality of the energy problem, their score was 2 (see 3.23.1, Appendix D, pages 198 and 199).

and (2) perceived problem in the availability of energy by fuel source (electricity, natural gas, and fuel oil) where recoding was done so that:

1) if both husband and wife agreed there was a problem in the availability of the fuel source, they received a score of 2.

2) if both husband and wife disagreed about a problem of the fuel source, their score was 1.

3) if both the husband and wife agreed that there was no problem about the availability of the fuel source, their score was 0 (see 3.23.2, Appendix D, p. 200 for details).

Belief in the reality of the energy problem.--is the measure of awareness of the energy problem as it existed during the winter of 1973-74. The measure of "belief" (for convenience) is a dependent variable in the first multiple regression run in order to assess the factors that contribute to its make up. It becomes an independent variable in the second multiple regression run as a factor hypothesized to affect energy consumption in single family detached dwellings. Husband and wife scores are aggregated within the family as the unit of analysis criterion.

What follows then is a development of the problem through a systems perspective, toward an analytical model that will be specific to the relationships to be hypothesized, tested, analyzed and discussed.

CHAPTER II

REVIEW OF ENERGY LITERATURE

Introduction

This chapter is basically a review of research literature related to energy concerns, in particular residential energy. The intent is to place this research endeavor in perspective vis-a-vis other related empirical works.

Often studies done gain insights from and are therefore influenced by other similiar works. This is not the case here. The major impetus for this study is systems theory (to be developed in Chapter III), which not only lends structure to the conceptual framework for this problem, but also gives direction to the analytic mode used.

The body of research to be reported here was largely conducted within the same time frame as the present study, thus making it unavailable as an influence in the development of conceptual structure, hypotheses generated or the research design of this study.

The Related Literature

Research centered on the technological development of energy (extraction and conversion methods) is abundant compared with studies of energy efficiency, consumption and conservation. A review of energy literature summarized in Energy: A Bibliography of Social Science and Related Literature (D. Morrison, 1975b) re-reveals that the major emphasis in both the empirical and non-empirical work in the field can be categorized into the following areas:

1) Development of energy supplies.
2) Energy demand studies.
3) Energy policy at the state, national and international levels.
4) The economics of energy.
5) The nature of energy industries and their regulations.
6) Impact of energy resource development on geographic areas.
7) Impact of energy on the environment.
8) Energy conservation.

Out of the 2,142 item bibliography only 35 items dealt directly or indirectly with energy in the built environment (commercial, industrial, transportation and residential combined), and only 15 of these items were specific to the residential sector, 10 of these items were research reports. This would suggest that the area of residential energy is wide open as a field of inquiry. It also highlights the fact that studies done are few and very recent.

An historical overview of energy related literature would indicate four main stages of development:

1) The technological development stage (empirical in nature), the Industrial Revolution, circa 1800's to the present.

2) The energy and society stage (basically non-empirical in nature), early 1950's to the present.

3) The energy and environment stage (both empirical and non-empirical), late 1960's (Earth Day to the present).

4) The energy crisis stage (empirical), starting immediately prior to the winter of 1973-74.

Until the late 1960's, early 1970's, very little research on energy was done outside the realm of technological efforts. However, as early as the 1950's various scholars were beginning to address themselves to energy and society issues on a speculative basis. Much of this work was related to energy and social and economic evolution (Sinnott, 1949; White, 1950; Egerton, 1951; Tirospolsky, 1952; Ayres and Scarlott, 1952; Cottrell, 1955; Mason, 1955; Thomas, 1956; Tanning, 1958; Jarret, 1958; Thirring, 1958; and Knowles, 1959).

The ecology-environmental movement marked by Earth Day, April 1970, accelerated the need for more information. Concerns about the impact of energy extraction methods and pollution caused by energy generation were foremost. Creeping increased costs of energy resources and the growing dependency on imported sources by the United States created a need for a statistical data base. Thus, most of the empirical work during the period prior to the "energy crisis," was done to close the statistical knowledge gap surrounding natural energy resource stocks, and to define the energy consumption patterns of various sectors of the economy. This effort could be classified as information gathering, national in scope and basically descriptive (Office of Science and Technology, Patterns of Energy Consumption in the United States, January 1972; Staff Study, Potential for Energy Conservation, Oct. 1972; RANN Report, Energy, Environment and Productivity, November 1973).

The first effects of the real energy shortages were felt during a period just prior to the energy crisis (Winter 1973-74) although electrical brown-outs and black-outs had been experienced in several parts of the nation earlier; i.e., "Big Alice" the black-out experienced in 1969 by some sections of New York City is considered the most serious. The period of energy uncertainty (during the winter of 1972-73 and the summer of 1973) encouraged a number of research starts, with particular emphasis on alternative energy futures given various economic and technological options (Ford Foundation Energy Policy Project, initiated 1973). Energy conservation also became important during this period, along with new priorities established for energy development and production research.

The energy crisis of the winter of 1973-74, exacerbated by the Arab Oil Embargo, elevated to a new level the urgency for energy research. The Federal Energy Office (FEO), created in January of 1974 by the Nixon Administration, initiated Project Independence, a study not unlike that of the Ford Foundation's, to investigate what it would take to bring the nation to energy independence by 1980 (Project Independence Report, November 1974).

The Federal Energy Office (FEO) became the Federal Energy Administration (FEA) in July of 1974 as a formal recognition of the long term, serious nature of the energy problem. In January 1975, the Energy Research and Development Agency (ERDA) was created to over-see federally funded energy research.

Michigan is 95 percent dependent on energy imports from outside the state (Annual Energy Report of the Governor, 1975). Therefore, Michigan was one of the first states in the nation to establish a State

Energy Office (March 1974). Michigan also created a non-profit corporation to coordinate state energy research efforts (Michigan Energy Resources Research Association -- MERRA, December, 1974).

This short-term historical overview simply points up the increased growth in interest and concern surrounding energy, generally. The concerns have changed over time from energy as the basis for enhanced economic growth and social development, to concerns for reducing energy consumption as energy short-falls and increasing costs threaten the economic and social fabric of this nation.

Literature Related to Residential Energy: Directly or Indirectly

A search of the literature related to residential energy use was conducted prior to the field survey (May-June 1974) from which this study evolved. Very little was found which lent insight into or support for this research problem. This is not surprising, taking into consideration the short-term historical review just discussed. What needs to be understood is that this research was designed and conducted simultaneously with most of the research important to this study. Therefore, rather than indicating an a priori influence on this research, most of what will be discussed is retrospective and hence comparative in nature. It must be kept in mind that some of the research concerned with residential energy consumption was generated in the year prior to the energy crisis and some during. Most, of course, were investigations within the general time frame of what was termed the period of "energy uncertainty," a period between the winter of 1972-73 and the energy crisis, the winter of 1973-74. The time lag between these research efforts and the research reports in several cases made them unavailable for consideration before the fall of 1974, when this research was well beyond the theoretical or methodological development stages. Therefore, prior research did not substantially contribute to the development of this research problem. The only exception to this is in the area of analysis; this investigation has been able to gain valuable insights from that dimension.

In order to cover effectively the literature related to residential energy, a summary of each study will be given in tabular form. Each will appear, by author(s), date, title, research considerations (method, theoretical concerns, hypotheses, variables) along with modes of analysis and findings. This will allow a broad, however, somewhat detailed overview of the present state of the art, which will make eventual analytic comparison to the present study possible. The following then is the review:

TABLE 5.--Review of Research Related to Residential Energy Consumption.

Robert A. Heredeen, March, 1973. An Energy Input-Output Matrix for the United States, 1963. User's Guide, Center of Advanced Computation, University of Illinois, C.A.C. Document No. 69, March 4, 1973.

Clark W. Bullard III, June, 1973. The Illinois Consumer's Role in Energy Conservation. Center for Advanced Computation, University of Illinois, C.A.C. Document No. 78, June 13, 1973.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Heredeen: Simulation based on vast data base. Simulation of direct and indirect energy inputs and dollar cost of sectors of the economy.	Economic Input-Output Analysis (W. Leontief 1966, 1970; W. H. Miernyck 1965).	None stated Measure of indirect and direct energy impact (BTU/$) of manufacture/production/ sales. - Protein production - Auto production	367 Sectors of Economy	Input-output analysis--matrix of coefficients of BTU/$.	No findings given here, importance is in the influence on other studies included.
Bullard: Simulation based on large data base. Simulation of energy consumption in Illinois private sector economy.	Economic Input-Output Analysis (Heredeen 1973).	None stated Examination of the components of energy demand.	82 types of expenditures Reduced to 18 categories - Residential demands - Fuel for transportation	Input-output analysis BTU/$	Findings: 1. Illinois consumers use more total energy than produced in the state by 85 million BTU/s per capita. 2. 281 million BTU's per capita is demanded. 3. Illinois consumers use 10% more direct and indirect energy than national average. 4. Space heating energy and higher GNP in Illinois may account for greater demand. Implications: 1. Reductions in home heating (changes in heating systems, changes in behavior patterns and insulation could reduce energy demand by 40%

Hittman Associates, Inc., March, 1973. Residential Energy Consumption: Final Report, Report No. HUD-HAI-2; (Publication No. HUD-PDR-29-2) Office of Assistant Secretary for Policy Development and Research, Department of Housing and Urban Development, March, 1973.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Simulation Research based on large data base. Simulation of a "Characteristic" house. Characteristic House defined as a 2-story single family dwelling.	Input/Output Analysis - Baseline Evaluation of Energy Consumed (measured in therms) one therm = 10^5 BTU - Modification introduced and evaluated toward minimizing energy consumption	None Stated None Implied	Input: Building Definition 1. Size (length, width, height) 2. Orientation 3. Number, size and location of windows and door 4. Wall, roof and floor construction 5. Shading Operational Characteristics 1. Heating and cooling plant size 2. Internal Heat Load (lights, equipment, occupants) 3. Room temperature and humidity 4. Attic fan size and temperature setpoint 5. Outside air cycle Weather Definitions 1. Calendar days 2. Local weather tape - wet and dry bulb - wind speed and direction - cloud cover Output 1. Room heating/cooling load 2. Infiltration load 3. Heating/cooling plant operation	Computer Programs 1. REAP--Residential Energy Analysis--Simulates thermal (heating/cooling) characteristics. 2. TAP-4--Therman Analyser Program. Studies structural components and simulates heat-transfer, convection and radiation. 3. CREAP--Correlated Residential Energy Analysis Program correlates weather input data. - Heating/cooling loads - Net infiltration etc. 4. R I P--Residential Infiltration Program. Measures wind speed, direction and infiltration.	Findings: Given a good quality, single family dwelling, annual energy consumption could be reduced by 40%, primarily through: 1. Reduction in air infiltration 2. Heat conduction Implications: Retro-fitting older dwelling using the more effective simulated modifications was considered possible, however, the total energy reduction would be less.

John Fox; Harrison Fraker, Jr.; Richard Grot; David Harrie; Elizabeth Schorske; and Robert Socolow, December, 1973. Energy Conservation in Housing: First Year Progress Report, July 1, 1972 to June 30, 1973--Report No. 6, Center for Environmental Studies, Princeton University. (Location of Study -- a new residential community: Twin Rivers, New Jersey.)

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Experimental Research Design (N=401 Townhouses) 248 standard 2-floor 153 split levels Instrumentation: 1. Weather station 2. Remote data acquisition system--place within home 3. A device to monitor rate of air leakage	None Stated Research Question: General What Factors Determine Energy Utilization? Research Question: Specific 1. How much variation in energy consumption occurs among physically similar units? 2. What proportion of the variation is attributable to specific physical variation and what proportion to variation in income and family size? Goals of Minitoring Effort 1. Determine load data for residential energy consumption 2. Determine experimentally the major components of heating and cooling loads 3. Determine the efficiency and adequacy of the mechanical distribution system. 4. Determine the significance of thermal storage for energy consumption 5. Determine the effect on the internal environment of appliance operation 6. Determine the variation in temperature and humidity in dwellings 7. Determine the frequency of occupant-inducted events and their significance for energy consumption.	None Stated Implied: H_o: No difference between standard 2-floor and split-level town-houses in energy utilization	Controlled Variables: - All units used natural gas for heating - All appliance packages were identical and electric - All were air conditioned electrically - All were insulated - Similar townhouse units Independent Variables: - 2 types of townhouses - Size (2,3,4 bedrooms) - Location (interior-end unit) - Orientation of major glass areas - Options in glass (double or single panes) - Family size - Family income - Weather conditions Dependent Variables: Monthly Energy Utilization: - Natural Gas Utility - Electricity Companies (measured in therms)	Multiple Linear Regression Correlation Matrix Scattergrams	Findings: 1. Gas savings due to double glass windows 2. Gas consumption greater due to being "end" unit 3. No significant correlation between gas and electric consumption a. Variation in gas explained by seasonal differences (not controlled to great extent by users) b. Electrical variation speculated to be explained by user difference (greater use control) 4. No significant correlation in gas use by family income or family size 5. Unexplained variation due to unmeasured subtle differences in structure and in user behavior. Implications: More needs to be studied concerning variability created in construction and in user behavior.

James R. Murray; Norman Bradburn; Robert Cotterman; Michael Minor; and Alan Pisarski. January, 1974. The Household Impact and Response to the "Energy Crisis": Initial Report (unpublished).

James R. Murray; Michael J. Minor; Norman M. Bradburn; Robert F. Cotterman; Martin Frankel; and Alan E. Pisarski, April, 1974. "Evolution of Public Response to the Energy Crisis," Science, Vol. 184, No. 4134, April 19, 1974, pp. 257-262.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
National Continuous Survey (NORC) (Crossectional) (N=Approx. 700) weekly from 1st week of November 1973 through February 1974.	Not based upon theory Could lend to theory development.	None Stated None Implied	Independent Variable - Energy Crisis (exposure to fuel oil, gasoline, electricity shortages - Family Income - Worker in household (occupation) - PAD district - Type of place Dependent Variables - Household conservation - Perception of most important problem - Preference for fuel distribution - Alternative forms of transportation available - Alternative gasoline pricing - Trouble obtaining fuel - Expectation about length of energy problems - Form of reduced energy consumption.	Descriptive Statistics Percent Reporting Correlation Analysis	Findings: Gasoline fuel source of greatest scarcity but not a "Big" problem--more inconvenience Reported Conservation Behavior: Household: - turn down heat - use appliances less - turn lights off Transportation--not reported here Energy Problem very important problem--not most important problem. Implications: Insights into methods for gathering systematic data as an important event unfolds to access 1. How the public is reacting 2. What social adaptions (constructive or destructive) are occurring--or likely to occur.

Thomas A. Heberlein, June, 1974. Conservation Information: The Energy Crisis and Electrical Consumption in an Apartment Complex (unpublished paper).

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Experimental Design Time Series (N=96)	The influence of attitudes on behavior, considering moral commitment and norms (McGuire, 1968; Hovland, 1970; Schwartz, 1970).	<u>Experiment I:</u> H_o: Of no difference between treatment groups. <u>Experiment II:</u> H_o: No difference between treatment groups. Taking into consideration effects of energy crises.	<u>Independent Variables:</u> 1. Decreased energy consumption information only. 2. Decreased energy consumption information plus information below: A. Economic cost of behavior B. Its consequences on other people C. Individuals' responsibility 3. Increased energy consumption information plus the three variables manipulated in 2 above. 4. No information (control). <u>Dependent Variables:</u> Actual electric energy consumption (meters read daily at 6:00 p.m.)	Analysis of Variance	<u>Findings:</u> No difference between before and after treatment and control groups in energy consumption. <u>Implications:</u> Moral sanctions not strong enough to influence behavior to conform to new norms (change in energy consumption) if behavior is not directly observed and if moral commitment is not strong.

Dorothy K. Newman and Dawn D. Wachtel, August, 1974. Energy, The Environment and the Poor (unpublished paper). Paper presented at the Society for the Study of Social Problems, Montreal, Canada, August, 1974.

October, 1974. The American Energy Consumer: Rich, Poor and In-Between. Chapter 5 in A Time to Choose: America's Energy Policy Project, The Ford Foundation, 1974, pp. 113-130.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
National Survey (N=1,455 Households) Survey of Utility Companies Serving Respondents	The Poor Pay More	Implicit Hypotheses: - Income is positively related to energy consumption. - Income is negatively related to energy cost.	Independent Variables: - Income - Dwelling Types - Heating Systems - Energy Using Appliances - Vehicles - Socio-economic Status - Living and Transportation Patterns Dependent Variables: Actual energy consumption 1. Natural gas 2. Electricity 3. Gasoline (measured in BTU's) Energy Cost (perceived)	Correlation Analysis and Descriptive Statistics	Findings: 1. The poor use less energy totality and tend to pay more as a percent of total annual income. 2. Very little difference in natural gas consumption. Implications: 1. Conservation through more efficient appliance, cars and also insulation would aid poor as well as others. 2. A system of special allocation programs to insure poor do not suffer disproportionate hardships.

T. P. Schwartz and Donna Schwartz-Barcott, August, 1974. The Short End of the Shortage: on the Self-Report Impact of the Energy Shortage on the Socially Disadvantaged. Paper presented at the Society for the Study of Social Problems, Montreal, Canada, August, 1974.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Telephone Survey (3 waves) N=200) not a strict panel study. Self-Report.	Power Theory: The socially disadvantaged suffer increased disadvantage (unemployment--cost increases) as efforts to upgrade environment increases (Krieger, 1970; Freeman, 1972; D. Morrison, 1972; D. Morrison, 1973).	1. Energy shortages discriminate against socially disadvantaged groups. 2. Energy shortages discriminate even more against groups that have multiple social disadvantages. 3. Discrimination increases as shortage endures and worsens.	Independent Variables: Social Disadvantages 1. Minorities 2. Elderly 3. Young 4. Females 5. Non-white 6. Low income 7. Low education 8. Low occupational status Dependent Variables: Perceptions of energy unavailability.	Correlation Analysis and Descriptive Statistics	Findings: 1. Very little evidence the energy (gasoline mainly) shortage discriminate against socially disadvantaged (except for young-marrieds). 2. Evidence suggest more strongly that shortages discriminated against the more advantaged. Implications: 1. Power theory--weak predictor in short run--may be better prediction in longer run. 2. Socially advantaged may report more discrimination effects of shortage because: A. More aware (education) B. More dependent on energy (Relative Deprivation Theory implied).

Donald I. Warren, Senior Researcher, December, 1974. Individual and Community Effects on Responses to the Energy Crisis of Winter 1974: An Analysis of Survey Findings from Eight Detroit Area Communities. Study conducted by the Program in Community Effectiveness, Institute of Labor and Industrial Relations, a joint unit of the University of Michigan and Wayne State University. Study conducted from April through June, 1974.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Crosssectional Survey of Eight Detroit Area Communities (N=766 families). Representative sampling of heads or spouse. 70 minute interview.	Helping behavior and linkages to social organization was used as the general framework for the evaluation of: 1. Individual's social context and response to energy problem. 2. Community social context (local values and social attitudes) related to reported behaviors during energy problem. 3. Neighborhood social context (typology of six neighborhood types) related to individual responses to energy problem. (No references given)	Hypotheses Implied: 1. Individual's socio-economic context is related to response to energy problem. 2. Community values and attitudes will influence individual behaviors and attitudes related to energy problem. 3. Neighborhood types will influence individual responses to energy problem.	Independent Variables: 1. Family income 2. Educational level 3. Occupational position 4. Sex 5. Age 6. Marital status 7. Place respondent grew up 8. Employment status 9. Information and help sources 10. Maintenance of home 11. Community 12. Neighborhood Dependent Variables: Response to Energy Crisis - Seriousness of Energy Crisis - Personal effects of Energy Crisis - Blame for Energy Crisis - Reality of Energy Crisis - Conservation practices - Life style changes - Voluntary vs. government action.	Descriptive Statistics (percentages) Cross Tabulations Correlation	Findings: 1. Energy Crisis (1973-74) seen as failure of American institutions. 2. Energy Crisis was mainly experienced by middle class. 3. Conservation behaviors reported exceed belief in the problem and expectations of government and other institutions. 4. Attitudes toward Energy Crisis appear to be anchored in individuals' social setting. Implications: 1. Importance noted between socio-economic level of family and social setting of individual--this implies that public policy focused on income needs to also considered the strength or weakness of surrounding social setting. 2. Volunteerism is important and needs to be encouraged as a part of social context.

Thomas A. Heberlein, January, 1975. Social Norms and Environmental Quality. A paper presented at the American Association for the Advancement of Science. Annual Meeting, January, 1975.

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Statewide telephone survey, March 1974, conducted by Wisconsin Survey Research Laboratory (N=114)	Theory of Norm Activation: 1. Awareness of negative consequences (AC) 2. A felt personal responsibility (AR) Help explain along with characteristic demographics, i.e., income, education data, the reported behaviors. The paper used 3 behaviors to test theory. 1. Littering behavior 2. Purchase of lead free gasoline 3. Household and transportation conservation behaviors.	Research Questions 1. How do norms influence behavior? 2. When and how does a norm influence action?	Independent Variables: - Awareness of negative consequences (AC) - Felt personal responsibility (AR) - Perceived social norm (sanctions) - Perceived social norm (behavior) - Anti-oil beliefs - Belief government should run oil industries - Republican - Education - Personal norms (to save energy) Dependent Variables: Reported general energy conservation (Behavioral Report--not observed behavior).	- Factor Analysis - Multiple Regression - Path Analysis	Findings: - Personal norm to conserve energy is substantial (98%) - Awareness of consequences of one's own conservation behavior and ascription of personal responsibility for energy shortage were important determinants of personal norm to conserve energy. - Personal norm to conserve energy predict composite-behavioral report--general energy conservation. Implications: - Attitudes do not readily predict behavior. A single variable does not predict behavior which is assumed to be determined by multiple effects. - This study does support robustness of activation theory--to broader social problems.

Rovena Kilkeary and Patricia J. Thompson, January, 1975. The Energy Crisis and Decision-Making in the Family: Report, Herbert H. Lehman College, City University of New York (unpublished, however reported in Sylvia Porter's column, January 3, 1975).

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESES	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Interviewer Localized Survey (N=602) Head of Household or Spouse.	None Stated. Some consideration was given to these questions. 1. Has energy crisis motivated conservation? 2. Are consumers aware of their role in energy crisis? 3. Reaction to energy crisis? 4. Does knowledge about the crisis affect consumption? 5. What does the public know about energy saving and wasting practices?	Energy conservation will be related to these factors: 1. Exposure to extended blackouts 2. Consumer's payment of utility bills 3. Car ownership 4. Belief in concerted family effort to save energy by all U.S. families. 5. Family income. 6. Education attainment. 7. Family composition. 8. Consumer's age. 9. Consumer's sex. 10. Consumer's pruchases of a major appliance in year previous to study.	Independent Variables: 1. Exposure to blackouts 2. Payment of own utilities. 3. Car ownership. 4. Belief in concerted effort to save energy by all U.S. families. 5. Family income. 6. Educational attainment. 7. Family composition. 8. Consumer's age. 9. Consumer's sex. 10. Purchase of a major appliance in year prior to the study. Dependent Variables: Energy conservation practices as measured by: 1. Energy Knowledge Inventory (EKI) 2. Changed Practices Inventory (CPI).	Analysis of Variance Chi Square Pearson's Correlation	Findings: 1. Car ownership, income, educational attainment, family composition are related positively to energy knowledge inventory score (EKI). 2. Exposure to blackouts, direct payment of utility bills, car ownership, belief in family effort, income, and family composition are positively related to changed practices inventory score (CPI) 3. Moderate income families are striving to be energy saving--higher income families who can afford to pay higher bills are doing less. Implications: Efforts must be made to induce affluent, well-educated consumers to practice energy conservation. Courses in Home Management could provide this opportunity.

Richard A. Winett and Michael T. Nietzel, 1975 (in press). "Behavioral Ecology: Contingency Management of Consumer Energy Use" in American Journal of Community Psychology, 1975

RESEARCH METHOD	THEORETICAL AND/OR RESEARCH CONSIDERATIONS	HYPOTHESET	VARIABLES	MODES OF ANALYSIS	MAJOR FINDINGS AND IMPLICATIONS
Experimental Design (N=31) all volunteers	Behavioral Ecology Model: Incentives-Motivate Behavior 1. The organization of consumers to provide input into environmental decision-making. 2. Pilot-level evaluation of alternative environmental protection programs. 3. Experimental comparisons of promising alternatives to existing environmental policies. 4. Empirically based attempts at implementation and dissemination of community-wide ecological programs.	H_o: Implied--no difference between treatment and control groups. H_o: Relationship between EQQ and energy use.	Pretest: Assessment via an Environmental Quality Questionnaire (EQQ, Nietzel and Winett, 1974). Independent Variable: 1. Treatment: - Informational and monetary incentives - Pay to participants who used less energy by a weekly criteria. 2. No Treatment: - Information only. Dependent Variable: Measured use of electricity and natural gas.	Analysis of Variance - One way - Two way - Repeated measures Correlation Analysis	Findings: H_o: Rejected experimental group with incentive used significantly less electrical energy (15% more reduction) Natural gas was more related to climate than experimental treatment. 2 month follow-up detected a tendency for the affect of experimental condition to wane. Implications: Different experiments needed to assess the incentives programs theory to change behavior in long run.

The listed studies give evidence of the scope and breadth of the research which has been done within the context of the "energy uncertainty" period mentioned earlier. Of the fourteen items reported, studies done by Murray, et al., and Newman-Wachtel, were issued first as papers or preliminary reports, and were later published (Murray, et al., April 1974, pp. 257-262; Newman and Wachtel, 1974, pp. 113-130), thus reducing the number to twelve separate, discrete pieces of research. Both the Schwartzs' and Kilkeary mentioned the unfortunate lack of related research from which to build research efforts (1974; 1975).

