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THE DIFFUSION OF ENERGY-EFFICIENT TECHNOLOGIES IN INDUSTRY

Final Report

By
Shin-yi Hsu

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State University of New York at Binghamton
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The Diffusion of Energy-Efficient Technologies in Industry

Chapter 1: Introduction

A. Energy Conservation in Industry

1. Overview of the energy consumption pattern in the United States

Oil imports in 1977 reached a record average of more than 8.6 million barrels a day, accounting for 47.5 percent of total domestic oil supplies. An increasing reliance on foreign oil in the United States has been evident from the fact that oil imports rose nearly 15 percent a year between 1970 and 1975, in contrast to a declining pattern with a annual rate of 2.2-3.5 percent experienced by Japan, France and West Germany (Economic Report of the President, 1978). Although this trend may level off by 1985 (New York Times, March 19, 1978), the degree of dependence on foreign oil will remain very high until alternative energy sources can be developed. In the meantime, United States energy policies aim at cutting down dependence on foreign oil in two ways: by energy conservation and by finding new domestic supplies. This study intends to investigate how the first goal can be achieved in the industrial sector (manufacturing) of the economy, which accounts for about 40 percent (about 7.3 million barrels per day) of the total energy consumption in the United States (Stanford Research Institute, 1972).

Basic data on energy consumption in industry are given in such sources as the Census of Manufactures (1972) and Fuel and Electric Energy Consumed (1974). Consumption patterns by industrial types have also been investigated, by both governmental and private agencies.[1]

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[1] For example: National Bureau of Standards, NBS Handbook 115; Federal Energy Administration, The Data Base and The Nine Selected Industries (Vols. 1-9); Environmental Protection Agency, Energy Consumption: Fuel Utilized and Conservation in Industries (1975); Stanford Research Institute, Pattern of Energy Consumption in the U.S. (1972); and The Conference Board, Energy Consumption in Manufacturing, (1974).

In the 1972 Census of Manufactures, industries are classified according to the Standard Industrial Classification (SIC) code with a four-digit number. Industries are grouped into classes in a two-digit system. Column A of Table 1.1 illustrates such a classification. The profile of industrial energy use by two-digit SIC group is given in Column B of this table.

TABLE 1.1: Percent Distribution of Energy Consumption by Industry

(Two-Digit SIC Code Groups)

	A	B
Industry	SIC	Percentage of Energy Consumption
Food	20	7.02
Tobacco	21	0.14
Textiles	22	2.37
Apparel	23	0.48
Lumber & wood products	24	1.98
Furniture & fixtures	25	0.41
Paper & pulp	26	9.84
Printing & publishing	27	0.67
Chemicals	28	11.61
Petroleum & coal products	29	22.52
Rubber	30	1.86
Leather	31	0.18
Stone, clay & glass	32	9.87
Primary metals	33	19.89
Fabricated metals	34	3.01
Non-electrical machinery	35	2.64
Electrical equipment	36	1.84
Transportation equipment	37	2.78
Instruments	38	0.52
Miscellaneous	39	0.37
		100.00

As the table shows, the six major industrial energy users are:

SIC	Product	1972 Percentage
29	Petroleum	22.52
33	Primary metals	19.89
28	Chemicals	11.61
32	Stone, clay & glass	9.87
26	Paper & pulp	9.84
20	Food	7.02
		80.75

Together they represent more than 80 percent of total industrial consumption, and the three highest users alone consume more than half of the energy used in manufacturing. No other industry group uses more than about 3 percent of the total energy purchased.

Industrial energy consumption can also be measured by "energy intensity," defined as the number of BTU's per dollar of output. However, the most energy-intensive industries are not necessarily the largest users. For instance, manufacturing of lime (SIC 3274) is the most intensive, and yet it accounts for only 5% of the energy use (Conference Board, 1974). Other highly energy-intensive industries are hydraulic cement (SIC 3324), and electrometallurgical products (SIC 3313). It is generally agreed that energy conservation opportunities lie primarily among these two groups of industries: large users and highly energy-intensive industries.

Industrial firms can also be classified by the number of employees, with firms with fewer than 250 employees considered "small firms," and firms with more than 450 employees as "large firms," using census size groups. Large firms represent only 5 to 10 percent of the total number of firms in the United States. Thus, to be effective in reducing energy consumption, conservation efforts should also be pursued by medium and small firms.

2. Awareness of the energy problem

Since 1967, industry has been facing two interrelated problems: higher energy costs and uncertain energy supplies. However, the severity of the problem was not recognized until the 1973 Arab oil embargo. Since the summer of 1975, some plants have been forced to shut down intermittently because of shortages of electricity, natural gas, and light fuel oils. The situation was the worst in the winter of 1976 in the Midwest region of the United States, with workers being laid off a common phenomenon. Industry's response to the energy problem has been rather gradual. For instance, in the April 1973 survey by the Conference Board (1974), industry showed only modest concern about energy supply difficulties. Since then, however, along with increasing difficulties in energy cost and supply, awareness of the problem has been heightening. In our survey, conducted in the spring and summer of 1977, it was noticeable that the firms in general had responded quite sensitively to the energy problem by both implementing good-housekeeping conservation measures and adopting energy-efficient technologies. Additionally, the firms are organized--for instance by having an energy committee or coordinator--to maintain their programs and keep the momentum. At the local level, energy councils have been formed around Chambers of Commerce to promote energy conservation and adequate energy supply efforts.

Governmental responses to the energy shortage come largely from the federal government in two forms: (1) conducting studies on energy conservation opportunities and methods and new energy sources, and (2) creating special agencies to deal with energy issues, such as the Energy Research and Development Administration and, more recently, the Department of Energy. The net effects are development of energy policies and establishment of regulatory measures in addition to providing and disseminating energy information.

With respect to the latter, Jones (1977) noticed that an "organized" response was not realized until 1974-1975 with the creation of specialized energy programs from the following components:

Executive
Executive Office of the President (Council of Energy Resources)
Department of the Interior
Federal Energy Administration (new agency responsible for managing short-term fuel shortages)
Energy Research and Development Administration
Nuclear Regulatory Commission

We may add the energy offices of the National Bureau of Standards and the Department of Commerce to the above list. All of these units were reorganized and combined into the Department of Energy in mid-1977. The neglect of the energy problem in the past by the federal government can be witnessed from the fact that of the 35 executive units, only three included "energy" in their title prior to 1974; approximately the same ratio occurs on the Congressional side (Jones, 1977).

3. Energy conservation opportunities in industry

The industrial sector accounts for a fairly large amount (about 40 percent) of total United States energy consumption. Until recently, it was widely assumed that industry, guided by economic rationality, made the most efficient use of energy. Accordingly, the bulk of energy conservation research prior to 1974 focused on target populations other than industry, especially on households and transportation (Macrakis, 1974; Connery & Gilmore, 1974; Berg, 1974). It is very clear today, however, that there is significant latitude for improving the efficiency of energy use in industry through measures that are economically justifiable. Some investigators have estimated that as much as 25-30 percent of the energy (about 1.8-2.2 million barrels a day) now used by industry could be saved (Berg/National Bureau of

Standards, 1973). Earlier experience of Dow Chemical, DuPont, Union Carbide, and others of the largest 100 United States corporations showed that in assessments undertaken by industry itself, technical feasibility and economic justifications were relatively minor barriers to industrial adoption of many energy-efficient technologies (Connery & Gilmore, p. 58; U.S. Senate, Committee on Commerce, 1974; U.S. House of Representatives, Committee on Science and Astronautics, 1974). The failure to use more energy-efficient technologies must be explained in terms of factors other than simple technological and economic reasons.

Former chief engineer of the Federal Power Commission, C. Berg, stated the problem cogently in Science (1974) as follows:

> Influences including those of political and institutional character may require examination if one is to explain why seemingly economically attractive fuel saving measures were not adopted in the past. It may, in fact, be necessary to find an explanation in order to plan for fuel conservation efforts in the future. If the influence of fuel price alone was not sufficient in the past to promote optimally efficient use of fuels, one may reasonably question the theory that the influence of higher fuel price will be sufficient to promote fuel efficiency to newly optimized levels. (Vol. 184, p. 264.)

A review of the literature on recent developments in industrial technological innovations and applications indicates that Berg's assessment of the institutional barriers is largely still valid. That is, the adoption of energy-efficient methods is technologically feasible and economically justifiable; however, the question remains as to how to encourage adoptions by industrial firms. Only a few studies dealing with strategies for the diffusion or spread of technologies appear in the 287 pages of the Bibliography of Relevent Literature (Industrial Application Study, Volume V) compiled by Brown *et al* (1976) under a contract with ERDA.

Opportunities for industrial energy conservation by type of industry have been well documented in a number of studies conducted by federal agencies including EPA (1975), the Department of Commerce (1973-74), the Office of Energy Preparedness (1972), and ERDA. ERDA has sponsored numerous studies by private research organizations, such as "Recommendations for Future Government-Sponsored Research and Development in the Paper and Steel Industries," by Thermo Electron Corporation (1976). One of the most thorough studies was carried out by Drexel University/United Technologies Research Center/Mathematica, Inc., under the sponsorship of the Division of Conservation Research and Technologies, ERDA (1977). In this work, which emphasizes the recovery of waste heat in industry, the technologies, with their costs and benefits and even their payback periods, are identified according to the two-digit industrial code. In general, it was determined that significant waste energies can be recovered from five areas:

* Condensor cooling water
* Contaminated process water
* Process product loss
* Boiler exhaust
* Furnace exhaust

Again, one finds that many studies on the energy conservation opportunities related to specific industries have been carried out, such as for the steel industry by Battelle Columbus Laboratory, and for the plastics and rubber industries by Foster Snell, Inc. Furthermore, a data base for nine industries was completed by the Federal Energy Agency (FEA) in nine volumes (selected plastics, petroleum refining, cement, copper, aluminum, steel, glass, paper products, and styrene butadiene rubber). All of these studies demonstrate that there are ample opportunities for conserving industrial energy in industry. To utilize fully the above mentioned studies and developed technologies, this information has to reach the potential users. After receiving the information, industrial firms will then evaluate it on its merits such as potential savings in fuel consumption for the technology, the cost related to purchasing and implementing the systems, whether the company can finance it without major capital investment, what is the payback period, and so on. Considering that dissemination of information is essentially the first step in innovative efforts, the Department of Energy has been conducting users workshops for the industrial community. Further dissemination of the workshops' results is by publication of the material involved directly with the workshop, such as Energy Conservation in the Pulp & Paper Industry (Advanced Energy & Technology Associates, 1977).

4. The purpose of this project

It is clear from the above discussion that industry is able to conserve as much as 25 to 30 percent of its energy consumption by adopting simple conservation measures and energy-efficient technologies; furthermore, these technologies can be implemented without major alterations of the original equipment. Yet the problem remains, since adoption rates have been low, plants are being forced to shut down intermittently, and energy supply shortages remain a threat.

This project was conducted to find answers to the following basic questions:

1. What is the current level of adoption of simple conservation measures and energy-efficient technologies?
2. Who are the "innovative" firms?
3. What are the possible energy policy options, and what would be the responses to them from industrial firms? What factors contribute to significant differences in firms' responses?
4. What are the most effective and workable policies that government can use to encourage more adoptions of energy-efficient technologies?
5. How do we model the effects of various policies on the rate of adoption?

These research questions have been formulated according to a comprehensive dynamic diffusion model of innovation which regards the adoption rate as a function of stimulation from the early adopters and policy influences within a specific environment. For example, the first question is designed to identify whether there is a problem relating to the use of energy conservation measures to cut down energy consumption in industry. The second question addresses the characteristics of the early adopters of the surveyed energy conservation practices and technologies. Here we intend to disseminate energy conservation information to the more receptive firms, hoping that after they become adopters, other firms will follow them. The rest of the question really deals with public policy issues, designed to foster a more rapid rate of adoptions by both the early adopters and their "followers."

The next section discusses the schools of thought on innovative processes; this will serve as the conceptual and methodological base of this project.

B. The Study of Innovative Processes

The diffusion* of innovations and sequential cultural changes has been of interest to researchers in many fields, including anthropology, geography, sociology, economics, and political science. The literature on the theory of diffusion has also been extensively reviewed by Brown (1965), Havelock (1969), Rogers and Shoemaker (1971), Hudson (1972), Gordon (1974), Rogers and Eveland (1975), and Yin <u>et al</u>. (1976). However, there is little interaction and communication among diffusion researchers in different disciplines. For instance, we noticed that in Yin's work, neither was Hägerstrand's work mentioned in the methodology review section, nor were any of the geographic studies included among the 140 case studies. In 1977, to bridge the communication gap among researchers in diffusion studies, the National Science Foundation sponsored a workshop on

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*"Diffusion" in this study is defined as the spread of the adoption/adopters of innovations such as energy conservation measures or efficient technologies.

diffusion studies, bringing 12 scholars from different disciplines to discuss the interdisciplinary aspects of diffusion studies and to map out future research directions (Radnor, 1976--The Proposal to NSF).

A further step towards an interdisciplinary approach has been carried out in this study of the diffusion of energy conservation measures in industry, sponsored by ERDA in 1976. We use survey research methods from sociology, spatial modeling from geography, systems from electrical engineering, and policy analysis from economics. In the following section, we will first present a general survey of the field, and then discuss different approaches, with comments on their strengths and weaknesses in terms of understanding and solving real-world problems. Finally we present a comprehensive approach and a model specifically designed for dealing with energy technologies in conjunction with public policies, which rarely have been considered in previous diffusion studies.

1. A General Review

While anthropologists and archaeologists emphasize cross-cultural diffusion, the work of sociologists concerns mainly the diffusion of innovations within a society. As late as 1938, however, the process of intro-societal diffusion had been little studied. Since the 1940's, diffusion studies in sociology have been carried out mainly by rural sociologists. Most of the literature has focused on the individual, with age, income, and social status as predictors of adoption. The source of information is used as a factor influencing the adoption of innovations, although little information is given about flow of the information which leads to final adoption (Hudson, 1973, p. 40). In contrast with geographers, rural sociologists consider the mass media (which are non-spatial) as a dominant factor influencing social changes through the adoption of innovations.

Sociologists have concentrated on the interpersonal communication aspects of the diffusion of innovations. Adopter characteristics and the role of the change agent have been emphasized. A few studies (Gordon, 1974; Yin, et al, 1976) focus on the structural characteristics of innovating organizations, such as wealth, size, and decision-making procedures. The research designs employed by sociologists take adoption of innovation as the ultimate dependent variable, and use regression analysis to identify characteristics of categories of adopters stratified by time of adoption. A recent review of diffusion research done by sociologists (Rogers and Shoemaker, 1971) shows that dynamic models of the diffusion process are absent. The standard research paradigm concentrates on ex post facto investigations of the adoption process that rely on respondents' recall of their own behavior. Little use is made of data produced concurrently with the adoption process and, although there is a considerable amount of literature dealing with the theory of interpersonal communication (for example, Festinger (1957), Homans (1961), Thibaut and Kelley (1959)), there are few bridges between the theoretical work and empirical diffusion studies.

Their analyses have been carried out mainly by regression models with a series of discrete-time regression equations. For example, a total time period from 1940 to 1960 can be divided into four stages: (1) 1940-1945, (2) 1946-1950, (3) 1951-1955, and (4) 1956-1960, and a regression model determined for each of the four stages. Then the diffusion process through time is evaluated by comparing the relative significance of independent variables such as firm size, degree of automation, etc., among the four equations (stages). Comments on this approach can be summarized as follows:

(1) The spatial dimension, specifically, neighbor-effect, is largely neglected.

(2) Regression analysis is usually a linear static approach; a dynamic approach has been attempted by so-called "two-stage regression models" (Mason & Halter, 1968).

(3) Mutual influences among independent variables are neglected.

(4) Recent attempts to explain the diffusion process in terms of organization behavior (Gordon, 1974; Yin et al., 1976) add a new

dimension to diffusion studies.

(5) Development of predictive models is only a recent phenomenon. (Martino, 1976).

The study of the effect of incentives on diffusion rates is also very recent. The classical work by Mansfield (1961) pointed out that profitability and initial cost are important factors in addition to the characteristics of the organization. This set of factors can be called "economic incentives."

Recently, Rogers (1973) investigated the impact of incentives on diffusion in the case of the diffusion of a family planning program and came to the following generalizations:

1. "Adopter incentives increase the rate of adoption of an innovation."
2. "Adopter incentives lead to adoption of an innovation by different individuals than those who would otherwise adopt."
3. "Although adopter incentives increase the quantity of adoptions of an innovation, the quality of such decisions to adopt may be relatively low, leading to limitations in the intended consequences of adoption."
4. "Diffusion incentives increase the rate of adoption of an innovation by encouraging interpersonal communication about the innovation with peers."

2. Different approaches

Havelock (1969), in his Planning for Innovation through Dissemination and Utilization of Knowledge, made a survey of the diffusion literature and classified the approaches used by the researchers into three groups:

(a) the research, development, and diffusion approach;

(b) the social interaction approach;

(c) the problem-solver approach.

This classification was also used by Yin *et al*. in A Review of Case Studies of Technological Innovations in State and Local Services. However, we would like to add one more approach employed by geographers, the spatial diffusion approach, which was highly successful in Hägerstrand's studies utilizing computer simulations. Thus, four approaches will be discussed below.

2.1. The research, development, and diffusion approach

This model is widely used in technology transfer and the diffusion of federally-developed technologies to the private sector. The sequence of events includes: (1) innovations are developed in the laboratory, (2) further tested and demonstrated in the field, (3) communicated and diffused to the potential users, (4) tested by the users, and (5) adopted or rejected by the users (Yin, *et al*., 1976). Case studies using this approach are cited by Havelock and Benne (1969), and in agricultural research and educational organizations, Brickell (1964) and Clark and Guba (1965). A recent study on "The Program to Conduct Ongoing Observations of Federally Premeditated Actions to Accelerate Utilization of Civilian Oriented Research and Development" by Innovation Systems Research, Inc., is an extension of this approach. It uses a tracking method to follow the detailed stages of decisions made on the development and diffusion of innovations together with factors associated with the decisions.

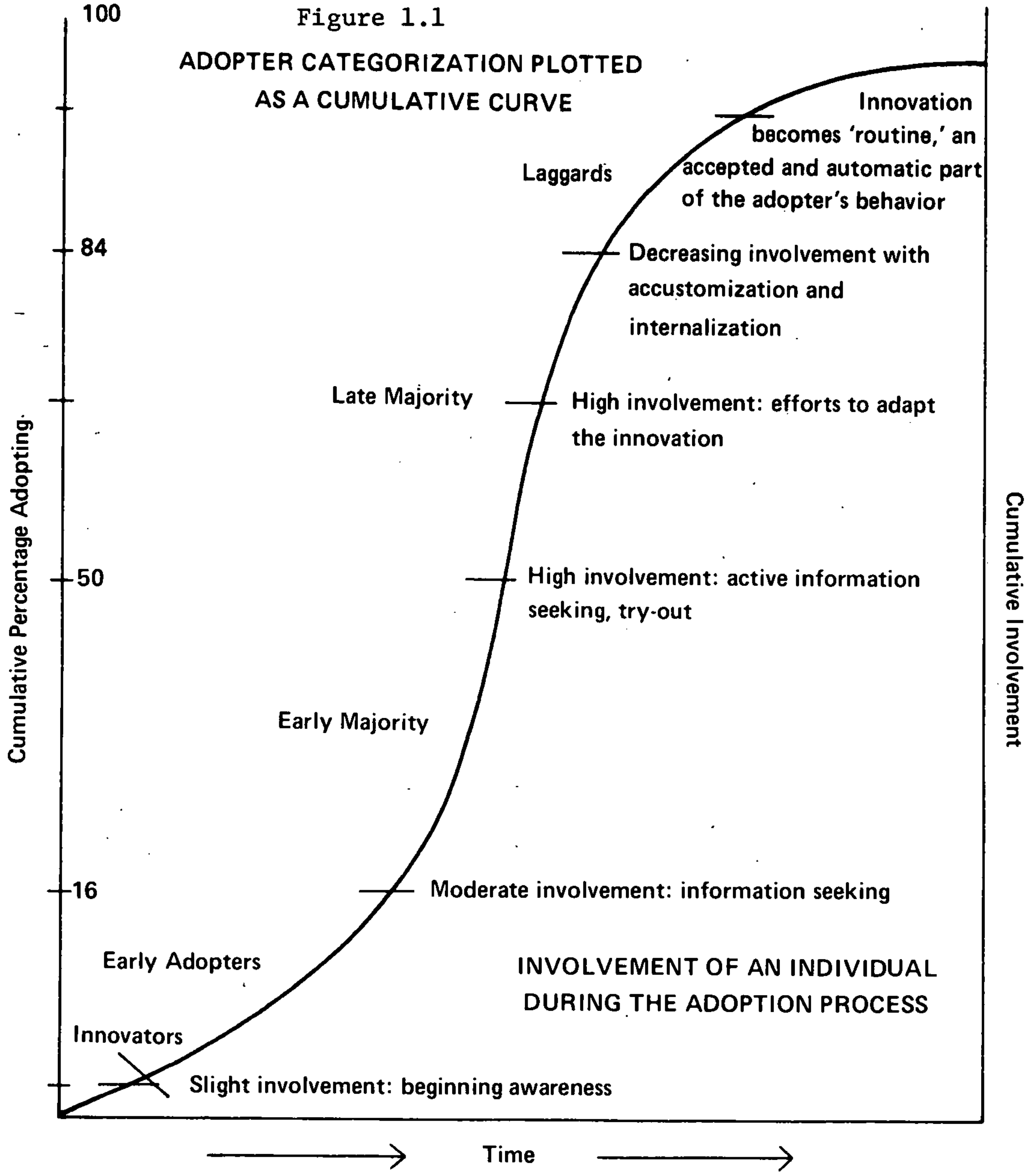
This approach places a major emphasis on the innovation itself rather than on the adopters. While this is valid for certain technologies, such as the EMI brain scanner (Hsu, 1975), in many cases the demand side of the innovative processes cannot be totally ignored.

2.2. The social interaction approach

This model is a classic diffusion approach developed by Everett Rogers (1962, 1971), where an adoption process is seen through a sequence of events: (1) potential adopters' awareness of the innovations, (2) potential adopters show interest in the innovation, (3) innovations are evaluated by the potential adopters, (4) innovations are given a trial, and (5) innovations are either adopted or rejected. In the model the adopters are grouped as (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards. Assuming a normal distribution of potential adopters, the cumulative proportion of adoptions over time appears as in Figure 1.1.

Figure 1.1

ADOPTER CATEGORIZATION PLOTTED
AS A CUMULATIVE CURVE



Source: Ronald G. Havelock, 'Planning For Innovation,' ISR, The University of Michigan,
Ann Arbor, Michigan, 1969

The cumulative frequency graph results in an s-shaped curve, which is approximately a logistic curve.

In essence, this model postulates that in a social system, individuals who have adopted an innovation will influence those who have not. Rogers further asserted that this interaction effect begins to decrease after half of the individuals have adopted.

This model has been proved successful in dealing with cases where the potential adopters are individuals (Yin, 1976). However, its application to innovative efforts by organizations is less successful (Warner, 1974). In view of this, a modification of the original model was attempted by Rogers and Eveland (1975).

It is our view that Roger's general model dealing with the categorization of adopters and stages of the adoption process is applicable to our study, using industrial firms as adoption units.

2.3. The problem-solver approach

This approach emphasizes the role of the adopter as the source of change. The individual or group first identifies the problem and then undertakes an effort to alter the situation independently or by using outside assistance. In this approach, the definition of innovation is broader than that of the previous two approaches. In industry, changes are constantly made by plant engineers with or without outside consultants. In many cases, such "innovations" will diffuse to other firms. Many such innovations clearly originate from the users themselves. The "innovator" in Rogers' model plays the role of modifying the original invention. The question of who is the original inventor is thus very difficult to answer.

While this approach emphasizes the importance of the receiver, it lacks methodological rigor in terms of diffusion processes. As Yin (1976) points out, in the case where the "innovation" originates from an organization, it is very difficult to define the specific organizational events related to innovative processes. This approach should thus be viewed as more conceptual than operational as a methodology for empirical diffusion studies.

As we can see, these three schools of thought actually cover and emphasize differently three major stages of the diffusion of innovations, namely, (1) origination of ideas and research; (2) development; and (3) diffusion and adoption. More precisely, Rogers' model emphasizes the adoption process, the research, development and diffusion approach emphasizes the earlier stages, and the problem-solver approach starts the innovation process from the user's end. The following schematic diagram illustrates these differences (Havelock, 1969, pp. 10-28).

FIGURE 1.2 Three Approaches to Innovative Efforts

Approach	Stages in Research	Stages in Development	Stages in Diffusion and Adoption
Social Interaction	Research Assumed	Development Assumed	Some diffusion Activity Assumed Awareness Interest Evaluation Trial Adoption
Research Development & Diffusion (R,D&D)	RESEARCH Basic Scientific Inquiry; Investigate Problems; Gather Data	DEVELOPMENT Invert & Design Engineer & Package Test & Evaluate	DIFFUSION Promote Inform Demonstrate Train Help Service Nurture ADOPTION Awareness Interest Evaluation Trial Installation Adoption Institutionalization
Problem-Solver (P-S)	Basic Research Assumed	Search for Solutions Establish Goals and Priorities Weigh & Evaluate Possible Solutions Select Best Alternative Plans for Implementation	Need Diagnosis Establish Relationship with Outside Expert Installation Evaluation Revision Institutionalization Change Relationship Terminated Possible Diffusion to Others

2.4. The spatial diffusion approach

Anthropologists were the first to study the subject of the diffusion of innovation. In 1927, Wissler proposed the cultural-area concept and his hypotheses postulated that an innovation initiated from a center and spread outwards until it covered an appreciable portion of the earth's surface. His basic model consisted of a series of concentric circles, each denoting a time lag from the center of dispersal. Therefore, they are also called age-areas. The process of diffusion is, in this view, similar to the propagation of waves. Let us explain this process in simple words: There is a new idea originated in a location (call it a cultural trait center), such as domestication of a species of plant, or invention of a new agricultural tool. This new idea will then spread from the center and be adopted by the neighboring people. The people closer to the center will learn innovations earlier than the people farther away from the center. The earlier school of thought maintained that the diffusion process is achieved by direct contact between people of two different regions. This has been modified by the theory that innovations can diffuse without direct contact, a theory known as stimulus diffusion. The approach here is essentially archaeological, historical (documentary), and by field investigations.

Diffusion studies in geography can be classified into two groups of thought, branching out from the original anthropological diffusion model. The Berkeley (Carl Sauer) school of cultural geography has a strong tradition of diffusion studies very similar to those of anthropologists. The classical work is Sauer's Agricultural Origins and Dispersal (1952). His followers have carried out "origin and dispersal" studies of other visible cultural traits, such as house types. The extension of this school is the "cultural landscapes" school of geography.

Since the 1950's, Hägerstrand (translated in 1967), of Lund University in Sweden, and his followers have launched a very different type of diffusion study in geography. Their approach is mathematical and in the framework of the wave model, although they still emphasize the importance of spatial processes and distributions over time.

The contributions of the Hägerstrand school of diffusion research can be noted as follows:

1. Introducing mathematical models into diffusion studies.
2. Introducing computer simulations for understanding diffusion processes.
3. Summarizing the total time/space diffusion results by a simple S-shaped curve of the logistic function (Morril (1968, 1970), Casetti and Semple (1969)).

The major contribution of Hägerstrand and his followers is in using mathematical models to simulate the time-space adoption phenomenon, with certain computed probability values assigned to potential adopters. If past adoption patterns can be simulated accurately and if the behavior underlying the model continues to hold, this approach should be capable of predicting future adoption patterns. Compared to Rogers' model, although this approach lacks sophistication as a sociocultural explanation, it does have a certain degree of prediction power which is quite useful in terms of commercialization of technologies.

The major drawback of this approach is that the diffusion process is analyzed only in terms of distance-decay functions, i.e., other non-spatial variables are neglected completely. Although Hägerstrand has demonstrated that diffusion factors of interaction and communication among individuals can be translated into the distance-decay function, there are some other obvious socio-economic factors that cannot be translated into spatial terms, such as institutional behavior and the profit incentive. Moreover, in some (non-Western) societies, the decision-making process regarding accepting or rejecting an innovation is done by community consensus. Such a case, for example, is the adoption of dairy farming by Japanese farmers. These cannot really be captured in spatial process analysis alone.

Recent methodological "adventures" by geographers have been carried out mainly by Brown (1969) and Hudson (1972). Brown proposed an epidemic diffusion model to study neighborhood effects, and Hudson takes into consideration the size of neighbors in a diffusion model. The former is called "neighborhood effect," and the latter, "hierarchical effect." The validity of these two approaches has not been extensively tested. Some of these ideas were discussed in a series of articles published in Economic Geography (Vol.

Brown and Hudson's models are mostly static in nature because they do not treat spatial and temporal diffusions as continuous processes. A more serious drawback arises from the fact that they completely ignore outside influences, such as policy efforts and institutional barriers. In this project, a dynamic model is developed to address these two aspects of diffusion simultaneously: a time/space continuous process and the influence of outside factors in Chapter 6.

3. A comprehensive approach for this energy technology study

Although approaches to diffusion studies vary according to the academic specialty of the investigator, a review of the several approaches shows that some invariant characteristics of the diffusion process emerge. These invariant characteristics provide a guideline for an integrated approach to solving real-world diffusion problems. We enumerate below these common factors and take them as a point of departure for the development of research hypotheses to be tested in the context of the diffusion of energy-efficient technologies.

1. The adopter's behavior is the central issue in diffusion research. Adopters may be individuals, groups, or institutions. The most important question should be: "Why do the potential adopters accept or reject, or favor or show indifference toward the innovation?"
2. A chain of information flow, or "telling," is a necessary but not sufficient condition for diffusion to take place. The information flow affects, and is affected by, certain identifiable factors. The factors that emerge as important predictors of diffusion patterns are:
    a. The distance friction or inverse factor, or neighbor-effect
    b. The size factor, as a measurable trait of both the adopter unit and its surrounding environmental system
    c. Perceived characteristics of the innovation
    d. Characteristics of the potential adopters
    e. Incentives exterior to the adopter
    f. Benefits to the adopter (for example, reducing fuel cost and reducing effects of uncertainty of adequate energy supply)

3. The diffusion process is essentially dynamic in both time and space. The choice of time and space intervals in a discrete approach to diffusion may artificially distort results.
4. Factors which influence the process have mutual impacts in a dynamic time-space framework. Therefore, diffusion models should be designed from a dynamic systems analytical point of view, similar to compartment systems in ecological analysis.

The approach used in this project takes into account all four of these characteristics. It is, therefore, an integrated approach combining (1) the behavioral/organizational, (2) the spatial and socio-economic, and (3) the time/space dynamic aspects of diffusion studies.

The behavioral approach will focus on revealing the decision-making processes of adopter units. Here we would like to know specifically the following items which may influence the diffusion rates:

1. The potential adopter's perception of the merits of the innovations, i.e., their technological capability; the expected consequences after adoption.
2. The influence of organization structure and the interaction among components of the structure on the adoption probability.
3. Direct answers as to why the adopter units accepted or rejected the innovations.
4. The role of information flow networks in the adoption of innovations, both among adopter units and between adopter units and change agents.

To accomplish these four goals, this project used a survey research method, i.e., we used field interviews to gather the data on adoption rates of energy-efficient measures and technologies, and on characteristics of the potential adopters, and to tape conversations on adoption decisions and comments on energy policy options. In addition, a system identification method is utilized to model and simulate the time-space dynamics of the adoption process,using policy behavioral types as "forcing functions," and "coupling coefficients of adoption probability" among neighboring adopters as "contagious effect" or "band-wagon effect."

Compared to past studies, the uniqueness of this approach can be summarized as follows:

1. Data on influencing factors were gathered concurrently with data on the adoption process.
2. A dual approach was employed: statistical analysis to ensure the objectivity of the data analysis, and behavioral process analysis to interpret the statistical results.
3. Policy analysis is coupled with the adoption rate and influence factor analyses.
4. A dynamic diffusion model was developed to simulate adoption rates under the impact of various policy options.

Aspects of the research design will be discussed in detail in the next chapter.

Chapter 2: Methodologies and the Data Base

To accomplish the research goals set forth in Chapter 1, a pilot study on the diffusion of energy-conservation measures was carried out using three complementary approaches: (1) field interviews to obtain concurrently (a) adoption rate information, (b) factors influencing adoptions, and (c) responses by industry to energy policy options; (2) statistical analysis to determine the significance of the factors, including firm characteristics and perceptions of policy options; and (3) systems analysis to simulate the effect of different types of policies on adoption rates. These approaches and related base-line data for the project are discussed below.

A. Survey Research Approach

1. Rationale and some background literature.

It was pointed out in Chapter 1 that diffusion studies generally failed to reveal precisely the **factors influencing** the adoption process because the data were collected after the facts, i.e., they were based on someone's recall or on secondhand material. Intended to pinpoint how adoptions take place, an empirical survey approach was utilized to collect the data. Specifically, the data dealing with adoption rates and the possible relevant factors, such as firm characteristics, information network, etc., were gathered concurrently in intensive interviews.

For this approach to be successful, cooperation of the industrial firms with the researchers is an absolute necessity. Thus, one of the major tasks in the project was to investigate how such cooperation can be achieved. Contacts made through common friends, local Chambers of Commerce, local energy Councils, utility companies, etc., were tried in a three month pre-test period. It was determined that the best strategy is highly dependent on the local conditions. Therefore, a "trial-and-error" method is necessary for arriving at the final strategies.

Since some industrial firms have been experiencing hardships from energy shortages, a direct way to obtain such knowledge is to let them tell us about their experiences with energy cut-backs, lay-offs, or similar problems and their feelings on energy policy options.

The literature on survey research is extensive. A general discussion of the subject is given by Selltiz (1976). An in-depth discussion of different approaches is given by Douglas (Sage Library of Social Research, Vol. 29, 1976). While these materials can give us general guidelines for research procedures, specific survey instruments have to be developed according to the subject matter of the inquiry. Here, our interest is in the diffusion of innovations and our sample selection and questionnaire design reflect that concern.

For intensive interviews, we designed fifty-nine questions covering these areas of concerns: (1) the plant's experience in energy cutbacks and its coping processes; (2) characteristics of the firm and its energy officers; (3) the adoption rate of the energy conservation measures and technologies of the firm; (4) the firm's response to energy conservation policy options. Whereas detail of the instrument is given in Appendix 1 of this chapter, the individual components of the instruments are discussed in the next sections.

2. The population and the sample

2.1. Background

Because the current project was intended as a pilot study for a larger study using a national sample, the study area was limited to two Standard Metropolitan Statistical Areas (SMSA's) located at Binghamton, New York, and Allentown, Pennsylvania. Using data from the 1972 Census of Manufactures and the 1976 Industrial Directory for the states of New York, Pennsylvania, and New Jersey, 16 firms were selected from the Binghamton area and another 16 firms from the Allentown area. These sampled firms were selected to represent small, medium, and large firms, as well as high and low energy-intensive firms. It was a cross-industry sample, based on the existing evidences that to a certain degree the energy problem is common to all industries, and that there are numerous groups of energy-efficient technologies that can be used by industry in general. Thus the study was not aimed at investigating a single type of industry.

The two regions studied also differ in that the Binghamton SMSA represents the industrial trend of the Northeast United States with its slightly declining industrial employment from 1958 to 1972, while the Allentown SMSA is closer to the United States norm of a slight increase in industrial employment during the same period. Additionally, the Allentown SMSA includes large, heavy industry in contrast to the small, light, industry makeup of Binghamton. With this design, then, a regional comparison can be made to reveal differences in industrial development and different communication networks and energy supply patterns. We were also interested in mutual influences or interactions among these forces which have acted together to produce different ways of coping with energy shortages. Conceptually, the basic design can be illustrated as follows:

Test 1: Regional and Energy Intensity

		Region	
		Binghamton SMSA	Allentown SMSA
Energy Intensity	High	Firms: (Bing., high)	Firms: (Allentown, high)
	Medium & Low	Firms: (Binghamton, low)	Firms: (Allentown, low)

From this test, we can investigate the influence of the two factors, location and energy-intensity, on the adoption rates in three ways: (1) the effect of a single factor (such as regional), (2) the effect of the factors together, and (3) the interaction between two factors. In the analysis, the adoption rates are called **dependent** variables, and the factors which influence them are the independent variables.

2.2. The sampling design

The population of this study thus encompasses all manufacturing firms in the Binghamton, New York SMSA (including Broome and Tioga Counties in New York and Susquehanna County in Pennsylvania) and Allentown, Pennsylvania SMSA (including Lehigh, Carbon, and Northampton Counties in Pennsylvania and Warren County in New Jersey). From the 1972 Census of Manufactures, we have the distribution of industrial firms by SIC code and number of employees.

Tables 2-1 and 2-2 list the number of firms by two-digit SIC code for each county, and by number of employees in four groups: 1 to 19, 20 to 99, 100 to 249, and 250 and above. Since the majority of industrial firms in the Binghamton SMSA are located in Broome County, the Binghamton sample was mostly drawn from that county.

From Table 2-2, it can be seen that the majority of the manufacturing firms in the Allentown SMSA are located in Lehigh and Northampton counties.

Sample firms were therefore selected mostly from these two counties.

In addition to the first test, the sample also permits a second test using firm size and energy intensity in combination as follows:

Energy Intensity	Size	
	Large (250 or more employees)	Small (Fewer than 250 employees)
High	Firms: large;high	Firms: small;high
Medium & low	Firms: large;medium & low	Firms: small;medium & low

The classification of sampled firms (Table 2-3) reflects the basic design for testing the hypotheses that regional, energy-intensity, and firm size differentiations, singly or in combination, have effects on the adoption rates of energy-efficient technologies.

TABLE 2-1: Number of Manufacturing Firms in the Binghamton SMSA by Number óf Employees and SIC Code[1]

	Number of Employees by County[2]											
	1-19			20-99			100-249			250 and over		
SIC CODE	A1	B1	C1	A2	B2	C2	A3	B3	C3	A4	B4	C4
20	14	0	3	8	2	0	4	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	2	0	1	0	0	0	0	0	0
23	5	2	4	6	2	10	1	0	1	0	0	0
24	6	8	12	3	1	2	0	1	1	0	0	0
25	2	1	0	2	2	0		0	1	1	0	0
26	2	0	0	2	0	0	1	0	1	0	0	0
27	39	3	5	6	0	1	0	0	1	3	0	0
28	2	2	0	6	1	0	1	0	1	0	0	0
29	2	0	0	1	0	1	0	0	1	0	0	0
30	6	1	2	3	0	1	3	1	1	1	0	0
31	2	1	2	3	0	0	0	0	0	0	0	0
32	10	1	2	3	0	0	0	0	0	0	0	0
33	0	1	1	0	0	0	1	1	1	0	0	0
34	10	1	0	4	0	0	5	0	1	1	0	0
35	25	5	0	8	1	2	2	0	1	3	0	0
36	6	0	0	4	1	2	2	0	0	4	1	1
37	2	0	0	1	0	0	0	0	0	0	0	0
38	3	0	0	1	0	0	0	0	0	3	0	0
39	2	1	0	1	0	0	0	0	0	0	0	0
CAD	6	1	1	6	0	0	2	0	0	0	0	0
TOTAL NUMBER OF FIRMS	149	27	30	81	10	20	24	5	3	20	1	1

[1] Source: <u>Census of Manufactures</u>, 1972, Vol.

[2] County Code: A-Broome, B-Tioga, C-Susquehanna.

TABLE 2-2: Number of Manufacturing Firms in the Allentown SMSA by Number of Employees and SIC Code[1]

SIC CODE	Number of Employees by County[2]															
	1-19				20-99				100-249				250 and over			
	D1	E1	F1	G1	D2	E2	F2	G2	D3	E3	F3	G3	D4	E4	F4	G4
20	19	19	7	4	16	6	1	2	2	2	0	0	5	1	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	13	6	4	3	29	9	3	1	6	0	1	3	4	3	0	0
23	18	24	3	7	60	101	26	8	14	21	9	3	5	7	1	0
24	5	5	5	2	1	2	1	1	0	0	0	0	0	0	0	0
25	3	5	3	1	7	4	1	0	1	0	0	1	0	0	0	0
26	3	4	1	0	2	3	0	5	2	1	0	2	0	1	0	1
27	37	24	1	11	9	4	1	5	1	4	0	2	2	1	0	0
28	7	4	1	3	8	4	0	4	0	1	0	1	1	1	1	2
29	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
30	2	2	0	5	5	4	0	1	0	2	0	3	0	1	0	2
31	0	0	0	2	0	0	2	0	2	1	0	0	0	0	0	0
32	17	12	6	3	4	13	1	2	1	7	0	0	0	1	0	0
33	5	2	2	0	2	2	3	0	3	0	2	1	0	4	1	2
34	20	16	1	7	11	11	1	6	3	2	0	1	4	3	0	0
35	27	14	2	7	8	3	1	3	1	3	0	0	3	1	0	4
36	6	4	1	7	1	1	2	2	4	2	1	0	6	1	0	1
37	1	2	0	4	2	0	0	0	0	0	0	0	2	1	0	1
38	3	2	0	1	2	1	0	0	0	0	0	0	1	1	0	0
39	7	6	1	3	2	1	3	0	0	2	0	0	1	3	0	0
CAD[3]	6	3	0	1	5	5	1	0	3	1	0	2	5	0	0	0
TOTAL	202	160	38	42	175	174	47	40	43	49	13	19	39	29	4	14

[1] Source: Census of Manufactures, 1972, Vol. , pp.

