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Energy Consumption Measurement

DATA NEEDS FOR PUBLIC POLICY

Committee on Measurement of Energy Consumption
Assembly of Behavioral and Social Sciences
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1977

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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COMMITTEE ON MEASUREMENT OF ENERGY CONSUMPTION

F. THOMAS JUSTER (CHAIRMAN), Institute for Social Research, University of Michigan

FRANK CANCIAN, School of Social Science, University of California, Irvine

JOHN GIBBONS, Environment Center, University of Tennessee

ROBERT KAHN, Survey Research Center, University of Michigan

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LAWRENCE MAYER, Department of Statistics, Princeton University

PETER ROSSI, Department of Sociology, University of Massachusetts

IRVING G. SNYDER, Dow Chemical Europe S.A.

JOSEPH STEINBERG, Survey Design, Inc., Silver Spring, Maryland

LESTER TAYLOR, Department of Economics, University of Arizona

BEATRICE N. VACCARA, Bureau of Economic Analysis, U.S. Department of Commerce

Staff

H. RICHARD HOLT, Study Director
EDWARD I. FRIEDLAND, Senior Research Associate
LYNDA T. CARLSON, Research Associate
JACQUELINE F. MANGUM, Administrative Secretary

CONTENTS

PREFACE

The Committee on Measurement of Energy Consumption was formed in September 1975 at the request of the Federal Energy Administration. Its mandate was to analyze energy consumption data, to determine their adequacy for public policy purposes, and to make recommendations for the collection of needed but unavailable data.

It was recognized that the Committee was not formed to resolve the "energy crisis." Over the last several years, a great deal of attention has been given to problems of energy supply--the benefits and costs of nuclear power, the possibilities of substituting coal for oil, the technical and economic feasibility of solar power and nuclear fusion as energy sources, the advantages and disadvantages of deregulating natural gas, etc. Far less attention has been given to issues of energy use in terms of consumption or demand. It was to examine these possibilities that the Committee came into being.

At the outset, it was the Committee's view that its principal focus should be on data needed to understand--that is, to model and predict--energy consumption patterns in the United States. We recognized that the data needed to describe energy consumption were essential to the formulation of appropriate public policies, but that such data would be far from sufficient. We agreed that the principal issues of public policy are related to data that would permit assessment of the impact of policy on energy consumption in the future. Thus, the determinants of energy consumption and whether and to what degree public policy can affect them became crucial issues in the Committee's deliberations; these issues comprise the bulk of the analysis in this report.

The reader should recognize that the Committee's task was not to specify models of energy consumption in the sense of arriving at judgments about the relative importance or responsiveness of price, income, public attitudes, or public regulation in the determination of energy consumption. Any committee studying issues such as these is necessarily composed of people who approach a problem from different perspectives--economic, physical, mathematical, psychological, sociological, administrative. As a consequence, a set of committee recommendations is more likely to represent agreement on factors that are of some importance than agreement on which factors are most important or just how important particular factors are.

Moreover, the Committee quite specifically took the view that it was inappropriate, given its composition and expertise, to deal with the "side effects" of energy policy, although we recognize that such effects exist and may ultimately determine what policy options are adopted. To illustrate:

policies designed to reduce energy consumption by sharply increasing energy prices may well be effective in achieving that objective, but there may be both income distribution and employment effects associated with such policies that make them undesirable. The Committee had neither the expertise nor the time to examine all the non-energy consequences and ramifications of possible energy consumption policies. Rather, it took as its task the specification of types of data that would be needed in order to estimate the effect of possible public policies on energy consumption without taking any view as to the overall desirability of these policies. This does not mean, of course, that members of the Committee do not have such views, but simply that this report limits itself to recommendations on the collection of data that would be essential to shape any well-informed public policy on energy consumption.

Finally, the fact that this report deals with public policy on energy consumption data does not by any means suggest that the Committee members feel that policy on energy consumption is more important than policy on energy supply. As indicated earlier, energy supply issues have been studied extensively, and such studies will continue. Whether the energy crisis will be solved by policies on supply or consumption was not of concern to the Committee; rather, we were concerned solely with identification of the kinds of data that public policy makers would need if they chose to adopt policies that were designed to have impact on energy consumption. That is a limited purpose, but an essential one.

The Committee is grateful for the assistance it has received from many sources. Many individuals and groups contributed directly and indirectly to this report by offering expertise, information, and suggestions. Staff from many parts of the federal government and the research community provided data and talked with Committee members and staff. The following individuals met with Committee members: Robert Borlick, John Curtis, J. Michael Power, Daniel B. Rathbun, Mark Rodekohr, Gilbert Rodgers, Kenneth Vagts, Daniel Wedderburn, and Eric R. Zausner, from the Federal Energy Administration; F. Thomas Sparrow, National Science Foundation; A. Michael Maher, Energy Conservation Program, Department of Commerce; Alan Pisarski, Department of Transportation; Thomas V. Long, III, University of Chicago; and Bruce Hannon, University of Illinois. Maurice Owens provided expert liaison for the Committee on National Statistics. Several consultants provided assistance to the Committee during the course of the project: Richard Curtin, University of Michigan; Frank J. Alessio and David B. Cohen, Criterion Analysis, Dallas, Texas; Fred D. Baldwin, Syracuse Research Corporation; Milton F. Searl, Electric Power Research Institute; and Bill Hughes and Joen Greenwood, Charles Rivers Associates.

The Committee also wishes to thank those persons actively engaged in energy modeling who provided thoughtful and detailed responses to a mail questionnaire about energy use data needed for improved modeling and analysis. The Committee also wishes to thank the many reviewers of drafts of the report who contributed a number of important suggestions.

Finally, we wish to acknowledge the assistance of the Committee staff and staff of the Assembly of Behavioral and Social Sciences of the National Research Council. H. Richard Holt, Study Director, organized the efforts of the Committee and the staff and made substantial contributions to the body of the report, particularly in the industrial and the commercial/services chapters. Lynda T. Carlson drafted substantive parts of the commercial/services chapter and wrote the appendix on state and local government data; she ferreted out

SUMMARY

The purpose of this report is to identify the major needs for improved data on energy consumption, to specify the types of data that should be collected, and to suggest some general methods of collecting and organizing these data for use in designing and evaluating public policy.

OVERVIEW

The nation's total energy consumption depends collectively on millions of separate decisions and on the social and institutional structures within which these decisions are made. The use of energy is deeply rooted in practically every aspect of contemporary social and economic behavior. Information about how energy is used is inherently more difficult to collect and organize than information about how energy is produced. There are several reasons for this: most energy use decisions are decentralized and highly diverse; detailed records are seldom kept; and energy costs are a small fraction of the total costs of many activities. Accordingly, no single scheme of data classification is likely to be applicable to the many public policies that may affect how energy is used.

We find it useful to discuss energy consumption in terms of the end users in different sectors of the economy: household, industrial, and commercial/ service (which includes governments). Our analysis is further organized by major end uses within each economic sector: space conditioning (the heating, cooling, and lighting of buildings), transportation (of both people and goods), and materials processing. This classification distinguishes among the different kinds of decisions that are made about energy use in each sector and for each use, the different kinds of information and incentives that influence those decisions, and the different types of data needed to design public policies that may influence those decisions.

The three major uses of energy are not equally important in each sector of the economy, and they are not given equal emphasis in the report. In the household sector, energy is used mainly for transportation and for space conditioning; relatively less is used for forms of materials processing, such as cooking food and heating water. Household uses of energy are usually associated with some type of capital equipment--a vehicle, a building, or an appliance. In the industrial sector, energy is used to produce goods and services that are used throughout the economy; for goods, use is concentrated in the processing of basic materials--metals, chemicals, paper, and fuels. In the commercial/service sector, energy use is concentrated in transportation and space conditioning. This is similar to use in the household sector (although with considerably wider variation within the sector); the decision processes, however, are similar to those in the industrial sector.

For each economic sector and end use, we also distinguish among three broad purposes to be served by improved energy consumption data: monitoring or describing, modeling, and assessment of public policies. Monitoring refers to descriptive time-series data about how much energy is consumed, the forms in which consumption takes place, and the end uses served. Modeling refers to the construction of statements of relationships between factors that explain how and why energy is consumed; the data needed for modeling are generally different from those needed for monitoring. Assessment of public policy requires knowing not only how and why energy consumption patterns may change, but how those changes may affect related aspects of the economy.

Data needed to monitor and to model energy use are discussed in Chapters 2, 3, and 4, which describe the household, industrial, and commercial/service sectors respectively. Data needed for assessment of public policies, which apply to all sectors of the economy, are discussed in Chapter 5, in which we concentrate on data collection methods, especially the design of controlled and randomized field experiments. In each of the chapters, the methods by which the necessary data might be collected are indicated.[1]

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Much of our work concentrates on the data needed to understand the present and future patterns of energy consumption. Many of our recommendations deal with data needed to specify the effects of public policy on future energy consumption rather than with descriptive data on current or historical energy consumption patterns. It would be possible, although expensive, to accumulate enormous masses of data on actual energy consumption, classified by every conceivable type of user, fuel, and function. But those data would be useless by themselves, in response to what the Committee feels is its principal mandate --to make recommendations about data needed to guide the formulation of energy policy over the next several decades. To achieve that objective, it is necessary to understand what determines energy consumption, which in turn requires systematic explanation of the social, behavioral, economic, and technical factors that influence energy consumption.

Given these objectives, better and more detailed data on actual energy consumption patterns represent a necessary but not sufficient first step. Because of this emphasis, some of our recommendations call for research rather

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[1]While the Committee's work was in progress, legislation was enacted (such as the Energy Policy and Conservation Act) that assigns responsibility for data collection and analysis to federal and state agencies; thus, for the most part, we have not specified which governmental agencies should carry out the data collection activities that are discussed here.

than for data collection operations alone, and most of our recommendations concern the data needed to understand and predict energy consumption rather than the data needed simply to describe it.

The Household Sector

Household purchases of fuels and electricity account for about one-third of total national energy consumption. Data to describe household energy consumption at highly aggregated levels are generally adequate, but those needed to describe and monitor energy consumption by use are insufficiently detailed. Basic benchmarks need to be established for future descriptive data collection. Specifically, the Committee recommends benchmark surveys of the detailed uses of energy by appliances and of the types and amounts of fuels used for space conditioning. For monitoring energy use for personal transportation, we believe that methodological work will be needed to develop survey research methods for use in combination with physical instrumentation.

Data required for modeling energy use in the household sector are seriously inadequate, and substantial improvements are needed for explanatory data that relate the social and behavioral characteristics of households to their use of energy for space conditioning and transportation. The Committee recommends a national panel survey of dwelling units to measure the interactions between the physical characteristics of buildings and the social and behavioral characteristics of the occupants. The Committee also recommends that such a panel survey obtain data on the technical characteristics and use patterns of household automobiles. These data should include information about consumer expectations of future gasoline prices and expectations of changes in the technical characteristics of vehicles as they may affect future automobile purchases.

For improved modeling of personal transportation, we also recommend that two special studies be undertaken. First, a special study is recommended to determine the sources and magnitude of variation in the fuel efficiency of the present stock of automobiles--variations due to design, manufacture, maintenance, driver practices, and feedback information on fuel efficiency. Second, a special study is recommended to investigate the factors that induce the purchase of more fuel-efficient automobiles and the use of alternative modes of transportation. This second study should include international comparisons.

The Industrial Sector

The industrial sector accounts for about 35 percent of the nation's total energy consumption. Of that total, about two-thirds is concentrated in a relatively small number of large firms that produce the basic chemicals, metals, paper, and fuels used throughout the economy. These industries are inherently energy intensive because they typically employ processes that change the chemical or molecular structure of materials. For these energy-intensive industries, the Committee recommends that data be collected on both total energy consumption by fuel type and on energy consumption per unit of product output, concentrating on production processes used by these industries to change the properties of materials. Because these processes account for such a large fraction of industrial energy use, we recommend that research be initiated to investigate the factors that influence the choice of alternative production processes, including uncertainty about future energy prices and fuel availability, regulatory practices, and the capital needed to modify the energy intensity of industrial processes.

For industries whose processes are intermediate or low in energy intensity, relatively adequate data are available to describe the energy used by manufacturing firms, but not the energy used in mining, agriculture, and construction. In the latter industries, we believe that the energy used for transportation and space conditioning accounts for more energy than that used for materials processing, but existing data are not adequate to determine this. For the industries with intermediate or low energy intensity, we recommend a benchmark survey to determine the distribution of energy uses among space conditioning, transportation, and materials processing. We also recommend that mining, agriculture, and construction be included in the Census Bureau's Annual Survey of Manufactures.

For the entire industrial sector, the Committee found significant opportunities to reclaim industrial by-products that are now wasted. We recommend additional study of these opportunities, especially to reclaiming waste heat for use in space conditioning or other lower-temperature processes.

The Commercial/Service Sector

Energy consumed in the commercial/service sector accounts for about 20 percent of the national total and is used predominantly for transportation and space conditioning of buildings. In contrast to the household and industrial sectors, basic descriptive data for this sector are inadequate or do not exist. There is not even a commonly accepted definition of what is included and what is not included in this sector. The Committee has three recommendations for data needed in the commercial/service sector. First, we recommend that federal agencies--both those that collect data in this sector and those that use these data--undertake a program to standardize the definition of the sector. Second, we recommend a benchmark survey of commercial buildings to determine how the energy used for space conditioning is affected by structural characteristics, occupant behavior and occupancy patterns, and the nature and extent of internal equipment and appliances. Third, we recommend that data about energy used in commercial transportation be obtained for cases in which shifts from one mode of transportation to another mode may be influenced by public policies and for the unregulated parts of commercial transportation, particularly trucking, for which there are insufficient data.

Data Needed For All Sectors

In the course of its work, the Committee explored several issues that apply to all sectors of the economy: data needed for the assessment of public policies; the use of energy for space conditioning; data about demographic changes; and the quality and timeliness of energy consumption data. Policy assessment is discussed primarily in Chapter 5; the other issues are discussed throughout the report.

Assessment of Public Policies

Data required for the assessment of the effects of public policies on energy consumption are more complex than those required for monitoring or modeling. Many public policies that could have a significant effect on U.S. energy consumption cannot now be properly assessed because there are no observations on behavioral responses. For this reason, the Committee recommends more extensive use of controlled and randomized field experiments to study the effects of energy policies in all sectors of the economy. Scientifically designed field experiments permit policies to be tested on a scale large enough to produce reliable results, yet small enough so that failures or unanticipated results can be tolerated.

Space Conditioning

Effective energy policy requires substantially more knowledge than is now available about the gross physical characteristics of buildings and the actual energy consumption characteristics of those buildings. Data are needed on a building-by-building basis for many investment decisions. We recommend special studies, on a nationwide basis, of the relation between energy used for space conditioning in buildings and the physical characteristics of the building, the activities of the occupants, and the use of equipment and appliances in the building. We further recommend research and development to produce energy monitoring instrumentation that is inexpensive and easy to use.

Demographic Data

The economic, social, and energy consequences of demographic changes can be very large within the time periods of interest to energy policy decisions. We recommend careful use of demographic data in energy policy analysis, especially data that describe fertility rates, household formation, labor force participation, and effective length of the work week.

Quality and Timeliness of Data

The quality of energy consumption data is relative to the purpose for which it is to be used. For each data collection effort, a clear specification is needed of how much precision, comprehensiveness, and detail is required, and how much this is worth, in terms of the engineering, regulatory, or financial decision to be made. We recommend that presentations of energy data be accompanied by relatively complete descriptions of how, why, when, and where the data are collected. Descriptions should include measures taken to ensure data precision and validity. We further recommend a systematic review of existing energy data collection systems, especially those that now collect data at 5- to 10-year intervals, to identify cost-effective opportunities for the more frequent collecting and reporting of data that are of current policy interest.

CHAPTER 1

MEASURING ENERGY CONSUMPTION

INTRODUCTION

Since the beginning of this century, energy has been plentiful in the United States; its price has declined relative to the price of other goods and services, and its use has increased as technological developments have made possible many new products and processes. In recent years, however, energy supplies have become uncertain, prices have risen, and the environmental impact of energy production and consumption practices have become a matter of concern. The nation is now making energy policy decisions that will affect international relations, the environment, the economy, and the legacy passed on to future generations.

Although problems of energy supplies are vexing and technologically complex, they are in many ways simpler than those of energy consumption. This is because total energy consumption results from literally millions of individual consumption decisions--decisions that cannot be separated from the social and institutional context in which they are made. Energy use is rooted in practically every aspect of contemporary social and economic behavior.

This report concentrates on the data needed to shape policies that affect energy consumption. It does not extend to data needed to determine whether particular energy consumption policies are, all things considered, in the national interest. Although energy consumption is an important subject, it is not synonymous with national well-being. Thus, policies with favorable consequences for energy consumption may, on balance, prove to be undesirable for other reasons that this report does not explicitly take into account. For example, policies that have socially desirable consequences for energy consumption may have adverse employment affects; they may have adverse environmental impacts; they may run counter to policies designed to foster competition among business firms; or they may alter the prerogatives of state or other levels of governments.

Throughout this report, the word "energy" is used as a generic term meaning fuels, potential fuels, and fuel equivalents such as electricity and other sources of chemical, thermal, or mechanical energy. One can measure the consumption of a specific fuel in precise physical units (e.g., gasoline measured in gallons), but one cannot, a priori, measure the amount of energy produced by that fuel or the amount applied to useful work.[1] One can calculate the maximum amount of energy theoretically available from the combustion of a fuel from a knowledge of its chemical structure, and one can also specify the minimum amount of energy theoretically required to perform a specific task (e.g., to raise the temperature of one kilogram of water by one Celsius degree); in practice, however, measurement of the energy used in specific processes requires detailed thermodynamic analysis of those processes to determine how much is actually used.

OBJECTIVES

Improved energy consumption data are needed for several purposes. First, data are needed to describe and monitor energy consumption. Second, data are needed to model and predict changes in patterns of energy use, both short-term and long-term. Third, data are needed to assess the effects of policy changes. All three functions--monitoring, modeling, and assessment--involve the collection and analysis of data. Each function requires different types of data, and those data are further differentiated by the needs of data users--individuals, firms, or governmental agencies at the local, state, or national level.

Describing and Monitoring Energy Consumption

Accurate description of energy consumption patterns is basic to the formulation and implementation of effective policies. Monitoring energy consumption provides information about the total amount of energy consumed, the forms in which energy is consumed, and the end uses served. Moreover, monitoring implies continuous or repeated measurement, so that information is provided about both the rate of energy consumption at specified times and changes in the rate of consumption from one time to another. Such data can be used to describe what happens to actual rates of energy consumption over time.

The limitations of monitoring for purposes of policy making are inherent in its all-inclusiveness: monitoring data reflect all the factors that influence energy consumption. The changes in energy consumption from one monitored time to another incorporate the effects of old policies as well as recent ones, changes in supplies and prices, public information about energy stocks and future trends, and many other institutional, social, and economic factors that influence energy consumption.

Modeling Energy Consumption

Policy makers must be aware of changes in consumption, but they require a more complex kind of information as well--information that helps to explain the cause of such changes. The purpose of explanation, in contrast to

[1]Useful work is that fraction of total work that can be delivered to things other than the system and its surroundings. The upper limit for such useful work is measured by the decrease in the Gibbs function of a reversible, isothermal, constant pressure, non-flow process.

description, is accomplished by the various analytic procedures called modeling. To model something is to identify its major causes and show how each of them enters into the processes that affect the outcomes.

Models of energy use are devices--such as statements of statistical relationships, mathematical functions, physical or engineering relationships, and the like--for explaining the factors that have affected energy consumption in the past and may determine future consumption under various possible circumstances. A model of energy consumption for the household sector, for example, would be based on analyses of how housing characteristics, appliance stocks, income levels, household composition, and energy prices affect household consumption of various forms of energy. Such a model could generate estimates of how changes in energy prices or subsidies for the replacement of existing appliance stocks would affect consumption.

Empirical models of energy consumption can provide explanations and even estimates of the effects of public policies, but models are always simplified versions of reality and their estimates are subject to error. Unanticipated events or forces not incorporated into a model may substantially weaken its ability to mimic real processes. Policy outcomes typically remain problematic to some degree, even when a model has apparently predicted or explained them.

Assessment of Energy Policy

Responsible policy assessment requires knowing not only how and why patterns of energy consumption change, but also how those changes may affect other economic, social, and institutional aspects of national life. Not all assessment activities require the collection of data different from those needed for monitoring and modeling: a good monitoring system can sometimes be used to assess changes resulting from a given policy, using statistical procedures to isolate the effects of the policy from the effects of other factors; and data collected for modeling are often useful for assessing the effects of policies. However, some assessment activities require collecting different kinds of data, both experimental and non-experimental.

The costs of implementing some proposed policies, the almost inevitable uncertainties and disagreements about their effectiveness, and the difficulty of identifying their specific effects contribute to the importance of controlled and randomized field experiments as a tool for policy assessment. Such experiments can be considered extensions of modeling; they test models and provide empirical estimates of the parameters of models. More importantly, they permit the testing and evaluation of policies on a relatively small scale--a scale on which failure or unexpected results can be tolerated and the information gained can be used to improve both models and policies.

ANALYTIC FRAMEWORK

In carrying out its work, the Committee found it useful to organize its analysis of energy consumption by three major categories: consuming sector, end use, and analytic approach. The consuming sectors correspond to three broadly defined economic sectors--household; industrial; and commercial/service, which includes a wide diversity of activities from government (including the military) to education and retailing. The end uses are broadly defined as transportation (of both people and goods), space conditioning (the heating, lighting, and air conditioning of buildings), and materials processing. The two analytic approaches are the direct, or stocks-and-flows, approach and the indirect, or embodied-energy, approach. This classification exists within the larger context of institutional practices, which also strongly affect how energy is used in this country. This analytic framework is illustrated schematically in Figure 1.

The Committee's analysis of energy consumption measurement begins with a description of energy use in the United States in 1970. Table 1 shows the major uses of energy (at a highly aggregated level) by economic sector, end use, and fuel type. Electricity is shown as both a source of energy and a consumer, with direct fuel use by electric utilities set off by parentheses to avoid double counting. The fuel equivalents of electricity have been assigned to end uses in the household, industrial, and commercial/service sectors. Table 1 also shows "other" uses, such as exports and feedstocks (i.e., fuels used for non-fuel purposes), that we are unable to allocate accurately to economic sectors. The estimates in this table have been assembled from several sources that are neither directly comparable nor in complete agreement. Thus, the numbers should be interpreted as illustrations of relative consumption, which the Committee believes are probably accurate within 10 percent.

Most of the Committee's work is based on the three economic sectors and end uses that collectively account for about 88 percent of the nation's total energy consumption. The next three chapters of the report examine the data needed for monitoring and modeling energy consumption in the household, industrial, and commercial/service sectors. In each chapter, the report concentrates on those end uses most important in that sector and the analytic approach (direct or indirect) most appropriate to that sector and end use. The final chapter of the report examines the data needed for the assessment of public policy across all sectors and end uses, emphasizing experimental methods of data collection.

Economic Sectors

The organization of this report by economic sector results from the different orientations to decision making that characterize the sectors. The industrial sector is made up primarily of firms organized to provide goods and services at a profit. The decisions of these firms can be expected to be strongly influenced by economic criteria and to be sensitive to policies that affect energy prices and supply availability, particularly as they affect operating and capital costs. Decisions in the commercial/service sector, which includes public and nonprofit organizations, educational institutions, and governmental agencies as well as retail and service businesses, are influenced by economic criteria but may be subject to other important influences as well. Energy use in households is of course related to economic factors but is also influenced by the less tangible needs and satisfactions associated with daily living. Decisions about energy use in households are highly decentralized and subject to widely varying sources and quality of information; thus, it is difficult to model or anticipate the effects of public policy in the household sector.