Themes of the studies.--Of the studies done, several themes emerge: (1) Energy demand and expenditures (Heredeen, 1973; Hittman Associates, 1973; Bullard, 1973); (2) Household response to the energy crisis (Murray, et al., 1974; Newman and Wachtel, 1974; Kilkeary, 1975); (3) Energy conservation through technological innovations (Bullard, 1973; Hittman, 1973, Fox, et al., 1973); (4) Conserving behavior (Heberlein, 1974, 1975; Winett and Nietzel, 1975; Kilkeary, 1975). Most of the studies were concerned in some degree with the implication that changes in behavior and/or technological modifications could or would have on future energy consumption.

Conservation of energy was the most prevalent theme. Eight out of the twelve studies either highlighted or gave implicit attention to it. A second theme, the impact of the energy crisis, was given attention in four of the works and reflected the most immediate concerns generated by the energy crisis itself.

Research methods.--A variety of research methods were employed in the studies reviewed in Table 5. Table 6 is a summary of the methods used to indicate the diversity.

Household characteristics.--Eight out of the twelve studies used some standard demographic data to describe the households. In two cases criteria were stated for selection of the respondents. Kilkeary and Warren both specified head of households or spouse, whereas the other six studies only implied using these criteria.

The four studies that did not use some descriptive variables of the households were the three simulations and the Heberlein (1974) study. Heredeen simulated sectors of the economy indirectly related to household consumption, whereas Bullard simulated sectors of the economy directly consumed by households, however, neither included households per se.

TABLE 6.--Research Methods Employed and the Sample Size, by Researchers.

Researchers	Sample Size	Research Method
		Simulation:
Heredeen	367 Sectors of Natl' Economy	Input/Output analysis
Bullard	82 Sectors of State Economy	Input/Output analysis
Hittman Assoc.	--	Input/Output energy analysis ("The Characteristic House")
		Experimental Research:
Fox, et al.	401 Townhouses	Comparison of two townhouse architectural styles
Heberlein, 1974	96 Apartments	Time series experimental design: 2 experiments; 3 experimental groups, 1 control group
Winett & Nietzel	N = 31	1 experiment; 1 experimental group, 1 control group
		Survey Research:
Murry, et al.	N = Approx. 700	National probability survey (continous weekly cross-sections)
Heberlein, 1975	N = 114	State wide telephone survey
Newman & Wachlet	N = 1,455	Natl' probability survey plus survey of utility companies
Schwartz & Schwartz-Barcott	N = 200	State wide telephone survey (modified panel study)
Warren	N = 766	Survey of 8 Detroit area communities
Kilkeary	N = 602	Survey of two New York area communities* Kingsbridge area of Bronx Jackson Height area Queens

*In the Kilkeary study 2 areas mentioned in the Table were included as control and experimental groups. The Kingsbridge area had not experienced a "black-out" since 1969, whereas the Jackson Heights area had experienced an extended black-out in August of 1973.

Hittman Associates simulated a typical family to be two adults and two children as a part of the "characteristic household." It is not clear that any demographic data were used as a basis for this simulation decision. The body heat contributed by the presence of the simulated family was the only characteristic used in the programmed analysis. Heberlein in his 1974 study used the apartment dwellers as recipients of the four experimental conditions concerning energy consumption; however, only the electrical data were used to measure changes in their behavior patterns vis-ā-vis the experimental treatments.

Fox, et al., indicated access to much data on the families of Twin Rivers and some description of the family characteristics were given; however, only income and family size were used in the analysis, which did not prove significant in relation to energy consumption. The homogeneity of the town-house dwellers was implied as the reason these factors washed out in the analysis as compared to the physical housing variables.

Residential Energy

Out of the twelve studies reported, five were directly related to residential energy (Hittman, 1973; Fox, et al., 1973; Heberlein, 1974; Newman and Wachtel, 1974; Winett and Nietzel, 1975), the other seven were indirectly focused on residential energy as a part of total energy use (household and transportation energy consumption), as a function of the energy problem generally.

Those studies directly related to residential energy were often most concerned with establishing a measure of energy consumption within the household as baseline data upon which to discover energy conservation guidelines. For example, the Hittman Associates study (the simulated "Characteristic House") and the Fox, et al., study (Twin Rivers, Townhouses) were both detailed studies of environmental climatic conditions and physical housing characteristics affecting energy consumption.

The Newman and Wachtel study was designed to study energy consumption and costs as related to family socio-economic status (family income was used to establish four groups: poor, lower middle, upper middle and well-off households); however, some physical housing and family transportation characteristics as well as energy types were included to give greater descriptive value to the study. This study was less interested in energy conservation per se and more interested in recommendations toward ameliorating the inequities between socio-economic groups which present energy policies appear to reinforce.

Both the Heberlein (1974) and the Winette-Nietzel studies were experiments set up to induce changes in energy consumption behavior, giving less attention to the detailed analysis of physical housing characteristics, although, Heberlein controlled housing by studying only apartments in six complexes with very similar physical features.

All the five studies most directly related to residential energy acquired, through utility companies or meter readings, the exact amount of energy consumed for the duration of the study. Hittman Associates, Fox, et al., and Newman and Wachtel gained the cooperation of the utilities providing natural gas and electricity to the areas or families studied. Heberlein used only electrical data from meters read daily at a specified time.[1] Winett and Nietzel acquired both electrical and natural gas data from bi-weekly meter readings done at specified hours. In both of these cases, students were trained and used as meter readers.

Three of the studies transformed or converted primary energy measures (gallons of gasoline, cubic

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[1]Access was gained to meters located in the apartment complex, through permission of the management. Apartment dwellers were unaware of this access.

feet of natural gas, kilowatt hours of electricity) into some other standard measurement. Therms and/or B.T.U.'s are the most convenient and widely understood conversion measurement employed.[2]

Hittman Associates and Fox, et al., used the therm in reporting energy consumption; Newman and Wachtel used the BTU (including in the conversion for electrical energy, the energy expanded in production and transmission or the indirect as well as direct BTU count). The two other studies used the primary forms of measurement.

Heberlein (1974) was concerned only with kilowatt hours of electricity, whereas each of the other four studies included both gas and electricity. In each of these cases the energy source measured was studied separately, except in the Newman and Wachtel research where both separate and combined totals in BTU's were used. The other seven studies did not use actual energy data as a part of the research design, with the exception of Bullard, who used aggregated energy data for the State of Illinois measured in BTU's.

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[2] A therm = 10^5 BTU
BTU = British Thermal Unit

Reviewed Research as Related to Present Study

Not much research has been done related to residential energy previously and, further, recent works were generated simultaneously or nearly so with the present research; therefore, most of what has been reported here has had little effect on the research design, the conceptual framework, the selection of sample or variables or hypotheses in the present study. However, there were a few exceptions. The telephone questionnaire used in the Schwartz and Schwartz-Barcott (1974) study was made available to the interdisciplinary research team prior to the field survey from which this study emerged. Some of the questions were included and some were modified for the energy portion of the self-administered questionnaire of the pilot study (to be discussed in Chapter V).

The Fox, *et al.*, study gave insights into the kinds of physical housing characteristics useful in studying energy consumption; however, less detail was requested from respondents of this present study. Fundamentally, this pilot study was designed as a broad overview of family functions related to energy consumption, not simply as a study of family energy consumption. This will also be discussed briefly in Chapter V.

The analytic mode adapted for this research was, however, influenced by Heberlein's (1975) study of energy conservation behavior, although neither the content nor the theoretical frame of his study had any bearing on this work. Heberlein's variables and hypothesized relationships lend themselves well to regression and path analysis. The Heberlein study is a model building exercise whereby factor analysis singled-out the variables of relative importance, the regression analysis indicated the relative strength of the selected variables and the path analysis gave both visual and correlational indication of the direction and strength of the variables as they contributed to the variance explained in the outcome variable. The determination of the variables explaining an outcome variable is what the Heberlein study has in common with the present work, however, a difference does exist.

This study is a test of a pre-conceived and structured model, thus it is not a model building exercise, per se, but rather a model testing enterprise. Multiple regression and path analysis will be the major mode of testing the viability of the hypothetical model.

CHAPTER III

SYSTEMS THEORY

Rationale for a Systems Approach

Theory construction and thus theory validation through empirical research have been hampered in broad areas of knowledge by specialization. Laszlo suggests, "As a result, the fields of knowledge are worked in patches, each man concerned with no more territory than his own, cultivating his own garden" (1972, p. 4).

In general, specialization has occasioned a fragmented, disconnected set of postulates, theories and empirical findings which tend to blind individual areas of investigation to the wholeness, unity, order and relatedness that exists within and between them.[1] In other words, there is a need that is not being fulfilled by specialization. This need is articulated by scientists and philosophers alike as indicated by these statements:

> There is a need today for bringing fresh and reliable empirical information into philosophy (and other endeavors); for overcoming the patchwork approach in the use of knowledge as a means of safeguarding ourselves against disaster due to

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[1]Appendix A is a glossary of systems terms.

> ignorance of the systematic interconnections in nature; and for gaining insight into general patterns of existence in this world as a means of providing meaning for the brute fact of being here (Laszlo, p. 7).

and

> In recent years increasing need has been felt for a body of systematic theoretical constructs which will discuss the general relationships of the empirical world (Boulding in Buckley, 1968, p. 3).

Thus, for the scientific community, at least, there has been a growing frustration with the barriers to communication which have developed with the specialization and compartmentalization of knowledge and scientific endeavors.

Perhaps the time has come for a re-examination of scientific goals, emphasizing the importance of integration and synthesis between and among apparently disparate fields of inquiry. This, in fact, is being called for both in the investigations surrounding the energy problem and in the study of the family. As the linkages between these two areas are of central importance in this study, the rationale for the adoption of a variant of systems theory will be developed here.

Systems Approach: The Energy Problem

The energy problem does not exist in a vacuum and, therefore, cannot be understood as an isolated phenomena. Odum suggests, that to understand fully the multi-dimensional aspects of the energy problem a systems approach is required; i.e., a "common sense overview" is indicated rather than the "tunnel-vision thinking" so often apparent in our specialized economic, technological, research approaches, where unidimensional paradigms focus on only one part of the system at a time (1974, p. 227).

Odum calls for a systematic-holistic approach to the study of energy, as illustrated in the following statement:

> As long-predicted energy shortages appear, as questions about the interaction of energy and environment are raised in legislatures and parliaments, and as energy-related inflation dominates public concern, many are beginning to see a unity of a single system of energy, ecology and economics (1974, p. 227).

Systems Approach:
The Family

The study of the family is no exception to the rule of specialization, witnessed by the profusion of conceptual frameworks that abound in the analysis of the family. At least twelve different frames of reference have emerged. They have been identified as: anthropological, structural/functional, demographic, institutional, interactional, situational, psychoanalytic, social-psychological, developmental, economic, legal and religious (Christensen, 1964; Nye and Berardo, 1966; Hill and Hanson, 1968; Broderick, 1971). Although each of the frameworks mentioned contributes insight into some aspect of family behavior, either as it relates to the socio-cultural system or as it relates to individual development and interaction, they do not contribute to an integrated understanding of the family as related to both its social and physical environments from a systematic-holistic perspective.

There is, however, evidence both in the theoretical literature and in the empirical work on the family that indicates the fruitfulness of a systems approach. Although the evidence is not strong, being limited in scope and non-empirical, it does lend support to the notion that families can be studied using systems frameworks. Families have been conceptualized as a social system (Parson and Bales, 1955), as an ecosystem (Hook and Paolucci, 1970; pp. 315-318; Auerswald, 1973) as a functional system (Giesmer, 1971; David, 1967), and further from a general systems perspective (Kantor and Lehr, 1975).

Some evidence of the use of ecosystems models for the study of the family have been identified. These have for the most part been theoretical models (Sims, et al., 1972; Vaines, 1974), that have been tested using traditional statistical analysis. Causal reflective models (with positive and negative feedback loops) have been recently used in family research

(Reiss, 1972; Black, 1972), however, no models of the cybernetic-morphogenic (closed/open) systems variety has been developed for the study of the family (Black and Broderick, undated paper). Hill has given serious attention to the use of General Systems Theory in conjunction with the family development framework, in order to speculate about the systemness or systems isomorphic between society at the macro- level and family as its microcosm (Hill, 1971a; 1971b). To this author's knowledge this has not been empirically tested.

It would appear that the use of ecosystems, cybernetic and general systems theory or some variant of these in the study of the family is becoming a viable approach to understanding the family from a wholistic, systematic perspective.

General Definition of Systems

A system, according to Webster, is an "assemblage of objects united by some form of regular interaction or interdependency; an organic or organized whole." Implicit in this definition is the idea of parts that make up a whole or unity. There is also implicitly expressed some form of arrangement, organization, order. A system can be organic or inorganic; physical, biological or sociocultural. In fact, a system can be a combination of things or parts that form a whole. That whole can be of any breadth or scope and complexity ranging from very simple to multi-dimensional, macro- or micro-, finite to infinite. Any of these attributes can be used to define a particular system.

Systems notions are not new; they have been known and studied for centuries, particularly as religious and philosophic interpretations of the relationships between man and nature.

> The earliest systematic speculation of mankind regarded the universe as a sphere of order and harmony, and considered it man's duty to fit himself into it with his conscious purposes (Laszlo, 1972, p. 282).

Laszlo further contrasts Oriental and Western thought, indicating that the Oriental ethic even today is "oneness" of self with nature, i.e., a reverence for nature as something to be held respectfully "for itself"; whereas, Western cultural thought since Christianity has been dominated by the Puritan ethic "of using nature for human ends" (1972, p. 282).

The most recent emphasis, however, in the study of systems is the attempt to understand systems as a whole or as Ackoff indicates to understand systems as an "<u>entity</u>" rather than simply "<u>a conglomeration of parts</u>" (1959). Thus, beyond the identification of the elements or components of a system under definition, it has become equally important to study the interactions within and between systems to uncover their linkages and interdependencies, i.e., to qualify and quantify the energy, material and informational exchanges across systems boundaries.

Three variants of systems theory will be discussed as an introduction to the more specific application utilized as the conceptual framework of this study.

Ecosystems, Cybernetic Systems and General Systems: Structure and Control

Ecosystems[2].--The word "ecosystem," coined by the late biologist, A.G. Tensley in 1935, is defined as "The whole system including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment" (1935, pp. 284-307). Most accepted definitions of ecosystems include the idea of a dynamic interaction, exchange, or interdependency between an organism (O) or an aggregate of organisms and the environment (E).

In the definition given earlier of a system there is not an explicit reference to the concept "environment", either as a setting for the interaction in the system or as a part of the dynamics of the interaction; therefore, a system is not an ecosystem except by definition.

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[2]"Eco" means environment; systems indicates an "interacting, interdependent complex" (Van Dyne, 1966, p. 31).

The ecosystems approach was developed in the biological sciences as a means of studying flora and fauna in symbiotic interrelationships with their natural habitat (environment). The formal recognition of the relatedness of organism and environment, introduces a unique perspective on the nature of systems.

> As L.J. Henderson took great pains to point out in his book, The Fitness of the Environment, the environment is just as basic as the organic system in the intimate system -- environment transactions that account for particular adaptation and evolution of complex systems (Buckley, p. 50).

Thus, within an ecosystems framework, organic and physical environmental systems are seen interactively, therefore, integratively. That is, the organism is considered interdependent with the environment, such that to study each in isolation is to deny, thus not include, important effects related to the interaction between them. Figure 1 illustrates this interdependence:

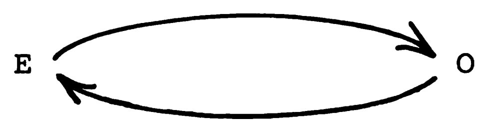

Figure 1.--Environment and Organism Interrelation.

The development of an ecosystems perspective has a history that can be traced to the writings of Darwin

(1892), who established the groundwork for what later became the science of ecology in the biological sciences mentioned above, and more recently in sociology, geography, anthropology, psychology and home economics.

An ecosystems perspective in the natural sciences focused on plants and animals as the organism of interest. The term ecology, first used by the German biologist Ernst Haekel in 1868 is derived from the Greek Oikes, means house or habitat (Hawley, 1950, p. 3). Sometimes the emphasis is on the individual organism as in micro-biology and at other times the unit of concern becomes the community or aggregated organisms. The environment of central interest is the natural physical environment.

The relationships of interest were identified as the behaviors which were observed as the outcome of the interaction between the organism and the environment. Therefore, such notions as symbiosis, adjustment, adaptation, territoriality, competition, dominance, invasion and succession became the central interrelational concepts. Emphasis was placed on "the processes of consequences of change" (Adams, 1935); i.e., on the dynamic aspects of the system rather than on the static dimensions.

As indicated, an ecological perspective eventually developed in both sociology and geography -- labeled Human Ecology.

Geography considers itself the science of human ecology defining its concerns to be "the relationships existent between the natural physical environment and the activities of man" (Barrows, 1923). Investigations in geography emphasize such deterministic variables as climate, natural resources, natural routes and topography as they influence human customs, beliefs, and attitudes (White and Renner, 1961).

Sociology on the other hand considers human ecology a subfield in the discipline that has been defined as the "study of spatial and temporal relations of human beings as affected by the selective, distributive and accomodative forces in the environment" (McKenzie, 1934, p. 288). Its particular focus is human aggregates related to spatial configuration in the man-made physical environment including the block, the neighborhood or some area of the city. The interrelative variables studied were social pathologies, such as crime and mental illness (Park and Burgess, 1921; Mckenzie, 1934; Faris and Dunham, 1939).

Anthropology also has contributed to an ecological perspective by emphasizing the relationships between "cultural behaviors and environmental phenomena" (Vayda, 1969). The organism of interest for the cultural anthropologist has become the human aggregate; i.e., the collective behaviors of particular groups. The environment of interest is the material world both natural and man-made. And, the interrelationships which link the behavior and environment are such variables as: values, ideologies, traditions, norms, linguistic characteristics, also including individual (personality structures) as well as cultural life patterns.

There are two basic approaches to the study of the linkages between cultural patterns and the environment. The first is a systems approach, whereby behavior is seen as a part of the total behavior/environment complex (Lee, 1966; Thomas, 1973; Gould, 1963; Geertz, 1963; Rappaport, 1967; Vayda, 1969). The second approach is the environmental deterministic perspective; i.e., the study of the extent to which environmental factors affect the origin and development of cultural behavior (Duncan, 1961; Flannery, 1965; Kroeber, 1939; Whiting, 1964).

Most recently psychology has also developed an ecological sub-area. Environmental psychology and ecological psychology are the labels used to identify it. The definition remains somewhat illusive due to the diversity of interests reflected within it. The human individual is of concern; however, varied human groupings and configurations are also studied. The environment of special interest has been the physical built environment, in particular the spatial arrangements within buildings and housing arrangements (Sommer, 1969; Proshansky, Ittleson and Rivlin, 1967; Rainwater, 1970; Altman, 1972; Newman, 1972). However, environmental psychology has not been limited only to internal spaces. Other spatial arrangements in the urban environment and even natural environment also have been considered (Jacobs, 1961; Criak, 1966; Barker, 1968; Michelson, 1970; Goffman, 1963; Cooper, 1975).

The interrelationships of concern have included: privacy, crowding, density, territorality, locomotion, perception and competence.

Nowhere in the fields mentioned above has the family and its environmental interdependency been of central concern. However, in the field of home economics, early developments were very much within an ecological perspective, largely due to the efforts of Ellen Swallow Richards,[3] who christened environmental science as "Oekology" and further emphasized its importance as a science stemming from everyday life which begins with sound environmental conditions and practices in the home.

Home Economics as a profession was founded on that principle. The definition developed in 1902 at the fourth annual Lake Placid conference is as follows:

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[3]Ellen Swallow Richards, during a period between 1870 and 1911, was the first woman student at M.I.T., its first female faculty member and a vigorous researcher and activist in the fight for pure water, air and food, good

> Home Economics in its most comprehensive sense is the study of the laws, conditions, principles and ideals which are concerned on one hand with man's immediate physical environment and on the other hand with his nature as a social being, and is the study specially of the relationships between those two factors (AHEA, 1902, pp. 70-71).

A recent re-emphasis of this ecological perspective has been initiated in the field of home economics with a change of name from Home Economics to Human Ecology within various universities, i.e., Cornell University, Michigan State University, and the University of Maryland.

The focal organism within this new re-emphasis, has become the family as an environed unit: an ecosystem within its near physical/biological and social/psychological environments (Hook and Paolucci, 1970; Steidl, 1969). The linkages between the family and other systems is the theme of the re-emphasis. This includes a particular interest in energy/matter/information flows (exchanges across and within the family system boundary) as processed and transformed by the family in everyday living. Thus, empirically establishing the degree of boundary maintainance within the family (its open or closedness to other systems) taking into consideration the social, economic, political and natural environmental constraints is central to a redefinition of the field.

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nutrition, product labeling, safety and sanitation in both the work place and in the home. (See Clarke, 1973 for the detailed account of Ellen Richards' contribution to home economics/human ecology).

The research endeavor undertaken here is indigenous to and developed within this family ecosystems perspective.

Summarizing then, the central organizing concepts around which all of the above mentioned ecosystems approaches have been developed are as follows:

1) Organism or environed unit (O),
2) Environment (E), and
3) The interrelation between the two (Sprouts, 1965, p. 25).

Ecosystems are structural interrelational systems suggesting the interface between one system and another. The following discussion of cybernetic and general systems indicates something of systems function and control.

Cybernetic systems.--Cybernetics, as proposed by its founder, Norbert Wiener in 1948, ". . . is the science of control and of information, whether applied to the living world or to the inanimate machine" (Parsegian, 1972, p. 9).

Although the science of cybernetics is relatively new, coming as it did into its own during World War II, its historical roots can be traced back as far as Plato, whose works contained the first known reference to the word "Cybernetics" (Parsegian, 1972, p. 6).[4]

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[4]Kyberns was the Greek term for steersman, which gave root to the Latin term gubernator and finally to the current term, governor.

> The Cybernetics of man, as you Socrates, often call politics. . . (Plato, 428-348 B.C.).

The reference here is to governmental control, however, its deeper implication is ". . . the idea of man's controlling his own fate. . ." (Parsegian, 1972, p. 6). This could, also, be expanded to include management in the household.

Mechanical control devices have been known and used by man in regulating aspects of his environment for generations. Such mechanisms as the windmill, the steam engine governor are early examples. More recently servo-mechanisms from thermostats to guided missiles and including guided manned space vehicles illustrate a few of the many possible examples.

The theory of control systems grew out of an understanding of mechanical systems. The application of the mechanical systems model to living systems was an attempt therefore to use the laws and principles of physical mechanics to explain the functions of organisms and social units with more precision; i.e., borrowing from the earlier success of physical scientists. Thus, such notions as time, space, attraction, fields of force, and energy (along with the laws of thermodynamics and especially equilibrium) were translated into terms such as social space (Lewin, 1947), social systems (Pareto, Parsons, Homans and others), social dynamics and social equilibrium (Buckley, 1967, pp. 8-9).

At one point such emphasis was placed on the analogies between mechanical and living systems that life was labeled "a living machine" and a counter force decried the de-humanization or mechanization of mankind (Bertalanffy, 1968, pp. 134-141).

In spite of the debate over the "fit" of the mechanistic model, the theory of control systems became the catalyst for a "crop of new approaches and theories." Information, game, decision, circuit, automata theory and systems analysis, to name a few, coalesced into the theory of systems cybernetics. Wiener, in his book Cybernetics (1948) formalized the discipline.

Although cybernetic systems can differ in the focal system of interest (for example, mechanical, social, organic, communications, neurophysiological, etc.) they do, however, have certain features in common.

Parsegian suggests that these factors are:

1) Each of the situations involves variables.

2) Each involves interactions of machines or organisms with the environment, although in the most general case limited.

3) Each involves an element of purpose, or object, and utilizes control principles addressed to these purposes.

4) The interaction involves feedback, wherein the results of any act are fedback to modify the initial act.

5) The feedback may take the form of information.

6) Each represents a dynamic situation in which <u>energy</u> (human or mechanical) is utilized to respond to changes and yet maintain stability (cf. Parsegian, p. 2).

The above description of a "closed" cybernetic system, including its general concepts and structural features, indicates something of the necessary conditions which must be present for the system to operate; however, it does not indicate the system functions. Therefore, the following will specify a conceptual model of the process dimensions of a "closed" cybernetic system. This model has been adapted from Buckley's "social goal seeking" model (1967, p. 197). Thus, any closed cybernetic system generally exhibits:

1) A <u>control center</u> (1) which establishes goal parameters toward self-regulation.

2) These goals are translated into <u>action outputs</u> (2) which affect the state of the system.

3) <u>Information</u> (3) about the state of the system is fedback to the control center.

4) The control center <u>compares</u> (4) the state of the system with the goal parameters, and,

5) takes <u>corrective action</u> (5) if the system is outside the parameters set (cf. Buckley, p. 174).

Figure 2 is a schematic interpretation of this process.

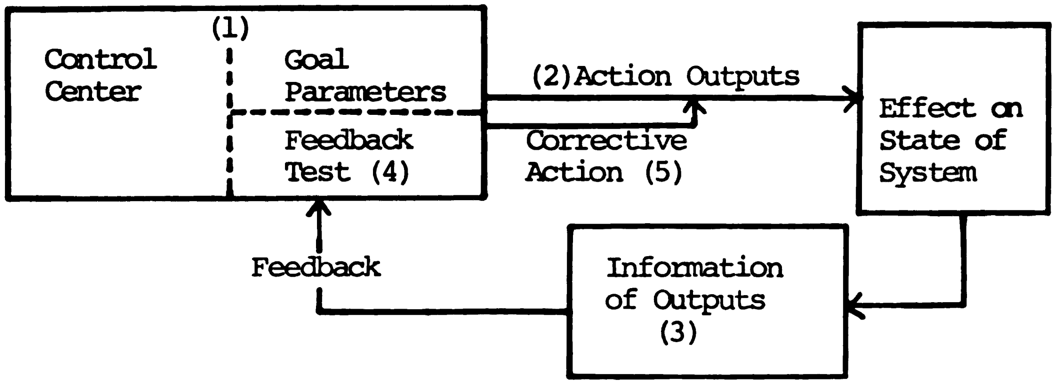

Figure 2.--Schema of Closed Cybernetic System Operations (modified from Buckley's, p. 173).[5]

This representation has been modified from Buckley's model of social goal seeking to exclude all exterior environmental systems effects which therefore allows the label of "closed" cybernetic system. Open systems which Buckley suggests in his model will be discussed as part of the general systems theory in the next section and a comparison between open and closed systems properties and conditions will be given at the end of the next section.