[2] County code: D = Lehigh, E = Northampton, F = Carbon, G = Warren

[3] CAD means

TABLE 2-3: Classification of Sampled Firms by Industry, Energy Intensity, and Size

	Binghamton SMSA				Allentown SMSA		
	Description	Intensity*	Firm Size**		Description	Intensity	Firm Size**
1	Fertilizer Company	L	1	1	Paper Box	H	4
2	Chemical/Paper	H	1	2	Food	H	4
3	Stone, Clay type	H	1	3	Heavy Industry	H	5
4	Plastics Company	L	1	4	Cannery	M	2
5	Forging	H	3	5	Stone, Clay	H	5
6	Camping Equipment	L	2	6	Cement	H	2
7	Candy Company	L	1	7	Printing	L	1
8	Food	H	2	8	Cement	H	5
9	Instrument	L	5	9	Food	H	5
10	Furniture	L	4	10	Primary Metal	H	5
11	Chemical	L	2	11	Insulation Material	L	1
12	Foundry	H	2	12	Chemical/dye	H	3
13	Casting	H	2	13		H	1
14	Light Instrument	L	3	14	Refrigeration	H	1
15	Printing	L	4	15	Brewing	L	4
16	Stone, Clay	M	1	16	Instrument	L	5

*Energy Intensity H = High, M = Medium, L = Low
(Conference Board: Energy Consumption in Manufacturing, 1974)

**Firm Size: 1 = < 100 4 = 501-1000
2 = 101-200 5 = >1000
3 = 201-500

If we enter the data from Table 2-3 into the test designs we have the following patterns:

Test 1:

	Binghamton	Allentown	Total
High Intensity	6	11	17
Medium & Low Intensity	10	5	15
TOTAL	16	16	32

Test 2:

	Large Firms	Small Firms	Total
High Intensity	7	10	17
Medium & Low Intensity	5	10	15
TOTAL	12	20	32

The above sampling design of firm characteristics is intended to serve several purposes:

1. A large number of industrial types can be represented,
2. Disproportional stratified sampling in favor of larger firms can be used, following the method of Census of Manufacturers.
3. Cell sizes in the above tests can be balanced so that better statistical results can be expected, in view of the fact that the total sample size is already small (N=32).

Since this is only a pilot study, statistical inference is not intended to go beyond the study area, thus lack of true randomness can be excused (Cochran, Sampling Techniques, 1963). The sampling scheme is close to stratified random sampling, however.

3. The measure of adoption rates (Question 19, Appendix 1)

In general, adoption rates are often defined as the ratio between adopters and potential adopters during a given time period. In terms of the adoption of innovations by industrial firms, this definition implies that the number of adopters is the number of firms. Then the potential adopters can be defined as the firms in a specific geographic area, such as a county or an SMSA. However, in this study, the adoption rate is defined as the number of technologies adopted over the total applicable technologies, since a number of technologies are applicable to each individual firm. Thus, for this project, the adoption unit is an individual firm instead of a geographic area.

Since the target population is industrial firms in general rather than specific types, energy-efficient technologies should be applicable to the majority of firms. With this criterion, 10 (generic) technologies were selected by Dubin-Mindell-Bloome Associates of New York City for assessing adoption rates. They are listed in Table 2-4. An eleventh category, "other technologies being adopted," was added to cover energy conserving devices that might have been overlooked.

TABLE 2-4: The Energy-Efficient Technologies List

1. Waste heat recovery devices from hoods, or from heat-producing equipment, or from hot stocks
2. Devices or equipment for pre-heating combustion air
3. Heat recovery devices, e.g., from compressors used for cooling, or others
4. Load levelers
5. Devices for raising suction temperatures for refrigeration units
6. Devices for using steam condensate for heat or using waste steam
7. Variable speed pumping devices
8. Recuperator or regenerator
9. Heat pump
10. Heat exchanger
11. Other technologies being adopted.

The list was pre-tested on five firms and proved satisfactory. The response options include:

1. Not applicable.
2. Applicable, but we have not adopted it.
3. We have adopted it, but it is a normal maintenance procedure rather than an energy conservation measure.
4. We have adopted it for energy conservation reasons.

Since some of the listed devices have been in existence for more than 30 years, they have been regarded as a part of normal maintenance practice in some cases. This is true for many of the large firms we interviewed. If the adoption of these technologies had occurred prior to the 1973 Arab oil embargo, response option (3) was recorded. On the other hand, some firms adopted technologies mainly in response to the recent energy crisis. This tended to be the case for smaller firms. Since this distinction in adoption processes exists, two measurements are used for the adoption rate:

(1) Recent adoption probability of a given firm equals the number of technologies adopted after 1972 divided by the total number of applicable technologies.

(2) Total adoption probability equals the number of technologies adopted (including post-and pre-1972 adoptions) divided by the total number of applicable technologies.

In the analysis, these are called Innovation 1 and Innovation 2. They can be analyzed singly or in combination. The former process yields two univariate analyses, and the latter produces one multivariate analysis. Therefore, altogether, there are three measurements for assessing the significance of the adoption rate.

4. Possible factors influencing adoption (Questions in Appendix 1)

In section B, Chapter 1, we discussed four approaches to understanding the process of adoption of innovations. Each school places a special emphasis on a certain portion of the total spectrum of the diffusion process that begins with the origination of ideas and ends with the final adoption by the users. Furthermore, there is no agreement among the researchers on the "common" factors which explain the general innovation diffusion phenomenon, although tens of possible factors have been hypothesized (Rogers, 1961; Yin, 1976). In view of this, we relied on our own judgment to compile a list of 26 possible factors that we think could have some explanatory value for the adoption of technologies by industrial firms (Table 2-5). The list is based largely on experience and on the knowledge gained from pre-test interviews with local firms and partially on the literature dealing with the measurement of organizational behavior (Price, Handbook of Organizational Measurement, 1972). For example, about half of the 26 possible factors are directly related to current energy issues, such as energy supplies, energy information, existence of an energy officer, and even energy management. Thus, we are hypothesizing that the diffusion of energy-efficient technologies is unique as compared with other diffusion studies. We should be able to contribute some new knowledge to the existing literature of diffusion studies.

In general, the 26 possible factors on our list can be grouped into four major elements of innovative effort, plus an unspecified category:

A. Immediate circumstances, consisting of both environmental and organizational factors;

B. General background, also with both environmental and organizational factors;

TABLE 2-5: Possible Factors Influencing Adoption

1. Regional (Binghamton vs. Allentown)
2. Energy cutback (cutbacks vs. no cutback)
3. Disruption of production (disruption vs. no disruption)
4. Dependence on natural gas (yes or no)
5. Energy officer 1: energy is officer's only responsibility
6. Energy officer 2: energy officer is also the chief officer
7. Energy officer 3: energy officer with technology/science background
8. Energy officer 4: energy officer with business/finance background
9. Energy committee (Yes or no, within the firm)
10. Energy intensity (high vs. medium & low)
11. Firm size (five levels)
12. Degree of automation (three levels)
13. Age of equipment (three levels)
14. Centralized authority (total autonomy vs. firm dependence on a mother company)
15. Degree of communication within the firm (four levels)
16. Energy information 1: industrial association (yes or no)
17. Energy information 2: utility company (yes or no)
18. Energy information 3: government (yes or no)
19. Energy information 4: other firms (yes or no)
20. Energy information 5: consulting firms (yes or no)
21. Energy information 6: within the firm (yes or no)
22. Member of an industrial association (yes or no)
23. Consideration of a longer payback period (yes or no)
24. Growth state (three stages)
25. R & D (yes or no)
26. Perceives the government as the major cause of the recent energy disaster (yes or no)

C. Economic factors;

D. Information network; and

E. Others

While the general background factors have been studied extensively by researchers in diffusion studies, our examination of the immediate circumstances that produced the energy problems and the ensuing responses of firms is unique. In our pretest interviews, we discovered that the industrial firms were the most concerned about energy supplies, specifically the supply of natural gas during the time of interview in 1977. This immediate environmental factor then leads to a set of organizational responses designed to cope with the energy problems. The two sets of factors constitute the first elements of the innovative effort listed above. Let us list them as follows:

TABLE 2-6: The Immediate Circumstance Variables (A)

Environmental Factors	Organizational Factors
1. Regional	5. through 8. Energy officers
2. Energy cutback	9. Energy committee
3. Disruption of production	
4. Dependence on natural gas	

The factors related to the general background setting, B. in the above grouping, are rather straightforward. Although they have been emphasized by classic diffusion researchers (Yin, et al. 1976), we will treat them only as working hypotheses because conflicting views exist. Table 2-7 lists these variables. It should be noted that we listed several more variables related to the "organizational setting" of the firms, such as "formalization" and "innovativeness," prior to our pre-test interviews; however, they were dropped from the final list because any measurement for these variables was very difficult to obtain.

TABLE 2-7: The General Background Variables

Environmental Factors	Organizational Factors
10. Energy intensity level	14. Centralized authority
11. Firm size	15. Degree of communication within the firm
12. Degree of automation	
13. Age of equipment	

The significance of economic variables in the innovative process has been well documented in Mansfield's work (1968), with findings that the adoption rate is (1) positively correlated with the profitability of the innovation; (2) negatively correlated with the capital investment needed to adopt the innovation; (3) positively correlated with firm size; and (4) does not appear to be correlated with the growth rate of the firm, with the past profits of the firm, with age of the firm's management, with liquidity of the firm, or with the profit trend of the firm (Martino, 1976). Extensions of his work can be obtained from Blackman, _et al_., (1971), and Bundegaard-Nielsen and Fiehn (1974).

From our pre-test interviews, we discovered the firms viewed economic factors as significant, and that an acceptable payback period for a technological adoption and the deregulation of energy prices would be "enough incentive" for investment in energy technologies. Since "deregulation of energy price" is a policy question, it was not listed as a factor. In the economic factor group, C., we then hypothesized that "consideration of a longer payback period" (23), "growth stage of the firm" (24), and "the existence of R&D at the firm" (25) were factors that could have significant effects on adoption rates. Data on other variables are difficult to obtain by interviews.

The information elements of innovative effort (D., above) are given in factors #16 through factor #22. While the use of industrial associations, utility companies, and the government as energy information sources is well-known, the use of outside consulting firms for improving energy conservation efforts is rather a recent practice. We feel that energy consulting services will become increasingly important in the near future.

The only factor we have not classified is the perception factor (#26) relating to the government as the major cause of the recent energy disaster. We place it as a hypothesized factor because many firms reported that they feel that way, and designed strategies for coping with the energy problem accordingly. For instance, several of the firms did not wait for "action" from the government and proceeded with their conservation efforts as early as possible. We thought this might have some effect on the adoption rate, and therefore, listed it as one of the factors.

In the next section, we will discuss the statistical methods used in this project to "sort out" these factors by evaluating whether they, singly or in combinations, have significant effects on the adoption rates.

5. Policy preference survey

In the past, public policies were rarely considered as factors influencing the innovative effort. In Yin's work (1976) where 140 case studies dealing with technological innovation in state and local governments were examined, it was concluded that federal policies had no concrete effect on specific innovative efforts although they may be important in creating an innovative environment.

Since the Arab oil embargo, however, energy policies have been pursued rigorously by the federal government with two goals: cutting down energy consumption and increasing the domestic production of oil and natural gas. It is hoped that the degree of dependence of the United States economy on foreign oil can be reduced gradually. This was epitomized by the 1974-75 "Project Independence" (FEA, August, November, 1974).

Therefore, it is likely that energy policy options will affect the rate of adoption of technologies from now on in many ways. Let us take the controversial "deregulation of energy prices" option, for instance. If energy costs increase, industrial firms will tend to install energy-efficient equipment for several reasons: (1) savings in energy from the new equipment will cut down the payback period of the capital expenditure and (2) to be competitive, they have to keep product cost down by using more energy-efficient technologies. Of course many other policy options, such as tax credits for the capital expenditure on energy-saving technology, can also provide such incentives, directly or indirectly.

To encourage energy conservation in industry, the federally proposed policy options can generally be grouped into three areas:

* Those dealing with tax incentives;

* Those using energy taxes to discourage consumption; and

* Those dealing with energy management programs.

In the popular idiom, we enumerated 12 policy options (Table 2-8), and submitted them to our industrial firms for evaluation and rating regarding (a) the firms' preferences, and (b) their perceptions as to the policies' effectiveness in energy conservation in general, and attractiveness to the firm in particular. The firms were asked to rate each option as follows:

1. Potential effectiveness for energy conservation (good, fair, no effect)
2. Attractiveness to industry in general (high, moderate, low)
3. Attractiveness to your firm (high, moderate, low)

TABLE 2-8: Policy Options

1. Use of recycled material: incentive for use coupled with penalties for use of virgin material.
2. Deregulation of energy prices.
3. Federal tax on energy purchases, based on national energy consumption patterns.
4. Price incentives for off-peak energy use combined with penalties on increments of energy consumed in excess of (peak) base.
5. Federally mandated energy allocation limits based on past energy use per unit of output.
6. Subsidized federal loans for energy conservation capital expenditures.
7. Federally guaranteed loans for energy conservation capital expenditures.
8. Tax credits for energy conservation capital expenditures.
9. Government sponsored services of energy conservation consultants at no cost to industry.
10. Tax credits for cost of implementing and maintaining energy management programs.
11. Federally sponsored R & D efforts in energy efficient technologies.
12. Industry based R & D efforts in energy efficient technologies, subsidized by the federal government.

These questions were designed to discover patterns in the firms' responses which might serve as guides for energy policy formation. We were looking for:

(1) Their general preferences with respect to each of the policy options.

(2) Whether there are statistically uniform responses to each option; if not, what factors contribute to the variability?

(3) From industry's perception, which policy options will be effective to increase adoption rates?

(4) How do we derive the "most workable policy options" that can be used by the federal government to design a comprehensive energy management program?

B. Statistical Approach

The statistical approach is intended to analyze the relationships among the data sets on the adoption rates, the factors influencing adoption, and the responses to the policy options. Specifically, discriminant analysis is used to determine the significance of the influencing factors as well as the policy responses, and some combinations of these, on the adoption rate.

Let us use the regional factor as an example to explain the basic model. Note that there are 16 sampled firms in the Binghamton, New York and 16 in the Allentown, Pennsylvania area and we have data on the adoption rates for each firm, using two measurements--the pre-1973 adoption rate, and the total adoption rate. The data structure for the first set of the discriminant analysis follows the following format (Test 3, Table 2-9).

In Table 2-9, Y denotes the adoption rate with the first subscript representing the firm identification, and the second subscript identifying which adoption rate is specified. Letter M stands for the average of the adoption rates, with the first subscription identifying the factor (e.g., Binghamton vs. Allentown), and the second subscript again, the particular adoption rate meant.

TABLE 2-9: Data Structure of Test 3 Discriminant Analysis

Sampled Firm	Binghamton Rate 1 (pre-1972)	Rate 2 (Total)	Firm Sampled	Allentown, Pa Rate 1 (pre-1972)	(Total) Rate 2
#1	$Y_{1,1}$	$Y_{1,2}$	#16	$Y_{17,1}$	$Y_{17,2}$
#2	$Y_{2,1}$	$Y_{2,2}$	#17	$Y_{18,1}$	$Y_{18,2}$
#3	$Y_{3,1}$	$Y_{3,2}$	#18	$Y_{19,1}$	$Y_{19,2}$
	.	.		.	.
	.	.		.	.
	.	.		.	.
#16	$Y_{16,1}$	$Y_{16,2}$	#32	$Y_{32,1}$	$Y_{32,2}$
Mean	$M_{B,1}$	$M_{B,2}$		$M_{A,1}$	$M_{A,2}$

The purpose of discriminant analysis, in this example, is to test whether there is a significant difference in the mean adoption rates, partitioned by a locational grouping. We can assess the possible outcomes in three ways (or statistical tests, to be precise):

(1) Is there a significant difference between $M_{B,1}$ and $M_{A,1}$?

(2) Is there a significant difference between $M_{B,2}$ and $M_{A,2}$?

(3) Is there a significant difference between the combination of ($M_{B,1}$ plus $M_{B,2}$) and ($M_{A,1}$ plus $M_{A,2}$)?

(1) and (2) are called univariate analyses because there is only one dependent variable (or adoption rate) involved, while (3) is referred to as a multivariate analysis because two or more dependent variables are utilized (Morrison, 1976).

A natural extension of Test 3 is to look at the effect of two factors on the adoption rate, corresponding to the sampling design mentioned earlier. Using regional and energy intensity in a two factor design, the data structure follows the format of Test 4, in Table 2-10.

TABLE 2-10: The Data Structure of Test 4 in a Two-Way Design

		Binghamton, NY		Allentown, PA	
		Adoption Rate 1	Adoption Rate 2	Adoption Rate 1	Adoption Rate 2
Energy Intensity	High	Cell $_{1,1}$	Cell $_{1,2}$	Cell $_{3,1}$	Cell $_{3,2}$
	Medium & low	Cell $_{2,1}$	Cell $_{2,2}$	Cell $_{4,1}$	Cell $_{4,2}$

In this table, "cell" represents a group of adoption rates corresponding to firms having specific characteristics governed by the factors. The first subscript stands for the location of the cell with respect to the factors (region and energy intensity),while the second subscript is the specific measure of the adoption rate, as Test 3. Using data outlined earlier, cell 1 contains 6 firms, cell 2, 10 firms; cell 3, 11 firms; and cell 4, 5 firms.

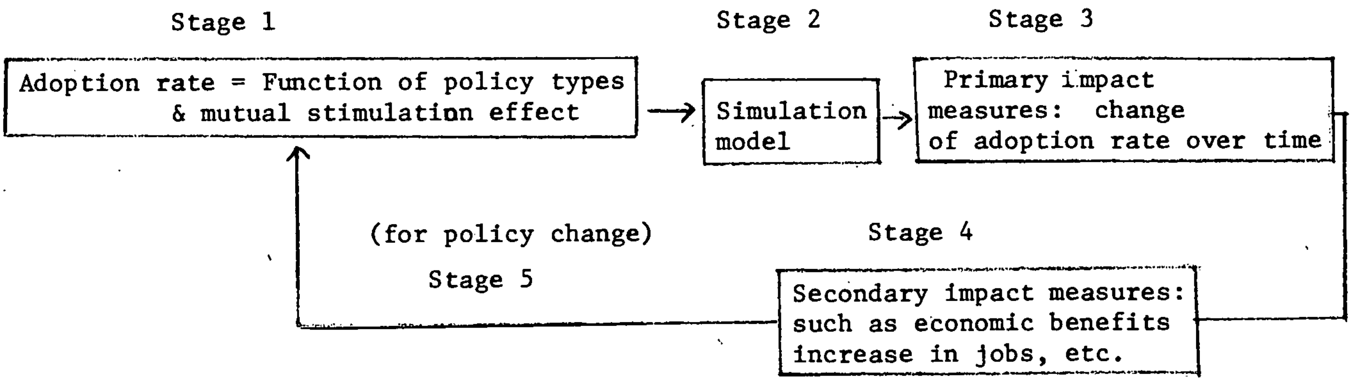
The objective of this analysis is to test whether there exists a second significant factor, when two factors are analyzed together. Additionally, it can determine whether the combined effect of Factor 1 and Factor 2, called interaction, is significant.

In this project, n-factorial design, that is, tests involving three or more factors, are not used for several reasons: (1) the interaction effects are difficult to explain when three or more variables are involved, (2) cell size in a n-way design tends to become zero for certain cells because our sample size is small; and (3) the sampling design follows essentially a two-way design rather than an n-way design.

C. Systems Identification Approach

As was discussed earlier, federal energy policies are designed to create a significant impact on the adoption rates of energy efficient technologies. However, past studies have ignored the question of how to assess such impacts using diffusion models. In this study, we propose to use a dynamic (i.e. time-space continuous) diffusion model to simulate changes in adoption rates over time, under the influence of two major elements: mutual effects among neighboring sites, and the type(s) of policy accepted by the specific site. The resulting model can be used as a policy impact simulator to check the performance of particular policy options against actual diffusion patterns obtained from field observations or a market monitoring system.

Conceptually, the system of this policy impact model can be illustrated as follows:



Here Stage 1 indicates the initial condition of the adoption pattern.

Stage 2 indicates that a model is constructed to assess the impact of the policy effect on the adoption rate under the conditions of mutual stimulation and the types of policy options accepted by the receivers.

Stage 3 indicates the performance of the policy option measured by changes in the adoption rate over time.

Stage 4 indicates that along with the adoption or energy-saving technologies the general socio-economic conditions are being affected also.

Stage 5 means that the policy maker can change the policies after a certain period of time, depending on the adoption trend.

In this study, effort will be placed on developing a policy impact simulation model indicated as Stage 2 and Stage 3. The general technique lies in the area of systems identification as given by Graupe (1972), Sage (1971), Tabak & Kuo (1971), and Eykhoff (1973). By doing this, we are able to integrate spatial diffusion processes with policy analysis and create a truly dynamic diffusion approach. Then the S-shaped pattern of cumulated adoptions can be simulated by changing the adoption probability values of mutually-influencing sites and for changing the policy types. If early adopters are identified by using the statistical analysis discussed earlier, we can use them as the "target population" for federally-sponsored technology transfer programs. This way, these early adopters will become a part of the sites in the dynamic diffusion model.

The resulting approach is then an integrated diffusion model which will allow for the following sequence of events:

1. Implement the most appropriate policy options to facilitate the development of technologically reliable and economically feasible technologies.
2. Use the statistical analysis to determine early adopters.
3. Transfer the technologies to the early adopters.
4. Stimulate more adoptions by implementing appropriate policies.
5. Use the dynamic diffusion model to assess the performance of the policies, i.e., their effects on adoption rates.

These topics will be discussed in the following chapters.

CHAPTER 3: Current Adoption Rates of Energy Conservation Measures

A. Introduction

Energy conservation measures are generally classified into two groups: minor equipment modification (or good housekeeping) and major process change measures. The first approach involves simple, low cost conservation methods such as setting back thermostats, plugging leaks to prevent heat loss, installing timers on light switches in little used areas, repairing insulation on condensate lines, and so on. The second approach usually requires capital investment in energy-efficient technologies, which range from simple heat exchangers to more sophisticated technologies for changing industrial processing methods. Since an industrial complex requires energy for space heating and cooling and for industrial production/processing, both kinds of conservation measures have been actively pursued. In many cases, "space heating and cooling" and "industrial processing" are treated as an integrated system, where industrial waste energy is recovered for space heating, and at the same time energy allocated for space heating or cooling is used for processing. This concept has been termed a total energy system.

Since the 1973 Arab oil embargo, awareness of energy shortage problems has been increasing. Methods of reducing energy consumption have been studied and proposed by many federal agencies and private corporations. For instance, from the earlier literature, we have the National Bureau of Standards' Handbook (EPIC) 115 (1974) for industrial energy conservation purposes, and the Federal Energy Administration/Dubin-Mindell-Bloome's handbooks for energy conservation opportunities in buildings (1975). More recently, the General Electric Corporation issued a handbook containing 101 ideas for energy conservation practices (GE: Industrial Energy Conservation: 101 Ideas at Work?).

Additionally, at local community levels, we have witnessed energy conservation groups being organized by local industries, merchants, utility companies and/or environmentalists, holding monthly meetings to promote conservation practices and giving out awards for "big" energy savers.

For industrial firms, reduction in energy consumption is a "must," for their own survival more than "for ethical and patriotic" reasons. This is because (1) fuel prices have been rising steadily; (2) mandated allocations have been instituted by utility companies in conjunction with some state public service commissions; and (3) natural gas supplies have been cut off intermittently. Thus, to keep plants open, which is the ultimate goal of industry under current energy shortages according to our survey, firm officials must determine out ways to keep energy supplies from being cut off. Making an effort to conserve energy is only one of many measures firms have taken to achieve their goals. Other strategies usually involve switching fuels or developing a dual fuel capability. Using oil plus natural gas, converting to coal, using a mixture of oil and coal systems, and changing to hydroelectric power by building a new plant near the energy source are examples. The extreme case is to move the plant from the "snow belt" to the "sun belt." Although many such alternatives exist, energy consumption by means of conservation techniques is certainly one of the best approaches for the obvious reason that saving fuel costs and recycling waste energy produces efficiency and thus profit. We will present our research findings regarding the current status of conservation efforts pursued by the sampled industrial firms in the next sections.

B. The Adoption of Short-Term Energy Conservation Measures

In terms of short-term energy conservation procedures, the National Bureau of Standards' Handbook 115 is very comprehensive as judged by the industrial firms questioned in our pre-test period. Thus we have used it to formulate our measure of the current adoption rate of short-term conservation measures. We originally selected 150 items from the Handbook for our survey, but we found many of the items were not applicable. Therefore we finally used an edited version composed of 63 items for the analysis. These are listed in Appendix 2.

The energy conservation opportunities are grouped into 7 areas as follows:

A. Buildings and grounds: 22 items
B. Electrical power : 5 items
C. Steam : 19 items
D. Heat recovery : 8 items
E. Combustion : 2 items
F. Scheduling : 3 items
G. Process changes : 4 items

Since it usually took 40 minutes or more to respond to this whole list of items, not all firms would consent to participate in the full questionnaire. Thus we have only 16 complete sets of the data: 10 from Binghamton firms and 6 from Allentown. Table 3-1 shows the adoption pattern by region with four measures used to assess the adoption rates:

Measure 1: Recent adoption rate -- number of items adopted plus adoptions in progress divided by applicable number of possible items as indicated by the firm

Measure 2: Old adoption rate -- number of items considered as standard operational procedures divided by the (same) applicable number of possible items as indicated by the firm

TABLE 3-1: Adoption Rates of the Short-Term Measures

Firms	Adoption Rates			
	Measure 1 (Recent)	Measure 2 (Old)	Measure 3 (Total)	Measure 4 ("Actual")
Binghamton				
1	0.77	0.22	0.99	0.29
2	0.74	0.00	0.74	0.32
3	0.48	0.46	0.94	0.84
4	0.80	0.01	0.81	0.74
5	0.72	0.00	0.72	0.46
6	0.77	0.02	0.79	0.56
7	0.76	0.00	0.76	0.38
8	0.90	0.05	0.95	0.61
9	0.55	0.00	0.55	0.38
10	0.04	0.63	0.67	0.24
MEAN	0.66	0.14	0.80	0.48
Allentown				
1	0.80	0.07	0.87	0.77
2	0.52	0.08	0.60	0.56
3	0.59	0.32	0.91	0.54
4	0.65	0.17	0.82	0.20
5	0.45	0.33	0.78	0.61
6	0.37	0.43	0.80	0.72
MEAN	0.56	0.23	0.80	0.56

Measure 3: Total adoption rate -- sum of (a) and (b)

Measure 4: "Actual" adoption rate -- total adoptions divided by the number of items (63) being surveyed.

From the summary statistics of Table 3-1 it can be seen that using the number of applicable procedures as the base, the total adoption rate (measure 3) is 0.80 for both Binghamton and Allentown. As for the recent adoption rate (post-1973), Binghamton is slightly ahead of Allentown, while the pattern is reversed for the old adoption rate. In terms of the 63 surveyed items, the average "actual" adoption rate, measure 4, is 0.48 for Binghamton and 0.56 for Allentown.

It can be concluded that these industrial firms have made progress in reducing energy consumption using available short-term measures. This was also reflected in their deep concern about fuel costs and mandated energy cutbacks. The use of an "energy officer" or an "energy committee" approach, which is almost a universal phenomenon,seems quite effective here. Another approach which proved to be effective for some firms was to keep the energy bill constant, regardless of increases in utility or fuel prices. These firms set an energy conservation target for themselves: attempting to offset the rise in fuel costs with savings in energy consumption, through conservation measures. Other firms have tried to use the same amount of energy consumed in a past period to manufacture more products in the next period. These last approaches are considered "visible goals" for the firm, specifically the energy officer to achieve. Moreover, the firms consider achieving the goals a measure of "success." Indeed, savings in terms of BTU's was too abstract a measurement for many workers and even some officers to understand.

While this sort of goal setting works well for implementing the minor conservation measure, it may not be effective for instituting major measures, the adoption of energy-efficient and process change technologies. The background material and the adoption rates relevant to these major measures will be discussed in the next section.

C. The Adoption of Energy-Efficient Technologies

1. Energy conservation opportunities

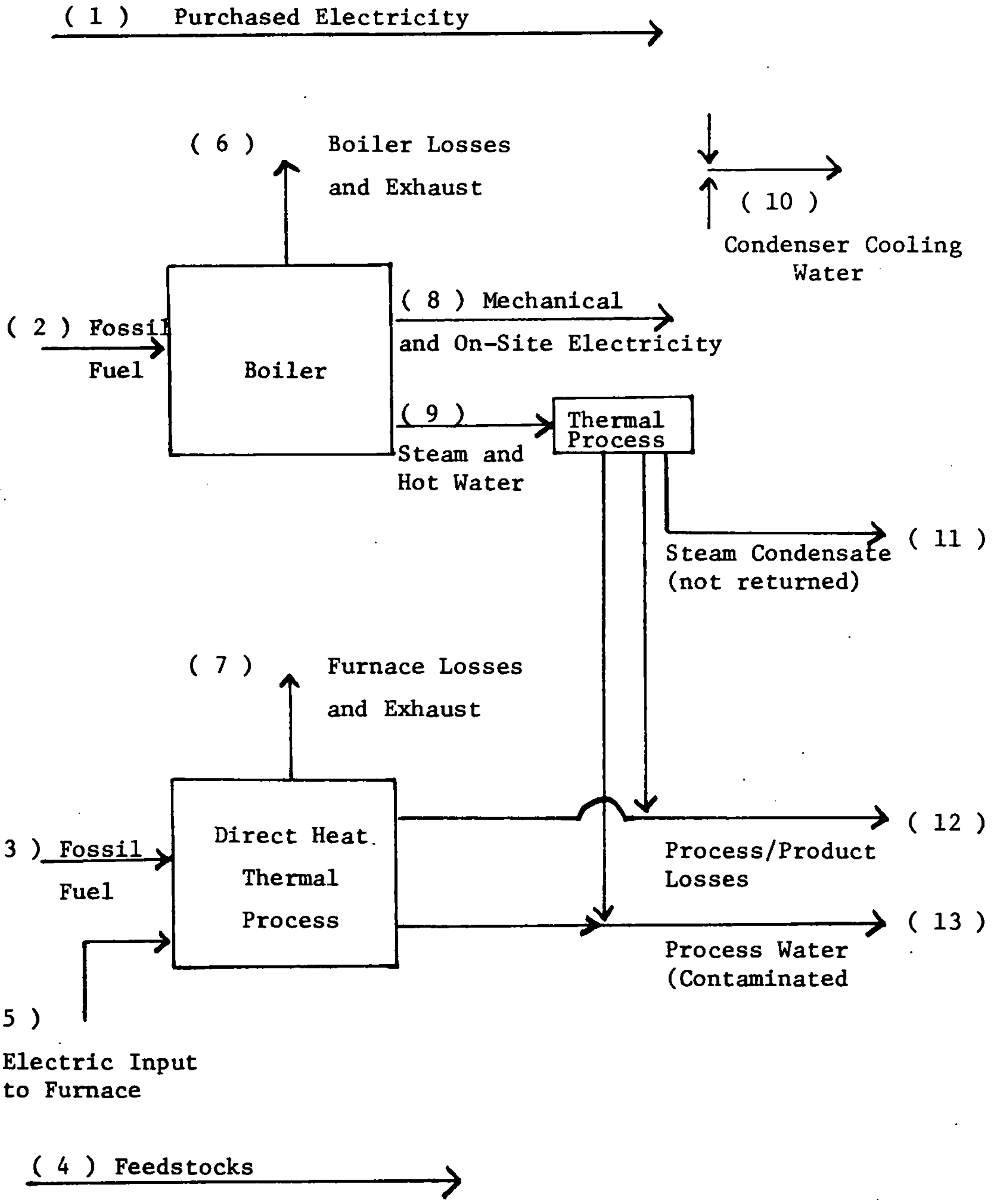
In Chapter 1 we mentioned that this study intends to investigate the adoption rates of energy-efficient technologies that can be used by industry in general (rather than industry-type specific devices or systems). Accordingly, the selection of technologies for this survey had also to be based on this criterion. A discussion of the general energy flow system at a generalized plant will thus be helpful for understanding the role of the 10 specific technologies surveyed (Table 2-4).

In a very broad sense, energies used in an industrial plant serve two functions: (1) space lighting, heating and cooling, and (2) production of industrial goods. While the first is more or less universal, the second varies from one type of industry to another in terms of specific processing methods. Typically, processing energies are derived from boilers and/or furnaces directly or indirectly, although in some cases electricity is used directly. However, in the course of this energy transformation, a certain amount of energy is lost, meaning not used for the intended purposes. For instance there is heat loss from boilers and furnaces, waste steam, etc.

A schematic diagram of an energy flow model applicable to industrial firms is given in Figure 3-1. The numbered items in this figure are described on the page which follows the diagram. With the description of each item is a rough estimate of the amount of energy involved for all manufacturing industries (SIC 20 through 39) in the United States for 1977 (DOE,CONS/2862-1 by Drexel University, 1976).

Figure 3-1

INDUSTRIAL ENERGY FLOW*



*Source: Industrial Application Study, Vol. 1 (DOE, CONS/2862-1, Drexel University, 1976), p. 73

Figure 3-1, Cont.

ITEM	DESCRIPTION	SIC 20-39 BTU x 10^{12}
1	Electric energy purchased for space heating, process heat, mechanical drives, refrigeration, cooling, lighting, etc.	2074
2	Fossil energy used for engines and steam generation	4560
3	Fossil energy used for direct heat thermal processes and space heating	5956
4	Chemical feedstocks	1200
5	Electric energy for proeess heat and space heating. Includes both purchased and on-site generated electricity	315
6	Stack and radiation losses from boilers	1177
7	Stack and radiation losses from furnaces	2528
8	Mechanical and electrical energy produced by turbine drives and engines	528
9	Steam and hot water used for thermal processes and space heating. Includes turbine steam which was initially used to produce mechanical and electrical energy in item 8. Does not include condenser cooling water or non-returned condensate from 8.	2314
10	Condenser cooling water from turbine drives and cooling and refrigeration systems	1100
11	Non-returned steam condensate from thermal processes, space heating, and turbine drives	156
12	Product/process losses from thermal processes	4016
13	Contaminated process water from thermal processes	1683
		27607

From the preceding model it is evident that industrial energy losses come from these areas: condenser cooling water, contaminated process water, process/product losses, condensate, boiler exhaust, and furnace exhaust. For some of the specific components the over-size amount of loss has been estimated as follows: process/product losses, 38 percent of energy input; for furnace exhaust, 25 percent; boiler exhaust, 9 percent; and condensate, 2 percent. However, these averages conceal a great deal of variability since the distribution of loss is highly dependent on the particular industry, at the four-digit SIC level.

Table 3-2 gives a more detailed description of the generalized sources of the waste streams. These may conveniently be grouped into two major areas of opportunities for energy conservation: (1) improving processing technologies, that is, item 2 in Table 3-2, and (2) recovery of waste energy and preventing excessive losses (the rest). Since the first area is specific to industry type, our surveyed technologies belong to the second.

Table 3-3 relates our surveyed technologies to the waste streams categories given in Table 3-2. The list of surveyed technologies was meant to cover essentially the whole range of waste energy recovery opportunities. This was confirmed in our field interviews.

TABLE 3-2: The Waste Streams*

1. Condenser Cooling Water
   - (a) Refrigeration
   - (b) Electric generation
   - (c) Converters

2. Process/Production
   - (a) Process water (contaminated in contact with product)
   - (b) Process cooling
   - (c) Forced air
   - (d) Natural conversion
   - (e) Product carry from process to process
   - (f) Radiative from process equipment

3. Steam Condensate
   - (a) Returned
   - (b) Not returned

4. Boiler Operations
   - (a) Radiative
   - (b) Stack
   - (c) Additional losses (improper operations & maintenance)

5. Furnace Operations
   - (a) Radiative
   - (b) Stack
   - (c) Additional loss (improper operation & maintenance)

---

* Industrial Applications Study: Vol. 1 (DOC/Drexel University, 1973), p.

TABLE 3-3: The Surveyed Technologies List in Relation to the Waste Streams

	Surveyed Technologies	Related Waste Streams
1.	Waste heat recovery devices from hoods or heat producing equipment	Boiler/furnace exhausts
2.	Device or equipment to preheat combustion air	Boiler/furnace system
3.	Heat recovery devices from compressor or others	Cooling system
4.	Load levelers	Electrical system
5.	Device for raising suction temperature for refrigeration units	Refrigeration system
6.	Use of steam condensate	Steam condensate
7.	Variable speed pumping	Electrical/mechanical system
8.	Recuperator or regenerator	Furnace exhaust
9.	Heat pump	Cooling water/condensate/process water
10.	Heat exchanger	Boiler exhaust/furnace exhaust/ cooling water/condensate/process water
11.	Other	Category for process/product technology changes

2. The adoption rates

In Chapter 2 we mentioned that the measurements we use for the technology adoption rates are (1) post-1973 adoption rate and (2) the total adoption rate. They are computed as the number of technologies adopted divided by the number of applicable technologies.

Using the regional breakdown, Table 3-4 presents both the recent and total adoption rates for each firm.

TABLE 3-4: The Technologies Adoption Rate

Firm	BINGHAMTON, N.Y.		ALLENTOWN, Pa.	
	Measure 1 (Post-1973)	Measure 2 (Total)	Measure 1 (Post-1973)	Measure 2 (Total)
1	0	0	0.33	0.67
2	1.00	1.00	0.42	0.71
3	0.60	0.60	0	0.71
4	0	0.14	0	0
5	0.57	0.57	0	0
6	0	0	0.50	0.50
7	0.20	0.60	0.50	0.50
8	0.42	0.42	0	0.57
9	0.74	0.75	0	0.44
10	0.14	0.14	0	0.83
11	0.75	0.75	0.17	0.33
12	0.13	0.13	0	0.43
13	0.28	0.28	0	0
14	0.41	0.41	0.80	0.80
15	0	0	0	0.43
16	0.16	0.16	0.11	0.22
MEAN	0.34	0.40	0.17	0.44

TABLE 3-5: Frequency Analysis of the Energy-Efficient Technology Adoption Rates

	Number and Percentage Distribution of Firms by Region							
	Binghamton, N.Y.				Allentown, Pa.			
	Measure 1 (Post 1973)		Measure 2 (Total)		Measure 1 (Post 1973)		Measure 2 (Total)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1. Very low rate (0.00-0.24)	8	50.00	7	43.75	11	68.75	4	25.00
2. Low rate (0.25-0.49)	3	18.75	3	18.75	2	12.50	4	25.00
3. Medium rate (0.50-0.74)	2	12.50	3	18.75	2	12.50	6	37.50
4. High rate (0.75-1.00)	3	18.75	3	18.75	1	6.25	2	12.50
TOTAL	16	100.00	16	100.00	16	100.00	16	100.00

The data in Table 3-4 can be summarized further by frequency distributions in four categories (Table 3-5) which we have labelled:

1. Very low rate : 0.00 - 0.24
2. Low rate : 0.25 - 0.49
3. Medium rate : 0.50 - 0.74
4. High rate : 0.75 - 1.00

It can be seen that the adoption of energy-saving technologies by the Binghamton firms is a recent phenomenon since there is little difference between the distribution of the post-1972 and the total adoption rates. The pattern is different for the Allentown firms where most of the adoptions occurred prior to 1972. For an additional regional comparison, slightly more Allentown firms belong to the (sum of the) medium and high adoption rate categories, although the average total adoption rate for each region is about 0.40 (Table 3-4).

D. Adoption Rates for Individual Technologies

In section C, we discussed the adoption rates for the 10 surveyed technologies as a group. We can show some differences in reactions to the technologies by examining the rate of adoption of each individual technology.

To do this, a new adoption rate is defined as the number of firms which adopted and are in the process of adopting the specific technology, divided by the number of the potential adopters; the denominator excludes firms which indicated that the technology is not applicable. Thus; the 32 surveyed firms are classified into three groups for each of the ten energy-saving technologies:

$$\left.\begin{array}{l}\text{(1) Adopters}\\ \text{(2) Not adopters}\end{array}\right\}\quad\text{potential adopters}$$

(3) Not applicable

TABLE 3-6: Adoption Pattern of the Ten Surveyed Technologies

Technologies	A Adopters	B Not Adopters	C Not Applicable	D Applicability ranking	E Adoption Rate (percent)	F Adoption Rate Ranking
1. Waste heat recovery	12	13	7	1	48	2
2. Preheater	9	13	10	2	41	4
3. Heat recovery from compressor	4	11	17	6	27	6
4. Load leveler	8	13	11	3	38	5
5. Raising suction temperature	1	7	24	7	13	8
6. Use of steam condensates	7	9	16	5	44	3
7. Variable speed pumping	4	13	15	4	24	7
8. Recuperator	8	8	16	5	50	1
9. Heat pump	3	21	7	1	13	8
10. Heat exchanger	12	13	7	1	48	2
Total or Average	68	121			36	

Table 3-6 shows the frequency distributions of these three groups, the adoption rates, and the ranking of the technologies by adoption rates.

In terms of the adoption rate ranking (column F of Table 3-6), the following technologies reached the rate of 40 percent or more:

Recuperators (50%)

Heat exchangers (48%)

Waste heat recovery devices (48%)

Use of steam condensates (44%)

Preheating combustion air (41%)

From the frequency data of "not applicable," we can also make some assessment of how widespread is the applicability of these technologies. From Column D, we can conclude that the five most widely applicable technologies of those surveyed as follows:

	Ranking in Applicability to Industry
Heat exchangers	(#1)
Waste heat recovery devices	(#1)
Heat pump	(#1)
Preheat combustion air	(#2)
Load leveler	(#3)

By comparing these two lists (adoption rates and applicability ranking), we can predict that load levelers and heat pumps will become more and more popular. In particular we expect a rapid rate of adoption of load levelers because they can really lower the cost of electricity since the price of electricity is closely related to the peak load, not the average.

Since heat exchangers are one of the most widely adopted technologies, they will be discussed further in the next section.

E. The Adoption of Heat Exchangers and Recuperators

In our interviews, we discovered that some highly energy-intensive firms have adopted heat exchangers recently in order to increase the efficiency with which they use energy. This is particularly true for firms who must use natural gas in their production processes, and whose supplies have been subject to limited allocations since 1973. The idea is to maximize the use of this scarce fuel in the industrial processes and to use waste energy from these processes for space heating and other non-product-processing needs. This helps the firm ensure full utilization of its capacity. The use of consulting engineers to implement this sort of system is a common phenomenon.

A heat exchanger is a device or a system employed to transfer heat from one energy source to another place for another function. A variety of types is available commercially: shell and tube, stationary and rotary matrix, plate fin, heat pipe, and intermediate fluid (DOE: CONS/2862-1, 1976). The most common one is the shell and tube, applicable to gas-gas, gas-liquid, and liquid-liquid heat transfers at an effective rate of about 85 percent. A comprehensive discussion of other types can be obtained from the above-quoted DOE document.