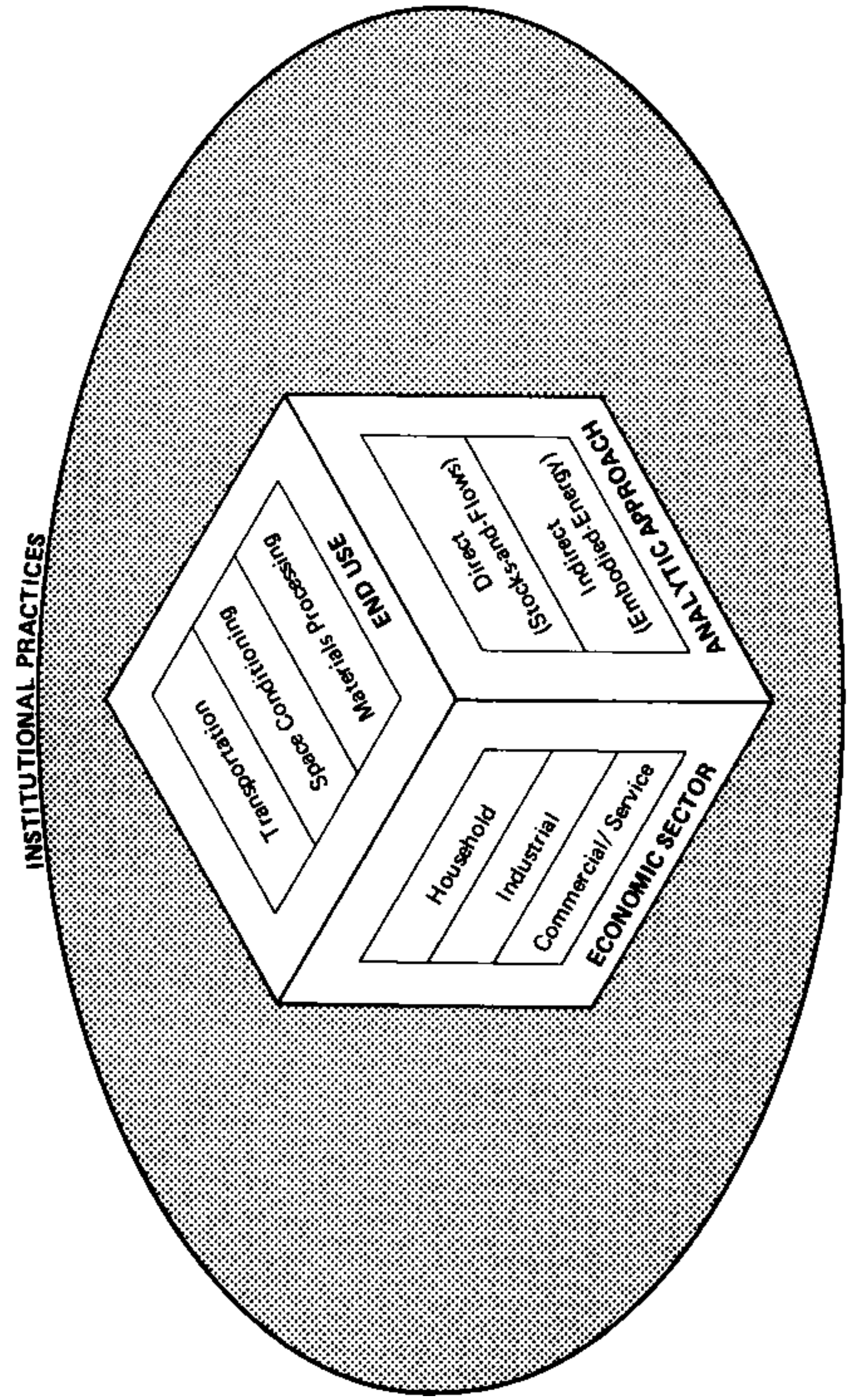

FIGURE 1   Analytic Framework

TABLE 1 Estimated Percentage of Energy Use by Economic Sector and End Use (1970)

Economic Sector Major End Use	Petroleum	Natural Gas	Electricity (Fuel Equiv.)	Coal	Total
Household sector					
Transportation	15.5	--[a]	--	--	15.5
Space conditioning[b]	4.0	4.7	1.4	--	10.1
Other	0.3	2.0	4.7	--	6.9
TOTAL	19.8	6.7	6.1	--	32.5
Industrial sector[c]					
Materials modification[d]	4.7	13.6	10.2	7.2	35.9
Commercial/Service sector					
Transportation	7.0	0.3	--	--	7.3
Space conditioning	2.2	2.5	1.6	0.6	6.9
Other	0.9	1.3	3.7	--	5.3
TOTAL	10.1	4.1	4.7	0.6	19.5
TOTAL: ECONOMIC SECTORS	34.6	24.4	21.0	7.8	87.9
Electric utilities	(2.9)[e]	(5.6)	--	(10.9)	(21.0)[f]
Other (Exports, feedstocks, etc.)	5.6	3.9	--	2.7	12.1
TOTAL	40.2	28.3	21.0	10.5	100.0

SOURCE: Estimates derived from: Earl Cook (1973); sectoral and functional allocations estimated from Penner and Icerman (1974) and Stanford Research Institute (1972). Totals may not add because of rounding.

a/Denotes value less than 0.1.
b/Includes multiple-family dwellings.
c/Includes agriculture, mining, manufacturing, and construction.
d/Data on transportation and space conditioning in the industrial sector are not available separately. Transportation in the industrial sector has been included, to the extent possible, in the commercial/service sector. Space conditioning in the industrial sector is included with materials modification processes.
e/Set off in parentheses to avoid double counting.
f/Approximately 1.6 percent of all energy derived from nuclear, hydro, and geothermal sources in 1970 is not shown.

For each sector, the Committee concentrates on data about the major uses of energy. In the household sector, which accounts for almost one-third of the nation's total direct energy consumption, energy is used primarily for transportation and for space conditioning; relatively less is used for materials processing such as cooking food and heating water. In the industrial sector, which accounts for more than one-third of total consumption, a small number of energy-intensive basic processing industries use most of the energy; relatively small proportions of energy are used for transportation and space conditioning in this sector. In the commercial/service sector, which accounts for almost one-fifth of total consumption, transportation and space conditioning account for more than two-thirds of the energy used.

End Uses

The broad end-use categories employed in this report are transportation, space conditioning, and materials processing. As shown in Table 1, each of these end uses has a different importance in each sector and each of these uses is subject to different variation within each sector. These factors influence the kinds of data and the methods of collection that may be useful for monitoring or modeling energy consumption.

Analytic Approaches

Two major approaches to energy consumption analysis provide insight into policy options. One approach concentrates upon the direct use of fuels (or electricity) to perform some function. This approach emphasizes the inventory of energy-using equipment, its physical characteristics, and its rates of use, and is sometimes referred to as the stocks-and-flows approach. Information about energy-using equipment and its use permits estimation of the potential for changes in the stock, either by retrofitting[2] or replacing existing stock. The other approach concentrates on the use of energy as embodied in various final goods or services in the process of their production and delivery--sometimes referred to as the embodied-energy approach.

Stocks-and-Flows Approach

Except for its use as feedstocks, energy is always used in conjunction with some type of equipment (or structure). Without light bulbs, washing machines, automobiles, furnaces, or drill presses, energy in the form of electricity or fuel would not produce results. Since energy must be used in conjunction with equipment, energy consumption can be monitored and modeled by

[2]Retrofit is a term used to describe the process by which an existing vehicle, structure, appliance, or other item of equipment is modified to reduce its use of energy (e.g., insulation, radial tires, etc.).

studying the relation between the stock of energy-using equipment and the flow of energy through this stock. Using this approach, energy consumption is related to: (a) the total size of the stock of all types of energy-using equipment; (b) the energy-consumption characteristics of that stock; and (c) the rate at which each piece of equipment is used over time.

Changes in the rate of use of existing equipment, while technically possible, are not easily accomplished. While electric lights can be turned off or unplugged, heating or cooling systems can be affected by dialing a thermostat up or down, and automobiles can be driven fewer miles, very little is known about the social or behavioral factors that may lead to such changes. Significant changes in rates of use seem to be less permanent than changes in stocks of equipment, so that significant long-run changes in energy consumption will depend mainly on changes in the energy-consumption characteristics of the stock of equipment and structures.

Embodied-Energy Approach

An alternative approach to analyzing energy consumption is in terms of embodied energy: energy as an attribute of the production and distribution of goods and services. A suit of clothes, a drill press, or a haircut require energy to be produced. For an item like a suit of clothing, energy is used to produce the raw materials for the fabric; to manufacture, shape, and fashion the fabric; to transport the clothing from the manufacturer to the wholesaler to the retailer; and to operate the retail store (to heat and cool the building, to operate the cash register, and to run the elevators) in which the suit is sold. In short, one can think of a complex series of energy flows associated with a product in the same way as the final cost is associated with all the direct and indirect costs of producing that product.

Usefulness of Alternative Analytic Approaches

The stocks-and-flows and the embodied-energy approaches can both be used to account for total energy consumption. Which is more useful from the point of view of monitoring and modeling energy consumption? The answer depends in part on whether technological change is more likely to occur at the end-product stage or the basic processing stage and in part on what kinds of policies are being considered.

In the household sector, the most useful way to analyze energy consumption is by using a stocks-and-flows approach, concentrating on the energy use associated with the size, distribution, and energy-using characteristics of equipment and its rates of use. This approach distinguishes between equipment that is relatively long-lived (such as houses), for which retrofitting policies are important, and equipment that is relatively short-lived (such as automobiles) for which both retrofitting and stock replacement are important. As detailed in Chapter 2, many of the needed data are available, although some of the most crucial pieces of information needed to model behavior are not currently collected. Household energy consumption is examined as a function of the factors determining rates of use and, more importantly, as a function of the factors determining changes in the amount, distribution, and energy-consumption characteristics of equipment owned by households.

In the industrial sector, the embodied-energy approach seems more useful for purposes of energy policy than the stocks-and-flows approach. The main elements of energy consumption in the industrial sector are in the transformation of raw materials into semi-finished products that are further processed or sold elsewhere in the economy. The embodied-energy approach highlights the characteristics of the processes and materials used to produce basic industrial products. As detailed in Chapter 3, our recommendations for data collection concern industrial processing technology, rather than consumer demand for final goods because it is our view that alternative materials processing technologies offer the most likely way of modifying energy use in the industrial sector.

In the commercial/service sector, discussed in Chapter 4, the relative usefulness of the two analytic approaches is not as clear. The major functional uses of energy (transportation and space conditioning) are similar to those in the household sector, although the range of variation in buildings and vehicles is much wider; the decision processes, however, are similar to those in the industrial sector. Thus, the data needed to monitor and model energy consumption in the commercial/service sector are similar, in part, to the data needed for space conditioning and transportation in the household sector: data on the size and type of structures, type of space conditioning equipment, and size of stock and energy-consumption characteristics of vehicles; however, the sector also includes a wide range of services (hospitals, restaurants, laundries, etc.), for which an embodied-energy approach may be more applicable.

Each of these approaches offers different insights into the measurement of energy consumption, providing distinct information about opportunities, limits, and broad implications of change in energy policy. The report concentrates on those combinations of economic sector, end use, and analytic approach for which improved data are most needed.

Institutional Practices

Patterns of energy use are heavily influenced by a variety of institutional factors, including present government policy. Analysis of energy consumption data that are relevant to public policy must consider these institutional factors because they account for a substantial amount of both present and future variation in energy consumption.

There is a tendency to treat institutional practices as preconditions or fixed parameters in studying energy consumption, but they are, in some ways, much like the stock of equipment: they evolved in a time of cheaper and more plentiful energy and are difficult to change rapidly in the short run. Clearly, such practices should be subject to reevaluation in an era of more expensive energy and of concern about the broader societal implications of present levels of energy use.

The influence of present institutional practices on current patterns of energy consumption is pervasive, but our study suggests that a variety of alternatives can be considered. Because these practices developed under fairly consistent supply and price conditions in the nation, it is often difficult to find significant variation within the United States. For this reason, alternative practices are often best studied by international comparison and field experimentation.

HUMAN AND TECHNOLOGICAL INTERACTION

Energy consumption involves interaction between technological and human factors. The achievement of what people and societies may want is limited by technological possibilities, just as the application of what is technologically possible in the laboratory is limited by human factors.

One of the most striking recent examples of the nature of the interaction between technological and human factors is the Green Revolution, which was supposed to alleviate the world's food problems through genetic changes in basic grain crops and different methods of planting and fertilization. Although increases in grain production currently provide the difference between starvation and caloric sufficiency for many people, those increases have been only a small fraction of the projections made by many responsible scientists and policy makers. The difference between the theoretical potential and the actual achievement has been attributed to miscalculation of the effects of natural field conditions compared to test plots, capital constraints of various kinds, poor distribution of information on cultivation techniques, and the fact that farmers and others involved have goals and problems other than increasing production. These latter, of course, include pressures for the maintenance of advantaged social and economic positions. The technologist-planner's assumption that it should be possible to make the world approximate the laboratory clashed with the view that life in general is more important than production in particular, creating the gap between potential and achievement. Abstract technological potential is properly constrained by human goals, just as human desires are often constrained by technological realities.

Individuals differ in their basic beliefs about the interaction of human and technological factors--about the roles of technology, economics, political processes, and human behavior. The members of the Committee, like other individuals, differ in their beliefs:

- Some think that technological innovations will permit production of the same amount of energy-dependent goods and services with less energy.
- Some think that improved information will alter the attitudes, habits, and customs that cause the present inefficient energy consumption by individuals.
- Some think that institutional practices that inhibit efficient and socially responsible management of energy resources will be changed by policy.
- Some think that higher energy prices will induce consumers and producers to find ways to modify their energy consumption.

These differences, however, do not affect the Committee's agreement on specification of energy consumption data needed to formulate effective and appropriate public policy. Energy consumption data, especially those needed for modeling change and for assessing the effects of energy policies, must cover all the factors if it is to be adequately informative to policy makers.

DATA QUALITY AND TIMELINESS: FINDINGS AND RECOMMENDATIONS

Throughout our work, we have been concerned with the quality and timeliness of data, both those presently available and those to be collected. The value of data to policy makers is severely diminished if the data are not good or not available when policy makers need them.

Energy Consumption Data Systems

Finding. Data quality cannot be specified in the abstract; it is a relative measure, relative to the purpose for which data are used. Since such purposes vary widely, no single standard of quality is likely to be applicable in all cases. Increased precision of data can usually be obtained only at higher costs, i.e., reducing sampling variance by increasing sample size or by more extensive or costly data collection procedures. Increased scope or increased detail can similarly be obtained by more extensive effort in data collection. What is needed for each effort is a clear specification of how much precision, scope, and detail are required and how much higher levels of precision, scope, and detail are worth in terms of the engineering, regulatory, or financial decision to be made.

Recommendation. *The Committee recommends that presentations of energy data be accompanied by a relatively complete description of how data were collected, including, as appropriate, sampling frame, sample design, estimates of sampling variability, non-response rates, forms of questionnaires used, validation methods, and characteristics of sources. Such a description would facilitate evaluation of the quality of the data for each specific purpose or application.*

The Committee further recommends that the design of each energy consumption data system include a clear specification of the purpose for which it is intended, a description of the completeness of its coverage, and estimates of non-sampling errors. Estimates of data precision can be obtained by a variety of techniques, including small-scale replication, independent cross-checks by alternative data acquisition methods, and audit and verification of data subsets.

Timeliness

Finding. Data have time value. For some purposes, preliminary estimates (with stated confidence limits) that are available quickly have greater value than more polished data available two years later. The timeliness of data is best measured by the extent to which it meets the schedule of decisions for which it was originally collected. National enumerative energy statistics, developed according to an earlier set of decision criteria, are now sometimes expected to meet shorter decision schedules.

Recommendation. *The Committee recommends that existing energy consumption data systems be systematically reviewed to identify opportunities for selective advance publication of material. The Committee recommends a review of systems that now collect data at 5- to 10-year intervals to identify cost-effective opportunities for more frequent reporting of those subsets of the data that are of more immediate policy interest.*

CHAPTER 2

HOUSEHOLD USES OF ENERGY

INTRODUCTION

Households consume, either directly or indirectly, about two-thirds of all energy used in this country: about one-third of all energy is used directly through the purchase of fuels and electricity, and roughly another one-third of the national total is used indirectly through the energy embodied in the purchase of goods and services for personal use. The remainder of U.S. total energy consumption (see Table 1) is attributable to capital formation, exports, or public goods, such as education and national defense (see Ford Foundation 1974, Bullard et al. 1975).

This chapter discusses the data needed to measure the direct use of energy by households for space conditioning in structures, energy uses associated with household appliances and hot water heating, and energy used for personal transportation. Table 2 (excerpted from Table 1) shows the estimated distribution of energy for major purposes in the household sector.

TABLE 2 Estimated Percentage of Energy Consumption by End Use in the Household Sector (1970)

End Use	Percentage of National Total	Percentage of Household Sector
Transportation	15.5	47.7
Heating, cooling, lighting	10.1	31.1
Other	6.9	21.1
TOTAL	32.5	100.0

The household sector is important in an analysis of U.S. energy consumption as a direct consumer of energy. In the judgment of the Committee, household energy consumption can be modified by a variety of energy conservation policies that could be adopted at the federal, state, and local levels. In contrast, energy consumption in the industrial and commercial sectors of the economy are likely to be more sensitive to policies that influence either the price of energy or the regulatory environment in which business decisions are made.

Energy consumption data requirements for the household sector can be classified under two general headings: (1) data required to describe and measure the amount of energy consumed and (2) data required to model and explain the amount of energy consumed. Data needed to evaluate the effects of public policy constitute a separate category, which is discussed in Chapter 5.

Measuring the amount of energy consumed means just that: collecting data on the number of kilowatt-hours (kwh) of electricity, cubic feet of natural gas, and gallons of motor gasoline and fuel oil consumed--in sufficient detail to account for important variations within categories, such as those due to local or regional differences. On the other hand, explaining the amount of energy consumed in the household sector requires the data necessary to answer such questions as:

- What would be the effect on the amount of energy consumed in the household sector between the present and 1985:
  --if per capita personal disposable income grew (in real terms) 2.5 percent per year?
  --if energy prices increased relative to the prices of other goods at the rate of 5 percent per year?

- What would be the effect on the amount of electricity consumed if the price of natural gas were decontrolled?

- What would be the effect on households in the lower quartile of the income distribution if the price of gasoline were increased to $1 per gallon?

- What would be the effect on the amount of electricity consumed if seasonal time-of-day tariffs were implemented in the sale of electricity?

- How might households change their use of appliances if they knew the actual energy costs of operating them?

- How might motorists adjust their driving speeds if their cars were fitted with a gauge that instantaneously showed gas mileage?

- To what extent would households retrofit their homes if they knew the costs and benefits of doing so?

Answering such questions requires other information besides the physical amounts of energy consumed. Information is also needed on the factors that determine the amount of energy consumed (e.g., prices of fuels and electricity, prices of other goods, consumers' incomes, and stocks of energy-consuming capital equipment) as well as a framework to organize and interpret data.

MEASURING HOUSEHOLD ENERGY CONSUMPTION

The direct consumption of energy by households is related to several factors, each of which entails different approaches to measurement:

- The social and institutional frameworks that encompass constraints on decisions stemming from legal regulations, for example, speed limits or building codes, and commonly shared norms or social and cultural conventions, such as the range of interior temperature of homes or the ownership pattern for household appliances and automobiles (Newman and Day 1975).

- Demographic and socioeconomic characteristics of the population, including distribution of families by age of head, family size and composition, and location of residence and place of work.

- Economic and financial factors, including current and expected prices of energy and stocks of energy-consuming equipment, income of the household, tax and subsidy rates, and financial incentives (or disincentives) arising from type of housing tenure.

- Factors affecting the "energy balance" of the residence, including such physical characteristics as size and interior layout of the structure, type and quality of construction, the amount, efficiency, and rates of use of energy-using equipment located in the residence, and weather and other environmental factors that account for regional variation (see, for example, Snell et al. 1976). Such factors include technical aspects, for example, degree of maintenance and engineering design, which affect the efficiency with which energy inputs are converted into outputs.

These four groups of factors, individually and with interactions, determine the direct consumption of energy by households. However, we have little firm information on which to base judgments about the relative importance of the factors or of the specific variables in each group. These factors influence the energy use of households primarily through two types of decisions: (1) decisions that determine the size, composition, and energy-consuming characteristics of stocks of vehicles, equipment, appliances, and residential structures owned and used by households; and (2) decisions that determine the rates of use of these stocks.

Short-run variations in the amount of energy consumed arise primarily through variation in the use rates of the existing stock of energy-consuming equipment; the size and composition of the stock cannot be changed quickly. The energy-consumption characteristics of the equipment can be changed only by modifying either the stock itself or the structure within which the equipment is housed. Since these types of adjustments take time and money to accomplish, variations in use rates are important to the understanding of short-term changes in patterns of energy consumption among households. In the long run, however, changes in the size, composition, and energy-consumption characteristics of the stock of equipment and structures and their regional variations become crucial factors.

Changes in rates of use generally are reversible, while changes in the size or energy-consumption characteristics of the equipment stock tend to be irreversible. For example, energy use can be reduced by driving fewer miles, turning thermostats down in the winter (Pilati 1975a), or using less hot water. However, backsliding on adjustments of this type is easy and evidently common, once the urgency to conserve energy appears to diminish. In contrast, the acquisition of a more fuel-efficient vehicle, installation of storm windows and insulation, and the elimination of pilot lights from furnaces or ovens are actions that are unlikely to be reversed, even if the importance of energy conservation fades in people's minds.

Social and Institutional Factors

The role of public understanding and attitudes in determining the demand for energy is illustrated by two simple propositions: (1) people cannot react to what they do not know and (2) the behavior of one consumer is determined partly by the actions of other consumers.

Consumer knowledge about energy cost of various items of household equipment or appliances provides an illustration of the first proposition. Bills that consumers receive do not indicate the cost of running a refrigerator, a television set, or any other specific appliance; rather, the bills provide consumers with only the total cost of using electricity, natural gas, or petroleum for their particular combination of appliances using that particular type of energy. Thus, rational decisions about minimizing the total cost of using a particular appliance are difficult, if not impossible, since consumers cannot calculate the cost of the appliance over its lifetime.

A similar situation exists for energy used in space conditioning. While most consumers know the total energy cost of heating and cooling, they are unlikely to know the cost of changing the efficiency of energy use for heating and cooling. Moreover, in the case of vehicles, drivers know the price of gasoline, but in general they do not know how much gasoline consumption is reduced by driving 30 or 50 miles per hour, or the cost/benefit ratio for engine tune-ups, because the observable variable is price per gallon, but the relevant variable is cost per mile traveled.[1]

A variety of feedback experiments on household energy-consumption information is currently in progress. These experiments are designed to provide information on an individual household level. One experiment in New Jersey found that when households were provided with this type of information on their energy use, they reduced their consumption by an average of about 8 percent (Seligman and Darley 1976).

[1]"Giving Households Feedback on Energy Consumption," a paper prepared for the Committee by Fred D. Baldwin of the Syracuse Research Corporation, provides a discussion of feedback experiments related to such situations.

The second proposition relates to the role of social mores, habits, and practices that determine household energy use patterns. Energy-use practices tend to be deeply ingrained in existing habits and styles of living, particularly in practices that affect the use of energy for space conditioning in structures and the use of energy for personal transportation. Many Americans have preferred to buy detached dwellings in suburban settings, with little regard for the energy implications of that choice. Such a choice is consistent with low energy prices and plentiful supplies, but when energy prices are high and rising and supplies are no longer plentiful or ensured, that choice may change.

Regarding personal transportation, the issue is once again the speed of adjustment to changed economic circumstances. The present stock of cars, indeed the entire transportation system in the United States, reflects the historically low price of energy. As the characteristics of the vehicle stock change in response to price and other pressures, those changes may reflect the social approval or disapproval associated with fuel-inefficient vehicles.

Institutional practices also influence energy use for space conditioning. Almost all construction in this country is subject to building codes that were fashioned when the supply of energy was cheap and plentiful. The building codes appropriate for high-priced energy are obviously different from those appropriate in the past, but modification of such regulations is a time-consuming process.[2] Moreover, the nature of the markets for fuel oil and electricity, for example, is inherently different. Data used to describe the use of fuel oil for home heating are decentralized and rarely collected, whereas data used to describe the use of electricity are highly centralized and theoretically available in real time.

Other institutional practices that influence energy use for space conditioning relate to differences between tenants and owners in their sensitivity to energy price changes. For example, tenants who do not have to pay utility bills have little economic incentive to modify energy consumption; landlords who do pay the bill have incentive but often have no effective way to exercise control. Even tenants who do pay their utility bills may be reluctant to modify the housing structure, simply because they do not expect to be living in the same place long enough to obtain the financial benefits. In addition, landlords of such buildings have little incentive to insulate or install storm windows, because they do not pay the heating bills.

Similarly, tenants who rent apartments ordinarily pay commercial rather than residential rates for energy use, because a single meter is usually used for multiple-family dwellings. These rates are generally lower than residential rates, so both tenants and landlords in apartment buildings may lack the incentive to invest in energy-saving improvements (see Midwest Research Institute 1975).

2"Regulation and Energy Consumption" a paper prepared for the Committee by Charles River Associates provides a discussion of this subject.

Demographic Factors

Understanding energy demand requires analysis of the demographic composition of households. The principal effect of demographic composition probably tends to work through the characteristics of the household stocks of equipment and their use patterns. Thus, to predict changes in the size and composition of the vehicle and housing stocks, changes in demographic composition are likely to be important.

Small families have energy-consumption habits that differ in important ways from those of large families, and the habits of families with children differ from those of families without children. According to Bureau of Labor Statistics data, for example, two-person households spent slightly more per capita for gasoline than single-person households and almost twice as much per capita as families of six or more (U.S. Department of Labor 1975). Thus, one should expect demographic differences to account for much of the variation in energy consumption in a cross section of households.

Recent trends in U.S. population growth rates and the demographic composition of families suggest that the demographic factors are likely to be important sources of variation in energy use in the future (Chapman et al. 1973). There is an increasing number of single-person households in the United States, mainly as the result of growing numbers of young unmarried and older people maintaining their own households. These single-person households use more electricity and natural gas per capita than households with more than one person. Birth rates have declined sharply, and there are birth-rate data that suggest that there will be more smaller-sized families in the future. These families generally use more energy per capita than larger families. Finally, labor force participation among women has been growing rapidly, although its effect on energy consumption is not yet well measured or understood.

Isolating the relationships between energy consumption and demographic characteristics is an important dimension of any effort to explain household energy consumption over the next several decades.

Economic Factors

The primary variables in most studies of energy demand in the household sector are the prices of fuels and electricity, the prices of energy-using equipment, and the incomes of consumers (Houthakker et al. 1974). Empirical studies show that households tend to consume less energy as the price of energy increases, indicating also that the response to a change in energy price tends to be greater for those items (such as cooked meals, passenger miles traveled, or internal temperature in the home) for which energy costs are a larger proportion of total costs. In addition, studies show that consumer demand for energy tends to vary directly with consumer income (King 1975; also see Taylor 1975, Taylor et al. 1976, and Blattenberger 1976).

Although the current price of energy plays an important role in determining the amount of energy consumed, expectations about future energy prices as well as associated expectations about the future prices and characteristics of energy-using structures, equipment, and appliances may be even more critical in determining the long-run demand for energy. For the most part, energy is consumed in the process of using capital goods to produce various types of services. The expected lifetimes of the relevant capital goods range from a few months for items like ordinary light bulbs to 60 to 100 years for housing. Most energy-using capital goods in the household sector have expected lifetimes between 5 and 20 years, depending on type of equipment or intensity of use (Kendrick 1974). Thus, from the point of view of consumers, the optimal energy-consumption characteristics of household capital goods depend not only on present energy prices but on the prices expected over the operating lifetime of the equipment; these expectations may also vary by fuel type.

In theory, consumers can be viewed as minimizing the expected lifetime costs of obtaining outputs from inputs of equipment, energy, time, and other factors. If energy prices are expected to rise, consumers will have an incentive to replace existing equipment with equipment that is technically more efficient, even if it is more expensive. The strength of the incentive depends on the expected lifetime of the equipment, the cost of replacing existing equipment, and the certainty with which consumers expect prices for different types of fuels to rise.[3] Moreover, incentives to replace existing equipment depend on expectations about the rate of technical change in the energy efficiency of equipment. If it is widely anticipated that much more efficient equipment will be available in five years, consumers have an incentive to postpone the replacement of existing equipment.