In summary, then, cybernetic systems are generally:

1) Systems which are controlled, self-regulating or adaptive self-stabilizing.

2) Systems which have a purpose and therefore are goal-directed.

3) Systems which respond to negative feedback as the controlling mechanism in the system.

[5]This cybernetic model was compared to Kuhn's (1974) detector, selector, effector process system and found compatible. However, Buckley's model is included because it is an "operational" rather than a "conceptual" model, demonstrating more clearly a systems operation or function.

4) Systems whose ultimate state is equilibrium toward entropy (cf. Laszlo, pp. 38-41).

<u>General systems theory</u>.--Bertalanffy's definition of General Systems Theory (GST for convenience) is given as, "an interdisciplinary doctrine elaborating principles and models that apply to systems in general, irrespective of their particular kind, elements, and forces involved." (Bertalanffy in Laszlo, 1972, p. xvii).

Boulding considers GST a "system of systems" (in Buckley, 1968, p. 4), whereas Caws considers it a ". . . metatheory" (Buckley, 1968, p. 10), or a theory of theory.

The notion of an all-encompassing theory of systems was introduced by Ludwig von Bertalanffy in 1937, mainly in response to the need to explain biological (living) systems in other than physical-mechanical "closed" systems terms (mentioned earlier, p. 62). Living systems display certain attributes which are not consistent with "closed systems" theory; i.e., closed systems require <u>no</u> (or very limited) interaction with an environment, fix goal parameters, self-stabilization through error reducing negative feedback within fixed parameters toward an equilibrium and increasing enthropy. Whereas, living (organic) systems, in contrast, exhibit characteristics which are counter to these. They display response to inputs from the environment, acquisition of new parameters, instead of predictable reaction to "fixed" parameters, amplification of deviation as a function of positive feedback toward self-organization, or increasing organization (decreased entropy) thus, non-equilibrium or instability. These characteristics are properties of an "open" system.

Open systems are not, however, synonymous with general systems theory. Rather, "the theory of open systems is a part of a <u>general</u> theory of systems" (Bertalanffy, 1968, p. 149). Although open systems gained their impetus within the GST current and thus are often discussed as the "more general case," recent developments particularly the work of Laszlo (1972) would include a continuum of closed to open systems referred to in the literature by various labels depending on the permeability of their systems' boundaries. Figure 3 indicates these distinctions.

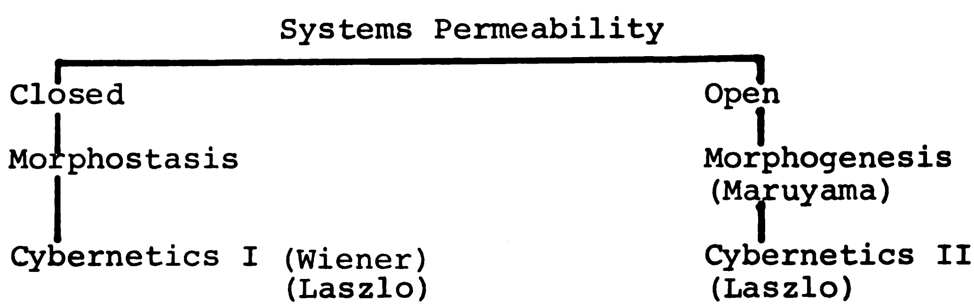

Figure 3.--Continuum of Systems, Closed to Open.

A general model of the process dimensions of an open system with characteristics listed below follows for greater clarity. Thus, an open system generally exhibits:

1) An <u>input</u> (1) that constitutes the control variable.

2) A <u>comparator element</u> (2) that tests input signal against the feedback.

3) A <u>converter</u> (3) that can amplify or dampen down the input signal.

4) A source of <u>energy</u> (4) and other environmental disturbances (5).

5) A <u>feedback</u> (6) information sensor.

6) And, an <u>output</u> (7) from the system to the external environment.

Figure 4 is an illustration of an open system.

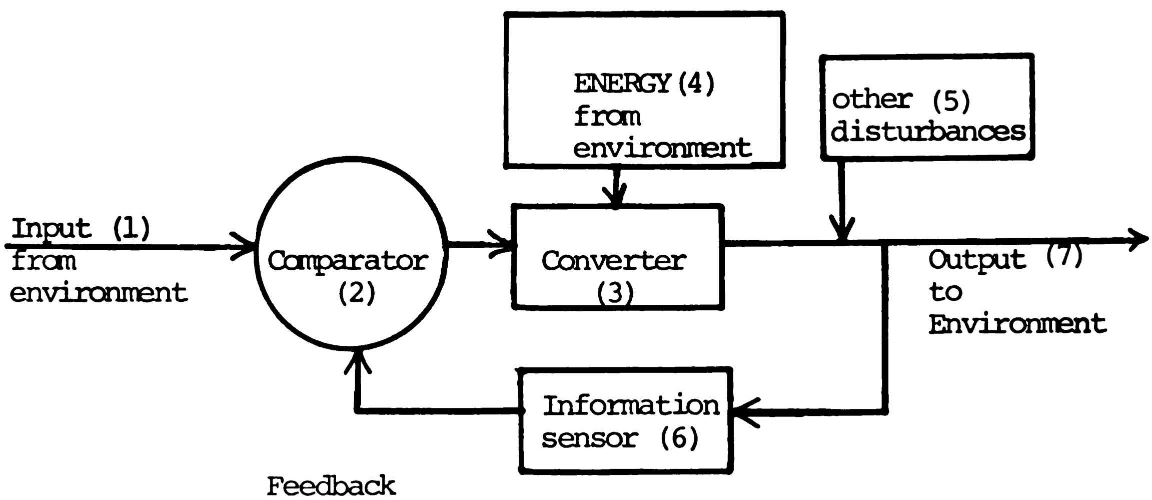

Figure 4.--Schema of an Open Cybernetic System (modified from Parsegian, 1972, p. 73).

It becomes possible now to compare open and closed systems (see pages 63 and 67). The greater complexity of open systems comes mainly from environmental inputs, both as control and as disturbance variables, as well as from the ability of the open system to convert or transform inputs.

> In general, the greater the range of effective interaction between the system and environment, the greater the effect of perturbations (disturbances) introduced. . . Consequently, the greater the requirements on enduring systems for correcting. . ., i.e, for adapting to conditions in the environment . . . (Laszlo, 1972, pp. 61-62).

Monge has suggested that "in order to conceptualize a phenomenon as an open system from the perspective of GST," a set of necessary and sufficient conditions must be meet (1972, p. 93). This listing follows:

1) Identification of the components of the system. These are the parts, which together with interactions, constitute the system. Parts may themselves be systems; if so, they are subsystems of the major system.

2) Specification of relations in the system. These are the laws of interaction among the components which form the <u>structure</u> of the system.

3) Determination of system behavior. This implies the identification of the <u>processes</u> which the system engages in over time, as well as the <u>properties</u> which these processes imply.

4) Stipulation of the environment. In open systems this is crucial because the system's exchange with the environment, i.e., its inputs and outputs, must be explained.

5) Determination of the system's evolution. Both history and future are included here. (cf. Monge, 1972, p. 93).

In summary, the central notions which general systems theory contributes to a systems perspective are the following:

1) The definition of systems as entities rather than sets of discrete but related parts (Ackoff, 1961; Bertalanffy, 1968; Laszlo, 1972).

2) The identification of systems hierarchies or levels and the relationships between them. (Laszlo, 1972; Bertalanffy, 1968).

3) The distinction between intra- and inter-systems hierarchies indicating both the "incorporative" (within system elements) and the "coactive" (between systems exchanges). (Laszlo, 1972).

4) The specification of the systems properties which are applicable to all levels and complexity of organized phenomena. This includes the natural system functions as most recently developed by Erwin Laszlo described by a functional model with these properties:

a) The systematic state property, i.e., the wholeness and order of the system.

b) System-cybernetic I, i.e., the adaptive self-stabilization of the system or systems closeness. (Morphostatic model: Wiener, 1961, Buckley, 1967; Bertalanffy, 1968).

c) System-cybernetics II, i.e., the adaptive self-organization of the system or systems openness. (Morphogenic model: Buckley, 1967; Black and Broderick, n.d.; Maruyama, 1963).

d) The Holon-property, i.e., the intra- and inter- systematic hierarchies, indicating the nature of the relationship between and within systems (Laszlo, 1972, pp. 35-53).

General Systems Theory is emerging as an integrating theory of systems which is tending to synthesize diverse systems paradigms (mechanical, organic, social, ecological) into one unified field theory. Thus, the vast diversity between specialization is giving way to the identification of the common systems properties underlying both the structure and function of systems, including levels from atoms to global systems.

Table 7 on the following page is a comparison of the major characteristic differences between closed and open systems.

The description of systems perspectives sketches in very broad outlines only the most general major contributions each approach makes to the unifying concept of systemness, i.e., toward a systematic, holistic frame of reference. Although necessary in order to place each systems approach into both a temporal and conceptual

TABLE 7.--Comparison of Closed and Open Systems Characteristics.

Closed System (Cybernetics I)	Open System (Cybernetics II)
1) Isolation from environment.	1) Exchanges between environment and system.
2) Systems state pre-determined by internal conditions.	2) Systems state determined and changing as influenced by internal and external conditions.
3) Equilibrium-stability rather than steady state.	3) Steady state some distance from equilibruim (equifinality or multifinality).
4) Negative feedback-reducing discrepancy between status quo & systems goals. (Morphostasis)	4) Positive feedback-elaborating structures to meet changing conditions surrounding goals. (Morphogensis)
5) Entropy increases.	5) Entropy decreases.

Sources: Buckley, 1967, Sociology and Modern Systems Theory, pp. 52-53, 58-59 and 70.
Black and Broderick, undated, Systems Theory vs. Reality, pp. 17-18, 23.
Monge, 1972, The Study of Human Communications from Three Systems Paradigms, unpublished Ph.D. dissertation, pp. 93-94.

frame, it does not go the full length toward making intelligible the conditions which allow the theories to become operational in empirical investigation. In other words:

1) What are the structural and functional identities common to all systems perspectives?

2) How are they made integral within this study?

Structural Commonalities

It is possible to see the commonality, though somewhat implicit, between these three conceptual systems formulations. For each systems approach whatever the label given, there is a focal physical or biological unit of organization which becomes the system of interest; there is a larger encompassing social or physical environmental surrounding and; further, there is a sub-set of physical, social and/or biological components which contribute to the make-up of the system of interest. Thus, for all systems perspectives mentioned there is a definition of a system of central concern as well as the identification of related inter- and intra- systems levels or hierarchies.

The Functional Unity

For each of the systems approaches mentioned there is also a reference to systems functions or processes which takes into account the influence the system of interest comes under and the processes of exchange (qualities or quantities) between that system and its environmental supra-system surrounds. And, further, the inner workings of the system are also of concern; i.e., the relationship between sub-system or inter-system parts as they influence the make-up and function of that system also are key functional considerations. In the discussion of each system, generally these functional or process dimensions were labelled in several ways. For ecosystems they are called the interrelationships or "observed regularities" between the organism and the environment. Several of these "regularities" were explicitly identified for each of the ecological approaches mentioned.

For controlled systems the function or process aspects were made explicit in terms of the closed cyberneticity of the system; i.e., the internal pre-determined control or comparator goal functions which necessitate the systems operation within a set of restricted parameters toward an equilibruim state and entropy.

When considering the general systems approach, particularly as viewed by Bertalanffy and Laszlo, the functions of the system are viewed within both a closed and an open cybernetic model (Cybernetics I and II). These cybernetic dimensions allow tracking the functioning of the system of interest from the initial systems state (point of first observation) through its various stages of adjustment and/or adaptation; i.e., either as the system stabilizes toward an equilibrium state becoming less open to external environmental (super-systems) influence or as it is organized toward a new complex state level, open to the external influences while further adapting internal structures and functions to meet the challenge of the external influence, via negative and/or positive feedback mechanisms.

Thus, as with the structural identity of the different systems approaches, included here, certain commonalities can also be detected within the functional dimensions. Each system is seen as a process with dynamic qualities that can be viewed in terms of spatial or temporal changes or stability. Therefore, a degree of interaction between and among systems levels can be measured in some qualitative or quantitative form; i.e., exchanges of energy, material or information occurs across or within system boundaries. "This exchange is identified as input to and output from the system" (Monge, 1972, p. 93).

Systems Integration: Unique Contribution to the Development of the Conceptual Framework

The major contributions made by each systems approach to the framework used here will not, however, be in the commonalities or unity found between them, but rather will be in the unique aspects each lends toward the development of a Human Ecosystems framework as generally employed here and within which specific systems relationships are empirically explored.

These unique factors will be highlighted and discussed briefly.

The ecosystem approach allows identification of the structural components and the hierarchy of systems levels considered of paramount importance to the conceptual framework. Thus, organism (environed unit) and environment are generally conceived as the central systems of concern. The organism being the central system; whereas, the environment is the supra-system surround.

Both closed and open cybernetic systems attributes taken from systems cybernetic and general systems theory will be employed to give clarity to the functional linkages between the central systems of concern. These linkages will specify the relationships in the system (particularly the inputs and outputs) which are the crucial interactions that give the system structure. The linkages between the organism and environment will be first developed within a broad conceptual framework. And, secondly, in Chapter IV the hypothesized relationships between a more narrowly defined subset of systems variables will be specified as the particular problem under investigation in this research.

CHAPTER IV

THE CONCEPTUAL FRAMEWORK AND HYPOTHESES

This chapter has two basic functions: first, to discuss the broad human ecosystems framework from which the more specific set of relationships to be tested empirically emerges and, second, to deduce the specific subset of systems components whose relationships (linkages) come under empirical test.

Development of the Conceptual Framework of this Study

Prior to the research undertaken here, the author developed a general analytic systems framework for the purpose of overcoming "past definitional and conceptual problems" related to the study of man/environment systems (B. Morrison, 1974, pp. 171-178). It will not be the purpose to review the framework in its entirety, but rather to extract portions of it to set the stage for the empirical investigation of this study.

This is by way of taking Ashby's "hypothetico-deductive" (Laszlo, 1972, p. 208) route toward the study of systems in contrast to Bertalanffy's "empirico-intuitive" approach (Buckley, 1968, p.15). Each approach has merit, depending on the intent of the systems researcher. For example, Ashby's approach lends itself particularly well to narrow systems analysis (the intent of this research); whereas the Bertalanffy method allows analogies to be drawn more broadly between systems; i.e., systems isomorphisms (not the intent of this research). These two positions or methods can be distinguished more clearly in Ashby's statement:

> Two main lines are readily distinguished. One, already well developed in the hands of von Bertalanffy and his co-workers, takes the world as we find it, examines the various systems that occur in it -- zoological, physiological, and so on -- and then draws up statements about the regularities that have been observed to hold. This method is essentially empirical. The second method is to start at the other end. Instead of first studying one system, then a second, then a third, and so on, it goes to the other extreme, it considers the set of all conceivable systems and then reduces the set to a more reasonable size. . . " (Ashby as quoted in Bertalanffy; Buckley (ed.), 1968, p. 15).

The latter position is the approach taken in this research, because the intent of this analysis is to investigate the relatedness (linkages) between systems, rather than the systems similarities (isomorphisms). In other words, it starts with the general phenomenon, attempts to see it wholistically and ends with a detailed scrutiny of the subset of the parts. However, an important qualification must be stated.

Although the Ashby approach is adapted generally, the particular mode of analysis for this research is different. Instead of using a series of differential equations[1] as the mode of analysis, multiple-regression and path analysis were the analytic tools used (to be explained in the Methodology Chapter). This is not to say that great differences exist between these two analytic modes, because they are in fact, quite similar; however, the use of multi-variate statistical analysis was an expedient taking into consideration the forms of analysis most familiar to this researcher.

The following then is the portion of the analytic framework considered useful in this research, modified somewhat to meet the present need for a broad systems perspective within which the specific problem can be explored.

A Conceptual Framework: Human Ecosystems Model

The Organism or Environed Unit: The Family

Within human ecology the organism or environed unit of concern are HUMANS, humans as individuals, humans

[1]For a review of summative and non-summative differential equations used in systems research see: Bertalanffy, General Systems Theory, 1968, Chapter 3, pp. 54-77.

as members of groups, humans as part of society. For the purpose of this research the notion of organism (O) as the first structural component will be expanded to include a small aggregated human group or system, the family.

Definitions of families have varied over time, from the traditional parent-child kinship household definition to a more contemporary view of "the family as a population aggregate or system, that is, a corporate unit which is circumscribed territorially within a household and which has some unit character differing from the characteristic of its individual members. . ." (Hook and Paolucci, 1970, p. 315).

Thus, the family (FS) is the system of central concern as the unit of analysis within this study. The family operates within and among several environmental realms as super-systems surrounds, each of which contribute to or hinder family life. These will be identified as the natural, built and behavioral environments.

The Environments of The Family

The notion of environment (E) the second structural component in the ecosystem approach is also of importance in the conceptual framework of this study.

Generally, environment is defined as "that which environs; surroundings; specifically the aggregate of all the external conditions and influences affecting the life and development of an organism, etc., human behavior, society, etc." (Webster, 1949).

Hall and Fagan have given further clarity to the relationships between systems and environment through this definition:

> For a given system, the environment is the set of all objects a change in whose attributes affect the system and also whose attributes are changed by the behavior of the system. (In Buckley, 1968, p. 83).

As suggested earlier, there are several environments within which the family interacts. These have been given definition by Luther Bernard, whose classification of environments follows, with some modification:

1) The natural environments (NE)
   a) Physical or inorganic environments (P)
   b) Biological or organic environments (B)

2) The built environments or derived environments (MBE)
   a) Socio-physical environments (S-P)
   b) Socio-biological environments (S-B)

3) Behavioral environment (BE)
   a) Socio-phychological (S-pys)
   b) Institutional (IE) (Bernard, 1925, p. 325).

Figure 5 follows to illustrate graphically the human ecosystems framework generally employed, showing the linkages between environmental systems as derived from Bernard's classification.

The Natural Environment

All life stems from the natural environment; it is the genesis of life. Thus, it is the ultimate environment of the individual and the family. In its unmodified form it "operates upon man and his social life" (Bernard, 1925, p. 325) through cosmic forces: the sun's heat and energy, climate changes, and natural mechanical processes. The natural environment is also the storehouse of organic and inorganic materials and energies which have potential for modification; i.e., natural materials (minerals, metals and natural fuels) make up the base supply of resources tapped by society, through skills and technology, in modifying or adapting nature to human needs and requirements. In other words, the natural environment is an uncontrolled ecosystem except to the extent that humans "impose conscious control on it" (Kuhn, 1974, p. 376 and 462).

Within this investigation climate, including temperature and seasonal change will not be of empirical interest. However, the inorganic resources in the form of natural fuels (particularly, petroleum, natural gas, and coal, to the extent it is used in electricity

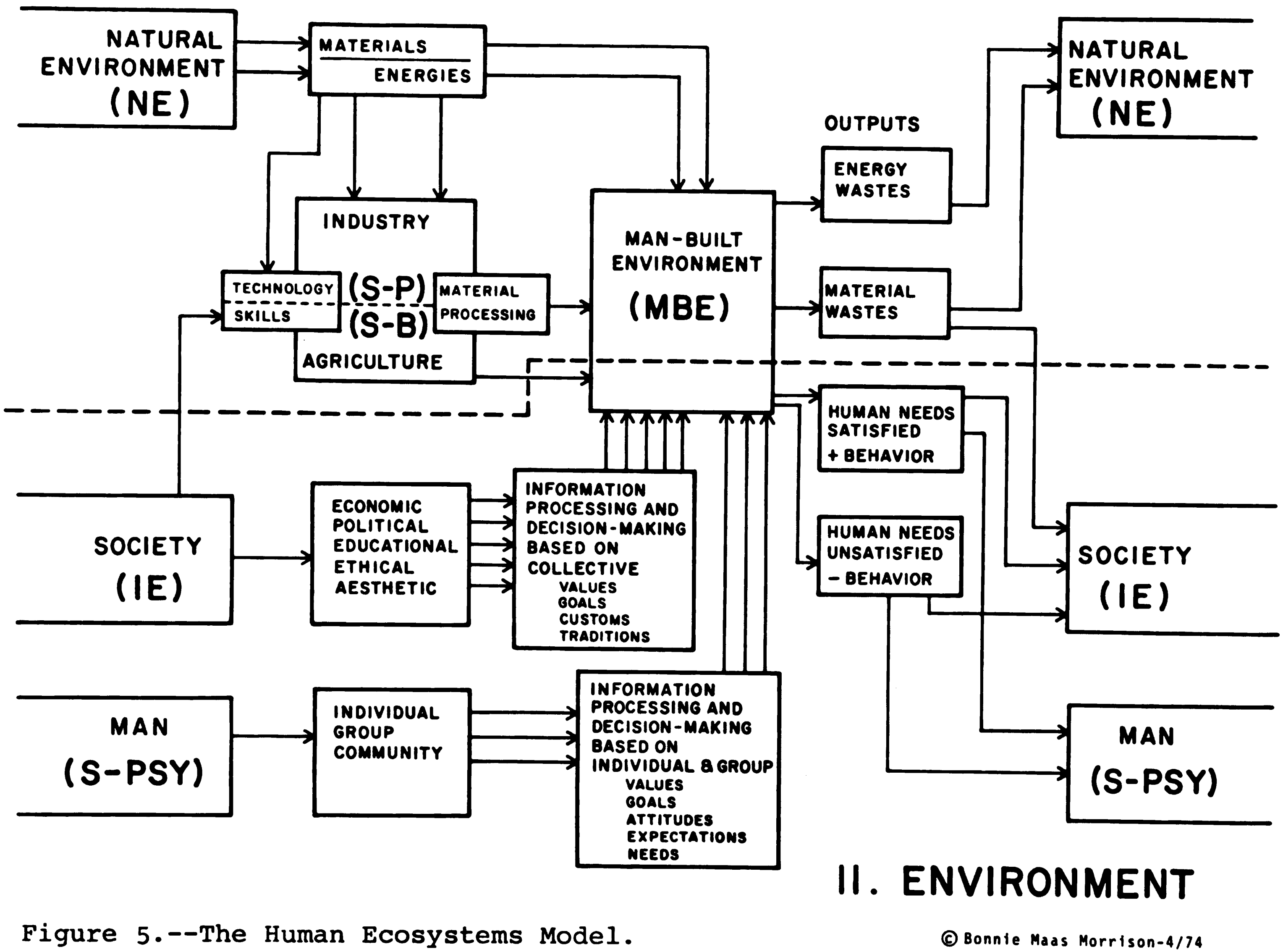

Figure 5.--The Human Ecosystems Model.

production) are of paramount concern. These resources are the major modified energy <u>inputs</u> in the systems framework. The consumption level, transformed to BTU's, will be the measured <u>output</u>, hypothesized to be determined by natural environmental, physical housing and family-social, economic and compositional factors.

The Built Environment

If the natural environment is the ultimate provider, the built environment allows life beyond mere survival. The built environment plays a critical role in mediating between the life of individuals and the family and the hostile forces of nature. The built environment is a person's nearest and most immediate physical environment and, in fact, is the primary environment for most of mankind most of the time. The environment derived from nature (cities, housing, clothing, transportation, communication and production systems) directly influences and configures human life and human interactions. For example, Studer suggested that the built environment is "essentially a system of energy-matter elements which are interposed between a collection of human participants and the antithetical forces in the general, impinging milieu" (1970, p. 58).

For the family one of the necessary built environments is the place of residence, the house. Thus, for the purpose of the empirical work to be undertaken here, i.e., the discovery of the major determinants of family residential energy consumption, the single family detached dwelling and its physical attributes will be the only built environment considered in detail.

Physical housing attributes such as, size in square feet, number of rooms, number of floor levels, number of openings to the exterior (windows and doors), insulation and type of construction, location and number of major appliances, will be taken into consideration as factors contributing inputs to energy use.

The Behavioral Environment

This environmental realm contains two systems levels relevant in this investigation. These are:

1) The socio-psychological, more intimate environment developed within the family.

2) The institutional environment which represents the social, economic, political, ethical and other societal forces which impinge on the family from outside.

Both systems levels involve information and decision making flows (inputs and outputs) as compared to the material and energy flows discussed previously (contrast the upper half of the conceptual framework with the lower half, p. 82).

The _institutional environment_ is organized around or defined in terms of problems and the collective means by which humans make adjustments to and manage their environments. Laws, rules, costs, knowledge, and collective values, expectations and goals, make up the aggregate information and decision-making processing which affects not only the consumption of materials and energies from the natural environment, but also exerts external influence over the collective activity of the family. Tallman suggests, for example, that linkages between the macro-social structure and individual behavior lie essentially in two spheres (institutional environments) i.e., the economic and political. He indicates that through the economic sphere, pricing and wage mechanisms influence the route to material goals. And, further, the political sphere influences through laws and other forms of regulation, the distribution, and thus the availability of goods and services (Tallman, n.d., p. 1).

Within this study the cost and availability of energy supplies as regulated by the economic and political institutions will not be hypothesized or tested, they will, however, be indirectly examined through family perceptions.

The _social-psychological environment_ is the more intimate environment of the family which reflects its values, attitudes, beliefs, expectations, goals, customs and traditions. It is the group informational exchange and decision making realm, which affects not only the family's internal interactions, but also affects its decisions about the purchase and use of material and energy resources.

As indicated before (Chapter III, page 49), most of the traditional approaches to the study of the family have been within one or both of these behavioral environmental realms, often referred to as the social environment or milieu.

Kuhn, for example, simulates an internal model of the family as "a small complex, multi-purpose, _semi-formal_, cooperative organization (1972, p. 493), whose internal interactions account for various social transactions, including procreation, sex, child rearing, mutual assistance and care for basic needs (1972, pp. 415-425).