One of the most frequently mentioned barriers to the adoption of energy-saving technologies is the long payback periods required for some of these investments. The firms we interviewed generally expect a payback period of three years or less for their normal equipment, while some energy-saving equipment does not generate enough saving to cover its costs in such a short time. The estimated payback periods for a number of heat exchanger technologies are given in Table 3-7, as presented in a DOE study (CONS/2862-1). Although for some industries and some types of heat exchangers the payback periods are less than three years, others--especially among the liquid/gas exchangers--take from 10 to 20 years or more to recover their costs at the installation and fuel costs used in the table.

TABLE 3-7: Payback Period For Heat Exchanger Technologies

(Average Fuel Costs: $2/10^6 BTU)

Industry SIC Code	Cooling Water		Process Water		Condensate		Boiler Exhause			Furnace Exhaust		
	Liq/Liq	Liq/Gas	Liq/Liq	Liq/Gas	Liq/Liq	Liq/Gas	Gas/Liq	Gas/Gas	Gas/Boiling	Gas/Liq	Gas/Gas	Gas/Boiling
20	A	D	A	C	A	D	B	B	B	A	B	A
21	A	D	B	D	A	D	B	B	B	B	B	A
22	A	D	B	D	B	D	B	B	B	B	B	B
23	B	D	B	D	B	D	B	D	B	D	D	D
24	B	D	B	D	B	D	B	C	B	B	B	B
25	B	D	B	D	B	D	B	C	B	*	*	*
26	A	C	A	B	A	C	A	A	A	A	A	A
27	B	D	B	D	B	D	B	C	B	B	D	C
28	A	C	A	B	A	B	A	A	A	A	A	A
29	A	C	A	B	A	B	A	A	A	A	A	A
30	A	D	A	C	B	D	B	C	B	B	B	A
31	A	D	B	D	B	D	B	C	B	B	B	B
32	A	C	A	B	A	B	A	B	A	A	A	A
33	A	C	A	B	A	C	A	A	A	A	A	A
34	A	D	A	C	B	D	C	C	B	B	B	B
35	A	D	A	D	B	D	B	C	B	B	B	B
36	A	D	A	C	B	D	B	C	B	A	B	A
37	A	D	A	D	B	D	B	C	B	A	B	A
38	A	D	B	D	B	D	B	C	B	B	C	B
39	B	D	B	C	B	D	B	C	B	B	C	B

Payback In Years

NOTE: A: 3
B: 3 - 10
C: 10 - 20
D: 20

*no significant furnace exhaust

Consulting services are ordinarily required for installation of heat exchanger units in specific plants, since plant layouts and equipment vintages differ. Once installed, however, in our experience, firms that have adopted heat exchangers are very satisfied with their performance and with the savings in fuel costs. The early adopters in our sample were foundries, in the primary metals industries. It is believed that other types of industries will pick up this approach to the reuse of existing energy sources rather quickly. It should be noted that these technologies are applicable to all industries.

Recuperators or regenerators are generally associated with the steel industry for recovering waste heat from blast furnaces. They are a standard practice with large furnaces historically, but they have been installed less frequently for small furnaces. For instance, it has been documented that until 1973 there were virtually no recuperators on radiant tube furnaces (Nydick & Dunley, 1976.) With higher fuel costs now, it is attractive for small firms to invest in such technologies, especially in view of the fact that a rate of return of 18 percent is easily available (Nydick & Dunley, 1976, p. 2-55).

In our field interviews, we found some small firms have either installed recuperators or are interested in knowing more about them from engineering consulting firms and/or their trade associations.

Since the payback period is a crucial variable to decision makers in the management of energy issues, we list this information for some technologies examined by DOE (in the CONS/2862-1 document) in Appendix 3. A matrix of the energy recovery possibilities from the different waste energy streams (of power, heating, and cooling systems) precedes these payback period tables.

Appendix 4 lists the names of the industries with their two-digit SIC codes.

F. Effect of Adoption Energy Conservation Measures

Though it is obvious that the net effect of the adoption of energy conservation measures will be some reduction in industry energy consumption, it is important to translate these savings into certain more tangible social meaning at both the plant level and national economic level.

At the plant level, we have been told as well as witnessed that the adoption of energy-saving devices has allowed some plants to stay open instead of being shut down after a substantial energy supply cut-back by the utility companies. One firm in Binghamton, New York, was able to double its production in four years with the same amount of energy allocation mainly through savings in both space-heating with energy-saving devices and production with process-change technologies.

On the national scene, the net effect is in the ratio between the increase in GNP and the increase in the total energy use. Historically (1950-1970), the ratio is one to one. However, recent data indicates that the ratio is 1:0.70 in 1976; and 1:0.60 to 0.65 in 1977. Again, this phenomenon can be obtained from another indicator; in 1977, when the economy grew at the rate of five percent, industrial use of energy increased only 1% (Time Magazine: August 21, 1978, p. 74).

CHAPTER 4: The Early Adopters

4.1 Introduction

In Chapter 1, we mentioned that the population of adopters can be categorized as: (1) the innovators, (2) the early adopters, (3) the early majority, (4) the later majority, and (5) the laggards. The early adopters are important for the processes of generating more adoption because they can disseminate information to and initiate contact with potential adopters. If adoptions spread in this way, the process can benefit from what is often called the "bandwagon" effect. Such a natural stimulation of innovative effort creates virtually no out-of-pocket costs for the diffusing party (or sender). It is important for us to identify those early adopters, since individuals or firms possessing characteristics similar to those of the sampled early adopters are the logical target population of the technology transfer effort on two grounds: (1) they can be expected to be more receptive to the innovations, and (2) they can be expected to become information senders, or opinion leaders of the innovation process without costly incentives. Point (2) may have to be examined further because these early adopters may not wish to become information senders.

To identify the characteristics of early adopters of the energy-efficient technologies discussed earlier, a field interview survey was conducted, using the same sample of 32 firms: 16 from the Binghamton, New York SMSA, and 16 from the Allentown, Pennsylvania, SMSA.

4.2 Hypotheses on Predictors for the Early Adopters

Diffusion theorists like Rogers and Mansfield have hypothesized that, in a broad sense, predictors for the adoption of technologies include three variables: characteristics of the innovations, characteristics of the firms, and characteristics of the decision-makers. In more detail, these variables consist of several parameters with respect to our study. They may be expanded as follows:

(1) Characteristics of innovations: cost-effectiveness, ease of implementation and removal (if unworkable), and technical complexity.

(2) Characteristics of firms: centralization, formalization, innovativeness, technological complexity, mechanization, coordination, communication, autonomy, size, and dispersion.

(3) Characteristics of decision-makers: position in relation to the energy coordinator, attitude toward energy problems, perception of cost-effectiveness of technologies, professional affiliation and activities.

To specify these and other parameters as potential predictors for technology adoption rates, a survey instrument was devised and an initial test made of its applicability to this industrial energy conservation study. This instrument was revised twice, after five interviews. The final format of the survey instrument is given in Appendix 1.

From this instrument, 26 variables can be extracted for tests of the hypothesis that a given factor can be used to discriminate between firms with high or low probability of adopting the technologies. These variables are:

(1) <u>Regional Factor</u>:

It is hypothesized that (or, H_0:) there is no significant difference* in the technology adoption rate between Binghamton, New York, and Allentown, Pennsylvania (16 firms in each group).

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*Because we are dealing with a sample of firms rather than all firms, random factors would lead to differences between the average adoption rates of our two areas even if the average rates are the same for all firms in each of the two places. If the differences in our sample averages are "large," however--for instance, larger than would be expected to occur 5 times in 100 chances if the averages for all firms in the two areas were really the same--we say there <u>is</u> a significant difference between the two adoption rates. Then the "null" hypothesis (H_0), that there is <u>no</u> difference, will be rejected. The probability level (5 times in 100 chances, 1 time in 100, 10 times in 100, or whatever) at which the hypothesis is rejected can be chosen by the investigator, and is called the "level of significance." Since the lower the level of significance the more unlikely it is that the sample difference occurred by chance, a lower probability here implies a higher likelihood that the factor is a predictor within the context of a specific experimental design. The actual probability levels are indicated in Appendix 6.

This procedure for defining significant differences follows for the rest of this list of hypotheses.

(2) Energy Intensity Factor:

H_o: No significant difference in adoption rates between firms with high energy intensity and firms with low energy intensity. (Low: 13 firms; Medium: 2; High: 17)

(3) Energy Cut-Back Factor:

H_o: No significant difference in adoption rates between firms which experienced energy cut-backs and firms with no cut-back. (19 firms vs. 13)

(4) Disruption of Production Factor:

H_o: No significant difference in adoption rates between firms which experienced disruption of production due to supply cut-backs by the utility companies and firms with no disruption of production. (8 vs. 24)

(5) Firm Size Factor:

H_o: No difference in adoption rates among firms of different sizes (measured by the number of employees). (In five groups of firms, from small to large: 10, 7, 3, 5, 7)

(6) Centralized Authority Factor:

H_o: No difference in adoption rates between firms with total autonomy and firms which are dependent on a "mother company." (14 vs. 18)

(7) Degree of Automation Factor:

H_o: No difference in adoption rates among firms with different levels of automation in production. (In three groups, from low to high: 12, 13, and 7)

(8) Dependence on Natural Gas Factor:*

H_o: No difference in adoption rates between firms dependent on natural gas and those independent of natural gas. (8 vs. 24)

(9) Age of Equipment Factor:

H_o: No difference in adoption rates among firms the bulk of whose equipment is either new, or not-quite new, or old. (14, 7, 11, scaled by three equipment age classes: 0-10 years, 10-20 years, and 20 years and older)

(10) Growth State Factor:

H_o: No difference in adoption rates among firms in a steady state and firms experiencing growth and rapid growth in business operations (10, 19, 3)

(11) R&D Factor:

H_o: No difference in adoption rates between firms with R&D effort and those without. (14 vs. 18)

(12) Special Consideration of Payback Period Factor:

H_o: No difference in adoption rates between firms that would give investment in energy-efficient technologies special consideration in pay-back period--that is, allow a longer pay-back period than for other types of investments--and firms giving no special consideration. (5 vs. 27)

(13) Energy Officer Factor 1--Only Responsibility:

H_o: No difference in adoption rates between firms which assign an officer whose sole responsibility is energy matters, and firms having energy officers with a mixture of duties. (5 vs. 27)

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*Natural gas is used by industry either for boiler fuel or for direct process, or both. "Dependence on natural gas" in this study refers to any form of use, i.e., heating, processing, and so on.

(14) Energy Officer Factor 2--Chief Officer:

H_o: No difference in adoption rates between firms whose chief officer is the energy officer and those having someone else as energy officer. (7 vs. 25)

(15) Energy Officer Factor 3--Technology/Science Background:

H_o: No difference in adoption rates between firms having an energy officer with science and technology background and firms having an energy officer with other types of background. (14 vs. 18)

(16) Energy Officer Factor 4--Business/Finance Background:

H_o: No difference in adoption rates between firms having an energy officer with a business/finance background and firms having someone else as energy officer. (8 vs. 24)

(17) Energy Information Factor 1--Industry Association:

H_o: No difference in adoption rates between firms which use industrial associations as one of their energy information sources and those that do not. (22 vs. 10)

(18) Energy Information Factor 2--Utility Companies:

H_o: No difference in adoption rates between firms which use utility companies as one of their energy information sources, and firms which do not. (18 vs. 14)

(19) Energy Information Factor 3--Government:

H_o: No difference in adoption rates between firms which use government as one of their information sources, and firms which do not. (8 vs. 24)

(20) Energy Information Factor 4--Other Firms:

H_o: No difference in adoption rates between firms which use other industrial firms as one of their energy information sources and firms which do not. (9 vs. 23)

(21) Energy Information Factor 5--Consulting Firms:

H_0: No difference in adoption rate between firms which use consulting firms as one of their energy information sources, and firms which do not. (10 vs. 22)

(22) Energy Information Factor 6--Within the Firms:

H_0: No difference in adoption rates between firms which use within-firm communication as one of their energy information sources, and firms which do not. (18 vs. 14)

(23) Industrial Association Factor:

H_0: No difference in adoption rates between firms which belong to industrial associations and firms which do not. (22 vs. 10)

(24) Energy Committee Factor:

H_0: No difference in adoption rates between firms which have an energy committee and firms which do not. (10 vs. 22)

(25) Perception that the Government is the Major Cause of Energy Crisis Factor:

H_0: No difference in adoption rates between firms which perceive the government as the major cause of the recent energy crisis and firms which do not. (12 vs. 20)

(26) Degree of Communication within the Firm Factor:

H_0: No difference in adoption rates between firms which have good communications within the firms and those which do not. (Ranked from satisfactory to poor in four groups: 7, 8, 4, 12)

4.3. Tests of Hypotheses and Findings*

The statistical method used to determine the predictors is essentially a discriminant analysis, a detailed discussion of which can be obtained from Morrison (1976). Since there are two dependent (adoption rate) variables as discussed in Chapter 3, the analysis can be either univariate or multivariate. In this study, three analyses are performed: two univariate analyses, taking each dependent variable separately, and one bivariate analysis using two dependent variables in combination. The purpose of discriminant analysis is to determine whether a given factor can be used to separate or discriminate groups on the basis of a given response. Using the technology adoption rates in Table 3-4 for example, we are interested in seeing whether there is a significant difference between the adoption rate of the Binghamton, New York firms, and that of the Allentown, Pennsylvania firms. If the difference is significant according to a statistical test, we can conclude that region can be used to help predict the probability of adoption by industrial firms. It may be that manufacturing firms located in a region where industrial energy supply has been a problem are more likely to adopt energy efficient technologies than firms located in regions where energy supply has not been a problem. With respect to commercialization of efficient energy technologies, the policy maker can then use this finding to direct his or her efforts to energy shortage areas, and expect to obtain a higher rate of success than if efforts were not geographically targeted.

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*This discussion assumes that the results of the present study can be generalized. Only a larger sample, covering more regions, types, and sizes of firms would allow for policy recommendations of this sort to be made with confidence.

Using the 26 factors listed in the preceding section against each of the two dependent variables (the adoption rates) discussed in Chapter 3 yields a series of significance tests of the effects of these factors on the adoption rates. The structure of the data for these tests can be represented by the entries in Table 4-1. In this table, each Y represents an actual adoption rate for a specific firm. The superscript indicates which of the dependent variables is being measured--(1) for the post-1973 rate or (2) for the total adoption rate. The first subscript stands for the measurement on the factor under consideration (for instance which region, which size group, whether or not there is an energy committee), while the second subscript identifies the firm (k = 1, 2, . ., 32).

TABLE 4-1: Structure of Data for the Significance Tests

Firm	Factor												
	Factor 1 (Region)				Factor 2 (Energy Intensity)				Factor 26 (In-Firm Communication)				
	Binghamton		Allentown		High		Low		Satisfactory		Good	Poor	
1	$Y_{11}^{(1)}$	$Y_{11}^{(2)}$	$Y_{21}^{(1)}$	$Y_{21}^{(2)}$	$Y_{11}^{(1)}$	$Y_{11}^{(2)}$	$Y_{21}^{(1)}$	$Y_{21}^{(2)}$	$Y_{11}^{(1)}$	$Y_{11}^{(2)}$	. . . . .	$Y_{41}^{(1)}$	$Y_{41}^{(2)}$
2	$Y_{12}^{(1)}$	$Y_{12}^{(2)}$	$Y_{22}^{(1)}$	$Y_{22}^{(2)}$	$Y_{12}^{(1)}$	$Y_{12}^{(2)}$	$Y_{22}^{(1)}$	$Y_{22}^{(2)}$	$Y_{12}^{(1)}$	$Y_{12}^{(2)}$	. . . . .	$Y_{42}^{(1)}$	$Y_{42}^{(2)}$
.													
.													
.													
k	$Y_{1k}^{(1)}$	$Y_{1k}^{(2)}$	$Y_{2k}^{(1)}$	$Y_{2k}^{(2)}$	$Y_{1k}^{(1)}$	$Y_{1k}^{(2)}$	$Y_{2k}^{(1)}$	$Y_{2k}^{(2)}$	$Y_{1k}^{(1)}$	$Y_{1k}^{(2)}$	. . . . .	$Y_{4k}^{(1)}$	$Y_{4k}^{(2)}$
Mean	$\bar{Y}_{1}^{(1)}$	$\bar{Y}_{1}^{(2)}$	$\bar{Y}_{2}^{(1)}$	$\bar{Y}_{2}^{(2)}$	$\bar{Y}_{1}^{(1)}$	$\bar{Y}_{1}^{(2)}$	$\bar{Y}_{2}^{(1)}$	$\bar{Y}_{2}^{(2)}$	$\bar{Y}_{1}^{(1)}$	$\bar{Y}_{1}^{(2)}$	. . . . .	$\bar{Y}_{4}^{(1)}$	$\bar{Y}_{4}^{(2)}$

Note

Y's are adoption rates of the long-run technologies

Superscripts: (1) = Post-1973 rate
(2) = Total period rate

Subscripts:
First subscript indicates classification of respondent with respect to factor, e.g. for factor 1, 1 = Binghamton region, 2 = Allentown region; for factor 26, 1 = satisfactory, 2 = good, 3 = fair, 4 = poor.

Second subscript indicates firm (k = 1, 2, 3, . . ., 32).

The null hypotheses to be tested for each factor are:

(1) Ho_1: $\bar{Y}_1^{(1)} = \bar{Y}_2^{(1)} = \dots\dots = \bar{Y}_i^{(1)}$ (i depends on the number of groups into which the factor is classified)

(2) Ho_2: $\bar{Y}_1^{(2)} = \bar{Y}_2^{(2)} = \dots\dots = Y_i^{(2)}$

(3) Ho_3: $\left[\bar{Y}_1^{(1)} \quad \bar{Y}_1^{(2)}\right] = \left[\bar{Y}_2^{(1)} \quad \bar{Y}_2^{(2)}\right] = \dots\dots = \left[\bar{Y}_i^{(1)} \quad \bar{Y}_i^{(2)}\right]$

(Here bracket [ ]refers to a vector, which is composed of a number of [dependent] variables.)

or, there is no statistically significant difference between adoption rates judged by (1) recent adoption rates, (2) total adoption rates, and (3) the two adoption rates.

Appendix 2 gives the results of the statistical analysis indicating the mean adoption rates by groups, the eigen values, and the probability values calculated from the tests. Here the eigen values can be interpreted as the percentage of variation (variance) in the adoption rates that can be accounted for by the factor. The probability levels indicate the chance that differences between (or among) the mean values as large as those observed would occur by chance even if the factor classification being tested has no bearing on the adoption rate. For this study, we chose to reject the hypotheses of no difference--that is, we consider that the factor in question does have an effect on the adoption rate--at a 6 percent level of significance (0.06).

Using this criterion, we have obtained eight significant factors that can be used to explain the energy technology adoption patterns in the study area. (See Appendix 2.) These eight factors, numbered as in the hypothesis list (section 4.2 above), with the percent of variance each explains in parentheses, are the following:

(1) Regional Factor (0.25)

(2) Energy Intensity Factor (0.21)

(8) Dependence on Natural Gas Factor (0.12)

(10) Growth Stage Factor (0.40)

(12) Consideration for a Longer Payback Period Factor (0.17)

(14) Chief Officer as Energy Officer Factor (0.20)

(19) Government as an Energy Information Factor (0.13)

(25) Perceiving Government as Major Cause of the Energy Crisis Factor (0.21)

In addition, the consultant factor (21) was chosen for further consideration because the difference in mean adoption rates between firms which do and firms which do not use consulting firms as sources of energy information is great, although the significant level is only at 0.18.

To help the reader interpret these factors, Table 4-2 lists these factors with the adoption rates, the eigen values, and the probability levels.

TABLE 4-2: The Significant Factors

		Mean Adoption Rates[3]			Test Results		
1.	Regional Factor	Group 1	Group 2	Group 3	Eigen value		Probability level[1]
	(recent) Measure 1	0.34	0.17		Ho 1:	0.08	0.12
	(total) Measure 2	0.40	0.44		Ho 2:	0.007	0.60
					Ho 3:	0.25	0.03
	Energy Intensity	0.23	0.08	0.30	Ho 1:	0.04	0.58
	Factor	0.33	0.08	0.53	Ho 2:	0.21	0.05
					Ho 3:	0.30	0.10
8.	Natural Gas	0.33	0.30		Ho 1:	0.01	0.57
	Factor	0.28	0.27		Ho 2:	0.12	0.06
					Ho 3:	0.17	0.09
10.	Growth Factor	0.20	0.21	0.74	Ho 1:	0.40	0.007
		0.49	0.34	0.74	Ho 2:	0.25	0.03
					Ho 3:	0.40	0.01
12.	Payback Factor	0.45	0.22		Ho 1:	0.09	0.11
		0.69	0.37		Ho 2:	0.17	0.03
					Ho 3:	0.18	0.08
14.	Chief Officer	0.43	0.20		Ho 1:	0.11	0.07
		0.43	0.42		Ho 2:	0.0004	0.91
					Ho 3:	0.20	0.06
19.	Government	0.35	0.22		Ho 1:	0.03	0.30
	Information Factor	0.60	0.36		Ho 2:	0.13	0.05
					Ho 3:	0.15	0.13
25.	Perception on	0.21	0.28		Ho 1:	0.014	0.50
	Government Factor	0.51	0.37		Ho 2:	0.05	0.20
					Ho 3:	0.21	0.06
21.	Consultant	0.36	0.21		Ho 1:	0.06	0.18
	Factor[2]	0.53	0.36		Ho 2:	0.06	0.18
					Ho 3:	0.07	0.35

[1] Probabilities of 6 percent or less underlined; factor considered significant with respect to that hypothesis.

[2] Considered for further investigation using two-way factorial design.

[3] Groups 1, 2, or 3 follow the research design in the hypothesis list of section 4.2.

4.4. Interpretation of the significant factors

While the above statistical analysis determined that nine factors out of twenty-six can be used to explain the differentiated patterns of adoption rates, the following process or behavior approach, using responses from the interviews, will substantiate these analytical results. It should be noted that sampled quotations were derived from transcribed conversations between firm officials and the researchers.

1. Regional factor.

This factor indicates that there is a significant difference between the adoption rates in Binghamton, New York and those in Allentown, Pennsylvania. Measure 1--recent adoptions--shows that Binghamton firms have a higher recent adoption rate, while measure 2 indicates a reverse pattern for the total (mostly old) adoption rate. In fact, the "significant difference" occurs in the case when both measures are combined in the analysis. A rapid recent adoption rate in Binghamton was induced by an acute shortage of natural gas supplies to industrial firms. In order for production to proceed without interruption, many firms installed waste heat recovery devices which recycle the heat produced in processing to heat the buildings. The saved natural gas can then be used for processing purposes.

This explanation is substantiated in the following quotation: ". . . this plant, up until four years ago, had created no major expansion, primarily because they felt there were no other means [by which] . . . they could expand. And suddenly, looking back at possible savings, possible changes in technology, we have found out that even though we tried to get large allocations of gas, we were not able to do so. So it was trying to make use of what we had--with supplemental items, changes in technologies, changes in the speed of our processing equipment to utilize the heat better. Those have been done, and I say, we have doubled our total production in the four-year period."

Since sampled firms in the Allentown area belong to a more established (older) category, most of the adoption of energy-saving technologies had occurred prior to 1973. Additionally, these technologies were considered part of normal maintenance procedures, instead of special energy conservation efforts. An adoption rate of 0.17 for recent adoption (versus 0.34 in Binghamton) can also be explained by the energy supply factor--less of a shortage is felt by the firms in the Allentown area. The following quotation illustrates this interpretation.

" . . . our energy costs were rising although they were artificially depressed through governmental action. . . . But at that time [1971] we always took a look at any new projects, as to the utilizing of energy. In other words, we are energy intensive: was there any use where we could be more energy efficient? So we were aware of it at that point. However, in the market place the economic justification of energy-saving devices was difficult to solve. Now we were able to take advantage of some, and are enjoying the benefits of them now. As an example, in 1972 our management had enough foresight to go with a marginal investment, marginal payback on waste heat incinerators. . . ."

2. Energy intensity factor.

The explanation for this factor is more or less straightforward. Since the significant difference occurs for the second hypothesis (total adoption rate), the difference in adoption rates can be attributed to "old" adoptions by the Allentown area firms, most of which rank high in energy intensity. It is also economically reasonable for firms that consume more energy to adopt more energy-efficient technologies.

The first quotation under the regional factor section above, already indicates the importance of natural gas for certain industrial processing uses. We will cite another, from an Allentown firm, that testifies to the same effect:

"We are an intensive industry; our budget for the 1978 fiscal year . . . is something in excess of 16 million dollars. . . .Our major fuel up there [the plant] is natural gas . . . operating on a 20 year firm gas contract."
(Question: What does that mean?)

"Which means that we--in 1959--we signed a contract which gave us 10,000 mcf a day of firm nautral gas, which turned out, starting in 1975, not to be firm. When natural gas shortages developed, because of the nature of our operation, we were damaged extensively. . . .It's a very critical situation with us."
(Question: Have you adopted any energy conservation programs?)

"Yes, we have been working on energy conservation for a long time and, of course, have intensified our studies on energy conservation since the price of energy has doubled, or tripled. (I don't know. Whatever you think it is.) All of our furnaces are equipped with recuperation, recuperators; we pre-heat our air, and in some cases to as much as 1000 degrees."

Another illustration, this one from a Binghamton firm, also indicates that high energy-intensive firms tend to adopt innovations more readily than low energy-intensive firms.

". . .It is a heat exchanger, and what we have done is, from the stack temperature, come along and put another heat exchanger in and reclaim some of that heat and bring it around. By doing this, we've increased the capacity, for an hour, to 250 pounds with the same amount of fuel. . . .That's one area that I think we're going to save a lot. . . . .I can find out whether it's to my advantage to run two fryers at 400 pounds an hour or one at 800 pounds per hour . . .this type of thing. Our utility bills to this plant alone last year was over one million dollars. We are one of the highest [fuel-using] plants; they're expensive in this area."

3. Natural gas factor.

That dependency on natural gas came out to be a significant factor is no surprise to us because of the recent energy crisis. Frequently industry people told us that the energy supply factor definitely had an impact on their decisions for adopting energy conservation measures. Since natural gas is purer than other energy sources and also has a lower price per unit firms prefer it for both processing and economic reasons. Since a significant difference occurs for Hypothesis 2 but not for Hypothesis 1, it can be concluded that the relationship between natural gas consumption and energy conservation is also a pre-crisis phenomenon.

4. The growth and payback factor.

The factors of growth and willingness to consider longer payback period can be interpreted together. Since firms experiencing rapid growth can afford to adopt energy efficient technologies, as well as to consider a longer payback period for investing in energy conservation efforts, these economic factors are helpful for predicting the probability of adoption.

The second quotation given under the regional factor already indicated that growth and a longer payback period may be taken into account on considering the adoption of energy-saving innovations. The firm that scored the highest adoption rate has this to say:

"Up until four years ago, it was slow growth, very slight growth for the first fifteen years here; and then with the past five years, we've really doubled overall capacity."

And related to payback period, the same firm said:

"I don't think whether payback is one year or ten years, from the standpoint of [that] we really can't consider payback periods when it's a shortage of fuel that we cannot get otherwise. . . .I like to say we have a two or three year payback period--we used to figure seven years was good--and most of our equipment out here we like to look at one [year payback] but on this [energy efficient technologies] we really cannot consider a total payback period; it is insurance money."

Relating to the growth factor, one firm in Binghamton said:

"I just now got the oil bills coming in. . . .This is all new to us and we grow so fast. . . .This has exhausted their [headquarters] management skills because they're spreading. . . .We're back now realizing what energy, how much, we can save."

One of the typical answers to our question on considering longer payback periods went like this:

(Question: What's the normal payback period for which you'd be willing to invest?)

"For us here . . .a lot of factors . . .enter into it: what our present financial position is, cash position, and so forth. They tell us that most of them are paying off in three and four years, which is--I don't know whether it's true or not. If it is, and we have the money to finance it, well certainly, we're going to do it with a payoff [period] like that."

From the last quotation, it seems that a "cash reserve" factor might be quite important in determining whether or not a firm is able to invest in energy efficient technologies. Another firm said that they have been contemplating installing a device to circulate air between the ceiling and the floor, but due to cash problems, they were not able to invest $10,000 in this project.

5. Chief officer factor.

Among the four energy officer factors tested, only the "chief officer is the energy officer" factor was significant. Specifically, this occurred for the combined hypothesis on adoptions. This means that the decision-making process relating to energy investment has had a significant effect on the recent adoption rate. Firms whose chief officer is the energy officer are more likely to implement energy conservation programs. Two quotations point out the significance of this decision making process:

"Fortunately, I'm a member of the board, so it's just a little easier to [do it]. I'm the vice-president of the corporation, and a member of the board and the president of this corporation here, this division. So I have some, a few strong points from the standpoint that at least I'm always aware of what's going on. It's a little easier to present some of these things (suggestions of different and better ways) under those conditions."
(Question: Is there a special committee or group of people here that is in charge of monitoring energy or take care of . . .)

From the chief officer: "Well, I've been the one who's been going to the meetings, and then we pass it on to whoever [it is] in our organization who would be involved in putting them into effect. We're all aware of it. I guess if you had to say one person, it would be me."

6. Government factor.

Government as a significant factor affecting energy conservation efforts occurs twice in the analysis. On the one hand, it can be used as an information source; on the other hand, government appears in the perception of managers as one cause of the energy crisis. It also seems that the "government effect" concerning information is more applicable to the old adoption rates than the new adoption pattern. Perception of government as a cause of energy problems was significant for the combined effect (Hypothesis 3).

According to our interviews, government information is perceived to be favorable, while government regulations are seen as barriers to the spread of energy-saving technologies. Some of the quotations which follow speak for themselves on this point.

"There has been an increase of literature coming from the federal government, which is of some help. I've received a couple [of] booklets from them where they just set up case studies of different plants: how to go about setting up a management team, whatever it takes, and the detail of paperwork, things like that; investigation of what was used previously."

"I answered a questionaire that came out about a year ago in regard to whether we did have an energy conservation project, which I answered no, and would be willing to work with the [government] and they would send in literature and such. I received this a year ago, and I've never heard a word back from them. Supposedly they were going to keep all participants that were interested advised as to energy conservation programs, projects and such. I don't know whether they ever created any, but that is the sole piece of information that I received from them. . . .I think the major cause [of the energy crisis] is the fact that the politicians, instead of looking at energy problems, are too busy trying to get re-elected for another term. Once they get in, and they put this way down on the priority list, and they do not take action on it. . . ."

"I'd say it's low there too [relating to the degree of attractiveness of government's tax incentive], because they had so many government regulations that keep you from using your time on energy [matters] or anything else. . . . Anything the government does costs you probably 500 percent more than it would cost anybody else to do it. . . .Keep the government out of it, yes; it's too expensive."

7. Consultant factor.

In our interviews, it seemed that the use of energy engineering consulting services definitely had an impact on the recent adoption rate of technological innovations. Although it is not statistically significant for discriminating levels of adoption rates, we believe it will become more important in the near future. The following quotations testify to this effect.

"A fellow from power engineering is coming in tomorrow to look over our situation. . . .They are not asking for [us to pay for] anything as far as to come in and look and come up with a recommendation. We will pay for it, of course, if we buy what they have to offer."

"A good share of what we want to do, even myself, I know what I have to do, where I want to go. But to invest that much money, $20,000, for them to tell me what's wrong and what we can do about it? I know what's wrong and I know basically how I'm going to go about it. I'd just as soon take that $20,000 and put it in my first project. . . ."

"Well, . . . this article I'm referring to, it was written by a consultant for the association. A fellow by the name of P.F. Dixon was retained by the National . . .Association to look into this matter [heat exchanger] and to make recommendations."

Relating to the question of whether the government or the private sector is more appropriate for providing consulting services, the following answer is a typical one:

"I think that this [private sector] would tend to be better. I would say the effectiveness of this would be good. The reason I say that is there would be a competitiveness when consultants have to come and compete as to who is going to be selected, because you are paying; the government isn't. And if they are not doing the job, they [have to] go out the door! So I think that would be better guarantee to quality in the job that's coming in."

4.5. Further Analysis of the significant factors: Two-way factorial design

1. Interaction patterns among individual factors.

While the analysis presented in section 4-3 deals with the determination of which individual factors influence adoption rates, the technique of two-way factorial design aims to discover whether or not there are significant interactions between pairs of factors. In this analysis, the source of variation (variance) is decomposed into three parts: a first factor, a second factor, and the interaction between the two. Here we are able to find out if either or both of the individual factors and/or their interaction are significant. The difference between one-way and two-way analysis is that the importance of a single factor may either be missed because it is masked by the influence of a second factor which works in an opposite way, or it may be considered significant only because its effect seems to be great but really is enhanced by the (unexamined) influence of a second factor which works in the same direction. Two-way analysis sorts out the effects of the two factors simultaneously. Moreover, in introducing an interaction effect and testing for it, the joint effects of the two variables may (or may not) be shown to have a significant influence on the dependent variable (adoption rate), independent of either factor individually.

Although it is possible to perform pair-wise analyses on all 26 factors, we decided to use only the 9 factors which were evaluated as significant in the one-way design, since we believed it would be more fruitful to investigate further these 9 factors under conditions of mutual influence (or interaction) with each other than to select new factors. This analysis results in 36 (or ${}_9C_2$) pair-wise comparisons and interactions.

Appendix 2 indicates the analytical results, showing the level of probability for each of the three hypotheses: (1) new adoption rate (Innovation 1), (2) total adoption rate (Innovation 2), and (3) the combination of new and old adoption rates in a multi-variate analysis mode.

The information contained in Appendix 2 is summarized in the following table, Table 4-3. The latter shows how each factor relates--or is unrelated--to the eight other factors, indicating (1) that the specific factor is not significant in the two-way analyses with certain of the other factors, and (2) that the specific factor is significant even when the influence of certain other factors is removed.

2. The key conclusions are:

1. The regional factor is significant in influencing adoption rates even when the contribution of four of the other factors is removed: dependence on natural gas, growth, consideration of a longer payback period for energy-saving technology, and perception of the government as a cause of the energy crisis. However, although region is significant when it is treated as a single influence on adoption rates, the relationships between region, on the one hand, and, on the other hand, energy intensity, chief officer as the energy officer, government as a source of information, or use of consultants, are such that the influence of "region" alone becomes insignificant when any one of these four factors is included in a two-way analysis with region. It may be that "awareness" of the energy problem--because the firm has high energy intensity, because the chief officer is concerned, or because the firm has received (or sought) information from the government or from consultants--differs between regions and this is what makes region alone seem to influence adoption rates.

2. Growth is the other factor which is significant even when four different influences are considered with it. Even if the impact of dependence on natural gas, or payback period considerations, or use of consultants, or viewing the government as contributing to the energy crisis is accounted for, the firm's

TABLE 4-3: Interdependence Patterns Among the Nine Significant Factors

Factor	(1) Not significant in Two-way Analysis with:	(2) Significant in Two-way Analysis with:*
1. Region	Energy intensity Chief officer Govt. information Consultants	Natural gas (H_o3) Growth (H_o3) Payback (H_o1, H_o3) Govt. as cause (H_o1, H_o3)
2. Energy intensity	Region Natural gas Payback Chief officer Govt. information Consultants (?)** Govt. as cause	Growth (H_o3)
3. Natural gas	Region Energy intensity Payback Chief officer Govt. information Consultants	Growth (H_o3) Govt. as cause (H_o2, H_o3)
4. Growth	Region Energy intensity Chief officer Govt. information	Natural gas (H_o1, H_o3) Payback (H_o1) Consultants (H_o1) Govt. as cause (H_o1, H_o3)
5. Payback	Energy intensity Natural gas Growth Govt. information Consultants	Region (H_o1, H_o2, H_o3) Chief officer (H_o1) Govt. as cause (H_o1)
6. Chief officer	Region Energy intensity Natural gas Growth Govt. as cause	Payback (H_o1) Govt. information (H_o1) Consultants (H_o1)
7. Govt. information	Energy intensity Natural gas Growth Payback Chief officer Consultants Govt. as cause	Region (H_o2)

Table 4-3 (continued)

8. Consultants	Region	Natural gas (H_o3)
	Energy intensity (?)**	Chief officer (H_o1)
	Growth	
	Payback	
	Govt. information	
	Govt. as cause	
9. Govt. as cause	Energy intensity	Region (H_o1, H_o2)
	Payback	Natural gas (H_o2, H_o3)
	Chief officer	Growth (H_o1, H_o3)
	Govt. information	
	Consultants	

*Considered significant if probability level 0.06 or less.

**Singular matrix; results unobtainable because the matrix cannot be inverted with a normal procedure.

growth status seems to influence its rate of adoption of energy-saving devices. The growth factor loses its importance when it is analyzed jointly with region, energy intensity, chief officer as energy officer, and government as information source. We suggested early in this study that the two regions might have different growth characteristics, and the mutual influences might cancel each other out. (The interaction term is significant for $H_0 3$.)

3. Factors 5, 6, and 9 (payback period, chief officer, and government seen as cause) are each significant in two-way analyses when three of the other eight factors are held constant. It might be noted that both growth and energy intensity might be expected to be linked to the payback period, and indeed, payback becomes non-significant when analyzed with these. The perception of the government as contributing to the energy crisis may be linked to the role of the chief officer and to the firm's information sources, making factor 9 lose its impact when these factors are separated out.

4. The four other factors--energy intensity, natural gas dependence, government as an information source, and use of consultants--are not significant when combined with six or seven of the remaining eight factors. Energy intensity and dependence on natural gas are both significant even when the growth factor is controlled, but in general these four factors probably must be considered in conjunction with several others.

These conclusions are summarized in Table 4-4. This table ranks the "relative strength" of the nine factors by the number of other factors whose influence can be removed without eliminating the significance of the ranked factor.

TABLE 4-4: Relative Strength of the Factors

Rank	Factor	No. of other factors that can be removed
1	Region	4
1	Growth	4
2	Payback	3
2	Chief officer	3
2	Government as cause	3
3	Natural gas	2
3	Consultants	2
4	Energy intensity	1
4	Government information	1

2. The Factor Pairs: Interactions

The two-way factorial analysis was originally designed to isolate significant factor pairs by evaluating the significance of the "interaction effect," although we have used it to investigate interdependences among pairs of factors in the previous section. An interaction effect which is significantly different from zero indicates that the particular pair of factors reinforce each other's impacts (positively or negatively) to make the adoption rates different from what they would be if the effects of each factor could be measured separately and the results added. It can be likened to the synergistic effects of two chemicals producing an effect in combination which is quite unlike that of each acting separately.

From the 36 possible factor pairs we have identified seven pairs whose interaction is significant at least at the 0.05 level (Table 4-5). They are:

1. Region and natural gas
2. Region and growth
3. Region and payback
4. Region and government seen as energy crisis cause
5. Natural gas and growth
6. Natural gas and government seen as energy crisis cause
7. Growth and government seen as energy crisis cause

In addition, the table (4-5) includes five factor pairs with interactions significant at the 0.05 to 0.10 level:

1. Energy intensity and chief officer as the energy officer
2. Payback and chief officer as the energy officer
3. Payback and government seen as energy crisis cause
4. Growth and use of consultants
5. Chief officer as the energy officer and use of consultants

TABLE 4-5: Significant Interaction Effects, Factor Pairs

	Factors	Significant Hypotheses*	Probabilities**
1.	Region & natural gas	H_o3	0.05
2.	Region & growth	H_o3	0.01
3.	Region & payback	H_o1	0.01
		H_o3	0.06
4.	Region & govt. as cause	H_o1	0.04
5.	Energy intensity & chief officer	H_o1	0.08
6.	Natural gas & growth	H_o3	0.04
7.	Natural gas & govt. as cause	H_o2	0.05
		H_o3	0.08
8.	Growth & consultants	H_o1	0.09
9.	Growth & govt. as cause	H_o1	0.08
		H_o3	0.0048
10.	Payback & chief officer	H_o1	0.10
11.	Payback & govt. as cause	H_o1	0.06
12.	Chief officer & consultants	H_o1	0.09

*H_o1: post-1973; H_o2: total; H_o3: combined adoption rate interactions equal zero

**Probability of (erroneously) rejecting the null hypothesis specified if it is true. (See Appendix 2.)

As we did with the factor relationships in the preceding section, we can also rank the relative importance of the individual factors in relation to their interactions with other factors by counting the frequency of their appearance in significantly-interacting factor pairs, as shown in Table 4-6. Among pairs with significant interactions, the most important individual factors are region, growth, and perception of the government as a cause of the energy crisis. The second most important group, in terms of frequency, includes dependence on natural gas, chief officer as energy officer, and willingness to consider longer payback periods for energy-saving innovations. Although "chief officer" appears in three pairs, all three interaction effects are only significant at the 0.08 to 0.10 levels. Use of consulting firms and energy intensity, which occur twice and once, respectively, also are significant only at the 0.09 and 0.08 levels (in that order).

TABLE 4-6: Frequency of Appearance of the Single Factors in the Factor Pairs with Significant Interactions*

Rank	Factor	Frequency
1	Region	4
1	Growth	4
1	Govt. as cause	4
2	Natural gas	3
2	Chief officer	3
2	Payback	3
3	Consultants	2
4	Energy intensity	1
		24

*Significance of 0.10 or less. (See Table 4-5.)

4.6 Summary: An Integrated Interpretation of the Significant Factors

The results of the analysis of the factors which influence firms' adoption of energy-saving technologies can now be reviewed (Table 4-7). Of the 26 initial factors tested, 9 individual factors seem to have significant impacts on adoption rates: region, energy intensity, dependence on natural gas, growth, willingness to consider a longer payback period than for other investments, chief officer as person responsible for energy policy, government as an information source, use of consulting firms, and government perceived as a cause of the energy crisis. When these 9 factors are analyzed in pairs, a few factors seem more important than the others. Comparing Tables 4-4 and 4-6,we see that region and growth rank first in both the ability to retain significance when other factors are removed and in the frequency of appearance with significant interactions. Payback period, chief officer as energy officer, and government as cause rank either first or second in both lists. While dependence on natural gas ranks second in interactions it is third in the two-way factor analysis ranking, and consultants and energy intensity rank third or fourth in both tables. Government as an information source is fourth in Table 4-4 and does not appear among the significant interactions at all.

It seems reasonable that both region and growth would interact with other factors--for instance, dependence on natural gas for region, and willingness to accept longer payback periods for growth--as well as with each other, and yet each might be strong enough an influence to stand alone as well. Clearly, only further study would allow one to generalize from two regions to regions as a whole.