Changes in energy prices and expectations of future prices influence decisions to change the characteristics of energy-using equipment by determining the characteristics of new additions to the stock, and by increasing the rate at which the existing stock is scrapped, since one of the consequences of a rise in energy prices is a decline in the value of relatively inefficient existing equipment.

The analysis above embodies the conventional assumptions of economists: that consumers are aware of prices; that they make rational calculations about costs and benefits; that they are relatively unconstrained by liquidity and wealth; and that they operate in an environment in which information can be obtained without cost. Reality is not quite like this, however, and in analyzing the relation between energy demand and economic variables, it is important to specify the time periods involved. Given that the energy-consumption characteristics of the existing stock of structures, equipment, and appliances are relatively fixed in the short run, one should not anticipate much short-run response to variations in either energy prices or consumer incomes. Although consumers can lower the temperature in their homes in the winter, or drive fewer miles, changes in equipment stocks imply major adjustments that take time to accomplish.

In the long run, much more response to both prices and income can be expected. As incomes rise, consumers tend to buy more housing space (including second homes), acquire larger or additional cars, and own more appliances, such as dishwashers and clothes dryers. However, as energy prices rise, consumers have incentives to buy more efficient equipment, usually at the cost of either higher prices for the equipment or smaller amounts of other

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[3]The importance of uncertainty about expected price change for a somewhat different problem is examined in Juster and Taylor (1975).

characteristics of the capital goods in question. For example, people can buy more efficient vehicles by trading off size, performance, and comfort for more fuel economy. They can acquire a "different" housing structure by installing insulation or storm windows to reduce the energy needed to maintain a given room temperature. In the long run, consumers can select multiple-family rather than single-family dwellings.

Energy Balance in the Residence

An important and generally overlooked aspect of energy consumption in the household sector is the interaction between energy used for space conditioning and energy used for other purposes within the residence. The basic point is simple enough: with a residence of given dimensions and thermal characteristics, the energy requirement for space conditioning is a function of the use levels of energy-consuming equipment (appliances and lighting) located within the residence. For example, a house in which an oven, a refrigerator, and a washing machine are in continual operation will use less energy for heating in the winter (and more energy for cooling during the summer) than an identical house in which identical appliances are less intensively used. Much of the energy used to operate ovens, regrigerators, and washing machines is "wasted" for the purpose of cooking, cooling, and cleansing. However, it is not entirely wasted; it contributes to heating the air within the residence, thereby reducing the need for heating in the winter and increasing the need for cooling in the summer.

Because of interactions of this sort, analysis of direct energy consumption by the household sector is best approached in terms of energy consumed outside of the residence, which is almost exclusively used for personal transportation and energy consumed within the residence itself. For the latter, an appropriate framework for analysis must account not only for the thermal characteristics of the residence, the personal or family preference for interior temperature, and the type of heating or cooling unit but also for the number and rates of use of the other appliances and equipment in the residence.

Direct Energy Use in Personal Transportation

This section describes direct energy use for personal transportation--defined to include cars, trucks, and other vehicles used for personal travel. Personal transportation accounts for approximately 15 percent of total national energy consumption.[4] Some 100 million automobiles and 10 million trucks are used for personal transportation (Motor Vehicle Manufacturers Association 1975, Commerce 1970, 1976a). (Trucks used for personal transportation are included in this category because the decisions governing their purpose and use are similar to those for automobiles.)

[4]See Table 1; also see U.S. Department of Commerce 1974a; hereinafter referred to as Commerce.

In the short run, variations in rates of vehicle use are the primary determinants of changes in energy consumption. The use of the existing stock of vehicles is directly affected by the price of gasoline. In the long run, however, the demand for gasoline varies primarily in accordance with the size and fuel-efficiency characteristics of the vehicle stock. Changes in the numbers of vehicles and their fuel-use characteristics--arising out of both the addition of new vehicles and the scrapping of existing ones--are the central concerns; rates of use play a more secondary role.

Demand for Gasoline

Before discussing the implications of developments in the private transportation sector for energy consumption data, it is important to distinguish between demand for vehicle miles and the demand for passenger miles. The measurement of vehicle miles is of central importance because it is vehicle miles, together with the number of vehicles and their fuel efficiency, that largely determine gasoline consumption. Variation in vehicle weight due to differences in the number of passengers, for example, is of lesser importance. On the other hand, the demand for passenger miles is of primary interest in investigating the substitution of other modes of transportation for private vehicles in meeting personal transportation needs. For a given passenger-mile demand, different levels of vehicle miles will be demanded for personal automobiles depending on the relative price of public and private transportation.

Changes in Vehicle Efficiency

Historical data indicate that gasoline consumption per vehicle mile tends to be greater than the ratings obtained from manufacturers or from estimates of the Environmental Protection Agency (EPA). The reasons underlying this difference are unclear. Part of the difference arises from the use of test methods that do not duplicate field conditions, but there may be other reasons as well. It is often suggested that the extent and regularity of vehicle maintenance has an important effect on fuel efficiency, as do differences in drivers or driving style. In addition, some variation, perhaps a significant amount, may result from variations in quality control in manufacture. This is of particular importance, because public policy now relies to a large extent on target fuel standards for manufacturers as a means of increasing overall efficiency in gasoline consumption. Depending on whether variations in fuel efficiency relate more to the skill with which the vehicles are manufactured or to the skill with which they are operated, the optimum public policy may vary from emphasis on more stringent production controls to emphasis on periodic maintenance inspections and driver education programs.

Aside from technical and behavioral variations in fuel mileage, policies have been initiated during the past several years to reduce gasoline consumption through vehicle use regulations. The 55-mile-per-hour speed limits, legalized right turns on red signals, and more stringent vehicle inspection requirements are examples of such policies (U.S. Congress, Senate 1975).

In addition, there is a wide range of policies designed to increase passenger load, such as lowered tolls and express lanes for vehicles carrying more than three persons; these policies also affect the aggregate number of miles driven.

Information on the factors that account for significant energy inefficiencies in vehicle use has to be monitored and fed back to consumers and policy makers alike. If energy savings accrue mainly to vehicles kept in good operating condition, devices are needed to indicate the dollar savings per mile driven to individual consumers. Methods must also be devised to ensure that vehicles are actually maintained. On the other hand, if significant gasoline savings can be achieved by better driving habits, then requirements for driver's licenses, rather than vehicle maintenance regulations, are at issue. Evaluating the effectiveness of such policies is an important task, because the basic energy savings from regulation may be illusory if the policies rely on the cooperation and support of individual consumers.

Changes in Rates of Use

As energy prices rise, intensive users of vehicles face a greater increase in total cost than less intensive users. More intensive users will tend to acquire more energy-efficient vehicles, prompting a chain of transactions, including the purchase and use of older and less efficient vehicles by people with lower incomes, that will place a larger fraction of the more efficient stock in the hands of more intensive users.

The same phenomena will also occur in households with more than one car. In 1973, 34 percent of all households in the United States owned more than one automobile (Motor Vehicle Manufacturers Association 1975). Higher gasoline prices thus provide economic incentive to shift the use within the household toward putting the more efficient car at the disposal of the more intensive user.

Vehicle use rates are of particular interest in the analysis of the effect of conservation policies. Regardless of the other adjustments made in vehicle-use patterns, simply driving fewer miles will, in general, reduce gasoline consumption. Substitutes such as car pooling, walking, biking, or eliminating vehicle trips are particular responses to situations characterized by gasoline shortages and a crisis atmosphere. Little is known, however, about the long-term potential of such actions, such as the extent to which people may attempt to live closer to their place of work.

In addition to providing information to consumers on the costs and benefits of different vehicle-use patterns, there are other gasoline and vehicle-use tax policies that have been or could be enacted to modify gasoline consumption patterns. The effectiveness of these policies will depend not only on the incidence of the taxes but also on their public acceptance. Tracing changes in vehicle-use patterns will make it possible to identify trip purposes as essential, essential but amenable to public transit, or able to be eliminated or curtailed. This will help identify those purposes for which public transit could most successfully be promoted.

Changes in Vehicle Stocks

In the long run, the demand for gasoline is derived from the characteristics of the stock of motor vehicles. In effect, consumers buy an entire set of characteristics when they purchase a vehicle. These characteristics include size, power, comfort, specific features such as air conditioning and automatic transmission as well as characteristics such as costs of maintenance, repair, and fuel. The optimal set of characteristics demanded can be expected to change because of changes in family size and geographic location or because the cost associated with the various characteristics changes. In general, higher gasoline prices provide consumers with the incentive to trade size, performance, and comfort for more fuel economy.

These trade-offs do not necessarily imply giving up size and performance for fuel economy. An alternative would be to acquire the same amount of size and performance at higher capital costs, using different materials or engineering specifications that produce the same results--for example, aluminum may be used to reduce weight and improve fuel economy, but only at an increased cost for the vehicle itself. The particular combination of vehicle characteristics that a family chooses to purchase depends in part on the expected lifetime costs of the various attributes and the cost and availability of transportation substitutes. Consequently, the family's preference for this mix of characteristics will change when the price of those characteristics changes.

The rate at which vehicle stocks turn over depends on the difference between past and present energy prices, the differences in vehicle performance characteristics, the difference in operating costs per mile between existing and new vehicles, the proportion of operating cost to total cost, the rate of increase expected in future gasoline prices relative to other prices, and expectations about the operating characteristics of future vehicles. The timing and strength of demand for new cars is poorly predicted by conventional models of stock adjustment, since replacement demand depends on expectations about future prices and operating characteristics. How these factors influence demand depends in part on whether future costs and rates of change are the result of legislated requirements and other public policy interventions or whether they result from a market response to higher gasoline prices. To the extent that change results from mandated requirements, the combination of higher future costs and better fuel economy will not necessarily provide incentives to change the characteristics of the vehicle stock. In fact, they may provide the reverse incentive, since mandated requirements may involve such high capital costs that savings from lowered operating costs would be neutralized. Expectations of rapid change in fuel economy or vehicle life may also postpone changeover in the vehicle stocks, since consumers can opt to wait for the expected more efficient vehicles.

Family size and living arrangements also play an important role in delineating the type, number, and fuel-efficiency characteristics of vehicle stocks. Current trends toward reduced family size and growing numbers of households can be expected to alter the distribution of transportation needs and preferences of households (see Commerce 1975b, 1976b). Although the demand for large automobiles may decrease because of decreases in family size, it may be offset by the increased need for vehicle miles for commuting in two-worker families. Moreover, an increase in the number of households often entails a corresponding increase in the number of vehicles, for example, when children leave home or the elderly maintain separate residences.

DATA NEEDS IN THE HOUSEHOLD SECTOR

Coverage and General Quality

In general, the quality and coverage of data currently available on energy consumed within the household vary from excellent to very poor. The Committee implicitly assumed that federal agencies collecting energy consumption data would take no steps to make them less comprehensive than those now being collected, but we have no guarantee that this will be the case. In quality, scope, and level of detail, the data are best for electricity and worst for heating oils (see Newman and Day 1975, Edison Electric Institute 1975). The data for natural gas are more or less comparable in quality to the data for electricity, although they are neither as well organized nor as refined (American Gas Association 1975). Virtually all of the electricity and natural gas data are derived from individual billing records. Thus, in principle, electricity and gas consumption data exist at the level of the individual residence (except residences in apartment buildings that have one meter for many units), although the data are never published at this level of detail.

The Committee notes several shortcomings, for the purposes of this report, in existing data on electricity consumption:

1. Data on the amount of electricity consumed in the home by detailed end use, particularly on a regional basis, are generally not available, except from the occasional special survey.[5] Unfortunately, there is not much prospect of this information ever becoming available on a routine, systematic basis because of the metering costs that would be involved in collecting the data.

2. The published historical record presents very little information on household electricity consumption by time of day. The data that are most accessible are highly aggregated and offer little scope for meaningful analysis. Undoubtedly, a great deal of time-of-day consumption data exists in the records of individual utilities, either in the form of special studies or in substation archives. Substation data have rich potential as a source of information and clearly merit analysis.

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[5]The Federal Energy Administration and the Electric Power Research Institute are sponsoring a national sample survey by the Midwest Research Institute (Contract RP333), conducted by personal interview and concentrating on electric appliance stocks and household characteristics. Appliance utilization data are being collected from a subsample of 150 households in which eight major electric appliances are individually metered.

3. Utilities do not as a rule publish the distribution of amounts of electricity consumed by different classes of customers. This information is central to an evaluation of the effects on economic and social welfare of changes in the structure of electricity rates (such as implementation of "life-line" rates, by which public utilities provide a minimum quantity of electricity, enough for "survival," to their customers at a low rate).

4. The data available from the utilities on electricity consumed by apartment dwellers are usually counted as commercial consumption because of the use of master meters.

As noted, the data for heating oils in the household sector are very poor in terms of both quality and coverage mainly because of the nature of the marketing and distribution system. One of the major problems is the allocation of consumption to residential and commercial categories; in many cases, the problem extends to industrial customers as well. There is virtually no information available on heating oil that is classified by the quantities used by different types of customers. Moreover, the data for heating oil prices are even more incomplete than the data on consumption.

Residential Structures, Equipment, and Appliances

As indicated earlier, in the long run the basic determinants of the amount of energy consumed by households are (1) the size, distribution, and thermal characteristics of the stock of residential housing and (2) the size and composition of the stock of energy-consuming appliances and equipment.

Although much information exists on housing, virtually none of the existing data include relevant information on energy use, at least at the national level. As a minimum, data on the square, or even better, cubic, footage of living space is needed, plus some measure of insulation characteristics, conduction rates, and structural-shell tightness. Square or cubic footage can possibly be estimated from existing data, but insulation characteristics cannot.

Data are especially needed on the relation between the physical characteristics of residences and the energy consumed for space conditioning. There is some small-scale experimental evidence suggesting that there is a great deal of variation in the amount of energy consumed in nominally identical structures, given the same exterior temperature and the same configuration and use rates of appliances. However, there are no data on the relationship between physical characteristics and energy consumption for structures that cover the full range of residential structures; nor do there exist well-developed methods for measuring the physical characteristics of structures that determine the amount of energy consumed for space conditioning among representative samples of U.S. households (Mayer and Robinson 1975).[6]

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[6]Also see Title III of the Energy Conservation and Production Act of 1976 (P.L. 94-385 1976).

Data of this sort would make it possible for individual consumers to make better judgments about the economic feasibility of various types of structural modifications. The effects of insulating and sealing joints and cracks on energy consumption may depend upon complex physical phenomena that differ among housing units. The incentive to make these modifications may depend upon information about economic returns that can be reliably demonstrated. Thus, the effectiveness of policies designed to promote energy conservation is likely to depend on the ability to predict the effect of structural modifications on individual structures, rather than on the ability to predict typical results for the average residence. Neither the strength of behavioral response of this sort nor the amount of variation in the energy-consumption characteristics of structures is now known with much reliability, but they seem to the Committee appropriate subjects for careful examination.

Data on appliance stocks is better than that on the stock of housing, but improvements are needed for both. The best and most complete existing data on appliance stocks were constructed by Verleger and Iascone (1976). However, data on appliance stocks have serious defects:

- Existing data refer to appliance saturation rates; that is, they provide estimates of the number of households that have a particular appliance. Ideally, one should have a measure of the capacity of the appliance and its use rate or, lacking this, a measure of the total number of appliances actually in use.

- Existing data provide little information on the energy intensity and hours of use of appliances. In principle, stocks of appliances should be measured after variations across vintages of the same appliance have been accounted for.[7]

- The accuracy of existing estimates of appliance stocks is unknown. Almost certainly, the accuracy can be improved on the basis of existing information.

- Information on appliance scrappage rates is very spotty.

- The data on appliance prices are especially in need of extension and improvement.

Despite the lack of information on the energy efficiency of appliances, the data existing in utility archives offer a potentially useful source for improving the quality of the Verleger-Iascone estimates of appliance stocks.

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[7]To develop consistent series on the age structure and the size-efficiency mix of the stock of appliances, the sales and production records of manufacturers and large distributors are probably the most feasible source, because the other sources--census and surveys conducted by utilities--have not identified the appliances in sufficient detail to ascertain appliance size.

Most major electric utilities conduct appliance ownership surveys, and these have been growing in frequency, size, and depth in recent years. These surveys vary widely in sample size, scientific rigor of sampling and data collection procedure, and comprehensiveness. The number of appliances included tends to be larger than that obtainable from other sources, but the surveys frequently collect information on only a few key appliance characteristics. For example, television sets are classified as black-and-white or color and refrigerators are classified as frostless or not. Demographic data are quite detailed in some surveys but limited in others, and the same is true of data on dwelling characteristics; very few collect data on income. A few utilities meter individual appliances of some homes on a time-of-day basis, and a few determine whether appliances were purchased during the year preceding the survey.

Utility survey data, except those obtained in conjunction with publicly funded programs such as the peak-load pricing experiments sponsored by the Federal Energy Administration, are generally proprietary. Utilities have furnished some of this information for outside publication, as in the case of appliance data supplied to _Merchandising Week_ (see, for example, _Merchandising Week_ 1975).

Because of the proprietary nature of the utility survey data and the unevenness of coverage and quality, these data are generally not a useful source for building up national data files on the use and ownership of appliances and customer characteristics. Nevertheless, it is clear that researchers analyzing electricity demand would profit from professional contact and cooperative research activities with the electric utility load analysts who conduct those surveys. In some instances, proprietary data may be released for special local studies; in any event the practical knowledge and experience of the load analysts are often rich sources of insight into electricity demand behavior. The depth and quality of research on electricity demand in the electric utilities (for forecasting, rate design, and load analysis) has increased greatly in recent years, but there is still comparatively little professional contact between the utility experts in the field and researchers outside the industry.

Personal Transportation

Data are available on the current vehicle stock and existing patterns of ownership cross-classified by the economic and demographic characteristics of households (U.S. Department of Transportation 1972; hereinafter referred to as Transportation). In addition to an inventory of household vehicles, information is available on trip purposes, distance, travel time, trip frequencies, and the number of passengers carried per vehicle mile.[8] This information gives a reasonably complete picture of how households currently satisfy their transportation needs by the use of private vehicles and public transit. There are, however, significant gaps in the current data available on actual fuel efficiency of the vehicle stock, amounts of fuel used for various purposes,

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[8]For example, three surveys that obtain these types of data are: the 1972-1973 Consumer Expenditure Survey of the Bureau of Labor Statistics and the 1973 Energy and Lifestyles Survey and the 1975 Survey of Household Energy of the Washington Center for Metropolitan Studies.

consumers' expectations of the cost and fuel efficiency of new vehicles, the long-term potential of conservation, and the effects of shifting transportation preferences on future vehicle demand.

The actual fuel efficiency of vehicle stocks is a crucial input into later modeling. Fuel-efficiency characteristics cannot be inferred from the technical characteristics of the vehicles themselves but must be measured directly. Fuel efficiency needs to be documented for different vehicle makes, models, optional energy-using equipment, and year of manufacture as well as for variations within these various vehicle specimens. These measures of fuel efficiency should reflect actual fuel use accurately so that variations within specimens can be analyzed. To determine the efficiency of the existing automobiles, it is important first to control for the variation among drivers and use patterns; to collect these data would require a research study with trained drivers or measurement devices. If there were significant variation between new cars and the same cars after several years of use, it would then be worthwhile to test several of the components of the older car to determine which had the greatest effect on the decline in efficiency. Following this, variations in fuel usage both among and within specimens should be related to the purposes for which the vehicle is used, distance, travel time, and frequencies of various trip purposes.

Current data are also needed on the cost of vehicle repair and maintenance. In addition, the cost of modifying the vehicle itself to improve gasoline mileage and the cost of devices that provide drivers with feedback on actual fuel efficiency should be determined and compared with potential gasoline savings. These data will make it possible to assess the economic incentives for households to maintain or improve their vehicle's fuel efficiency. Other physical data needs include information on the energy costs of mandated antipollution control equipment, safety devices, and other legal restrictions related to vehicle use. Finally, data are needed to assess indirect effects, such as changes in accident frequency and severity.

To study the responsiveness of conservation behavior to current price and supply conditions, existing Federal Energy Administration data are useful for a variety of research objectives. However, in view of the decline in conservation behavior since these data were collected, more should be known about changes in consumers' attitudes and perceptions, especially toward public policy alternatives. It is of particular importance to determine the long-range implications of conservation motivations. While conservation attitudes in the short run may be reflected by a range of consumer reactions, including more efficient driving habits, car pooling, and greater use of alternative means of transportation, more basic adjustments are required in the long run. For example, it is not clear how much of the total household demand for transportation could be satisfied by public transit. More emphasis should be placed on collecting data about trip purposes and vehicle use patterns that could be used to analyze the demand for public transit. International comparisons may also be useful in providing illustrations of social and institutional arrangements that affect the demand for public transit (Schipper and Lichtenberg 1976).

Since research on the factors associated with changes in the size and energy-consumption characteristics of the vehicle stock involves developments that take place mainly in the future, currently available data are likely to be of limited usefulness. Data on consumer expectations are needed to model near-term adjustments in vehicle stocks, and measures of evolving preferences for different transportation modes are needed to model longer-term trends in private vehicle demand.

The prominent role of expectations in the consumer decision model outlined above is matched only by the absence of the appropriate data. Extrapolating past price changes as a proxy for future expected movement is not sufficient, just as the past rate of technical improvement in vehicle mileage is likely to be a poor indicator of future changes. Since changes in expectations can occur rapidly, constant monitoring is needed to model the transition from the present vehicle stock toward one that achieves greater fuel efficiency. Since expectational measures are hypothesized to be useful to understanding the on-going transition from fuel-inefficient to more fuel-efficient vehicle stocks, the benefits derived from their measurement will be greater the earlier these measures are implemented.

Information on transportation mode preferences is a less pressing data need, since these changes occur slowly and after a substantial lag. To monitor long-term transportation preferences adequately, much more needs to be known about the impact on vehicle demand of the changing age structure trends in marriage and birth rates, and the resulting trends in family life cycle distributions and needs as well as in preferred patterns of residential location, including time and distance traveled to work and shopping.

FINDINGS AND RECOMMENDATIONS: HOUSEHOLD SECTOR

Household purchases of fuels and electricity account for about one-third of total national energy consumption. Of this total, about half is used for personal transportation and one-third is used for space conditioning. The Committee found that most data used to describe aggregate household energy consumption are adequate at present, at least in aggregate terms.

However, there are important exceptions: few systematic data collections are available at present to describe consumption of energy by detailed end uses (e.g., refrigeration, cooking, and lighting). Second, present data are inadequate to isolate and account for all sources of energy supplies used by private households for space conditioning, especially data on petroleum used for heating. Third, data needed to describe the uses of energy for personal transportation (although not collected on an ongoing basis) seem to be adequate for broad descriptive purposes, but the accuracy of some of the basic information is open to question.

Systematic Data Collection

Recommendation. *The Committee recommends that benchmark surveys be undertaken to measure detailed uses of energy in households by end uses. These data are best obtained by a listing of household appliances (including information on type, size, vintage, and location within the structure) and appliance use rates. For a subset of this sample, physical measurements of actual quantities of energy used should also be taken, permitting correlation of equipment type and size with data on energy use.*

Recommendation. *The Committee recommends that methodological work be undertaken on the use of survey and other measurement techniques, including vehicle instrumentation, to monitor energy used in personal transportation by trip purpose, travel time, and distance. In addition, surveys should be undertaken to update this information periodically. Methodological work is necessary, since the level of detail and the time span needed for data of this type go beyond usual survey research applications.*

Recommendation. *The Committee recommends that a benchmark survey of types and amounts of fuel used for space conditioning by households be undertaken to provide the necessary background information on quantities of fuel oil used for home heating.*

Modeling Direct Energy Consumption

Finding. The data needed to understand and model direct energy consumption in the household sector (as distinguished from merely describing it) are seriously inadequate. It is useful to divide direct energy consumption by households into two categories: energy used within the residence and energy used outside. The latter is dominated by energy used for personal transportation; the former is mainly energy used for space conditioning, although use of most equipment and appliances also takes place within the residential structure. For understanding direct energy consumption within the housing structure, data are needed on the stock and use rates of equipment and appliances, cubic footage of space to be conditioned, the physical characteristics of the structure itself, the demographic and behavioral characteristics of the occupants, the relevant energy prices, and expectations about future energy prices. Very little of the necessary information is currently available, and no available collection of data contains all of these essential variables.

More specifically, estimates of responses to price changes are obtained almost entirely from data based on a history of declining relative energy prices, while the present environment is one of rising relative energy prices. In addition, there are almost no data necessary for a national sample of the physical characteristics of housing structures that affect energy used for space conditioning, nor are there relevant data on expected prices. Much of the crucial information needed for understanding how the stock of structures and energy-using equipment and appliances may change over time is thus not currently available.