This set of behaviors can be viewed as sets of social interrelationships between family members. Figure 6 illustrates:

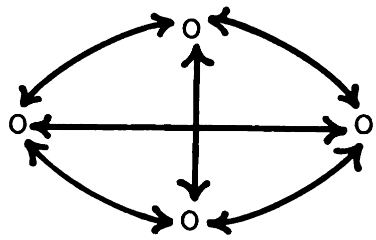

Figure 6.--Inter-family Social Behavior (depending on number of family members).

In this case the family is conceived of as a relatively "closed" behavioral environment, or system, encompassing the social interactions that take place within it. This behavioral environment can, therefore, be characterized as an inter-familial social control system. Its importance within this study is related to the perceptual or subjective measures hypothesized to determine family residential energy consumption.

Parsons and Bales (1955) have explored a broader set of social behaviors that included not only the within family exchanges and influences, but also social institutional (societal) pressures exerted on the family from outside the system; these are hypothesized to affect the unit character of the family system and in turn the personality of the child within the family. This relationship can be viewed in Figure 7.

IE ⟶ FS ⟶ I/O

IE = Institutional Environment (society)
FS = Family (system).
I/O = Child and/or individual (as organisms)

Figure 7.--Social Relationship Between Society, Family and Child and/or Individual.

Tallman has hypothesized a similar relationship (see Figure 7 above). He indicates that the family "is conceived as a prime mediating agent between the social structure and the individual" indicating that the replication of social structure within the family system is mainly through "occupational roles" (n.d., p. 10).

Therefore, this behavioral environmental realm is the environment providing information and, thus, external *control* over the collective activity of the family. These controls are imposed on the family from the outside, thus, indicating the "openness" of the family system to influences (inputs) from society. These will be labelled *external-familial social controls*.[2] Within the study, the indirect measurement of this form of control will be the *perceived* cost and availability of energy resources and

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[2]Both the internal and external familial controls imposed by these two behavioral environments can be regarded in general as *information* exchanges from within and between these environmental systems.

will be hypothesized to affect belief in the reality of the energy problem as the intervening variable considered to determine energy use.

The Utility of the Human Ecosystems Framework

The usefulness of any conceptual framework, such as the Human Ecosystems model, lies in its application. The attempt has been to provide a broad and wholistic perspective of a total system, indicating its structural components (organism and environment), their linkages and the interdependencies. It is in a sense a generalized hypothetical model developed for the purpose of conceptualization and analysis.

Within the conceptual framework presented the family has been identified as the central system of interest. It will, therefore, become the unit of analysis in this research. The environments (natural, built and behavioral) with which the family interacts are identified as the supra-system surrounds. The linkages (inputs and outputs) have been broadly identified as material, energy and information flows (inputs and outputs); however, these have not been made specific. Therefore, in the following sections the hypothetical relationships between a reduced subset of systems components will be derived and tested empirically.

Deduction Toward the Hypotheses

> The family is an energy-driven ecosystem, and the family members are inextricably linked to the environment through energy flows (Paolucci and Hogan, 1973, p. 12).

This statement is fundamentally the theoretical hypothesis underlying this investigation, and as such it is prophetic for this work in two essential domains: the conceptual and the analytic.

Conceptually, the notion of "an energy-driven ecosystem" suggests a process; whereas "energy flows" indicate inputs from and outputs to the environment. Figure 8 illustrates these notions graphically.

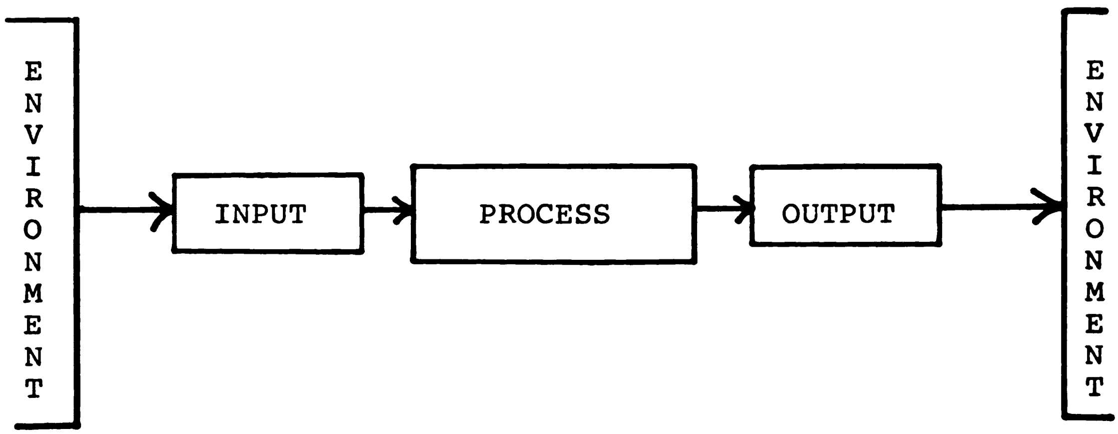


Figure 8.--Basic Input/Output Model (adapted from Burk, 1970, p. 319).

Analytically, the theoretical statement also indicates the method most appropriate to test the notions. In this case regressive path analysis was adopted as the analytic mode (to be discussed in detail later) as it allowed measurement of the linkages (paths of influence) between the hypothesized inputs and outputs.

Thus, the bridge from the broad human ecosystems framework to the deduced subset of systems components (to be articulated as modeled hypothetical relationships) is greatly enhanced by the delineating function this statement performs. Therefore, from this point forward deduction is used logically to narrow and specify the subset of systems components, first indicated in the human ecosystems framework, toward the researchable problem.

The Generalized Family Ecosystem Input/Output Model

For the purpose of this study the family is assumed to be a "living open adaptive system", requiring continual exchanges (inputs and outputs) with its environment in order to sustain itself and function at survival levels and beyond. These inputs and outputs are processed and/or transformed within the family ecosystem and include the following:

1) Processing of materials.
2) Processing of energies (food & fuels).
3) Processing of information.

Examples of these processes are given to illustrate the pertinence of this set of notions. The family transforms a number of material, energy and information flows including: 1) material flows in the form of objects (housing, equipment, transportation, clothing, etc.); 2) energy flows in the form of converted fossil fuels (natural gas, petroleum, coal and electricity) and nutrient flows in the form of food; and 3) information flows as abstract or concrete messages which transmit notions about reality (systems states).

This study is not concerned with nutrient or material flows, per se; it is particularly interested in energy and information flows, as illustrated in the following more explicit, however, still somewhat generalized model of family ecosystem energy and information flows. Figure 9 follows.

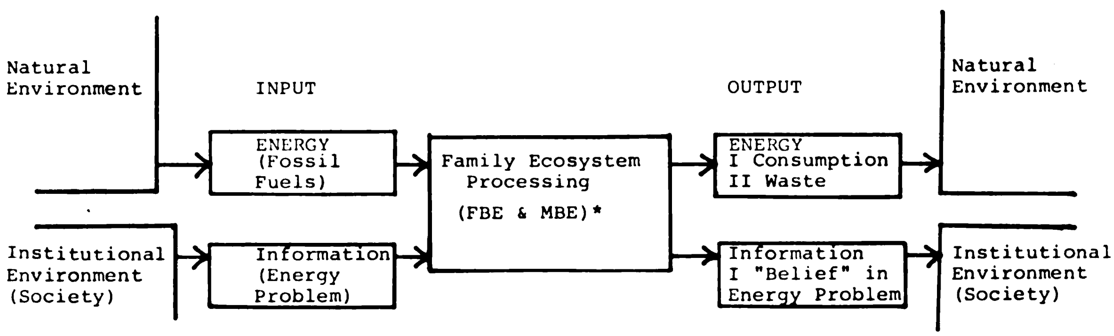


Figure 9.--Generalized Family Ecosystem, Energy and Information Input/Output Model.[3]

*FBE = Family Behavioral Environment
MBE = Man-built Environment -- Residential Dwelling.

[3]Note the parallelism between this illustration and the material-energy and information flows in the Human Ecosystem Framework, Chapter IV, page 82.

To elaborate further, the family transforms fossil fuels as direct inputs to energize the various mechanical processes within the place of residence (heating, cooling, lighting, are examples) for comfort, convenience and efficiency. The level of comsumption within the living place is the total amount of direct energy used to support these mechanical processes (Output I), plus heat loss and energy waste (Output II).

The level of energy the family consumes, however, not only depends on inputs of the fuels, per se, but also depends on information concerning the costs and availability of such fuels which, in this study, reflect processed information about the energy problem (energy crisis, Winter 1973-74).

The major concern of this study is to discover the factors anticipating energy consumption in single family detached dwelling units, including belief in the reality of the energy problem. Therefore, such elements as family income (being a good predictor of both energy and housing consumption patterns: Newman and Wachtel, 1974), environmental factors, physical housing factors and family compositional characteristics become the input (independent) variables considered pre-existent to the consumption of energy.

Educational attainment (generally a good predictor of preceptions and beliefs) along with family income, preceptions of the cost and availability of energy and housing tenure are considered anticipatory of belief in the reality of the energy problem. The "belief" variable is itself considered an intervening input variable assumed to be a percursor to energy consumption. The amount of energy consumed is the output (dependent) variable assumed to be determined by these factors.

The First-Order Input/Output Model and Variables of the Study

The prior discussion along with the presentation of the first-order hypothetical model (Figure 10), followed by the tabled input/output variables (Table 8) specific to the study, sets the stage for the final deductive process; i.e., the presentation of the second-order hypothetical model and the statement of the study hypotheses. Figure 10 and Table 8 follow as transitive steps in the deductive process.

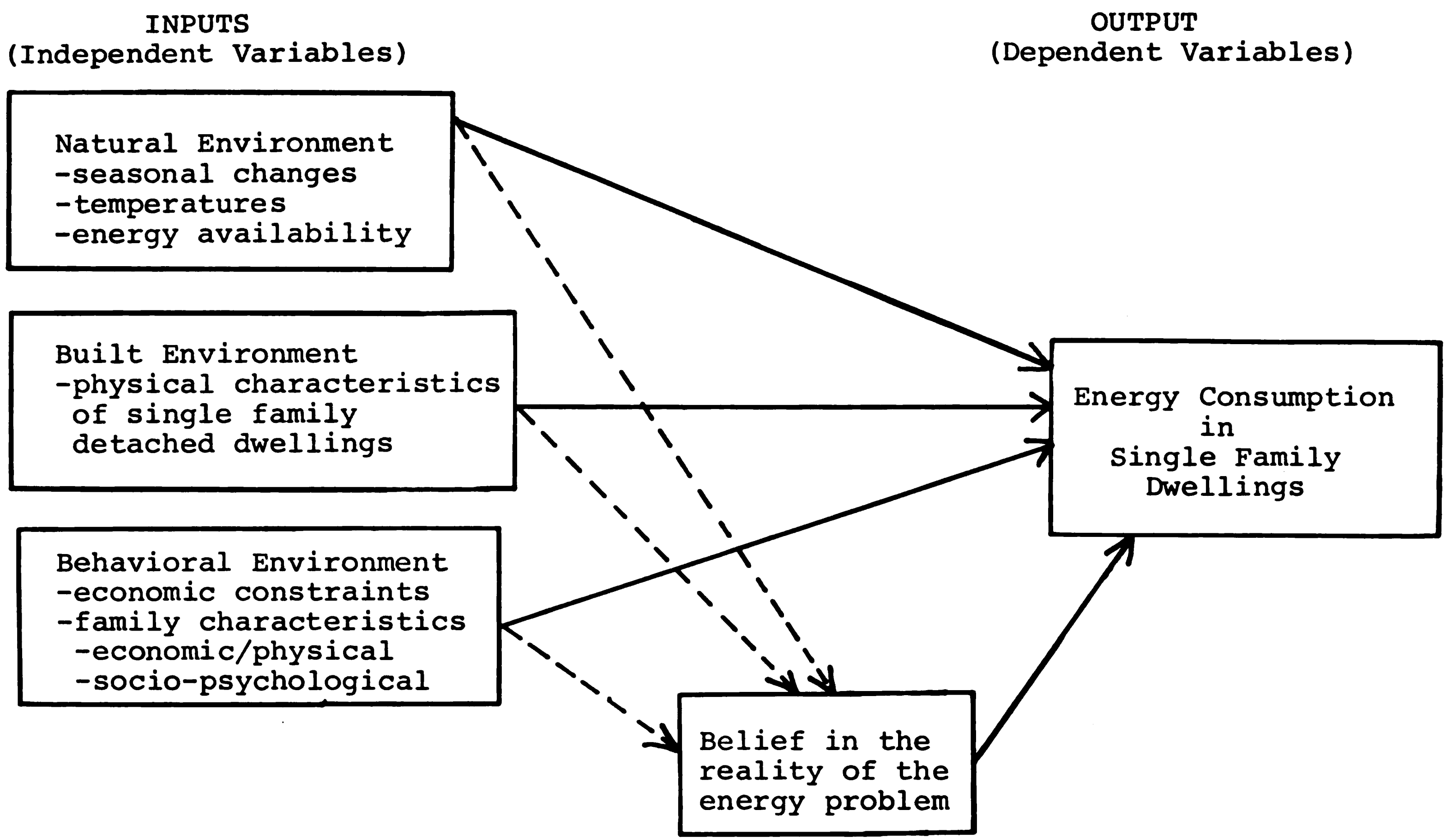


Figure 10.--First-Order Hypothetical Input/Output Model. Schema of Study Input/Output Variables and Their Hypothetical Relationships: Determinants of Energy Consumption in Single Family Detached Dwellings.

TABLE 8.--Outline of Study Input/Output Variables and Their Measurement.

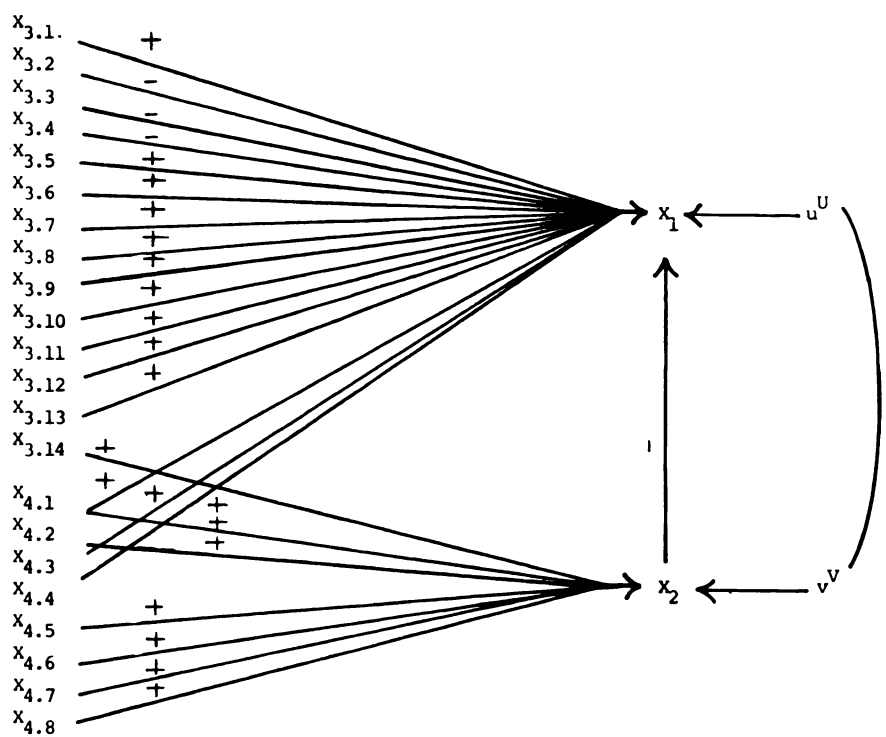
INPUT/OUTPUT	MEASUREMENT
INPUT	
1.00 Natural Environment 1.1 - Seasonal changes 1.2 - Temperatures 1.3 - Energy Availability	Variables not tested within this study
2.00 Built Environment 2.1 - Physical characteristics of single family dwellings	2.21 - Total square feet 2.22 - Presence of insulation (ceiling, walls & floor) 2.23 - Number of floor levels 2.24 - Total number of rooms 2.25 - Number of rooms heated 2.26 - Number of rooms air conditioned 2.27 - Total number of windows 2.28 - Total number of doors to exterior 2.29 - Type of exterior construction material 2.30 - Number of major appliances 2.31 - Location of dwelling (rural/urban)
3.00 Behavioral Environment 3.1 - Economic constraints	Variables not tested within this study
3.11 - Cost of energy (actual) 3.12 - Availability of energy (allocation programs)	
3.2 - Family Characteristics	
3.21 - Physical factors	3.21.1 - Number of persons living in dwelling 3.21.2 - Family life cycle
3.22 - Economic factors	3.22.1 - Educational attainment (husband/wife) 3.22.2 - Gross family income (1973) 3.22.3 - Housing tenure (owner/renter)
3.23 - Socio-psychological factors	3.23.1 - Belief in the reality of the energy problem (husband/wife) 3.23.2 - Perceived cost of energy 3.23.3 - Perceived availability of energy by type
OUTPUT	
4.00 Built Environment 4.1 - Total amount of energy consumed in single family dewelling	4.11 - Measured in BTU's (British Thermal Units)

The Second-Order Input/Output Model: The Model to be Tested

This second-order hypothetical input/output model indicates the specific set of relationships to be examined empirically. The model contains all the variables to come under consideration to predict and explain total direct energy consumption in single family detached dwellings. It demonstrates graphically the hypothesized relationships including: the directionality of influence, as well as the expected polarity of the relationships (positive or negative correlations). The second-order hypothetical model follows in Figure 11.

It should be noted that the natural environmental factors (seasonal change, temperature and energy resource availability) have been deleted from the second-order hypothetical model (note Table 8 , page 96). This deletion occured for two reasons; namely:

1) Temperatures and seasonal changes are the same for the sampled community (the greater metropolitan area of Lansing, Michigan). Thus, for this study the conditions do not vary; i.e., each household experienced similar conditions during the energy consumption period (June 1973-May 1974).



KEY

X_1 = Energy consumption

X_2 = Belief in energy problem

X_3 = Physical housing factors

- $X_{3.1}$ = Square feet
- $X_{3.2}$ = Ceiling insulation
- $X_{3.3}$ = Wall insulation
- $X_{3.4}$ = Floor insulation
- $X_{3.5}$ = Number of floor levels
- $X_{3.6}$ = Number of rooms
- $X_{3.7}$ = Number of rooms heated
- $X_{3.8}$ = Number of rooms air conditioned
- $X_{3.9}$ = Number of major appliances
- $X_{3.10}$ = Construction materials
- $X_{3.11}$ = Number of windows
- $X_{3.12}$ = Number of doors
- $X_{3.13}$ = Location (rural/urban)
- $X_{3.14}$ = Housing tenure

X_4 = Family factors

- $X_{4.1}$ = Gross family income
- $X_{4.2}$ = Education attainment
- $X_{4.3}$ = Household size
- $X_{4.4}$ = Family life cycle
- $X_{4.5}$ = Reported energy costs
- $X_{4.6}$ = Electricity availability
- $X_{4.7}$ = Fuel oil availability
- $X_{4.8}$ = Natural gas availability

u^U = Unexplained variance in energy consumption variable.

v^V = Unexplained variance in the belief variable.

Figure 11.--Second-Order Hypothetical Input/Output Model. The Path-Analysis Model of the Hypothesized Relationships to be Tested: Determinants of Energy Consumption in Single Family Detached Dwellings.

2) There were no reliable measures of the change in energy resource availability during the energy consumption period (indicated above).[4] Therefore, no measurement could be included here.

The following then is the statement of study hypotheses.

The Statement of Study Hypotheses

Hypothesis 1: Physical housing and family socio-economic factors relate to belief in the reality of the energy problem;

1) In the directions indicated by the signs below:
2) In the rank ordered magnitude of relationships stated below:

1 - Family heads educational attainment (+).
2 - Gross family income, 1973 (+).
3 - Reported cost of energy consumed in single family detached dwellings by energy type (+).
4 - Perceived availability of electricity (+).
5 - Perceived availability of fuel oil (+).
6 - Perceived availability of natural gas (+).
7 - Housing tenure (+).

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[4] Interviews with fuel oil dealers and officials of the utility companies, surveyed for energy consumption data were less than successful at tapping a measurement of energy availability. Outside a description of the "allocation program" for fuel oil, instigated during the energy crisis (Winter 1973-74), none of those interviewed had any hard data on how short energy supplies actually were. In fact, the general impression given was that no real problem existed in terms of shortages in energy availability. Those interviewed consistently mentioned increasing energy costs as an economic constraint to the use of available energy supplies.

Hypothesis II: Physical housing and family socio-economic factors relate to the total amount (in BTU's) of direct energy consumed in single family detached dwellings;

1) In the direction indicated by the signs below:
2) In the rank ordered magnitude of relationships stated below:

1 - Gross family income, 1973 (+).
2 - Total square feet in the dwelling (+).
3 - Presence of insulation in ceiling (-).
4 - Presence of insulation in walls (-).
5 - Presence of insulation in floors (-).
6 - Number of floor levels (+).
7 - Number of rooms in the dwelling (total) (+).
8 - Number of rooms heated (+).
9 - Number of rooms air conditioned (+).
10 - Number of major appliances in the dwelling (+).
11 - Type of construction material (+).
12 - Number of windows (+).
13 - Number of doors to exterior (+).
14 - Location of dwelling (urban or rural) (+).
15 - Number of persons living in dwelling (+).
16 - Family life cycle (+).
17 - Belief in the reality of the energy problem (-).

Hypothesis III: Family socio-economic factors will explain more of the variance than housing physical factors for belief in the reality of the energy problem.

Hypothesis IV: Housing physical factors will explain more of the variance than family socio-economic factors for total direct energy consumption in single family detached dwellings.

CHAPTER V

METHODOLOGY

Introduction

This investigation, focused on the socio-physical determinants of energy consumption in single family detached dwellings, is a part of an interdisciplinary study, entitled "Functioning of the Family Ecosystem in a World of Changing Energy Availability," funded by the Michigan Agricultural Experiment Station.[1]

The initial funding period (January through June 1974) was proposed for the purpose of designing and conducting a cross-sectional field survey to act as a pilot study to and a benchmark study for a five-year statewide longitudinal study. The pilot field survey was conducted within the greater metropolitan area of Lansing, Michigan, during the months of May and June, 1974.

The discussion within this Chapter will center on the following points:

1) The research method including: the justification for its use, a description of the data collection, and a brief description of the data processing.

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[1]Agricultural Experiment Station Project #3152, Michigan State University. This researcher was the project director from the date of initial funding, January 1974 thru December 1974.

2) The sample including: the sampled community, the design and selection of the sample, and tables describing the subsample characteristics.

3) The mode of analysis including: a description of the independent, dependent and intervening variables.

The Survey Research Method

The fundamental research design for the pilot study was a cross-sectional field survey (a survey at one point in time), undertaken for the purposes of instrument testing, sample description and preliminary determination of relationships.

In general, survey research is considered a very efficient and effective mode of data gathering when a particular situation is occuring or has occured affecting a large population and about which description and/or explanation is desired using a relatively large number of variables. This mode of data acquisition is often used during political campaigns and in market research as a method to gain quick, representative bodies of information upon which to base campaign strategy or product distribution (Babbie, 1973; Moser and Kalton, 1972).

The cross-sectional survey research method was considered logical and justifiable as the methodology for the field survey on these grounds:

1) The energy crisis was a particular situation, differentially impacting on a large proportion of the

population, and about which both description and explanation was desired.

2) The survey research method, in combination with self-administered interview schedules (used as the major means to elicit information) was considered the most efficient and economically feasible approach within the time and budget constraints of the initial funding period.

Neither experimental research nor observational methods would have allowed the collection of data on such a vast number of variables (thirteen interview schedule sections with approximately 46 major variable categories), on such a large sample (217 families, including 479 individuals questioned), in such a relatively short time period (May and June 1974). Nor would other research methods have encouraged or allowed the development of a number of alternative explanatory models to emerge from the data, each of which contributed insight into the multi-dimensional energy problem. The research undertaken here is but one of several models under investigation, within the initial study, made possible by the survey research model.

The Survey Instrument and Data Collection Procedure

Although the data analysis within this study draws from a small portion of the data gathered in the field survey, a discussion of the instrumentation and the data collection procedure will be useful in understanding the total system used for data procurement.

Interview Schedules

Three discrete sets of interview schedules were developed and employed in the pilot study: 1) a set of self-administered questionnaires concerned with energy, food and the family; 2) a set of self-administered questionnaires assigned by the interviewer to the appropriate family decision-maker to gain information concerning food, housing and transportation; and 3) a set of interviewer-administered questionnaires to gain data about the family demographics including income, education, occupation and age.

The first set of self-administered questionnaires was designed to elicit information from three family members: husband, wife, and when present in the family, one child over age twelve. In order to eliminate confusion for the individual family respondents, packets of interview schedules were labeled and color coded;[2] i.e., each responding member was assigned a folder containing questionnaires on energy, food and family attitudes and perceptions. This first set of questionnaires

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[2]Color coded folders and questionnaires were assigned: Red = labeled husband or adult male; Blue = labeled wife or adult female; Yellow = labeled child over twelve years of age.

was designed to allow comparisons among family members (individual scores) and also comparisons between families (family scores).

The second set of interview schedules was answered by only one individual in the family; i.e., the identified family decision-maker, depending on area of questioning. The third set was also answered by one family member. In most cases this was the adult female.

The Interview Procedure

The interview proceeded in three stages: 1) the initial contact by the interviewer; 2) completion of self-administered interview schedules by the families; and 3) the re-contact and retrieval of the schedules by the interviewer.

Initial contact stage.--Twelve professional interviewers were trained to conduct and monitor the field study.[3] The initial contact by the interviewer with an adult member of the household, introduced the purpose of the study, determined fitness of the household to the family criterion, gained permission for family participation, and explained the interview procedure. The interviewer also gave assurance of confidentiality and

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[3]A day of training just prior to the field work was conducted at the Institute of Family and Child Studies, May 8, 1974 for the urban sample, and June 6, 1974 for the rural sample. The field supervisor, along with members of the interdisciplinary research team planned and conducted these sessions.

instructed on the importance of the individuality of each family member's response indicating that payment (a stipend of $10.00 per family) for cooperation would be based on completion of the set of questions and the individuality of the responses.