Among the hypotheses, H_o1, the post-1973 adoption rate differences, appears to give significant results most often. H_o2, the total adoption rate, appears rarely, while the combination of those two rates in the multivariate hypothesis, H_o3, is rejected--i.e., differences are significant--almost as often as H_o1.

TABLE 4-7: Significant Individual and Two-Way Factors

Significant Factor in One-Way Analysis	Significant Factors in Two-Way Analysis
1. Region	1. Region & natural gas
2. Energy intensity	2. Region & growth
3. Natural gas	3. Region & payback
4. Growth	4. Region & government perceived as energy crisis cause
5. Payback	5. Natural gas & growth
6. Chief officer	6. Natural gas & government perceived
7. Government information	7. Growth & government perceived
8. Consultants	[Above significant at 0.05 level]
9. Government perceived as cause of energy crisis	8. Energy intensity & chief officer
	9. Payback & chief officer
	10. Payback & government perceived
	11. Growth & consultants
	12. Chief officer & consultants
	[Above significant at 0.05-0.10 level]

CHAPTER 5: Policy Options Survey and Analysis

5.1 Introduction

Whatever specifics are agreed to by Congress, the federal energy policy now being formulated will have twin goals--to cut down United States dependence on overseas oil and to encourage the American public to consume less of our finite supply of domestic energy. The magnitude of the energy problem, thus the significance of energy policies, can be realized from the fact that the United States is still importing 8.6 million barrels of oil a day (April, 1978), which accounts for 47.5 percent of total domestic oil consumption.

It is a historical fact the United States is a big energy user, since it consumes almost 30 percent of the total world's energy with less than 6 percent of the world's population (Statistical Abstract, 1977, pp. 905, 891). This behavior is expected to continue for a long time as evidenced from the post-1973 international energy consumption pattern: total energy consumption fell much less rapidly in the United States than in the other major industrial countries except Japan. Correspondingly, oil imports rose more than 60 percent in the United States between 1973 and 1976, in contrast to the declines experienced by Japan (2.2 percent), France (3.5 percent), and West Germany (3.5 percent). (Economic Report of the President, 1978, p. 187.)

A number of factors, including relatively low energy prices, government policies favoring highways over mass transit, and lack of environmental legislation, which encouraged energy consumption, had locked the United States economy into a capital stock tailored to low-cost oil and natural gas by the end of 1972 (72 trillion BTU were used in 1972). (Economic Report of the President, 1978, p. 181.)

In essence, many had found it more profitable to substitute energy for other factors (such as labor and raw materials) to produce goods and services, without realizing that one of these days energy supply could become a problem.

October 17, 1973 has been called "Energy Pearl Harbor Day" by Freeman (Freeman, Energy: the New Era, 1974, p. 3). With the Arab oil embargo, energy prices skyrocketed, and energy shortages have become a continual threat to industrial firms. Since we cannot transform the United States economic system from one of high energy-dependence to one of less energy-dependence (comparable to other industrial countries) overnight, energy policy-makers are charged with the important responsibility of insuring a smooth transition: that is, securing supplies of energy to meet a growing economy and at the same time inducing basic changes in consumption patterns and production methods which will diminish our energy dependence.

Energy conservation efforts by all sectors of the economy can provide time for a healthy transformation from our high energy-dependence to a less energy-dependent economy. This process has begun to take place, as witnessed from the change in the energy growth to GNP growth ratio, which fell to between 60 and 65 percent last year from 70 percent in 1976. More explicitly, GNP, after adjustment for inflation, has grown by 11 percent since 1973, while energy consumption increased only 3 percent, in contrast to the historical ratio (1956-1970) of one to one. (The New York Times, April 16, 1976.)

5.2 Public Policies

To provide some background for the approach used to analyze energy policy options, this section will discuss a general concept of public policies.

Jones, in An Introduction to the Study of Public Policy, summarizes the basic elements of public policy as follows:

> ...public problems exist in society as a result of the perception of needs by people, some people have problems in common, some of these organize and make demands or demands are made by those who seek to represent people, demands are perceived and judged by those with authority to make decisions, decisions are made and enforced, public problems are affected by those decisions, people react to the decisions, some people have common reactions, demands are made, and so forth. (p. 9)

According to this way of looking at the policy process, energy issues clearly belong to public policies.

The United States energy policies in the past have been generally evaluated as failures (Mancke, 1974; Kalter & Vogely, 1976; Jones, 1977; Freeman, 1974). The national energy plan proposed by President Carter (summarized in the Economic Report of the President, 1978, pp. 188-194) has been actively debated in Congress for more than a year. The goals of this plan are to solve the short-term and long-term energy problems related to energy supplies, conservation, and alternative energy sources. To achieve these goals, problems have to be specified carefully and then solutions to the problems are to be formulated. Programs are required to carry out the identified tasks. Finally, the effectiveness of these programs has to be examined for designing policy changes if necessary. These are a series of public policy processes. Jones has also outlined a model for policy analysis as shown in Table 5-1.

TABLE 5-1: The Policy Process

Functional Activities	Categorized in Government	And as Systems	With Output
Perception Definition Aggregation Organization Representation	problems to government	problem identification	problem to demand
Formulation Legitimation Appropriation	action in government	program development	proposal to budgeted program
Organization Interpretation Application	government to problem	program implementation	varies (service, payments, facilities, controls, etc.)
Specification Measurement Analysis	program to government	program evaluation	varies (justification, recommendation, etc.)
Resolution/ Termination	problem resolution or change	program termination	solution or change

From C. O. Jones: An Introduction to the Study of Public Policy, p. 12.

Since national energy policies are still being formulated, we used a survey research approach to obtain reactions to or feelings about certain energy policy options which have been proposed by policy makers. The purpose here is to give federal policy makers some views from industry as one of the inputs into the formulation of national energy policies.

5.3 The Conservation Policy Options Surveyed

Based on the suggestions of federal policy makers and Congressional staff, specifically those mentioned in Joint Hearings before certain Subcommittees of the Committees on Government Operations and on Science and Astronautics of the House of Representatives (93rd Congress, First Session, 1973), we selected for analysis twelve policy options related to energy conservation. The strategies for encouraging conservation efforts in general are (1) tax incentives for implementing conservation measures and energy management programs, (2) penalties, for instance energy taxes, for excessive energy consumption, and (3) pricing and mandated allocation methods to discourage consumption. The specific examples of these policy options which were included in our survey are listed in Table 5-2.

In this survey, each of the twelve policy options was subjected to evaluation and rating by the firm according to three points of view:

A. Potential effectiveness of the policy for energy conservation, rated according to these levels: good, fair, no effect;

B. Attractiveness to industry in general, rated according to three levels: high, moderate, low; and

C. Attractiveness to your firm, also rated according to three levels: high, moderate, low.

TABLE 5-2: Energy Conservation Policy Options

1. Use of recycled material: incentive for use coupled with penalties for use of virgin materials
2. Deregulation of energy prices
3. Federal tax on energy purchases based on national energy consumption patterns
4. Price incentives for off-peak energy use combined with penalties on increments of energy consumed in excess of (peak) bases
5. Federally mandated energy allocation limits based on past energy usage per unit of output
6. Favorable loan terms for energy conservation capital expenditures (plant insulation, energy-efficient equipment, etc.)
7. Federally guaranteed loans for energy conservation capital expenditures
8. Tax credits for energy conservation capital expenditures
9. Government-sponsored services of consultants at no cost to industry
10. Tax credits for cost of implementing and maintaining energy management program
11. Research and development of energy-efficient production technologies: research efforts sponsored by federal government agencies
12. Industry-based R&D efforts in energy-efficient technologies, subsidized by federal incentives

5.4 Policy Options Preferred by Industry

The first method of measuring the response to the surveyed energy policy options uses a simple voting scheme. Each firm was asked to rate each option according to the three above-mentioned responses (effectiveness for energy conservation, attractiveness to industry in general, attractiveness to your firm). In the survey, 30 firms out of 32 responded, yielding the response pattern given in Table 5-3.

Using the first policy option (use of recycled material) for example, we have the following pattern:

#1. Use of recycled material

Response	A	B	C	Sum
Good, high	11	7	6	(24)
Fair, moderate	5	7	4	(16)
No effect, low	9	9	17	(35)

Here, A, B, and C refer to the three effects of the policies: effectiveness in conservation, attractiveness to industry, and attractiveness to the particular firm. Using the numbers of Column A, for instance (11, 5, 9), means 11 firms rated the policy option as very effective in energy conservation, 5 firms rated it as fair, and 9 firms thought it would have no effect whatsoever. Since not all the firms responded to each of the questions (missing responses should be interpreted as "no opinion"), the columns will not always add up to 30. In this example 25 responded to A, 23 to B, 27 to C.

One measure of the preferences of the firms with respect to each option is simply to sum the number of responses to A, B, and C for the most favorable reaction (good, high). Using the same example we can suggest that the sum of

(11, 7, 6), which is 24, is an indicator measuring how effective and attractive firms consider this policy option to be. It should be noted that the highest possible score is 90 if all 30 firms voted (good, high) for all three effects. A summary of this indicator is given in Table 5-4, which ranks the policy options according to the "good, high" sum (column A).

One can also use the sum of row (3) (no effect, low) to measure the perceived preference of each policy option. Since this index is inversely related to the first index (good, high), the lower the score the higher the rank becomes (column B, Table 5-4).

In general, the firms prefer policy options involving tax credits, favorable terms for energy capital expenditures, and deregulation of energy prices, and dislike policy options related to energy taxes and mandated energy allocations. Policy options involving research and development in energy efficient technologies and incentives for energy management programs are ranked in between the two extremes--the "carrots" and "sticks".

TABLE 5-3: Preference Response Pattern for Policy Options

where:

A: Effectiveness in energy conservation
B: Attractiveness to industry in general
C: Attractiveness to your firm

1. Use of recycled material

	(response)	A	B	C	SUM
good, high	(1)	11	7	6	(24)
fair, moderate	(2)	5	7	4	(16)
no effect, low	(3)	9	9	17	(35)

2. Deregulation of energy prices

	(response)	A	B	C	SUM
good, high	(1)	24	16	17	(57)
fair, moderate	(2)	2	4	2	(8)
no effect, low	(3)	3	6	9	(18)

3. Federal tax on energy

	(response)	A	B	C	SUM
good, high	(1)	5	4	3	(12)
fair, moderate	(2)	8	3	4	(15)
no effect, low	(3)	8	15	15	(38)

4. Incentives for off-peak use

	(response)	A	B	C	SUM
good, high	(1)	11	5	6	(22)
fair, moderate	(2)	5	6	3	(14)
no effect, low	(3)	10	13	18	(41)

5. Federally mandated energy allocation

	(response)	A	B	C	SUM
good, high	(1)	9	1	3	(13)
fair, moderate	(2)	7	7	6	(20)
no effect, low	(3)	12	20	20	(52)

6. Favorable loan terms for capital expenditures

	(response)	A	B	C	SUM
good, high	(1)	21	18	18	(57)
fair, moderate	(2)	6	6	4	(16)
no effect, low	(3)	0	2	6	(8)

TABLE 5-3 (cont'd)

7. Federally guaranteed loans

	(response)	A	B	C	SUM
good, high	(1)	14	15	15	(44)
fair, moderate	(2)	6	5	4	(15)
no effect, low	(3)	5	6	8	(19)

8. Tax credits for energy capital expenditures

	(response)	A	B	C	SUM
good, high	(1)	21	21	22	(64)
fair, moderate	(2)	6	3	2	(11)
no effect, low	(3)	1	2	3	(6)

9. Government sponsored consulting services

	(response)	A	B	C	SUM
good, high	(1)	10	7	10	(27)
fair, moderate	(2)	6	8	5	(19)
no effect, low	(3)	13	14	14	(41)

10. Tax credits for energy management program

	(response)	A	B	C	SUM
good, high	(1)	13	13	12	(38)
fair, moderate	(2)	10	8	7	(25)
no effect, low	(3)	4	6	8	(18)

11. R&D by federal agencies

	(response)	A	B	C	SUM
good, high	(1)	11	8	10	(29)
fair, moderate	(2)	6	8	7	(21)
no effect, low	(3)	11	12	12	(35)

12. Industry-based subsidized R&D

	(response)	A	B	C	SUM
good, high	(1)	14	12	12	(38)
fair, moderate	(2)	5	7	7	(19)
no effect, low	(3)	2	2	3	(7)

TABLE 5-4: Ranking of the Preferred Policy Options

Rank from Column A)	Policy Options*	Score A**	Score B***	Rank (by Column B)
1	Tax credits for capital expenditure (8)	(64)	6	1
2.5	Deregulation of energy prices (2)	(57)	18	4.5
2.5	Favorable loan terms for capital expenditures (6)	(57)	8	3
4	Federally guaranteed loans (7)	(44)	19	6
5.5	Tax credits for energy management program (10)	(38)	18	4.5
5.5	Private R&D subsidized by government (12)	(38)	7	2
7	R&D by federal agencies (11)	(29)	35	7.5
8	Government sponsored consulting services (9)	(27)	41	10.5
9	Use of recycled material (1)	(24)	35	7.5
10	Incentives for off-peak use (4)	(22)	41	10.5
11	Federally mandated energy allocation (5)	(13)	52	12
12	Federal tax on energy (3)	(12)	38	9

*Number in parentheses is policy option number of Tables 5-2 and 5-3.
**Sum of "good, high" responses; see Table 5-3.
***Sum of "no effect, low" responses; see Table 5-3.

5.5 Interrelationships of Policy Responses and Firm Characteristics

While section 5.4 describes the general response patterns of the firms regarding energy policy options, this section will discuss the differentiations among the responses associated with different characteristics of the firms, using statistical discriminant analysis. The objective here is to determine which characteristics of, or factors influencing, the firms can be used to describe significantly different policy responses among them. For instance, we might determine that firms with different degrees of automation or with different sources of energy information will respond differently to a certain policy.

The statistical technique employed here is essentially univariate and multivariate discriminant analysis, using the three response options--effectiveness, attractiveness to industry in general, and attractiveness to the specific firm--and a combination of the three as dependent variables, and the 26 characteristics or factors as independent variables. Thus, there are 104 (26 x 4) tests for each policy option, and 1,248 tests for all twelve policy options. The results are given in Appendix 7 and are summarized in Table 5-5.

From the bottom line of Table 5-5 we can see that the four most "controversial" (most frequent significant differences among firms) policy options are: (1) incentives for using recycled materials; (2) deregulation of energy prices; (10) tax credits for energy management programs; and (6) favorable loan terms for energy-saving investment. Each has more than 12 percent of significantly different responses out of a possible 104 responses.

TABLE 5-5: Frequency of Significant Differences of Responses to Policy Options by Factors Influencing Firms*

		Policy Option												Total Frequency for factor
	Factor	1	2	3	4	5	6	7	8	9	10	11	12	
1.	Region	0	0	0	0	0	0	0	0	0	0	2	0	2
2.	Energy cutback	0	0	0	0	1	0	3	0	1	0	0	0	5
3.	Disruption of prod.	1	1	0	0	2	0	0	0	0	0	0	0	4
4.	Natural gas	0	0	3	0	1	0	0	0	0	0	0	0	4
5.	Energy officer 1: only responsibility	0	0	0	1	0	1	0	0	0	0	0	0	2
6.	Energy officer 2: chief officer	2	2	0	1	0	3	0	0	0	0	0	0	8
7.	Energy officer 3: technology/science	0	2	0	1	0	0	0	0	0	3	0	0	6
8.	Energy officer 4: business/finance	0	3	0	0	0	3	2	1	0	3	0	0	12
9.	Energy committee	0	2	0	0	1	0	0	0	0	0	2	0	5
10.	Energy intensity	2	2	0	0	0	1	0	0	0	0	0	0	5
11.	Firm size	0	0	1	0	0	0	3	0	0	3	0	0	7
12.	Automation	0	0	0	0	0	0	0	2	0	0	0	0	2
13.	Age of equipment	0	0	2	0	0	0	1	1	0	0	0	0	4
14.	Centralization	2	0	0	0	0	0	0	3	0	0	0	0	5
15.	Communication within firm	0	0	1	0	2	0	0	0	0	0	0	0	3
16.	Information 1: industrial assn.	1	0	0	0	0	0	0	0	0	0	0	0	1
17.	Information 2: utility company	0	1	0	0	0	2	0	2	0	1	0	0	6
18.	Information 3: government	0	0	0	1	0	2	0	0	0	0	2	0	5
19.	Information 4: other firms	4	0	1	1	0	0	0	0	1	3	0	0	10
20.	Information 5: consulting firms	0	1	0	0	0	0	0	1	0	0	0	0	2
21.	Information 6: within the firm	0	0	1	0	0	0	0	0	0	0	3	2	6
22.	Member of industrial association	3	1	0	0	0	0	0	0	0	0	0	0	4
23.	Payback period	0	0	1	0	0	1	0	0	1	0	0	0	3
24.	Growth state	0	0	1	0	0	0	0	0	0	0	0	0	1
25.	R&D	0	0	0	0	1	0	0	0	1	1	0	0	3
26.	Govt. seen as cause	0	0	0	0	1	0	0	0	2	0	0	0	3
	Total frequency for policy option	15	15	11	5	9	13	9	10	6	14	9	2	118
	Rank	1	1	4	8	6	3	6	5	7	2	6	9	

*Factors are discussed in Chapter 2 (see Table 2-5) and policy options in section 5.3 (see Table 5-2). Maximum possible cell frequency is 4 significant differences (policy is expected to be effective, attractive to industry in general, attractive to your firm, and a combination of these three). Maximum possible row total is 48, column total 104. Frequency appears if difference is significant with respect to the factor, for a given policy option, with probability of 0.10 or less. (See Appendix 7)

If we compare this result with the general response pattern given previously (section 5.4) we can see some inconsistencies between these two patterns, as illustrated in Table 5-6. For instance, policy options (2) and (6), deregulation of energy prices and favorable loan terms, are tied for second place among the most preferred policies in the earlier ranking (column C in Table 5-6), yet they are also among the more controversial policies as measured by the frequency of significant differences of responses by firms with different characteristics. On the other hand, policy option (4), incentives for off-peak energy use, is disliked rather consistently. The most preferred policy, tax credits for capital expenditures on energy-saving equipment (policy option 8), ranks below the middle in consistency of response. This means we cannot confidently expect to see a uniform response from industry regarding energy policy issues, even with respect to the "most popular" policy suggestions.

This result leads us immediately to the next question: What are the factors that contribute to inconsistency in policy responses? We can obtain this information from the last column of Table 5-5, which gives the total number of significant differences in attitudes toward policy options for each firm characteristic. Listing the four most disagreed-on policies extracted from Table 5-5 in Table 5-7, we see that the most important contributing factors are:

8. Energy officer with a business or finance background;
6. Energy officer is also the chief officer of the firm;
19. Information 4: firm gets its energy information from other firms;
7. Energy officer with a technology or science background; and
10. Energy intensity of the firm.

TABLE 5-6: Ranking of Policy Preferences by Simple Enumeration and by Discriminant Analysis*

	Policy Option	A Inconsistency Ranking	B Consistency Ranking (Reverse of A)	C Preference Ranking
1.	Use of recycled materials	1	11.5	9
2.	Deregulation of energy prices	1	11.5	2.5
10.	Tax credits for energy management	2	10	5.5
6.	Favorable loan terms	3	9	2.5
3.	Federal tax on energy purchases	4	8	12
8.	Tax credits for energy capital exp.	5	7	1
5.	Federally mandated allocations	6	5	11
7.	Guaranteed loans	6	5	4
11.	Federal R&D	6	5	7
9.	Government-sponsored consulting services	7	3	8
4.	Incentives for off-peak use	8	2	10
12.	Private R&D subsidized by government	9	1	5.5

*For column A, see Table 5-5; for Column C, see Table 5-4. Rankings have been renumbered, from 1 through 12, with fractions as needed for ties, to make the two sets of ranks (columns B and C) equivalent.

Except for the last, energy intensity, these factors are clearly "personality" related attributes. This means that in terms of energy policy issues, we should look for behavioral factors, or persons who are directly in charge of the firm's energy management programs, instead of non-behavioral factors such as degree of automation and centralization. In addition, if we examine further the information in Table 5-5, we can also conclude that the firm-size factor and other information factors are also important. This further confirms the significance of the behavioral aspects of responses to policy issues. In general, the analysis indicates that firms with energy officers having different backgrounds, and receiving energy information from different sources tend to respond differently regarding energy policies. Additionally, firms with different energy intensity levels, sizes, and organization (centralization; energy committee), may also respond differently. This is a significant finding in the sense that it can provide government officials and policy makers guidance for obtaining support from certain industrial sectors regarding energy policy legislation.

TABLE 5-7: Factors Influencing the Four Most Controversial Policies*

	Factor	Policy Option				Total frequency for factor
		1 Recycling incentives	2 Deregulate prices	10 Credits for energy mgt.	6 Favorable loan terms	
1.	Region	0	0	0	0	0
2.	Energy cutback	0	0	0	0	0
3.	Disruption of production	1	1	0	0	2
4.	Natural gas dependence	0	0	0	0	0
5.	Energy officer 1: only responsibility	0	0	0	1	1
6.	Energy officer 2: chief officer	2	2	0	3	7
7.	Energy officer 3: technology/science	0	2	3	0	5
8.	Energy officer 4: business/finance	0	3	3	3	9
9.	Energy committee	0	2	0	0	2
10.	Energy intensity	2	2	0	1	5
11.	Firm size	0	0	3	0	3
12.	Automation	0	0	0	0	0
13.	Age of equipment	0	0	0	0	0
14.	Centralization	2	0	0	0	2
15.	Communication within firm	0	0	0	0	0
16.	Information 1: industrial association	1	0	0	0	1
17.	Information 2: utility company	0	1	1	2	4
18.	Information 3: government	0	0	0	2	2
19.	Information 4: other firms	4	0	3	0	7
20.	Information 5: consulting firms	0	1	0	0	1
21.	Information 6: within the firm	0	0	0	0	0
22.	Member of an industrial association	3	1	0	0	4
23.	Payback period	0	0	0	1	1
24.	Growth state	0	0	0	0	0
25.	R&D	0	0	1	0	1
26.	Govt. seen as cause	0	0	0	0	0
	Total	15	15	14	13	57

*Derived from Table 5-5.

In trying to discover the direction of relationships between attitudes toward the policy options and the characteristics of the firms, several hypotheses can be suggested. For instance, firms with energy officers who have technology or science backgrounds might be expected to find incentives for recycling attractive, while firms whose energy officers have backgrounds in business or finance might be more inclined to like favorable loan terms for energy-saving investments. Firms high in energy intensity might be expected to think deregulation of energy prices would be effective, but unattractive to the firm.

Looking at the four policy options which seemed most controversial (as indicated by the number of significant differences with respect to firm characteristics, Table 5-4), the predicted directions for relationships between attitudes toward these policies and the five factors singled out above (Table 5-7) appear in Table 5-8, along with the actual findings. For the first policy option--incentives for using recycled materials--for example, it seems reasonable to expect energy-intensive firms will find such a policy attractive and might consider that the policy would be effective as well. The relationship, however, is negative for effectiveness and attractiveness to industry in general, and not significant in terms of attractiveness to the specific firm. Perhaps energy-intensive industries are aware of complications in using recycled materials (and/or afraid of penalties for using virgin materials) that dampen their enthusiasm about such a policy.

While it is not clear a priori how the factor "energy officer is the firm's chief officer" (factor 6) would affect attitudes toward recycling incentives, we hypothesized that firms with this characteristic might tend to think that recycling would be attractive to industry in general, although

TABLE 5-8: Relationships Between Significant Factors and Policy Option Attitudes: Predicted and Found*

	Policy Would be:					
	Effective		Attractive:			
			To industry in general		To your own firm	
Policy Option and Factor	Predicted	Found	Predicted	Found	Predicted	Found
1. Recycling incentives						
Factor:						
6. Chief officer	?	n.s.	+	-	?	-
7. Technology/science	+	n.s.	+	n.s.	?	n.s.
8. Business/finance	?	n.s.	+	n.s.	+	n.s.
10. Energy intensity	+	-	+	-	+	n.s.
19. Information: other firms	+	-	?	-	?	-
2. Deregulating prices						
Factor:						
6. Chief officer	+	n.s.	-	+	-	+
7. Technology/science	?	n.s.	-	n.s.	?	+
8. Business/finance	+	+	-	n.s.	-	+
10. Energy intensity	+	n.s.	-	+	-	+
19. Information: other firms	+	n.s.	?	n.s.	?	n.s.
6. Favorable loan terms						
Factor:						
6. Chief officer	?	+	+	+	?	+
7. Technology/science	?	n.s.	+	n.s.	?	n.s.
8. Business/finance	+	n.s.	+	+	?	+
10. Energy intensity	+	n.s.	+	n.s.	+	+
19. Information: other firms	?	n.s.	+	n.s.	?	n.s.
10. Tax credits for energy management program						
Factor:						
6. Chief officer	+	n.s.	+	n.s.	+	n.s.
7. Technology/science	?	+	+	+	+	+
8. Business/finance	+	n.s.	+	+	+	+
10. Energy intensity	+	n.s.	+	n.s.	+	n.s.
19. Information: other firms	?	n.s.	+	-	?	-

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*Significant factors are drawn from Table 5-4 and the four most controversial policies are from Table 5-7. Direction of relationship is "+" if firms where the energy officer has the characteristic under factor (is chief officer, has a background in technology or science, or in business or finance) or where energy intensity is high, or information about energy is received from other firms (as opposed to is not), tend to view the policy option favorably in terms of its effectiveness or unattractiveness. A negative relation "-" associates these factors with anticipated ineffectiveness or unattractiveness of the policy. A question mark indicates the predicted direction is uncertain; n.s. means the factor was not significant for that aspect of the policy.

not necessarily to their own firm. There seems to be a negative relationship, however, between attractiveness of this policy and the energy officer as chief officer attribute. The predicted direction for this policy with respect to the factor "receives energy information from other firms" (factor 19) is also uncertain in terms of attractiveness, although we predicted that firms which receive energy information from other firms would be more likely to think recycling incentives effective than if they do not, assuming they would be made aware of recycling possibilities that are not open to their own firm. However, both effectiveness and attractiveness seem to be negatively related to this source of information, so perhaps the information received concerns problems with using recycled materials.

Policy option 2, deregulation of energy prices, seems a little more open to prediction. In general, the economic impact of deregulation--higher prices--should indicate that deregulation would be considered effective in conserving energy, especially for firms with business-oriented energy officers and for energy-intensive firms, but negatively associated with attractiveness. The findings, however, are mixed. A large proportion of the respondents (81 percent) think deregulation would be highly effective. However, although all the responses from firms where the chief officer is the energy officer said deregulation would be very effective, three-quarters of those with other energy officers also felt this way, and this factor (factor 6) was not significant. When it comes to attractiveness, all the firms with chief officers as energy officers again thought deregulation would be attractive, even for their own firms, while only about half felt this way if the energy officer was not head of the firm.

Predictably, firms having energy officers with business/finance backgrounds thought energy price deregulation would be effective (90 percent of them) in contrast to just over half of those whose energy officers do not have business backgrounds. However, the predicted direction for this group's attitude toward attractiveness for their own firms was in error: deregulation was also more attractive for firms where the energy officer has a background in business or finance, in spite of the likelihood of higher costs. The predictions for energy intensity and deregulation are also surprising when it comes to attractiveness; we found a positive relationship between energy intensity and attractiveness. Perhaps high-intensity firms are so concerned with assurance of energy supplies that deregulation of prices seems a lesser evil than regulation, with its danger of cutoffs of supply. Further research might shed more light on this question. Energy intensity was not a significant factor in relation to beliefs about the effectiveness of deregulation.

For policy option 6, favorable loan terms for energy-saving capital expenditures, the expected positive relationships between "attractiveness to industry in general" holds for firms with chief officers as energy officer and for firms with energy officers with business backgrounds. Both groups of firms find such an option attractive to their own firms as well, although we expected that differences among firms would make the predicted relationship uncertain. Energy intensity was not significant for effectiveness or attractiveness to industry in general for this policy, but, as expected, energy-intensive firms do find favorable loan terms attractive for themselves.

The last of the "controversial" policies, tax credits for energy management programs (policy option 10), shows firms where energy officers have backgrounds in technology or science find such a policy attractive for industry in general and for their firms in particular, both as predicted. Presumably their duties as energy officers as well as their backgrounds favor energy management programs, and their firms would be expected to find subsidies for such programs (in the form of tax credits) attractive. Energy officers with business backgrounds also respond favorably to the idea of such credits, as expected. Energy intensity is not a significant factor as far as this policy is concerned, while getting energy information from other firms seems to go with finding this policy unattractive. Again, it is not clear why this should be the direction of the relationship, and more probing research might disclose an explanation which the present data do not indicate.

Chapter 6. Analysis and Modeling of the Effects of Energy Policies on the Adoption Rates of Energy-Efficient Technologies

6.1 Introduction

Although the national energy plan proposed by the Carter Administration in 1977 addressed the immediate concerns of rapidly rising oil imports and growing natural gas shortages, it was actually designed to achieve both the short- and long-term goals of conserving existing energy resources and developing alternative energy sources. The plan relies principally on mechanisms that will balance energy prices and the social costs of energy (Economic Report of the President, 1978). This concern was epitomized in the debate on the deregulation of natural gas prices in Congress during the winter of 1977 and the spring of 1978. The Senate and House conferees finally agreed, in May, to deregulate these prices gradually so that newly-produced gas will be deregulated by 1985.

Economists generally believe that raising energy prices to reflect costs closely will discourage consumption. However, in the view of some, these prices should grow slowly over time in order to lessen the social costs which would accompany large, sudden increases. Another approach to encourage conservation* without producing significant social costs is to adopt energy conservation measures, in particular, for manufacturing firms to use energy-efficient technologies. The resulting savings in energy consumption implies a reduction in product cost which may be quite significant in terms of a firm's operation. The overall impact thus might be less inflationary. It is therefore important to identify and develop policies that could have a significant impact on the adoption of energy-efficient technologies.

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*Conservation in this study is defined as efficient use of energy in the production of manufacturing goods.

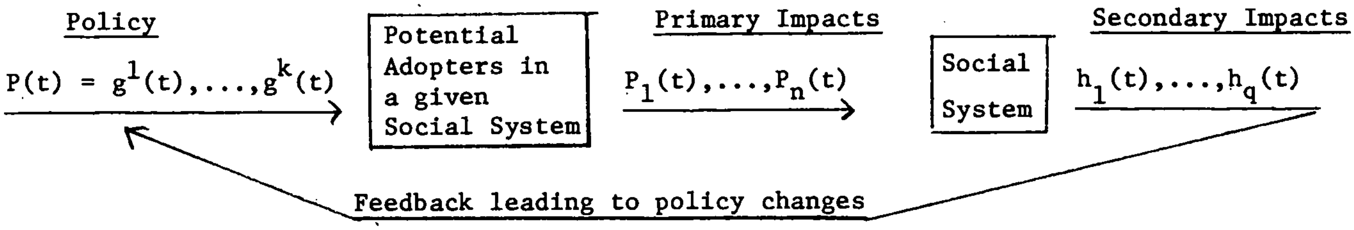
In this chapter, we will analyze the potential effects of the policy options discussed previously, and present a simulation model that could bring together adoption rates and the behavioral pattern (over time) of a given policy option.

6.2 Overview of a Policy Impact Analysis

As mentioned earlier, many economists view pricing as a key factor in energy consumption. Consequently, if a policy is instituted to increase the price of energy it is expected that energy consumption will be reduced. This is an example of a policy impact analysis.

In our context, effective policies are those which can induce significant changes in adoption rates. A policy impact model can be formulated to show changes in adoption rates as the primary impacts, with side effects from these changes in adoption rate as secondary impacts such as decreases in production cost. Since each policy option may include several parameters or components influencing adoption rates, a schematic representation of such a model can be illustrated as in Figure 6-1.

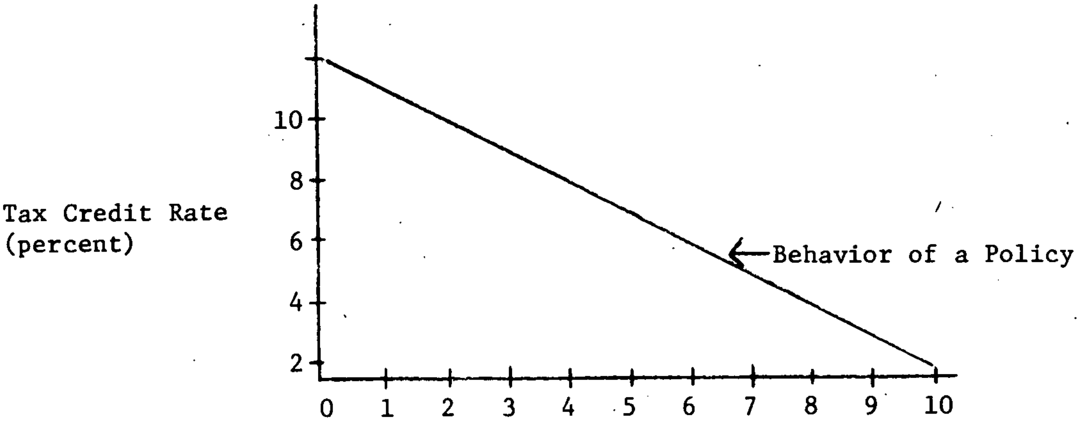
FIGURE 6-1: A Policy Impact Model



Here $P(t)$ denotes adoption probabilities at time (t); $g^1(t),\ldots, g^k(t)$ indicates that there are k influencing factors which constitute a given policy; $P_1(t),\ldots,P_n(t)$ denote adoption probabilities of n sites at time (t); and $h_1(t),\ldots,h_q(t)$ denote q secondary impacts, such as increases in employment related to energy conservation at the n sites, resulting from changes in the adoption rates.

We have also included a time (t) factor in the model to show that a policy may have to be changed or terminated after a period of time. This time factor may also govern the behavior of a given policy option. For instance we may specify a policy as: the initial rate for tax credits is 10 percent, but the rate will decrease 1 percent every year for the next 10 years. This is a decreasing function that can be graphed as follows:

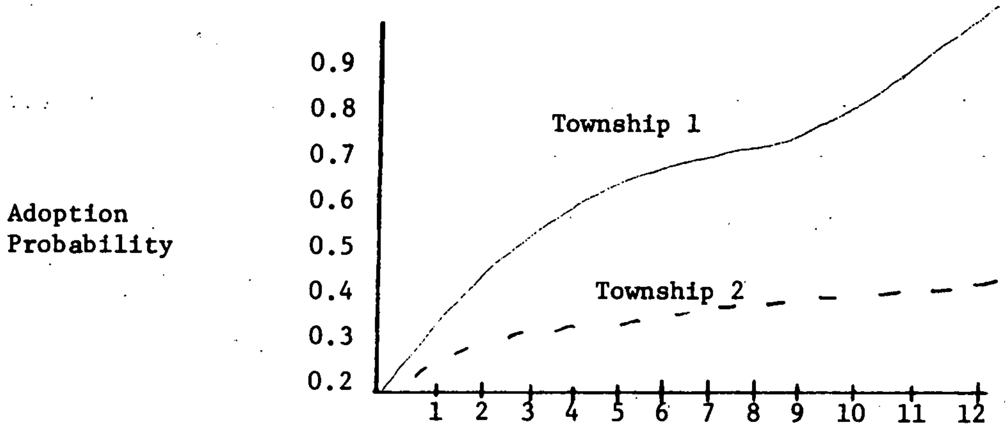
FIGURE 6-2: A Possible Policy Behavior Over Time



If we relate the behavior pattern of Figure 6-2 back to Figure 6-1, the policy impact model, we obtain a dynamic diffusion model, indicating that changes can occur in both policy behavior and adoption rates. For instance, we define adoption probability as the number of firms in a given area, such as a township, that have adopted a specific technology divided by the total number of firms in that township. Then P(1) denotes the adoption rate for township 1 and P(2) the adoption rate of township 2.

Assuming that the firms in township 1 accept an incentive policy, and firms in township 2 reject the offer from the government, after 10 years the adoption rates in townships 1 and 2 may look like the following graph:

FIGURE 6-3: Dynamics of the Adoption Rate



In Figure 6-3, the solid line indicates an increasing trend of adoption of the specific technology, whereas the dotted line shows little change in adoption rate over time.

In the next two sections we will first examine the static aspects of the policy impact analysis using the survey data, and then present a computer simulation to show the dynamics of the diffusion model in the context of policy analysis.

6.3 Relationships Between Policy Attitudes and Technology Adoption Rates

The effect of a policy is generally analyzed by observing the impact of that policy after it is instituted. Since the energy policy options examined in Chapter 5 are proposed rather than instituted, we have not been able to conduct an actual policy impact analysis. However, we are able to assess the potential effect of these policy options by relating the attitudes of the industrial firms toward these policy options to their technology adoption rates. In other words, these data sets can be used to determine whether or not the firm's perception of policy options has any effect on the firm's behavior regarding the adoption of new technologies. The investigation is carried out in the same discriminant analysis framework, using the three adoption rates as dependent variables--recent, total, and combination, and the twelve policy options, each with three responses--effectiveness, attractiveness for industry, attractiveness to the firm--as independent variables. There are thus 36 sets of tests, listed in Appendix 8.

Each of the 36 sets includes three separate tests, one for each of the three adoption rates. Where the tests yield significant results, we can say that these particular policy options might have an effect on actual adoption rates. This information can then be used to pursue the enactment of these policies with more confidence that they will indeed affect the adoption of energy-efficient technologies. These policy options may not be the most popular ones as perceived by industry, but they may be the most effective in spite of--or perhaps because of--that.

The tests which indicate significant differences, taken from Appendix 8, are listed in Table 6-1. From the list we see that high adoption rates are associated with policy options 3, a federal tax on energy prices, 4, incentives for off-peak use, tax credits for energy saving capital expenditures and for energy management programs (8 and 10), and the two R&D options (11 and 12). These can be considered potentially effective policies if one is willing to assume that policies viewed favorably by firms with high adoption rates are likely to provide successful incentives for future adoptions. All the significant results in the table refer to responses based on attractiveness to industry in general or to the particular firm; considerations of effectiveness of the policies are not significantly associated with any policy option. It may be that effectiveness in general is not closely related to the operation of the firm but may reflect only the personal opinion of the person being interviewed.

TABLE 6-1: Policy Options with Statistically Significant Relationships to Adoption Rates*

Policy Option and Response		Adoption Rate and Probability Level			
C3:	Federal tax on energy prices--attractiveness to the firm	C3:			
		Post-1973:	0.01		
		Total:	0.07		
		Combined:	0.05		
B4&C4:	Incentives for off-peak use--attractiveness to industry in general; attractiveness to firm	B4:		C4:	
		Post-1973:	0.02	Post-1973:	0.01
		Total:	0.17	Total:	0.27
		Combined:	0.06	Combined:	0.01
B8&C8:	Tax credits for energy-saving capital expenditures--attractiveness to industry in general: attractiveness to firm	B8:		C8:	
		Post-1973:	0.05	Post-1973:	0.04
		Total:	0.04	Total:	0.08
		Combined:	0.11	Combined:	0.13
B10:	Tax credits for energy management programs--attractiveness to industry in general	B10:			
		Post-1973:	0.16		
		Total:	0.04		
		Combined:	0.12		
B11&C11:	Energy-saving R&D by federal government--attractiveness to industry in general; attractiveness to firm	B11:		C11:	
		Post-1973:	0.02	Post-1973:	0.02
		Total:	0.006	Total:	0.006
		Combined:	0.02	Combined:	0.02
B12&C12:	Private R&D, federally subsidized--attractiveness to industry in general; attractiveness to firm	B12:		C12:	
		Post-1973:	0.17	Post-1973:	0.09
		Total:	0.03	Total:	0.05
		Combined:	0.11	Combined:	0.15

*Derived from Appendix 8.

Looking at Appendix 8 again, we can also attempt to rank the policy options in terms of their potential effects on adoption rates by examining the frequency of significant differences and the probability levels. Table 6-2 summarizes the results, confirming that the policy options concerning technology development and some of those affecting energy consumption rank highest. The least effective ones are those related to energy regulation or deregulation and loan guarantees. This finding may be surprising in the sense that some government officials might think that a federally-mandated energy allocation policy is effective, and, on the other side, industry aften claims that deregulation of energy prices will definitely provide enough economic incentive for adopting more energy-efficient technologies. However, these views do not show up in the analysis. This may be because the statistical tests are based on perceptual data rather than "real" data, since none of these policies had been implemented yet. Further investigation using a large sample may be needed to clarify the questions.

Energy issues are indeed complex and controversial, as witness the debates among members of the Senate and House of Representatives. The complexity and controversiality also show up in our interviews. To summarize this point, Columns A, B, and C of Table 6-3 give the rankings of the three different aspects of each of the policies we have investigated: its popularity, its relationship to adoption rates, and the consistency or inconsistency among the firms' responses to it. These rankings, developed in Chapter 5 and Table 6-2, vary noticeably for many of the policies, as can be seen in Table 6-3. For example, policy 2, deregulation of energy prices, ranks high in popularity but low in association with adoption rates and consistency. On the other hand, incentives for off-peak use, policy 4, are unpopular but rank high in consistency and association with high adoption rates.

TABLE 6-2: Rank of Policy Options by Frequency of Significant Associations with Technology Adoption Rates*

Rank	Policy Option	Frequency of Significant tests (out of possible 36)
1	#11 - Federal R&D	6
2	# 4 - Incentives for off-peak use	3
2	# 8 - Tax credits for energy-saving capital exp.	3
3	# 3 - Federal tax on energy prices	2
3	#12 - Private R&D	2
4	#10 - Tax credits for energy mgmt. program	1
5	# 9 - Government-sponsored consulting services	0 (1 at 0.10 level
6	# 6 - Favorable loan terms for energy capital exp.	0 (1 at 0.11 level
7	# 1 - Incentives for use of recycled materials	0
7	# 2 - Deregulation of energy prices	0
7	# 5 - Federally mandated allocation of energy	0
7	# 7 - Federal loan guarantees for energy capital exp.	0

Source: Appendix 8.

*Probability of 5 percent or less.

We can go one step further to derive a composite index, using the sum of the three ranks, as shown in Column D. Ranking this sum, as in Column E, we have derived a ranking for "promising policy options." In some sense that last column is a compromise solution to the conflicting facets of reactions to the policy options. From this limited study, then, we can conclude that the five most promising policies are: tax credits for energy-saving capital expenditures, private (subsidized) and federal R&D, incentives for off-peak use, and government-sponsored consulting services. Federally-guaranteed loans and favorable loan terms for energy-saving capital investments follow closely.