Recommendation. *The Committee recommends that a national sample of dwelling units be surveyed in a panel format, with some planned rotation over time. Data should be obtained periodically both from occupants of these units and, where feasible, from instrumentation of the energy-using equipment in these units. The basic sample would be one of dwelling units, periodically augmented by samples of new construction. The information to be obtained from this panel would include:*

- *Physical characteristics of the housing structure: number and size of rooms, insulation characteristics, glass area, structural shell tightness, and type and efficiency of* *heating and cooling system, duct work, and controls. Consideration should be given to housing units that use solar or other currently unconventional sources of energy for space conditioning and water heating.*

- *Location and siting of the residence: Location data refer to information about distances from modal destinations as a determinant of gasoline use. Siting data include orientation, vegetation, distance from adjacent structures, weather, and other environmental factors that affect heating and cooling loads.*

- *Consumption of various forms of energy in physical units.*

- *Energy-using equipment and appliances located within the housing structure, including type, vintage, and typical rate of use. Equipment and appliances to be covered are central air conditioners, window air conditioners, furnaces or heat pumps, types of thermostat or other controls, water heaters, cooking ranges, refrigerators and freezers, washing machines, clothes dryers, dishwashers, television sets, and lighting fixtures. Other pieces of equipment or appliances were judged not to warrant inclusion, because they account for such small contributions to total present energy use. In some areas of the country, or over longer time periods, this list should be expanded to include equipment such as swimming pool pumps and heaters or saunas, which may be more widely used in the future.*

- *Demographic and socioeconomic characteristics of the occupants.*

- *Present prices, expected prices, and the distribution of price expectations for different forms of energy.*

- *Data to permit specific estimates to be made of expected payoffs from investments in structural modifications on a structure-by-structure basis.*

- *Other explanatory variables, including income, ownership, and expected time of occupancy, knowledge of energy and energy-related problems, and attitudes toward energy consumption.*

Personal Transportation

Finding. The predominant use of energy external to the residence is gasoline for personal transportation, and data are mainly needed for the factors that determine the short- and long-run demand for gasoline. From the point of view of energy policy over the next several decades, the principal points of leverage are changes in the energy-consumption characteristics of personal transportation vehicles and changes in automobile use patterns, which are the major factors accounting for gasoline use.

Recommendation. *The Committee recommends that, as part of the dwelling unit panel described above, data be obtained on the following factors needed to understand and predict the demand for gasoline:*

- *Technical characteristics of each household's personal transportation vehicles.*
- *Annual mileage driven, by purpose, travel time, travel distance, and gasoline consumption for each vehicle in the household's stock of cars and other vehicles.*
- *Present prices, expected prices, and the dispersion of expected prices for gasoline.*
- *Expectations about changes in the energy-consumption characteristics of vehicles and associated expectations about future purchases.*

As an essential adjunct to the interpretation of data on vehicles and equipment used within households, research and analysis should be initiated on the costs of manufacturing, operating, and maintenance and their lifetime energy use and cost. Such data would be most useful in determining minimum life-cycle energy cost strategies and in the measurement of the energy efficiency of specific household equipment.

Recommendation. *The Committee recommends that a special study be undertaken to determine the variation in the energy efficiency of similar vehicles in the present stock of automobiles. The purpose of this study would be to determine: how much variation actually exists in the fuel efficiency of vehicles of a given type and vintage; how much of the actual variation is a consequence of variation in manufacturing design, differences in maintenance, and driving practices and habits; and the effect on fuel consumption of providing the driver with real-time information on fuel efficiency.*

Recommendation. *The Committee recommends that a special study be undertaken to explain present variation in the energy intensity of personal transportation. This study would aim at determining the factors that induce the purchase of more energy-efficient vehicles and use of alternative modes of transportation, such as carpools, bicycles, and public transportation. Comparison with practices in other industrial countries should be part of this study.*

Building Structures and Space Conditioning

Finding. Effective energy policy requires substantially more knowledge than we now have about the relation between the gross physical characteristics of building structures and the actual energy-consumption characteristics of those structures as well as between the technical characteristics of equipment and the energy flows through that equipment. We know that energy consumption within residential structures varies considerably, even for structures of the same size and configuration and the same demographic characteristics of occupants. Little is known about the actual behavior of occupants or how norms governing behavior affect energy-use practices and decisions. The Committee presumes that such data for a wider range of structures in the U.S.--both residential and non-residential--would show an even larger variation in energy consumption, related in an undetermined way to the physical characteristics of the structure, the behavior of the occupants, and the size and use rates of internal equipment. Since the returns on investments in modifying structures seem to depend to a significant degree on idiosyncratic features of structures themselves, methods of estimating returns on investment are needed for structural modifications at the level of the individual structure, rather than at the level of the average structure, since that may be the most effective way to encourage individual decision makers to invest in more energy-efficient structures.

Recommendation. *The Committee recommends that studies be made, on a nationwide sample of structures, of the relation between energy consumed for space conditioning within structures, the physical characteristics of structures, the behavior of occupants, and the intensity of equipment use within structures. We also recommend that research and development be undertaken to develop instruments for measuring the relevant energy-consumption characteristics of existing structures, with an eye toward simple, inexpensive, and easy-to-operate instrumentation. Such instrumentation falls into two general categories: (1) that which enables individual building occupants to monitor and control the use of existing equipment, and (2) that which supplies data needed to precipitate constructive investment decisions.*

Demographic Data

Finding. The United States is currently undergoing a period of rapidly changing fertility rates and other demographic transitions. The energy and economic consequences of these changes can be very large within the time periods of interest to energy policy decisions.

Recommendation. *The Committee recommends that careful use be made of existing demographic data (1) to improve understanding of the effects on energy consumption of changing fertility rates and other demographic characteristics, especially household formation, labor force participation, and the effective length of the work week, (2) to project with greater assurance the plausible directions that energy consumption may take in the future, and (3) to understand better the energy and economic impacts of demographic trends and changes.*

CHAPTER 3

ENERGY USES IN THE INDUSTRIAL SECTOR

INTRODUCTION

In the broadest sense, the industrial sector consists of all non-household activity that involves the production of goods and services that are used throughout the economy. Most of the energy embodied in the manufacture of goods is concentrated in the early stages of the processing of basic materials and in a relatively small number of industries. Thus, for public policy applications, it is preferable to examine data on energy use in the basic materials processing industries rather than through the household demand for the final goods and services that use these materials as inputs. Most of the energy used to provide services is for transportation and space conditioning in buildings. Unlike that used to produce goods, energy used to provide services is not concentrated in any particular group of industries.

In this report, the non-household sector is organized into two categories. The industrial sector, which primarily produces goods, is discussed in this chapter; the commercial/service sector is discussed in Chapter 4. These two categories are defined by the major divisions of the Standard Industrial Classification system.

The Standard Industrial Classification

The Standard Industrial Classification (SIC) provides a systematic framework within which economic activities are defined and organized (U.S. Office of Management and Budget 1972). This coding and classification system is widely used by both government agencies and private industries to maintain comparability of statistical data. Major industries that are functionally similar are called divisions, designated by the letters A-K. Major groups of industries within divisions that use similar processes or produce similar products or services are designated by a numerical code in which the first two digits correspond to divisions. Additional digits may be used to provide a subclassification of industries within major groups. The major divisions of the SIC system are listed below:

Division	Industry Description	Numerical Codes (first two digits)
A	Agriculture, Forestry, and Fishing	01 - 09
B	Mining	10 - 14
C	Construction	15 - 17
D	Manufacturing	20 - 39
E	Transportation, Communications, Electric, Gas, and Sanitary Services	40 - 49
F	Wholesale Trade	50 - 51
G	Retail Trade	52 - 59
H	Finance, Insurance, and Real Estate	60 - 67
I	Services	70 - 89
J	Public Administration	91 - 97
K	Non-Classifiable Establishments	99

This chapter will discuss energy consumption data in Divisions A through D and that part of Division E containing utilities in the SIC system. These divisions are commonly referred to as the industrial sector in most energy accounting systems.[1]

The relative importance of the major end uses of energy (transportation, space conditioning, and materials processing) differs significantly among SIC divisions. For industries in Divisions A through D (and the electric, gas, and sanitary services part of Division E), it is our view that needs for data on industrial energy consumption are related most directly to changes in materials processing.

For Divisions F through K and that part of Division E containing transportation and communication, described in this report as the commercial/service sector, energy consumption data needs are related most directly to the characteristics of buildings and vehicles. The end uses of energy in the commercial/service sector are similar to those of households except the range of variation is considerably wider and the decision processes for energy use are more like those in industries in Divisions A through D.

PATTERNS OF INDUSTRIAL ENERGY USE

The industrial sector, as described above, directly consumes approximately 35 percent of the total energy used in the United States, including almost half of all energy from natural gas, half of all electricity, and about 70 percent of all coal (see Table 1). Industrial energy consumption is dominated (almost 90%) by processes that use fuels and electricity to produce heat (U.S. Department of the Interior 1975; hereinafter referred to as Interior). Much of this heat is now exhausted to the atmosphere; however, significant

[1]Data on the demand for transportation are quite different in the household, industrial, and commercial sectors of the economy. In this report, transportation is considered as an end use in the household sector and an industry in the commercial/service sector.

opportunities exist for re-use (cascading) in lower-temperature processes. About 60 percent of all energy consumed by industry is used by a small number of basic processing industries in which the capital investment required for effective operation is very large. In these industries, energy costs are a significant fraction of total operating costs, and management decisions are strongly influenced by energy prices.

Table 3 shows the estimated energy consumption by U.S. industries for 1972. Industries have been grouped into three categories to emphasize the nature of the different types of materials processing and the typical range of energy used per dollar of output.

The largest users of energy are industries whose processes are intrinsically energy-intensive because they typically alter the basic chemical or molecular structure of materials: the chemical, metal, paper, and fuel industries. The second most energy-intensive industries are those whose processes change the state of materials, such as melting for castings or heat for drying or heat treatment. (For example, glass is manufactured by melting sand to a liquid state and cooling it back to a solid state again.) The third category of energy intensity includes those industries whose processes typically change the physical arrangement or location of materials, such as automobile assembly plants, electronics manufacturing plants, and printing and publishing establishments; these processes are least energy-intensive.

This empirical distinction among types of industries emphasizes some differences that are useful in analyzing industrial data. The energy use in the first group is basically a function of energy intensity per physical unit of materials processed rather than the absolute size of the industry's output. The second group has lower energy use per unit of output but high total energy use because these types of products typically have very high levels of outputs in the U.S. economy; the combination of intermediate energy per unit output and high levels of output results in a large total consumption of energy for this group. For industries in the third group, lower energy use per unit output, when combined with smaller absolute size of the industry output, results in lower overall consumption of energy.

As an example of these distinctions in industrial energy use, the total estimated energy required to produce a single 3500-pound automobile is shown in Table 4. In this table, the energy contributions to a single final product from different contributing industries are shown. (In the calculation, a net-free energy change in manufacture is used, assuming no recycling.) Energy embodied in the manufacture of basic materials accounts for the predominant share of the total energy used: about 70 percent. Fabrication and assembly, which are less energy-intensive, account for about 25 percent, and transportation of materials and the finished product accounts for about 2 percent.

Most of the energy in industry is used in the process of making relatively homogeneous intermediate products, such as steel or plastics. These products are then typically sold to other industrial firms for additional processing, but most of the energy embodied in final products is determined by the energy used in the basic process of making the steel or the plastic and to a much lesser extent by the energy required to modify it into its final useful form. In these processes, energy is used, as elsewhere in the economy, as an input into some piece of capital equipment. Hence, industrial energy consumption could be approached by analyzing the equipment used in the processing, the use rate of the equipment, and the energy-consumption characteristics of the

TABLE 3 Estimated Annual Industrial Energy Consumption (1972)

SIC Code	Industry	Btu x(10^{15})[a]	Percentage Total Industrial	Typical[b] Btu Per Dollar of Output
I:	Processes that change molecular structure of materials[c]			
28	Chemicals and allied products	4.4	61.9	150,000-
33	Primary metal industries	3.9		250,000
29	Petroleum and coal products	3.3		
26	Paper and allied products	2.3		
13	Oil and gas extraction	1.4		
	SUBTOTAL	15.3		
II:	Processes that change state or configuration of materials			
32	Stone, clay, and glass products	1.3	22.0	50,000-
15-17	Construction	1.2		150,000
20	Food and kindred products	1.05		
--	Agriculture	1.1		
35	Machinery (except electrical) manufacturing	0.4		
22	Textile mill products	0.4		
	SUBTOTAL	5.45		
III:	Processes that change physical arrangement or location of materials			
--	All other industry in divisions A-D of the SIC system	3.97	16.1	50,000 and less
TOTAL:	ALL INDUSTRY	24.72	100.0	

SOURCE: See notes at end of this chapter.

a/Data includes feedstocks, self-generated fuels, and electrical energy.
b/Dollars refer to producers' price in 1967 (see U.S. Department of Commerce 1976).
c/Energy use in these industries is highly concentrated in the earliest stages of processing basic materials, but much of the economic activity in these industries at the three- or four-digit SIC level is more properly part of group III below, e.g., drugs and stationery.

TABLE 4 Energy Required to Manufacture One Automobile

Item	Energy		Percentage
	Kwh	Btu (x10)	of Total
Manufacture of metallic materials	26,185	273.6	70.2
Manufacture of other materials	865	9.0	2.3
Fabrication and assembly	9,345	97.7	25.1
Transportation of materials	655	6.8	1.8
Transportation of assembled auto	225	2.3	0.6
TOTAL	37,275[a]	389.4	100.0

SOURCE: See Berry and Fels (1973).

a/By way of comparison, 37,000 kwh (thermal) is equivalent to about 3,000 gallons of gasoline.

equipment. However, there are literally thousands of different types of equipment used in industry, with highly variable use rates--such as machines that stamp out entire sections of vehicles, furnaces that heat iron ore to several thousand degrees, and refineries that produce a wide range of petrochemicals.

Obtaining data on this wide range of industrial processing equipment would probably be costly and unfruitful as a means of monitoring or modeling industrial energy consumption or as a means of assessing the effects of policy. The equipment is not only frequently complex in its own right; it is also often interdependent in its operation on other equipment--one machine feeds another. Detailed examination of equipment stocks would thus require a large number of complicated energy-use models to gain any real insight into industrial energy consumption.

Alternatively, the energy content per unit of material output in the most energy-intensive industries can be thought of as a measure of industrial energy consumption. Modification of the processes, the technical characteristics of machinery and equipment, or the types of materials used will result in measurable changes in energy input per unit of output. The resulting energy content is likely to be significantly influenced by both actual and expected energy prices and the availability of energy supplies. Thus, it seems better to monitor energy content per unit output and to construct models explaining change in energy content per unit output in these industries. To do this effectively, it is important that the measure of energy content per unit output include both the direct and indirect energy costs associated with the production processes. For example, it would be misleading to produce a measurement that showed a decline in energy per unit output of aluminum siding for houses --if the reason for the decline were that the basic aluminum raw material was being imported rather than produced domestically, and the energy input measure included only domestic energy inputs.

The Committee's judgment is that analyzing the specific industrial operations and processes that produce materials subsequently distributed throughout the economy is the preferable method for examining the effect of public policies on the largest energy-consuming industries. There are three reasons for this view: (a) the most important determinant of energy consumption in the energy-intensive industries is the nature of the process used to modify the properties of basic input materials; (b) there are a number of alternative ways to process these raw materials; and (c) the attractiveness of these alternatives is strongly affected by energy prices. In short, we feel that changes in processing with the same end product are a more likely development than major changes in the demand for end-product with the same processes, especially in the short-to-intermediate term. For example, the energy consumed to produce aluminum can be modified more readily by changing the production process than by changing the demand for the large number of different aluminum products.

One of the important determinants of energy use in the most energy-intensive firms is the present and projected cost of energy. Changes in energy use will come about primarily through the adaptation of processing techniques to changes in energy costs. It is important here to distinguish between energy costs and energy prices. As used in this report, the costs of energy to the business decision maker depend not only on the price of fuels but also on the costs of compliance with the regulatory policies associated with the use of specific types of fuel, the costs of capital required to change from one fuel type to another, and the costs of contingency management induced by uncertainty about future fuel prices or fuel availability.

Price Factors

Business decision makers are concerned about the price of energy as well as its availability and regulation. The degree to which this concern results in a change in business practice is related to the importance of energy costs in overall production costs as well as their visibility. Importance can be measured by the ratio of energy costs to total production costs; visibility can be considered a function of the rate of change of energy prices: cost items that continue along stable historical trends are less likely to come to the attention of decision makers than cost items that behave differently from the past.

On both counts, energy prices, both present and expected, are important information to decision makers in energy-intensive businesses--but price is not all that matters. The uncertainty of future supplies of a particular form of energy will concern business decision makers as much as price. In addition, decision makers are inevitably concerned about the regulatory environment in which they will be operating, since much regulation directly affects energy consumption.

These considerations suggest that the expectations of business decision makers regarding future energy prices affect both the availability of future supplies of particular forms of energy and the regulatory environment in which business expects to be operating. In general, data used to understand and predict business decision making simply do not exist. Information on past and current energy prices, the supply situation that currently prevails, and the present regulatory environment is available, but we do not know what business decision makers (or regulatory agencies) see as probable, which would have an important bearing on their decisions to make changes in processes.

It is not only changes in energy prices that are relevant to industrial energy consumption behavior but also the degree of uncertainty about future prices. Decision makers who think it most likely that relative energy prices will double in ten years but could vary by a factor of three are not likely to act in the same way as decision makers who think it likely that prices will double in ten years but assign very little likelihood to a different outcome. The first forecast calls for planning with a great deal of flexibility in the event that the best guess is wrong, while the second calls for planning with less flexibility, because the best guess is not considered likely to be wrong.

The second group of industries shown in Table 3--those that use somewhat less energy per unit of output but are very large in absolute size and consume a substantial proportion of the energy consumed in the industrial sector--are also subject to the same forces as the most energy-intensive users, although clearly not to the same degree. The industries in this group are so numerous and heterogeneous, as measured by the kinds of processing they do and the sources of energy demand that they have, that modeling changes in energy consumption are more costly and probably have a smaller payoff than modeling process changes in the most energy-intensive industries.

For industries in the third group--those with low energy consumption per unit of output and insufficient size to produce more than a modest proportion of the total of energy consumption in the industrial sector--energy is more likely to be used for space conditioning and transportation than for materials processing, and the problems of modeling future consumption are much like those described in Chapter 4, in which energy use in commercial buildings and transportation is examined.

Electric Utilities

Electric utilities consume about 20 percent of the total fossil energy used in this country, about as much as the combined total of the five most intensive consumers of energy listed in Table 3. Increasing prices for fossil fuels will undoubtedly induce significant changes in the types of fuels used by electric utilities as well as changes in the utilization of by-product heat produced in the power generation process. However, problems related to the production of electricity are not discussed in this report, since they involve political, technical, financial, and engineering issues beyond the Committee's scope. Therefore, we limit our concern to the demand for electricity by end users in the household, industrial, and commercial/service sectors and the data that utilities can provide to describe the details of that demand. Energy used to generate electricity, including (whenever possible) the fuel equivalents of losses in generation and transmission, has been assigned to the end-use consumers of electricity.

INDUSTRIAL ENERGY USE DATA

Time Periods

Short-term changes in industrial energy consumption are most likely to come about through such housekeeping measures as improved process control and eliminating wasteful uses of energy, as in the household sector. Data used to accomplish these changes are primarily internal management data, including energy flow sheets, analyses of fuel purchases, and monitoring data on stack temperatures and gas composition.

In the intermediate term, changes in industrial energy consumption can be expected to come about through improving existing processes, upgrading of the energy efficiency of existing equipment, and relatively minor capital investments. Data to assist in analysis of the effects of these changes remain primarily internal management data but can be expected to include more comprehensive energy audits of an entire plant's operation, data on retrofit costs and estimates of expected fuel cost savings, and case studies of other industries.

Long-term changes in industrial energy use are likely to come about through more basic changes in the equipment used for processing materials and in the demand for different types of products. Information to describe these changes is related to engineering data on technical feasibility (including evaluation of research and development outcomes), financial data on capital investment, data needed for analysis of regulatory practices, and estimates of long-term trends in energy prices. There have also been long-term societal trends shifting the economy toward relatively more services and less manufacturing in the economy and historical trends within manufacturing toward more advanced stages of fabrication or processing (e.g., computers, microprocessors) that tend to be less energy intensive.[2]

Data Availability

Data to describe U.S. industrial energy use in such time periods vary widely in scope and availability. For the short-to-mid term, data primarily take the form of internal management information and are available mainly for individual firms, or perhaps at the trade association level. For the mid-to-long term, there are several sources of industrial energy-use data that are collected by government agencies.

The most complete sources of industrial energy-use data are the quinquennial Census of Manufactures (Commerce 1973) and the Annual Survey of Manufactures (Commerce 1974) of the Bureau of the Census. These data include fuels and electric energy consumed for heat and power by the manufacturing industries (SIC 20-39). Purchased fuels and electricity consumed by the mineral industries (SIC 10-14) are reported separately by the Bureau of the Census (Commerce 1975a), currently also at five-year intervals.

[2]The Conference Board Report (Myers et al. 1974) noted an overall decline of 1.6 percent per year in energy use per unit product between 1954 and 1967.

The Federal Reserve Board also publishes a monthly survey of industrial electric power use (Federal Reserve Board 1976). These data consist of monthly indexed records of electric power use by the major industrial groups at the three-digit SIC coding level. There are, in addition, two major federal sources of data on energy supply and production that provide some information on industrial end-use consumption. The Bureau of Mines conducts an annual survey of distributors and medium-to-large retailers of petroleum products (U. S. Department of the Interior 1973) which identifies end use by broad categories. The Federal Power Commission[3] collects monthly data on fuels used by electric utilities, from which some industrial end-use allocations may be estimated, again by broad categories (e.g., industrial, residential, commercial).

Within the past several years, the Department of Commerce and the Federal Energy Administration have developed a voluntary program of industrial energy conservation. In this program, industrial groups simultaneously report both total energy use and total product output as well as energy-use goals stated in terms of a percentage reduction in energy use per unit output (Commerce and Federal Energy Administration 1976; hereinafter referred to as FEA). These data are collected primarily by the trade associations for the various industries and are not necessarily related to the industrial group of the Standard Industrial Classification. Since these trade associations use different methods of accounting and their coverage of an industry is variable, these data have been difficult to organize into a common format.

In addition to the primary sources of data described above, there are numerous sources of secondary or derived data on industrial energy consumption. These data sources are mainly a synthesis of primary data, which may be reprocessed to meet the analysis needs of specific organizations (see, for example, Beller 1975, Commerce 1976, FEA 1976, Gordian Associates 1974, International Research and Technology Corporation 1974, Austin and Winter 1973, Bullard et al. 1975).

Data Needs

The types of data needed for industrial energy consumption depend upon the primary user of these data and the use to which they will be put. The corporate user requires internally generated energy-use data to manage the processes in a given establishment's operations and to describe the consequences of management decisions as required by the Energy Policy and Conservation Act and other legislative and regulatory requirements. In both cases, energy accounting is an increasingly important corporate activity that requires new information on energy-intensive processes and prices to be incorporated into management decisions.

The governmental user needs data not only to monitor overall industrial energy use but also to identify areas in which public policies may have the greatest potential for modifying practices of industrial energy consumption.

[3]The Federal Power Commission, Bureau of Power, Division of Power Surveys has a monthly compilation of Form-4 data, published monthly as a press release.

Data are needed to permit national reporting, modeling, and analysis of industrial energy use, to anticipate the response to various price trajectories by industry group, and to estimate the effects of cross-fuel elasticity on decisions about industrial energy use and alternative energy systems. Although specific industries may have adequate data to model energy use within an industry, better data are needed to model energy use between industries. Such data include energy for extraction and transport of raw materials, energy used in processing and fabrication, fuels and electricity required for manufacturing processes, and energy needed for waste disposal or recycling.

To monitor changes in energy use in industrial processes, current data on total industrial energy consumption are, in themselves, not sufficient. Industrial energy use is a product of two separate factors: the energy use per unit of product and the quantity of product produced. Without this separation, it is difficult to determine whether changes in industrial energy use are due to changes in the energy efficiency of processes or to changes in the quantity of production. When several different processes may be used to produce the same product, it would be desirable to have data on energy use per unit output on a process-by-process basis as well. Such data are most useful in those industries in which the processes are significantly different in energy use but otherwise directly comparable, as for example, in the production of steel or aluminum. In the chemical industry, on the other hand, the numerous processes used to produce phenol, for example, may not be directly comparable, due to differences in feedstocks used or by-products produced.

Although many industries are moving toward routine collecting and reporting of energy consumption data, there is little consistency among industries and their respective programs. The Census Bureau Annual Survey of Manufactures' data on fuels and electrical energy consumed is the only survey of energy use that is consistent across manufacturing industries and that protects the confidentiality of individual data submissions. As a tool for the measurement of industrial energy conservation, it would be useful to improve this survey in three respects:

1. The present survey is published 15-18 months after the data are reported; a more timely presentation of data would be useful.

2. Fuel consumption in agriculture, mining, and construction should be included in the survey, since these industries are major users of energy. Industrial energy consumption should be allocated among the functional end uses--materials processing, transportation, and space conditioning. In addition, the survey should include the consumption of hydrocarbons used for feedstocks as a separate category (as discussed in the notes to Table 3). This change would permit a better match with the Bureau of Mines fuels and energy production data.

3. Data should be collected (and identified separately) on self-generated fuels, including currently unconventional sources such as solar energy, to compare efficiency on a process-by-process basis within specific industries.

These data are most useful when both energy intensity (energy per unit output) and total volume of output are reported in physical units and on a consistent basis. Such consistency would be improved by (a) uniform treatment of purchased energy, feedstocks, and self-generated fuels, (b) uniform sectoral compositions in the tabulations provided by various federal agencies, and (c) more precise allocation of industrial energy consumption to the functional end uses of materials processing, transportation, and space conditioning.

POTENTIAL FOR CHANGE IN INDUSTRIAL ENERGY USE

Modern industry has built an enormous capital plant in an era of relatively cheap energy. The design of individual equipment, plants, and entire systems of production has been based on the implicit premise that the cost of energy is small compared to practically any other cost of production. Inefficiency and heat losses in processing could be economically justified because fuel prices were low.

There is evidence that the price of energy will continue to increase. This price is not related just to the cost of a barrel of oil, but also to the costs of environmental protection, the costs of the safety and health of both workers and the community, and the less tangible but very real costs of complexity in an increasingly interdependent society. The questions of how these costs are levied and who shall pay them are important issues for public policy. The individual industrial decision maker is concerned with the relation between fuel prices, process efficiency, and return on investment. Public policy is concerned with the collective effects of these individual decisions, the difference between market prices and total costs, and the data required to assess their larger societal consequences.

Over the next 20 years, new industrial processes may have the potential to reduce energy consumption per unit of output perhaps as much as 50 percent. If the present production volume and product output mix were to remain constant, this would constitute a significant reduction in industrial energy consumption. However, both production volume and product mix may also be expected to change significantly over the next 20 years. Changes in processes (including changes in fuel types) and changes in product volume and mix are thus useful categories for data on industrial energy consumption.