The self-administered stage.--A set of color-coded materials for each identified family member was left at the household. A period of approximately three days was given for the completion of the self-administered questionnaires. The family respondents each answered a set of self-administered questionnaires having to do with energy, family and food. Another set of questions was assigned also to the family decision-maker, according to his or her knowledge and level of involvement with the area of questioning. These specific sets of questions were concerned with family transportation, housing and food, including expenditures for each.

The re-contact interview stage.--The interviewer returned at an appointed time, checked the questionnaires, and asked one adult family member (usually the female) a set of questions concerning family characteristics such as income, age, education and occupation.

The field survey provided data on many dimensions of the family as suggested by the variety of topics reflected in the three sets of interview schedules (See Appendix B for a comprehensive listing); however, this was not the only information gathered.

The Procurement of Utility Data

Beyond the initial survey, two more limited surveys were also conducted. The first was among the utility companies providing the study sample with energy (electricity, natural gas and fuel oil). The second was a survey of tax assessment records to gain precise information about the physical characteristics of the family dwelling units.

Energy data.--Very early in designing the research methodology for the initial study, it was decided that precise energy consumption data were absolutely necessary in order to measure actual levels of energy use. Therefore, cooperation was gained from the two utility companies[4] providing electricity and natural gas to the study respondents. Each company compiled a set of data for each household which included month by

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[4]Consumer Power Company provided data in cubic feet of natural gas consumed. The Board of Water and Light provided electrical data in kilowatt hours of electrical power consumed.

month meter readings for a period between June 1973 and May 1974. These data were coded in a form ready for key punching and computerization.

Fuel oil data were also gathered through a three stage process:

1) Letters were sent to all respondents who used fuel oil, requesting their cooperation and permission to seek their fuel consumption data.

2) Respondents then returned a signed, dated permission slip which included the name and address of their oil distributor. A stipend of $3.00 was paid for each returned permission.

3) This researcher personally contacted each dealer.[5] The signed permission slips and a letter of introduction provided the necessary entry and access to the requested data. All dealers contacted were cooperative.

These fuel oil distributors provided data in gallons of fuel oil consumed for each delivery date corresponding to the time period for data gathered from the utility companies. These data were in raw form and had to be made ready for coding, before key punching and computerization could take place.

Tax record data.--Data were gathered from tax assessment offices in three townships, plus Lansing, East Lansing and Holt. This survey of tax records[6]

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[5]Some of these fuel oil dealers operated in the City of Lansing, making access to them convenient, others were found in the outlying areas, requiring more effort and many call-backs.

[6]Tax assessment records are open to the public, therefore, no written permissions were sought from the respondents.

for the study respondents provided accurate data about property value, size of dwelling in square feet, type of construction, and other factors particularly important to the hypotheses considered in this study.

Selected portions of the information gained in the broader cross-sectional survey, along with the energy data from the utility and fuel oil companies and the housing assessment data areused within this study as operational, independent, dependent and intervening variables. These will be discussed in a later section of this Chapter.

Data Processing

During the summer of 1974 the collected data were coded, checked for coder reliability and accuracy, key punched and verified. Code books were designed for each section of the interview schedule and a system of quality control was established for the coding. Two persons supervised the ten coders and four persons rechecked all the work of the ten coders. Coding instruction and resolution of coding questions was done only by two process supervisors, again adding reliability and consistency to the procedure. A commercial firm was contracted to do the key punching and verifying.

The Sample

The Sampled Community: The Near Environment

The site selected and sampled for the pilot survey was the greater metropolitan area of Lansing, Michigan. This Standard Metropolitan Statistical Area (S.M.S. A.) was acknowledged to be a well defined social, economic, political and ecological metropolitan system, characterized uniquely by its diverse functions, being the seat of state government, the location of both heavy and light industry (basically related to the automotive industry), the sight of a major state university (Michigan State University), as well as being a central area of commercial enterprise, surrounded by a productive agricultural sector diversified by both crop and cattle production.

S.M.S.A. Lansing, Michigan, containing 1,702 square miles of contiguous land area, has a total population of 378,000 persons and 89,610 families (1970 census). This S.M.S.A. is a tri-county area with some portion of Eaton, Clinton, and Ingham Counties falling within its boundaries. It is considered to be a viable geographical entity with a relatively heterogeneous population from which a multi-stage probability sample of urban, suburban, and rural families could be drawn. S.M.S.A. Lansing, Michigan, therefore, offered the opportunity to study the impacts of the energy problem, broadly defined by the interdisciplinary research team and more specifically defined by this investigator, on a relatively contained geographical area with a diverse economic and social environment. This has particular meaning for the problem under investigation here because the community assured an adequate sample both of family socio-economic characteristics and of one unit housing structure types (single family detached dwelling units) upon which the hypotheses of this study could be tested.

Sample Design and Selection

The pilot field survey employed a multi-stage area probability sampling technique in which the randomly selected urban and rural areas of S.M.S.A. Lansing, Michigan were successively subdivided into smaller and smaller sampling units. In the urban area, sampling was done from census tracts to blocks to individual addresses. Outside the urban area sampling was done from counties, to enumerated districts, to sections and last to individual household addresses.

A goal of at least 150 urban and 50 rural families was set, reflecting in general, the proportions of urban and rural families in the S.M.S.A.

The Urban Sample

> Two sources of household information for the Greater Lansing Area were available: (1) the 1970 Census Tract publication from the U.S. Bureau of the Census, and (2) the 1973 Polk City Directory for Lansing and Suburbs. Of the two possible procedures for sample selection; i.e., directly from the City Directory with a correction factor for new construction, or an area probability selection from census tract information and enumeration of all households in selected blocks, we developed a combination of the two procedures. Either process alone would have entailed added costs; the combined procedure involved the sampling of geographical areas from census tract and city block statistics, but the final housing list was developed from the City Directory. Such a compromise insured first a representative sample of households with the savings of a clustered sample and the availability of a prepared list of households that needed only to be updated (Zuiches, Morrison and Gladhart, Occasional Paper No. 2, April 1975c, p. 3).

The compromise procedure used did, however, encounter one problem. The two listings did not encompass identical urban areas. Thus, a check was made and the discrepancy between listings (eight tracts) were discovered to be largely rural (built up area around Lansing); since the rural sample was to be drawn separately, these tracts were simply omitted from the urban sampling frame.

The random selection of ten census tracts was made with a total of 478 blocks (each tract and each block having a known probability of selection proportionate to the number of households therein). With a random start blocks were selected (thirty-nine blocks were dropped because they were apartment complexes on the M.S.U. campus; a sample out of proportion to total population in the Lansing S.M.S.A. of students and faculty). Thirty-four blocks then remained in the sample. In order to insure a sample of families (not just households), in keeping with the study criterion, two extra randomly selected addresses per initially selected sample household (or 615 households) were included to cover reductions by screening, refusals, or other contingencies (vacant, never at home and such).

A check of housing value and rents along with an examination of median incomes within the selected tracts indicated a reasonable approximation of socio-economic levels in the Lansing metropolitan area, with a slight over-representation of lower income areas, not considered problematic (Zuiches, et al., 1975).

The Rural Sample

The rural sample was a random selection of the townships taken from a listing of twelve townships within the three counties indicated in the Lansing, S.M.S.A. having no incorporated place or concentrated aggregation of populations. This was done to insure the rural nature of this portion of the sample. The three sections selected were sampled and a listing of each household per section was made. Again, each household had a known probability of selection within the section and, again, an over sample of two additional households per initially selected address was included to cover reductions and to insure at least 50 rural families as respondents.

Using the area probability sampling technique employed (with every sampling unit possessing a known probability of selection) does give some assurance of the representative nature of the 217 families (160 urban, 57 rural families) that became the respondents, within the population of families in the Lansing Metropolitan area.

As stated earlier, only a portion of the three surveys (discussed above) was used in this research, this is also true for the sample. The subsample for this study was controlled on three variables all considered necessary for the precision of prediction desired in testing the structural model developed for this study.

The subsample for this study was selected using three criteria: 1) families living in single family detached dwelling units with, 2) a year's complete energy data (total BTU's by household mix of electrical, natural gas or fuel oil) for the period from June 1973 to May

1974, and 3) a precise measure of dwelling size in square feet. This set of criteria served as controls and reduced the sample of 217 families to 97.

Demographic and Socio-economic Characteristics of the Subsample

Tables 9 through 15 below report the basic socio-economic and demographic data for the subsample. Appendix C shows similar tables for the Lansing S.M.S.A. and the large field survey sample. These latter tables are provided for comparisons; none will be discussed in the text.

TABLE 9.--Family Type.

Family Type	Present Study Subsample: Lansing S.M.S.A.	
	Number	Percent
Husband-Wife (with children)	65	(67.0)
Husband-wife (without children)	26	(26.8)
Female heads (with children)	6	(6.1)
Male heads (no wife-with children)	--	--
TOTAL	97	(100.0)

Seventy-three percent of the study's subsample have children living at home. The number of children per family range from a mean number of 2.5 for urban families to a mean number of 3.2 for rural families, indicating small differences (0.7) in numbers of children for this subsample (B. Morrison, March 1975a).

TABLE 10.--Educational Attainment.

Years of School Completed	Present Study Subsample: Lansing SMSA (combines husband and wife) Number	Percent
0-8 years (elementary school and junior high)	38	(20.2)
9-11 years (partial high school)		
12 years (high school completed)	76	(40.4)
1-3 years college	34	(18.0)
4 years or more (college graduate and professional training)	40	(21.3)
TOTAL	188	(100.0)

Seventy-nine, almost 80 percent of this subsample (combined husband and wife) have completed a high school education and beyond, indicating a high level of educational attainment in this study sample. This can be explained by the educational opportunities available in Lansing, which has two institutions of higher learning (Michigan State University and Lansing Community College).

TABLE 11.--Occupational Categories by Sex.

	Present Study Subsample: Lansing, SMSA			
	Males		Females	
Occupational Categories	#	%	#	%
Professional	21	(23.6)	12	(12.3)
Managerial	9	(10.1)	4	(4.1)
Clerical & Sales	9	(10.1)	32	(33.0)
Skilled	27	(30.3)	4	(4.1)
Semi Skilled	22	(24.7)	9	(9.3)
Unskilled or Service Workers	1	(1.1)	36	(37.1)
TOTAL	89	(100.0)	97	(100.0)

Males in this subsample split on occupational characteristics. They are divided between white-collar (43.8 percent) and blue-collar (56.1 percent) occupations. The opportunities provided in the Lansing area, being the seat of government, a university community, as well as being a auto production center gives rise to this finding. Females in this subsample appear in two main categories: employed outside the home or homemakers. A high proportion have some form of employment indicated by 62.8 percent in the labor force, a figure considerably higher than the national average which is 44 percent of all married women with husbands (Hayge, 1974, p. 23).

TABLE 12.--Income Characteristics.

Income Categories (Family Gross Income 1973)	Present Study Subsample: Lansing SMSA	
	Number	Percent
Less than $4,999	6	(6.2)
$5,000 to $9,999	11	(11.3)
$10,000 to $14,999	28	(28.9)
$15,000 to $24,999	31	(32.0)
$25,000 or more	21	(21.6)
TOTAL FAMILIES	97	(100.0)
Median Income	$15,000	

The median income, 1973, for this study's subsample is high, $15,000, compared to the national median for 1973 which was $10,236 (see page 9 in Chapter I). There is very nearly $5,000 difference between median income for the same year. This indicates a relatively affluent subsample, who are well educated and have a high percentage of females in the labor force (62.5 percent).

TABLE 13.--Age Characteristics by Sex.

	Present Study Subsample: Lansing SMSA			
	Male		Female	
Age Categories	#	%	#	%
under 18 years	--	--	--	--
18-29 years	16	(17.7)	23	(24.2)
30-44 years	32	(35.5)	31	(32.6)
45-64 years	38	(42.2)	36	(37.8)
65 years & over	4	(4.4)	5	(5.2)
TOTAL	90*	(100.0)	95*	(100.0)

*Reduction due to respondents not reporting age (subsample N=97).

A high proportion of the subsample are in the age range between 30 and 64 years of age (77.2 percent for males and 70.4 percent for females. This finding also supports the level of affluence identified in Table 12, as many of the individuals in the subsample are in their most productive years.

TABLE 14.--Housing Structural Types.

Housing Structural Types Units in Structure	Present Study Subsample: Lansing SMSA Number	Percent
1 (including mobile homes)	96 (SHD)	(99.0)
	1 (MH)	(1.0)
2	--	--
3 and 4	--	--
5 or more	--	--
TOTAL	97	(100.0)

This finding is self-explanatory, as the subsample has been controlled on the criteria of single family detached dwellings.

TABLE 15.--Housing Tenure.

	Present Study Subsample: Lansing SMSA	
Housing Tenure	Number	Percent
Owner occupied	84	(86.6)
Renter occupied	13	(13.4)
Vacant	--	---
TOTAL	97	(100.0)

The 86.6 percent owner-occupied housing tenure is not surprising considering the single family detached dwelling unit control. It is somewhat larger than the 1970 census, which indicates that 62.9 percent of single family detached dwellings are owner-occupied. (See Chapter I, page 13).

The Mode of Analysis

Path Analysis

Path analysis based on multiple-regression was deemed the appropriate mode of analysis for this research problem based on several theoretical and methodological considerations: (1) The problem in this study is defined as a test of the viability of a model of hypothesized relationships, the determinants of energy consumption in single family detached dwellings; thus, some form of structured mathematical model is indicated. (2) Systems analysis suggested by the modelled input/output process assumed in the research problem necessitates the definition of a causal structure whereby linkages (path networks) are established, indicating the identification of the parameters of causation or the quantitative contributions each causal linkage has in determining the overall variance.

"Given the dual goals of specifying causal paths and identifying causal parameters in a structural model" is as Heise suggests, a complex consideration of the relationships between variables, which is not concerned with correlational sizes alone (1969, p. 41). Consideration must also be given to how the variables are related; the spuriouness of the relationship and if mutual causation, direct or indirect, exists.

The Assumptions of Path Analysis: A Recursive Model

The specific hypotheses generated to be tested from the second order hypothetical systems model (pages 99 and 100) are based on the intrinsic characteristics of input/output models generally and, reinforced by the assumptions underlying the mode of analysis; i.e., the recursive path model.

The following assumptions are considered necessary criteria to be met when the recursive path analytic mode is employed:

1) Linearity; i.e., in the system of interest a change in one variable occurs as a linear function of changes in other variables (Heise in Borgatta (ed.), 1969, p. 44).

2) Recursive; i.e., the system of concern contains no reciprocal causations or feedback loops; that is, if X causes Y, Y cannot affect X either directly or through a chain of other variables (Heise, 1969, p. 45).

3) Causal Priorities; i.e., the causal laws governing the system are established sufficient to specific causal priorities among variables (Heise, 1969, p. 52). Time ordering is one method for inferring causal linkages.

4) Uncorrelated Disturbances; i.e., correlations between variables are assumed not spurious. The assumption is that the correlations in the model are functions only of the variables being considered, and are not due to mutual dependencies of some variables on others outside this model (Heise, 1969, p. 56).

These assumptions along with the basic assumptions which hold for multi-variate regression (sample independence, homoscedasticity, independence of variation and reasonable approximations to ratio or interval scales) are considered necessary requirements for developing linear recursive models and using path analytic procedures.

In structuring the hypothetical second-order input/output model from which the study hypotheses emerge, all of these requirements are assumedly met, within reasonable limits. The exception to this is the assumption of a "reasonable approximation" to ratio or interval scale, required by multivariate regression. Some of the scales used to measure variables in this study are ordinal. This is not considered problematic in the present study for two reasons: 1) not all the scales used in this study are ordinal, and 2) the issue of ordinal verses interval and ratio measurement remains an unsettled empirical question well beyond the ken of this study.[7]

The assumptions of linearity and recursiveness were investigated. It was not known prior to testing the model if these assumptions hold. Therefore, an examination of the results was done to test for

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[7]Although a controversial issue, the use of ordinal measures is often done in regression and path analysis. In other words, the purist position is not the accepted position. It has not been demonstrated empirically that using ordinal measures makes any difference in the conclusion reached -- the opposite has, in fact, been the case (Baker, et al., 1966; Borgatta, 1968; Labovitz, 1967).

idiosyncrasies. Time ordering was used as the method for inferring causal linkages in this research (refer to discussion in Chapter IV, page 93 and 94).

The Operational Variables

Table 16 lists the operationalized dependent, independent and intervening variables used in this study. They are adapted from Table 8 developed in Chapter IV (page 96), as input/output variables and their measurement. These will appear once again (Table 16), using the same numbered notations given in that previous listing. The procedures used to operationalize the variables appear in Appendix D.

Note should be taken of the fact that some of the variables listed in Table 16 can be classified as objective measures while others are subjective. Objective measures include all data provided from sources other than the respondents (utility companies, oil dealers and tax records), and also include some respondent reported data of a factual nature. Subjective measures include all data reflecting respondent beliefs and perceptions. These are listed in Table 17.

A totally subjective study reflecting only family perceptions (beliefs and attitudes) would not have given the desired reliability of measurement needed to identify the determinants of actual energy consumption; thus, a

TABLE 16.—Operational Variables .

Theoretical Variables	Operational Variables[8]
INPUT (Independent)	
2.00 Built Environment	2.21 - Total square feet
2.1 - Physical characteristics of single family detached dwellings	2.22 - Presence or absence of insulation
	2.23 - Number of floor levels
	2.24 - Total number of rooms
	2.25 - Number of rooms heated
	2.26 - Number of rooms air conditioned
	2.27 - Total number of windows
	2.28 - Total number of doors to exterior
	2.29 - Type of exterior construction material
	2.30 - Number of major appliances
	2.31 - Location of dwelling (rural/urban)
3.00 Behavioral Environment	
3.2 - Family Characteristics	
3.21 - Physical factors	3.21.1 - Number of persons living in dwelling
	3.21.2 - Family life cycle
3.22 - Economic factors	3.22.1 - Educational attainment (husband/wife)
	3.22.2 - Gross family income (1973)
	3.22.3 - Housing tenure (owner/renter)
3.23 - Socio-psychological factors	3.23.1 - Belief in the reality of the energy problem (husband/wife)
	3.23.2 - Perceived cost of energy
	3.23.3 - Perceived availability of energy by type (husband/wife)
OUTPUT (Dependent)	
4.00 Built Environment	
4.1 - Total amount of energy consumed in single family detached dwelling	4.11 - Measured in BTU's (British Thermal Units)

[8]The measurement of operational variables are listed in Appendix D.

TABLE 17.--Objective and Subjective Measures within the Study.

Objective Measures	Subjective Measures
<u>Data from outside sources</u>	<u>Data reflecting belief and perceptions</u>
Climate data (1.1, 1.2)	Belief (3.23.1)
Housing data (2.21, 2.23, 2.29, 2.31)	Perception (3.23.2, 3.23.3)
Energy data (4.11)	
<u>Factual respondent data</u>	
Housing data (2.22, 2.24, 2.25, 2.26, 2.28, 3.22.2)	
Family physical factors (3.21.1, 3.21.2)	
Family economic factors (3.22.1, 3.22.2, 3.22.3)	

balance between subjective and objective measures was initiated to introduce greater rigor into the research design. Table 17 indicates that the balance between objective/subjective measures in this study is weighted in favor of the objective, thus assuring, to the extent possible, a desirable level of reliability in the measurements.

CHAPTER VI

FINDINGS

Introduction

This chapter will be a presentation of the study findings with a twofold purpose. This is as follows:

1) To evaluate the relative effects (net and gross) of a set of selected socio-physical factors as determinants of the total amount of direct energy consumed in single family detached dwelling units.

2) To assess in relative terms the viability of the theoretical second-order, input/output model hypothesized to reflect the factors critical to the energy consumption in single family detached dwelling units.

These goals will be accomplished by systematically presenting the components (the data array) that make up, thus contribute to, the generated findings including:

1) The structural equations.
2) The zero-order correlation matrix (Appendix E, page 208).
3) A table of means and standard deviations (Appendix E, page 207).
4) The tables displaying the essential data for both dependent variables:

a) Belief in the reality of the energy problem.
b) Amount of total direct energy consumed in single family detached dwelling units.

5) The path diagram including the standardized path coefficients (β) and the amount of unexplained or residual variance (u^U, v^V) not accounted for in the model.

6) The correlation coefficient between the residuals (u^U and v^V), as a measure of the extent of feedback existing in the assumed recursive model.

7) A discussion of the test for linearity.

The model that is utilized in this study was presented in hypothetical form in Chapter IV (Figure 11, page 98). It is assumed that the paths do not violate any of the theoretical assumptions (linearity, recursiveness, mentioned in Chapter V), and further, it is assumed that the independent or input variables are predetermined (exogenous) and therefore, determinants of the endogenous (dependent) variables. This ultimately suggests a system of simultaneous equations that permit the assessment of the relative effects of the independent variables. The structural or simultaneous equations used were:

$$X_1 = P_{14.1}\,X_{4.1} + P_{13.1}\,X_{3.1} + P_{13.2}\,X_{3.2} + P_{13.3}\,X_{3.3} + P_{13.4}\,X_{3.4} + P_{13.5}\,X_{3.5} + P_{13.6}\,X_{3.6} + P_{13.7}\,X_{3.7} + P_{13.8}\,X_{3.8} + P_{13.9}\,X_{3.9} + P_{13.10}\,X_{3.10} + P_{13.11}\,X_{3.11} + P_{13.12}\,X_{3.12} + P_{13.13}\,X_{3.13} + P_{14.3}\,X_{4.3} + P_{14.4}\,X_{4.4} + P_{12}\,X_2 + P_1\,u^U.$$

$$X_2 = P_{24.2}\, X_{4.2} + P_{24.1}\, X_{4.1} + P_{24.5}\, X_{4.5} + P_{2.46}\, X_{4.6} + P_{24.7}\, X_{4.7} + P_{24.8}\, X_{4.8} + P_{23.14}\, X_{3.14} + P_2\, v^V.$$

where:

X_1 = Energy consumption
X_2 = Belief in energy problem
X_3 = Physical housing factors

$X_{3.1}$ = total square feet
$X_{3.2}$ = ceiling insulation
$X_{3.3}$ = wall insulation
$X_{3.4}$ = floor insulation
$X_{3.5}$ = number of floor levels
$X_{3.6}$ = number of rooms
$X_{3.7}$ = number of rooms heated
$X_{3.8}$ = number of rooms air conditioned
$X_{3.9}$ = number of major appliances
$X_{3.10}$ = construction materials
$X_{3.11}$ = number of windows
$X_{3.12}$ = number of doors
$X_{3.13}$ = location (rural/urban)
$X_{3.14}$ = housing tenure (owners/renters)

X_4 = Family factors

$X_{4.1}$ = gross family income
$X_{4.2}$ = mean education (husband and wife)
$X_{4.3}$ = household size
$X_{4.4}$ = family life cycle stage
$X_{4.5}$ = reported energy costs
$X_{4.6}$ = energy perception - electricity
$X_{4.7}$ = energy perception - fuel oil
$X_{4.8}$ = energy perception - natural gas

u^U = Unexplained residual and/or measurement error in the energy consumption variable.

v^V = Unexplained residual and/or measurement error in the belief variable.

Each of these model equations is multiplied through by each of the exogenous variables. Using a two-stage least squares procedure, the subset of exogenous variables that are thought to correlate best with the endogenous variables are used to reduce the source of estimation error. The process involves an ordinary regression of each of the endogenous variables on all the predetermined exogenous variables, termed an ordinary regression on the independent variables. This technique takes advantage of the fact that the regressed values are independent of error terms and, therefore, yields the exact number of simultaneous equations needed to reflect the hypothetical model.

The analysis will not be directly concerned with the means and standard deviations or with the zero-order correlation matrix. Therefore, they are not included in the findings Chapter, but rather will be found as Appendix E, pages 207 and 208.

Belief in the Reality of the Energy Problem

Findings

This research is designed to examine the net effects of a set of theoretical values on total direct energy consumption in single family detached dwelling units. One of those values is an intervening variable called "belief in the reality of the energy problem" (hereafter "belief") thought to be the outcome of several exogenous (independent) variables. Thus, before establishing the total effects of all the independent variables, including the "belief" variable on energy consumption, the belief variable will be examined to allow an understanding of its make up or determinants.

Hypothesis I indicates both the hypothesized direction of the assumed linear relationships plus the rank ordering of the independent variables as follows:

Hypothesis I: Physical housing and family socio-economic factors relate to belief in the reality of the energy problem;

1) In the directions indicated by the signs below:
2) In the rank ordered magnitude of relationships stated below:

1 - Family heads educational attainment (+).
2 - Gross family income, 1973 (+).
3 - Reported cost of energy consumed in single family detached dwellings by energy type (+).
4 - Perceived availability of electricity (+).
5 - Perceived availability of fuel oil (+).
6 - Perceived availability of natural gas (+).
7 - Housing tenure (+).

The findings of this multiple regression analysis using standardized (β) regression coefficients are presented in Table 18.

TABLE 18.--Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Seven Independent Variables on Belief in the Reality of the Energy Problem.

	Belief Variable		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Mean Family Educational Attainment	.361	16.07	≃.001
Perception of Electricity Availability	.315	13.05	<.005
Reported Cost of Energy	.183	4.58	<.05
Gross Family Income	.113	1.33	>.25
Perception of Natural Gas Availability	.099	.75	>>.25
Perception of Fuel Oil Availability	.087	.61	>>.25
Housing Tenure	.053	.37	>>.25
Overall F		9.48	<.0001

$R = .653$ df regression 7
$R^2 = .427$ df residual 89

Percentile points of F distribution at 6 and 88 degrees of freedom:

Percentile	Tabled F
75 = .25	1.74
90 = .10	2.76
95 = .05	3.74
97.5 = .025	4.96
99 = .01	7.06
99.5 = .005	9.12
99.9 = .001	16.21

Discussion

Hypothesis I, Part I, indicates a positive (+) directional relationship for all the independent variables with the "belief" variable. This suggests that there is an expectation for stronger belief (husband and wife agreement) in the reality of the energy problem, with each appropriate or designated change in the independent variables. For each of the seven independent variables the hypothesized positive relationships can be stated thus:

1) As mean family educational attainment increases, there will be more agreed belief in the energy problem.