Since the first four most "promising policies" are consistent with high rankings of "potential effect on the adoption rate" (shown in Column B), we can conclude that future policies for generating more use of energy-efficient technologies seem to lie in the areas of R&D efforts, in encouraging the installation of the developed technologies by means of tax credit incentives, and in providing incentives for off-peak energy use. This finding is consistent with the field interviews.

6.4 Computer Simulation of Policy Impact Analysis

We will discuss the computerized method of policy impact analysis in two sections: (1) the theoretical concept and model, and (2) a simulation model. It should be kept in mind that the material discussed earlier, potentially effective policy options, can be used as guidelines for the formulation of this computerized model.

A. The Theoretical Model

(1) Overview

Our approach to modeling the dynamics of the spatial diffusion of adoption probabilities over time assumes that the change (through time) in the probability of adoption at a given site, as explained earlier in Figure 6-3, is determined by the existing probability of adoption at neighboring sites and by certain influencing factors (see also Figure 6-1), in effect at the site of interest.

TABLE 6-3: Different Aspects of Policy Options--Ranks and Rank of Sum*

	A	B	C	D	E
Policy Option	Popularity ranking	Effect on adoption rate ranking	Consistency Ranking	A+B+C	Rank of Sum
# 1 - Use of recycled materials	9	10.5	11.5	31	10
# 2 - Deregulation of energy prices	2.5	10.5	11.5	24.5	8
# 3 - Federal tax on energy prices	12	4.5	8	24.5	8
# 4 - Incentives for off-peak use	10	2.5	2	14.5	3
# 5 - Federally mandated allocations	11	10.5	4.5	26	9
# 6 - Favorable loan terms for energy-saving capital expenditure	2.5	8	9	19.5	6
# 7 - Federal loan guarantees for energy-saving capital expenditure	4	10.5	4.5	19	5
# 8 - Tax credits for energy-saving capital expenditures	1 (most popular)	2.5	6.5	10	1 (best compromise)
# 9 - Government-sponsored consulting services	8	7	3	18	4
#10 - Tax credits for energy management programs	5.5	6	10	21.5	7
#11 - Federal R&D	7	1 (most effective)	6.5	14.5	3
#12 - Private R&D, federally subsidized	5.5	4.5	1 (least controversial)	11	2
	78	78	78	234	

*Sources (Ranks changed to fractions so that column sums are equal)

Column A: Table 5-4.
Column B: Table 6-2.
Column C: Table 5-6.
Column D: Composite index--sum of columns A, B, and C.
Column E: Rank of composite index.

$$\frac{dP_i}{dt}(t) = F\left[a_i, P_1(t), \ldots, P_n(t),\ g^1(t), \ldots, g^k(t)\right]$$

$$P_i(0) = P_i(0),\ i = 1,2,\ldots,n \qquad (1)$$

when: $P_1,\ldots,P_n$ are the adoption probabilities at the n sites;

$g^1,\ldots,g^k$ are k influencing factors, and

a is a parameter vector characterizing the i^{th} site.

In this context, a policy consists of the k policy instruments, i.e., the influencing factors $g^1,\ldots,g^k$. In fact Equation (1) is only a mathematical expression of Figure 6-1.

The adoption probabilities are considered as primary impact measures from the viewpoint of policy impact studies and optimal policy determination. These considerations are elaborated below.

(2) System Identification

The model given by (1) completely determines the diffusion process when the function F and the n parameter vectors $\bar{a}_1$, $\bar{a}_2,\ldots,\bar{a}_n$ are specified. With the form of F fixed, the parameter values which yield a specific model representing the measured diffusion process are obtained by using data consisting of the n sets of adoption probability values $\left[P_i(t)\right]$, the trajectories, and the k influence functions $\left[g^j(t)\right]$ over a given period of time. The values of the n parameter vectors $\bar{a}_1,\ldots,\bar{a}_n$ are chosen to be those which best approximate the data. Thus the data-based approach to identifying the specific system model is to estimate the values of the parameters $\bar{a}_i$ according to given criteria for measuring the accuracy of the estimated values.*

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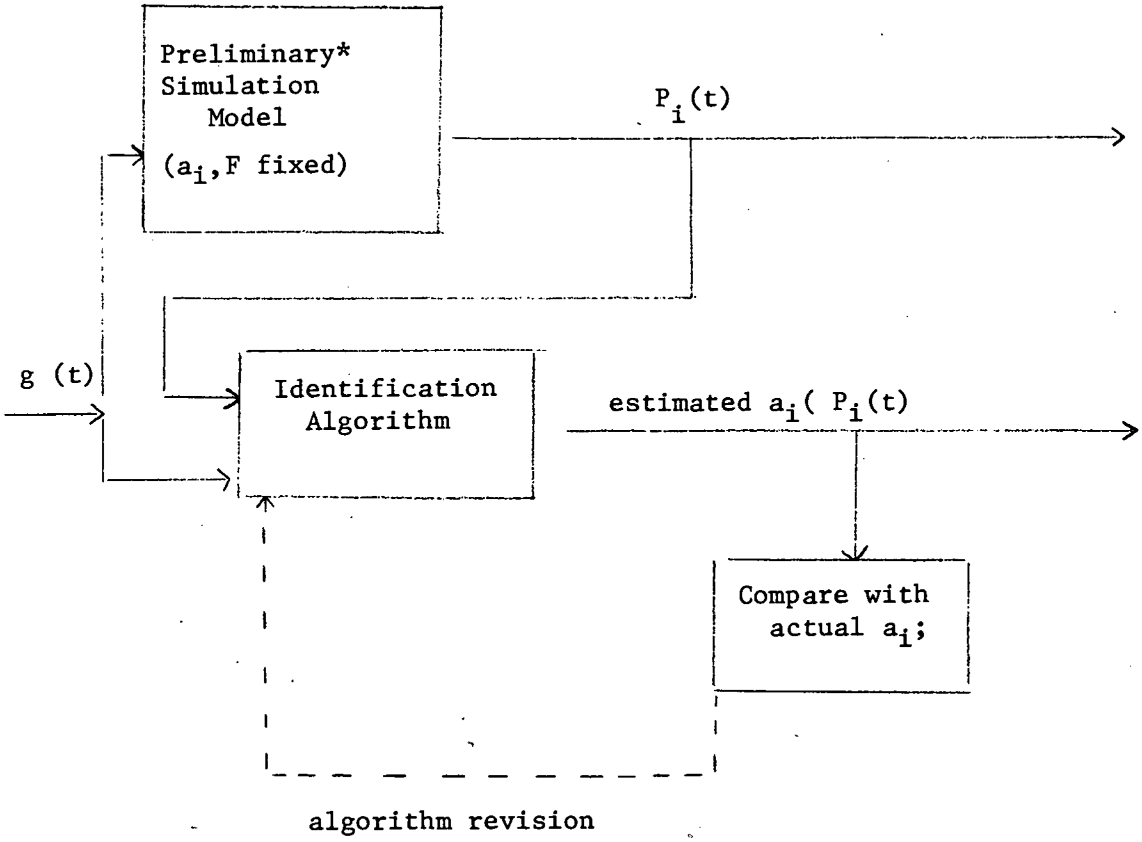
*We will assume that the $P_i(t)$ can be measured with sufficient accuracy so that the problem of state estimation does not arise here (Graupe, Sage & Melsa).

To estimate the values of the parameters $\bar{a}_i$ in the model (1), the function F must be specified, and the trajectories corresponding to a given policy $P(t) = [g^1(t),\ldots,g^k(t)]$ must be available.(Some of the forms approximating the real-world situation are given in Figure 6-7.) In addition, a specific criterion for measuring the error in the parameter approximation must be specified. Finally, since the data will not be available continuously in time, sampled values of the $P_i(t)$ and $g^j(t)$ must be used. Thus, the sampling period must either be chosen where possible, or, if fixed, must be accounted for, in a manner which will maximize the accuracy of the estimated parameter values.

Since we do not have such real-world data for performing our system identification, we have developed a simulation to observe the behavior of the parameters in the context of experiments. The purpose of these experiments will be to explore convergence behavior and the sensitivity and accuracy of parameter estimates for assumed forms of F, size of parameter vector a_i, sampling frequency, and trajectory length (time duration of samples). The simulation will be performed by integrating the system of n-coupled first order differential equations under conditions corresponding to the assumptions. The Runge-Katta method will be utilized to perform the integration.

A schematic representation of the identification experiments, using simulated data to refine, or tune, the identification methodology as described here, is illustrated in Figure 6-4.

FIGURE 6-4



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*"Preliminary" as used here, refers to the system (1) where parameter values are not necessarily those ultimately determined by the identification analysis using measured data. When the latter are used, the corresponding computer-implemented model is called the <u>dynamic simulation model</u>.

(3) Application of the Dynamic Model to Track the Diffusion of New Technologies

Having "tuned" the identification methodology using simulated data as described earlier, we can then perform the identification of the system modeled, provided that appropriate data are available.

These measurements will include sampled values of the adoption probabilities $\left[P_i(t)\right]$ and the influencing factors $\left[g^j(t)\right]$. The sampling period and the length of the time interval will be specified on the basis of the simulation experiments and/or a pilot study.

The parameter estimates obtained here will yield a dynamic simulation model that can be used for the quantitative study of policy impacts. This is a step toward the development of a practical quantitative tool for the determination of optimal policy, within the limitations of this model.

(4) Quantitative Policy Input Analysis

To perform quantitative policy impact studies, we will consider each of the components of benefits and costs to be <u>secondary impact measures</u>, i.e., effects which are results of the primary impact measures--the adoption probabilities, P_i. Denoting the secondary impact measures as $h_1, h_2, \ldots, h_q$ (assume there are q of them), the dependence of the secondary impact measures on the adoption probabilities will be accounted for by the q functions $h_1(P_1, \ldots, P_n)$, $\ldots, h_q(P_1, \ldots, P_n)$. Thus, with the q <u>secondary impact functions</u> known, a quantitative study of the impact of policy $P(t) = \left[g^1(t), \ldots, g^k(t)\right]$ can be obtained using the dynamic simulation model as described next.

In this attempt, we will use the dynamic simulation model discussed earlier to assess quantitatively the impact of assumed policies. The quantitative aspects of the policy impact study to be performed here will be obtained by determining the effect of a given policy expressed through the policy instruments--

the influence factors $g^1(t),\ldots,g^k(t)$--on the behavior of the secondary impact measures, $h_1(t),\ldots,h_q(t)$. The effect of a given policy will be obtained via the dynamic simulation model; schematically, this process was illustrated earlier, in Figure 6-2.

The problem of optimal policy determination for a dynamic diffusion process quantitatively modeled by the system(1), and implemented in the dynamic simulation model, is defined as follows: We assume an <u>objective</u>, or criterion function G which measures the return or cost of a policy $P(t) = g^1(t),\ldots,g^k(t)$. That is,

$$G\left[P_i(t)\right], \quad \left[g^j(t), t\right]$$

is maximized or minimized, depending upon its interpretation as a return or a cost. (We assume a single decision maker context here.) Letting F represent the set of feasible policies, the problem can be stated as: maximize (or minimize) $G\left[(P_i), (g^j), t\right]$ over all $(g^1,\ldots,g^k)$ in F where (P_i) are solutions to the system (1). This is an optimal control problem (Tabak & Kuo) in the policy $P = (g^1, g^2,\ldots,g^k)$.

Solution methods to be used will include the computational methods of mathematical programming (Tabak & Kuo, Cannon, Cornacchio & Ittig).

As an aid for policy analysts, we will develop a prototype interactive computer graphics capability, designed around the dynamic simulation model and the results of this section. This will allow the user to explore quantitatively, and with immediate response, the effect of various policy options, including constraints and desired objectives. This is presented in Appendix 2.

B. A Simulation for the Policy Impact Analysis

(1) Overview

This program, "ENERGY", is a policy impact simulation which is designed to help energy policy-makers assess the impact of certain quantifiable policies on the adoption rates of energy-efficient technologies by industrial firms. Since the program is an APL language, the user can interact with the computer in seeing the behavior of the technology adoption rates (over time) graphically, by changing the policy options and policy patterns over time.

(2) The Simulation

This dynamic diffusion simulation consists of one main routine called ENERGY with three sub-routines: INITIAL, RUNGE, and PRINT. The sub-routines will be automatically activated in sequence without calling statements. The structure of the program is diagramed in the following pages (Figure 6-5).

While the first level structure indicates the main routine, the second level structure shows the user options of the sub-routines, INITIAL and PRINT. The RUNGE sub-routine is the main computing program for the adoption probabilities.

In using the program, users are first led to make a decision whether or not to use existing coefficients of mutual influence among the industrial firms (sites) being studied. The coefficients will be entered as a row whose elements equal the number of sites. For instance, we might have four sites, whose coefficients are: 0,2,1,0, or

	site 1	site 2	site 3	site 4
Site 1	0	2	1	0

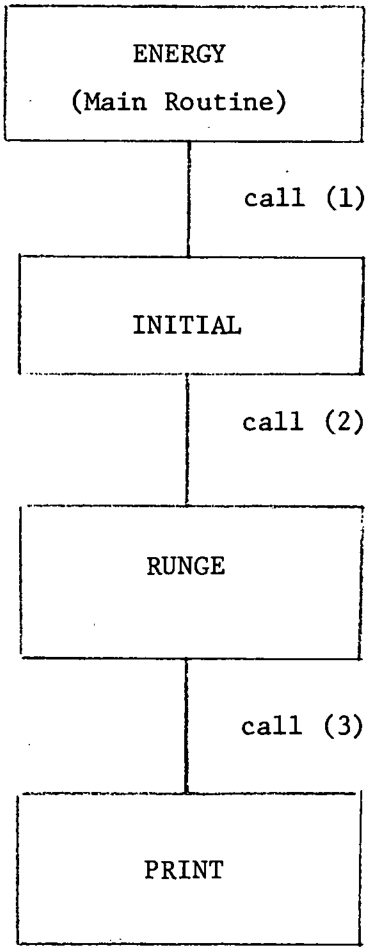
The vector (0 2 1 0) means that the magnitude of the influence on site one, from site one through site four are 0, 2, 1, 0, respectively. Here "0" means "the influence on itself is zero; "2" means the influence of site two on site one is 2 times the adoption probability of site two, etc. These coefficients can be viewed as the <u>magnitude</u> of the interaction among the sites. They may be estimated by using some procedure like a "gravity model"; that is,

$$\text{coefficient} = \text{constant}\frac{(\text{firm}_1\text{size})\ (\text{firm}_2\text{size})}{(\text{distance})^2}$$

However, the appropriateness of this gravity model has to be tested using real-world data.

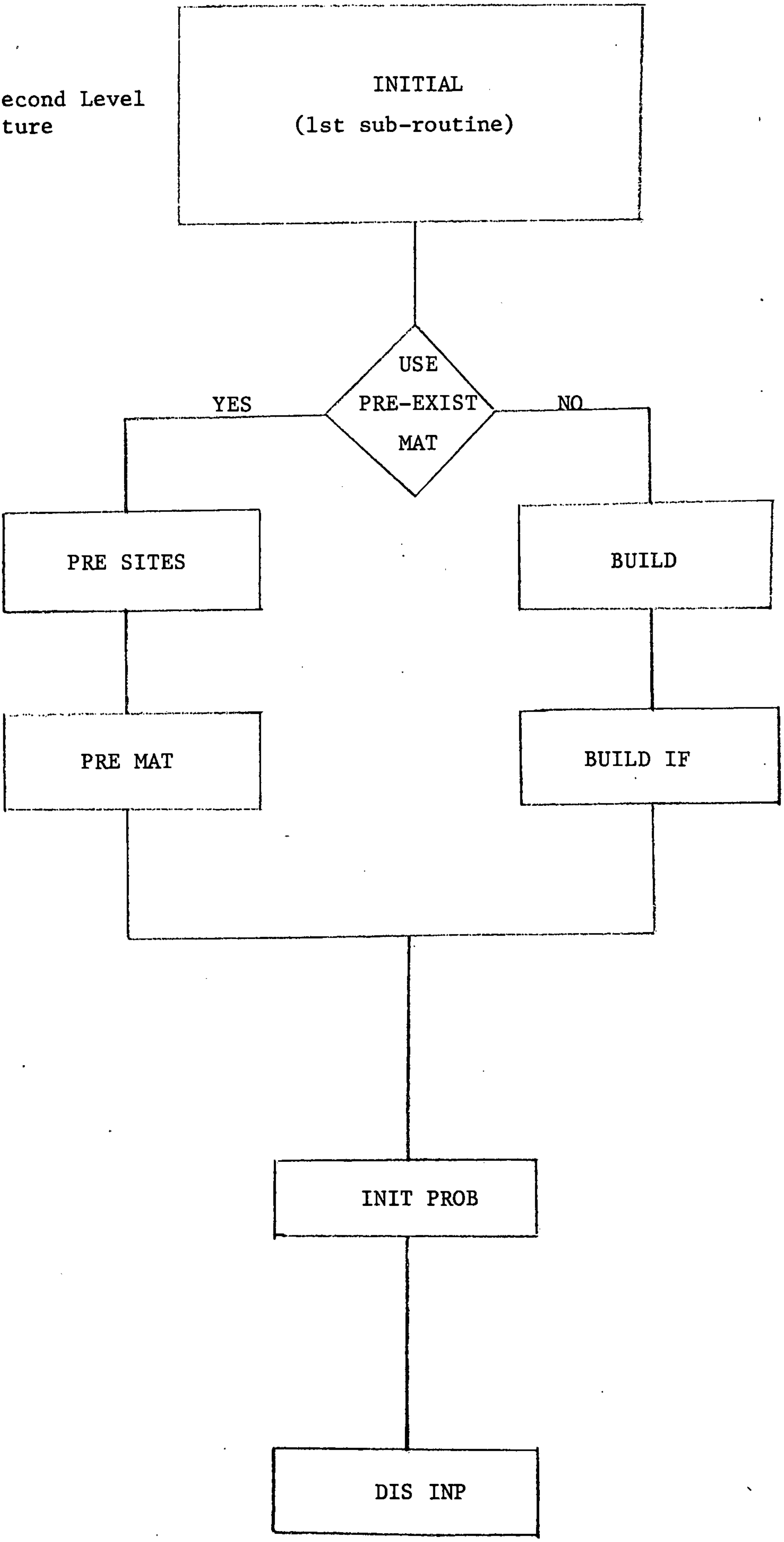
FIGURE 6-5. The Program Structure of the Dynamic Diffusion Model

A. The First Level Structure

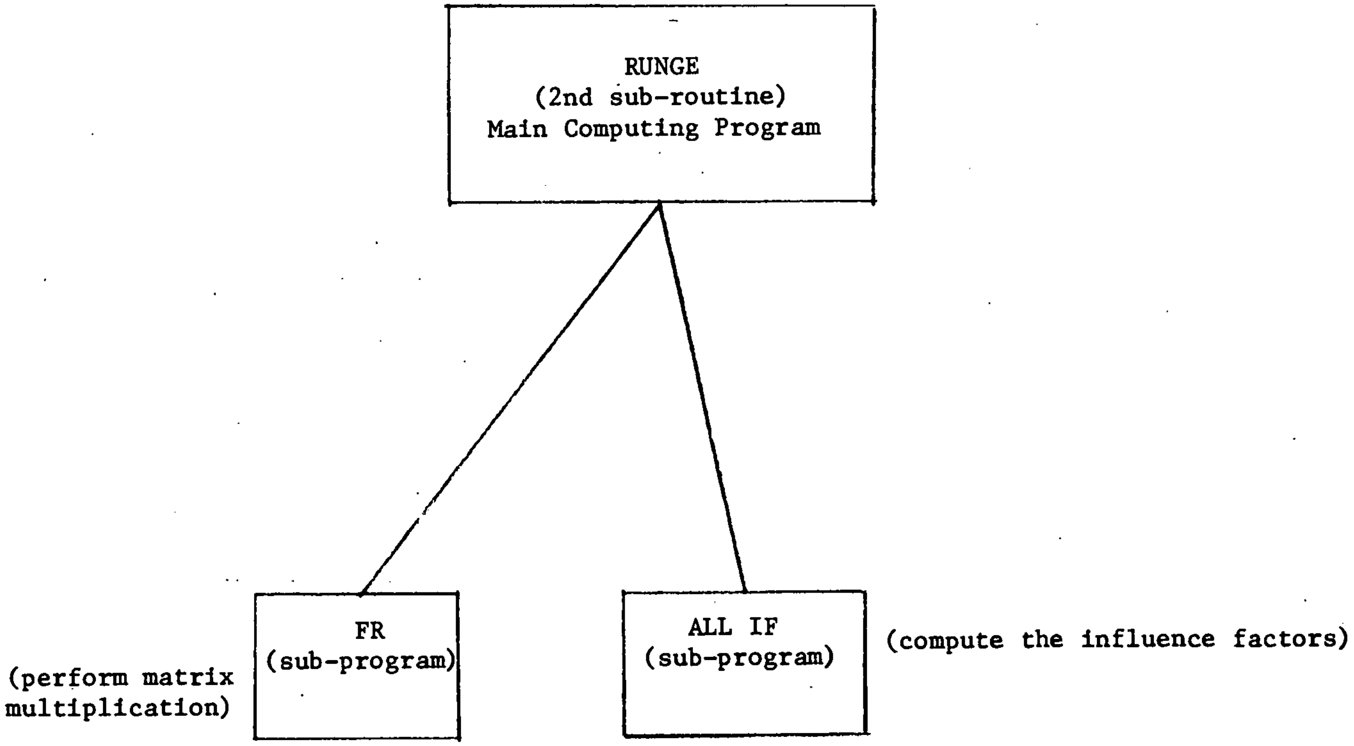


B. The Second Level Structure

B.1



B.2


RUNGE
(2nd sub-routine)
Main Computing Program
FR
(sub-program)
(perform matrix multiplication)
ALL IF
(sub-program)
(compute the influence factors)

After the user enters all the coefficients, he is to enter the type of function and two associated parameters (a and b) for the policy options specified in the simulator. Three types of policy functions can be employed by the user, for each site, as follows (Figure 6-6).

Type 1 can be interpreted as: "the government's investments in energy incentives first increase with time," (say, for the first 5 years), "and then decrease with time," say, for the next 5 years.

Type 2 can be interpreted as: "the incentive will decrease with time." Examples might be tax credits for home insulation, or for the adoption of solar energy technologies.

Type 3 can be interpreted as: "the incentive will increase with time," for example, the budget allocation in the government's R&D effort.

The next step is to enter the initial adoption probability value for each (sample) site. These values should be determined by field investigation. For instance, if one finds out that site one has adopted only one energy efficient technology out of 10 applicable devices, the probability value is 0.1. Other methods can be used to determine the initial probability value. For instance, the investigator may, instead, use a grid system or political unit to define a study area,and call it a "site." The adoption probability is then computed by dividing the number of forms that have adopted innovations by the total number of firms in the given area.

After this step, the RUNGE sub-program takes over the computation of adoption probability values with the coupling coefficients estimated earlier and influencing factors (policy options) specified.

In fact, there is a class of methods under the name Runge-Kutta algorithms for solving either a single or a system of differential equations.* In

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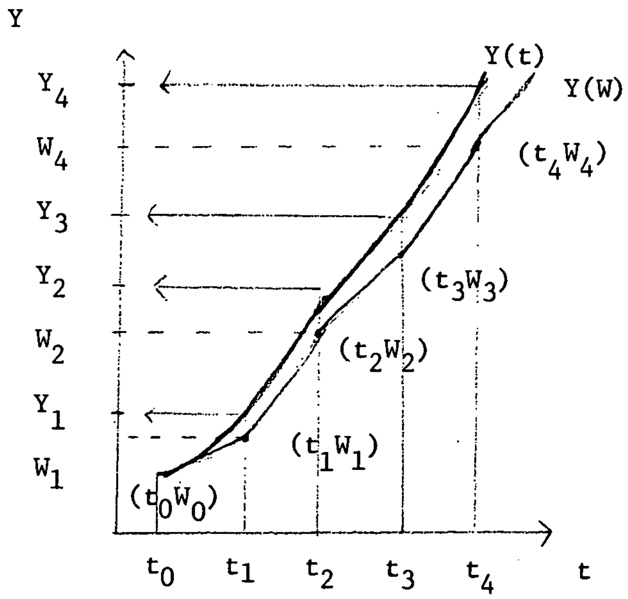
*For further explanation of Runge-Kutta methods, see Burden, et al Numerical Analysis (Boston: Prindle, Weke & Schmidt, 1978).

simple terms, the Runge-Kutta methods use a successive approximation technique to reach the finally value (estimation), which, in our case, is adoption probability at a given time period. Of course, there will be a difference between the real and estimated value, and this difference is called the error term. These various Runge-Kutta methods are particularly developed for reducing the error term at each step of estimation.

Let us use a simple graph to illustrate the idea of successive approximation using Figure 6-6.

FIGURE 6-6. Basic Model Runge-Kutta Methods



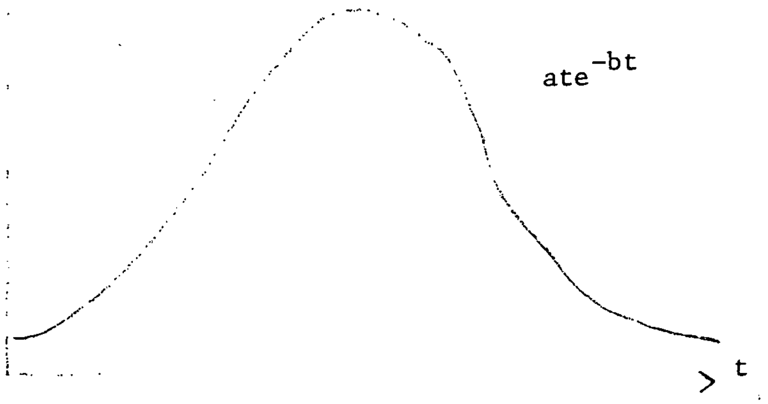
In Figure 6-6, Y(t) is the true curve, whereas, Y(W) is an estimated "curve" (connected usually by a series of straight lines). Then projected from the t-axis, we have several pairs of values corresponding to the time intervals $(t_0, t_1, \ldots)$. The error terms are the difference between each pair, such as $e_{t_1} = (Y_1 - W_1)$, $e_{t_2} = (Y_2 - W_2)$, and so on. Runge-Kutta methods are developed to approximate the curve Y(t), by the "curve" Y(W), such that the error term can be minimized.

In our study, the Runge subroutine is programmed to solve a system of differential equation, instead of a single equation as illustrated in Figure 6-6. However, the concept of using a successive approximation method for achieving the final solution remains the same.

The Runge sub-program will then yield computed adoption probability values for each site over a time period in both numerical and graphic forms under a set of specified coupling coefficients, and a certain policy trajectory form adopted by each site. Figure 6-7 illustrates several possible trajectory forms.

FIGURE 6-7: Types of Functions for Policy Options

Type 1



Type 2

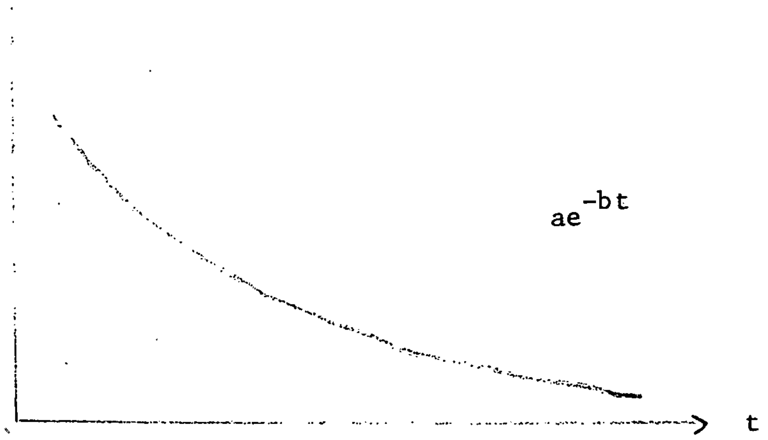
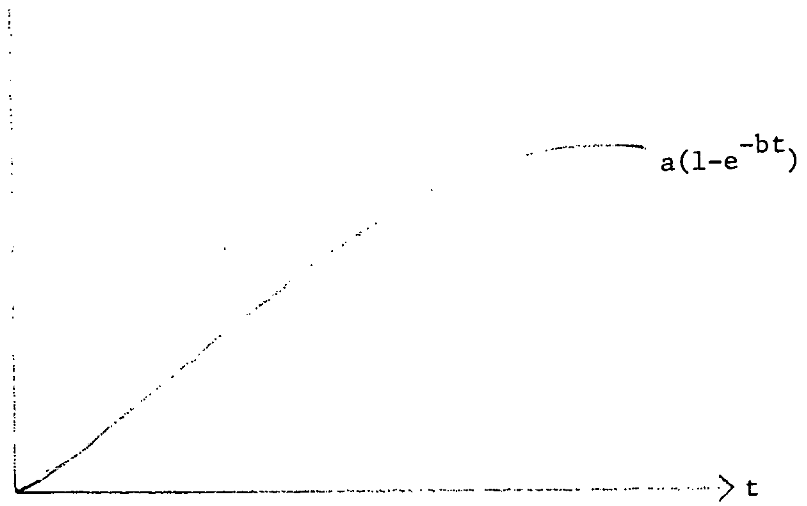


FIGURE 6-7: Continued

Type 3



6.5 Integration of Potentially Effective Policies and the Simulator

As one can notice from the simulation, the model specifies only the functional forms of the policy instruments. That is, they are either a decreasing function, an increasing function, or a bell-shaped function in the dimension of time. The socio-economic meanings of the policy options are not defined. Thus, to have a substantial influence we have to select the most effective policy options first, and then assess their impacts according to functional forms specified by the analyst. Therefore, an integrated approach, using empirical data as well as simulation models, is required to achieve the maximum usage of this policy simulator.

Another approach to assessing the influence of given policy options is to observe their impacts (from real-world data) over time, and compare them to the simulated results. The policy options that produce results closest to the simulated figures should be the most effective ones, since ineffective policy options will not create significant changes in the adoption rates over time.

If we bear these points in mind, it is believed that the model will help the policy maker devise policies which will be effective in coping with the rapidly changing energy problems which we expect to face in the next decades.

CHAPTER 7. SUMMARY AND PERSPECTIVE

A. The Specific Research Problems

It has been estimated that the industrial sector of the American economy absorbs about 40 percent of all fuel and electricity (7.24 million barrels/day) consumed in the United States. A fairly large portion of the fuel comes from the OPEC countries since, as a whole, the United States is importing more than 8.6 million barrels a day, which accounts for 47.5 percent of total domestic oil consumption. The problem of energy shortages has become more complicated because imports of foreign oil have increased at an average rate of 15 percent a year between 1970 and 1977, contrarily to a declining pattern of 2.2 to 3.1 percent experienced by Japan, France, and West Germany (Economic Report of the President, p. 187, 1978). Yet as early as 1973 and 1974, it was estimated in separate studies by the National Bureau of Standards and by the largest 100 firms in the U.S. that 25-30 percent of industrial energy (1.81-2.17 million barrels/day) could be saved by the adoption of simple conservation measures and energy-efficient technologies by industrial firms. The failure in the United States cannot really be explained totally on technological and economic grounds. That is, for meaningful answers, we have to look at other factors such as political, institutional, and even human inertia.

Since 1974, many studies on energy conservation opportunities have been conducted by the federal government and by private industrial corporations; and they confirm again the basic findings of the 1973-75 estimate. Moreover, the literature on energy conservation technologies is fairly complete. (Bibliography of Relevant Literature, Industrial Application Study Volume V, Energy Conservation, by Harry Brown, B. Hamel contract with Division of Conservation Research and Technology, ERDA, 1976.)

These studies tell us one basic fact: for energy conservation efforts, we have technologically reliable and economically justifiable devices and systems available today. For instance, waste-heat recovery technologies with their payback periods were well documented in a five-volume study by H. Brown and B. Hamel (1976-77), and technologies applicable to paper and pulp industries were also examined with cost-benefit analysis. Yet one basic problem remains: the adoption of these technologies has been very slow; our industrial firms still face continued threats of energy shortages, one winter after another.

It is therefore clear that to solve our industrial energy conservation problem, efforts should be directed toward developing a more comprehensive system to encourage adoption of developed and to-be-developed energy-efficient technologies. However, to achieve this goal requires first, a detailed field investigation regarding the existing conditions of firms and their attitudes toward energy technologies, and then, careful planning of energy policies to foster a more rapid adoption rate.

For this purpose, this study was sponsored by the Department of Energy and carried out by Professor Shin-yi Hsu and his colleagues at the State University of New York at Binghamton from January 1977 to May 1978, to answer the following questions:

(1) What is the current level of adoption of simple conservation measures and energy-efficient technologies?

(2) Which are the "innovative" firms or the early adopters of energy-efficient technologies, with what characteristics useful for identifying others like them?

(3) Which energy policy options are the most preferred? What factors contribute to significant differences in response?

(4) What are the most effective and workable policy options government can use to encourage more adoptions of energy-efficient technologies?

(5) Finally, how do we measure the effect of the policies, and design an optimal policy?

These research questions are formulated in accord with a comprehensive, conceptual model of the diffusion of energy-efficient technologies, with a range of policies serving as the facilitators for achieving a rapid and higher adoption rate.

The random sample included 32 industrial firms, half in Binghamton, New York--representing the Northeastern United States norm in terms of a declining trend of industrial employment--and half in Allentown, Pennsylvania--representing the United States norm of slightly increasing employment. The research findings are derived from two integrated approaches: (1) statistical procedures to maintain objectivity of the analysis, and (2) personal interviews (with notes and tapes) to substantiate the interpretation of the numerical facts and results.

B. The Conceptual Framework of the Project

The process of adoption/commercialization of energy-efficient technologies is fairly analogous to the diffusion of new ideas, culture traits, etc. Researchers in the diffusion of innovations have discovered that, in general, there is a set of processes operating in the system which will advance adoptions gradually through time and over space.

First of all, innovations start with origination of ideas; and let us call this stage 1. Following that come research, development and demonstration, or stage 2. Once some people are aware of the existence of the innovations, they may start to adopt them; and they are called the early adopters (stage 3). By natural stimulation and further demonstration of the projects, the adopters will increase in number through time and over space (stage 4). If the project is successful, the majority of potential adopters will eventually adopt these innovations.

The rate of adoption can be influenced by public policies. With energy-efficient technologies, for instance, the federal government may want to institute a tax-credit program to encourage the adoption of solar technologies by more people.

Using this conceptual framework of innovative processes, we have constructed a model to carry out the research project. It is a sort of systems approach indicating the "flow" of adopters under the influence of natural stimulation and of public policies, which will in turn be influenced by the pattern of adoption. For instance, we may want to change the original policy if the adoption rate seems too slow for the projected goal. Thus, for the system to perform well, there should be a monitoring mechanism to observe the rate of adoption constantly. This system is essential to the management of energy information dissemination systems, consumer responses, policy formulation, and policy changes.

C. Research Findings

1. The current adoption rate of both simple conservation measures and energy efficient technologies.

The efficient use of energy can be achieved by two types of procedures: (1) adoption of simple energy conservation practices, such as insulation, repair of leaks, setting back thermostats, reducing lighting, sometimes called "good housekeeping" or minor equipment modification; and (2) adoption of energy-efficient technologies, such as heat pumps, waste heat recovery devices to eliminate waste and increase productivity, etc., referred to as major process changes.

To determine the current adoption rate of the minor (equipment modification) measures, we used 63 items selected from the NBS EPIC program Handbook 115. From our field survey data, we found that 80 to 85 percent of these items have been adopted by the industrial firms, resulting in substantial savings in space heating and cooling.

With respect to the major process changes we selected ten energy-saving devices (Appendix 10) as the basis for determining adoption rates. Any newly-adopted technologies reported by the firms but not in our list are also incorporated in the analysis.

Since our field work revealed that the 1973 oil embargo had a significant impact on the adoption rate, we used two measurements for the analysis: measurement 1 is the post-1973 adoption rate, and measurement 2 is the total adoption rate--a sum of the post-1973 and pre-1973 adoptions, divided by the total applicable technologies.

Using the Binghamton area against the Allentown area for a regional comparison, we have the following statistics:

TABLE 7-1: The Technology Adoption Rate Survey

Area:	Binghamton Area	Allentown Area
Measurement 1 (post-1973)	0.34	0.17
Measurement 2 (pre & post)	0.40	0.44

Table 7-1 shows that the industrial firms in the sample have adopted about 42% of the applicable energy-efficient technologies to cope with energy shortages. The discrepancy in the post-1973 adoption rate between Binghamton and Allentown will be explained in the regional factor section below.

In summary, 80-85% of the short term measures, and 42% of the long term measures have been adopted.

2. The characteristics of the early adopters.

To reveal the characteristics of the early adopters of the energy-efficient technologies, we used a hypothesis-testing procedure (discriminant analysis) to determine important factors which explain significant differences in adoption rates.

A list of 26 possible factors was selected from the established literature and used in six pre-test interviews (see Appendix 11).

Using Table 7-1, for instance, we tested whether the variable "region" was significant in explaining the different adoption rates of Binghamton and Allentown. To test other variables, say, "energy intensity", we simply replaced "region" with the "energy intensity" factor, and so forth. With this change, the grouping of firms with different adoption rates was determined by energy intensity levels, instead of by the location factor. After testing all 26 factors, a list of "significant factors" was obtained, and this in turn told us what kinds of firms were more receptive to innovations. The results of this analysis can be used as a guideline for determining a target industrial population at the initial stage of the dissemination of energy-efficient technologies. That is, with this type of analysis, we will know which firms should be approached first.

In testing the hypothesis, Measurement 1 (post-1973) and Measurement 2 (total adoption rate) were used separately and in combination. We obtained nine significant factors as follows:

1. Regional factor
2. Energy intensity
3. Natural gas dependency
4. Growth stage
5. Consideration for a longer payback period
6. Energy officer as the chief officer
7. Government used as the information source
8. Government perceived as the cause of the energy crisis
9. Use of consulting service

Let me explain these factors in detail, since the findings and their implications from the field interviews may give us better understanding and more insights into the complexity of energy issues.

Regional Factor

This actually represents a combination of many variables which worked together and contributed to a significant difference in the adoption rates of the Binghamton and Allentown firms. Since "the significant difference" occurred when Measurement 1 and Measurement 2 were combined, the explanation should be focused on a combined effect using the post-1973 and pre-1973 adoption-rate contrast between two regions.

From our field work we found that since 1973, because the energy shortage produced natural gas cutbacks for industrial use in the Binghamton area, firms in that region have adopted energy-efficient technologies to make better use of allocate amounts. In the Allentown area, however, there were no severe shortages; moreover, the firms there were more advanced in utilization of the surveyed technologies before 1973 and considered them normal plant maintenance instead of as energy conservation efforts. In other words, the impact of and response to the recent energy crisis and the level of sophistication in the utilization of technologies created a regional difference in the adoption rate.

Energy-Intensive Factor

This is measured by energy use per unit of output, or the number of BTU's per dollar of output. Examples of high energy-intensive industries are lime (SIC 3274), hydraulic cement (SIC 3241), alkalis and chlorine (SIC 2812), primary aluminum (SIC 3324) ,and electro-metallurgical products (SIC 3313).

Our field work confirmed that high energy-intensive firms are more sensitive to the energy problem. As some firm officers put it, "it is a survival issue," and "we are buying insurance policies with energy conservation efforts."

Natural Gas

Dependence on natural gas (i.e., natural gas users versus non-users) as a significant factor in adoption rate is also confirmed because it affects industry in two ways: (1) it is an absolute necessity for the processing needs of certain industries since it is purer than other forms of energy, and (2) it is the least expensive energy source in most cases due to federal regulations. Because of supply problems, there is a significant difference in the total adoption rates of gas-using and non-gas-using firms.

Growth and Payback Period

These two factors are interpreted together because they are closely related in the context of adopting energy technologies. The growth factor was obtained by asking the energy officer whether the company is expanding rapidly, growing slightly, holding steady, or expecting a decline. The payback factor, on the other hand, is related to the question of whether the firm would consider a longer payback period for energy-saving investment than for its other equipment.

The data indicate that firms experiencing growth in business and also giving special consideration to a longer payback period for energy expenditures tend to adopt more energy-efficient technologies.

Chief Officer Factor

We investigated the effects on the adoption rate of the role, position, and background of the energy officer. Only when the energy officer is also the chief officer of the firm does the effect become significant. Thus, in order to be effective, the energy officer should have decision-making power. This is crucial, at least in the early stages of the diffusion of energy technologies.

Government Factor

This factor is significant on two accounts: government as an energy information source, and government perceived as the cause of the recent energy crisis. The data indicate that "government as information source effect" is more applicable to the old adoptions than the new adoptions. Since most of the old adoptions occurred in the Allentown area we may be able to infer that this factor has more effect on larger firms than on small firms. Indeed, we discovered that the government information had not reached the small firms even in 1977.

Since the "government perceived as cause of the energy crisis" factor was significant only in the analysis of the recent adoption rate, it may be interpreted together with the post-1973 adoption pattern, a phenomenon induced largely by the energy-shortage problem experienced in the Binghamton area. To the firms affected, the energy crisis is viewed largely as a result of the government's regulation of energy prices, which in turn induced under-production. The cost of energy to those firms was secondary to the survival issue of energy availability at the time of interview.

Consulting Services

Not surprisingly, firms seeking energy conservation consulting services voluntarily tend to adopt more technologies. One engineering consulting firm in the Binghamton area has become highly visible recently through its work for local firms. We expect that this factor will become increasingly important in the very near future. The following quotation testifies to this assessment: "A fellow from power engineering is coming in tomorrow to look over our situation. They are not asking [us to pay] for anything as far as to come in and look and come up with a recommendation. We will pay for it, of course, if we buy what they have to offer."

Further Examination of the Combined Effect

So far we have largely investigated the influencing factors individually. In many cases, however, two or more factors may work together and produce a significant combined effect and interaction. The following structure, using "region" and "energy-intensity" in combination, is an example.