Changes in Industrial Processes

Alternate processes for industrial products offer significant potential for reducing industrial energy consumption per unit output. Within the range of existing technology, for example, the electric furnace process for making steel is about 50 percent more efficient than the blast furnace process; the dry cement process has a major energy advantage over the conventional wet process (Cook 1976). Research and development of new technologies can also be expected to provide significant changes in the efficiency of industrial processes. During World War II, the average U.S. aluminum smelter required 12.5 kwh per pound. The average smelter today uses 8.0 kwh per pound, and one aluminum company is experimenting with a new process which requires only 4.5 kwh per pound.

The rate at which these types of basic changes in industrial processes will occur is difficult to estimate. The data that will probably have the most usefulness in estimating industrial response are those that help to specify future energy costs. Data on industry's average and marginal cost expectations for energy would give economic modelers at least some indication of how actively industry can be expected to pursue energy conservation measures. Improved data on future ranges of fuel prices and availability would aid in narrowing the uncertainty that currently constrains business planners to use a high discount rate in making process-change investments; data of this type do not now exist. The energy conservation goals developed under the joint Federal Energy Administration/Department of Commerce Voluntary Industrial Energy Conservation program represent industry's own integration and estimation of the collective effects of these factors (FEA 1975a, Commerce and FEA 1976a).

Changes in Fuel Types and Applications

Some types of process changes may also involve the use of a different type of fuel, or different applications for fuels currently used. The change to a different type of fuel depends partly on price and partly on availability. A gas-fired furnace for glassmaking is significantly more efficient than an electric furnace, but the availability of natural gas as well as the uncertainty about its future availability is at least as important a factor as price in industrial decision making. Highly aggregated data at the national level may not be adequate to evaluate the effects of state or local variations in energy availability and price. A local shortage that has little effect on national data may have much more severe effects on specific industries at the state or local level. Thus, data on fuel use are likely to be most useful when they are collected, maintained, and subsequently utilized at the local, state, or regional level rather than at the more highly aggregated national level. Fuel use within local or regional areas may also vary significantly according to the time of year. For this reason, quarterly or even monthly data on industrial fuel use may be needed for the design and implementation of allocation policies.

A different type of data problem arises when an industry shifts its application of fuels. In some industries, there is significant potential to use waste heat from a primary process in secondary processes or in space heating. There is also the potential for recovery and use of fuels such as still gas or coke gas.[4] These uses of internally generated fuels or fuel equivalents may appear to reduce industrial energy consumption if data are available on only sales and purchases of commercial energy. At the extreme, extensive industrial use of heat and electricity from solar or other internally generated sources would show up in existing data series only as a reduction of utility sales. Current data used to estimate future energy demand are likely to overstate that demand unless realistic estimates of internal shifts in fuel types and applications are taken into account.

[4]Still gas is a residual product of petroleum distillation; coke gas is a residual product of coking ovens.

Changes in Product Volume and Product Mix

Long-term changes in the demand for goods and services can be expected to affect both the volume and the mix of current industrial output. In some cases, the demand for certain types of products, such as beverage containers or more durable automobile bumpers, may be altered directly and significantly by public policy. Public policy may also be effective in changing the energy-consumption characteristics of such products as automobiles and air conditioners. In addition to such changes induced by public policy, there is the potential for large and slowly shifting changes in preferred styles of living and levels of consumption, which will reflect the demand for energy in the industrial sector. These long-term shifts will affect both the size and the structural composition of the gross national product.

A useful way to determine the effects of these types of changes for industry is to study countries that have historically had wide differences in energy costs. Many of these studies in the past have suffered from the fact that the industry segments being analyzed were not comparable. For example, a paper mill in West Germany, which imports bleached pulp from Scandanavia, is not directly comparable to a firm in the United States that grows and harvests trees, bleaches pulp, and makes paper. International comparisons also provide qualitative insight into a range of possible industrial and societal alternatives. The use of heat recovered from the generation of electricity for district heating in Sweden and the Soviet Union and the accelerating use of nuclear electricity in France are examples of areas in which such qualitative differences may be observed, provided differences in social and economic conditions are taken into account (Stanford Research Institute 1975, Schipper and Lichtenberg 1976).

SUMMARY

The quinquennial Census of Manufactures and the Annual Survey of Manufactures provide a useful base for improvement of existing data series of industrial energy consumption. These data can be improved by more timely publication, inclusion of agriculture, mining, and construction data, and a consistent and inclusive treatment of self-generated fuels and feedstocks. Data on both total energy use and energy use per unit output are needed in physical units, classified by fuel type. Process-by-process data are needed for some industries in which alternative processes are widely used.

Industry's statements of conservation goals may be considered an estimate of the combined effects of changes in processes, prices, regulatory practices, and fuel availability. However, much more detailed data are needed to analyze the energy embodied in finished products and to identify potential changes in materials and processes at each stage of manufacture.

Much of the information needed to monitor and predict industrial energy consumption is related to engineering data on the feasibility of technical modifications to industrial processes, financial data on capital investment, and data needed for analysis of the impacts of public policies such as regulation. It is beyond the scope of the Committee to discuss fully all these diverse data needs. Nevertheless, it is our view that energy consumption practices in industry exist within a wider context of energy consumption practices in society.[5] Improvement in data on energy use can aid significantly in identifying and evaluating the most productive ways to influence those public policies that apply to industrial energy use. In the time periods appropriate to energy research and development planning (i.e., 25 years or more), the impact of plausible social change, such as fertility rates and lifestyle choices, can be as profound as energy price projections in shaping long-range industrial decisions about energy use.

FINDINGS AND RECOMMENDATIONS: INDUSTRIAL SECTOR

A principal deficiency in non-household energy consumption data is the lack of a consistent classification of both end users and end uses of energy. We have defined the non-household use of energy in terms of the industrial sector and the commercial/service sector. In the industrial sector, the Committee concentrates on the most energy-intensive industries and suggests that baseline data be obtained for those parts of industry in which little systematic information has been gathered. An urgent need for the analysis of energy use is to specify a systematic classification for both industry and commerce in which all energy-consumption activities can be located and on which both data-collecting agencies and data-using agencies can agree.

Findings. The five most energy-intensive industries in the United States --chemicals, primary metals, petroleum and coal products, paper and paper products, and oil and gas extraction--account for over 60 percent of total industrial energy in the U.S. For the most part, these industries change the chemical or molecular structure of materials, a fact that accounts for their intrinsically energy-intensive nature. To project future energy consumption for these industries, it is the Committee's view that data on potential changes in methods of materials processing are most needed, since major changes in energy use in the energy-intensive industrial sector will probably take place as a consequence of shifts in processing methods and techniques over the next several decades.

For industries in the category of moderate-to-low energy use per unit of output, reasonably adequate data are currently available for manufacturing firms but not for other firms, such as mining, agriculture, and construction. These industries are characterized by a great deal of heterogeneity in the processes employed, and it does not seem cost-efficient to study firm-specific processing operations. Rather, the most important task is to categorize and monitor energy consumption within these industries by the major functional uses of space conditioning, transportation, and materials modification. It is our belief that space conditioning and transportation uses are relatively more important in these industries, but basic data need to be obtained first to document the existing patterns of energy consumption across industrial groupings.

[5]". . . goods, as well as jobs that require materials, fit into other social activities in an interlocking scheme that is hard to change; social configurations are as solid a reality as raw materials" (Keyfitz 1976).

Energy-Intensive Industries

Recommendation. *For energy-intensive industries, data are needed on both total energy consumption and energy consumption per unit of specific product output. These data should be in both physical and dollar units and should be classified by fuel type. In general, annual or biennial data would be sufficient for these industries, since major process changes take place gradually. Moreover, for some industries, studies should be made to determine the amounts of energy used for alternative processes that are in active use for the same basic product but that are significantly different in energy use.*

Recommendation. *Because energy is such an important part of costs in these energy-intensive industries, the Committee recommends research to study the factors that influence the choice of alternative production processes, as well as materials substitutes, in the energy-intensive industries. It is important to obtain data on plausible trajectories of future energy prices, the uncertainty surrounding expected price changes, and expectations about the future regulatory environment in which energy-use decisions will be made. It is also important to obtain data on the capital costs needed to modify or change the energy intensity of industrial processes and on decision makers' estimates of the uncertainties attached to future supplies of various forms of energy. All these types of data are essential for building models capable of providing an adequate understanding of possible future changes. These measurements should be repeated at intervals, as expectations, costs, and policies change.*

Industrial Sector as a Whole

Recommendation. *For the industrial sector (aside from the five most energy-intensive industries), we recommend a benchmark survey be done to determine the distribution of energy uses among space conditioning, transportation, and "all other" uses. In the course of developing this survey, a reasonably small list of "other" uses should be selected to organize data about the myriad of energy-consumption activities in this category.*

It is unlikely that energy used for space conditioning and transportation is significant in the energy-intensive industries, but there are insufficient data available to examine that question fully. At a lower level of priority, we recommend that the benchmark survey of the moderate-to-low energy-intensive industries also include sufficient sampling of the most energy-intensive industries to provide at least order-of-magnitude estimates of the energy used for transportation and space conditioning.

Recommendation. *We recommend that fuller advantage be taken of the data presently available in the Bureau of the Census Annual Survey of Manufactures and that the Annual Survey of Manufactures be augmented to include agriculture, mining, and construction. This will further require more consistent definition and reporting of self-generated fuels and fuels used as feedstocks. A more timely presentation of preliminary data would be useful, accompanied by estimates of appropriate confidence limits.*

Recommendation. *Although analysis of technical change in energy supply conditions is outside the scope of the Committee, we recommend that attention be given by the appropriate advisory bodies to the possibilities of reclaiming industrial by-products that are now wasted, such as use of waste heat for space conditioning of nearby structures or for re-use in other lower-temperature processes. The issues involved are both technical and institutional, and largely outside the Committee's scope--but we think it is important for energy policy generally to examine them. Further, it is important to obtain data on the potential for industrial shifts in fuel types. While fuel shifting may not result in a net change on energy use, the cumulative effects of such shifts can be important nationally. Improved data are needed to investigate the extent to which such shifting can occur and the conditions that might hinder or facilitate it.*

Demographic Data

Recommendation. *The Committee recommends, as they did for the household sector (see Chapter 2), that careful use be made of existing demographic data (1) to improve understanding of the effects on energy consumption of changing fertility rates and other demographic characteristics, especially household formation, labor force participation, and the effective length of the work week, (2) to project with greater assurance the plausible directions that energy consumption may take in the future, and (3) to understand better the energy and economic impacts of demographic trends and changes.*

Notes to Table 3

In the preparation of Table 3, several inconsistencies among existing sets of industrial data became apparent. First, three of these industries, oil and gas extraction, new construction, and agriculture, do not usually appear in most tabulations of this type. Second, recent tabulations by the Federal Energy Administration include feedstocks in chemical and allied products because they are not easily separable from fuels in the basic petrochemical plants. Coke used in steel manufacturing is not included in the Federal Energy Administration tabulations but has been included in Table 3.

The total energy consumption estimates for the 11 largest energy-consuming industries in Table 3 include three factors: energy purchased for heat and power, fuel materials used as feedstocks, and self-generated fuels created incidentally in the production process. Although self-generated fuels do not contribute to depletion of energy supplies per se, they are important to the analysis of alternative production processes in some industries. Feedstocks and self-generated fuels represent a significant fraction of the total energy use for each of the five largest industries shown in Table 3. There is currently no existing national program of energy data collection that collects and publishes industrial energy consumption on this basis. Consequently, Table 3 has been derived from several different sources and assumptions, which are discussed separately for each Standard Industrial Classification (SIC) code entry below.

Chemicals and Allied Products (SIC 28)

From the 1971 Census survey discussed above, fuels used for heat and power for SIC 28 were 2.78 quads (Commerce 1973). This was adjusted by the Federal Reserve Board (FRB) production indices for 1971 and 1972 to obtain 3.1 quads, not including feedstocks. Using data from the Bureau of Mines Mineral Industry Survey, the 1974 petrochemical feedstock domestic demand was 0.7 quads (reported as 363,000 BBD) (Commerce 1975c, Interior 1975b). Again, adjusting by the FRB production indices for 1974 and 1972, a feedstock equivalent of 0.6 quads is obtained. Natural gas used as feedstocks has been estimated from the Bureau of Mines' April 5, 1976 news release summarizing domestic supply and demand for natural gas (Interior 1976). This release shows 727 trillion Btus of natural gas energy used for chemical feedstocks in 1974. Again, adjusting by 1974 and 1972 FRB production indices, we estimate 0.7 quads of natural gas feedstocks used by the chemical industry in 1972. This brings our estimate of the total energy used in 1972 by SIC 28 to 4.4 quads (3.1 + 0.7 + 0.6).

Primary Metal Industries (SIC 33)

This category represents the producers of iron and steel plus the producers of nonferrous metals. Since the Fuels and Electrical Energy Survey of the Census of Manufactures does not include the coal used in iron and steel production, the total iron and steel mill energy use was obtained from a detailed survey conducted by the American Iron and Steel Institute (American Iron and Steel Institute 1972). This survey is conducted annually and obtains consumption figures for each fuel and feedstock. Based on responses from companies representing 89 percent of steel mill product shipments in 1973, an estimated total of 3.0 quadrillion Btus of energy was consumed for fuel and feedstock by blast furnace and steel mill (SIC 3312) operations. To get the total for SIC 33, the energy use for the remaining industries in this group was obtained from the 1971 Survey of the Census of Manufactures and then adjusted to 1972 using the ratio of the FRB durables production indices for the primary nonferrous industry for the two years (Federal Reserve Board 1972). This gave a total of 0.9 quadrillion Btus for these remaining 3- and 4-digit sectors and a total of 3.9 quads for the SIC 33 totals.

Petroleum and Coal Products (SIC 29)

This category is dominated by petroleum refining, which represents more than 95 percent of the energy used. Energy attributable to petroleum refining includes only the energy used to separate and reorganize the various components of crude oil, not the energy embodied in the crude oil being processed. Again, for this industry the Census Survey of Manufactures covers only the petroleum products that are defined as fuels (e.g., fuel oils, natural gas, etc.) and specifically does not cover still gas, tars, etc., which constitute a very substantial portion of refinery fuel. From the survey, we find a total of 1.6 quads of fuels and energy purchased in 1971, which adjusts to 1.7 quads for 1972. Again, the Bureau of Mines monthly petroleum statement (Interior 1975a) gives a figure for still gas as fuel of 1.1 quads (481,000 bbl/day) in 1974, which converts to 1.0 quads in 1972 on the basis of FRB production indices. This figure appears to be low, since other studies have indicated that natural gas and still gas are used in almost equal amounts. The Census survey shows 1.4 quads of natural gas used by this industry. Therefore, it was assumed that 1.4 quads of still gas were used and to that 0.2 quads were added (6% of total) for the other miscellaneous materials used for fuel to get the total of 3.3 quads. This may be somewhat high, but it corresponds with the Conference Board study figures (Myers et al. 1974) for the petroleum industry's energy use.

Paper and Allied Products (SIC 26)

Since the paper industry uses waste liquor and wood waste for a large fraction of their energy requirement, it is not possible to use the Census survey for the total energy demand of this industry. However, the American Paper Institute conducts an annual survey of energy use within this industry, and their 1972 total of 2.2 quads has been used. This number does not include the converted products segment (SIC 284) of the industry. Based on the total shown in the 1971 Census survey for SIC 264 (.07Q) and adjusting for 1972 production, 0.1 has been added to get the total of 2.3 quads shown in Table 3.

Oil and Gas Extraction (SIC 13)

As a separate activity, the Census Bureau publishes a Census of Mineral Industries (Commerce 1975a), including an analysis of fuels and electric energy consumed. This report includes not only purchased fuels and power but also fuels produced and consumed within the same establishment for heat or power. Since the mining industries consume no hydrocarbons for feedstocks, we are able to obtain the total fuel and energy used in oil and gas extraction from the Census study. For SIC 12, a total energy use of 1.4 quads in 1972 was reported, and this figure was used in the tabulation.

Stone, Clay, and Glass Products (SIC 32)

Since this industry uses no hydrocarbon feedstocks and produces no self-generated fuels, we have used the energy consumption total shown in the Census of Manufactures 1971 survey (1.3 quads). Adjusted to 1972 on the basis of FRB production indices, it remains 1.3 quads.

New Construction (SIC 15-17)

There is no routine, formal collection of energy data for the construction industry. The University of Illinois analysis entitled "Energy Flow Through the U.S. Economy" (Commerce 1976) is based on 1967 energy use by sectors of the economy. This shows 1.05 quads of direct energy for construction from petroleum (1.031Q), natural gas (.016Q), and electricity (.007Q). This was increased by 11.5 percent, representing the difference in construction expenditures (in constant dollars) between 1967 and 1972. From this figure were obtained the 1.2 quads listed in the table.

Food and Kindred Products (SIC 20)

This industry covers the processing of food following agricultural harvesting. Again, this is an industry that uses no hydrocarbon feedstocks and uses no self-generated fuel materials. Accordingly, we have used the 1971 Census survey fuel and energy use of 1.03 quads. Adjusting to 1972 on the basis of production indices, we get 1.05 quads as shown in Table 3.

Agriculture

The agriculture industry is similar to construction in that no routine, formal collection of energy use data is being made. For our tabulation, we found that the U.S. Department of Agriculture had prepared an estimate of 1974 energy use in agricultural production at the request of the Federal Energy Administration (U.S. Department of Agriculture 1976). The following data from this study were given to us by the Economic Research Service of the Department of Agriculture:

Fuel	1974 Use
Gasoline	3.6×10^9 Gals
Diesel fuel	2.6×10^9 Gals
LPG	1.7×10^9 Gals
Natural gas	92.0×10^9 Gals
Electricity	32.3×10^9 Gals

Employing standard conversion factors to obtain equivalent heating value gives a total of 1.2 quads in 1974, which in turn converts to 1.1 quads for 1972, using the ratio of farm input indices for the two years.

Total Industrial Energy Use

The annual totals published by the U.S. Bureau of Mines showing demand distribution for fossil fuels are the accepted source for total industrial consumption of fuels and feedstocks. Some adjustment and additions are required, however, to obtain "total industry" on the same basis as our previous tabulations of the largest energy-consuming industries. The adjusted data are shown below:

Energy Source	1972 Btu x 10^5
Coal	4.27
Petroleum and synthetic gas[a]	5.78
Natural gas[a]	10.59
Asphalt[b]	.91
Electricity[c]	2.27
Process residuals[d] (Paper industry)	.92
INDUSTRIAL TOTAL	24.72

From this total, the energy use in the 11 largest energy-consuming industries was subtracted to obtain the "all other" entry of Table 3.

a/These data are based on Bureau of Mines reports of fossil fuel consumption for 1972 and have been converted to Btu equivalents by the Federal Energy Administration. The data are from the "Project Independence Blueprint," Table H-8, Appendix A-1, prepared by the Federal Energy Administration, November 1974.
b/Since the Bureau of Mines allocates asphalt to the commercial sector, this figure is based on 80 percent (estimate) of total asphalt used in construction.
c/This value is based on Edison Electric Institute statistics for 1972 as reported by the Federal Energy Administration in "Project Independence Blueprint," Table H-8, Appendix A-1.
d/This value is from the American Paper Institute (API) survey of 1972 energy use in the U.S. pulp and paper industry; it was received from Jeffrey Duke of API in a telephone conversation April 26, 1976.

CHAPTER 4

ENERGY USES IN THE COMMERCIAL/SERVICE SECTOR

INTRODUCTION

In this report the commercial/service sector refers to Divisions F-K of the Standard Industrial Classification (SIC, discussed in Chapter 3), which include wholesale and retail trade, financial services, health and education services, governmental activities, and non-household transportation. Multiple-family rental housing, although frequently included in the "commercial sector," is treated in this report as part of the household sector, because energy use decisions in multiple-family dwellings are roughly similar to those of owner-occupants.

The estimated functional end uses of energy in this sector (excerpted from Table 1) are presented in Table 5.

TABLE 5 End Uses of Energy in the Commercial/Service Sector

End Use	Estimated Percentage of National Total	Estimated Percentage of Commercial Sector
Space conditioning	6.9	35
Transportation	7.3	37
Other	5.3	27
TOTAL	19.5	100

This chapter is concerned primarily with the energy used for space conditioning in buildings and transportation in the commercial/service sector. The "other" category covers a number of highly diverse ancillary activities--running typewriters and elevators, street lighting, cooking and refrigerating food, and operating X-ray machines. Although the "other" category is fairly large, its great heterogeneity suggests that the data needed to monitor and understand patterns of energy consumption in this category would be relatively more expensive to obtain and relatively less productive as an instrument of public policy. Hence, we have not discussed the "other" category of energy consumption in the commercial/service sector in detail. However, this category should receive some attention after other high priority concerns have been attended to.

As discussed in greater detail below, the Committee finds that data needed by building owners and operators, utilities, the financial community, and government agencies to describe and monitor energy consumption for space conditioning (as well as "other" uses) in commercial buildings are currently inadequate. In contrast, data needed to describe and monitor fuel use for commercial transportation, except for certain unregulated areas, are markedly better and may be significantly improved by minor modifications to existing systems of data collection.

ENERGY USE IN COMMERCIAL BUILDINGS

Definitions and Assumptions

The problems of energy consumption measurement for commercial buildings are more difficult than those of the other sectors covered in this report. These difficulties stem from several causes: (1) the lack of uniformity in the definition and concept of the various activities that constitute this sector; (2) the wide diversity of activities covered by the sector and the diversity in the types of structures and equipment used; and (3) the lack of basic data necessary to describe energy use even at the aggregate level.

There are several definitions of the commercial sector used by government agencies and private trade associations. In most cases the definition is obtained by the process of elimination and includes all industries and services that are not in the household, agricultural, transportation, mining, or manufacturing sectors. Sometimes the definition excludes utilities; in other cases, not. Governmental activity also may or may not be included (FEA 1974, Stanford Research Institute 1972).

The Federal Energy Administration defines the commercial sector as Divisions F-K and part of E of the SIC (U. S. Office of Management and Budget 1972).[1] Divisions F and G cover wholesale and retail trade (p. 241); Division H is the Finance, Insurance, and Real Estate Division (p. 259), including both residential and non-residential rental property. Division I includes a wide range of service establishments and is defined by the Standard Industrial Classification Manual (p. 295) as

[1]See, for example, contract CO-03-5-346-00 (June 30, 1975) of the Federal Energy Administration with Jack Faucett Associates, Inc. (p. 7): ". . . provide data or estimates of energy consumption and prices for the commercial sector of the U. S. economy" (SIC Divisions F, G, H, I, J, and K plus the remainder of Division E).

> . . . establishments primarily engaged in providing a wide variety of services for individuals, business and government establishments, and other organizations. Hotels and other lodging places; establishments providing personal, business, repair, and amusement services; health, legal, engineering and other professional services; educational institutions; membership organizations, and other miscellaneous services, are included.

Public administration, which includes the activities of all branches of federal, state, and local government, forms Division J (p. 334). Division K includes those establishments that cannot be classified with other divisions (p. 347-8).

The remainder of Division E included in the Federal Energy Administration definition of the commercial sector are establishments providing communications service (including the postal system) and electricity, gas, steam, water, and sanitary services (p. 219). The transportation segment of E is not included in this definition.

The American Gas Association (1975) has developed a much broader definition, based upon the definitions of individual gas utilities. Commercial service customers as defined by the American Gas Association include establishments in the agriculture, forestry, fisheries, and transportation sectors, in addition to the sectors included in the FEA definition.

The Edison Electric Institute (1975) reports variation in the way that electric utility companies define the commercial sector. Some companies may define commercial users as those whose kilowatt or electricity demand exceeds a certain number of kilowatt hours per month. This definition actually determines the rate at which the company bills, rather than defining the sector. However, other electric companies define it as those users who fit into the SIC categories listed above. Still other companies define it as the SIC divisions, including rental and non-rental residential buildings that have over four units and more than three stories and are serviced by a single master meter (Midwest Research Institute 1975). There are many other examples of diversity in definitions of the commercial sector used in energy studies by private research organizations and governmental agencies (University of Oklahoma 1975).[2]

This lack of consistency in definitions of the commercial sector used by different groups who develop information for this important sector of the

[2]See, for example, the questions related to the commercial sector that Data Resources, Inc. lists in their proposal to the Electric Power Research Institute. These questions include "How do definitions (of the commercial sector) vary by state or utility?" "Are commercial electricity, gas, or oil customers the same as commercial establishments, as defined by the U. S. Census Bureau (government, trade and services)?" "Who are commercial customers for electricity?" (Data Resources, Inc., "proposal to develop a model of the demand for energy in the commercial sector," Technical Proposal RFP-3198 to EPRI).

economy causes problems for researchers in analyzing present and future energy use and leads to substantial differences in the estimates of the amounts of energy consumed (compare FEA 1974 and Stanford Research Institute 1972). Even if a standard definition of activity to be covered by this sector were developed and agreed to, it would still be very difficult to model energy consumption, because the range of activities conducted within the sector and by individual units themselves is so wide. Hospitals, for example, operate around the clock, utilize a variety of medical equipment, and provide meals and laundry service. For this reason, they have higher energy requirements per square foot than, for example, warehouses, which are used mainly for storage, have low requirements for space conditioning, and utilize very little in the way of auxiliary equipment.

A recent study of energy consumption in commercial establishments in Baltimore (Hittman Associates 1975) illustrates some of the problems involved in measuring energy consumption for commercial buildings. The number of each type of commercial establishment and its square footage were not available for buildings in the Baltimore central business district. The survey gathered data on the height, square footage, glass characteristics, age, and space conditioning systems. It was found that individual types of buildings vary by a factor of five in the amount of energy used per square foot, according to both the function for which the building was used and its structural characteristics. Table 6 indicates how energy-consumption characteristics in commercial buildings vary with use.