2) As gross family income increases, there will be more agreed belief in the energy problem.

3) Families who report total yearly residential energy costs will agree more in the reality of the energy problem than non-reporters.

4) Families who agree on perceiving problems in the availability of energy forms (separate hypothesis for electricity, natural gas and fuel oil) will also agree on belief in the energy problem.

5) Families who own their dwelling unit will agree more in the reality of the energy problem than families who rent.

It is apparent from Table 18 that the hypothesized positive direction of relationships holds true for all seven variables. There is a positive correlation (β) between each of the seven independent variables and the "belief" variable, therefore, Hypothesis I, Part I is supported by the findings.

Hypothesis I, Part 2, hypothesizes the rank ordering (the relative magnitude or strength) of the relationships between the seven independent variables and the "belief" variable. This hypothesis is not fully supported. Some deviation from the modelled ordering occurs.

Three of the independent variables hold their hypothesized rank (educational attainment, reported costs and housing tenure), whereas four variables shift their ranked positions.

This shifting is not considered extremely problematic, however, on the grounds that the second-order hypothetical model tested here is considered a first crude estimate of the relative magnitude of relationships between belief in the reality of the energy problem and the seven variables hypothesized as determinants.[1]

The important aspect, therefore, of this set of findings is not so much in the deviation from rank ordering, but rather in the overall amount of variance explained

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[1]The rank ordering undertaken in this study (both Hypothesis I and II) was not based on prior empirical and/ or theoretical insight, thus the importance of the ranking was not so much in testing the ranking per se, but rather in this case it was important as a means to determine meaningful, explainable magnitudes of relationships. In other words, rank ordering prior to regression gives greater explanatory capacity compared to entering the variables randomly or without attempted structuring into the regression. In this study step-wise regression was used.

by the seven hypothesized independent variables when considered as collective determinants. In this case 42.7 percent (or $R^2 = .427$) of the variability in the "belief" variable is explained by the multiple squared effects of the independent variables. This is considered a relatively substantial level of explanatory capacity in social science research where R^{2}'S of .30 or less are often considered of interest (Herberlien, 1975).

Some of the rank ordered findings are, however, interesting in and of themselves. For example, mean family educational attainment does remain (as hypothesized) the most important explanatory variable ($\beta = .361$, $p \simeq .001$). This is not surprising considering the fact that education is generally a good predictor of attitudes, perceptions and beliefs (as indicated in Chapter III, page 94).

Perception of electrical availability as a problem ranks second in order ($\beta = .315$, $p < .005$). This finding is somewhat curious. However, when taking into consideration the fact that all of the study's subsample depend on electrical power to some degree, and very likely have experienced the inconvenience of interrupted service, this finding becomes more logical.

The perception of fuel oil availability as a problem which ranked sixth in the findings ($\beta = .087$, $p >> .25$) is the most challenging to explain. During the energy crisis period (Winter, 1973-74), fuel oil was the only energy source (considered in this study) to come under government allocation. This would suggest that for those using fuel oil it could have been considered a problem. This, along with the wide media coverage of petroleum shortages in general, and the allocation program in specific, should have, on logical grounds, made it more important in affecting belief in the energy problem.

There may be several reasons this rank ordering shifted: 1) there were only 18 families in the study (N=97) who used fuel oil as a form of energy in their homes and, as suggested before, this was not the sole energy source; 2) as indicated earlier (footnote 4, page 99) the fuel oil dealers did not report delivery problems to consumers during the allocation period. These reasons are seen as possible explanations for the ranking discrepancy found.

Total Amount of Direct Energy Consumed in Single Family Detached Dwellings

Findings

Hypothesis II is a test of the major hypothetical concerns of this study. The "belief" variable is now included along with sixteen other independent input variables to be tested as net determinants of energy consumption in the single family detached dwelling unit.

Hypothesis II is restated below giving both expected directional signs and the rank ordering of magnitude.

Hypothesis II: Physical housing and family socioeconomic factors relate to the total amount (in BTU's) of direct energy consumed in single family detached dwellings;

1) In the direction indicated by the signs below:
2) In the rank ordering magnitude of relationships stated below:

1 - Gross family income, 1973 (+).
2 - Total square feet in the dwelling (+).
3 - Presence of insulation in ceiling (-).
4 - Presence of insulation in walls (-).
5 - Presence of insulation in floors (-).
6 - Number of floor levels (+).
7 - Number of rooms in the dwelling (total) (+).
8 - Number of rooms heated (+).
9 - Number of rooms air conditioned (+).
10 - Number of major appliances in the dwelling (+).
11 - Type of construction materials (+).
12 - Number of windows (+).
13 - Number of doors to exterior (+).
14 - Location of dwelling (urban/rural) (+).
15 - Number of persons living in dwelling (+).
16 - Family life cycle (+).
17 - Belief in the reality of the energy problem (-).

As in Hypothesis I, the signs give an indication of the anticipated direction of relationships. A few examples will be given for increased clarity; however, in this case most are forthright and non-problematic.[2]

1) For rank orders 1, 2, 6, 7, 8, 9, 10, 12, 13 and 15 an hypothesis of increasing values in any of the independent variables is considered concomitant with increasing energy consumption in BTU's, therefore, positive signs are hypothesized.

2) For rank orders 3, 4 and 5 the hypothesis being tested is that with the presence of insulation (ceiling, walls, and floors) less energy will be consumed, thus negative signs are hypothesized.

3) Rank order 11 is testing the hypothesis that differences in exterior surface, construction materials, differs positively with energy consumption.

4) Rank order 14 hypothesizes that rural dwelling units will consume more energy than urban dwellings.

5) Rank order 16 hypothesizes that families in the mid-cycle of life will have a more positive, direct effect on energy use in the dwelling than families at the younger or older end of family life cycle stages.

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[2]See Appendix D for the operational definition of the variables used.

6) Rank 17, belief in the reality of the energy problem is hypothesized to have a negative effect on energy consumption. The more the agreed belief in the reality of the energy problem, the less energy consumed.

Table 19 indicates the outcome of this multiple regression.

TABLE 19.--Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Seventeen Independent Variables on the Amount of Direct Total Energy Consumed in Single Family Detached Dwelling Units.

	Amount of Direct Total Energy Consumed		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Household size	.280	8.02	<.001
Major appliances	.211	3.19	< .01
Number of rooms	.173	1.30	≃ .25
Number of exterior doors	.168	2.38	< .05
Number of rooms heated	.165	1.71	< .25
Square feet	.081	.56	>>.25
Family gross income	.064	.35	>>.25
Number of floors	.055	.37	>>.25
Number of windows	.049	.24	>>.25
Insulation - floors	.027	.94	>>.25
Construction materials	.024	.73	>>.25
Family life cycle stage	.024	.58	>>.25
Number of rooms air conditioned	-.007	.56	>>.25
Belief in energy problem	-.095	1.02	> .25
Insulation - walls	-.096	1.00	> .25
Location (rural/urban)	-.127	2.14	< .05
Insulation - ceiling	-.161	3.41	>.005
Overall F		4.38	>.0001

$R = .696$ df regression 17

$R^2 = .485$ df residual 79

Percentile Points of F distribution at 16 and 78 degrees of freedom:

Percentile	Tabled F
75 = .25	1.36
90 = .10	1.87
95 = .05	2.25
97.5 = .025	2.63
99 = .01	3.12
99.5 = .005	3.49
99.9 = .001	4.37

Discussion

Hypothesis II, Part 1, is substantially supported by the findings; i.e., most of the hypothesized directional relationships hold. There were, however, two exceptions: 1) presence of insulation in floors, where a negative relationship with energy consumption was expected, but a positive relationship was found; and 2) rural dwellings, where a positive relationship was expected with energy consumption, but a negative relationship was found.

In both of these cases the magnitude of relationships to energy consumption is near zero (β = .027 for floor insulation and β = -.127 for rural dwellings) which indicates a weak standardized correlation exists between these two variables and energy use.

In a further analysis of the data it was discerned that each of these variables had small cell numbers out of the total (N=97). Only 10 families reported floor insulation,[3] and there were only 15 rural families in this subsample.[4] This helps explain both the weak correlation

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[3]Floor insulation would not be common in mid-Michigan where basements are prevalent, thus decreasing the need for this form of insulation.

[4]Controls for total energy consumption for a year, and square feet measurement eliminated a number of rural dwellers from this subsample.

(magnitude of relationships) with energy consumption and the reversal in sign direction (fluctuation + or - near zero correlation).

Hypothesis II, Part 2, is not supported by the findings. Most of the a priori rank orderings of magnitude shifted their positions in the outcome ordering when using standardized correlations (β) as the measure. This is considered neither surprising nor extremely problematic. The rationale for rank ordering the independent variables prior to the analysis was to have a means to enter the data into the multiple step-wise regression with some structure (rather than randomly), as suggested for Hypothesis I, Part 2).

The selected variables and their rank ordering were considered at the offset a first approximation model and, therefore, misjudgments were considered very much in the realm of the possible.

The important finding here (as in Hypothesis I, Part 2), is not so much the ranked input per se, but rather: 1) the outcome, in terms of the rank ordering after the step-wise regression occured, and 2) the amount of variance in the energy consumption variable explained.

Nearly 50 percent (48.5 percent or R^2 = 485) of the variance is explained by the array of seventeen independent variables selected as predictors (determinants) of energy consumption in single family detached dwelling units. This is a most important finding because it appears that the variables selected to explain energy consumption come a very great distance toward doing just that.

Rarely in social science research will multiple regression outcomes be near 50 percent of variance explained. This may be due to any number of factors: 1) poor measurement techniques; 2) flaws in the theory; 3) use of subjective measures; and 4) measurement and random errors, to name a few. Using mainly objective measures, as in this study (indicated in Chapter V, page 126), may have cut down some of the factors giving rise to lower explanatory or predictive power often found in other studies.

Table 19 above, indicates the outcome rank ordering which will be given some attention before presentation of the path model and findings.

Discussion of Some of the Interesting Findings

Household size is the first variable of importance in magnitude of relationship (β = .280) with energy consumption. This finding is of particular interest because it is contrary to the only study which is directly comparable to this one. Fox, et al., in the Twin River study found that household size washed out as a critical factor explaining energy consumption as compared to physical housing factors. In their study, homogeneity of household size (approximately three persons per household) was given as the reason it did not hold up in the analysis.

In this study, however, a mean of 3.96 persons lived in the dwelling units, which ranged in number from two to twelve persons per household. This greater variability could help explain why household size becomes important as a predictor of energy consumption in this study.

The other interesting aspect of this household size finding is that it shifts in rank ordering from position 15 to position 1, thus outranking all other factors including other family factors and all physical housing factors in this study. The implications of this finding suggest that it is the people within the dwelling unit and their aggregate demands[5] (habits, behaviors and/ or life styles) on energy using facilities that made the

[5] Gladhart in a recent analysis of a larger subsample (N=131) from the same pilot study used here, looked at per capita household energy consumption, which indicates economies of scale involved in larger households. Although interesting, it does obscure aggregate energy consumption or that the more persons in a household the more energy used, in spite of the fact that each person uses less (B. Morrison, AHEA Speech, June 1975b).

difference, rather than the characteristics of the facilities themselves. This has very important energy conservation implications.

The number of major appliances within the dwelling place ranks second in order of importance ($\beta = .211$) in predicting energy consumption in the household. This finding is of interest because it suggests that along with the number of persons living in the dwelling, it is the number of energy consuming appliances used by these persons which makes a difference in energy consumption, as compared to the physical aspects of the dwelling place alone. In this subsample the mean number of appliances per household was 9.2, with a range from 4 to 16 major appliances, depending on household. This also has important implications for energy conservation practices.

In the rest of the findings three or four others stand out as interesting to discuss. Gross family income which was hypothesized to be the ranking variable predicting energy consumption in the second-order model, shifts to seventh position in the findings. The logic behind ranking it first was that with greater family economic resources, more energy would be consumed in the place of residence. This turns out to be only partially true. What was not taken into consideration was the interdependency of income with other variables included here and perhaps with some not measured. In other words gross family income turns out not to be solely and directly related to energy consumption, but was also related indirectly through other variables (house size, number of major appliances, home ownership, and such) to energy consumption. Also not accounted for here is the use of economic resources for other expenditures such as food, clothing, entertainment, education, medical expenses, which would also reduce the amount of income available for energy and energy consuming items, thus making it a less potent predictor of energy consumption alone.

Measurement of house size by square feet (tax assessment records) was used as a control variable, indicating its importance as a predictor of residential energy consumption; in fact, it was ranked 2nd in the hypothesis tested. In the findings it takes the 6th position, whereas number of rooms in the dwelling unit ranks 3rd. This finding indicates that the exact square foot measurement ($\beta = .081$) is superseded by a good approximation (number of rooms) as a predictor of ($\beta = .173$) energy consumption, indicating that perhaps less precise detail was needed in the hypothetical model than thought prior to this analysis.

Insulation in the ceiling turns out to be a good predictor of energy consumption in magnitude of relationship ($\beta = -.161$). The negative direction of the relationship was hypothesized; i.e., presence of insulation in the ceiling should be related to decreased energy consumption.

Insulation in the walls was similarly negatively related to energy consumption; however, its magnitude of relationship to energy consumption was less strongly correlated ($\beta = -.096$). These findings tend to support the practice of energy conservation through home insulation.

Belief in the reality of the energy problem turns out to have the negative directional relationship hypothesized with energy consumption, but the magnitude of relationship is not strongly correlated with the energy consumption variable ($\beta = -.095$). This finding is important because it indicates that although there was information in the environment about energy shortages and increased costs, this information does not have a serious impact on the amount of total direct energy consumed in single family detached dwelling units; in fact, the standardized correlation was almost zero, indicating relatively no effect at all. This finding also has important implications to be discussed in the following Chapter.

The Path Model

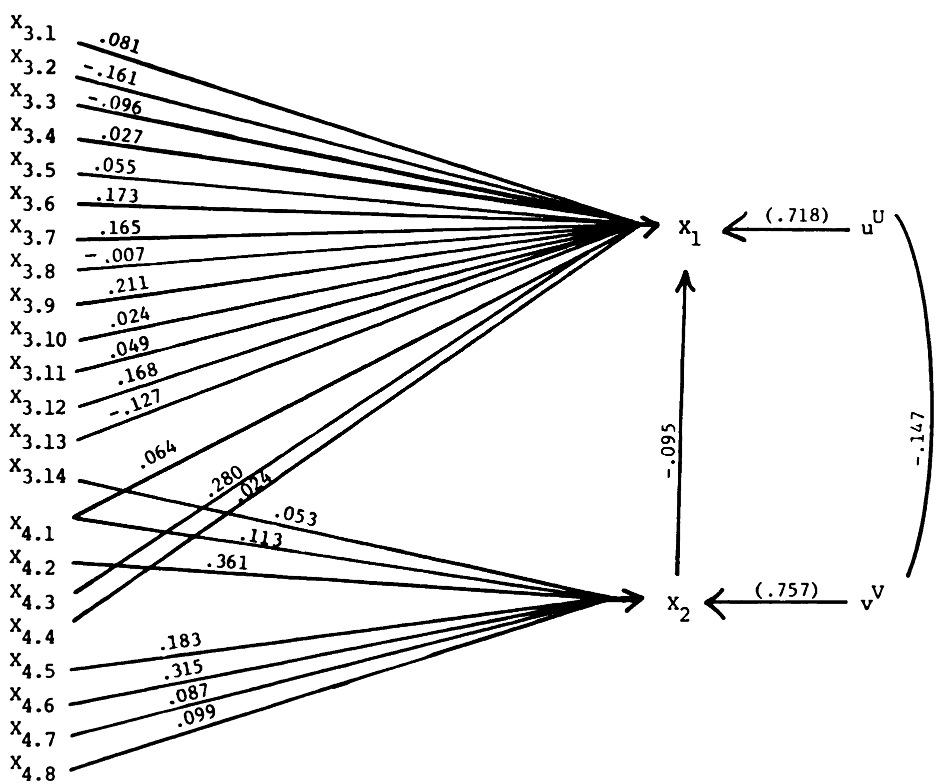
Having presented some of the more interesting findings from the multiple regression analysis, it now becomes important to see this in structural modelled form. Thus, the second-order hypothetical model will be presented here, including all the path coefficients, the residuals not explained in the model, as well as the correlations between the residuals as an indicator of the feedback present in this model.

The second-order specified input/output model of paths of relationships follows on page 148 as Figure 12.

The specified path model indicates again the standardized path coefficient (β) as seen in Tables 18 and 19 for each of the independent variables with the two dependent variables: 1) belief in the reality of the energy crisis; and 2) total direct energy consumption in single family detached dwelling units.

Beyond this, the path model also indicates the amount of unexplained or residual variance ($1- R^2$) not explained in the model. For the "belief" variable, when used as a dependent variable, the path from the residual is $1-R^2 = .557$ or in other words, 57.7 percent of the belief variable remains unexplained.

For the energy consumption variable, where "belief" becomes one of the seventeen independent variables, 51.5 percent ($1- R^2 = .515$) of the energy consumption variable remains unexplained. In both cases the residual which remains may be due to sampling error or more likely to a



KEY

X_1 = Energy consumption

X_2 = Belief in energy problem

X_3 = Physical housing factors

- $X_{3.1}$ = Square feet
- $X_{3.2}$ = Ceiling insulation
- $X_{3.3}$ = Wall insulation
- $X_{3.4}$ = Floor insulation
- $X_{3.5}$ = Number of floor levels
- $X_{3.6}$ = Number of rooms
- $X_{3.7}$ = Number of rooms heated
- $X_{3.8}$ = Number of rooms air conditioned
- $X_{3.9}$ = Number of major appliances
- $X_{3.10}$ = Construction materials
- $X_{3.11}$ = Number of windows
- $X_{3.12}$ = Number of doors
- $X_{3.13}$ = Location (rural/urban)
- $X_{3.14}$ = Housing tenure

X_4 = Family factors

- $X_{4.1}$ = Gross family income
- $X_{4.2}$ = Education attainment
- $X_{4.3}$ = Household size
- $X_{4.4}$ = Family life cycle
- $X_{4.5}$ = Reported energy costs
- $X_{4.6}$ = Electricity availability
- $X_{4.7}$ = Fuel oil availability
- $X_{4.8}$ = Natural gas availability

u^U = Unexplained variance in energy consumption variable.

v^V = Unexplained variance in the belief variable.

Figure 12.--Second-Order Specified Outcome Input/Output Model of Energy Consumption in Single Family Detached Dwellings.

combination of sampling errors and variables not examined in the model. However, the <u>overall F</u> was significant for each portion of the model ($p<.0001$), indicating that there was negligible probability that the overall results were due to sampling error. This gives rise to a search for other variables that will help explain more of the variance in both portions of the model in future endeavors.

<u>Tests for Recursiveness and Linearity</u>

Two of the assumptions which underlie the structural model and, therefore, the multiple regression and path analysis in this study, indicated that this model was assumed <u>recursive</u>; i.e., contained no feedback; and, further, that the relationships within the model were <u>linear</u>; i.e., a change in Y corresponds to a similar change in X. These two assumptions could not be examined prior to the analysis; therefore, they come under consideration here.

The path model indicates a correlation between the two residuals u^U and v^V. This coefficient indicates a test of any remaining variance hypothesized in the paths that is not accounted for in other ways. If the correlation between the residuals is low or near zero, all or nearly all of the variance has been accounted for in the model, thus, no or very little feedback exists in the system. The correlation between the two residuals is -.147 for this model, indicating a low (near zero) as well as negative correlation between the residuals. Thus, it is relatively safe to assume that a recursive model, without feedback, was structured and tested in this study.

Linearity between the dependent and independent variables also comes under examination. Lintest[6] was used to establish if the assumption of linearity was grossly violated in this recursive path model. The outcome of this examination indicates that linearity was not violated in this model. Two variables appear to be slightly less linear than all the others. These are: 1) exterior construction materials when examined indicates four of the 23 possible relationships are greater than .20; in other words, 17.4 percent of this variable appears non-linear; and 2) number of windows, which shows 11 of the 23 relationships greater than .20, or 47.8 percent of the variable appears non-linear.

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[6]Lintest is a test for linearity devised and programmed by Dr. Bernard Finifter. It is a test of the difference between ETA (the measure of non-linearity) and R^2 (the measure of variance) or E^2-R^2, considered a reasonable measure of the degree of conformity to or deviation from linearity. It does not give indications of the shape of relationships, if non-linearity is found.

Lintest was performed mainly to detect non-linear relationships. Since no gross violation of the assumed linearity was found, no further analysis of the situation was done.

The Gross Analysis

Hypotheses III and IV are an indication of the expected gross relationships to be found in the two modelled dependent variables: 1) belief in the reality of the energy problem; and 2) total direct energy consumption in single family detached dwelling units, when factors are aggregated into two categories: 1) family socio-economic factors, and 2) physical housing factors.

The following, then, is a presentation and discussion of these findings.

Belief in the Reality of the Energy Problem

Hypothesis III: Family socio-economic factors will explain more of the variance than housing physical factors for belief in the reality of the energy problem.

Findings

TABLE 20.--Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Two Independent Variables on Belief in the Reality of the Energy Problem.

	Belief in Energy Problem		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Physical housing factors	.053	.446	>>.25
Family factors	.661	69.29	<.10
Overall F		35.5	<.0001
R = .653		df regression 2	
R^2 = .427		df residual 94	

Discussion

The findings in Table 20, above, overwhelmingly support Hypothesis III. Family factors are highly correlated (β = .661) with belief in the energy problem when compared to physical housing factors (β = .053). This finding has important implications for future public policy and educational programming toward energy conservation. It now appears that in order for "belief" to have a more important impact on energy consumption patterns, which in this study it does not have (β = -.095), more must be done with family perceptions either through social reform or economic disincentives. This will be discussed in a total perspective in Chapter VII.

Total Direct Energy Consumption

Hypothesis IV: Housing physical factors will explain more of the variance than family socio-economic factors for total direct energy consumption in single family detached dwelling units.

Findings

TABLE 21.--Standardized Regression Coefficients, F-ratios, Probability of Sampling Error and Multiple Correlations of Two Independent Variables on Energy Consumption in Single Family Detached Dwelling Units.

	Energy Consumption		
Independent Variables	β	F	Probability of Sampling Error, One Tailed Test
Physical housing factors	.573	58.26	<.10
Family factors	.310	17.05	<.10
Overall F		44.28	<.0001
$R = .696$		df regression 2	
$R^2 = .485$		df residual 94	

Discussion

Hypothesis IV is also supported by the findings. In this case housing physical factors are more highly correlated with energy consumption ($\beta = .573$), when measured in a gross sense, than family factors. However, it should be noted that family socio-economic factors have a respectable correlation with energy consumption ($\beta = .310$).

Therefore, both physical housing factors and family factors need to be given serious consideration as determinants of energy consumption in single family detached dwellings.

In Summary

It would appear from the findings generated and discussed in this chapter, that the exercise of specifying an input/output model of the determinants of energy consumption in single family detached dwelling units has merit. The amount of variance explained in belief in the energy problem (42.7 percent) and energy consumption (48.5 percent) is relatively high for this study's subsample.[7]

This along with the substantial support for all but Hypothesis II, Part 2, gives further evidence for the meaningfulness of this model structuring endeavor. Caution should, however, be raised as the detailed accounting of the correlations between the "belief" variable (Table 18) and energy consumption variable (Table 19) with the selected set of independent variables does reveal a number of low and non-significant correlations, indicating that some variables have very little meaning when accounting for the explained variance found

[7]For the population as a whole the shrinkage in the variance explained would be $\hat{R}^2 = .382$ for the belief variable, and $\hat{R}^2 = .375$ for the energy consumption variable.

This can, however, become important only in future refinements of the model as presented and tested in this study. The findings given here lend themselves to either: 1) structuring a more parsimonious model with fewer variables, or 2) including yet unspecified other variables which could help increase the level of variance explained, or 3) a combination of the two.

CHAPTER VII

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Summary Overview of the Research Problem

> In today's world, the combination of a rapidly growing population, extraordinary changes in income distribution, and a revolution in expectations has put most resources under great pressure. Symptoms of this situation are worldwide inflation, energy and resource shortages, concern about population growth and food supplies, and the movement toward greater planning in the conservation of natural resources. In the United States, families are making complex adjustments to changes in the economic environment and to changes in the rules by which resources are acquired and allocated (Zuiches, 1975b).

Families are inextricably linked to several external environing systems, social and physical, natural and man-made, near and distal. These linkages are identified as the flow of matter/energy and information which the family receives, processes and transforms in its day to day living.

Energy dependency and the information upon which families make decisions about energy use are the crucial concerns of this research. Implicit in the objectives and research problem undertaken here is a measure of the openness and closedness of the family system both to energy flows and information changes. In other words, beyond testing the viability of a systems input/output model, via examination of direction, strength, and variance explained in the hypothesized relationships, there is a covert agenda. This agenda, although not tested explicitly in the research, will be discussed as a basically preliminary and speculative step beyond the research findings toward an indication of boundary maintainance in the family; that is, knowing the factors that contribute to energy consumption in the place of residence gives some very tentative indication of the present state of the family system, its openness or closedness to both energy and informational inputs.

Systems Approach and Analysis Mode

The approach taken in this research was essentially systems analysis, which gives rise to both the overt test of the hypothetical model and the covert speculations about its meaning. The system input/output model of energy consumption in single family detached dwelling units was based in systems theory (ecosystems, cybernetics and general systems theory), using an adapted human ecosystems model as the wholistic integrative conceptual and analytical frame from which (through the process of deduction) a subset of selected and specified systems components was derived; i.e., the subset of hypothetical socio-physical determinants of energy consumption.