Region		Factor 1	
Energy Intensity		Binghamton, NY	Allentown, PA
Factor 2	High	Adoption rate for high-intensity firms in Binghamton	Adoption rate for high-intensity firms in Allentown
	Low	Adoption rate for low-intensity firms in Binghamton	Adoption rate for low-intensity firms in Allentown

We used the nine significant factors to obtain 36 pair-wise comparisons and interactions. From these we are able to measure the relative strength of each individual factor, ranking them by the frequency of occurrence in the single and paired-factor tests. The results are given in Table 7-2.

TABLE 7-2: Relative Strength of the Factor

Ranking (by frequency)	Factor	Frequency of significant factors in paired analyses
1	Growth	4
1	Region	4
2	Payback	3
2	Chief officer	3
2	Govt. as cause of crisis	3
3	Natural gas	2
3	Consulting service	2
4	Energy intensity	1
4	Govt. as information source	1

From the data dealing with the interaction component of the significance tests, the pattern is almost identical, since the significant factor pairs are as follows: (1 through 7 at the 0.05 level, 8 through 12 at the 0.10 level)

1. Regional and natural gas
2. Regional and growth
3. Regional and payback
4. Regional and government perceived
5. Natural gas and growth

6. Natural gas and government perceived
7. Growth and government perceived
8. Intensity and chief officer
9. Payback and chief officer
10. Payback and government perceived
11. Growth and consulting firms
12. Chief officer and consulting firms

The pattern of ranking in Table 7-2 indicates that the behavioral and economic factors, such as "growth," "payback," and "chief officer" (some of which are contained in "region"), seem to play a more significant role than the "environmental factors" such as natural gas, energy intensity, and information sources, in the context of technology transfer.

In summary, the early adopters seem to be those experiencing growth, willing to consider a longer payback period for energy technologies, and using the chief officer as the energy officer. They are also energy intensive, highly dependent on natural gas, and willing to pay for outside consulting services for implementing energy conservation measures.

3. Industry's responses toward energy policy options.

The question of industry's response to energy policy options has been investigated from two aspects: (1) simple voting in the interviews with respect to the firm's preferences for selected policy options, and (2) the frequency of disagreement on selected policies among the firms. By using a list of twelve policies suggested by federal policy makers and Congressional staff (listed in Appendix 12), we asked for responses to the policy options regarding (a) potential effectiveness for energy conservation, (b) attractiveness to industry in general, and (c) attractiveness from the individual firm's point of view.

To find the most preferred policy options, we used the sum of voting frequencies on the (good, high) rank from all three responses. Using policy #1 (incentives for using recycled materials), for example, we have the following data:

#1. Use of Recycled Material

	Rank	Response			Total
		A	B	C	
Good, high	(1)	⑪	7	6	(24)
Fair, moderate	(2)	5	7	4	(16)
No effect, low	(3)	9	9	17	(35)

The circled number, 11, means 11 of the 30 surveyed firms gave a "good, high" ranking to policy option #1 with respect to its effectiveness in energy conservation (A). On the same row, the numbers "7" and "6" indicate that 7 and 6 firms rank policy #1 high in attractiveness to industry in general and to the specific firm, respectively. The number "24" is a row sum indicating cumulative scores for policy option #1.

We summed the "good, high" totals to measure the relative popularity of each policy option with the results shown in Table 7-3. Note that the scale ranges from 0 to 90, with the highest total (90) possible only if each of the 30 firms had ranked a particular policy option "good" or "high" on all three characteristics: effectiveness (A), general attractiveness (B), and attractiveness to the specific firm responding (C).

TABLE 7-3: Ranking of the Preferred Policies

Preference Ranking	Policy Options	Score*
1	Tax credits for capital expenditure	(63)
2.5	Favorable loan terms for capital expenditure	(57)
2.5	Deregulation of energy prices	(57)
4	Guaranteed loans for capital expenditure	(44)
5.5	Private R&D subsidized by government	(38)
5.5	Tax credits for energy management programs	(38)
7	Federally sponsored R&D	(29)
8	Government sponsored consulting services	(27)
9	Incentives for use of recycled material	(24)
10	Incentives for off-peak use	(22)
11	Federally mandated energy allocations	(13)
12	Federal tax on energy purchases	(12)

*Range is from zero to 90, for responses from 30 firms (see text).

Tax credits and subsidized loans for energy-saving investments are popular policies. Tied with favorable loan terms, deregulation, with higher prices, was viewed as a means to provide economic incentive to invest in energy technologies, in addition to being an incentive for a higher energy supply. In other words, if energy costs are low, it takes a very long (payback) period for the firm to recover any investment in energy savings. Thus deregulation is popular, assuming that higher energy costs can be incorporated into higher product prices and the energy-saving capital expenditures can be recaptured in the normal payback period (about 3 years).

It is no surprise that industrial firms dislike proposals for energy taxes, just from a profit point of view, although higher energy costs from deregulation would tend to have similar effects.

Regarding mandated energy allocation, firm officers felt that it would be very difficult to set a fair base upon which the amount of energy is to be allocated to an individual firm. In addition, it would cost too much to set up a government bureaucracy just to run the program.

4. Factors contributing to the different policy responses.

To extend the above analysis, we conducted a series of tests to determine whether particular policy option preferences could be differentiated by characteristics of the firms. For instance, we tested whether high energy-intensity firms as compared to low energy-intensity firms had a significantly different response regarding energy policy #1 (recycled material). Since there are 4 responses (effectiveness in general, attractiveness to the industry, attractiveness to the firm, and a combination of these three) to each of the 26 firm characteristics, there are 104 (26 x 4) tests for each policy option.

We used the frequency of occurrence of significant differences (out of the possible 104 related to each policy) to measure the degree of disagreement. The result is given in Table 7-4. Note that the highest score in only 15, which is about 14% of the total 104.

TABLE 7-4: Least-Controversial Ranking

Ranking	Policy Option	Frequency of sig. difference*
1	#12 Private R&D subsidized by government	2
2	# 4 Price incentives for off-peak use	5
3	# 9 Government consulting services	6
5	# 5 Federally mandated allocations	9
5	# 7 Guaranteed loans for capital expenditure	9
5	#11 Federally sponsored R&D	9
7	# 8 Tax credits for energy capital expenditure	10
8	# 3 Federal tax on energy purchases	11
9	# 6 Favorable loan terms	13
10	#10 Tax credits for energy management programs	14
11.5	# 1 Incentives for use of recycled material	15
11.5	# 2 Deregrulation of energy prices	15

*Possible maximum frequency: 104

Table 7-4 indicates further that there is some significant disagreement on the policy options among the firms. The four most controversial ones are: #1: use of recycled material, #2: deregulation of energy prices, #6: favorable loan terms, and #10: tax credits for energy management programs. The interpretation of this pattern obtained from our interviews is as follows: (1) not all the firms are able to use recycled material; (2) while deregulation may help to solve the energy supply problem, it may also bring economic hardships--high cost--for some firms; (3) "favorable loan terms" does not mean they are costless; and (4) with tax credits for an energy management program some firms are afraid there may be more government regulations and involvement. These are both philosophical and economic concerns.

Comparing this finding with the preference response pattern, we discovered that there is an inconsistency between them. For instance, while policy options #2 and #6 (deregulation and favorable loan terms) are regarded as the second and third most preferred policies (actually there is a tie between them), they are also among the most controversial policies. Thus, our preference ranking alone cannot be used to measure the "workability" of the policy. For this, we included another measure regarding the "effectiveness" on the adoption rate, summarized in the next section.

Analysis of the policy views indicates that the factors which contribute to significant disagreements on policies are almost exclusively behavioral factors, rather than environmental. The five most important ones are:

Ranking	Firm Charactericstics	Frequency counts for the four most controversial policies
1	Energy officer with business/finance background	9
2	Energy officer as the chief officer	7
3	Information from other firms	7
4	Energy officer with technology background	5
5	Intensity factor	5

This implies that in terms of energy policy issues, we should look for opinions of the person directly in charge of the firm's energy management program. This finding is very significant when industrial viewpoints are to be taken into consideration for formulating energy policies even though controversy exists.

5. Policy options having the greatest effect on the adoption rate.

To obtain the effect of policy options in the adoption rates, one should compare data showing adoptions after the implementation of a given policy with data collected before the policy is instituted. Although this kind of data does not now exist, we do have a set of data regarding the firms' attitudes towards the selected policy options. This data set can be used to assess potential effects when analyzed together with the technology adoption-rate data.

There are 12 policy options, each with three responses, and there are three measurements of the adoption rate in each response, the post-1973, total, and combined measures. Thus, we have 108 (12 x 3 x 3) tests for trying to determine the effects of policies on the adoption rate. Six policies have been identified as significant for having potential effects on the adoption rate. They are:

Ranking	Policy	Frequency of Significant tests
4.5	Federal tax on energy purchases (#3)	2
1	Federally sponsored R&D (#11)	6
2.5	Price incentives for off-peak use (#4)	3
4.5	Private R&D subsidized by government (#12)	2
2.5	Tax credits for energy capital expenditure (#8)	3
6	Tax credits for energy management programs (#10)	1

As we can see, most of these policies are primarily R&D related and price/tax incentive related. The least effective ones are those related to energy regulation and loan guarantees.

6. Derivation of the most "workable" policies.

So far we have discussed three aspects of the policies, namely, preferences, controversiality, and effectiveness. Since each aspect possesses a certain kind of merit for energy conservation, it is logical to combine them into an integrated measure for assessing the "workability" of the policies. Ranking each of the 3 responses to the 12 policy options and using an equal weight assignment, we obtained such a rating for each policy given in Column D of Appendix 13. The six most "workable" policies identified are:

Ranking	Policy	Rating (sum)
1	Tax credits for energy capital expenditure (#8)	10
2	Private R&D (#12)	11
3	Federally sponsored R&D (#11)	14.5
3	Price incentives for all-peak use (#4)	14.5
5	Government sponsored consulting services (#9)	18
6	Favorable loan terms for energy capital expenditure (#6)	19.5

From this list we can conclude that the promising policies involve incentives for the adoption and development, of energy-efficient technologies, in view of the fact that four of the most workable policies are also four of the most effective policies. In other words, energy policies aimed at fostering an effective technology transfer should be centered around R&D efforts, coupled with tax incentives for adopting them and pricing policies to encourage conservation measures. While this conclusion seems logical, it could not be verified until this study because of the lack of empirical data.

Let us explain this reasoning again. To conserve energy, first we need to have reliable, economical, energy-efficient technologies available to industry, so that changes in processing methods (the long-term measures) are possible on both technological and economic grounds. Second, we need public policies with which a rapid rate of adoption can be achieved, and tax incentives are among such policies.

7. Development of operational policy.

Effects of the policies can be assessed by two methods: (1) field investigation after policies are implemented, and (2) computer simulations before policies are implemented--the dynamic diffusion model.

Since we are still at the policy development stage, method (2) is more applicable. In our model, the effect of a policy will be defined as the change in the adoption rate over time. Since both natural stimulation (for instance, the example of neighboring firms) and policy influences are contributing factors, the rate of change can be defined as follows:

> Effect on the adoption rate is a function of mutual effects among firms plus policy influence on a given firm.

We have developed a computerized method to assess the change in adoption rate over time under a number of scenarios regarding the mutual stimulation patterns and the behavior of a given policy option. Since real-world data are lacking, this model is only a policy simulator at this moment.

Optimal policy should be defined according to the objectives of the policy and certain constraints. Once those are given, optimal policies can be derived from the dynamic diffusion model.

D. Perspectives on Technology Transfer and Public Policies

The use of energy-efficient technologies in place of existing inefficient methods is a viable approach for solving industrial energy shortages, since on the average as much as 25 to 30 percent of industrial energy consumption can be reduced thereby. This has begun to take place, as seen by the change in the energy-growth to GNP-growth ratio, which fell from 70 percent in 1976 to between 60 and 65 percent in 1977. It should be noted that the historical ratio (1950-70) is one to one.

The fact that adoption of these technologies has been slow, even though they have been proved to be reliable and economical, is further confirmed in our study. The adoption rate of ten types of existing (old) technologies by the industrial firms in our sample is only 42 percent. A much lower rate of adoption may be expected with respect to newly developed process-change technologies.

After 18 months of extensive examination of documents and intensive field interviews with our industrial firms (specifically with people in charge of energy matters), it is very clear to us that the major problems lie in the system of innovative efforts. Simply, the questions are: first, how do you get technologies from the hands of developers to potential industrial users; second, from the other end, how can potential receivers obtain the technologies from the developers; and third, how do we speed up the technology transfer and interaction processes between these two groups? Solving the problems will not be easy because there is little interaction between the groups to begin with, as witnessed in our field work. On the other hand, we feel confident that it can be accomplished by carefully planned, comprehensive, innovative efforts involving all the concerned parties--the federal government, state and local public agencies, industrial firms, and other groups with an interest in the efficient use of energy.

From our experience, industrial cooperation can be obtained without much difficulty, since industrial firms are very concerned with their energy problems and are eager to seek interactions with other interested parties. What is required is to build active linkages among these innovative system components. The following efforts, based upon the findings of our study, will give us a strong start toward building an active and viable technology transfer system.

1. <u>To develop and implement policies to help produce energy-efficient, reliable and economical technologies</u>: Technology transfer should begin with the availability of technologically reliable, economically affordable systems or devices. Our study suggests that R&D effort is potentially the policy option most effective for increasing the adoption rate. Thus policies centered around federal and federally-supported private R&D will lay a sound foundation for transferring energy-efficient technologies to the users. An inventory of existing and near-future technologies, such as the effort by Systems Consultants, Inc., is the first step in this direction. Appendix 13 ~~Table 7-5~~ is an example of the technology list. A comprehensive technology diffusion program should be developed along with this technology development program to insure that there is a market demand, and that there are easily understandable documents available regarding potential users, conservation opportunities, costs and payback periods, maintenance procedures, etc. It seems to us that a specific technology diffusion program under the Division of Industrial Energy Conservation of the Department of Energy could facilitate this task. An effort aimed at identifying target industrial populations for transferring newly developed technologies to industry will also be helpful to this program.

2. <u>To formulate workable public policies to foster a speedier rate of adoption</u>: From our study and others conducted by the Department of Energy, a list of workable policy options can be developed and instituted to facilitate more adoptions of energy-efficient technologies. Past studies on innovative efforts have been

based on historical data; the conclusions are therefore essentially hindsight judgments. However, the use of up-to-date data is essential for understanding technology adoption processes. Moreover, we discovered that decision-making processes regarding capital investments significantly affect the innovative efforts. To be effective, a system of data collection regarding firms' capital budgeting methods and the potential effect of these policies on firm behavior should also be established. After a given policy is "instituted," by means of either computer simulation or legislative processes, it is advisable to project the adoption rates, and at the same time to collect the real-world data. The discrepancy between the actual and projected rates can then be used to modify the simulation model or experimental policies to guide policy changes.

3. To develop a regional comparative data base for a comprehensive technology transfer program: It is not difficult to understand that there are regional differences in the production and consumption of energy resources in the United States. For instance, the Northeast region of the United States is essentially a non-energy producing area, as well as one which uses a considerable amount of imported oil, while in the South and Southwest regions the pattern is reversed. The Northwest region is highly dependent on hydro-electrical power, whereas the Midwest relies heavily on energy supplies from energy-producing regions elsewhere in the United States. Thus it seems that any energy policy will not be optimal without consideration of regional factors. Technology transfer programs should also reflect the regional diversity of energy issues.

To be effective, state and local efforts in energy conservation and production should also be taken into consideration. This means regional and statewide energy policies should be designed to enhance federal policies, and vice versa. An industrial energy conservation out-reach program, similar to that of the agricultural extension services, might be made a part of a comprehensive scheme of energy-saving technology diffusion.

APPENDIX I

THE INTERVIEW SURVEY INSTRUMENT

Page One

MANAGER INTERVIEW: ENERGY CONSERVATION AND PLANT ORGANIZATION

The purpose of this study is to help develop efficient methods for energy conservation planning and promotion in manufacturing. This plant was selected as part of a pilot study in this geographical area; we will be talking with people in a wide variety of industries here.

We ask your assistance in identifying factors that bear on energy conservation in this industry, as well as this plant's energy use patterns. There are four parts to our survey: a checklist of energy-conservation practices, a checklist of energy conservation technologies used in your manufacturing process, a few questions about decision-making in this firm, and this interview with you to learn about your energy situation and the federal energy policy you would like to see.

Before we get started, I have a short questionnaire that we would like answered by three or four others in management here. Can you help us distribute it now so we may pick them up as we leave? It will take about four minutes--the questions are check-off items about the organization of the plant. (show questionnaire to R)

	Coal	Coke	Light Fuel	Heavy Fuel	Nat Gas*/Prop	Purchased Electricity	Other (Specify)
			(State Approximate Percent of Total Energy Use)				
(1) A. What were the three main fuel or energy forms used by your company in the past year?					/		
B. Which three do you expect your company will use most ...in 1980					/		
...in 1985					/		

*Piped natural or manufactured gas

Page Two

2. Has your plant experienced a mandated cutback in energy allocation?
no/yes source of cutback:

date of first cutback:

extent of cutback:

3. (If yes) How has your plant coped with the cutback?

4. Are there any special problems faced by your firm that make energy supply problems different for you compared to other firms in this industry
no/yes specify:

5. Are there any special problems faced by this industry as a whole that affect its energy situation compared to other industries? no/yes specify:

6. Have you changed your product mix in response to energy problems? no/yes specify:

7. Is your firm a member of an industry association? no/yes specify:

8. (If yes) Can you tell me if your firm has been working with the industry association in volunteer energy conservation efforts?
filing reports attending meetings monitoring energy use other:

9. Are there any special situations here at this plant that have helped or blocked you from accomplishing your energy conservation efforts?

10. Is there a special committee or task force here to formulate energy management strategy? yes, permanent date begun: ______________
yes, ad hoc
no

11. Has primary responsibility for energy management been designated to a specified person? No/yes title: ________________________________

12. Has your firm participated in any energy use program sponsored by a group outside the firm such as the power company or chamber of commerce?
no/yes specify:

Page Three

13. Has your firm contacted any consultants (engineers or others) to assist you in conserving and managing energy use? no/yes specify:

14. Have you talked much with people around here about the energy problem? no/yes, some / yes, a great deal

15. In your opinion, are energy problems something we Americans are going to have to learn to live with?

yes, will worsen no, are only temporary will stay same

16. In your opinion, what is the major cause of energy shortages and higher prices for energy?

17. Can you identify for me your main sources of information about the country's energy problems?

mass media: specify

talking with co-workers

talking with others:

special committees, boards:

industry association journals:

government speakers, President Carter:

other:

18. We are interested in your views of proposed federal energy policies. (hand policy preference survey to R.)
We can go through the list of proposals together so you can give us your comments on each proposal. How effective do you think the policy will be for energy conservation? How attractive is the proposal for industry generally? How attractive is the proposal to your firm? (give R time to look over all policy proposals. Begin taping here.)

ENERGY CONSERVATION POLICY PREFERENCES--MANUFACTURING FIRMS

In preparing a comprehensive energy policy for the country as a whole, the federal government is most interested in the recommendations of people in industry who will be strongly affected by the policy. We need your evaluation of the following energy conservation policy proposals suggested by congressional committees and presidential advisors. We are interested in your reactions to the proposals from three points of view:

1. Potential effectiveness for energy conservation.
2. Attractiveness to industry in general
3. Attractiveness from the point of view of your firm.

Any comments or further policy proposals you may have are most welcome.

1. Use of recycled materials: incentives for use coupled with penalties for use of virgin materials.

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

2. Cost of energy: deregulation of energy prices.

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

3. Cost of energy: federal tax on energy purchases based on national energy consumption patterns.

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

4. Supply of energy: price incentives for off-peak energy use combined with penalties on increments of energy consumed in excess of (peak) bases.

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

5. Supply of energy: federally mandated energy allocation limits based on past energy usage per units of output.

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

6. Financing energy conservation measures: favorable loan terms for energy conservation capital expenditures (plant insulation, energy-efficient equipment,etc).

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

7. Financing energy conservation measures: federally guaranteed loans for energy conservation capital expenditures:

effectiveness: good fair no effect
attractiveness generally: high moderate low
attractiveness here: high moderate low

8. Financing energy conservation measures: tax credits for energy conservation capital expenditures.

   effectiveness: good fair no effect
   attractiveness generally: high moderate low
   attractiveness here: high moderate low

9. Energy systems management programs: government-sponsored services of consultants at no cost to industry.

   effectiveness: good fair no effect
   attractiveness generally: high moderate low
   attractiveness here: high moderate low

10. Energy systems management programs: tax credits for cost of implementing and maintaining energy management program.

   effectiveness: good fair no effect
   attractiveness generally: high moderate low
   attractiveness here: high moderate low

11. Research and development of energy-efficient production technologies: research efforts sponsored by federal government agencies.

   effectiveness: good fair no effect
   attractiveness generally: high moderate low
   attractiveness here: high moderate low

12. Research and development of energy-efficient production technologies: research based in industry subsidized by federal incentives.

   effectiveness: good fair no effect
   attractiveness generally: high moderate low
   attractiveness here: high moderate low

13. Do you have any suggestions of your own for policy measures to promote energy conservation in industry?

Page 6

19. Here is a list of ten energy-efficient technologies. All of these devices have been in use for about twenty years. I would like to go through this list with you to see if any of these technologies are in use here in the plant. (hand R a copy of the list of technologies.)

    1. Waste heat recovery devices from hoods or from heat-producing equipment hot stocks.
       not applicable   no   yes: adoption date:
    2. Devices or equipment for pre-heating combustion air.
       not applicable   no   yes: adoption date:
    3. Heat recovery device for compressors used for cooling.
       not applicable   no   yes: adoption date:
    4. Load levelers.
       not applicable   no   yes: adoption date:
    5. Devices for raising suction temperature for refrigeration units.
       not applicable   no   yes: adoption date:
    6. Devices for using steam condensate for heating.
       not applicable   no   yes: adoption date:
    7. Variable speed pumping devices.
       not applicable   no   yes: adoption date:
    8. Recuperator or regenerator.
       not applicable   no   yes: adoption date:
    9. Heat pump.
       not applicable   no   yes: adoption date:
    10. Heat exchanger.
       not applicable   no   yes: adoption date:

20. In the past five years, has your plant tried, purchased, or installed any new energy-efficient technologies in addition to those on the list? no/yes

21. What is your normal payback period planned for in the purchase of new equipment?

22. From your point of view of this plant's operation, have you suggested or thought about any ways the work could get done just as well but with some savings in the plant's use of energy? no/yes

23. Do you have an R&D section in this company? no/yes

24. (if yes) Do you share your research findings within the industry?
    articles in industry journals
    papers at meetings
    demonstration visits
    marketing of R&D results

25. What are your main sources of information on how to cope with energy problems here at the plant? (probe for specific persons, articles in magazines, seminars, training sessions.)

end taping here

26. What is the most automatic piece of equipment used here?
name of equipment:
What does it do?

27. Which of these categories most accurately describes the most automatic piece of equipment used here in the workflow?

handtool, manual machines
power machine and tools
single-cycle automatics and self-feeding machines
automatics which repeat cycles (all energy mechanized)
self-measuring and adjusting by feedback
computer controlled

28. Which of the following categories most accurately describes the bulk of equipment used here in the workflow?

handtools and manual machines
power machines and tools
single-cycle automatics and self-feeding machines
automatics which repeat cycles (all energy mechanized)
self-measuring and adjusting by feedback
computer controlled

29. About how old is the bulk of equipment used here in the workflow?

30. How long has your company been in this plant?

31. Was this building designed for its current use?

32. Which of these phrases would you say best describes the stage of growth of production here?

cutting back   steady state   growing slowly   growing rapidly   growing very rapidly

33. Does your firm have a copy of NBS Handbook #115? (show handbook)
(if yes) Where did you get your copy?
I would like you or perhaps the plant engineer to go through this summary of the recommended energy conservation procedures from the NBS Handbook, and return it to us. The list will take about 15 minutes to complete. (leave checklist and cover sheet with relevant person.)

There are some questions we would like to ask about the organization of decision-making here, and how the day to day work is accomplished.

34. Where is the home office of this firm located?

(if only one location, skip next page.)

Page Eight

(Ask Q35 only in plants that are a part of a larger organization.)

35. We need to get some idea about whether or not many decisions that affect your firm are made here at the plant or outside. Would you indicate for me, where the authority to decide these specific things is, either inside the plant or from outside?

	Authority Inside Plant	
Supervisory establishment	Yes	No
Appointment of supervisory staff from outside the plant?	Yes	No
Promotion of supervisory staff	Yes	No
Salaries of supervisory staff	Yes	No
To dismiss a supervisor	Yes	No
To determine a new product or program	Yes	No
To determine marketing territories covered	Yes	No
The extent and type of market to be aimed for	Yes	No
The price of output	Yes	No
What type,or what brand, new equipment is to be	Yes	No
What shall be costed (to what the costing system, if any, shall be applied)	Yes	No
What shall be inspected	Yes	No
What operations shall be work studied	Yes	No
Which suppliers of material are to be used	Yes	No
Buying procedures	Yes	No
Training methods to be used	Yes	No
What and how many welfare facilities are to be provided	Yes	No
To spend unbudgeted or unallocated money on capital items	Yes	No
To spend unbudgeted or unallocated money on revenue items	Yes	No
To alter responsibilities/areas of work of specialist departments	Yes	No
To alter responsibilities/areas of work in line departments	Yes	No
To create a new department	Yes	No
To create a new job	Yes	No

36. In general, how do you feel about the kind of communication which you receive from your immediate superior?

The kind of communication from my superior is completely adequate

Very adequate

Rather adequate

Inadequate

37. How many times in the past year have you suggested to your immediate superior a different or better way of doing something on the job?

Never had occasion to do this during the past year

Once or twice

About three times

About five times

Six to seven times

More than ten times had occasion to do this during the past year

38. How often do you get chances to try out your own ideas on your job, either before or after checking with your superior?

Several times a week or more

About once a week

Several times a month

About once a month

Less than once a month

39. In your kind of job, is it usually better to let your superiors worry about new or better ways of doing things.

Strongly agree

Mostly agree

Mostly disagree

Strongly disagree

40. In your kind of work, if a person tries to change his usual way of doing things, how does it generally turn out?

Usually turns out worse; the tried and true methods work best in my work

Usually doesn't make any or much difference

Usually turns out better; our methods need improvement

Page Ten

41. To what extent do people from different departments who have to work together do their jobs properly and efficiently without getting in each other's way?

    To a very great extent

    To a great extent

    To a fair extent

    To a small extent

    To a very small extent

42. How well planned are the work assignments of the people who must work together?

    Extremely well planned

    Very well planned

    Fairly well planned

    Not so well planned

    Not well planned at all

43. How frequently do you usually participate in the decisions on the promotions of any staff?

    never seldom sometimes often always

44. How frequently do you participate in decisions on the adoptions of new policies?

    never seldom sometimes often always

45. How frequently do you participate in the decisions on the adoption of new programs and/or procedures?

    never seldom sometimes often always

Tell me if, from your point of view, the following statements are true or false about this plant: are these statements definitely false, false, true, or definitely true?

46. There can be little action taken around here until a supervisor approves a decision.

    definitely false false true definitely true

47. A person who wants to make his own decisions would be quickly discouraged here.

    definitely false false true definitely true

48. Even small matters have to be referred to someone higher up for a final decision.

    definitely false false true definitely true

Page Eleven

49. We would like to have some background information from you as an individual involved in energy conservation in industry: are you a member of any industrial or professional societies? (list)

50. Do you attend meetings of any of these associations?

51. What is your educational or professional training background? (college degrees, professional school training, company training)

52. What is the position of the person here with whom you work most closely in day to day decision making?

53. Is this person considered by you to have a position higher than yours? about the same? not as high in the company as yours?

54. What is your job title?

55. How long have you been in this job?

56. How long have you been with this firm?

57. Can you tell me the position you held right before this one?

58. Have you ever been in business for yourself?

59. Here is a copy of an energy survey prepared by the Conference Board in 1974. Please look it over, especially questions three and five; can you estimate for me how easy or difficult it would be for someone here to complete these questions? (Leave CB survey with R for return.)

APPENDIX 2

SURVEY OF SHORT-TERM ENERGY CONSERVATION MEASURES PROPOSED BY
NATIONAL BUREAU OF STANDARDS
ENERGY CONSERVATION PROGRAM GUIDE FOR INDUSTRY AND COMMERCE

Key to Conservation Opportunity Checklist

1. This is routine to our operation, but not specifically related to energy conservation.
2. We have already done this for energy conservation purposes.
3. This is a good idea and we plan to adopt it.
4. We did this in the past but discontinued it.
5. We did not know this could be done.
6. This is not economical for us.
7. This is not technically possible for us.
8. This is not applicable here.

Other: please write in your own comments or explanations

APPENDIX 2

Conservation Opportunity Checklist (from NBS Handbook 115)

A. Buildings and Grounds

1. Shut off airconditioning in winter heating season*

   1 2 3 4 5 6 7 8

   Other reasons, please comment:

2. Eliminate unused roof openings or abandoned stacks

3. Reduce building exhausts and thus make-up air

4. Reduce temperature of service hot water

5. Shut down air conditioning during non-working hours

6. Install timers on light switches in little used areas

7. Close holes and openings in buildings such as broken windows, unnecessary louvers and dampers, cracks around doors and windows

8. Repair faulty louvers and dampers

9. Analyze pipe and duct insulation--use amount necessary to accomplish task

10. Centralize control of exhaust fans to ensure their shutdown

11. Close outdoor air dampers during warm-up or cool-down periods each day

12. Reduce air conditioning load by evaporating water from roof

13. Convert to fluorescent, mercury, sodium, or high intensity direct lighting

14. Insulate walls, ceilings, and roofs

15. Install timers on air conditioning for summer operation

16. Periodically calibrate the sensors controlling louvers and dampers on buildings

17. Use "heat wheel" or other heat exchanger to cross-exchange building exhaust air with make-up air

*See preceding page.

18. Use photocell control on outdoor lights

19. Size air handling grills, ducts, and coils to minimize air resistance

20. Recover heat in waste service hot water

21. Use separate switches on perimeter lighting which may be turned off when natural light is available

22. Interlock heating and air conditioning systems to prevent simultaneous operation

B. Electrical Power

1. Size electric motors for peak operating efficiency--use most efficient type of electric motors

2. Use power during off-peak periods--store heated/cooled water for use during peak demand periods

3. Use immersion heating in tanks, melting pots, etc.

4. Reduce load on electrical conductors to reduce heating losses

5. Increase electrical conductor size to reduce distribution losses

C. Steam

1. Turn off steam tracing during mild weather

2. Repair leaks in lines and valves

3. Repair insulation on condensate lines

4. Repair faulty insulation on steam lines

5. Repair or replace steam traps

6. Eliminate leaks in high pressure reducing stations

7. Cover condensate storage tanks

8. Use correct size steam traps

9. Minimize boiler blowdown with better feedwater treatment

10. Use steam sparging or injections in place of indirect heating
11. Install adequate dryers on air lines to eliminate blowdown
12. Install compressor air intakes in coolest locations
13. Recover and reuse cooling water
14. Use flow control valves on equipment to optimize water use
15. Eliminate or reduce compressed air used for cooling product, or equipment, or for agitating liquids
16. Replace water cooling on processes with air cooling where possible
17. Recover heat from compressed air dryers
18. Operate cooling towers at constant outlet temperature to avoid sub-cooling
19. Recycle treated water

D. Heat Recovery

1. Use heat in flue gases to preheat products or material going into ovens, dryers, etc.
2. Use hot process fluids to preheat incoming process fluids
3. Use waste heat from hot flue gases to heat space conditioning air, process or service water
4. Use waste heat from hot flue gases to preheat combustion air or boiler feedwater
5. Recover heat from hot waste water
6. Use oven exhaust to preheat air
7. Recover fuel value in waste by-products
8. Recover heating or cooling effect from ventilation exhaust air to precondition incoming ventilation air

E. Combustion

1. Improve combustion control capability
2. Convert combustion to more efficient fuel

F. Scheduling

1. Locate causes of electrical power demand charges, and reschedule plant operations to avoid peaks
2. Reduce temperature of process heating equipment when on standby
3. Consider three or four days around-the-clock operation rather than one or two shifts per day

G. Process Changes

1. Schedule baking times of small and large components to minimize use of energy
2. Convert from indirect to direct firing
3. Use small number of high output units instead of many small inefficient units
4. Change product design to reduce processing energy requirements

APPENDIX 3

Thermal Waste Energy Recovery Technologies, the Waste Streams Patterns and Payback Periods at the Two-Digit SIC Level

(From DOE: CONS/2862-1 by Drexel University, 1976)

THERMAL WASTE ENERGY RECOVERY FROM IDENTIFIED INDUSTRIAL SOURCES

STATE-OF-THE-ART TECHNOLOGY UNLESS NOTED

WASTE HEAT SOURCE	COOLING WATER	CONDENSATE	PROCESS WATER	BOILER EXHAUST	FURNACE EXHAUST
TEMPERATURE LEVELS F°	90-130	140-200	100-140	300-600	500-1000
POWER SYSTEMS o RANKINE	NO	YES	NO	YES	YES
o STIRLING	NO	NO	NO	YES*	YES*
HEATING SYSTEMS o HEAT EXCHANGERS LIQUID/LIQUID	YES	YES	YES	N/A	N/A
LIQUID/GAS	YES	YES	YES	N/A	N/A
GAS/LIQUID	N/A	N/A	N/A	YES	YES
GAS/GAS	N/A	N/A	N/A	YES	YES
GAS/BOILING	N/A	N/A	N/A	YES	YES
o HEAT PUMPS (EXTERNAL POWER REQ'D)	YES	YES	YES	N/A	N/A
COOLING SYSTEMS o ABSORPTION	NO	YES	NO	YES	YES
o RANKINE DOUBLE LOOP	NO	YES	NO	YES	YES
o STEAM JET	NO	NO	NO	YES	YES

N/A - APPLICATION NOT APPROPRIATE
NO - TEMPERATURE INSUFFICIENT EVEN IN NEAR TERM
YES - TEMPERATURE SUFFICIENT, STATE-OF-THE-ART TECHNOLOGY
YES*- TEMPERATURE SUFFICIENT, NEAR TERM TECHNOLOGY

MATRIX OF TECHNOLOGIES AND WASTE ENERGY STREAMS

Technologies	Waste Energy Streams				
	Condenser Cooling Water	Contaminated Process Water	Condensate	Boiler Exhaust	Furnace Exhaust
A. Power Cycles: Production of Electrical Energy					
1. Rankine Engine			X	X	X
2. Stirling Engine				X	X
B. Heat Exchangers: Preheat Water, Air, Process Req't					
1. Liq/Lig	X	X	X		
2. Lig/gas	X	X	X		
3. Gas/liq				X	X
4. Gas/gas				X	X
5. Gas/boiling				X	X
C. Refrigeration/Air Conditioning: Production of Refrigeration or A/C. (In analysis energy units of recovery are mechanical or electrical)					
1. Absorption			X	X	X
2. Rankine Cycle			X	X	X
D. Industrial Heat Pump	X	X			

PAYBACK PERIODS FOR POWER CYCLES*

(average electricity costs: $ 8.00/10^6 BTU)

Waste Energy Streams

	Condensate	Boiler Exhaust		Furnace Exhaust	
SIC	Rankine	Rankine	Stirling	Rankine	Stirling
20	D	D	D	C	D
21	D	D	D	D	D
22	D	D	D	D	D
23	D	D	D	D	D
24	D	D	D	D	D
25	D	D	D	-	-
26	D	C	B	B	B
27	D	D	D	D	D
28	D	C	B	B	B
29	C	C	B	B	A
30	D	D	D	D	D
31	D	D	D	D	D
32	D	C	C	B	B
33	C	C	C	B	B
34	D	D	D	D	D
35	D	D	D	D	D
36	D	D	D	D	D
37	D	D	D	D	C
38	D	D	D	D	D
39	D	D	D	D	D

Note:

	Payback Periods (Years)
A	<3
B	3-10
C	10-20
D	>20

*Rankine cycle equipment is commercially available, and hence the cost estimates are more reliable than for the Stirling cycle equipment which is still in the development stage.

PAYBACK PERIOD FOR REFRIGERATION/AIR CONDITIONING TECHNOLOGY*

(average electricity costs: $ 8.00/10^6 BTU)

	Condensate		Boiler Exhaust		Furnace Exhaust	
SIC	Absorption Refrig.	Rankine Cycle Refrig.	Absorption Refrig.	Rankine Cycle Refrig.	Absorption Refrig.	Rankine Cycle Refrig.
20	C	D	B	C	B	B
21	C	D	B	C	B	C
22	D	D	B	C	B	C
23	D	D	D	D	D	D
24	D	D	D	D	C	C
25	D	D	C	D	C	-
26	B	D	B	B	A	B
27	D	D	D	D	C	D
28	B	C	B	B	A	B
29	A	B	A	B	A	A
30	D	D	C	D	B	C
31	D	D	D	D	C	C
32	B	C	B	B	B	B
33	B	D	B	B	A	B
34	D	D	D	D	D	C
35	D	D	D	D	D	D
36	D	D	C	D	D	C
37	D	D	C	D	D	C
38	D	D	C	D	C	C
39	D	D	D	D	D	D

Note:

	Payback (Years)
A	< 3
B	3-10
C	10-20
D	> 20

---

*Absorption cycle equipment is commercially available while Rankine cycle equipment is still under development. Costs for the latter relative to the former can be expected to decrease.

PAYBACK PERIODS FOR HEAT PUMP

(average electricity costs: $8.00/10^6 BTU)
(average fuel costs: $2.00/10^6 BTU)

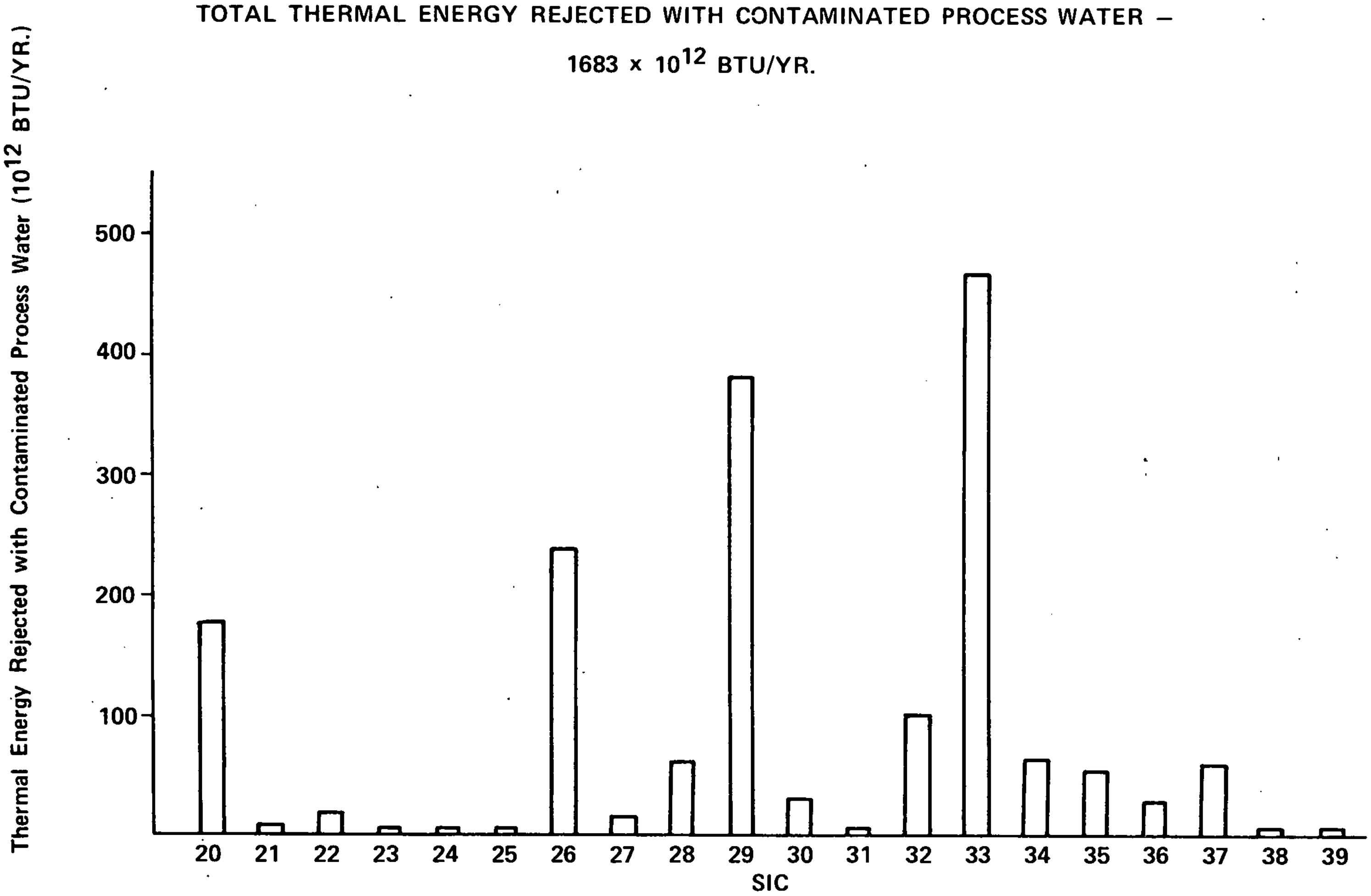
SIC	Condenser Cooling and Process Water Waste Streams
20	B
21	C
22	B
23	B
24	B
25	B
26	A
27	B
28	A
29	A
30	B
31	B
32	A
33	A
34	B
35	B
36	B
37	B
38	B
39	B

Note:

	Payback in Years
A	< 3
B	3-10
C	10-20
D	> 20

APPENDIX 4

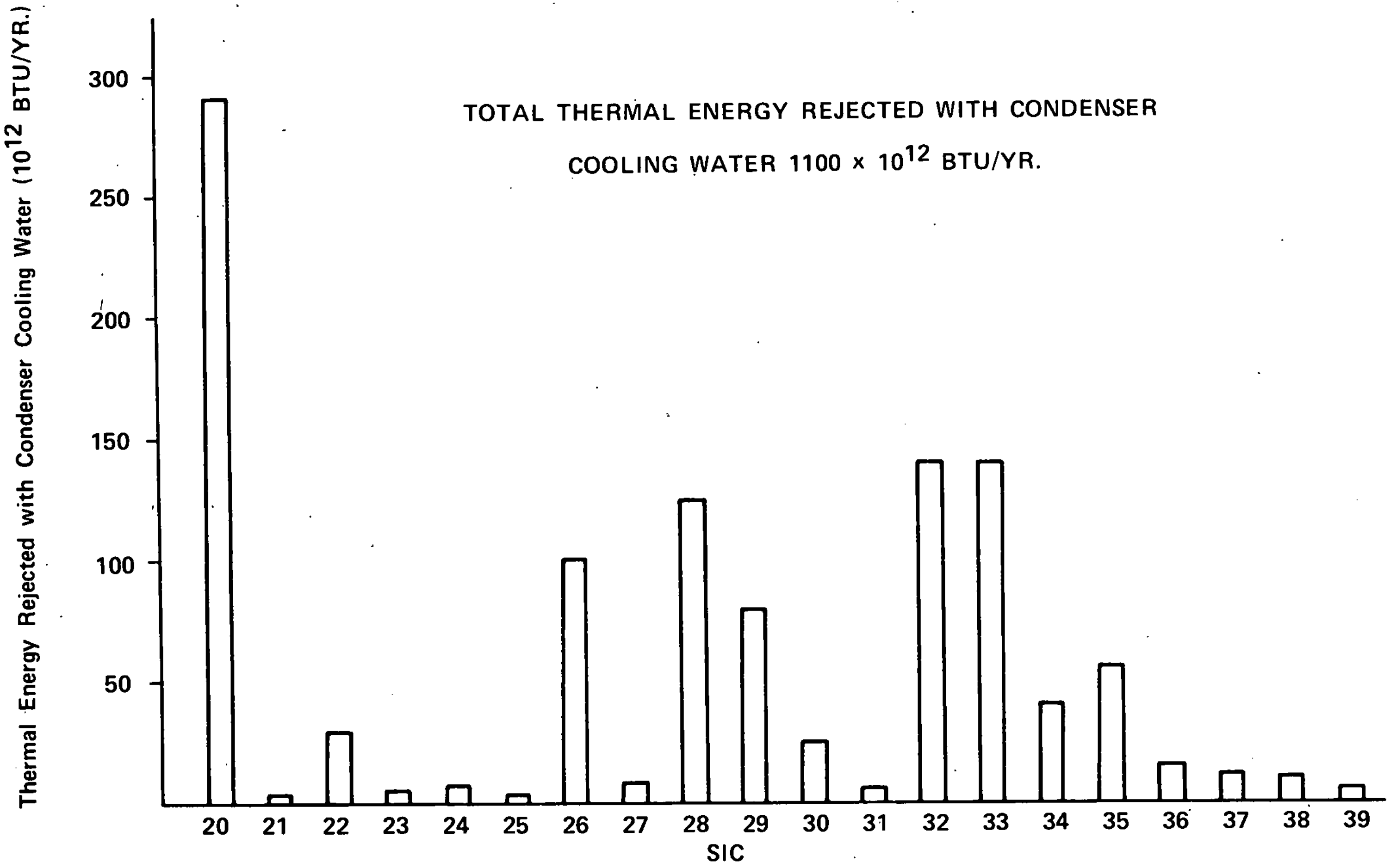
SIC	Industry
20	Food
21	Tobacco
22	Textiles
23	Apparel
24	Lumber & wood products
25	Furniture & fixtures
26	Paper & pulp
27	Printing & publishing
28	Chemicals
29	Petroleum & coal products
30	Rubber
31	Leather
32	Stone, clay & glass
33	Primary metals
34	Fabricated metals
35	Non-electrical machinery
36	Electrical equipment
37	Transportation equipment
38	Instruments
39	Miscellaneous



TOTAL THERMAL ENERGY REJECTED WITH CONTAMINATED PROCESS WATER – 1683×10^{12} BTU/YR.