TABLE 6 Energy Consumption of 383 Existing Commercial Buildings in Baltimore

Type of Use	Average Annual Energy Use Rate (in Btu/Sq Ft Per Year)	Number in Sample Size	Total Square Footage in Sample
Restaurants	300,000	25	70,991
Night clubs	253,192	23	42,479
Drug stores	232,672	6	15,303
Food stores[a]	206,986	5	5,704
Department stores	164,412	27	1,142,175
Hotels/motels	146,597	6	950,400
Banks	144,634	15	68,743
Offices	124,647	87	6,477,049
Personal services	117,318	26	46,299
Small stores	95,378	132	383,443
Theaters	75,844	2	51,608
Warehouses	61,973	29	439,470

SOURCE: Hittman Associates 1975.

a/Does not include supermarkets.

When data of this sort on energy use in commercial buildings are reported in aggregate form as "commercial" sector or as "residential/commercial" sector, important sources of variation may become obscured. For many purposes, such as zoning, building codes, land use planning, and lending practices, data are needed at a much lower level of aggregation.

Existing Data in the Commercial/Service Sector

Data on energy consumption in the commercial/service sector consist of disparate bits and pieces for different segments of the sector collected by numerous government agencies, utilities industry groups, and trade associations, without any coherent organizing principle.

The Bureau of Mines survey on reserves, production, and consumption of fuels and electricity has been the most frequently used source of data in recent studies (Interior 1973, annual). However, the Bureau of Mines data do not generally provide information on which components of the sector are consuming fuel, the specific fuel consumed, and the quantities of the individual fuels consumed by end use.

The Federal Energy Administration and the Energy Research and Development Administration are conducting a series of studies to collect data on energy consumption in office buildings, schools, and hospitals in different parts of the country. The hotel and motel industry is developing a survey to determine how energy is consumed in the industry and how it can be conserved.

The National Retail Merchants Association surveyed the segment of the retail industry that engages in interstate commerce (i.e., large multi-state chain stores) and found that 80 percent of the total energy consumption was electricity--used primarily for air conditioning and lighting. The retail sales industry does not have a systematized data collection effort under way, but individual chains of stores and shopping center management firms collect internal data on energy consumption.[3] Since 1970, data on energy consumption and prices have been collected for office buildings by the Buildings and Office Managers Association (1975) for prime commercial office buildings in central business districts. In 1971, as part of a study of depreciation practices of building owners, the Treasury Department conducted a survey of the characteristics of the 1969 stock of non-residential buildings (U. S. Department of Treasury 1975).

There is no consistency in the definitions of the activities included, the functional uses covered, the design characteristics of the buildings in which the energy is consumed, the units in which energy consumption is measured, or the time period to which the consumption is related. Data collection efforts in this sector would be much more useful if they were coordinated in order to establish consistent definitions and baseline periods for data collection.

[3]Comments of Lawrence R. Green, Corporate Energy Administrator, Sears, Roebuck and Co., for the National Retail Merchants Association at the Ad Hoc Industry Group for Energy Conservation in Buildings, National Bureau of Standards, March 17, 1976.

Data Needs for Monitoring Energy Consumption

Despite the diversity of activities included in this sector, the major end use of energy is space conditioning. As shown in Table 5, about 35 percent of energy consumption in this sector is for this purpose. The three major determinants of space conditioning consumption levels in commercial buildings are the physical, operational, and temporal occupancy characteristics of buildings. The physical characteristics include the location, the climate, and the site of a building within a specific geographic area. The architectural design and thermal properties of the shell determine the basic parameters of the energy use. In addition, the design and operation of the heating, ventilating, and air conditioning systems strongly influence energy consumption. The operational characteristics refer to the stock of equipment and energy-using appliances within the specific structure--universities, for example, have a different inventory of energy-using equipment than retail stores. These characteristics in turn depend upon the number of people who occupy the building and the nature of their activities. Temporal characteristics refer to the time patterns of occupancy of the building. Hotels are occupied on a 24-hour basis; office buildings may be occupied only 50 hours a week. The consumption patterns of these types of buildings are significantly different.

Thus, a basic data need in this sector is for information on the existing stock of buildings and on their energy-using characteristics, as well as information on the functional uses of the structure. Data are needed, for example, on the design and type of building, heating or air conditioning system, control system, lighting system, building material, amount of glass, and insulation characteristics.

A definition of the relevant physical parameters to be measured should be established. For example, some reports have defined the area to be measured for energy consumption by the physical dimensions of the building, while others define it in terms of the rental area alone. Major problems arise in the absence of a standard definition of area or volume--for instance, is an indoor garage in a building considered part of the energy-consuming space of a building? Standardization of the definition of the space and use of space would be a major step toward better description and modeling of the energy-consuming characteristics of buildings.

Information is also needed on the technical requirements of building construction and operation. At present, not very much is known about the relationship of building standards to the use of the buildings, e.g., do office buildings need more or less ventilation than movie theaters to maintain comparable comfort levels? Information should also be collected on the rates of measured heat flow through specific types of buildings. Data should be collected to determine where potential savings are available now through modification and where design changes in construction are possible in the future. For instance, one of the potential modifications that has been suggested is a change in lighting standards in retail stores and office buildings. It may be that the cost of making changes in lighting is very high to retail store owners; however, when proposed as part of a normal renovation cycle, retailers might be amenable to these changes.

Information is needed to determine the savings under different standards of ventilation and lighting and the costs in terms of comfort, work efficiency, and health. The Energy Research and Development Administration is designing a program to change ventilation standards in hospitals, but information is not yet available on the standards necessary to maintain the operations of different types of hospitals and health institutions. Furthermore, data are scarce on the stock and thermal characteristics of buildings as occupied by health institutions.

An examination of the data currently available for energy consumption in this sector suggests that data on energy consumption should be collected on a sample survey basis to establish benchmark energy consumption data. The survey design and the sample size should be developed to yield estimates for the many disparate units of the commercial/service sector.

Several mechanisms of data collection exist that could be used for the first step of data collection. The National Center for Education Statistics collects a variety of data on primary and secondary schools directly or through contractors. It might be possible to design and attach questions on energy consumption to the individual surveys of the Center to collect initial information on the energy-using characteristics of schools by type of building and geographic location. For institutions of higher learning, the American Council on Education could be asked to include questions on its higher education sample surveys.[4]

The General Services Administration lists all buildings owned or leased by the federal government (FEA 1975b). The Department of Defense has a listing of buildings owned or leased and used by the military (U. S. Office of Management and Budget 1976). These lists could be used as sampling frames for consumption surveys of federal establishments.

Individual states list the buildings that they own or lease. A sample within each of the census regions could be designed to determine the space and the energy-using characteristics of the buildings used by local governments. A sample could be used to survey local governments to determine the number of buildings they occupy, the square (or better, cubic) footage, the energy-consuming characteristics of these buildings, and information on energy actually consumed in recent years (see, for example, Hess et al. 1976).

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[4]Letter to H. Richard Holt from David I. Newton, Executive Director of the American Council on Education, Association of Physical Plant Administrators, National Association of College and University Business Offices Energy Task Force, dated January 20, 1976: "Having received a grant from the Exxon Corporation, we are now in the process of designing an overall energy management program to assist institutions of higher education in their efforts to effectively manage resources, both fuel and financial. A critical part of this program is the assembling of accurate data to represent the cost, consumption and conservation investment trends across higher education. In cooperation with the Higher Education Panel of the American Council on Education, a survey has been developed and mailed to a statistically relevant sample of 642 colleges and universities."

Summary

The data on energy consumption for commercial buildings are very incomplete. A standard definition of the sector should be developed so that the data from different sources would be comparable. Next, data should be collected on the number, cubic or square footage, energy-consuming characteristics, and uses of commercial buildings. Data needed for measuring energy consumption in these buildings relate to a broad spectrum of policy issues; for instance, data are needed for builders and managers to design energy management programs for individual buildings. Similarly, data from experiments and case studies are needed by financial institutions, architects, building owners, and operators. These data would be useful in analyzing the costs and returns of capital investment made to conserve energy. Finally, energy consumption data are necessary for the development of improved utility demand projections and modeling of national demand for energy.

ENERGY CONSUMPTION IN COMMERCIAL TRANSPORTATION

Background

Commercial transportation is not organized as a separate sector in any current federal data series. However, this component of transportation is important because it accounts for an estimated 7 percent of total national energy consumption and 17 percent of all petroleum consumption, second only to the private automobile.

Commercial transportation includes a large number of diverse combinations of vehicles, fuels, and types of operation. It illustrates the complexity of attempting to systematically organize potential federal energy policies and associated energy consumption data: (1) the sector is quite heterogeneous, including vehicles from motorcycles to ships; (2) there exists no commonly agreed upon definition of the sector; (3) at least a dozen federal agencies[5] have policy authority in some aspect of commercial transportation; and (4) fuel-use data are uneven in quality and availability; existing data are widely scattered among federal and state agencies, trade associations, and proprietary sources.

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[5] U. S. Department of Transportation
- National Highway Traffic Safety Administration - vehicle safety
- Federal Highway Administration - highways, truck size and weight
  - Bureau of Motor Carrier Safety - driver and in-use safety, noise enforcement
- Federal Aviation Administration - air safety
- Federal Railroad Administration - railroads
- U. S. Coast Guard - shipping
- Urban Mass Transit Administration - public transit

Environmental Protection Agency - noise and gaseous emissions

Interstate Commerce Commission - truck, bus, and rail routes, rates, and entry

In transportation as a whole, an estimated 141 billion gallons (18.5 x 10 Btu) of petroleum products were consumed in 1973.[6] We estimate that about one-third of this total (47 billion gallons) was used in the commercial/service and industrial sector. The remaining two-thirds were consumed by cars, trucks, and other vehicles used for personal transportation.

Patterns of Fuel Use

The major uses of fuel by commercial transportation are shown in Table 7. This table also includes fuels used by a relatively small number of vehicles belonging to the residential and industrial sector that cannot be identified separately. Trucks used for freight account for over 50 percent of non-household transportation fuel use--a major use of fuels.

Commercial aviation is the second largest consumer of fuels, accounting for about 23 percent of total commercial transportation fuel use. Most commercial aviation is regulated and submits periodic financial and operating data to the Civil Aeronautics Board (Civil Aeronautics Board 1975), from which fuel consumption data may be obtained in detail. Some small fraction of commercial aviation fuel use, such as that consumed by non-regulated intra-state airlines, is not included in reports of the Civil Aeronautics Board but may be reported to state agencies. Data on air freight, which is growing rapidly, as well as improved data on passenger origins and destination, may be of particular interest in the future (Pilati 1975). In addition, fuel used for commercial aviation is not easily separable into that used for passenger transportation and that used for freight. With these exceptions, fuel-use data in commercial aviation are better than those for any other mode of transportation.

Data availability varies widely for fuel used by the other modes of transport. All Class I railroads report fuel costs in detail to the Interstate Commerce Commission. Fuels used in inland waterways are largely untaxed and unregulated, so few data are available. Data are scant for off-road vehicles.

The remainder of this chapter will concentrate primarily on federal policies and associated fuel consumption data needed for trucks used for freight. The trucking industry is highly diverse and accounts for a large fraction of total commercial transportation fuel consumption. Commercial

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Civil Aeronautics Board - airline routes, rates, and entry
U. S. Department of Labor
  Occupational Safety and Health Administration - worker health and safety
Army Corps of Engineers - inland waterways, barge traffic
General Services Administration - government transportation and procurement
U. S. Department of Interior - park service
U. S. Postal Service - mail trucks
U. S. Department of Defense - all services

[6]Estimates derived from U. S. Department of Transportation (1975). Non-petroleum fuels are also used for transportation, but they account for only about 4 percent of total transportation energy use.

TABLE 7 Estimated Fuel Consumption by Mode of Transportation (1973)[a]

Mode of Transportation	Gallons (in Millions)	Percentage of Total
Highway		
Trucks used for freight	24,200	51.4
Buses	847	1.8
Air		
Certificated carriers	10,682	22.7
General aviation (estimated)	925	2.0
Marine		
Ships and barges	5,701	12.1
Rail		
Locomotives	4,246	9.0
Other		
Transit (electric) $2{,}331 \times 10^6$ Kwh[b]	190	0.4
Transit (non-electric)	310	0.6
TOTAL	47,143	100.0

SOURCE: Estimates derived from U. S. Department of Transportation (1975). Non-petroleum fuels are also used for transportation, but they account for only about 4 percent of total transportation.

a/Automobiles, trucks, and motorcycles used for personal transportation excluded.

b/Kwh converted to gallons, using a conversion factor of 1 kwh = 0.08 gallons as derived from "Monthly Energy Review," PB 272-769-10, FEA, October 1975. "Transit" includes city and local bus, local railway, subway, trolley, airport transportation service, and other.

aviation, rail, pipeline, and marine transportation are either more fully regulated or account for smaller fractions of fuel use, or both. These modes of transportation present less difficulty for the acquisition and maintenance of fuel consumption data. The other modes will not be discussed further, except when mode shifts may be important to monitor future trends in fuel use.

We have not discussed fuels used for military purposes, although they account for a significant share of national petroleum consumption and an even larger share of petroleum consumption attributable to the federal government. In 1973, military uses accounted for approximately 10 billion gallons of fuel. Cook (1976)[7] has estimated military uses of fuels, based on Department of Defense data; they are shown in Table 8.

TABLE 8 Estimated Use of Fuels by the Military (1973)

Type of Fuel	Millions of Barrels	Millions of Gallons
Jet fuels	150	6,300
Aviation gasoline	7	290
Navy special fuel oil	28	1,100
Distillates and diesel	45	1,890
Motor gasoline and other	8	340
TOTAL	238	10,000

Both the data needs and the public policy options for energy consumption for military transportation are significantly different from those of the household, industrial, and commercial/service sectors of the economy and are not treated further in this report.

Trucks[8]

In 1974, 23.9 million trucks were registered in the United States (Motor Vehicle Manufacturers Association 1975a). More detailed data on trucks are available only for 1972 (Commerce 1975d), and we use this year as a basis for discussion. In 1972, 19.7 million trucks were in use (excluding government-owned trucks), and they traveled a total of approximately 244 billion miles. Slightly more than 8 million of these trucks (41%) and 79 billion truck miles (32%) were accounted for by the use of trucks as personal transportation (see

[7]It should be noted that these figures do not agree with those of U. S. Department of Transportation (1975), which, for example, reports about 16,000 million gallons of jet fuel used in 1973. Subtracting the 10,700 million gallons by commercial aviation implies 5,300 million gallons used by the military. Classified data on military consumption are not included in these figures.

[8]Trucks used for personal transportation are excluded from all weight classes in this discussion.

Chapter 2). Some of these trucks used for personal transportation are undoubtedly also used partially for commercial purposes, but existing data do not permit separation of personal and commercial use.

Trucks used for freight illustrate a range of potential federal policies for which improved energy consumption data are needed: (1) to monitor total national consumption of petroleum; (2) to model the effects of technological developments upon future fuel use; (3) to estimate the effects of regulatory practices on fuel consumption; and (4) to help the industry make decisions about opportunities for energy conservation. The range of policies includes voluntary and educational programs to modify fuel use, fuel price changes through increased taxes, mandatory fuel-efficiency standards (such as those imposed upon automobiles by the Energy Policy and Conservation Act of 1975) and regulatory and other non-price policies, such as highway speed limits.

Data on Fuel Consumption

Data Availability

Extensive data on numbers and types of trucks are available. Data on registrations, vehicle stocks, sales, truck types, and miles driven are collected by the Department of Transportation (Federal Highway Administration), Interstate Commerce Commission, Bureau of the Census, state motor vehicle departments, and trade associations such as the American Trucking Associations and Motor Vehicle Manufacturers Association. Data on numbers of trucks, types of trucks, miles traveled, major use, and commodities carried have been collected by the Bureau of the Census Truck Inventory and Use Survey in 1963, 1967, and 1972 (Commerce 1975); the survey will be repeated in 1977. The sample for this survey is composed of about 100,000 trucks, stratified by state and by size of truck within states. Trucks owned by governments are not included in this survey, but some data on federally owned trucks are available from the General Services Administration (annual), and data on trucks owned by state and local governments are available from the Federal Highway Administration (1973). In spite of the relatively large amount of data on trucking in general, specific data on fuel consumption by trucks are not available. Data in the Truck Inventory and Use Survey provide estimates of the numbers of trucks using gasoline or diesel fuel, but quantities of fuel used are not reported.

For expositional purposes, it is possible to estimate the relative proportion of fuels used by trucks of differing weight classes by making plausible assumptions about fuel efficiency. Table 9 shows estimated fuel consumption by weight class for trucks used for purposes other than personal transportation.

TABLE 9 Estimated Fuel Consumption of Trucks by Weight Class

Department of Commerce Weight Category	Gross Vehicle Weight (lbs.)	No. of Trucks[a] (thousands)	Truck Miles (millions)	Assumed MPG [b]	Estimated Gallons Consumed (in millions)
Light	≤ 10,000	6,800	78,600	9	8,700
Medium	10,001-20,000	2,510	25,900	7	3,700
Light-heavy	20,001-26,000	810	8,600	6	1,400
Heavy-heavy	≥ 26,001	1,480	51,800	5	10,400
TOTAL		11,600	164,900		24,200

a/Based on U. S. Department of Commerce (1975); trucks used for personal transportation are excluded from all weight classes in this discussion.

b/Assumptions based on U. S. Department of Transportation and Environmental Protection Agency (1975); see also FEA (1974).

This table shows the distribution of fuel consumption by weight class to be bimodal. Light trucks account for roughly 40 percent of all fuels consumed by trucks simply because there are so many of them. Trucks with gross vehicle weight in excess of 26,000 pounds also consume roughly 40 percent of all fuels used by trucks because of their combined high mileage and low miles per gallon.

It is planned that the 1977 Truck Inventory and Use Survey will collect two additional items of data not previously collected: first, miles per gallon for each truck and whether or not the miles per gallon reported are "accurate or estimated"; second, whether the truck is equipped with any of three specific types of fuel conservation equipment: radial tires, air shield, or clutched fan.

The remainder of the discussion will concentrate on heavy duty freight trucks for several reasons:

1. Since almost all of these trucks are used for business purposes, the decisions on purchase and use of these vehicles are made primarily according to economic criteria.

2. These vehicles comprise about 13 percent of all commercial trucks, but account for about 30 percent of all truck miles and about 40 percent of the total consumption of fuels by trucks.

3. Many of these trucks are regulated and thus present several practical opportunities to improve existing data series in terms of energy use.

4. There are extensive fuel conservation programs for these trucks under way within the

Department of Transportation, the Environmental Protection Agency, the Federal Energy Administration, and the trucking industry. Improved fuel consumption data are needed to evaluate the effectiveness of these programs and to estimate future fuel demand.

The demand for fuel used by trucks is influenced by several factors. Trucking activity is strongly dependent on the level of activity in those businesses that use trucks to transport products or to provide services. The fuel consumed by trucks is a function of the physical characteristics of the truck, the weight and size of its load, truck speed, trip type, and distance. Driver behavior as well as the regulatory environment in which some trucks operate also influence fuel consumption by trucks.

Types of Data Needed

Current federal and trucking industry programs to modify the fuel consumption of large trucks deal with:

- Technological modifications to existing and new stocks of trucks, such as improved aerodynamic characteristics, driveline changes, demand-responsive fans, low-rolling resistance tires, and turbo-charged diesels. Such modifications affect the fuel used on a given trip.

- Regulatory modifications such as more uniform size and weight limits, utilization of double trailers, routing and load utilization restrictions, and model shifts. These regulations affect the number of trips, routes, and equipment type used.

Programs also cover modifications to truck operating procedures, including reduced idling time, load make-up, and dispatching practices, improved driver training, and observation of 55-mph speed limits. However, these fuel conservation measures do not readily lend themselves to systematic data collection or analysis. This section will discuss specific examples of technical and regulatory data needed.

Technological Modifications. Fuel costs for commercial trucking are a smaller proportion of total operating costs than they are for transportation in the household sector; driver wages and terminal costs account for a large part of this difference. For this reason, commercial trucking fuel-use decisions may be less sensitive to fuel price than they are to expected future availability of fuel and the regulatory environment.

In the short run, however, fuel-use decisions are sensitive to fuel prices, primarily because they affect profits. Recent increases in fuel costs have stimulated programs sponsored by both government and the trucking industry to promote fuel conservation.[9] One such method of promoting fuel conservation is to install devices to reduce aerodynamic drag on large trucks (California Institute of Technology 1974, Innocept Inc. 1975). These devices consist of retrofitted equipment designed to streamline the air flow over a truck body, thereby reducing air drag and decreasing fuel consumption at a given speed.

The costs of these devices, when compared with the expected fuel savings, seem to indicate a pay-back period of about 60,000 miles of operation (Motor Vehicle Manufacturers Association 1976), which is less than twice the average annual mileage of heavy duty trucks. This trade-off seems quite attractive, but very little information is available on the extent to which drag reduction devices have actually been installed by truck owners. As mentioned earlier, collection of these data is planned for the 1977 Truck Inventory and Use Survey.

Drag reduction devices are just one example of fuel-conserving equipment. Similar data are also needed for other devices, such as diesel turbochargers, high-torque rise diesel engines, radial tires, tag axles, and more efficient driveline components, including automatic transmissions and clutched fans. Behavioral data also needed include data to evaluate the effectiveness of driver training and driver monitoring programs and other operational modifications. As with other types of data on fuel consumption, data are needed to design policies to modify the demand for fuel, even though fuel costs are a relatively small but noticeably increasing fraction of total cost.

Much of this type of data already exists in the form of research reports, but it is fragmented and incomplete in terms of what is needed by either governmental agencies or the trucking industry. Many of the existing data have not been synthesized into information that is usable to those individuals and firms who make decisions about the installation and use of retrofit equipment.

Regulatory Practices

Effects of Truck Size and Weight Limits. States place varying limits on truck size, weight, and configuration. Non-uniform state limits affect both the route and the equipment used on interstate freight in such a way as to increase total fuel consumption. In particular, size limits, weight limits, and restrictions of multiple trailers may cause trucks to be limited either in volume, for low-density cargo, thus increasing the numbers of truck trips required to haul a given volume, or in weight, to the lowest state limit of an interstate route (American Trucking Associations 1975).

Fuel consumption by trucks is not directly proportional to payload weight. Increases in payload weight result in less than proportional increases in specific fuel consumption. Consequently, fuel efficiency may be improved by increasing size and weight limits, but increased size and weight may also have consequences unrelated to fuel use, such as increased damage to roads, increased noise, and decreased safety. Few data are available on the combined effects of changes in size and weight limits, highway damage, noise abatement, and safety

[9] For example, the Truck and Bus Voluntary Fuel Improvement Program sponsored by the Department of Transportation, the Environmental Protection Agency, and the Federal Energy Administration.

and emissions control equipment.[10] Controlled field experiments may be necessary to measure the effects of these variables, both singly and in combination.

Mode Shifts

Previous discussion of fuel use by trucks emphasized the data needed to analyze the efficiency of a particular mode of transportation; such analysis concerns owners, operators, and design engineers. The customers of commercial transportation, concerned with analyzing the efficiency of alternative modes of transportation, need a different kind of information. Truck, rail, and air freight are not fully substitutable due to differences in bulk and weight of commodities shipped, distance, timeliness, and convenience. For the modes of transportation that are interchangeable, data are needed on a commodity-by-commodity and route-by-route basis to analyze (a) those route and commodity combinations for which shifts are feasible and (b) the net fuel consumption consequences of such shifts. In general, these data tend to be produced as a result of specific analytic studies rather than enumerative surveys (Roberts 1975).

Increased truck-train piggybacking and increased use of containerization to permit truck-ship, truck-rail, or truck-aircraft integration of transportation modes are examples of long-term trends that will affect the demand for fuels in commercial transportation. Such shifts also have effects upon safety, noise, and pollution, which must be evaluated. (Mode shifting for passenger transportation is discussed in Chapter 2.)

Load Utilization

Some fraction of all truck miles are run empty or with partial loads. Published estimates of empty miles vary widely, from 8 percent to 40 percent. Part of this failure to utilize load capacity fully is a characteristic of equipment specialization for the commodity shipped (automobile carriers, dump trucks), or geographic imbalance (e.g., the amount of freight shipped out of Washington, D.C. does not equal the amount shipped in). Data are needed to measure the actual extent of empty backhauls and their potential reduction, exclusive of irreducible factors of the distribution system.[11] As in the case of shifts in modes of transportation, such data are needed on a commodity-by-commodity and route-by-route basis.

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[10] A preliminary study of these factors is contained in a draft entitled U. S. Government Interagency Commercial Vehicle Post - 1980 Goals Study.

[11] The Federal Energy Administration and the Interstate Commerce Commission are currently conducting an empty mileage survey. The Department of Transportation also conducts an annual survey of empty-loaded distribution.

Summary of Data Needs

Because of the highly differentiated nature of the trucking industry, data quality and availability are uneven. Data on private fleet trucking and other unregulated carriers are inconsistent and incomplete compared to those for the regulated fleets, who must report operating and financial data. Much research data exists at the federal level on the potential of technical devices to improve fuel efficiency, but they do not appear to be well disseminated within the trucking industry.

The extreme diversity of truck types, routes, and commodities carried makes it unlikely that fuel efficiency standards, such as those for automobiles in the Energy Policy and Conservation Act of 1975, could be agreed upon for trucks, at least not based on weight class alone. The effects of technological changes, either for new or modified trucks, as well as the effects of tax or fuel price policies, can be estimated accurately only if very detailed data are available on trip types, load size and weight, vehicle characteristics, and route conditions.

At the beginning of this discussion of trucks, four general areas were listed in which improved fuel consumption data were needed for federal policies. For trucks, such data are those needed to monitor national consumption, to model the effects of technological changes, to evaluate regulatory practices, and to inform users.

Monitoring National Consumption

Data from the Truck Inventory and Use Survey of 1977 will provide adequate information to monitor national fuel consumption by trucks, both through published data and through other tabulations made possible through the public use tapes. Annual updates on a subset of the larger sample would be desirable. In addition, it would be useful to have fuel-use data on the 40 percent of all trucks whose major use is personal transportation but that may also be used partly for commercial purposes.