Path analysis based on multiple regression was used as the method of analysis. This model was considered suitable for this research problem on theoretical and empirical grounds. A systems problem requires systems analysis, thus the need for a structural mathematical model indicating causal direction and linkages justified the use of path analysis. The assumption of a process system without feedback justified the adoption of the recursive path model.

Need for Residential Energy Research

The area of residential energy consumption was considered a particularly rich territory for research for these reasons: 1) the energy problem, although seemingly less critical than during the crisis period (Winter 1973-74) remains a problem; and 2) not much research has been done (especially from a wholistic systems perspective) which lends insight into the determinants of direct energy consumption in the place of residence.

Conclusions

Testing a Systems Model

Testing the viability of a systems input/output model of energy consumption in single family detached dwelling units was the major explicit objective of this research. To this end four hypotheses were developed which examined both the net and gross determinants, first, of belief in the reality of the energy problem, and second, of energy consumption (See Chapter IV, pages 99 and 100 for stated hypotheses).

The hypotheses were generated mainly as non-random points of entry for the step-wise regression process, rather than as formal hypotheses to be rejected on the basis of the findings. The important aspect of this research is not so much what was hypothesized but what was found based on some initial speculation by the researcher. This research does not test an established theory of residential energy consumption, nor is it a replication of prior research. Therefore, the direction and magnitude of relationships hypothesized were based on the considered judgements of the researcher. Thus, the shifting which occured in the rank order of magnitude (Hypothesis I and II, Parts 2) was more expected than surprising, and gives rise to some interesting speculations.

The most critical aspects of this research are the findings themselves, indicating the direction (positive or negative correlations) and the strength (magnitude of the correlations) in the relationships found and especially the amount of variance explained by the modelled socio-physical variables hypothesized as determinants of belief and of energy consumption.

Belief in the Reality of the Energy Problem

Analytic Conclusions

Treating belief as a dependent variable, indicates that 42.7 percent of the variance was explained by the modelled factors.

The findings of the net analysis (Hypothesis I) suggest that family educational attainment, is positively and substantially correlated with belief as expected ($\beta = .361$, $p \simeq .001$). This along with perceived problems in electrical availability ($\beta = .315$, $p < .005$) and the reporting of yearly costs of energy consumption ($\beta = .183$, $p < .05$), were the major factors affecting belief in the energy problem. Other factors, with non-significant correlation, also contributed to the variance explained (Table 18, page 132).

The findings of the gross analysis (Hypothesis III) of the belief variable (family factors vs. physical housing factors), indicated a substantially higher correlation between family factors and belief (β = .661), than between physical housing factors and belief (β = .053). Thus, the net and gross analysis of the determinants of the belief variable support the notion that elements in, or characteristics of, the family contributed to agreed belief in the reality of the energy problem.

In the analysis for the belief variable, Hypothesis I, Part 1, was supported by the findings, all of the directional signs between the relationships hypothesized hold. Hypothesis I, Part 2 was substantially supported, with only minor shifting in the rank ordering hypothesized and further, Hypothesis III was supported by the highly correlated significant relationships between family factors and belief in the energy problem.

Speculative Conclusions

The families who believe in the reality of the energy problem are relatively open family systems. They have achieved higher educational attainment; they have perceived problems in electrical availability (perhaps from experiencing electrical brown-outs or black-outs); they have consistently reported the total yearly cost of energy supplied to their residence.

To say it more succinctly, they have used both information about energy costs and availability, and experiences with energy shortages as inputs into the formulation of what they believe. The important immediate question is, does this belief, created by the openness of this family system to information and experiences, become activated in a conservative use of energy? The following analysis of energy consumption will in part address this question.

Energy Consumption in Single Family Detached Dwelling Units

Analytic Conclusions

Examination of the portion of the model treating energy consumption as the variable dependent on seventeen independent variables, including the belief variable, indicates that 48.5 percent of the variance in energy use is explained. The net analysis (Hypothesis II) provides some interesting shifting in the rank ordering of magnitude while holding quite consistently to the posited direction of relationships (two exceptions were noted). The shift in ordering indicates that the size of the household (number of persons living in the dwelling unit) is the most important factor contributing to energy consumption ($\beta = .280$, $p < .001$), followed by number of major appliances ($\beta = .211$, $p < .01$), number of rooms in the dwelling ($\beta = .173$, $p \simeq .25$), number of doors to the exterior ($\beta = .168$, $p < .05$), and number of rooms heated ($\beta = .165$, $p < .25$). These factors along with insulation in ceiling ($\beta = -.161$, $p < .005$) and rural location ($\beta = -.127$, $p < .05$) were the major factors contributing most to the variance explained in residential energy consumption. Other factors also contributed, however, to a much less significant degree (Table 19, page 139).

The rank order shifting away from gross family income and square feet of dwelling was somewhat surprising, although when income was given further consideration (speculation concerning its interdependency with other variables included in the model and perhaps some not included), this ranked finding was made more understandable. Number of rooms in the dwelling also appears interrelated with the measurement of dwelling space in square feet, thus making the number of rooms in the dwelling a better overall predictor of dwelling size. The belief variable was hypothesized to be last in the rank ordering and negatively related to energy consumption. The negative relationship holds but it is of a low order magnitude ($\beta = -.095$), although not the lowest (several other variables contributed less to the variance in energy consumption explained).

The gross analysis of the findings on energy consumption (Hypothesis IV) where physical housing factors are hypothesized to contribute more to the variance explained than family factors, shows both factors to be substantially correlated with energy consumption. Physical housing factors are more highly correlated with energy use ($\beta = .573$, $p < .10$); however, family factors, though somewhat less correlated with energy consumption ($\beta = .310$, $p < .10$), still have a substantial and, therefore, essential relationship to energy use. The gross analysis of the findings simply indicates that both factors are important considerations in the consumption of total direct energy in the single family detached dwelling unit.

Speculative Conclusions

Families are apparently unrestricted in their openness to energy inputs from the environment. In other words, as long as supplies of energy (in whatever form) exist without undue constraints (critical shortages and severe price increases), families will continue to expect to use and, therefore, make demands on energy supplies.

This study strongly suggests that it is the number of persons in the household and their aggregate demands on energy consuming appliances, plus certain aspects of the dwelling unit that make the difference in the amount of energy consumed. The weak negative correlation between belief in the reality of the energy problem[1] and energy consumption gives further evidence that even the energy crisis (Winter 1973-74) with its concomitant increased energy costs added little to deter energy use.

Thus, in spite of the families' openness to informational inputs (awareness of and experiences with the energy problem), which affect their belief in the problem, the evidence is not strong that belief affects actions (behavior changes, life style changes) toward reduced energy consumption.

Evidence that further underscores this statement was revealed in a survey (The New York Times, July 2, 1975) conducted since this research, that indicates that residential electrical consumption is on the upswing (national comparison of electrical usage for the first five months of 1974-1975) and, that the conservation efforts were weakening, "despite record high utility bills, wide spread unemployment and recession" (Stuart, July 1975, p. 45 and 51).

The family in its present state, as implied by this study, is one of openness: open to information and

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[1] Belief in the energy problem was hypothesized to have a negative direction of relationship and a low order of magnitude with energy consumption, indicating that it was thought to deter energy consumption, but within the time frame of the study it was postulated not to have much effect on energy use.

and to energy input; i.e., families are open to external environmental impacts without internal familial con- constraints. The very openness of the family system is allowing it to receive mixed messages about the energy problem, its reality, and the need, therefore, to change behavior in response to the problem. There are mixed messages in the societal environment about the real nature of the nation's energy supplies, reinforced by the absence of a national energy policy, reports of out- rageous profit taking by energy suppliers, while simul- taneously receiving higher energy bills in spite of attempts to conserve. It would appear that during the period of this study and since, families have not known how to interpret the conflicting messages they are receiving from the environment, in order to adapt to the changing circumstances (adaptive self-organization toward a new dynamic steady state in relation to the supplies of energy).

Families appear to be (at least in the short- run) in an unstable state (negative entropic state) vis a vis the energy and information environment; i.e., they continue to increase demands for energy supplies, despite the decreasing finite supplies of fossil fuel resources.

The second law of thermodynamics reveals that decreased entropy (negative entropy) within an open system (the family in this case) is always offset by the increase of entropy (positive-equilibrating entropy) in its surroundings (the finite fossil fuel supplies in this case) (Laszlo, 1974, p. 44).

This statement suggests that in the long-run (period greater than the period during and since the energy crisis), families through external environmental realities (forcings) will come to terms with the energy problem through internal constraints; i.e., they will acquire new parameters (less BTU's of energy consumed) in their steady states, if they continue to be subjected to the action of a physical constant (decreasing fossil fuels) in their environment.

This study of energy consumption within single family dwelling units reveals short-term reactions to the energy problem, which suggest either very little reaction or no change in past habits and behavior patterns concerning energy usage. This study does not indicate an adaptive self-organizing state of the family toward new systems parameters of energy use. Only in the long-run (longitudinal study) will this information become apparent.

Study Limitations

Prior to discussion of the implications of this research some comments on the study limitations are suggested.

Major Limitations

The most critical limitation of this study is its cross-sectional nature (study at one point in time, T_1). A cross sectional study does not allow comparisons over time (T_1 compared to T_2, T_3 . . . T_X). As the speculative conclusions indicated, only short-term family system reactions to the energy problem were identified and, those amounted to little or no reaction at all. The empirical analysis supports this contention via the low correlation between the two residual variables (-.147), as well as the low standardized correlation between the belief variable and energy consumption ($\beta = -.095$). Said differently, the test of the input/output systems model of energy consumption in single family detached dwelling units, based on cross-sectional data, was basically recursive (as hypothesized), with little feedback. The use of cross-sectional data did not detect changes in the family in relation to the energy problem.

Other Limitations

Some of the hypothesized relationships between the independent variables had low and non-significant correlations with the belief variable and the energy consumption variable. This may have been due to: 1) poorly selected variables, 2) poor measurement of the variables, or 3) the small sample used in the research. However, in structuring and testing a first hypothesized approximation model (as this model was), findings of this kind are generally expected.

The sample size was barely within the lower limits for multiple regression and path analysis (N=97). Most regression texts suggest a large sample size as best for multiple regression, thus assuring reasonable numbers in all cells. The affect of the sample size on this research is hard to detect, but it probably has some effect on the correlation between variables (suggested above) and may have given rise to some of the residual, unexplained variance.

Other Variables

Variables not included in this study might very well contribute to the explanation of the two dependent variables used, belief and energy consumption. Speculation about this notion would include measurement of changing environmental factors such as climate (humidity, temperature, and wind) and measurement of changes both in the availability and costs of energy forms. Physical housing variables which might have been included are: orientation of the house, comparison between single family and multiple dwellings, indicators of heating and cooling equipment efficiency, measurement of duration and frequency of appliance usage, to name a few. Family factors might have included measurement of changes in employment status and in family composition, indicators of feeling-states about the energy situation, the social milieu, and about themselves as family members and as individuals. Some of these variables could be examined for their possible importance for belief, and others for prediction of energy consumption.

From these limitations and the study conclusions, some implications for future research, public policy and educational programming will be discussed.

Implications

Future Research

The ability to make comparisons from time-series (longitudinal) data is considered essential in future research concerning family energy consumption. Comparisons between time periods would expand the capacity to trace changes in family behavior patterns in relation to energy consumption. To put it in systems terms, time-series data would allow empirical testing (rather than speculation, as here) for the openness or closedness of the family system either as it adapts through self-stabilization (Cybernetics I, closed system, Laszlo, 1972, p. 38-39) or through self-organization (Cybernetics II, open system with internal constraints, Laszlo, 1972, p. 41-47) to changes in the energy and information from the environment.

Future research needs to be done to test the validity and reliability of the measurements used within this research. At the point when these were sufficiently established, the model could be used for the purpose of simulating family energy consumption patterns. Simulation based on refinements in this model (using the best measurements of the most powerful variables) would give efficient and effective predictive capacity to parametric changes in the model having the most effect on family residential energy consumption.

Public Policy

The findings of this study indicate that, although families are receiving messages about the energy problem, they are not changing behavior in response to the messages. This raises serious questions about the ability of families to move voluntarily toward energy conservation. During the energy crisis period (especially during the Arab oil embargo), when uncertainty about fuel supplies was prevalent, an ethic of conservation seemed to appear. The New York Times study called it "a patriotic effort to reduce energy consumption" (1975); Warren called it "evidence of the Protestant ethic" (1974). However, since fuel supplies have become less problematic, the efforts to conserve have dissipated, despite increased energy costs. The implication here is that private energy policies (familial internal controls) are not working; therefore, public policy may have to fill the voluntary conservation gap. Zuiches reports on the acceptability of specific energy related policies (data from the present pilot project), which encompassed a wide range of voluntaristic policies as well as policies requiring government intervention. In general, Zuiches found that the more voluntary policies received greater support (larger percentages of acceptance) than those requiring governmental restrictions (draft of a paper, April, 1975a). Families, it appears, do not support government controls over energy consumption and yet the evidence from this research indicates families are not controlling, through voluntary means, their use of energy. This situation has its parallel in Hardin's "Tragedy of the Commons" where he postulates that "Each man (family in this case) is locked into a system that compels him to increase his herd (in this case energy consumption) without limit -- in a world that is limited" (Hardin, 1968). Further, Hardin states that "Ruin is the distinction toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruins to all" (1968, p. 1244). Although a dire commentary, it nonetheless points out the necessity for a sound public energy policy which will be acceptable to residential energy consumers.

A sound public energy policy would not through drastic, coercive means (quotas, rationing, and other restrictive rules and regulations) turn energy consumption patterns toward more conservative usages in a short, disruptive period of time, but would, rather, ease the residential consumer over a reasonable period of time into using less energy in the dwelling unit. One of the less restrictive and more palatable means of achieving this goal would be through a public policy of energy education (D. Morrison, 1975a).

Educational Programming

"Education can counteract that natural tendency to do the wrong thing, but the inexorable succession of generations requires that the basis of knowledge be constantly refreshed" (Hardin, 1968, p. 1245).

Educational institutions are middle range institutions which operate between strict governmental intervention and pure voluntaristic behavior. An energy education policy which incorporated in its purview the major residential energy consumers (the families who pay the energy bills) as well as future energy consumers would, given enough economic resources and time, re-socialize the energy consumer away from the ethic of rising expectations for energy consumption, toward a more conservative ethic. Thus, a crucial implication of this research is that more education about the facts of the energy problem (both in the short run and over time) would strengthen the belief in the reality of the energy problem, thereby, increasing the probability of incorporating the value of energy conservation not only as an ethic, but also as an active reality.

A system that decreases entropy gathers information (Laszlo, 1972, p. 44).

APPENDICES

APPENDIX A

Glossary of Terms

Glossary of Terms

Abstract System: a pattern system whose elements consist of signs or concepts (Kuhn, 1974, p. 483).

Acting System (Action or Behaving) Systems: is a pattern two or more elements of which interact (Kuhn, 1974, p. 484).

Adaptation (Adaptive Behavior): behavior that in some ways changes the relation of a system to its environment (supersystem) or its internal components (subsystem), either by alternating itself, the environment or both (Kuhn, 1974, p. 484).

Behavioral System (Human): the system of the human that selects the behavioral outputs and guides their execution -- a control system in contrast to a maintainance system (Kuhn, 1974, p. 485).

In Individual the nervous system and associated organs; i.e., eyes, ears that decode information from its environment (Kuhn, 1974, p. 485).

In Society the social institution which Bernard calls the "composite or derivation control environments" (1925, p. 325), which have been "organized around or defined in terms of problems or ways of looking at things or of making adjustments of man to his environment" (1925, p. 329) -- they are more in the nature of institutions such as this non-exhaustive list: economic, political, educational, aesthetic, ethical, etc. (1925, p. 330).

Biological System (Human): the biological entity of the individual human bounded by skin, hair, nails and the like -- a maintainance rather than a control system (Kuhn, 1974, p. 486).

Boundaries (of an Interaction): an interaction is bounded analytically by specifying the systems involved, and the time duration (Kuhn, 1974, p. 486).

Boundaries (of a System): logically the boundaries of a system are defined by listing all the components of the system; any elements not listed are construed as falling outside the system (Kuhn, 1974, p. 486).

Closed System: a system in which interactions occur only among components of the system; i.e., there are no inputs from or outputs to the environment (Kuhn, 1974, p. 486). Closed systems in absolute terms "do not exchange energy or information with any body outside itself, although it may experience all kinds of internal change. That is, the system is completely isolated" (Parsegian, 1973, p. 28). However, most would agree that "there is no such thing as a completely closed system" (1973, p. 28). The term closed system is used in a relativistic sense to mean:

1) a very limited system that performs functions without variation, or
2) a system in which the energy (information or material) that is exchanged with the environment can be identified and measured (1973, p. 28).

Closed Human System: a system which filters but cannot reject energy and other inputs (Vaines, 1974, p. XV).

Controlled System (Cybernetic System): any acting system whose components and their interactions remain at least within some specified range or return it to within that range if the variable goes beyond it, despite changes in forces that influence the state or level of that variable (Kuhn, 1974, p. 489). The success of a controlled system is the ability to "hold the variable within acceptable departures from the desired value" (Parsegian, 1973, p. 61). A controlled system can also be defined as a goal-oriented system. It must have identifiable detector (also called sensory), selector (also referred to as comparator), effector (also called generator) subsystems (Kuhn, 1974, p. 45-54).

Cybernetics: the study of controlled systems.

Ecological System (Ecosystem): an uncontrolled system, some of whose components subsystems are controlled, namely, organisms. The ecological system is defined precisely by the set of assumptions that constitute the model of it (Kuhn, 1974, p. 491).

Energy: is the vitality of all living systems. It is the capacity to do work or the powers to adapt, change or maintain the system. The sun is the ultimate source of energy.

Entropy: in the opposite of pattern and order; it is in effect randomness, disorders, chaos; i.e., loss of organization.

negentropy: is a system in a state of elaborating structure, or a gain in organization and complexity.

Environment: anything outside the boundaries of a defined system.

near environment are conditions having proximity to the organism, thus having a more immediate effect.

distal environment are conditions either more distant spatially or more abstract in concept, thus having less immediate effect.

Equifinality: the principle that: in a closed system the final state of the system is unequivocally determined by the initial condition of the system. In an open system a given final state may be reached from different initial conditions and by different ways (Buckley, 1967, p. 60).

Equilibrium: a defined point or stated set of limited parameters which tends to be maintained.

static equilibrium: a situation in which the forces acting on or exerted by all components in an acting system have come to a state of rest and no further changes take place.

dynamic (steady-state) equilibrium: a situation in which components of an acting system or their states continue to move or change but are balanced so that at least one variable remains within some specified range (Kuhn, 1974, p. 491).

DSE: a convenient reference for detector, selector and effector system (Kuhn, 1974, p. 491).

detector (of a controlled system): the function by which a system acquires information about its environment (Kuhn, 1974, p. 490).

selector (of a controlled system): the function of selecting a response to a given environmental state (Kuhn, 1974, p. 505).

effector (of a controlled system): the function of executing the behavior selected by the selector (Kuhn, 1974, p. 491).

Family (as Organism): it is a system of individual organisms, that is a complex organization with a history and rules (Vaines, 1974, p. xxi).

open family system: it is an identified unit of interacting organisms "who have a common theme and goals, having a commitment over time, and share resources and living space" (Hook and Paolucci, 1970, p. 316). This family system also processes energy/matter and information from the environment in the course of day to day living.

closed family system: a small, complex (if children are involved), multipurpose, cooperative organization with such dominant functions as procreation and sexual relationships, child-rearing, mutual assistance, and care of basic biological needs of its members (Kuhn, 1974, p. 493).

Feedback: a mutual interaction between a system A and some element in its environment B such that an action by A on B produces a return action by B on A (Kuhn, 1974, p. 493).

A ⇄ B = a non-recursive system.

A ⟶ B = a recursive system.

negative (equilibrating) feedback: an oppositely paired mutual interaction. The result is if A changes from some initial state its action back on itself through B moves it back toward, if not precisely to its initial state. Negative feedback is also known as deviation-correcting (Kuhn, 1974, p. 28).

positive (nonequilibrating) feedback: a similarly (not oppositely) paired mutual interaction. The result is if A changes from some initial state its action back on itself through B is to move it even further from the initial state. This relationship is known variously as self-aggravating, deviation-amplifying, explosive (if the initial changes is upward), or shrinking or decaying (if the initial changes are downward) (Kuhn, 1974, p. 28).

Flow: the movement of matter/energy or information across the boundaries of a system or across an arbitrary boundary within it (Kuhn, 1974, p. 493).

Hierarchy of Systems: any relations between systems in which one is a subsystem or supersystem relative to another system (Kuhn, 1974, p. 495).

Homeostasis: a condition in which a controlled system successfully maintains a steady state equilibrium of one or more system variables (Kuhn, 1974, p. 495).

Information (Contained): a system is said to contain or possess information about its environment when some state or pattern within it is functionally related, as a dependent variable, to some state or pattern in its environment (Kuhn, 1974, p. 496).

Input: any movement of matter/energy or information from the environment across the boundaries into an acting system (Kuhn, 1974, p. 496).

Interaction: reciprocal action, A acts on B, and in turn B acts on A.

Interdependence: mutual dependency (Vaines, 1974, p. xxvi).

Interface: a point of contact between two or more systems; i.e., the interpenetration of boundaries -- one system with the other (Vaines, 1974, p. xxvi).

Linkages: in this study linkages are the paths connecting the independent input variables with the output dependent variables. The measure of which is the strength of the relationship (β).

Morphogenesis: refers to those processes which tend to elaborate or change a systems given form, structure or state. Biological evolution, learning and societal development are examples (Buckley, 1967, pp. 58-59).

Morphostatic: refers to those processes in complex system-environment exchanges that tend to preserve or maintain a system's given form, organization, or state -- self regulation, homeostatic processes of organism, customs, rituals and traditions in cultural are examples (Buckley, 1967, p. 58).

Multifinality: refers to similar initial conditions which may lead to dissimilar end-states -- a morphogenetic process (Buckley, 1967, p. 60).

Parameter (of a System): any trait of a system that is relevant to a particular analysis but does not change during the course of the analysis (Kuhn, 1974, p. 501).

parameter (of a system's environment): any trait of a system's environment that is relevant to a particular analysis but does not change during the course of analysis (Kuhn, 1974, p. 501).

Open System: a system that receives inputs from or produces outputs to its environment; i.e., it is influenced by and influences its environment (Kuhn, 1974, p. 500).

Output: any movement of information or matter/energy from any acting system across its boundaries to the environment (Kuhn, 1974, p. 501).

State (of a System or Systems State): a condition of some system variable, such as its temperature, color, rate of flow, magnitude, physical location, chemical composition, degree of excitation, on-or offness, or amount or type of information processed (Kuhn, 1974, p. 25).

Steady State: the dynamic behavior of a system over time, in which there are free exchanges of energy/matter and/or information in response to the external systems state (Kuhn, 1974, p. 491).

Structure: the pattern of an organization described in terms of its subsystems and their roles (Kuhn, 1974, p. 507).

Subsystem: a system that is a component of some larger system (Kuhn, 1974, p. 507).

Supersystem (suprasystem): a larger system of which a given system is a component (Kuhn, 1974, p. 508).

System: any pattern whose elements are related in a sufficiently regular way to justify attention (Kuhn, 1974, p. 508).

Uncontrolled System: any acting system that does not fill the definition of a controlled system; i.e., it has no goal, no variables are maintained within a given range. No specific equilibrium (Kuhn, 1974, p. 509).

Systems Cybernetics I (Self-Regulation): stable equilibrium in systems; i.e., the capacity for self-regulation by compensating for changing conditions in the environment through coordinated changes in the system's internal variables

- self-stabilization
- adaptive self-stabilization (Laszlo, 1972, p. 39).

Systems Cybernetics II (Adaptive Self-Organization): the dynamics of the system itself and the action of evolutionary forces on populations of such systems produce structure, merges some subsystems, subdivides others, reduces total interaction on some parts, gives spontaneous activity, organizes hierarchy, and transforms discrete systems and fields into each other (Levins, in Laszlo, 1972, p. 43).

APPENDIX B

Major Variable Groups to be Assessed in the Pilot Study

Major Variable Groups to be Assessed in the Pilot Study

A. Present family socio-economic status
- A.1. Total family income according to source
  - A.1. Income of each family member
  - A.2. Occupation and employment status of each family member, including type of work, industry, hours, wage, rate, length of job tenure
  - A.3. Educational attainment of each family member
  - A.4. Housing value
  - A.5. Family net worth, assets, obligations, insurance

B. Family resource status
- B.1. Housing structure described as to type of structure, number of units in structure, number of stories, size and location of each window, dimensions of rooms and attic. Types of rooms. Construction material; extent and location of insulation; type and size of home heating/cooling systems, type of fuel used; types and sizes of major energy consuming appliances
- B.2. Transportation resources -- number, size, age and fuel consumption of family vehicles
- B.3. Nutritional status of family members

C. Family energy use
- C.1. Consumption of energy in the household, measured by meter reading and utility records; fuel/electricity/water
- C.2. Costs of energy consumption measured in C.1
- C.3. Transportation expenditures -- fuels and other
- C.4. Transportation patterns -- distance, frequency, intensity of vehicle use
- C.5. Food consumption patterns, food consumption costs

D. Present household structure
- D.1. Family size
- D.2. Household size
- D.3. Ages
- D.4. Race
- D.5. Religious preference
- D.6. Political preference
- D.7. Family life cycle/family formation

E. Family functioning
- E.1. Self
- E.2. Roles/inter-familial relations
- E.3. Kinship/input-output dependency
- E.4. Community/society -- social alienation
- E.5. Division of labor
- E.6. Decision making
- E.7. Present state of family functioning: High/Medium/Low

F. Family knowledge/definition of situation
- F.1. Knowledge of energy crisis/shortages-increased costs
- F.2. Belief in energy crisis/short-term/long-term
- F.3. Knowledge of energy consumption costs and amounts
- F.4. Nutritional knowledge
- F.5. Knowledge of transportation costs
- F.6. Knowledge of alternate transportation forms
- F.7. Environment sensitivity/belief in fixed nature of resources

G. Family expectations/values
- G.1. Future housing expectations/changes/improvements
- G.2. Future family size expectations
- G.3. Future transportation expectations
- G.4. Future appliance purchase expectations
- G.5. Future family income expectations
- G.6. Future family food consumption expectations

H. Changes in energy/resource consumption
- H.1. Willingness to change energy and resource consumption (household)
- H.2. Energy conservation practices/heating/electrical (household)
- H.3. Willingness to change transportation patterns
- H.4. Changes in transportation patterns/use/distance/speed/type
- H.5. Changes in food consumption patterns

APPENDIX C

Tables of Total Lansing SMSA Families and Pilot Study Sample Families

TABLE 22.--Family by Type, Total Lansing SMSA Families, Pilot Study Sample Families.