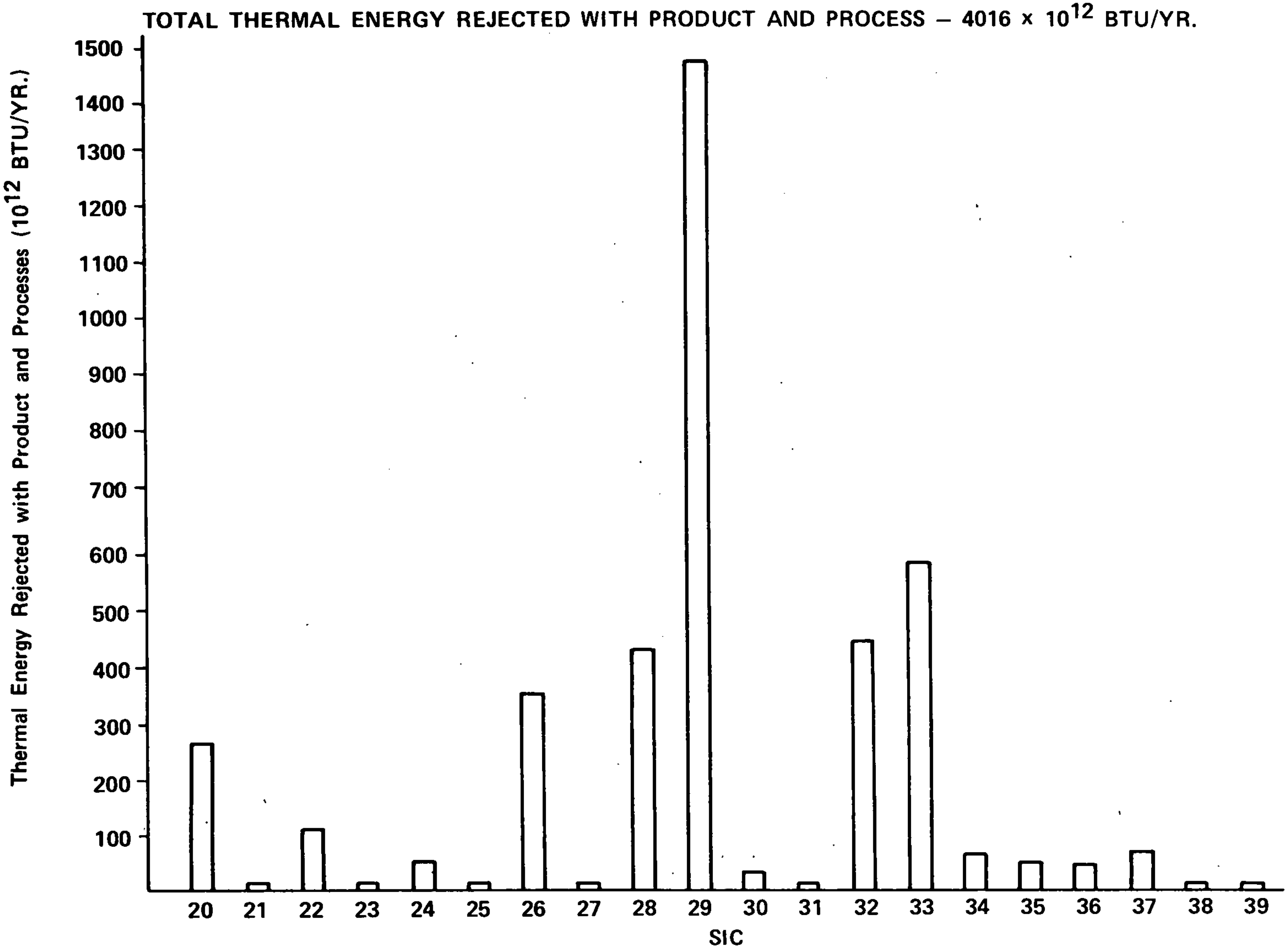
Thermal Energy Rejected with Contaminated Process Water by Each 2-digit SIC Industrial Group

Source: Industrial Applications Study, Vol. 1, Dept. of Energy, CONS/2862-1



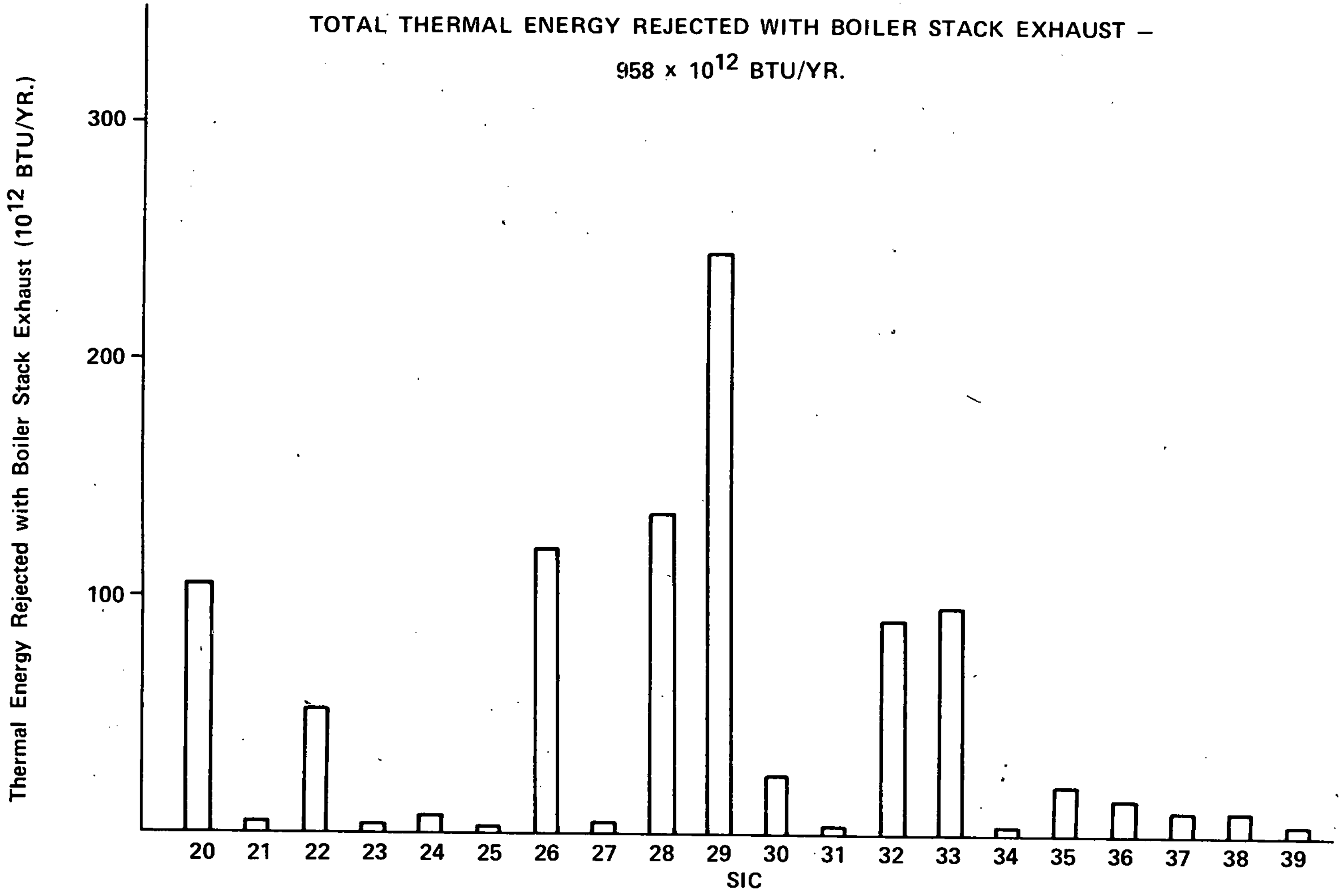
Thermal Energy Rejected with Condenser Cooling Water for Each 2-digit SIC Industrial Group

Source: Industrial Applications Study, Vol. 1, Dept. of Energy, CONS/2862-1



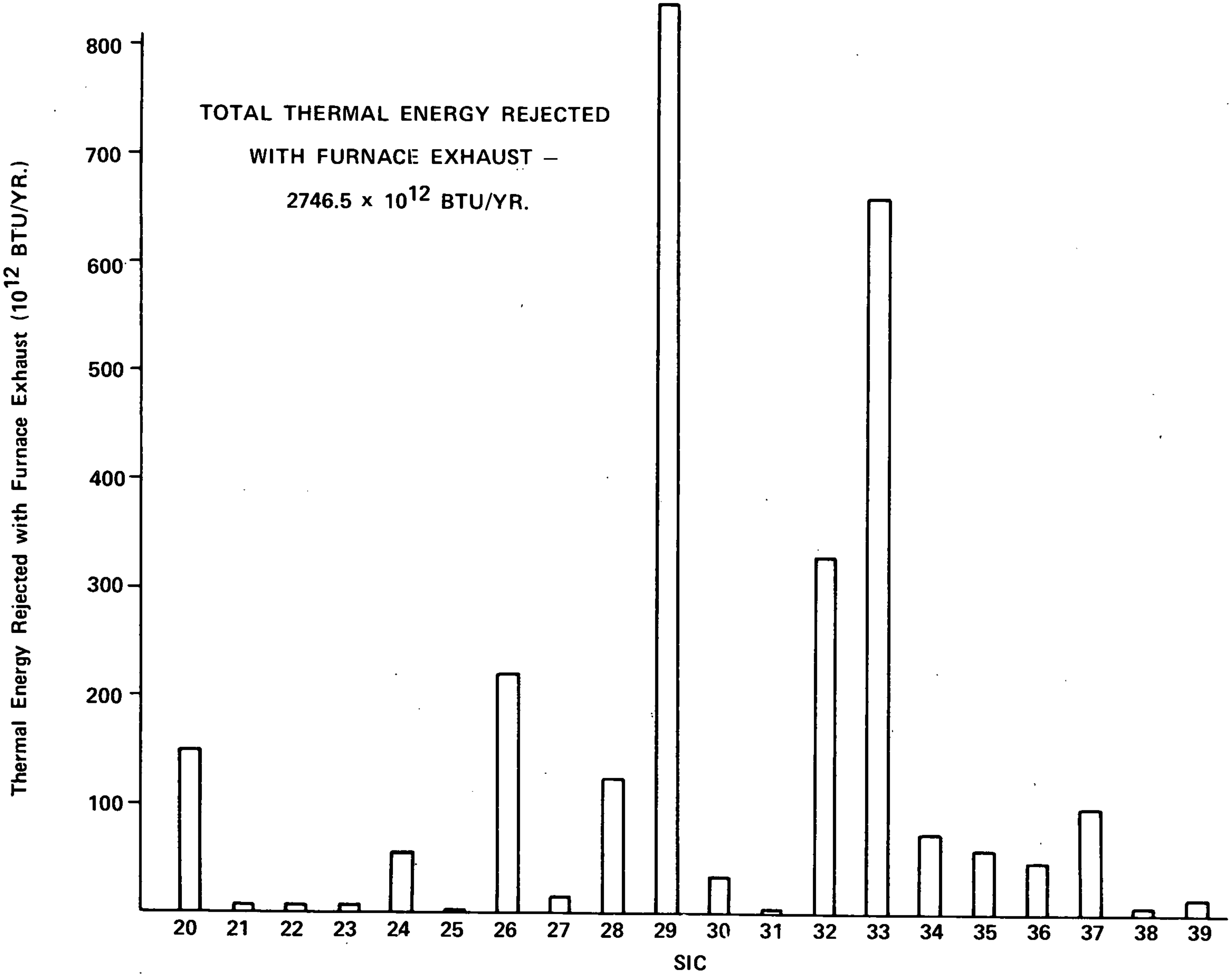
Thermal Energy Rejected with Product and Process by Each 2-digit SIC Industrial Group

Source: Industrial Applications Study, Vol. 1, Dept. of Energy, CONS/2862-1



Thermal Energy Rejected with Boiler Stack Exhaust by Each 2-digit SIC Industrial Group

Source: Industrial Applications Study, Vol. 1, Dept. of Energy, CONS/2862-1



Thermal Energy Rejected with Furnace Exhaust by Each 2-digit SIC Industrial Group

Source: Industrial Applications Study, Vol. 1, Dept. of Energy, CONS/2862-1

APPENDIX 5 : Results of the Significance Tests

Factor 1. Regional Factor

	Binghamton, NY		Allentown, PA		Total	
	Measure (1)	Measure (2)	Measure (1)	Measure (2)	Measure (1)	Measure (2)
A. Mean Adoption Rate	0.34	0.40	0.17	0.44	0.26	0.42

B. Test Results	Analysis 1	Analysis 2	Analysis 3
Eigen Value	0.08	0.007	0.25
Significance Level	0.12	0.60	0.03

Factor 2: Energy Intensity

	Low		Medium		High		Total	
A. Mean Adoption Rate	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	0.23	0.33	0.08	0.08	0.30	0.53	0.26	0.42

B. Test Results	Analysis 1	Analysis 2	Analysis 3
Eigen value	0.04	0.21	0.30
Sig. level	0.58	0.05	0.10

Factor 3. Energy Cut-back

	Yes Group		No Group		Total	
	(1)	(2)	(1)	(2)	(1)	(2)
A. Mean Adoption Rate	0.24	0.45	0.28	0.38	0.26	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen Value Sig. Level	(Singular matrices; solutions cannot be computed)		

Factor 4: Disruption of Production

	Yes Group		No Group		Total	
	(1)	(2)	(1)	(2)	(1)	(2)
A. Mean Adoption Rate	0.29	0.43	0.25	0.42	0.26	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen Value:	0.003	0.003	0.004
Sig. Level:	0.70	0.92	0.90

Factor 5: Firm Size

	1		2		3		4		5		Total	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
A. Adoption Rate	0.34	0.41	0.30	0.36	0.32	0.47	0.18	0.39	0.122	0.502	0.26	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen value	0.10	0.03	0.39
Sig. Level	0.59	0.90	0.29

Factor 6: Centralized Authority

		Group 1		Group 2		Group 3		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.30	0.54	0.24	0.36	0.14	0.19	0.26	0.42
B.	Results	Analysis 1		Analysis 2		Analysis 3			
	Eigen Value	0.02		0.15		0.25			
	Sig. Level	0.70		0.12		0.20			

Factor 7: Degree of Automation

		low		medium		high		total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.27	0.23	0.28	0.50	0.19	0.44	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3			
	Eigen value	0.01		0.06		0.15			
	sig. level	0.80		0.37		0.34			

Factor 8: Dependence on Natural Gas

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.33	0.30	0.28	0.27	0.30	0.29
B.	Test Results	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.01		0.12		0.17	
	Sig. level	0.57		0.06		0.09	

Factor 9: Age of Equipment

		0-10		10-20		20 ±		Total	
A.	Adoption Rate	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
		0.34	0.53	0.21	0.40	0.18	0.30	0.26	0.42

Factor 9 (cont'd)

B. Results	Analysis 1	Analysis 2	Analysis 3
Eigen value	0.07	0.12	0.13
sig. level	0.34	0.17	0.44

Factor 10: Growth Stage

	steady		growing		rapid growth		total	
A. Mean	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Adoption Rate	0.20	0.49	0.21	0.34	0.74	0.74	0.25	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen value	0.40	0.25	0.40
Sig. level	0.007	0.03	0.012

Factor 11: R&D Effort

	yes		no		total	
A. Mean	(1)	(2)	(1)	(2)	(1)	(2)
Adoption Rate	0.23	0.41	0.28	0.43	0.26	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen Value	0.005	0.0005	0.006
Sig. level	0.69	0.89	0.9

Factor 12: Special Payback Period Consideration

	yes		no		total	
A. Mean	(1)	(2)	(1)	(2)	(1)	(2)
Adoption Rate	0.45	0.69	0.22	0.37	0.26	0.42

B. Test Result	Analysis 1	Analysis 2	Analysis 3
Eigen Value	0.09	0.17	0.18
Sig. level	0.11	0.03	0.08

Factor 13: Energy Officer 1--only Responsibility

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.20	0.48	0.27	0.41	0.26	0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 3
	Eigen Value	0.006	0.007	0.04
	Sig. Level	0.67	0.65	0.56

Factor 14: Energy Officer 2--Chief Officer

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.43	0.43	0.20	0.42	0.26	0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 3
	Eigen Value	0.11	0.0004	0.20
	Sig. Level	0.07	0.91	0.06

Factor 15: Energy Officer 3--Technology/Science Background

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.19	0.45	0.31	0.40	0.25	0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 2
	Eigen Value	0.04	0.005	0.13
	Sig. Level	0.25	0.70	0.16

Factor 16: Energy Officer 4: Business/Finance Background

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.22	0.33	0.27	0.45	0.26	0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 3
	Eigen Value	0.003	0.029	0.035
	Sig. Level	0.75	0.35	0.60

Factor 17: Information 1: Industrial Association

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.25	0.47	0.27	0.31	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.0007		0.008		0.16	
	Sig. Level	0.88		0.16		0.115	

Factor 18: Information 2: Utility Company

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.26	0.42	0.25	0.43	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.001		0.002		0.003	
	Sig. Level	0.80		0.90		0.95	

Factor 19: Information 3: Government

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.35	0.60	0.22	0.36	0.25	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.03		0.13		0.15	
	Sig. Level	0.30		0.05		0.13	

Factor 20: Information 4: Other Firms

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.25	0.44	0.26	0.41	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.0002		0.002		0.005	
	Sig. Level	0.90		0.80		0.90	

Factor 21: Information 5: Consultants

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.36	0.53	0.21	0.36	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.06		0.06		0.07	
	Sig. Level	0.18		0.18		0.35	

Factor 22. Information 6: Within Firm

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.26	0.37	0.25	0.48	0.25	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.0001		0.03		0.07	
	Sig. Level	0.90		0.31		0.30	

Factor 23: Industrial Associations

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.24	0.46	0.29	0.33	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.007		0.04		0.14	
	Sig. Level	0.60		0.20		0.13	

Factor 24: Energy Committee

		Yes		No		Total	
A.	Mean	(1)	(2)	(1)	(2)	(1)	(2)
	Adoption Rate	0.22	0.44	0.27	0.41	0.26	0.42
B.	Test Result	Analysis 1		Analysis 2		Analysis 3	
	Eigen Value	0.007		0.0015		0.02	
	Sig. Level	0.60		0.80		0.70	

Factor 25: Perception: Government as Major Cause for the Energy Crisis

		Yes		No		Total	
A.	Mean Adoption Rate	(1) 0.21	(2) 0.51	(1) 0.28	(2) 0.37	(1) 0.25	(2) 0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 3
	Eigen Value	0.014	0.05	0.21
	Sig. Level	0.50	0.2	0.06

Factor 26: Communication Within Firm

		Level 1		Level 2		Level 3		Level 4		Total	
A.	Mean Adoption Rate	(1) 0.33	(2) 0.51	(1) 0.26	(2) 0.26	(1) 0.21	(2) 0.35	(1) 0.17	(2) 0.42	(1) 0.25	(2) 0.42

B.	Test Result	Analysis 1	Analysis 2	Analysis 3
	Eigen Value	0.05	0.09	0.12
	Sig. Level	0.68	0.40	0.58

APPENDIX 6. THE RESULT OF TWO-WAY FACTORIAL ANALYSES

Two-way Factorial Design: Probability Levels of Factors Influencing Adoption Rates*

	Ho 1 (Post-1973)	Ho 2 (Total)	Ho 3 (Combined)
Region	0.83	0.81	0.97
Energy Intensity	0.16	0.34	0.38
Interaction	0.28	0.73	0.49
Region	0.24	0.35	0.01
Natural gas	0.35	0.95	0.30
Interaction	0.38	0.43	0.05
Region	0.34	0.12	0.001
Growth	0.73	0.13	0.11
Interaction	0.66	0.13	0.01
Region	0.008	0.18	0.03
Payback	0.006	0.04	0.02
Interaction	0.01	0.16	0.06
Region	0.66	0.90	0.72
Chief Officer	0.86	0.79	0.82
Interaction	0.43	0.81	0.34
Region	0.08	0.16	0.22
Govt. information	0.09	0.04	0.13
Interaction	0.17	0.13	0.30
Region	0.47	0.38	0.68
Consultants	0.46	0.19	0.42
Interaction	0.79	0.32	0.52
Region	0.01	0.14	0.06
Govt. as cause	0.06	0.06	0.14
Interaction	0.04	0.11	0.13
Energy intensity	0.62	0.12	0.22
Natural gas	0.69	0.21	0.38
Interaction	0.65	0.14	0.27
Energy intensity	0.26	0.46	0.04
Growth	0.62	0.94	0.71
Interaction	0.21	0.90	0.14
Energy intensity	0.84	0.53	0.62
Payback	0.35	0.44	0.64
Interaction	0.75	0.82	0.82

*Significant factors (probability 6 percent or less that factors have no effect) are underlined

	Ho 1	Ho 2	Ho 3
Energy intensity	0.08	0.20	0.23
Chief officer	0.23	0.29	0.48
Interaction	0.08	0.35	0.20
Energy intensity	0.40	0.21	0.47
Govt. information	0.58	0.56	0.82
Interaction	0.42	0.31	0.59
Energy intensity**			
Consultants			
Interaction			
Energy intensity	0.35	0.67	0.20
Govt. as cause	0.43	0.76	0.68
Interaction	0.23	0.96	0.25
Natural gas	0.22	0.35	0.02
Growth	0.04	0.86	0.01
Interaction	0.04	0.86	0.01
Natural gas	0.94	0.48	0.61
Payback	0.69	0.34	0.61
Interaction	0.93	0.67	0.82
Natural gas	0.49	0.81	0.74
Chief officer	0.31	0.83	0.26
Interaction	0.55	0.82	0.55
Natural gas	0.19	0.12	0.30
Govt. information	0.13	0.12	0.25
Interaction	0.18	0.21	0.37
Natural gas	0.16	0.72	0.25
Consultants	0.08	0.98	0.06
Interaction	0.14	0.87	0.10
Natural gas	0.46	0.01	0.02
Govt. as cause	0.71	0.03	0.03
Interaction	0.57	0.05	0.08
Growth	0.04	0.52	0.08
Payback	0.37	0.76	0.35
Interaction	0.10	0.55	0.22
Growth	0.20	0.11	0.28
Chief officer	0.62	0.13	0.24
Interaction	0.35	0.11	0.28
Growth	0.08	0.64	0.14
Govt. information	0.33	0.84	0.32
Interaction	0.19	0.65	0.36

	Ho 1	Ho 2	Ho 3
Growth	0.04	0.15	0.13
Consultants	0.16	0.26	0.37
Interaction	0.09	0.12	0.22
Growth	0.02	0.78	0.0006
Govt. as cause	0.05	0.48	0.0006
Interaction	0.08	0.72	0.0048
Payback	0.05	0.08	0.13
Chief officer	0.05	0.21	0.15
Interaction	0.10	0.21	0.26
Payback	0.92	0.35	0.54
Govt. information	0.83	0.48	0.56
Interaction	0.73	0.69	0.70
Payback	0.18	0.28	0.40
Consultants	0.24	0.48	0.52
Interaction	0.35	0.64	0.65
Payback	0.02	0.11	0.07
Govt. as cause	0.10	0.26	0.26
Interaction	0.06	0.32	0.16
Chief officer	0.04	0.34	0.12
Govt. information	0.07	0.16	0.20
Interaction	0.11	0.33	0.28
Chief officer	0.04	0.26	0.12
Consultants	0.06	0.12	0.18
Interaction	0.09	0.20	0.25
Chief officer	0.27	0.90	0.22
Govt. as cause	0.58	0.93	0.76
Interaction	0.50	0.84	0.48
Govt. information	0.17	0.24	0.38
Consultants	0.13	0.44	0.31
Interaction	0.18	0.47	0.42
Govt. information	0.43	0.52	0.73
Govt. as cause	0.79	0.75	0.95
Interaction	0.63	0.94	0.83
Consultants	0.66	0.76	0.65
Govt. as cause	0.88	0.72	0.93
Interaction	0.96	0.48	0.60

**Singular matrix; results unobtainable. Singular matrices means that one or more row/column entries in a matrix is (are) linear combination of other row/column entries. This property would not allow for inversion of the matrix with normal procedures (except by means of a generalized inverse method). Thus solutions cannot be obtained in the analysis.

APPENDIX 7:

Significance Tests From Policy Option Responses by Firm Characteristic Factors

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

	Policy Option 1: Use of Recycled Material			Policy Option 2: Deregulation of Energy Prices		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region (Binghamton vs Allentown)	A1	4.1	0.36	A2	0.4	0.76
	B1	0.0	1.000	B2	1.8	0.52
	C1	3.3	0.4	C2	7.3	0.19
	M		0.5	M		0.28
2. Energy cutback (cutbacks vs. no cutback)	A1	0.0	1.00	A2	1.1	0.60
	B1	4.7	0.33	B2	1.9	0.57
	C1	2.4	0.48	C2	1.8	0.52
	M		0.34	M		0.93
3. Disruption of production (disruption vs. no disruption)	A1	11.4	0.12	A2	0.4	0.73
	B1	1.4	0.59	B2	8.0	0.17
	C1	15.8	0.06	C2	12.3	0.08
	M		0.14	M		0.30
4. Dependence on natural gas (yes or no)	A1	1.7	0.56	A2	5.6	0.25
	B1	0.0	1.00	B2	5.6	0.25
	C1	1.5	0.58	C2	8.0	0.16
	M		0.83	M		0.54
5. Energy Officer 1: energy is officer's only responsibility	A1	3.1	0.43	A2	1.9	0.50
	B1	3.4	0.40	B2	1.9	0.50
	C1	8.0	0.20	C2	0.8	0.66
	M		0.60	M		0.33
6. Energy officer 2: energy officer is also the chief officer	A1	5.7	0.28	A2	8.7	0.15
	B1	14.5	0.08	B2	19.4	0.02
	C1	20.9	0.03	C2	24.0	0.013
	M		0.14	M		0.11
7. Energy officer 3: Energy officer with technology/science background	A1	0.0	1.00	A2	0.0	0.90
	B1	1.1	0.6	B2	8.3	0.06
	C1	8.3	0.19	C2	2.6	0.44
	M		0.53	M		0.10

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
8. Energy officer 4: Energy officer with business/finance background	A1	11.4	0.12	A2	13.2	0.07
	B1	5.7	0.28	B2	3.6	0.36
	C1	5.5	0.73	C2	14.8	0.05
	M		0.48	M		0.01
9. Energy Committee (yes or no, within the firm)	A1	10.4	0.14	A2	3.3	0.38
	B1	5.2	0.30	B2	10.4	0.11
	C1	0.0	0.96	C2	24.0	0.012
	M		0.42	M		0.05
10. Energy intensity (high vs. medium & low)	A1	12.9	0.099	A2	5.8	0.24
	B1	14.6	0.07	B2	11.3	0.09
	C1	6.5	0.25	C2	19.8	0.026
	M		0.3	M		0.15
11. Firm size (five levels)	A1	1.8	0.54	A2	1.0	0.64
	B1	1.1	0.63	B2	2.1	0.48
	C1	4.6	0.33	C2	0.0	0.97
	M		0.81	M		0.48
12. Degree of Automation (three levels)	A1	6.4	0.25	A2	0.6	0.73
	B1	11.2	0.12	B2	4.9	0.28
	C1	2.4	0.48	C2	6.1	0.23
	M		0.13	M		0.64
13. Age of equipment (three levels)	A1	8.0	0.20	A2	1.9	0.50
	B1	1.4	0.59	B2	1.4	0.56
	C1	2.9	0.44	C2	2.0	0.49
	M		0.24	M		0.89
14. Centralized authority (total autonomy vs. firm dependence on a mother company)	A1	2.6	0.55	A2	0.0	0.91
	B1	0.0	1.00	B2	0.0	0.94
	C1	21.0	0.03	C2	0.4	0.74
	M		0.09	M		0.94
15. Degree of communication within the firm (four levels)	A1	0.2	0.85	A2	0.4	0.74
	B1	0.2	0.84	B2	1.5	0.55
	C1	1.6	0.56	C2	3.5	0.37
	M		0.71	M		0.81
16. Energy information 1: industrial association (yes or no)	A1	10.4	0.14	A2	0.0	0.94
	B1	20.9	0.03	B2	0.3	0.77
	C1	4.6	0.33	C2	5.2	0.27
	M		0.22	M		0.33

	Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
17.	Energy information 2: utility company (yes or no)	A1	0.0	1.00	A2	11.4	0.098
		B1	1.1	0.63	B2	8.3	0.16
		C1	0.3	0.79	C2	2.6	0.44
		M		0.87	M		0.311
18.	Energy information 3: government (yes or no)	A1	0.0	1.00	A2	7.0	0.19
		B1	0.57	1.6	B2	0.4	0.75
		C1	0.2	0.85	C2	1.8	0.52
		M		0.89	M		0.35
19.	Energy information 4: other firms (yes or no)	A1	29.1	0.009	A2	0.4	0.73
		B1	20.9	0.03	B2	8.0	0.17
		C1	21.4	0.03	C2	2.7	0.43
		M		0.04	M		0.30
20.	Energy information 5: Consulting firms (yes or no)	A1	9.8	0.15	A2	8.7	0.15
		B1	11.0	0.13	B2	11.3	0.10
		C1	3.9	0.37	C2	15.4	0.05
		M		0.48	M		0.27
21.	Energy information 6: within the firm (yes or no)	A1	0.0	1.00	A2	5.3	0.26
		B1	1.2	0.61	B2	5.6	0.25
		C1	1.5	0.58	C2	10.0	0.12
		M		0.60	M		0.42
22.	Member of an industrial association (yes or no)	A1	17.4	0.05	A2	4.7	0.29
		B1	30.7	0.007	B2	3.7	0.35
		C1	1.6	0.56	C2	11.4	0.09
		M		0.05	M		0.21
23.	Consideration of a longer payback period (yes or no)	A1	0.0	1.00	A2	5.6	0.25
		B1	0.0	1.00	B2	5.6	0.25
		C1	1.5	0.58	C2	0.4	0.75
		M		0.39	M		0.31
24.	Growth state (three stages)	A1	0.6	0.73	A2	1.7	0.53
		B1	0.6	0.71	B2	5.0	0.28
		C1	6.3	0.26	C2	2.7	0.42
		M		0.73	M		0.73
25.	R&D (yes or no)	A1	4.1	0.36	A2	4.4	0.39
		B1	10.3	0.14	B2	1.7	0.52
		C1	3.3	0.41	C2	3.3	0.38
		M		0.55	M		0.75
26.	Perceives the government as the major cause of the recent energy disaster (yes or no)	A1	0.0	1.00	A2	3.8	0.34
		B1	5.7	0.20	B2	0.6	0.70
		C1	9.7	0.15	C2	2.7	0.43
		M		0.27	M		0.54

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

	Policy Option 3: Federal Tax on Energy			Policy Option 4: Off-Peak Use Incentive		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region (Binghamton vs. Allentown)	A3	4.3	0.36	A4	0.0	1.00
	B3	7.6	0.22	B4	3.9	0.39
	C3	5.1	0.32	C4	6.9	0.20
	M		0.68	M		0.34
2. Energy cutback (cutbacks vs. no cutback)	A3	2.4	0.50	A4	0.8	0.66
	B3	0.1	0.88	B4	0.6	0.71
	C3	5.1	0.32	C4	3.7	0.35
	M		0.19	M		0.50
3. Disruption of production (disruption vs. no disruption)	A3	1.3	0.62	A4	1.0	0.63
	B3	1.3	0.62	B4	0.6	0.70
	C3	0.0	0.92	C4	0.0	1.92
	M		0.64	M		0.54
4. Dependence on natural gas (yes or no)	A3	0.0	0.97	A4	1.3	0.59
	B3	22.7	0.029	B4	0.2	0.82
	C3	16.0	0.07	C4	1.4	0.57
	M		0.04	M		0.59
5. Energy Officer 1: energy is officer's only responsibility	A3	5.1	0.32	A4	2.7	0.43
	B3	2.1	0.52	B4	8.4	0.16
	C3	2.0	0.52	C4	1.9	0.50
	M		0.81	M		0.07
6. Energy officer 2: energy officer is also the chief officer	A3	0.0	0.97	A4	17.5	0.03
	B3	3.8	0.39	B4	4.6	0.30
	C3	6.1	0.27	C4	7.0	0.20
	M		0.63	M		0.11
7. Energy officer 3: Energy officer with technology/ science background	A3	0.7	0.70	A4	3.2	0.38
	B3	0.7	0.70	B3	5.7	0.24
	C3	0.1	0.87	C4	11.7	0.09
	M		0.85	M		0.20
8. Energy officer 4: Energy officer with business/ finance background	A3	0.0	0.93	A4	1.0	0.63
	B3	0.0	0.93	B4	1.7	0.52
	C3	1.5	0.59	C4	3.6	0.36
	M		0.80	M		0.44

Policy 3 & 4 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
9. Energy committee (yes or no, within the firm)	A3	0.2	0.85	A4	0.9	0.64
	B3	1.2	0.19	B4	0.3	0.78
	C3	5.3	0.31	C4	0.0	0.92
	M		0.51	M		0.74
10. Energy intensity (high vs. medium & low)	A3	1.4	0.60	A4	1.9	0.50
	B3	1.4	0.60	B4	3.4	0.37
	C3	4.8	0.33	C4	6.9	0.20
	M		0.44	M		0.13
11. Firm size (five levels)	A3	24.4	0.02	A4	3.2	0.39
	B3	6.5	0.26	B4	3.1	0.39
	C3	6.5	0.26	C4	5.4	0.26
	M	0.17		M		0.12
12. Degree of automation (three levels)	A3	0.2	0.83	A4	3.2	0.39
	B3	2.6	0.47	A4	1.0	0.62
	C3	2.8	0.46	C4	3.6	0.36
	M		0.89	M		0.39
13. Age of equipment (three levels)	A3	9.1	0.18	A4	2.4	0.46
	B3	23.1	0.02	B4	0.5	0.73
	C3	20.6	0.038	C4	0.6	0.71
	M		0.19	M		0.89
14. Centralized authority (total autonomy vs. firm dependence on a mother company)	A3	2.5	0.49	A4	11.3	0.10
	B3	3.3	0.42	B4	0.7	0.67
	C3	2.9	0.45	C4	1.6	0.54
	M		0.88	M		0.21
15. Degree of communication within the firm (four levels)	A3	12.8	0.11	A4	0.1	0.86
	B3	0.0	0.96	B4	1.5	0.55
	C3	3.9	0.38	C4		1.00
	M		0.06	M		0.27
16. Energy information 1: industrial association (yes or no)	A3	8.1	0.21	A4	3.7	0.35
	B3	6.0	0.28	B4	0.3	0.78
	C3	2.7	0.47	C4	1.4	0.56
	M		0.58	M		0.36
17. Energy information 2: utility company (yes or no)	A3	0.0	0.93	A4	3.5	0.37
	B3	2.3	0.51	B4	4.5	0.31
	C3	1.5	0.59	C4	1.9	0.51
	M		0.85	M		0.59

Policy 3 & 4 (cont'd)

	Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
18.	Energy information 3: government (yes or no)	A3	6.0	0.28	A4		1.00
		B3	1.3	0.62	B4	1.7	0.52
		C3	2.7	0.47	C4	0.0	0.92
		M		0.27	M		0.08
19.	Energy information 4: other firms (yes or no)	A3	4.5	0.35	A4	3.7	0.35
		B3	0.7	0.71	B4	12.4	0.08
		C3	10.3	0.15	C4	8.0	0.17
		M		0.08	M		0.28
20.	Energy information 5: consulting firms (yes or no)	A3	0.1	0.88	A4	3.5	0.37
		B3	2.4	0.50	B4		0.95
		C3	5.1	0.32	C4	1.9	0.51
		M		0.64	M		0.17
21.	Energy information 6: within the firm (yes or no)	A3	2.3	0.51	A4	0.9	0.64
		B3	8.1	0.21	B4	0.2	0.83
		C3	1.5	0.59	C4	0.0	0.92
		M		0.09	M		0.60
22.	Member of an industrial association (yes or no)	A3	2.9	0.46	A4	0.9	0.65
		B3	2.9	0.46	B4	3.5	0.36
		C3	0.8	0.60	C4	6.5	0.21
		M		0.81	M		0.24
23.	Consideration of a longer pay-back period (yes or no)	A3	7.2	0.23	A4	0.0	1.00
		B3	19.7	0.04	B4	0.1	0.86
		C3	12.0	0.12	C4	0.2	0.80
		M		0.25	M		0.61
24.	Growth state (three stages)	A3	12.6	0.11	A4	0.1	0.73
		B3	8.9	0.18	B4	0.1	0.88
		C3	17.8	0.056	C4	0.6	0.72
		M		0.18	M		0.88
25.	R&D (yes or no)	A3	1.1	0.63	A4	0.0	1.00
		B3	0.8	0.69	B4	0.6	0.70
		C3	2.2	0.48	C4	0.6	0.71
		M		0.86	M		0.96
26.	Perceives the government as the major cause of the recent energy disaster (yes or no)	A3	2.9	0.46	A4	0.9	0.64
		B3	0.7	0.71	B4	2.2	0.48
		C3	0.2	0.84	C4	0.6	0.70
		M		0.66	M		0.32

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

	Policy Option 5: Fed. Mandate Energy Allocation			Policy Option 6: Favorable Loan Terms		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region Binghamton vs. Allentown)	A5	3.2	0.36	A6	0.0	0.91
	B5	0.0	0.91	B6	2.8	0.41
	C5	0.6	0.70	C6	0.8	0.66
	M		0.43	M		0.52
2. Energy cutback (cutbacks vs. no cutback)	A5	0.1	0.87	A6	14.5	0.27
	B5	5.4	0.23	B6	8.9	0.14
	C5	7.8	0.15	C6	9.8	0.12
	M		0.34	M		0.52
3. Disruption of production (disruption vs. no disruption)	A5	16.2	0.03	A6	0.0	0.93
	B5	4.7	0.27	B6	1.4	0.56
	C5	5.3	0.24	C6	2.2	0.47
	M		0.007	M		0.77
4. Dependence on natural gas (yes or no)	A5	10.2	0.10	A6	3.6	0.36
	B5	6.2	0.20	B6	1.6	0.54
	C5	6.2	0.20	C6	2.1	0.49
	M		0.02	M		0.31
5. Energy officer 1: energy is officer's only responsibility	A5	0.6	0.70	A6	3.1	0.39
	B5	2.8	0.39	B6	0.4	0.75
	C5	1.8	0.50	C6	6.5	0.21
	M		0.66	M		0.0025
6. Energy officer 2: energy officer is also the chief officer	A5	1.0	0.60	A6	12.3	0.08
	B5	4.7	0.27	B6	26.5	0.07
	C5	5.3	0.24	C6	12.9	0.07
	M		0.41	M		0.29
7. Energy officer 3: energy officer with technology/ science background	A5	1.1	0.59	A6	6.6	0.21
	B5	9.4	0.11	B6	1.4	0.55
	C5	5.3	0.24	C6	0.2	0.82
	M		0.13	M		0.19
8. Energy officer 4: energy officer with business/ finance background	A5	0.9	0.63	A6	0.9	0.64
	B5	0.8	0.68	B6	18.0	0.03
	C5	0.0	0.92	C6	12.3	0.08
	M		0.27	M		0.02