Modeling the Effects of Technological Change

Data on the adoption of three specific fuel conservation devices is planned for the 1977 Truck Inventory and Use Survey, but information is also needed for other devices and for new truck designs that incorporate a total systems approach for fuel efficiency. An open-ended question on the Truck Inventory and Use Survey would provide these data.

Evaluating Regulatory Practices

In the past, regulatory practices were designed to accomplish objectives other than modifying fuel consumption. Even today, data on fuel consumption are only one aspect of a multiple-criteria decision. For example, truck size and weight regulations interact with the factors of noise, road damage, safety, and pollution in regulatory policy design. Specific analytic studies rather than extensive enumerative data are needed to evaluate the fuel consumption consequences of regulatory practices.

Informing Users

Data and information are needed by the individuals and firms who make decisions about the use of more fuel-efficient equipment. Some such data now exist but are usually not organized or disseminated in a form usable by the industry.

Although trucking has been discussed here as a specific example, these conclusions about needs for data on energy consumption apply to other modes of commercial transportation as well. Data are needed that include fuel use by both regulated and unregulated portions of fleets of similar vehicles. The unregulated portion of the trucking industry is quite large; the unregulated portion of commercial aviation is small. Data are needed to separate personal and commercial uses of fuel in vehicles that are used for both purposes; this applies primarily to light trucks. Finally, data are needed that separate fuel used for passenger transportation from those used for freight, primarily to evaluate the effects of shifts of freight from trucks to aircraft.

FINDINGS AND RECOMMENDATIONS: COMMERCIAL/SERVICE SECTOR

Finding. The lack of a consistent definition of the commercial sector seriously interferes with careful accounting of energy consumption. Energy used in the commercial/service sector is dominated by transportation and the space conditioning of buildings. So few details are known about energy use and the characteristics of energy-consuming structures and equipment in this sector (except for certain regulated uses in the transportation area) that the most urgent need is for a benchmark survey of energy consumption patterns.

Definition of the Sector

Recommendation. *The Committee recommends that federal agencies with authority to make policy in energy consumption areas of the commercial/service sector undertake a program to specify and standardize the definition of this sector. The definition may be based upon the Standard Industrial Classification system but need not be limited to it for energy accounting purposes. Such a program should also standardize elements, such as floor space, within the sector. Greater consistency would be especially useful in defining and reporting in those areas of the commercial/service sector that currently cannot be accurately separated from the household or industrial sectors, particularly multiple-family dwellings, light trucks, and some portions of agriculture.*

Commercial Buildings

Recommendation. *The Committee recommends that a benchmark survey of energy use in commercial buildings be undertaken. This survey should obtain information on energy used for space conditioning, and all "other" uses, with appropriate specification of subcategories. In this benchmark survey, attention to space conditioning should be primary, since it is our view that it represents the most important prospect for changes in energy use in this sector. Data on space conditioning include type of building material and construction, type of heating, ventilating, and air conditioning system and associated regulation controls, and variations in comfort levels. Because energy use in commercial buildings is so heterogeneous, we further recommend that, as a minimum, this survey classify energy use in buildings on the basis of age, size (cubic footage), nature and use of internal equipment, temporal patterns of occupancy, the public or private (lessor and lessee) nature of decisions concerning energy use, and the nature of the operation and control of heating, cooling, and lighting equipment.*

Space Conditioning

Recommendation. *For the commercial/service sector as well as the household sector (see Chapter 2), the Committee recommends that studies be made, on a nationwide sample of structures, of the relation between energy consumed for space conditioning within structures, the physical characteristics of structures, the behavior of occupants, and the intensity of equipment use within structures. We also recommend that research and development be undertaken to develop instruments for measuring the relevant energy-consumption characteristics of existing structures, with an eye toward simple, inexpensive, and easy-to-operate instrumentation. Such instrumentation falls into two general categories: (1) that which enables individual building occupants to monitor and control the use of existing equipment, and (2) that which supplies data needed to precipitate constructive investment decisions.*

Commercial Transportation

Recommendation. *For the transportation component of the commercial/service sector, data are needed principally for unregulated modes of transportation and for those routes and commodities for which shifts from one mode of transportation to another mode may be influenced by public policies. The largest users of petroleum products for commercial transportation are trucks, and significantly improved data on their fuel use will be collected by the 1977 Truck Inventory and Use Survey. However, these data may be improved further for policy purposes by (a) separating personal and business uses of trucks, (b) obtaining additional data on the extent to which technological modifications that improve vehicle fuel efficiency have been adopted and with what effect, and (c) more frequent reporting on subsets of the larger sample. Data needed to evaluate the effects of changes in regulatory practices must come from analytic studies rather from than from enumerative surveys.*

CHAPTER 5

ASSESSMENT OF ENERGY POLICY

INTRODUCTION

Throughout this report, data on energy consumption have been discussed in terms of three broad purposes: monitoring, modeling, and assessment. Previous chapters have stressed the monitoring and modeling of energy consumption; this chapter concentrates on assessment--especially the assessment of public policies intended to affect patterns and levels of energy use in the nation.

Some policies may be designed to reduce energy consumption either in general or in certain forms. Other policies may be designed to shift to more efficient patterns of energy use. Still others may be designed to encourage the substitution of one fuel for another. Whatever the objectives of a policy, it is usually possible to express those objectives in measurable terms. If a public policy is designed to reduce the use of gasoline by households, then it is possible to express the reduction in quantitative terms: number of gallons of gasoline used by households. Even when the intended effects of a public policy are stated in more abstract terms, it is possible to give it quantitative expression. If the objective of a policy were to achieve distributive justice in the use of energy, for example, it would be difficult to express this quantitatively, but it would be possible to develop formulas for per capita entitlement.

Even though policy objectives can be transformed into measurable terms, other difficulties may impede policy assessment. Many factors other than public policy affect the patterns and levels of energy use. For example, an unusually severe winter may produce fluctuations in fuels used for home heating that obscure the effects of a recently instituted policy that provides incentives for home insulation. In short, a change in energy consumption that occurs after a change in policy has been adopted may reflect many other changes as well.

The art of assessing public policy depends on designing data collection and analysis to remove the effects of non-policy factors and thus estimate the "pure" effects of policy. Essentially, there are two strategies for removing the effects of extraneous factors in policy research: statistical and experimental. Statistically, such effects can be removed through the use of multivariate statistical analyses. The effectiveness of this approach is heavily dependent on good (properly specified) models of the phenomenon being studied. To the extent that a model correctly identifies causal factors for the energy consumption at which the policy is aimed, the model also prescribes the factors to be held constant statistically in order to assess the policy. (For a comprehensive discussion of policy assessment and evaluation, see Guttentag and Struening 1976 and Rossi and Williams 1972.) The modeling activities discussed earlier are thus critical to policy assessment because they provide an inventory of plausible competing explanations of changes in energy consumption; an analyst demonstrates the effects of a policy by testing and statistically eliminating alternative explanations.

The second major approach to the assessment of public policy is controlled and randomized field experimentation. In experimentation, changes in factors other than the policy being studied are eliminated from analysis by means of experimental control. By designing experimental conditions under which a policy is implemented and otherwise comparable control conditions under which the policy is not implemented, the purest possible estimate of the policy effects can be obtained. Such controlled experimentation is particularly important in assessing policies that are beyond the range of data on which available models are based. Models of consumer behavior based on past gasoline prices might not apply, for example, to circumstances in which gasoline prices are five times higher. The more innovative a proposed policy and the more qualitatively different its content and the context in which it is likely to be adopted, the more important it is that there be prospective experimentation. (See Riecken and Boruch 1974 and Bennett and Lumsdaine 1975 for excellent discussions of experimentation.)

The disadvantages of experimentation are substantial, however. Experiments are usually more expensive than non-experimental procedures, and they are more difficult to prepare and conduct. Sometimes they also present ethical problems in the treatment of human subjects, as when people in the experimental group are to enjoy some special advantage that those in the control group by definition will not receive. For these reasons, we advocate the extensive use of non-experimental as well as experimental methods of policy assessment.

NON-EXPERIMENTAL METHODS

Non-experimental methods are built around naturally occurring variations in policies and in energy use, including differences between localities, states, regions, and nations. Non-experimental studies or quasi-experimental studies can also be designed around naturally occurring policy changes and the effects of policy implementation.

Local Variations in Policy

Since the United States contains a variety of local political jurisdictions, each of which may have developed energy policies appropriate to its situation and authority, there may be enough variation in policy among regions, states, or smaller political jurisdictions to provide assessments of the effects of some alternative policies on energy consumption. For example, public utilities in different parts of the country charge different base prices for electricity: the effects of price levels on electricity use can be approximated by comparing consumption of electricity for similar households under different pricing systems. The value of such analyses depends heavily on the ability of the analyst to adjust for competing explanatory factors, such as climate, characteristics of housing, the prices of substitute fuels, and household income.

International Comparisons

Comparisons with other countries provide an opportunity to study a broader range of policies than is available in the United States. A number of European countries have a level of per capita income close to that of the United States, yet their per capita energy consumption and their energy consumption per dollar of gross domestic product is substantially less than those in the United States. Despite the limits on conclusions imposed by the many factors that make countries different, international comparisons can serve policy makers in two ways. First, they can suggest the varying effects of the broad range of policies found in countries that use less energy than the United States. Second, they can display some of the limits of human adaptation within the institutional and technological constraints of Western industrial society. In designing policies intended to capture the advantages of alternative energy consumption practices, especially alternatives provided by new technology, it is important to estimate the practical potential within the limits set by social structures comparable to our own.

Before-and-After Studies

Policies and practices change over time, and it is possible to take advantage of those changes to evaluate the effects of the policies themselves. For example, automobile purchase patterns in 1972-73 can be compared with those of 1975-76, or the size, number, and efficiency of air conditioners sold in those years can be compared. Average insulation used in new building construction can be compared before and after changes in FHA regulations. Such comparisons require that the "before" data are available or can be reconstructed and that effects of other simultaneously changing variables can be estimated with sufficient precision to permit attribution of cause and effect to the policy being studied.

The real world is one in which many processes occur simultaneously. Policy-induced changes may either be masked or exaggerated by such processes. The ability of an analyst to unravel the skeins of cause and effect in assessment studies depends on the availability of good models of energy consumption processes, models that provide reasonable explanations of what causes shifts in energy consumption. Such models can be used to hold constant the non-policy factors that might be obscuring the effects of policy. The most obvious limitation of before-and-after studies is also the most serious: the naturally occurring events available for study may not include sufficient variation in factors relevant to the policy changes that are of interest.

Implementation Studies

The question of how a policy is implemented is critical for evaluative activities, and it must not be answered by casual assumption. Efforts at policy assessment during the past two decades have unearthed a problem not ordinarily dealt with by either monitoring or modeling: failure to carry out an announced policy. All too often it turns out that the policies adopted are either imperfectly carried out or not carried out at all (see Williams and Elmore 1976).

For example, there is consensus that decisions to enrich the school curriculum for underprivileged children under the Elementary and Secondary School Act of 1965 were poorly carried out in some school systems and were not carried out at all in others. If an enacted policy is not really placed into operation, it cannot have an effect.

Policies that involve little organizational change are easier to carry out than those that require considerable organizational change. For example, a policy that involved changing the price of energy through taxation might not be as difficult to implement as a policy that imposed maximum standards in the lighting of commercial buildings. In general, the more ambitious and innovative a policy, the more important it is to do research on the policy as implemented. In particular, any policy that depends on changes in the behavior of large numbers of people or organizational units should be monitored to ascertain the extent to which the policy is implemented in practice.

FIELD EXPERIMENTATION

Non-experimental studies, such as those described above, usually involve the assessment of policies already in place or about to be implemented. There is also an important role for evaluation research that is future oriented, looking to the problem of choosing among policies that may be adopted.

No matter how well designed a prospective policy may seem or how strong the reasons marshalled to argue for its necessity, it is quite possible that the policy, when implemented, will have results that differ from expectations. Indeed, it seems likely that most policies aimed at changing human behavior in significant ways will not meet their objectives in some major degree. Such uncertainty of success suggests two important reasons for conducting field experiments: allowing failure on a scale that can be tolerated and demonstrating principles of change that can be applied in other situations.

Another reason for experimentation is that many policies are difficult to implement in the manner thought appropriate by decision makers. Further, policy interventions, even if implemented as designed, may be too weak to overcome the countervailing effects of other events in the environments of individuals. Finally, there are the obvious defects in existing theories of human behavior, which provide only a modest basis for predicting the outcomes of intervention; many efforts to create change generate increased resistance. Whatever the reasons in a particular case, the outcome of a proposed policy is usually unclear.

The risks involved in adopting policies whose outcomes are unclear are the strongest arguments for a program of scientifically designed field experimentation. Such experiments provide better estimates of the associated costs and benefits--of the actual outcome--of a proposed policy. Such a program can also provide policy makers with assessments of the relative effectiveness of alternative proposals.

Field experiments, even when successful, are not definitive predictors of the effects of full-scale programs. The extrapolation from samples to total populations always involves errors. But field experiments can reduce areas of ignorance and replace guesses with estimates of probable effects, wanted and unwanted, of a proposed policy.

The Essential Features of Field Experiments

A field experiment should enable one to determine whether change of the intended kind has occurred in the experimental population and whether related unintended changes have occurred. (For detailed discussions of field experiments, see Campbell and Stanley 1966 and Cook and Campbell 1975.) This is needed to permit a reasonable inference about the cause of the changes. One should also be able to make inferences about how larger populations would react if the experimental treatment were to become policy.

It is, of course, much easier to stipulate the desirability of such properties than to design them into a field experiment (see, for example, General Accounting Office 1975). To calculate the confidence intervals for the parameters of the larger population at real interest, for example, requires that the experimental participants be selected with known probability, without bias, and in sufficient numbers from the larger population. The extrapolation from experimental groups to larger populations rests on replication, intuition, and judgment as well as on inferences of statistical probability. The success of such extrapolation is determined by the external validity of an experiment.

Criteria of internal validity also need to be established to ensure that an observed change in the experimental population really was caused by the experimental treatment rather than by some other factor. Studies without control groups, without measures made prior to experimental treatment, or without adequate follow-up are often described as experiments. Indeed, there is at least colloquial sanction for using the word "experiment" to describe any innovation, any trial.

We wish to reserve the word "experiment" to designate only a very specific type of endeavor: the administration of a treatment to a group of persons, households, firms, or other units, for a specified period of time, with the treatment being withheld from a statistically comparable group, the control group. Both the treatment group and the control group are observed during the experiment, and the differences between the two groups at the end of the trial period indicate the effects of the policy.

A critical feature of field experiments is the way in which the treatment (experimental) group and the control group are divided. Although there are several ways to make the division, the essential procedure is randomization: whether participants in the experiment are in the treatment group or the control group is decided by an appropriate randomizing device. Randomization ensures that the treatment group and the control group are statistically comparable before the experiment (within the range of differences generated by random error). It also ensures that the post-experiment differences between the treatment and control groups are not the result of initial differences between the two groups.

Experiments have long been carried out in laboratories, where the conditions for randomization, isolation of treatment and control groups from each other, and careful measurement of possible effects are relatively easy to maintain. Experiments carried out with persons and social groups in their usual environments involve special problems--problems of cost, problems of scale, and problems of meeting the criteria of experimental design within the limits set by the principle of informed consent by participants. In spite of these problems, field experiments have become standard procedure in the development of medical products and they are becoming more commonplace in other fields of research.

Within the past decade, field experiments have been used for assessing prospective social policies, an extension of experimental technique made possible by the development of sample survey procedures. Field experiments have been conducted (or are currently under way) to test the effects of negative income tax policies, the effects of federally sponsored health insurance on the demand for medical care, and the use of rent vouchers to improve the quality of housing occupied by the poor. (For detailed descriptions, analyses, and critiques of the negative income tax experiment, see Kershaw 1972, Kershaw and Fair 1976, Pechman and Timpane 1975, and Rossi and Lyall 1976.)

Our main interest is in the application of these methods of data collection and analysis to energy policies. Randomized experiments are now under way to test the effectiveness of alternative pricing policies for electricity. One of the better designed of these experiments is being conducted by the Department of Water and Power (DWP) of the City of Los Angeles in cooperation with the RAND Corporation. The purpose of this experiment is to observe whether pricing policies that take into account time-of-day and demand differentials will affect household consumption of electricity. Approximately 2,000 households were selected to participate in three treatment groups, each of which will experience a different pricing policy, along with approximately 300 control households. The treatment and control households will be observed over a 30-month period, and changes in the use of electricity and in the household stocks of appliances will be measured during this time. At the end of the experiment, it will be possible to gauge the effects of several pricing policies on household electrical consumption in Los Angeles.[12]

Some Applications of Experiments to Assessments of Energy Conservation Policies

Proper design of a program of field experimentation on energy conservation first requires specification of the alternative conservation policies that are contemplated for the future. It is not necessary to guess which programs and policies will be adopted, but only those that might be seriously considered.[13] To illustrate the possible applications of field experimentation to energy policies, this section describes a number of specific examples. These must be

[12]This description is taken from the proposal submitted to the Federal Energy Administration (FEA) by the Los Angeles Department of Water and Power and the RAND Corporation, "Analysis of the Desirability and Effects of Alternative Electric Rate Structures," dated March 1975. It is quite likely that the specific features of the experiment described in the proposal will have been modified somewhat to take into account actual field experiences in implementing the proposed experimental plan. There are many other "experiments" funded by FEA that are designed to test pricing policy variations in other utility systems. The RAND-Los Angeles DWP experiment is used as an illustration here because it is the most extensive and apparently best designed of the experiments that were funded by FEA.

[13]See, for example, "Energy Conservation Strategies," a 1973 study done by Marquis Seidel, Steven Plotkin, and Robert Reck in the Office of Research and Monitoring, U.S. Environmental Protection Agency.

taken as illustrations of process and design, rather than as informed guesses about the future directions of energy policy. Although the examples involve mainly households and individual consumers, the experimental units could also be firms, governmental agencies, or other entities.

Feedback Experiments

This is a class of experiments in which the treatments consist of providing timely information or signals to consumers on their consumption of energy.[14] The information might be displayed in terms of price and in terms of the consuming appliance or source. The rationale behind such experiments is that most consumers do not know the rates at which they are consuming energy nor how much each appliance uses. Such experiments hypothesize that with such knowledge, consumers would alter their behavior to reduce energy expenditures (or, possibly to reallocate energy use to conform more closely to their subjective priorities).

Treatments would consist of installing metering devices that would provide the appropriate information for each major appliance to a set of experimental groups; control groups would have only their total energy consumption measured in accordance with usual practice. Comparisons between experimental and control groups over a period of time would provide estimates of the savings that could be effected by the installation of such feedback devices. Appliances and other energy-consuming equipment to which such metering devices might be applied are: furnaces and space heaters, stoves, washing machines, and dryers. For automobiles, meters indicating miles per gallon or vacuum gauges indicating relative efficiency could provide similar information.[15] The critical question is whether the energy savings resulting from the use of such devices would offset the energy embodied in metering devices and expended in their installation, so that there would be a net savings of energy used.

Various elaborations of this design are possible. By modification of utility bills, consumers might be given data to indicate trends in their energy use, comparisons with a previous month or year, or comparisons with community or neighborhood norms. The feedback principle might also be extended from households to business firms, office buildings, or government agencies. Experience with feedback experiments related to other public policies suggests that feedback is more effective when it is combined with other efforts, such as public communication, education, and group decision making. For purposes of example, however, such programs are described here as separate kinds of experiments.

Educational Campaigns

An educational campaign can be defined as an attempt to change people's beliefs, attitudes, values, or behavior by providing generalized information, instruction, or exhortation. Such campaigns can be conducted through television

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[14] "Giving Households Feedback on Energy Consumption," by Fred D. Baldwin, a paper prepared for the Committee, discusses such experiments.

[15] In a recent experiment, one type of relatively expensive ($130) device was tested; see Transportation 1976.

or radio, through newspapers or other printed material, by mail, or through meetings or other forms of direct contact.

Educational campaigns are attractive devices for effecting changes in behavior. A well-mounted educational campaign can have wide and economical coverage of a target population: a spot commercial on prime-time TV, for example, may reach tens of millions of families; a direct mailing of a pamphlet can reach almost all households in the United States. Measured in terms of the costs of delivering the treatment, such educational campaigns usually have very low per capita costs, and their effectiveness is too often measured in these terms alone. In terms of behavioral changes per exposure, however, the effectiveness of such campaigns is usually very slight. An educational campaign on energy conservation would be truly effective only to the extent that it induced changes in behavior sufficient to offset the energy expended in its conduct and thus yielded a net savings in energy: if only one person in fifty showed a behavioral change in response to the campaign, that person would have to change enough to cover the energy costs of reaching the 49 people who did not change.

A variety of field experiments can be designed to measure the effectiveness of educational campaigns. Media campaigns are perhaps best tested by randomizing treatment sources: a campaign of TV spot announcements on energy conservation could be tested by showing the set of announcements on a randomly selected sample of television stations and not showing them on a comparably selected set of control stations. The effectiveness of such a campaign could then be determined by measuring changes in household energy consumption in areas covered by the television stations that showed the announcements and comparing them to the changes (if any) in the areas where the announcements were not shown.

Another type of field experiment might involve selecting households in a specified community for direct mail campaigns. In such a field experiment, it would be necessary to get records of energy consumption for both the experimental and control households. The Federal Energy Administration's Project Conserve, for example, solicited information about storm windows and insulation by a mailing to all households in a given area and returned computer-processed data about the costs and benefits of their home heating practices to those who responded. Follow-up was carried out on non-respondents, who provided the control group.[16]

Within any of these designs, a number of experimental groups can be used simultaneously, each testing a different appeal, thereby increasing the amount of knowledge gained about a variety of educational approaches. For example, some campaigns might appeal to self-interest, stressing the financial savings that would result from more careful habits of energy consumption; others might rely on appeals stressing the benefits to American society. Some might feature messages from prestigious people, while other campaigns might feature persons whom the general public would see as more like themselves.

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[16] See the Description of Major Programs of the Office of Energy Conservation and Environment, dated November 1975, and the Project Conserve Final Report, Conservation Paper No. 5, dated October 1975, of the Federal Energy Administration.

Pricing Experiments

Perhaps the most frequently discussed energy conservation policies involve pricing strategies: in particular, differential pricing for peak demand periods in order to shift excess loads to off-peak periods, pricing that would be weighted inversely to demand, and price discounts for energy-efficient equipment. A number of projects have been designed to test incentives, and some of them have been presented as experiments. With few exceptions (for example, the RAND-Los Angeles DWP), descriptions of the "experiments" indicate that they tend not to be experiments in the sense used in this chapter, but are rather more in the way of demonstrations, using volunteer subjects and lacking adequate controls. It is difficult to interpret the results of such demonstrations, since almost any finding may be the result of the self-selection of volunteers rather than of the pricing policies being tested.

Pricing policy experiments can involve some ethical dilemmas. (For a useful discussion of this issue, see Rivlin 1971.) For example, a policy that would involve the possibility of higher energy costs for the experimental group, without the possibility of lower costs, might be regarded as exposing experimental groups to harm or at least to disadvantage. Such action might be justified only if the social need were overwhelming and no other mode of policy assessment would suffice. Perhaps a way out of the ethical dilemma would be to promise the experimental group reimbursement for excessive costs at the completion of the experiment, although the promise inevitably becomes part of the treatment.

Field Testing of Materials and Technical Devices

Field experimentation need not be restricted to attempts to change human behavior. New energy-conserving materials, technical procedures designed to reduce energy consumption, and other devices may also be tested in field experiments to assess their energy-conserving capacities in actual use. Materials or procedures that work well under laboratory conditions when installed and operated by trained persons may work considerably less well under actual field conditions. For example, a new insultaing material may work very efficiently under laboratory conditions, but, when installed by ordinary installers or used under ordinary conditions, may work much less efficiently and fail to provide the expected improvements.

Field testing should be designed and carried out as experiments rather than as demonstrations with volunteer households or firms. Volunteers may be so committed to conservation that it becomes difficult to separate out the effects of the newly installed device or materials from the effects of other conservation efforts they are making outside the experiment. Even among non-volunteers, however, Hawthorne effects may exist.[17]

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[17]The Hawthorne effect refers to the fact that people who are included in an experiment (whether in a treatment or control group) may alter their behavior solely as a consequence of being studied, so that it may be impossible to separate the effects of this general reaction from the reactions, if any, to the specific experiment.

Legal and Administrative Interventions

Proposed changes in laws and administrative rulings may also be tested through field experimentation. For example, recent federal legislation encourages states to permit right-hand turns on red lights, to conserve the gasoline used by automobiles and trucks waiting to make right-hand turns. Some states (e.g., California) have permitted such turns for some time, but it is not possible to estimate clearly the energy-saving effects of the new legislation from an analysis of gasoline consumption in such states. Field experimentation in communities and states that do not presently have such laws but are likely to enact them could provide an appropriate test of the energy-saving effects of such legislation, as well as associated effects on traffic safety and congestion.

The effect of proposed legislation or administrative rulings pertaining to speed limits and their enforcement or to gasoline sales might also be tested through field experimentation.

Summary

Systematic and repeated assessment of existing energy policies is important, and provision for such assessment often can be built into data-collection activities undertaken for other purposes. Data collected to monitor levels and patterns of energy consumption, for example, can also gauge the effectiveness of public policies aimed at changing those levels or patterns. Such research is valuable, but it is essentially retrospective: it provides information about policies already enacted.

For the assessment of prospective policies, field experiments have unique advantages, since they can provide advance estimates of the relative effectiveness of alternative energy policies that might be considered in the future. The results of such experiments should be continuously available to decision makers as proposed energy policies and competing energy needs come before them for action.

FINDINGS AND RECOMMENDATIONS: ASSESSMENT OF PUBLIC POLICIES

<u>Finding</u>. Many public policies that could have a significant effect on U.S. energy consumption cannot now be properly assessed because there are no observations on the behavioral response of the public. Because of this, the Committee finds that more extensive use of field experimentation would be useful to study the effects of policies designed to influence energy consumption. Some of these policies should be designed to provide wider differential incentives to consumers than those that exist in present pricing structures; others should provide feedback information to consumers about the relevant costs of energy consumption; and still others should be designed to test persuasion and exhortation as means of influencing energy consumption.