Family Type	Total Population LANSING, SMSA 1970 Census Number	Percent	Pilot Study Sample: Lansing, SMSA Number	Percent
Husband-Wife (with children)	47,351	(52.8)	138	(63.6)
Husband-Wife (without children)	36,474	(40.7)	59	(27.2)
Female Heads (with children)	4,815	(5.4)	19	(8.8)
Male Heads (no wife-with children)	970	(1.1)	1	(0.5)
TOTAL	89,610	(100.0)	217	(100.0)

Source: Lansing, SMSA data calculated from Table 156, Detailed Characteristic, Michigan, U.S. Dept. of Commerce, U.S. Census of Population, 1970, p. 747.

TABLE 23.--Educational Attainment, Total Families Lansing SMSA, Pilot Study Sample Families.

Years of School Completed	Total Population: Families Lansing SMSA		Pilot Study Sample: Families Lansing SMSA	
	Number	Percent	Number	Percent
0-8 years (elementary school & junior high)	15,920	(17.8)	87	(21.2)
9-11 years (partial high school)	16,431	(18.3)		
12 years (high school completed)	29,671	(33.1)	158	(38.4)
1-3 years college	12,074	(13.5)	78	(19.0)
4 years or more (college graduate & professional training)	15,514	(17.3	88	(21.4)
TOTAL	89,610	(100.0)	411	(100.0)

Source: Families by type and composition, Education and Labor Force Participation of Head and Wife. Table 158, Detailed Characteristics, Michigan, U.S. Dept. of Commerce, Bureau of the Census, 1970, pp. 24-753.

TABLE 24.--A Comparison of Occupational Characteristics by Sex, Total Lansing SMSA[1] and Sample Families.

Occupational Categories	Total Population Employed, 16 years or over, Lansing SMSA Males %	Total Population Employed, 16 years or over, Lansing SMSA Females %	Pilot Study Sample: Lansing SMSA Males %	Pilot Study Sample: Lansing SMSA Females %
Professional	17.3	17.3	20.7	16.3
Managerial	9.6	2.9	10.9	4.7
Clerical & Sales	13.6	48.6	10.9	33.5
Blue-Collar	47.0	10.7	56.0	11.2
Service Workers, Household, and Farm Labor	12.5	20.5	1.5	34.3
TOTAL	100.0	100.0	100.0	100.0
(N)	91,823	57,608	193	215

[1] Source: Labor Force Characteristics of Population, 1970, Table P-3. Census Tracts, Lansing, Michigan, U.S. Dept. of Commerce, Bureau of the Census 1970, p. P-21.

TABLE 25.--Income Characteristics, Total Families Lansing SMSA, Pilot Study Sample Families.

Income Categories (Family Gross Income 1973)	Total Population:[1] Families Lansing SMSA		Pilot Study Families Lansing SMSA	
	Number	Percent	Number	Percent
Less than $4,999	11,814	(13.2)	17	(8.0)
$5,000 to $9,999	25,235	(28.2)	43	(20.5)
$10,000 to $14,999	28,358	(31.6)	65	(31.9)
$15,000 to $24,999	19,716	(22.0)	56	(26.7)
$25,000 or more	4,487	(5.0)	28	(13.3)
TOTAL FAMILIES	89,610	(100.0)	210	(100.0)
Median Income	$11,213		$13,425	

[1]Source: Income Characteristics of the Population: 1970, Table P-4, Census Tracts, Lansing, Michigan, U.S. Dept. of Commerce Bureau of the Census, 1970, p. P-31.

TABLE 26.--Marital Status by Sex and Age, Total Lansing SMSA, Pilot Study Sample.

Age Categories	Total Population Married:[1] Lansing SMSA, 1970 Census				Pilot Study Sample: Lansing SMSA			
	Male		Female		Male		Female	
	#	%	#	%	#	%	#	%
under 18 years	107	(0.1)	405	(.005)	--	--	--	--
18-29 yrs.	21242	(25.6)	26869	(31.9)	58	(29.7)	72	(34.1)
30-44 yrs.	26758	(32.2)	26725	(31.7)	70	(35.1)	77	(36.5)
45-64 yrs.	26680	(32.1)	24764	(29.4)	56	(28.7)	53	(25.0)
65 yrs. & over	8268	(10.0)	5533	(7.0)	11	(5.6)	9	(4.0)
TOTALS	83055	(100.0)	84296	(100.0)	195	(99.9)	211	(100.0)

[1]Source: Lansing SMSA data calculated from Table 152, Detailed Characteristics Michigan, U.S. Dept. of Commerce, U.S. Census of Population, 1970, p. 728.

TABLE 27.--Housing Structural Types, Total Lansing SMSA, Pilot Study Sample.

Housing Structural Types, Units in Structure	Total Population[1] Lansing, SMSA		Pilot Sample: Lansing, SMSA	
	Number	Percent	Number	Percent
1 (including mobile homes)	88,219	(76.0)	175	(80.6)
2	7,689	(7.0)	10	(5.0)
3 and 4	4,202	(4.0)	2	(1.0)
5 or more	15,676	(13.0)	30	(13.8)
TOTAL	115,786	(100.0)	217	(100.0)

[1]Source: Structural, Equipment, and Financial Characteristics of Housing Units: 1970, Table H-2, Census Tracts, Lansing, Michigan, U.S. Dept. of Commerce, Bureau of Census, 1970, p. P-11.

TABLE 28.--Housing Tenure, Total Lansing SMSA, Pilot Study Sample.

Housing Tenure	Total Population[1] Lansing, SMSA 1970 Census		Pilot Study Sample: Lansing, SMSA	
	Number	Percent	Number	Percent
Owner Occupied	77,135	(66.6)	147	(67.7)
Renter Occupied	33,390	(28.8)	70	(32.3)
Vacant	5,264	(5.0)	--	--
TOTAL	115,789	(100.0)	217	(100.0)

[1]Source: Occupancy, Utilization and Financial Characteristics of Housing, 1970 Census Tracts, Lansing, Michigan, U.S. Dept. of Commerce, Bureau of the Census, 1970, p. H-1.

APPENDIX D

Operational Variables and Parts of Questionnaires

Operational Variables

Variables	Where Found
2.21 - Total square feet (including basement)	Tax records
2.22 - Presence or absence of insulation recorded	Housing facilities & Utilities
Code - Ceiling pres. = 1 abs. = 0 Walls pres. = 1 abs. = 0 Floors pres. = 1 abs. = 0	q 2
2.23 - Number of floor levels	q 1.7
Coded 1-99 (actually levels)	
2.24 - Number of rooms	q 1.1 & 1.2
Coded 1-99 (actually # of rooms)	
2.25 - Number of rooms heated	q 1.5
Coded 1-99 (actual rooms heated)	
2.26 - Number of rooms air conditioned	q 1.6
Coded 1-99 (actual rooms a.c.).	
2.27 - Total number of windows	q 1.10
Coded 1-99 (actual #)	
2.28 - Total number of doors to exterior	q 1.9
Coded 1-99 (actual #)	
2.29 - Type of exterior construction material	Environmental evaluation, q 4

Coded

01 = Wood	11 = Aluminum siding
02 = Stone	12 = Wood & Aluminum siding
03 = Brick	13 = Brick & Stone
04 = Cement Block	14 = Siding (UNSP)
05 = Stucco	15 = Brick, Cement Block & Siding
06 = Combination of several above	16 = Wood; Asphalt Brick Look
07 = Wood & Brick	17 = Brick & Siding
08 = Brick & Aluminum siding	18 = Shingle
09 = Metal (Mobile Home)	19 = Wood, Brick & Siding
10 = Stone & Aluminum siding	20 = Wood, Aluminum & Siding

Variables	Where Found
2.30 - Number of Major Appliances	H F & U, q 12

Coded

1. Electric Stove with surface burners
2. Gas stove with surface burners
3. Self-cleaning electric oven
4. Electric oven
5. Gas oven
6. Dishwasher
7. Micro-wave oven
8. Color television
9. Black & white television
10. Washing machine
11. Electric clothes dryer
12. Gas clothes dryer
13. Electric space heater
14. Humidifier (winter)
15. Dehumidifier
16. Room air conditioner (summer)
17. Central air conditioning (summer)
18. Self-defrosting electric refrigerator
19. Electric Refrigerator (without defrost)
20. Gas Refrigerator
21. Self defrost home freezer
22. Home Freezer (without defrost)
23. Electric water heater
24. Gas water heater

Recoded
- if household has = 1
- if household does not have = 0

Recoded
- Summed the 1's

2.31 - Location of Dwelling — Housen File

rural = 1 — Var. .001
urban = 0

3.21.2 - Number of Persons Living in dwelling — Var. 343

Raw Count of Persons

3.21.2 - Family Life Cycle — Var. 344

Recoded

Young families without children = 1
Families with children under twelve = 2
Families with children at home over twelve = 3
Older families without children = 4

Variables	Where Found
3.22.1 - Educational Attainment	Housen File Var. 305 & 317
Mean husband & wife scores	
3.22.3 - Gross Family Income (1973)	Confidential Report q. 5
Coded a) Under $2,000 b) $2,000 - $2,999 c) $3,000 - $3,999 d) $4,000 - $4,999 e) $5,000 - $5,999 f) $6,000 - $6,999 g) $7,000 - $7,999 h) $8,000 - $8,999 i) $9,000 - $9,999 j) $10,000 - $10,999 k) $11,000 - $11,999 l) $12,000 - $12,999 m) $13,000 - $13,999 n) $14,000 - $14,999 o) $15,000 - $15,999 p) $16,000 - $17,999 q) $18,000 - $20,999 r) $21,000 - $24,999 s) $25,000 - $29,999 t) $30,000 - $49,999 u) $50,000 and above	
3.22.3 - Housing Tenure	Card 50
Owner = 1 Renter = 0	
3.23.1 - Belief Variable	Energy Questionnaire q.2
Do you believe that the energy problem is real? (Check ( ) one). 1_____Yes 2_____Yes, but will be solved by the recent end of the Arab Embargo. 3_____No 4_____No, but there might be in the near future. 5_____No, but there might be in the distant future.	

Variables	Where Found
These five responses were reordered to accomplish a continuum.	

1 = yes
2 = Yes, but. . . end to Arab Embargo
3 = No, but in the near future
4 = No, but in the distant future
5 = No

These were further recoded to:

1 and 2 = 2
3-4-5 = 1

Then the Husbands (Var. 066) and the Wives (Var. 005) responses were summed in this fashion within the family as unit of analysis criteria:

If both agree, yes = 4
If they disagree = 3
If both agree, no = 2

3.23.2 Perceived Cost of Energy — Housing Facilities & Utilities q. 5

Total for 1973

*1. Electricity	5. Sewage
*2. Natural Gas	6. L.P. Gas
3. Garbage	7. Butane
4. Water	*8. Fuel Oil

$______________(3 columns)

Codes: Specify number of dollars nearest whole dollar: If exactly half (e.g. 50¢) round to the nearest even dollar.

For example:
010 = $10.25
011 = $10.75
010 = $10.50
012 = $11.50
000 = Not Applicable. If N A, code the next 4 columns 0000.
Blank = missing data (code only if while section is skipped).

Variables	Where Found
* Only these categories were used in the study.	
Recoded to: if they reported total 1973 costs = 1 if they did not report = 0	
3.23.2 - Perceived Availability of Energy by Type (Husband/ Wife)	Energy Questionnaire q. 3

To what extent has each of the following been a problem for the people of Michigan, since the Fall of 1973? (check ( ) one on each line)

*1. A shortage of gas for cars.
2. A shortage of electricity.
3. A shortage of natural gas for home heating.
*4. A shortage of coal for home heating
5. A shortage of fuel oil for home heating.

Coded: 1 = very great extent
2 = great problem
3 = some problem
4 = slight problem
5 = no problem at all

Recoded: very great problem
great problem
some problem
slight problem = 2

no problem at all = 1

Then the husbands (Vars. 068, 069, 071) and wives (Vars. 007, 008, 010) were summed in the following fashion within the family as unit of analysis criteria.

Recoded:
if both agree (2) to problem = 2
if they disagree = 1
if both agree (1) no problem = 0

*In this transformation of data both number 1 and number 4 were deleted as not being relevant to this study.

Variables	Where Found
4.11 - Total Amount of Energy (BTU's) Consumed in Single Family Detached Dwellings.	

Total direct residential energy consumption.-- is the summed amount of energy consumed, measured in British Thermal Units (hereafter BTU's) in the place of residence depending on household mix. Each source of energy for each residence in this study was identified (a mixture of electricity and natural gas or electricity and fuel oil) using data supplied by utility and oil companies. These data were received from the companies in the Standard units of energy measurement; i.e., cubic feet of natural gas, kilowatt hours of electricity, gallons of fuel oil. Each type of energy was then summed for a twelve month period (June 1973 to May 1974) and then converted to BTU's. Once the conversion to BTU's for each energy source was accomplished they were simply added together, depending on household mix, to gain the total amount of energy consumed per residential unit. The measurements conversion included in this study are as follows:

1 cubic foot of natural gas = 1,031 BTU's
1 kilowatt hour of electricity = 3,413 BTU's
1 gallon of fuel oil - 130,000 BTU's

A British Thermal Unit (BTU) is the amount of energy needed to increase the temperature of one pound of water one farenheit degree.

ENERGY

INSTRUCTIONS: Please read all questions carefully and check (✓) answers you believe to be right for you. (There is no right answer.)

1. No doubt you have heard of the "energy crisis"; when did you first hear about it? (check (✓) one)

   1. ________ less than 6 months ago
   2. ________ about 6 months ago
   3. ________ about 1 year ago
   4. ________ about 2 years ago
   5. ________ over 2 years ago

2. Do you believe that the energy problem is real? (check (✓) one)

   1. ________ yes
   2. ________ yes, but it will be solved by the recent end of the Arab Embargo
   3. ________ no
   4. ________ no, but there might be in the near future
   5. ________ no, but there might be in the distant future

3. To what extent has each of the following been a problem for the people of Michigan, since the Fall of 1973? (check (✓) one on each line)

	Very Great Problem	Great Problem	Some Problem	Slight Problem	No Problem At All
1. A shortage of gas for cars	________	________	________	________	________
2. A shortage of electricity	________	________	________	________	________
3. A shortage of natural gas for home heating	________	________	________	________	________
4. A shortage of coal for home heating	________	________	________	________	________
5. A shortage of fuel oil for home heating	________	________	________	________	________

4. How wide spread is the energy problem? (check (✓) one)

   1. ________ the whole world
   2. ________ the Western nations only
   3. ________ the United States only
   4. ________ the larger cities in the United States
   5. ________ other________________________ (specify)

HOUSING FACILITIES AND UTILITIES

(for both owners and renters)

1. The following questions have to do with this particular dwelling, its space, size and utilities. Please answer the questions below as exactly as you can.

    1. How many rooms are in this dwelling, not counting bathrooms? _____ No. of rooms
    2. How many bathrooms? _____ No. of bathrooms
    3. How many bedrooms? _____ No. of bedrooms
    4. How many rooms are used for sleeping? _____ No. of rooms
    5. How many rooms are actually heated? _____ No. of rooms
    6. How many rooms are actually air-conditioned? _____ No. of rooms
    7. How many floor levels in this dwelling? (including basements if used as living or play space. Also, number of floors if this is an apartment building) _____ No. of floors
    8. How many doors inside the dwelling? _____ No. of doors
    9. How many doors to the outside of the dwelling? _____ No. of doors
    10. How many windows in the dwelling? _____ No. of windows

2. Is this place insulated? (check (✓) ALL that apply)

    1. ______ in the ceiling?
    2. ______ in the walls?
    3. ______ under the floors, if no basement?

3. How is this place heated? (check (✓) ALL answers that apply to your dwelling place)

    1. ______ Portable heaters
    2. ______ Fixed space heaters
    3. ______ Baseboard heaters (electric)
    4. ______ Central furnace
    5. ______ Wood stove
    6. ______ Baseboard heaters (hot water)

4. What type of energy is used to heat this place? (check (✓) ALL answers that apply according to the type of heating used)

    1. ______ Wood
    2. ______ Coal
    3. ______ Fuel Oil
    4. ______ Bottle Gas L.P.
    5. ______ Butane
    6. ______ Natural Gas
    7. ______ Electricity

5. For each utility in your home you receive a bill. We would like you to report the amount you paid for the last billing period and tell us if it was by the month, by the quarter, by the season. (If by the month, please give the amount you paid for February 1974.)

(EXCEPTION: For renters who have some utilities included in rent payment give only dollar amounts for the utilities you pay.)

			By the Month (Feb. 1974)	By the Quarter	By the Season	Total For 1973 *See Below
1.	Electricity	$ ______ per	______	______	______	$ ______
2.	Natural Gas	$ ______ per	______	______	______	$ ______
3.	Garbage	$ ______ per	______	______	______	$ ______
4.	Water	$ ______ per	______	______	______	$ ______
5.	Sewage	$ ______ per	______	______	______	$ ______
6.	L.P. Gas	$ ______ per	______	______	______	$ ______
7.	Butane	$ ______ per	______	______	______	$ ______
8.	Fuel Oil	$ ______ per	______	______	______	$ ______

*NOTE: (If you do not have your receipt stubs available, please try to estimate as closely as possible.)

6. Do you have a budget plan for fuel purchases? (check (✓) one)

______ No, if no, go to question 7.

______ Yes, if yes, answer question A and B

A. What is your monthly payment on this plan? $______

B. Total paid in 1973 on this plan? $______

7. Do you have a way to control the temperature in your place? (check (✓) one)

______ No, if no, answer questions 8, 9 and 10.

______ Yes, if yes, answer questions A and B, and skip to question 11.

A. What method do you have to control the temperature? (check (✓) one answer that applies)

1. ______ thermostat control
2. ______ turning on and off radiators
3. ______ turning on and off built-in space heaters
4. ______ other ______ (what?)

B. About what temperature have you and your family kept this place? (give approximate degrees)

	Winter 1974	Winter 1973
Daytime	______ degrees	______ degrees
Nighttime	______ degrees	______ degrees

Go to Question 11.

12. **Part of the energy used in the home comes from the use of individual appliances. How many, what age and how many times per week are your family's appliances used?**

INSTRUCTIONS: In the two spaces to the left of the appliance listed, please give:

(1) the number of each appliance your family has (0 if none, 1, 2, 3 etc.)

(2) the age approximately of each (model year or year of purchase)

In the spaces to the right of the appliance listed, please:

(1) check (✓) the number of hours approximately the appliance is used per week.

Number of each	Age of each		Less than one hour per week	1–4 hours per week	5–10 hours per week	11–50 hours per week	51–100 hours per week	All the time
____	____	Electric stove with surface burners	____	____	____	____	____	____
____	____	Gas stove with surface burners	____	____	____	____	____	____
____	____	Self-clearning electric oven	____	____	____	____	____	____
____	____	Electric oven	____	____	____	____	____	____
____	____	Gas oven	____	____	____	____	____	____
____	____	Dishwasher	____	____	____	____	____	____
____	____	Micro-wave oven	____	____	____	____	____	____
____	____	Color television	____	____	____	____	____	____
____	____	Black & white television	____	____	____	____	____	____
____	____	Washing machine	____	____	____	____	____	____
____	____	Electric clothes dryer	____	____	____	____	____	____
____	____	Gas clothes dryer	____	____	____	____	____	____
____	____	Electric space heater	____	____	____	____	____	____
____	____	Humidifier (winter)	____	____	____	____	____	____
____	____	Dehumidifier (summer)	____	____	____	____	____	____
____	____	Room air-conditioning (summer)	____	____	____	____	____	____
____	____	Central air-conditioning (summer)	____	____	____	____	____	____
____	____	Self-defrosting electric refrigerator	____	____	____	____	____	____
____	____	Electric Refrigerator (without defrost)	____	____	____	____	____	____
____	____	Gas Refrigerator	____	____	____	____	____	____
____	____	Self-defrost home freezer	____	____	____	____	____	____
____	____	Home freezer (without defrost)	____	____	____	____	____	____
____	____	Electric water heater	____	____	____	____	____	____
____	____	Gas water heater	____	____	____	____	____	____

APPENDIX E

Tables of Means and Standard Deviations,
Matrix of Raw Correlations

TABLE 29.--Study Means and Standard Deviations.

Variable	Mean	Standard Dev.	Cases
HOUSEN	199.7708	58.3209	97
HOUSIZ	3.9691	1.9496	97
MAJAPP	9.1789	2.8210	97
NROOMS	8.0412	2.1598	97
NDOORS	2.7010	.9913	97
RHEAT	6.2887	2.0613	97
SQFT	1097.2474	490.3113	97
FAMING	14.1722	4.8356	97
NFLORS	2.4742	.7513	97
NWIND	15.9897	5.8157	97
INSUF	.1031	.3057	97
EXTSID	7.2577	6.3971	97
FAMLC	2.4021	1.1149	97
RACOND	1.2062	2.4492	97
BEPIR	2.9175	.8375	97
INSUW	.7113	.4555	97
LLRES	.1546	.3634	97
INSUC	.8866	.3187	97
MEDUCA	12.8247	2.6975	97
EPEREL	.8969	.8099	97
RPCOST	.4330	.4981	97
EPERNG	1.8557	.5202	97
EPERFO	1.7113	.7065	97
HHSTEN	.1340	.3424	97

TABLE 30.--Raw Correlation Matrix.

	HOUSEN	HOUSIZ	MAJAPP	NROOMS	NDOORS	PHEAT	SOFT	FAMINC	NFLORS	NWIND	INSUF	EXTSID
HOUSIZ	.37814											
MAJAPP	.39937	.03582										
NROOMS	.53187	.22799	.45367									
NDOORS	.42113	.05446	.41286	.57993								
PHEAT	.48916	.27699	.29018	.73663	.48619							
SOFT	.36403	.13559	.43196	.54477	.41613	.40505						
FAMINC	.29578	.01228	.56052	.33073	.29335	.19339	.38292					
NFLORS	.19211	.11579	.13560	.23818	.05249	.22692	-.00821	.11205				
NWIND	.34139	.19749	.34470	.49346	.28134	.34434	.23543	.12741	.31821			
INSUF	.04904	.16272	.00471	.11972	-.05911	.03494	-.00003	.05834	-.03357	.17054		
EXTSID	-.04345	.07030	-.06737	-.15513	-.23741	-.14078	-.16080	.05674	.00465	-.10240	.10880	
FAMLC	.31809	.48023	.19217	.20154	.11933	.28439	.21595	.23330	.19283	.19701	.02994	-.07018
RACOND	.21605	-.00093	.47350	.31541	.24018	.29345	.25247	.27858	.14444	.18653	.06871	.01785
BEPIR	.06666	-.00159	.23557	.24375	.08291	.18891	.33128	.33610	.14559	.11744	.07425	.05845
INSUW	.19849	.22444	.30569	.37223	.31443	.32265	.33246	.22757	.03391	.15616	.21597	-.05642
LLRES	.02528	.09503	.12513	.23055	.15859	.16225	.08156	.03211	.03382	.23732	.04253	-.25030
INSUC	.01771	.06135	.24085	.24897	.22127	.19303	.24514	.12759	.09642	.12299	.12125	-.00084
MEDUCA	.14299	-.10404	.38232	.36957	.35224	.30144	.44996	.39804	.21620	.25021	-.18000	-.00158
EPEREL	.09416	.18927	-.06397	.05010	.18179	.09912	.04754	.13305	.04695	-.04004	-.04078	.00116
RPCOST	.11156	-.01825	.11480	-.12329	-.07265	-.14330	.18523	.05820	.05797	-.06577	-.02257	.05942
EPERNG	.16094	.18042	.21653	.07952	.11745	.17525	.09154	.28323	-.03627	.05459	.09455	.13550
EPERFO	.10741	.17495	.13072	-.00577	.08372	.12934	-.03443	.19154	.10359	.03476	-.15018	.06734
HHSTEN	-.22562	.08428	-.30544	-.14839	-.05485	-.04062	.01953	-.35635	-.04717	-.18759	-.03386	.13148

	FAMLC	RACOND	BEPIR	INSUW	LLRES	INSUC	MEDUCA
RACOND	.12955						
BEPIR	-.05335	.23689					
INSUW	.23093	.21264	.19269				
LLRES	.12775	.12764	.00811	.02076			
INSUC	.10033	.13701	.12069	.27443	.06304		
MEDUCA	.09468	.19473	.48458	.16611	-.09957	.25531	
EPEREL	-.10359	.16837	.38561	.03144	-.01605	-.08611	.10131

	FAMLC	RACOND	BEPIR	INSUW	LLRES	INSUC	MEDUCA	EPEREL	RPCOST	EPERNG	EPERFO
RPCOST	.13344	-.08249	.21136	.14343	-.20111	-.01555	.19276	-.17225			
EPERNG	-.18628	.05630	.30711	.17403	.00909	.02591	.07087	.31045	.09249		
EPERFO	-.14207	.08291	.31143	.05207	-.14889	-.05437	.08796	.27514	.12207	.67905	
HHSTEN	-.11533	-.10781	-.07002	-.08330	-.00085	.04525	-.06452	-.06234	-.09949	-.12418	-.09676

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