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
9. Energy committee (yes or no, within the firm)	A5	4.3	0.29	A6	2.6	0.43
	B5	7.1	0.17	B6	1.0	0.62
	C5	10.6	0.09	C6	2.8	0.42
	M		0.32	M		0.62
10. Energy intensity (high vs. medium & low)	A5	0.8	0.65	A6	0.0	1.00
	B5	1.5	0.54	B6	10.7	0.11
	C5	2.7	0.40	C6	12.5	0.08
	M		0.53	M		0.16
11. Firm size (five levels)	A5	0.0	0.92	A6	6.6	0.21
	B5	4.2	0.30	B6	0.8	0.66
	C5	1.6	0.52	C6	0.0	1.00
	M		0.40	M		0.18
12. Degree of automation (three levels)	A5	4.9	0.42	A6	1.3	0.58
	B5	0.3	0.76	B6	0.4	0.82
	C5	0.1	0.84	C6	1.0	0.62
	M		0.83	M		0.47
13. Age of equipment (three levels)	A5	0.0	0.94	A6	1.1	0.59
	B5	2.2	0.45	B6	3.1	0.39
	C5	0.5	0.72	C6	1.1	0.61
	M		0.50	M		0.40
14. Centralized authority (total autonomy vs. firm dependence on a mother company)	A5	0.0	0.96	A6	9.7	0.12
	B5	4.5	0.28	B6	0.0	0.95
	C5	4.5	0.28	C6	0.0	0.92
	M		0.70	M		0.18
15. Degree of communication within the firm (four levels)	A5	10.7	0.09	A6	5.5	0.25
	B5	3.1	0.37	B6	4.6	0.30
	C5	4.8	0.27	C6	7.4	0.18
	M		0.02	M		0.48
16. Energy information 1: industrial association (yes or no)	A5	1.5	0.53	A6	3.3	0.37
	B5	4.5	0.28	B6	1.4	0.56
	C5	7.2	0.17	C6	0.0	0.90
	M		0.46	M		0.21
17. Energy information 2: utility company (yes or no)	A5	1.4	0.54	A6	9.4	0.13
	B5	1.3	0.57	B6	14.5	0.05
	C5	0.3	0.77	C6	15.6	0.05
	M		0.61	M		0.28

Policy Option 5 & 6 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
18. Energy information 3: government (yes or no)	A5	0.8	0.64	A6	11.6	0.09
	B5	0.1	0.87	B6	0.0	0.90
	C5	0.3	0.77	C6	0.6	0.69
	M		0.85	M		0.09
19. Energy information 4: other firms (yes or no)	A5	4.1	0.30	A6	0.0	0.93
	B5	4.7	0.27	B6	1.4	0.56
	C5	5.3	0.24	C6	2.2	0.47
	M		0.18	M		0.77
20. Energy information 5: consulting firms (yes or no)	A5	0.1	0.87	A6	7.5	0.18
	B5	2.8	0.39	B6	0.5	0.72
	C5	3.7	0.33	C6	1.0	0.62
	M		0.68	M		0.15
21. Energy information 6: within the firm (yes or no)	A5	0.0	0.25	A6	0.2	0.08
	B5	0.1	0.85	B6	2.7	0.42
	C5	0.0	0.96	C6	3.7	0.35
	M		0.53	M		0.74
22. Member of an industrial association (yes or no)	A5	0.2	0.82	A6	0.0	0.88
	B5	2.5	0.42	B6	1.0	0.62
	C5	4.6	0.27	C6	2.8	0.42
	M		0.55	M		0.45
23. Consideration of a longer pay-back period (yes or no)	A5	3.0	0.38	A6	0.2	0.82
	B5	6.2	0.20	B6	8.3	0.16
	C5	6.2	0.20	C6	8.3	0.16
	M		0.65	M		0.46
24. Growth state (three stages)	A5	1.3	0.55	A6	1.3	0.57
	B5	2.2	0.45	B6	1.4	0.56
	C5	2.2	0.45	C6	0.8	0.66
	M		0.63	M		0.87
25. R&D (yes or no)	A5	13.8	0.05	A6	1.3	0.56
	B5	0.2	0.79	B6	0.7	0.52
	C5	0.9	0.62	C6	3.4	0.37
	M		0.24	M		0.28
26. Perceives the government as the major cause of the recent energy disaster (yes or no)	A5	13.3	0.06	A6	0.4	0.75
	B5	0.0	0.98	B6	0.5	0.72
	C5	0.1	0.87	C6	0.0	0.90
	M		0.21	M		0.39

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

		Policy Option 7: Federally Guaranteed Loans		Policy Option 8: Tax Credits		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region (Binghamton vs. Allentown)	A7	0.0	0.93	A8	0.0	0.95
	B7	1.5	0.56	B8	5.0	0.27
	C7	0.4	0.75	C8	1.6	0.53
	M		0.59	M		0.16
2. Energy cutback (cutbacks vs no cutback)	A7	13.5	0.07	A8	0.1	0.85
	B7	21.6	0.02	B8	7.8	0.17
	C7	16.4	0.04	C8	8.3	0.16
	M		0.10	M		0.19
3. Disruption of production (disruption vs. no disruption)	A7	6.3	0.23	A8	0.1	0.85
	B7	2.2	0.49	B8	0.0	0.93
	C7	3.2	0.40	C8	0.9	0.64
	M		0.62	M		0.48
4. Dependence on natural gas (yes or no)	A7	1.5	0.56	A8	0.6	0.72
	B7	6.5	0.23	B8	4.2	0.32
	C7	7.9	0.18	C8	4.4	0.31
	M		0.30	M		0.66
5. Energy officer 1: energy is officer's only responsibility	A7	2.7	0.43	A8	2.4	0.45
	B7	1.7	0.53	B8	1.4	0.56
	C7	1.4	0.58	C8	1.5	0.55
	M		0.85	M		0.91
6. Energy officer 2: Energy officer is also the chief officer	A7	6.3	0.23	A8	0.3	0.78
	B7	6.4	0.23	B8	0.5	0.73
	C7	3.2	0.40	C8	0.9	0.64
	M		0.20	M		0.73
7. Energy officer 3: Energy officer with technology/ science background	A7	0.1	0.89	A8	4.1	0.32
	B7	2.6	0.44	B8	6.6	0.21
	C7	4.1	0.32	C8	2.6	0.43
	M		0.17	M		0.31
8. Energy officer 4: energy officer with business/ finance background	A7	5.4	0.27	A8	5.4	0.26
	B7	15.0	0.06	B8	16.7	0.04
	C7	12.9	0.08	C8	10.7	0.11
	M		0.24	M		0.11

Policy Option 7 & 8 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
9. Energy committee (yes or no, within the firm)	A7	0.1	0.69	A8	4.0	0.33
	B7	0.1	0.86	B8	7.8	0.17
	C7	0.0	1.00	C8	8.3	0.16
	M		0.71	M		0.58
10. Energy intensity (high vs. medium & low)	A7	5.7	0.25	A8	0.6	0.71
	B7	12.7	0.08	B8	7.7	0.17
	C7	9.1	0.15	C8	3.4	0.37
	M		0.29	M		0.15
11. Firm size (five levels)	A7	6.9	0.21	A8	3.0	0.40
	B7	14.5	0.06	B8	4.9	0.28
	C6	19.0	0.03	C8	1.0	0.63
	M		0.06	M		0.17
12. Degree of automation (three levels)	A7	0.1	0.83	A8	9.4	0.13
	B7	0.8	0.67	B8	14.6	0.05
	C7	2.0	0.50	C8	15.4	0.05
	M		0.54	M		0.30
13. Age of equipment (three levels)	A7	0.6	0.71	A8	1.4	0.55
	B7	4.5	0.31	B8	11.4	0.09
	C7	2.8	0.43	C8	9.7	0.12
	M		0.07	M		0.22
14. Centralized authority (total autonomy vs. firm dependence on a mother company)	A7	0.1	0.84	A8	9.7	0.13
	B7	1.6	0.54	B8	21.7	0.01
	C7	0.5	0.73	C8	11.6	0.09
	M		0.70	M		0.02
15. Degree of communication within the firm (four levels)	A7	9.3	0.14	A8	0.9	0.64
	B7	8.9	0.15	B8	0.0	0.96
	C7	6.2	0.23	C8	0.5	0.71
	M		0.30	M		0.65
16. Energy information 1: industrial association (yes or no)	A7	0.7	0.69	A8	1.4	0.55
	B7	1.9	0.51	B8	2.5	0.44
	C7	1.0	0.63	C8	0.9	0.64
	M		0.84	M		0.71
17. Energy information 2: utility company (yes or no)	A7	9.9	0.13	A8	18.5	0.03
	B7	4.9	0.29	B8	11.2	0.10
	C7	7.0	0.21	C8	11.8	0.09
	M		0.45	M		0.21

Policy Option 7 & 8 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
18. Energy information 3: Government (yes or no)	A7	0.4	0.76	A8	1.4	0.56
	B7	0.7	0.69	B8	5.3	0.26
	C7	1.3	0.59	C8	5.5	0.25
	M		0.30	M		0.66
19. Energy information 4: other firms (yes or no)	A7	0.0	0.96	A8	4.0	0.33
	B7	0.4	0.75	B8	1.8	0.52
	C7	0.1	0.86	C8	0.1	0.88
	M		0.91	M		0.24
20. Energy information 5: consulting firms (yes or no)	A7	0.4	0.76	A8	1.4	0.55
	B7	9.5	0.14	B8	1.8	0.52
	C7	5.1	0.28	C8	0.1	0.88
	M		0.10	M		0.07
21. Energy information 6: within the firm (yes or no)	A7	0.7	0.69	A8	5.4	0.26
	B7	0.1	0.86	B8	1.4	0.56
	C7	1.0	0.63	C8	3.5	0.37
	M		0.63	M		0.43
22. Member of an industrial association (yes or no)	A7	1.7	0.54	A8	0.6	0.72
	B7	3.0	0.42	B8	1.4	0.56
	C7	2.3	0.53	C8	0.4	0.77
	M		0.76	M		0.76
23. Consideration of a longer pay-back period (yes or no)	A7	0.0	0.95	A8	0.6	0.72
	B7	1.8	0.53	B8	4.2	0.32
	C7	2.5	0.45	C8	4.4	0.31
	M		0.35	M		0.66
24. Growth state (three stages)	A7	0.8	0.66	A8	0.1	0.82
	B7	4.7	0.30	B8	0.7	0.68
	C7	1.6	0.55	C8	2.1	0.78
	M		0.25	M		0.75
25. R&D (yes or no)	A7	0.0	0.93	A8	9.9	0.12
	B7	0.5	0.73	B8	0.7	0.67
	C7	0.1	0.87	C8	1.6	0.53
	M		0.87	M		0.19
26. Perceives the government as the major cause of the recent energy disaster (yes or no)	A7	0.4	0.76	A8	1.4	0.55
	B7	0.1	0.89	B8	2.5	0.44
	C7	0.0	1.00	C8	5.7	0.27
	M		0.75	M		0.53

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

	Policy Option 9: Government Sponsored Consultants			Policy Option 10: Tax Credits for Energy Management Program		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region (Binghamton vs. Allentown)	A9	8.6	0.13	A10	3.7	0.34
	B9	0.0	0.94	B10	2.8	0.41
	C9	0.5	0.70	C10	1.0	0.61
	M		0.25	M		0.70
2. Energy cutback (cutbacks vs. no cutback)	A9	18.6	0.02	A10	0.0	0.95
	B9	7.9	0.15	B10	6.5	0.20
	C9	7.9	0.15	C10	6.0	0.22
	M		0.16	M		0.25
3. Disruption of production (disruption vs. no disruption)	A9	2.0	0.47	A10	1.9	0.49
	B9	2.7	0.41	B10	1.4	0.56
	C9	1.3	0.57	C10	4.6	0.29
	M		0.66	M		0.12
4. Dependence on natural gas (yes or no)	A9	5.2	0.24	A10	0.5	0.86
	B9	0.3	0.76	B10	3.9	0.32
	C9	0.9	0.63	C10	6.3	0.21
	M		0.68	M		0.47
5. Energy officer 1: energy is officer's only responsibility	A9	0.3	0.76	A10	0.4	0.76
	B9	0.5	0.72	B10	0.6	0.69
	C9	0.8	0.65	C10	1.3	0.57
	M		0.82	M		0.93
6. Energy officer 2: energy officer is also the chief officer	A9	7.0	0.18	A10	8.2	0.15
	B9	0.9	0.63	B10	0.9	0.64
	C9	1.9	0.48	C10	4.3	0.30
	M		0.59	M		0.14
7. Energy officer 3: energy officer with technology/science background	A9	3.7	0.33	A10	16.4	0.03
	B9	5.5	0.23	B10	20.6	0.02
	C9	0.3	0.25	C10	21.2	0.01
	M		0.68	M		0.12

Policy Option 9 & 10 (cont'd)

	Factor	Dependent variable	Percent of variance explained	Prob. $>$ F.	Dependent variable	Percent variance explained	Prob. $>$ F.
8.	Energy officer 4: Energy officer with business/ finance background	A9	0.1	0.88	A10	6.7	0.20
		B9	4.0	0.31	B10	26.9	0.006
		C9	1.9	0.48	C10	17.2	0.03
		M		0.56	M		0.02
9.	Energy committee (yes or no, within the firm)	A9	0.9	0.22	A10	1.9	0.49
		B9	1.6	0.51	B10	0.7	0.67
		C9	0.8	0.65	C10	2.9	0.40
		M		0.24	M		0.61
10.	Energy intensity (high vs. medium & low)	A9	0.7	0.66	A10	3.8	0.33
		B9	5.4	0.24	B10	7.7	0.17
		C9	4.6	0.24	C10	1.7	0.52
		M		0.70	M		0.17
11.	Firm size (five levels)	A9	5.4	0.24	A10	18.2	0.02
		B9	3.5	0.34	B10	15.8	0.04
		C9	3.7	0.33	C10	16.7	0.03
		M		0.69	M		0.16
12.	Degree of automation (three levels)	A9	0.4	0.76	A10	0.0	0.98
		B9	0.0	0.94	B10	0.9	0.64
		C9	0.0	0.92	C10	2.6	0.42
		M		0.96	M		0.70
13.	Age of equipment (three levels)	A9	0.5	0.72	A10	0.1	0.85
		B9	0.3	0.77	B10	1.1	0.60
		C9	1.3	0.57	C10	1.5	0.54
		M		0.80	M		0.92
14.	Centralized authority (total autonomy vs. firm dependence on a mother company)	A9	0.2	0.81	A10	1.6	0.53
		B9	0.0	0.97	B10	5.1	0.26
		C9	0.1	0.85	C10	0.4	0.76
		M		0.90	M		0.14
15.	Degree of communication within the firm (four levels)	A9	1.7	0.51	A10	0.6	0.70
		B9	5.1	0.25	B10	1.5	0.54
		C9	8.8	0.13	C10	0.2	0.82
		M		0.32	M		0.75
16.	Energy information 1: industrial association (yes or no)	A9	0.3	0.76	A10	0.7	0.67
		B9	0.1	0.87	B10	4.9	0.27
		C9	0.0	1.00	C10	1.4	0.56
		M		0.94	M		0.42
17.	Energy information 2: utility company (yes or no)	A9	0.8	0.65	A10	11.5	0.08
		B9	4.4	0.29	B10	3.8	0.33
		C9	1.5	0.53	C10	4.6	0.30
		M		0.40	M		0.38

Policy Option 9 & 10 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
18. Energy information 3: government (yes or no)	A9	0.8	0.64	A10	1.3	0.57
	B9	0.1	0.90	B10	7.2	0.18
	C9	0.4	0.73	C10	10.6	0.10
	M		0.90	M		0.35
19. Energy information 4: other firms (yes or no)	A9	2.0	0.47	A10	4.0	0.32
	B9	13.3	0.06	B10	18.2	0.02
	C9	8.9	0.13	C10	25.5	0.008
	M		0.25	M		0.04
20. Energy information 5: consulting firms (yes or no)	A9	0.2	0.82	A10	0.7	0.87
	B9	0.1	0.85	B10	0.7	0.67
	C9	0.5	0.72	C10	0.0	0.91
	M		0.93	M		0.35
21. Energy information 6: within the firm (yes or no)	A9	1.0	0.61	A10	0.2	0.80
	B9	3.7	0.33	B10	0.1	0.88
	C9	2.4	0.43	C10	2.0	0.49
	M		0.76	M		0.13
22. Member of an industrial association (yes or no)	A9	0.6	0.70	A10	1.5	0.54
	B9	0.0	0.98	B10	5.8	0.23
	C9	0.0	0.92	C10	1.7	0.52
	M		0.96	M		0.37
23. Consideration of a longer pay-back period (yes or no)	A9	11.5	0.08	A10	1.0	0.63
	B9	3.2	0.37	B10	0.6	0.70
	C9	4.2	0.30	C10	1.9	0.49
	M		0.40	M		0.50
24. Growth state (three stages)	A9	2.1	0.46	A10	0.4	0.76
	B9	6.9	0.18	B10	1.1	0.61
	C9	7.3	0.17	C10	0.3	0.78
	M		0.61	M		0.91
25. R&D (yes or no)	A9	1.1	0.59	A10	9.0	0.13
	B9	10.7	0.09	B10	0.5	0.72
	C9	0.3	0.25	C10	3.7	0.34
	M		0.17	M		0.09
26. Perceives the government as the major cause of the recent energy disaster (yes or no)	A9	0.4	0.76	A10	10.2	0.11
	B9	12.7	0.06	B10	6.5	0.20
	C9	12.9	0.06	C10	6.0	0.22
	M		0.20	M		0.48

Key to dependent variables
A = Effectiveness
B = Attractiveness to industry in general
C = Attractiveness to own firm
M = Multivariate
Numbers following variable letters refer to policy options (1, 2, ..., 12)

	Policy Option 11: R&D Sponsored by Government Agencies			Policy Option 12: R&D by Industries Subsidized by Federal Incentives		
Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
1. Region (Binghamton vs. Allentown)	A11	18.9	0.02	A12	5.0	0.34
	B11	1.3	0.55	B12	0.6	0.75
	C11	1.4	0.55	C12	0.6	0.75
	M		0.02	M		0.37
2. Energy cutback (cutbacks vs. no cutback)	A11	2.5	0.43	A12	0.8	0.70
	B11	3.3	0.37	B12	0.8	0.70
	C11	3.3	0.37	C12	0.8	0.70
	M		0.66	M		0.71
3. Disruption of production (disruption vs. no disruption)	A11	1.7	0.52	A12	0.2	0.83
	B11	2.1	0.47	B12	4.5	0.36
	C11	2.1	0.47	C12	4.5	0.36
	M		0.76	M		0.46
4. Dependence on natural gas (yes or no)	A11	0.2	0.83	A12	1.7	0.58
	B11	5.3	0.25	B12	0.1	0.85
	C11	5.3	0.25	C12	0.1	0.85
	M		0.36	M		0.85
5. Energy officer 1: energy is officer's only responsibility	A11	4.4	0.30	A12	0.0	1.00
	B11	3.7	0.34	B12	0.0	1.00
	C11	3.7	0.34	C12	0.0	1.00
	M		0.56	M		
6. Energy officer 2: energy officer is also the chief officer	A11	2.1	0.47	A12	0.2	0.83
	B11	1.9	0.49	B12	4.5	0.36
	C11	1.9	0.49	C12	4.5	0.36
	M		0.16	M		0.46
7. Energy officer 3: Energy officer with technology/science background	A11	2.7	0.42	A12	0.3	0.79
	B11	1.1	0.61	B12	0.8	0.70
	C11	1.1	0.61	C12	0.8	0.70
	M		0.72	M		0.92
8. Energy officer 4: energy officer with business/finance background	A11	0.3	0.79	A12	0.1	0.85
	B11	2.9	0.40	B12	4.6	0.36
	C11	2.9	0.40	C12	4.6	0.36
	M		0.31	M		0.46

Policy Option 11 & 12 (cont'd)

	Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
9.	Energy committee (yes or no, within the firm)	A11	19.4	0.02	A12	7.6	0.23
		B11	2.3	0.42	B12	1.2	0.63
		C11	2.3	0.42	C12	1.2	0.63
		M		0.03	M		0.17
10.	Energy intensity (high vs. medium & low)	A11	5.2	0.20	A12	67.0	0.92
		B11	8.5	0.14	B12	3.2	0.44
		C11	8.5	0.14	C12	3.2	0.44
		M		0.30	M		0.61
11.	Firm size (five levels)	A11	0.4	0.75	A12	3.0	0.45
		B11	0.4	0.75	B12	1.3	0.62
		C11	0.4	0.75	C12	1.3	0.62
		M		0.70	M		0.76
12.	Degree of automation (three levels)	A11	4.1	0.32	A12	1.1	0.65
		B11	3.2	0.38	B12	0.7	0.71
		C11	3.2	0.38	C12	0.7	0.71
		M		0.60	M		0.89
13.	Age of equipment (three levels)	A11	9.6	0.12	A12	1.8	0.57
		B11	5.3	0.25	B12	1.6	0.59
		C11	5.3	0.25	C12	1.6	0.59
		M		0.31	M		0.83
14.	Centralized authority (total autonomy vs. firm dependence on a mother company)	A11	0.1	0.88	A12	0.0	0.94
		B11	0.9	0.64	B12	3.6	0.42
		C11	0.9	0.64	C12	3.6	0.42
		M		0.70	M		0.65
15.	Degree of communication within the firm (four levels)	A11	7.6	0.17	A12	0.1	0.85
		B11	0.1	0.84	B12	8.2	0.22
		C11	0.1	0.84	C12	8.2	0.22
		M		0.20	M		0.27
16.	Energy information 1: industrial association (yes or no)	A11	1.7	0.52	A12	1.7	0.58
		B11	2.1	0.47	B12	0.1	0.85
		C11	2.1	0.47	C12	0.1	0.85
		M		0.76	M		0.85
17.	Energy information 2: utility company (yes or no)	A11	0.0	0.94	A12	1.2	0.63
		B11	0.7	0.68	B12	4.5	0.36
		C11	0.7	0.68	C12	4.5	0.36
		M		0.87	M		0.67

Policy Option 11 & 12 (cont'd)

Factor	Dependent variable	Percent of variance explained	Prob. > F.	Dependent variable	Percent of variance explained	Prob. > F.
18. Energy information 3: government (yes or no)	A11	2.4	0.45	A12	0.1	0.85
	B11	12.0	0.08	B12	9.1	0.19
	C11	12.0	0.08	C12	9.1	0.19
	M		0.17	M		0.35
19. Energy information 4: other firms (yes or no)	A11	6.2	0.21	A12	11.3	0.14
	B11	0.2	0.82	B12	1.7	0.57
	C11	0.2	0.82	C12	1.7	0.57
	M		0.12	M		0.34
20. Energy information 5: consulting firms (yes or no)	A11	0.3	0.77	A12	4.5	0.36
	B11	2.3	0.45	B12	0.8	0.70
	C11	2.3	0.45	C12	0.8	0.70
	M		0.71	M		0.66
21. Energy information 6: within the firm (yes or no)	A11	14.6	0.05	A12	11.3	0.14
	B11	15.0	0.05	B12	19.9	0.04
	C11	15.0	0.05	C12	19.9	0.04
	M		0.11	M		0.13
22. Member of an industrial association (yes or no)	A11	1.0	0.55	A12	4.5	0.36
	B11	1.5	0.54	B12	1.2	0.63
	C11	1.5	0.54	C12	1.2	0.63
	M		0.40	M		0.67
23. Consideration of a longer pay-back period (yes or no)	A11	2.4	0.45	A12	0.1	0.85
	B11	5.3	0.25	B12	0.1	0.87
	C11	5.3	0.25	C12	0.1	0.87
	M		0.53	M		0.94
24. Growth state (three stages)	A11	0.2	0.83	A12	2.3	0.51
	B11	5.1	0.26	B12	2.3	0.51
	C11	5.1	0.26	C12	2.3	0.51
	M		0.38	M		0.37
25. R&D (yes or no)	A11	0.6	0.71	A12	19.5	0.05
	B11	1.1	0.61	B12	2.5	0.50
	C11	1.1	0.61	C12	2.5	0.50
	M		0.88	M		0.13
26. Perceives the government as the major cause of the recent energy disaster (yes or no)	A11	5.1	0.26	A12	8.4	0.21
	B11	0.2	0.82	B12	1.7	0.57
	C11	0.2	0.82	C12	1.7	0.57
	M		0.38	M		0.13

APPENDIX 8

Significance Tests of Adoption Rates
by Policy Responses

Dependent Variables

Measure 1: Post-1973
Measure 2: Total
M: Combination of 1 and 2

Independent Variables: Policy Options 1 through 12 with:
A = Effectiveness in energy conservation
B = Attractiveness to industry in general
C = Attractiveness to the firm
* Significant at 0.05 level

Policy Options

	Dependent variables	Percent of variance explained	Probability level
A1	Post-1973	0.5	0.66
	Total	0.0	0.96
	Combined		0.67
B1	Post-1973	0.0	0.87
	Total	0.5	0.70
	Combined		0.87
C1	Post-1973	0.0	0.80
	Total	2.7	0.41
	Combined		0.58
A2	Post-1973	0.0	0.95
	Total	1.3	0.53
	Combined		0.62
B2	Post-1973	0.4	0.67
	Total	0.0	0.80
	Combined		0.86
C2	Post-1973	1.7	0.49
	Total	0.9	0.61
	Combined		0.78
A3	Post-1973	7.4	0.21
	Total	8.8	0.18
	Combined		0.40
B3	Post-1973	10.2	0.14
	Total	4.4	0.35
	Combined		0.35
*C3	Post-1973	27.3	0.01
	Total	14.8	0.07
	Combined		0.05
A4	Post-1973	5.1	0.26
	Total	1.9	0.46
	Combined		0.53

Policy Options

	Dependent variables	Percent of variance explained	Probability level
*B4	Post-1973	20.1	0.02
	Total	7.7	0.17
	Combined		0.06
*C4	Post-1973	24.3	0.01
	Total	4.8	0.27
	Combined		0.01
A5	Post-1973	0.0	0.78
	Total	0.4	0.64
	Combined		0.39
B5	Post-1973	0.4	0.71
	Total	0.0	0.99
	Combined		0.80
C5	Post-1973	0.8	0.60
	Total	0.0	0.91
	Combined		0.72
A6	Post-1973	0.0	0.78
	Total	1.4	0.53
	Combined		0.36
B6	Post-1973	1.3	0.52
	Total	2.4	0.45
	Combined		0.75
C6	Post-1973	7.4	0.16
	Total	9.7	0.11
	Combined		0.28
A7	Post-1973	0.9	0.59
	Total	0.0	0.98
	Combined		0.66
B7	Post-1973	2.6	0.42
	Total	1.4	0.54
	Combined		0.72
C7	Post-1973	5.0	0.63
	Total	1.8	0.49
	Combined		0.78
A8	Post-1973	3.8	0.32
	Total	1.7	0.49
	Combined		0.61
*B8	Post-1973	15.1	0.05
	Total	16.0	0.04
	Combined		0.11

Policy Options

	Dependent variables	Percent of variance explained	Probability level
*C8	Post-1973	16.0	0.04
	Total	12.3	0.08
	Combined		0.13
A9	Post-1973	2.5	0.40
	Total	9.8	0.10
	Combined		0.21
B9	Post-1973	1.2	0.54
	Total	0.0	0.88
	Combined		0.47
C9	Post-1973	0.8	0.60
	Total	0.0	0.97
	Combined		0.67
A10	Post-1973	0.0	0.94
	Total	1.3	0.53
	Combined		0.65
*B10	Post-1973	7.7	0.16
	Total	15.7	0.04
	Combined		0.12
C10	Post-1973	2.9	0.38
	Total	7.7	0.16
	Combined		0.36
A11	Post-1973	0.4	0.75
	Total	5.2	0.24
	Combined		0.30
*B11	Post-1973	18.2	0.02
	Total	27.0	0.006
	Combined		0.02
*C11	Post-1973	18.3	0.02
	Total	26.3	0.006
	Combined		0.02
A12	Post-1973	0.0	0.80
	Total	1.8	0.52
	Combined		0.41
*B12	Post-1973	10.0	0.17
	Total	21.4	0.03
	Combined		0.11
*C12	Post-1973	14.0	0.09
	Total	17.3	0.05
	Combined		0.15

APPENDIX 9: EXISTING ENERGY-EFFICIENT TECHNOLOGIES

1. Waste heat recovery devices from hoods or from heat-producing equipment hot stocks?

Response: not applicable/ no / yes adoption date

2. Devices or equipment for pre-heating combustion air.
3. Heat recovery device for compressors used for cooling, or other.
4. Load levelers.
5. Devices for raising suction temperature for refrigeration units.
6. Devices for using steam condensate for heating.
7. Variable speed pumping devices.
8. Recuperator or regenerator.
9. Heat pump.
10. Heat exchanger.
11. Others adopted by your firm.

APPENDIX 10: FIRM CHARACTERISTIC FACTORS

1. Regional
2. Energy intensity
3. Energy cut-back
4. Disruption of production
5. Firm size
6. Centralized authority
7. Degree of automation
8. Dependency on natural gas
9. Age of equipment
10. Growth state
11. R & D
12. Consideration for a longer payback period
13. Energy officer 1--only responsibility
14. Energy officer 2--chief officer
15. Energy officer 3--technology/science background
16. Energy officer 4--business/finance background
17. Energy information 1--Industrial association
18. Energy information 2--utility company
19. Energy information 3--government
20. Energy information 4--other firms
21. Energy information 5--consulting firms
22. Energy information 6--within the firms
23. Industrial association
24. Energy committee
25. Government perceived as the cause of the energy crisis
26. Degree of communication within the firm

APPENDIX 11: POLICY OPTIONS

1. Use of recycled materials: incentives for use, coupled with penalties for use of virgin materials.

Response: A. effectiveness in energy conservation in general:
good fair no effect
B. attractiveness to industry generally: high moderate low
C. attractiveness to your firm: high moderate low

2. Cost of energy: deregulation of energy prices.
(same as above)

3. Cost of energy: federal tax on energy purchases based on national energy consumption patterns.

4. Consumption of energy: price incentives for off-peak energy use combined with penalties on increments of energy consumed in excess of (peak) bases.

5. Supply of energy: federally mandated energy allocation limits based on past energy usage per unit of output.

6. Financing energy conservation measures: favorable loan terms for energy conservation capital expenditures (plant insulation, energy-efficient equipment, etc.)

7. Financing energy conservation measures: federally guaranteed loans for energy conservation capital expenditures.

8. Financing energy conservation measures: tax credits for energy conservation capital expenditures.

9. Energy systems management programs: government-sponsored services of consultants at no cost to industry.

10. Energy systems management programs: tax credits for cost of implementing and maintaining energy management program.

11. Research and development of energy-efficient production technologies: research efforts sponsored by federal government agencies.

12. Research and development of energy-efficient production technologies: research based in industry subsidized by federal incentives.

13. Do you have any suggestions of your own for policy measures to promote energy conservation in industry?

APPENDIX 12: Derivation of the Most Workable Policies

	A	B	C	D	E
Policy Options	Popularity ranking	Effect on adoption rate ranking	Consistency ranking	A+B+C	Rank of Sum
# 1 - Recycled materal	10	9	10	29	12
# 2 - Deregulation	12	2.5	12	26.5	11
# 3 - Federal tax on purchases	5	12	8	25	10
# 4 - Off-peak use	2	10	2	14	4
# 5 - Allocation	9	11	4	24	9
# 6 - Favorable loan terms	8	2	9	19	6
# 7 - Guaranteed loans	11	4	5	20	7
# 8 - Tax credits for energy expenditures	3	1 (most popular)	7	11	2
# 9 - Consulting services	7	8	3	18	5
#10 - Tax credit for energy management	6	6	11	23	8
#11 - Federal R&D	1 (most effective)	7	6	14	3
#12 - Private R&D	4	5	1 (least controversial)	10	1 (most workable)

APPENDIX 13:

Group A: Near-Term Technologies

Indus Code	Project Title	Annual Energy Savings (10^9 BTU's Yr/Unit)	Primary Target Industry	Date of Commercialization				Type of Technology			Process Description/ Application
				1	2	3	4	Hardware	On Site Mod	Process Change	
7	Paint Curing Ovens	390.0	Roll Coating	X				X			Modification of paint curing system in order to reduce cold dilution air and capture waste solvent gases to fuel retrofitted zone incinerators to reduce natural gas use.
8	Textile Process Modification	2.5	Textiles			X			X		Consolidation of textile cleaning steps, dye bath reuse, more efficient vacuum drying of dyed cloth and dye beck modification.
10	Moving Beam Furnace	2,300.0	Steel				X	X			Utilization of a newly developed monobeam furnace for metal reheating that includes a water cooled and protected skid mechanism supported by water cooled pipes.
11	Cupula Furnace Modification	42.0	Iron & Steel Foundaries				X		X		Modification of Cupola furnaces used in working iron for casting and steel making by changing air flow patterns in the furnace.
12	New Fertilizer Process	20.0	Nitrogen Fertilizer Industry	X				X			Retrofit T.V.A.—developed pipe-cross reactor in order to utilize the chemical heats of reaction for the drying of nitrogen fertilizer granuals.

Indus Code	Project Title	Annual Energy Savings (10^9 BTU's Yr/Unit)	Primary Target Industry	Date of Commercialization				Type of Technology			Process Description/ Application
				1	2	3	4	Hardware	On Site Mod	Process Change	
14	Boiler Fuel Controls	50.0	Chemical			x		X			Development of instrumentation including a spectral flame analyzer, instack monitor and microprocessor in order to optimize and reduce fuel consumption in large industrial boilers
19	Blended Cement Study	0.00134	Cement and Construction	X						X	Standards setting allowing for greater use of blended cements (composed of Portland cement and slag or fly ash) to save energy used in cement production
21	Paper Pulp Fiber Characterization	72.0	Paper	X						X	Standards setting and characterization of waste paper pulp fiber to allow for greater use of recycled paper and energy savings
33	Ceramic Heat Recuperator	35.2	Primary Metals	X				X			Capture and utilization of furnace waste heat with a ceramic recuperator for preheat combustion air above 1500°C
34	Metallic Heat Recuperator	35.2	Primary Metals				X	X			Capture and utilization of flue gas waste heat with a metallic recuperator for use in aluminum remelt and steel reheating processes.
35	Ultra Hi-Temp. Recuperator	35.2	Steel				X	X			Capture and utilization of high temperature combustion air for use in industrial furnaces with a need for very efficient recuperators (i.e. steel soaking pits)

Indus Code	Project Title	Annual Energy Savings (10^9 BTU's Yr/Unit)	Primary Target Industry	Date of Commercialization				Type of Technology			Process Description/ Application
				1	2	3	4	Hardware	On Site Mod	Process Change	
37	Reradiant Recuperators	35.2	Aluminum			X		X			Capture and utilization of waste heat as precombustion air for direct heating furnaces in processes such as calcining cement, remelt of aluminum, melting of glass, etc.
41	Hi-Temperature Heat Pump	30.6	Multiple Application			X		X			Capture and utilization of waste heat with heat pump with organic bottoming cycle and acetone vapor recovery system for steam production and compression to be used for mechanical drive
45	Textile Drying & Finishing Operations	61.2	Textiles Drying and Finish			X				X	Parameter setting standards for tenter frame optimization (Phase I) dye house optimization with software package (Phase II not started)
49	Organic Ranking Bottoming	67.0	Glass				X	X			Utilization of an organic rankin bottoming cycle for the production of power from exhaust gases
50	Slot Forge Furnace	17.0	Metal Forging		X			X			Slot forge furnace for heating steel for forging operations. New furnace includes heat recuperator, recirculation burners, temperature and fuel air controls
78	Paper Pulp Sludge Drying	213.1	Paper		X			X			Development of centrifuge for sludge drying and waste fuel production. Tetra ethyl amine is the chemical to be used to separate water from the sludge

Indus Code	Project Title	Annual Energy Savings (10^9 BTU's Yr/Unit)	Primary Target Industry	Date of Commercialization				Type of Technology			Process Description/ Application
				1	2	3	4	Hard-ware	On Site Mod	Process Change	
123	Welding Power Supply	0.1	Fabrication **Industries**				X	X			Compact high efficiency ARC welding power supply for industrial use
135	Polypropylene Waste to Fuel Oil	3,600.0	Plastic (Polypropylene)				X	X			Conversion of waste plastic (attatic polypropylene) to fuel oil
148	Cement Kiln RDF	550.0	Cement			X		X			Utilization of refuse derived fuel (RDF) for Portland cement kilns
182	Egg Cleaning & Handling	Insig.	Egg		X					X	Acid chemical cleaning of eggs

Group B: Mid-Long-Term Technologies

Indus Code	Project Title	Primary Target Industry	Estimated Date of Commercialization						Process Description/ Application
			1980	1981	1982	1983	1984	1985+	
9	Hot Beef Boning for Energy Conservation	Meat Processing Industry						X	Pre-chill deboning of bovine carcasses Process and equipment development
16	Energy Conservation/Distillation	Petroleum Refining	I. X				II. X		Phase I - optimization handbook Phase II - predistillation flashing
32	Refinery Energy Audit	Petroleum Refining		X					Energy audit to define energy intensive processes in small to medium size refineries
38	High Temperature Range Recuperator	Glass				X			Waste heat recovery for use in annealling furnaces, plant buildings and other industrial processes
39	High Temperature Industrial Heat Pump	Paper					X		Process steam from 150° to 250° waste heat with heat pump
40	High Temperature Industrial Heat Pump	Dry Milk Processing Industry				X			Waste heat recovery with heat pump for utilization in milk processing operation
42	Coal in Aluminum Remelt	Aluminum						X	Not defined
51 (105)	Improved Aluminum Reduction Cell Cathode	Aluminum			X				Use of refractory hard materials (RHB) such as T1B2 for wettable cell cathodes
52	Glass Conglomerates	Glass		X					Use of waste heat from glass melting furnace exhaust to preheat furnace charge materials and for drying

Indus Code	Project Title	Primary Target Industry	Estimated Date of Commercialization						Process Description/ Application
			1980	1981	1982	1983	1984	1985+	
53	Closed Cycle Textile Dying	Textile		X					Reuse of hot process water during textile dying
81	Direct Reduction of Aluminum	Aluminum						X	Waste CO and coal derived fuel for use in the smelting of aluminum
82	ARC-Coal Acetylene Process	Plastic						X	Acetylene derived directly from coal for use as a vinyl polymer feedstock
85	Irrigation Water Conservation	Agriculture				X			Not defined
93	Foam Fiber Technology	Textile		X					Foam applications in textile industry processes
94	High Consistancy Forming Process for Paper Making	Paper				X			Mechanical dewatering with the use of high consistency head boxes
101	GASPAK-Solid Food Preservation	Food Processing			X				Utilization of GASPAK sterization/ preservation technology for food packaging
102	Fabric Filtration	Textile			X				Bag filtration efficiency in comparison to state of the art electrostatic precipators
112	Gas Evolution at Aluminum Electrodes	Aluminum			X				Aluminum reduction bubble reduction at anode
119	Steam Calcination of Limestone	Cement						X	Utilization of steam in the calcination of limestone

Indus Code	Project Title	Primary Target Industry	Estimated Date of Commercialization						Process Description/ Application
			1980	1981	1982	1983	1984	1985+	
124	Brayton Cycle	Glass				X			Electric power generation from waste heat from high temperature waste streams
129	Slag Waste Heat Recovery in Elemental Phosphorous	Iron and Steel					X		Economic feasibility of using slag waste heat in blast furnaces and slagging boilers
132	Nitrogen based Carborizing Atmosphere	Iron and Steel						X	Utilization of electric power in place of natural gas in iron neat treating
134	Flat Glass Energy Reduction	Glass		X					Waste glass reduction through better production controls and the thinning of pane thickness
137	Energy Conservation in Finished Concrete Products	Cement	X						Insulation and modifications to cement block curing operations
138	Low Energy Fluid Food Processing	Food Processing				X			Optimization of various methods of fluid food concentration
141	Dry Coke Quenching	Steel						X	Heat recovery with dry coke quenching
146	Blast Furnace Gasifier	Various						X	Conversion of a blast furnace to an industrial fuel gas generator
147	Freeze Crystallization	Textile					X		Freezing versus evaporation to recover water in black liquor concentration and water extraction operations
155	Farm Energy Conservation/ Demonstration	Agriculture						X	Not defined

Indus Code	Project Title	Primary Target Industry	Estimated Date of Commercialization						Process Description/ Application
			1980	1981	1982	1983	1984	1985+	
157	Dawsonite/Nahcohlite Study	Oil Shale						X	Utilization of tailings from the extraction of oil from oil shale
158	Sterile Fluid Milk	Milk Processing						X	Asceptic packaging of sterile fluid milk
161	Advanced Black Liquor Systems	Paper						X	Not defined
166	Glass Polymer Composite Sewage Pipe	Cement					X		Sewage pipe manufacture with waste glass materials
169	Blast Furnace Gasifier							X	Not defined
175	Industrial Coal Combuster							X	Not defined
176	Waste Tire Reclamation	Tire Retread Manufacture				X			Waste tires as fuel for small industrial energy users
177	CO for Methanol	Chemical					X		CO as a feedstock substitute for natural gas
180	Lube Oil Recovery	Petroleum			X				Reprocessing of waste lube oil to fuel
191	Conservation in Ethyl Polymers	Plastic						X	Production of degradable plastics from waste streams using electro machine radiation
192	Sugar Cane Processing	Sugar Processing			X				Not defined

Indus Code	Project Title	Primary Target Industry	Estimated Date of Commercialization						Process Description/ Application
			1980	1981	1982	1983	1984	1985+	
193	Beef Sugar Processing	Sugar Processing			X				Not defined
194	Starch Extraction	Sugar Processing						X	Not defined
197	Heat Pump-Grain Dryer	Grain					X		Fuel substitution (electricity for L.P. gas utilizing heat pump)

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