The potential of these types of policies is as yet unknown. It is important that policy makers be able to assess which types of conservation policies are likely to be most cost-effective and which ones least. Energy conservation strategies, as well as supply development strategies, should be subject to careful evaluation before they are widely implemented, and in many cases the only feasible method of assessing impact is by field experimentation.

Scientifically designed field experiments permit policies to be tested on a scale that is sufficiently large that reliable results can be obtained and that is sufficiently small that failures can be tolerated. The proper design, implementation, and analysis of field experiments require continuity and stability in sponsoring agencies.

Field Experimentation

Recommendation. *The Committee recommends more extensive use of controlled and randomized field experimentation to assess the impact of alternative energy-conservation strategies in the household, industrial, and commercial/service sectors of the economy. A brief listing of possible policies that might be (or are being) assessed in this manner is provided below. These policies are illustrative, being neither comprehensive nor even necessarily the ones that warrant highest priority:*

- *Experiments to determine the effects of time-of-day pricing for electricity (this kind of experiment is now being undertaken);*
- *Experiments to determine the impact of instrument feedback systems, including appliance labeling and metering devices that provide real-time information on energy consumed in the home or on miles-per-gallon for automobiles;*
- *Experiments to determine the effectiveness of informational campaigns to encourage modifications of buildings based on analysis of the financial returns to such investments;*
- *Experiments to determine the effectiveness of various regulatory strategies in areas where federal or other governmental agencies have regulatory authority.*

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APPENDIX

STATE NEEDS FOR DATA ON ENERGY CONSUMPTION

Lynda T. Carlson

INTRODUCTION

The American energy crisis of 1973-1974 found most states without an existing mechanism to cope with the problems or to coordinate their activities with those of the federal government. Individual states followed many different administrative avenues in attempting to solve the problems: some states set up temporary agencies; others assigned allocation functions to state public utility commissions; and a few established permanent state energy offices. More recently, federal legislation has encouraged the establishment of permanent state energy offices to coordinate activities with the federal government and to implement state programs of energy conservation. These offices need data on energy consumption to determine where within the state energy consumption is greatest and shortages most intense and where there is greatest potential for energy conservation. These data are also useful to states and the federal government as a mechanism for monitoring trends in energy consumption.

The manner in which each state established an energy office reflects its political structure and philosophy of involvement in public problems as well as the effects of energy on the state's economy. Every state has individual energy needs and needs for specific sets of data on energy consumption, some of which are addressed by ongoing data collection programs at either the state or federal level.

This paper attempts to describe some of the specific data needs of states, how these needs are being met, and the data gaps facing many states. It outlines patterns in data needs and programs of the 50 states and describes the specific characteristics of a number of them. The experiences of the state energy offices of New Jersey, Washington, California, Montana, Texas, Minnesota, Oregon, Georgia, and of the New England states provide illustrations of the different kinds of problems encountered by states and the variations in needs and solutions. Problems with existing data on energy consumption at the state level are described, and improvements for the future are indicated.

States' energy data needs and programs are in a state of tremendous flux. Programs are now being developed that will change both the needs of states for data and their own energy consumption data programs. This paper attempts to spell out the minimum data needs that most states share.

STATE ENERGY OFFICES

In the past several years, the function of state energy offices has been mainly to deal with short-term emergencies: the disruption of energy supplies, changes in energy prices, the allocation of scarce fuel, and the varying needs of energy consumers. Because individual states have different fuel consumption needs, the roles of their energy offices have varied with the energy needs of the state. Perhaps most important in determining the role of an energy office, however, is the political infrastructure of the state. Energy policies have had to operate within existing state institutions such as tax codes, land use policies, auto licensing standards, and building codes. The short-term policies of these offices have often not been integrated with other policies, either long or short term, of the state.

The requirements of the Energy Policy and Conservation Act of 1975[1] and the Energy Conservation and Production Act of 1976 will significantly change the functions and data needs of state energy offices (DeForest 1975). States that participate in the voluntary program are required to enact energy conservation programs, submit feasibility and action plans, and carry out conservation plans. The state energy conservation programs will not be large planning programs, but rather action programs that were to be in place by November 1976. Although states will design them, implementation of the programs will be at the local level. The requirements of the Energy Policy and Conservation Act provide for interaction among different levels of government within a state on energy conservation measures. Local-level programs will require both small-area data on energy consumption to evaluate the effects of conservation programs and state-level data for comparison and planning.

In the winter of 1973-1974, individual states created either emergency (New Jersey and Washington, for example) or permanent (California, for example) state energy offices. By October 1975, the Federal Energy Administration had identified 44 states with state energy offices or state energy representatives (Federal Energy Administration 1975). These offices were generally responsible for distributing the fuel oil and gasoline allocations that had been made by the Federal Energy Office during the oil embargo of 1973-1974. They have contingency and emergency powers for allocating fuels during periods of shortages, designing short-term conservation programs, and occasionally developing conservation policies and programs, although in some states, several of the programs have expired and have not been renewed. Under the Energy Policy and Conservation Act, the functions of the energy offices have expanded for those states that have voluntarily chosen to participate in the program.

[1]See U.S. Congress, Senate 1975. The Act calls for the reduction of projected state energy consumption of 5 percent by 1980. The program is voluntary: states are not penalized if they do not participate, but they receive federal conservation funds only if they commit themselves to the objectives of the program. In addition, states that choose to participate are required to make a minimum of five specific conservation actions.

Responding to Crises

In the winter of 1973-1974, each state energy office was responsible for allocating fuel oil and gasoline within the state, attempting to ameliorate shortages in specific areas, and creating emergency planning and allocation mechanisms for a continued overall shortage. The state energy offices communicated almost daily with the Federal Energy Office to try to increase their state's allotment of specific fuels and to alter components of the federal allocation system. Many larger cities and counties (Los Angeles, for example) established similar energy offices, which coordinated the fuel allocations within their jurisdictions, attempted to develop emergency fuel oil conservation programs, and implemented state and local regulations for alternate-day gasoline sales and priority sales of home heating fuels.

Structural Organization

The structure and function of the individual energy offices reflect the different interests and needs of the separate states as well as regional variations. The responsibilities of each office are for the most part a consequence of the legal and political character of the state. Several examples illustrate the range of differences.

The New Jersey constitution allows for the creation of only a limited number of state agencies; the governor and state legislature are prohibited by law from creating new ones. This prohibition is to prevent the creation of overlapping agencies performing similar functions. For this reason, New Jersey's energy office is officially situated within the State Public Utility Commission, but functions as an adjunct to the governor's office and is entitled the Energy Cabinet Commission. The Commission has no permanent staff, budget, or permanent mandate.

In California, the state Energy Administration has an official mandate from the state legislature and governor. The Energy Administration is structured on the administrative lines of the Federal Energy Administration, with regulatory, conservation, analysis, and data staff performing energy planning, information, and policy functions. The Administration can also initiate primary data collection projects.

The Montana Energy Advisory Council is chaired by the lieutenant governor who oversees its work; the Council develops energy policies for the state.

In Washington, after several years of debate, a state energy office has been established within the governor's office. The office is responsible for creating alternative energy forecasts, dealing with specific energy problems, and coordinating activities with other energy-related agencies in the Northwest.

Texas has established the Governor's Energy Advisory Council, which includes representatives of the governor and the state egislature as well as many independent agencies in Texas. The Council has a rather large staff and a legislative mandate to coordinate and plan statewide energy policy.

The Minnesota Energy Office was established by the state legislature in 1974 to develop energy conservation policies for the state and to provide forecasts of future Minnesota fuel requirements. The Energy Office also reviews rate structures of utilities operating within the state (Minnesota Energy Agency 1975).

Functions of the Offices

One of the first functions of a state energy office is to determine what energy problems the state has. Generally, the office will survey the existing fuel supplies, consumption levels, and fuel-use mix within the state to determine what steps should be taken to maintain the existing supply and reduce consumption. Such energy planning and analysis by states was sporadic prior to 1973. Since then, most states have developed an approximation of the energy flows within their states. This information is of little value, however, without corresponding information on future energy prices and the types of future supply situations states can expect to encounter.

The problems faced by state energy offices are exemplified by those of several states. In Montana, the major question is how that state will respond to demands for development of its coal supply--one of the largest strippable supplies of coal in the nation. In New Jersey, the problem is to maintain the supply of petroleum needed for the state's residential sector and the petrochemical industry, one of the state's largest industries; 68 percent of the fuel consumed in the state is petroleum.

In Texas, perhaps the most important energy issue is consumption of the state's natural gas supply. Planners and policy makers in the governor's office and the Governor's Energy Advisory Council are concerned about the state's role as a major exporter of natural gas to the rest of the nation. In 1974, Texas exported approximately 3,766 trillion cubic feet of natural gas, much of it supplied on non-interruptible contracts to industries or commercial establishments that hypothetically could consume other fuels. The Governor's Energy Advisory Council is particularly concerned with the use of natural gas to generate electricity that could be generated by coal. Of particular interest to the governor and state legislature are estimates, made by the Advisory Council, of how variations in the price of individual fuels will affect the economy of Texas. In 1975, tax receipts on the production of oil and natural gas were 19.7 percent of Texas's total tax revenues (Grubb and Holloway 1974).

Planning for the Future

Both the legal authority exercised by state energy offices and their energy planning, forecasting, and program development are functions of the ways in which the various states experienced the energy crisis of 1973-1974. The amount of effort and money a state spends on energy planning and policy development is partly determined by how state policy makers perceive the effect of energy supply and consumption issues on the economy of the state and the economic well-being of its residents. The Energy Policy and Conservation Act provides funds as an incentive for states to set up workable programs in energy conservation.

In Oregon, environmental concerns for the maintenance of the state's natural resources and the quality of life now enjoyed in the state are important to the state legislature and the governor. Energy conservation policies developed by the Oregon Department of Energy are linked closely to maintaining the state's environment and natural resources. A report of the Oregon Department of Energy (1975) notes that it has very broad authority to obtain "information to be furnished annually to the Department of Energy by utilities, petroleum suppliers and coal suppliers regarding future energy demand, supply and other information". Oregon is attempting to play an active role in regulating the consumption of energy within the state.

In Montana, energy consumption data is needed by the Montana Energy Advisory Council because natural gas prices in that state are increasing rapidly and curtailments of supply from Canada in the next few years have become a possibility. In addition, the state's large supply of coal and the national demand for it are affecting Montana's economy, ecology, and consumption patterns. The demand for coal may lead to the growth of towns and greater demand for governmental services. For these reasons the state's energy policy makers are very interested in energy consumption patterns, in both Montana and the nation (Christiansen and Clack 1976).

Planning for Specific Fuel Shortages

Because of their differing employment, economic, and population bases, states are differentially affected by fuel shortages. For instance, the potential cutback of Canadian natural gas strongly influences Montana's plans for alternative fuel sources as well as its concern for the fuel conversion needs of industrial plants and residential users. Montana is also concerned about the dislocation of workers in establishments supplied by natural gas and the effect of rising fuel prices on the state's economy. Oregon, Washington, and other states in the Northwest are similarly concerned; they all need data on fuel consumption related to the natural gas shortages that would result from the curtailment of Canadian supplies. The North Central states and Texas may also be affected by the cutback; there may be employment impacts since other natural gas-producing states may be called upon to supply consumers in the Northwest on a short-term basis. Texas and the North Central states will also need data on the consumption of natural gas in their own and other states--but not necessarily the same data needed by states in the Northwest.

Many states need information on coal prices and the effect of coal strikes or environmental legislation on the price of coal. In states in which coal is the main fuel used to generate electricity, a coal strike could have a greater effect than an oil embargo. In Montana, Wyoming, Utah, Kentucky, Tennessee, West Virginia, North Dakota, Indiana, and Ohio, over 90 percent of the fuel used for generating electricity is coal.[2]

The New England states and New Jersey are more concerned with information on petroleum consumption than are most other states. Because petroleum constitutes 68 percent of the fuels consumed in the state, New Jersey is concerned with data on its current and future consumption. In comparison with New Jersey, petroleum constitutes 46 percent of the nation's energy needs. Furthermore, most of the petroleum refined and consumed in New Jersey is imported from foreign sources (Governor's Task Force on Energy 1974). Information on the foreign and domestic mix of state petroleum consumption is needed by coastal states, especially those that have large refining or petrochemical industries. The inland states are not as concerned with the mix of foreign and domestic petroleum they consume, because it is difficult to trace this breakdown and

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[2]See Edison Electric Institute 1975; data derived from Table 14.

involvement in the petroleum industry is minimal. Washington is interested in projections of refiner and user demand for crude oil during the next ten years to determine sites for marine transportation and to develop rules for transporting and unloading crude oil.

Political and Policy Functions

State energy offices fill political needs of both governors and state legislatures by creating the image that the state is doing something about fuel shortages and, at the same time, providing a ready scapegoat for state energy problems.

Policy makers need data on the possible effects of proposed changes in policy. To evaluate such a change or even to participate in the federal energy conservation program, policy makers need information on which segments of the population will be affected by the proposed changes. Perhaps the most important information needed is on the costs and potential savings of alternative conservation measures. For instance, policy makers want to know the actual and potential costs and benefits of implementing proposed changes in building standards. Policy makers need information to compare the long-term-costs and benefits of various energy conservation proposals, such as solar development. They must also consider the financial and political costs of specific proposals in light of other programs that are competing for the state's resources. The potential programs available to policy makers include those to change building standards for new buildings, develop programs to retrofit residences with insulation, create new standards for appliances sold within the state, change energy utility excise taxes, and provide tax incentives for the installation of solar devices.

Individual states may plan for potential shortages and take steps to minimize predicted shortages, like a Canadian natural gas curtailment. If such emergencies do not occur, state energy planners may have a problem: the credibility of their planning processes and the predictability of their data. A good example of this kind of situation is the natural gas shortage that was predicted for the winter of 1975-1976 but never occurred.

State energy offices appear to serve a function for the governor analagous to that of federal energy agencies for the President. Like any government office, they provide quick data points or reactions to legislative initiatives. Lack of valid or detailed energy consumption data impedes the ability of state energy offices to perform this function.

CONSUMPTION DATA NEEDED BY STATES

Baseline Data

In order to respond to current crises, develop ways to respond to future crises, and create policy initiatives, perhaps the consumption data most crucially needed by states is a baseline of their historical and current consumption patterns for each fuel type in each consuming sector. At present, when available historically, these data are either highly aggregated or nonexistent, particularly in the commercial sector. For planning purposes, state-level data are often too highly aggregated for planning for the needs of diverse areas within a state--counties or cities, for example. In addition to baseline data on energy consumption, states need baseline descriptions of the characteristics of that consumption: what type of houses make up the housing stock and the characteristics of these dwellings--i.e., insulation, storm windows, and type of fuel consumed. Information is also needed on many other items besides homes, for instance the characteristics of the stock of automobiles and the use and disposal of wastes.

Comparative Data

States need data to determine their consumption patterns relative to both the nation as a whole and the surrounding states in their geographic region. The New England states are interested in obtaining consumption data that provide petroleum use by sectors for many purposes, specifically to determine the competitive advantage of industries in a state to similar ones in other states (particularly states the industries might be considering for relocation) and the nation as a whole.

Of major interest to states that suffered severe shortages during the 1973-1974 crisis is obtaining current data on fuel consumption and related factors of change, such as population, the number and composition of automobiles owned, and the composition of the housing stock. States vary widely in the kinds of these data collected and the analysis of them. State energy offices need valid data for their own states and others so that each office has a standard base of data on which to estimate future fuel allocation requirements.

At present, data sets collected by various states are not always comparable. The Federal Energy Administration (1975) has noted these problems in comparing state data on gasoline consumption: "The Federal Highway Administration collects its data from state data on taxed gallons, exemptions, and refunds. In some states refund claims are clearly excessive for gasoline used for nonhighway purposes. Some figures have necessarily been estimated by FHA. This is particularly true for the nonhighway use of gasoline." The definitions used in data collection by different sources can also differ.

There are also likely to be differences in the time period in which individual states collect energy data. Such noncomparability of data creates difficulties in reconciling allocations from the federal government and setting regional energy policies. In the Pacific Northwest, the governors of Oregon, Washington, and Idaho are interested in determining coordinated energy needs for the region so they can interact in the planned siting of electric generating facilities. Energy consumption data that are comparable for these regions would facilitate the planning of the coordinated energy policies.

Determining Policy Priorities

Energy consumption data are needed by various states to determine what energy questions should concern them and which fuels are most important. For instance, consumption and supply data on Georgia's energy needs permitted state energy planners to determine that the state's use of natural gas was not a critical issue. However, Georgia planners did need data on energy consumption for specific agricultural crops in the state. This information enabled them to forecast state energy needs for petroleum and natural-gas-based fertilizers.

State Economic Planning

State energy planners also interact with other kinds of planners to evaluate the effect of energy policies and future energy prices on such things as employment, economic development, and land development. New Jersey has considered the implications of changing natural gas rate structures on an emergency basis for the glass industry. The state's energy planners must evaluate the policy in the context of both state economic policies designed to supply natural gas to all users and state economic development policies designed to maintain industries in southern New Jersey. If the New Jersey Energy Office recommends that the Public Utility Commission lower gas rates for the glass industry, the state would implicitly be subsidizing an industry that may currently be noncompetitive with those in other states; New Jersey energy planners would then be temporarily ensuring jobs in southern New Jersey. If this happens, a precedent will have been established for the state to intervene with specific energy policies to protect employment opportunities in individual industries. Lower gas rates have not yet been requested for the glass industry, because the state economic planners are evaluating the total effect on the state of such an intervention policy. Energy data are, therefore, a necessary component of the total economic and demographic data set that states may need to design policies in an era when energy fuel shortages are important.

Evaluation of Federal Policies

Energy consumption data are needed to evaluate the effect of many federal policies on states. For instance, the federal regulation requiring a speed limit of 55 miles per hour on highways might be evaluated within each state according to the type of trips taken, the types and condition of roads, and the forms of commerce and industry that are predominant. It is possible that the regulation might be dysfunctional in states in which households are highly dispersed, roads are comparably empty, and farmers, ranchers, and families have to travel great distances routinely. If states knew the actual savings in gasoline resulting from the lower speed limit and whether an increase in the rate would affect gasoline consumption, then state officials might develop a case for changing the state data used by the federal government in establishing national speed limits. Similarly, mortgage regulations and standards set by the Federal Housing Administration and building standards proposed by the National Bureau of Standards and the Department of Housing and Urban Development are being examined by states to determine their potential effect on long-term consumption levels of various fuels. For short-term consumption levels, states are examining the usefulness of energy labeling of new appliances, increased energy efficiency of appliances, and electric load leveling.

CONSUMPTION DATA AVAILABLE TO STATES

The energy consumption data collected by the states varies with their individual needs, the fuel shortages experienced or anticipated, their capabilities to manipulate and analyze large data bases, and the extent to which each state's government engages in planning for its economy. To state energy offices that are interested in planning for energy shortages and forecasting demand, both federal data and some data related to fuels and collected within the state are available. Several states are developing planning programs to collect energy data; others are relying on the data system created by the State/Federal Energy Conservation Program of the Federal Energy Administration for individual states.[3]

To facilitate the development of energy data bases by the state, the Federal Energy Administration, upon the advice of the National Governors' Conference, worked with the states to develop a series of historical statistics and baseline energy consumption forecasts for each state. A uniform data classification system was created to be used as a base for energy forecasts to 1985. After the Federal Energy Administration collected the forecasts and data, the data were sent to the states for verification and necessary correction; a data set for each state is now operational.

National Data Sources

The principal source for data on fuel consumption available to the states comes from the state's own gasoline tax receipts. Additional data come from the Federal Highway Administration, the Bureau of Mines, the Federal Power Commission, the Bureau of the Census, the Ethyl Corporation, the Edison Electric Institute, the American Petroleum Institute, the American Gas Association, the Army Corps of Engineers, and the National Coal Association. For the most part, these sources produce data for specific fuel types consumed by a broad sector of the state's economy.

The data used by states from both the federal government and private sources create a number of problems for them, the primary one being the matter of definitions. In some instances, the reported years are fiscal years; in other cases, calendar years are used, depending on bookkeeping and historical practices. Such differences are not problems for the individual states, but they do make it difficult for the federal government to use the data for state-by-state comparisons. The reliability of data is currently a concern of the Federal Energy Administration, as is illustrated by their program to collect petroleum data independent of those collected by the petroleum industry.

The data provided by industry sources such as the Edison Electric Institute, the American Gas Association, the American Coal Association, the American Petroleum Institute, and the American Trucking Institute are collected on a voluntary basis from their members. These data relate only to energy supply and sales data, and the data on sales are related to depletion from primary

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[3]See Fels 1976; this research is part of a project carried out by several members of Princeton University's Center for Environmental Studies for New Jersey's Cabinet Energy Commission.

stocks, rather than actual consumption. Trade associations are interested in protecting market shares information about individual companies, and their data may be subjected to standards of confidentiality that might not necessarily constrain a federal regulatory agency or the Census Bureau. In the Texas energy report (Grubb and Holloway 1974), data on gasoline consumption per capita for the state had to be supplied by the American Petroleum Institute. The only complete data series on fuel reserves, consumption, and consumption by fuel type for oil and gas are available from the oil and gas industry trade associations.

For the data supplied by the federal government, there are many problems. It is difficult to verify the data from many of the surveys and reporting forms. Many data, such as the price of fuel products sold to specific industries, are not being collected as frequently or at the level of detail that individual states (Oregon, Texas, and the New England states, for example) require. In several cases, the sector types used for these data compilations do not coincide because of discrepancies in the definitions used. In the Federal Power Commission data, electric energy use in apartment houses is included in the commercial sector; in other data, it is included in the residential sector.

Most states have very few detailed data on the use of coal by utilities and industrial consumers. Lack of information on coal consumption limits the ability of energy planners to deal with potential emergencies such as coal strikes and to obtain alternative fuel supplies. With regard to petroleum, states have few end use data on petroleum either shipped into or refined in the state. The Texas analysis of the state's energy consumption noted (p. 55): "Data on consumption of Texas refinery output by end user in Texas for all petroleum products is not available from recorded information. However, quantitative data reported to the Bureau of Mines, U.S. Department of Interior show refinery output by product type; . . . The existing data do not distinguish between Texas consumption of these products and those which are exported." Neither Texas nor New Jersey, with large petrochemical industries, has actual data on petrochemical production, capacity, or feedstock requirements for these industries.

States appear to need energy supply and consumption data at 3-digit SIC levels[4] and to want the information for counties or county groups within the state. Geographic areas such as counties differ markedly in their industrial base, employment mix, and economy. An aggregate figure on consumption needs for a specific fuel does not help state energy planners in determining which county has a specific fuel shortage or specific energy planning needs.

State Data Sources

In addition to data acquired from the federal government, the states collect some primary data, although rarely is the collection designed specifically to fit the needs of their energy planners. Collection of specific energy-related data is at an incipient stage in many states. Data may be collected within the state, but the energy planners do not necessarily know

[4]See Chapter 3 of this report for an explanation of the Standard Industrial Classification.

of their existence because they may not have been documented or even entered into a data file by the other agency. In Texas this problem occurred with the state tax files. A great deal of information is collected by state revenue offices, but only small segments of it are included in the state tax files. (The information included in the state tax data files is often designed to be linked to the federal/state data files so that the states can determine who has not filed state tax forms.)

Most states collect data for sales taxes, franchise taxes, severance taxes (that is, taxes on minerals extracted from the ground), corporate income taxes, and state personal income taxes. From these data, the state can develop a picture of the fuels consumed in the state. For instance, state data on taxed gallons of fuels can potentially provide information on nonhighway (marine, aviation, etc.) and highway use of gasoline. However, the quality of this information varies from state to state, depending on what uses they exempt from taxation, how aviation fuels are classified, which fuels are taxed, and how rapidly the data is processed. Data are generally not standardized to reflect population growth, fluctuations within states due to tourists, and division between personal and commercial uses of gasoline. It is questionable whether the data presently available could take these changes into account.

Generally, states also have gas and electric utility consumption data for the residential, industrial, and commercial sectors, although these data are usually at the broad sectoral level and not available for individual components of a sector. Some states have broken down the data by sample surveys of user categories and then extrapolated patterns of use to the general population in that user category. However, sample surveys on utility consumption have not been conducted in most states.

SUMMARY OBSERVATIONS

From an examination of energy policies and data needs, a few general observations can be made about the procedures that states are following, and some alternative approaches for energy data use can be described.

The degree of sophistication in the collection and use of energy consumption data differs drastically among states, depending upon their fuel needs. California, Oregon, Texas, Minnesota, and Washington have very sophisticated methodologies and forms of data collection. These states can provide the federal government with advice and are presently providing informal advice to other states. South Dakota, by contrast, has little information on the data that are available to the state. Many states are using the resources of either state universities or independent contractors to do some energy consumption data collection, compilation, and analysis, rather than undertaking these tasks within the state government.

There are three major considerations that determine the differences in the energy policies and data needs of states: First, the reasons for gathering the data--for planning, allocations, or perhaps only to satisfy one of the requirements of the Energy Policy and Conservation Act. Second, the planned use for the data--for the development of policy alternatives, conservation plans, or emergency program planning. Finally, the specific policies for which the data will be used--does the available data answer the questions raised in the policy formation process?

Many states are overwhelmed by "data overload," that is, many of them have too many data of the wrong type for state planning and not enough basic historical data relating to functional end use in the state. It would be better for states to start with non-emergency energy data policies that the states and local jurisdictions can implement and then define the data needs related to those policies. In addition, many states are overwhelmed by the number of data bases on energy consumption that are currently being developed in which they are expected to take part. The Federal Energy Administration has constructed longitudinal state energy data bases (as was previously noted) as well as a consumption data base for the various sectors that has state-level data for some sectors. Several of the regional governors' councils are planning to create energy data bases. As might be expected, such a duplication of effort creates multiple problems in terms of both costs and the different interpretations of the same data for each state.

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